NSW Department of Planning and Environment

Bays West Stage 1 Rezoning

Acoustic Review

286355-AC03

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Contents

1 Introduction

Arup has prepared this acoustic review of the Bays West Stage 1 rezoning proposal on behalf of NSW Department of Planning and Environment (DPE).

At this stage of the planning process, a detailed quantitative assessment of the proposal has not been undertaken. A largely qualitative review has been carried out of the current Proof of Concept Masterplan prepared by Turf and Cox (8 August 2022). Quantitative evaluation of impacts to proposed residential uses within the site has been carried out to inform land-use planning.

This report provides a high-level review of the potential uses with consideration of the potential from existing and known future sources, impacts within the development site given the mix of uses, and on the surrounding land uses and community. This report discusses the likely suitability of the proposed uses which has been informed by relevant NSW policies and guidelines. Potential mitigation and management strategies are also outlined, including recommendations for more detailed assessment where the feasibility of typical design strategies is less certain. Notwithstanding, more detailed acoustic assessment would be expected during future planning, design and delivery stages.

1.1 Project overview

The White Bay Power Station and Metro precinct is located to the west of Sydney CBD, situated north of the ANZAC bridge, east of Victoria Road and west of the Glebe Island and White Bay Ports (see Figure 1).

Figure 1: Site location

The proposed land uses are shown in Figure 2, and include a range of commercial, retail, recreational and cultural uses. The draft Masterplan indicates that residential uses are possible in the south western urban blocks (Wedge and Southern Development Blocks), but expected to be above any adjoining commercial.

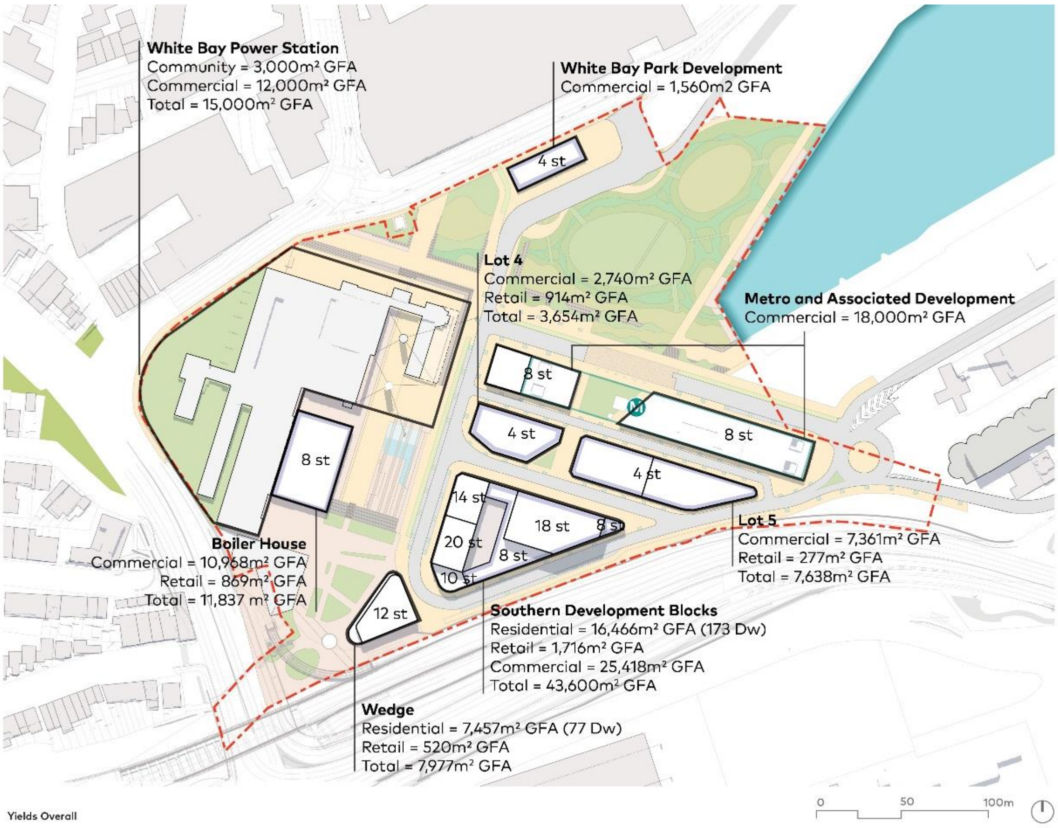

Figure 2: Land use and yields (Turf + Cox)

An indication of building massing and their relationship to the ANZAC Bridge and Victoria Road is shown in Figure 3.

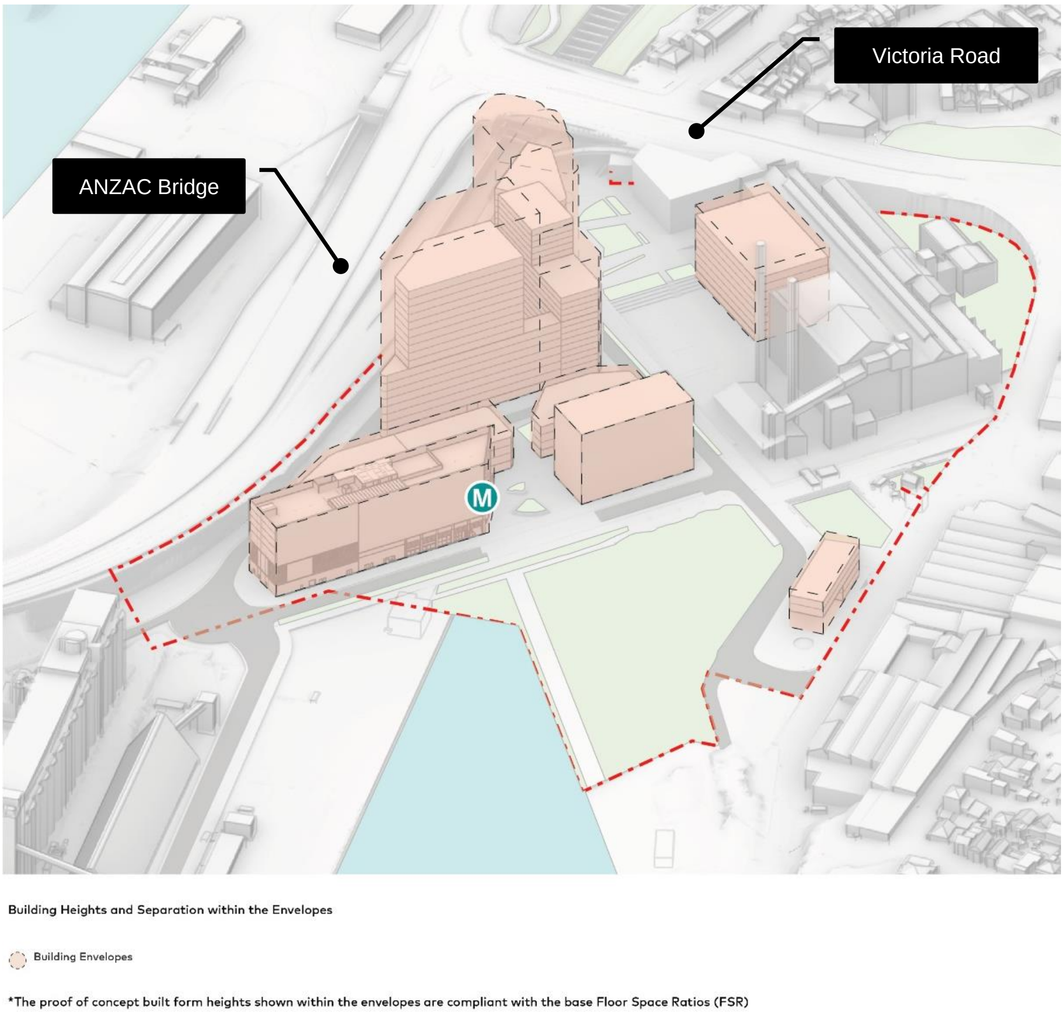

Figure 3: Built form – relationship to ANZAC Bridge and Victoria Road

2 Acoustic review

The acoustic review is structured as follows:

- Discussion regarding potential impacts upon the development, and
- Discussion regarding potential impact from the development, onto both existing surrounding development and future uses within the site.

2.1 Impact upon the development

The primary environmental acoustic factors with the potential to influence the development are:

- Road traffic noise from the ANZAC Bridge and Victoria Road
- Port activity, including vessels and landside activity
- Future Sydney Metro West station and rail operations

2.1.1 Road traffic noise

Criteria

Statutory requirements for road traffic noise apply only to residential, education, hospitals, and places of worship in accordance with the NSW *State Environmental Planning Policy (Transport and Infrastructure) 2021* (‘TISEPP’) [1] and the supporting *Development Near Rail Corridors and Busy Roads – Interim Guideline* [2]. The TISEPP applies only to development impacted by roads with an Annual-Average Daily Traffic (AADT) volume above 20,000. By reference to the Westconnex M4-M5 Link Rozelle Interchange Modification Noise Assessment [3], the two-way AADT for the ANZAC Bridge is approximately 190,000, and for southern end of Victoria Road approximately 70,000.

The Guideline [2] clarifies that the noise criteria in the TISEPP apply to the following time periods:

- Day 7:00am - 10:00pm $L_{Aeq(15hr)}$
- Night 10:00pm - 7:00am $L_{Aeq(9hr)}$

The TISEPP [1] criteria apply inside the development with windows and doors closed. The Guideline [2] also states:

> “*If internal noise levels with windows or doors open exceed the criteria by more than 10dBA, the design of the ventilation for these rooms should be such that occupants can leave windows closed, if they so desire, and also to meet the ventilation requirements of the Building Code of Australia*.”

Table 1 presents the TISEPP internal noise criteria along with the equivalent external noise criteria for residential premises, being the primary concern for impacts within the proposed rezoning.

Table 1: TISEPP noise criteria for new residential development

Room	**Location**	**$L_{Aeq, 15hr}$ Day 7am – 10pm**	**$L_{Aeq\ 9hr}$ Night 10pm – 7am**
Bedrooms	Internal, windows closed	40	35
	Internal, windows open	50	45
Other habitable rooms[2]	Internal, windows closed	40	40
	Internal, windows open	50	50

Notes:

1. The Guideline [2] states that where internal noise criteria are exceeded by more than 10 dB(A) with windows open mechanical ventilation is required. Assumed windows open to 5% of floor area in accordance with the BCA requirements.
2. Anywhere else in the residential accommodation (other than a garage, kitchen, bathroom or hallway)

Assessment and recommendations

While noise measurements have not been carried out, a preliminary quantitative assessment has been carried out for the residential uses proposed near the ANZAC Bridge, given their high risk of impact. A coarse calculation based on CoRTN [4] has been carried out based and the aforementioned traffic data for the nearest residential uses as outlined in the draft Masterplan and is summarised in Table 2.

Table 2: Road traffic noise assessment, external noise levels at residential buildings

Building	**Distance to nearest carriageways**	**$L_{Aeq, 15hr}$ Day 7am – 10pm**	**$L_{Aeq\ 9hr}$ Night 10pm – 7am**
Wedge	ANZAC bridge on-ramp: 18 m ANZAC bridge main carriageway: 43 m	75	70
	Victoria Road: 55 m	65	59
Southern Development Block	ANZAC bridge on-ramp: 33 m ANZAC bridge main carriageway: 55 m	73	68
	Victoria Road: 115 m	63	56

Notes: Noise predictions are 'free-field'

The level of noise exposure predicted in Table 2 will require very high sound insulation to be provided by the building façade/envelope to achieve the TISEPP internal noise goals. Such double glazing with large airspace between (approximately 100-200 mm or wintergarden arrangement). The windows open criteria for natural ventilation would also be exceeded.

Building ventilation

There is no clear policy position on the provision of ventilation to noise affected sites. The *Development Near Rail Corridors and Busy Roads – Interim Guideline* [2] allows for alternative forms of ventilation, such as mechanically assisted, where the windows open criteria cannot be satisfied. However, there is some conjecture regarding the requirements for residential apartments due to various aspects in the SEPP 65 [5] Apartment Design Guide (ADG) [6].

Section 4B of the ADG relates to Natural Ventilation, for which the ADG describes as "*the movement of sufficient volumes of fresh air through an apartment to create a comfortable indoor environment*". Objective 4B-1 of the ADG is "*all habitable rooms are naturally ventilated*". This is achieved by providing operable windows/doors to all rooms of at least 5% of the floor area. The ADG does not stipulate noise criteria that need to be achieved with windows open.

Section 4H of the ADG relates to Acoustic Privacy, but notes that for constrained sites, such as sites near a rail corridor, major roads or underneath flight paths, reference is to be made to Section 4J Noise and pollution.

Section 4J – Noise and pollution, refers to the NSW *Development Near Rail Corridors and Busy Roads – Interim Guideline* [2]. The ADG states that SEPP 65 development must have regard to this Guideline. As noted, the Guideline allows for alternative mechanically supported ventilation systems in noise and pollution affected sites. The design guidance outlined in Objective 4J-2 also focus on providing well sealed buildings to limit noise ingress:

> *Design solutions to mitigate noise include:*
>
> - *limiting the number and size of openings facing noise sources*
> - *providing seals to prevent noise transfer through gaps*
> - *using double or acoustic glazing, acoustic louvres or enclosed balconies (wintergardens)*
> - *using materials with mass and/or sound insulation or absorption properties e.g. solid balcony balustrades, external screens and soffits*

However, potentially relevant to the planning requirements are the requirements of the City of Sydney. The City of Sydney's interpretation of SEPP 65 and the supporting ADG is that natural ventilation must be provided while also satisfying specific noise criteria. This requirement is not stated in the ADG. The City of Sydney has released a draft guideline for the assessment of alternative natural ventilation [7]. The draft guideline provides an alternative natural ventilation pathway whereby airflow rates are defined, rather than relying on an opening size proportional to floor area. The airflow rates are consistent with the mechanical ventilation standard for outdoor air outlined in the National Construction Code (NCC) [8, 9], which are for 'adequate air quality', not for comfort in accordance with the ADG objective. While the site is not part of the City of Sydney LGA, it is an adjoining LGA that has considered this issue in depth and is considered as a case study only.

While the airflow requirements are low, relatively large openings are often required to suitably perform under relatively still external wind conditions (worst case 85-90% over year) and overcome the increased pressure loss through the obstructed openings and airflow paths.

Providing alternative natural ventilation solutions at noise affected sites can have a considerable impact on apartment design, amenity, and sustainability outcomes, including, but not limited to:

- additional spatial requirements, reducing net floor space,
- added complexity for cleaning and maintenance,

- added complexity for user operation. There are no standards or requirements regarding ease of operation. Suitable ventilation performance may be contingent on specific external openings and ventilation paths though the apartment being open to achieve the ventilation rates, which is also a function of the current wind speed and more importantly direction.
- Need for controls or ability to close the ventilation system under high wind speeds. Variable dampers would be needed to maintain usage, else closure would inadvertently reduce the time when the background ventilation is provided. Dampers increase the risk of aeroacoustic noise when not well sealed.
- Inability to provide filtering of external air quality due to airflow restriction.
- Potential need for automated control systems to minimise impacts under high wind and pollution events.
- Large openings will impact building thermal performance and may otherwise need to be sealed during high and low temperatures.
- Overall design complexity and certification due to the need for often bespoke and untested design solutions.

Accordingly, given the absence of a formal policy, consideration could be given to allowing residential development provided that satisfactory sound levels are achieved with windows closed, and providing appropriate background ventilation through mechanically supported means consistent with the National Construction Code (NCC) [10], or ideally at higher ventilation rates for improved ventilation. Any background ventilation system is recommended to achieve a noise level 5-10 dBA below the noise intrusion criteria.

It is noted that external amenity for residential apartments will also be compromised. While the TISEPP does not set external criteria, balcony areas are likely to provide poor amenity outcomes, particularly those on the southern aspects and if fully open. Some noise reduction could be achieved by semi-enclosed wintergardens with sound absorptive finishes to the soffit and potentially some solid walls.

Road traffic noise also has the potential to impact land uses where statutory requirements don’t apply, including commercial offices. Building proposed near the ANZAC Bridge would require increased sound insulation from that typically adopted in the Sydney CBD. Careful siting of any balconies or other external amenity areas is recommended.

Road traffic noise also has the potential to impact the external amenity of public areas. However, the ground plane is expected to be partially shielded from road traffic due to the elevation of the roadway and shielding provided by the proposed buildings. Higher exposure would be expected at the southwest corner of the site near the Southern entry and Power Station Plaza. It is not known whether any specific measures have been incorporated into the Westconnex to reduce noise onto the site, however it is recommended that noise barriers along the road edge be investigated and included if they are found to provide reasonable noise reduction. It is noted that early review of the Westconnex tender schemes on behalf of DPIE recommended that such measures be investigated due to the desire to maximise amenity of Bays West. Detailed modelling is recommended for this purpose.

2.1.2 Port vessels and landside activity

The site is near multiple berths and landside operations associated with the Glebe Island and White Bay Ports (see Figure 4).

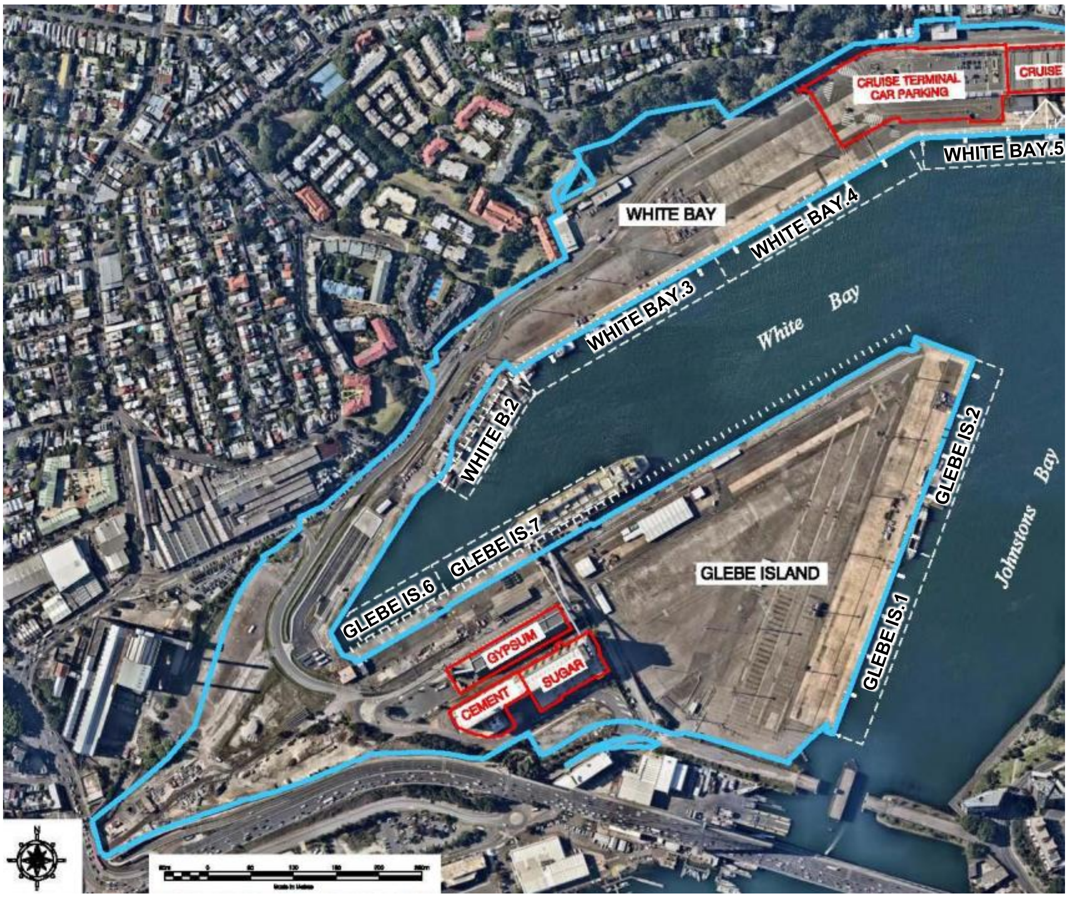

Figure 4: Glebe Island & White Bay Port boundary, berth locations and key port uses [11] (Figure 1)

Reference has been made to the Glebe Island and White Bay Port Noise Policy [11] which is a relatively new policy developed for the management of the ports. It includes noise modelling of port operations and recommended criteria for new development in proximity to the port. Recommended planning controls for new residential developments near the port are $L_{Aeq,1hour}$ 40 dB in the day (7am to 10pm) and 30 dB at night (10pm to 7am).

Appendix I of the Policy includes noise predictions for both vessel and landside operations, which have been relied upon for review (see Figure 5 and Figure 6 on following pages). While a noise descriptor is not stated on the figures in the Policy, it is understood that they show $L_{Aeq,15\ hour}$ for the day/evening (7am to 10pm) and $L_{Aeq1,hour}$ for the night period (10pm to 7am) consistent with the trigger levels in Table 3 of the Port Noise Policy [11]. The Policy notes that Glebe Island 6 and 7, and White Bay 3 and 4 berths, which are closest to Bays West Stage 1, are currently the best suited for overnight stay of vessels. This is reflected in a negligible difference in the day and night noise levels across the site.

It is important to note that port noise can include annoying characteristics that are not described by the L_{Aeq} parameter, such as tonal and low frequency noise. While the Policy defers to the NSW *Noise Policy for Industry* [12] for assessment of potentially annoying characteristics, it notes that an alternative low frequency noise criterion is being developed for the ports.

The figures indicate that noise exposure across the site would exceed the Port Vessel Trigger Levels (60 $dBL_{Aeq(15hr)}$ for the day and 55 $dBL_{Aeq(1hour)}$ at night) for approximately 30% of the site during the day and the majority of the site at night. Factoring the potential low frequency noise characteristics, port noise is likely to be a key feature of the site and influence the amenity and design of proposed land uses. Impacts on retail and commercial uses is likely to be low to moderate respectively, but should not unreasonably inhibit such development.

For more sensitive uses, such as residential, learning and education, and some performance spaces, port noise may be a more significant factor influencing building design and amenity outcomes.

For the potential siting of residential uses, noise from the ports will impact opposing façades to major roads, resulting in building orientations being impacted by existing environmental noise. Given the proximity of potential residential uses to the port and the greater challenge in satisfactorily mitigating low frequency characteristics of port noise, a preliminary assessment has been carried out to inform land-use planning.

Table 3 presents an assessment based on:

- Night period for worst case bedrooms
- External port noise based on 10 years into future predictions (Figure 6)
- Vessel noise spectra based on Mareeba March 2022 (Table 4)
- Bedroom: floor area 12 m^2, glazed area 8 m^2, indicative façade construction R_w 49, 6 mm glass / 200 mm air gap / 10 mm glass (operable elements may limit achieved performance. Wintergarden arrangement may be required).
- Low frequency criteria are based on the original reference curves that informed Table C2 of the NPfI, as the NPfI criteria are for external locations [13]. The arithmetic average of the one-third octave levels is presented being an appropriate for the octave band assessment.

Table 3: Port noise assessment to residential bedrooms

Residential building location	**External vessel noise level[1] $L_{Aeq(1hour)}$**	**Internal noise levels[1]**			
		L_{Aeq}	**Octave band frequency (Hz), dB**		
			31.5	**63**	**125**
Wedge	56	29	49	42	30
Southern Development Block	58	**31**	51	**44**	32
Internal criteria		*30*	*56*	*42*	*36*

The assessment indicates that high sound insulation performance is required for the building envelope, not limited to the glazed areas. Marginal exceedance is predicted at the southern development block for the outlined assumptions. The required sound reduction is higher than required to address road traffic noise due to the low frequency characteristics. While compliance may be predicted it is noted that other vessels, with marginally lower overall noise levels exhibit strong tonal characteristics (such as CSL Thames – January 2022). These characteristics may still be audible dependent on whether they are attenuated to below the threshold of hearing, which might occur at 31.5 Hz one-third-octave band [14]. Further analysis of this aspect is potentially warranted.

As the building will need to be well sealed, provision of natural ventilation will be impacted. Reference should be made to previous discussion under the road traffic noise assessment.

Figure 5: Port noise predictions – 10 years into future (Daytime and evening period) – Vessel and landside representative worst-case [11] (Figure 15)

Figure 6: Port noise predictions – 10 years into future (Night period) – Vessel and landside representative worst-case [11] (Figure 18)

Table 4: Vessel noise reference spectrums (GHD reports from Port Authority website)

Measurement reference	**Broadband**		**1/3 Octave Band Centre Frequency, Hz***																				
	dB(C)	**dB(A)**	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1k**	**1.25k**	**1.6k**	**2k**	**2.5k**
January 2022 Vessel: CSL Thames Location: L03	69	62	56	**67**	60	58	58	56	56	52	50	54	56	55	54	56	57	55	53	49	46	47	46
January 2022 Vessel: Pioneer Location: L03	69	61	63	66	56	59	61	57	54	54	52	57	51	53	57	53	56	53	52	50	47	44	41
Feb 2022 Vessel: Mareeba Location: L03	64	54	56	54	54	57	56	52	51	48	49	51	52	53	48	46	44	44	44	42	42	39	37
March 2022 **Vessel: Mareeba** **Berth: GLB7** **Monitoring location: L03 (White Bay 2)**	**71**	**58**	**63**	**65**	**65**	**65**	**64**	**61**	**57**	**54**	**53**	**53**	**52**	**52**	**50**	**49**	**49**	**48**	**49**	**48**	**46**	**46**	**45**

Notes:

* Frequencies up to 10 kHz included in assessment but not represented

2.1.3 Metro West rail line

Impact from the Metro West line would primarily relate to ground-borne noise and vibration from the rail operations in the tunnel, and noise emission from the station and tunnel services equipment.

The mechanical and electrical services associated with the station should readily be controlled to achieve typical environmental criteria at the nearest surrounding land uses. The design targets for Metro West should account for the most sensitive potential use within the site, and apply at an assessment location up to the maximum building height proposed in the Masterplan.

Ground-borne noise and vibration from rail operations is best mitigated through vibration isolating the rail track. Mitigating vibration via the design of buildings is more complex and costly, and not feasible for existing structures such as the White Bay Power Station (WBPS). Typically, infrastructure projects would only be required to address impacts on development approved prior to the infrastructure approval. Given the potentially sensitive uses within the WBPS (theatre and library), it is recommended that Metro West be designed to achieve appropriate ground-borne noise and vibration targets for all buildings within Bays West. Detailed criteria should be developed in consultation with Sydney Metro.

2.2 Impact from the development

Whether the development has the potential to impact on land use outside Bays West is dependant of the nature and intensity of uses proposed. Noise generated by local traffic, building service equipment (e.g. air-conditioning and ventilation systems), and general pedestrian activity is expected to have negligible impact on the on the surrounding land use, particularly given the high existing background and ambient noise levels. Emission from building services equipment should readily meet standard criteria such as the NSW *Noise Policy for Industry* [12] and NSW *Assessing Vibration: A Technical Guideline* (AVTG) [15]. It is expected that impacts upon the uses within Bays West would govern mitigation and management requirements rather than the surrounding land uses.

The draft Masterplan also proposes a range of cultural, community and recreational uses that are to cater for the broader community during the day, evening and night. Given the limited extent of noise sensitive receivers near the site, and the otherwise high background and ambient noise levels in the area, Bays West offers significant opportunity and flexibility to create a highly active and vibrant location with a range of indoor and outdoor uses, while limiting impact on surrounding existing development.

However, the types of uses within Bays West have the greater potential to limit this opportunity. The inclusion of sensitive uses that typical warrant higher levels of outdoor amenity, such as residential and educational development, are likely to introduce greater constraints or require more considered assessment of noise impacts. For entertainment and recreational uses, current NSW noise policy places the onus of noise control solely on the emitter of noise, which can unduly restrict opportunities to incorporate active and vibrant uses. A master planned development however provides an opportunity to improve upon this situation and seek a more balanced approach, particularly for future noise sensitive development within the entire Bays West Precinct. While exclusion of sensitive uses provides greater flexibility, approaches have been implemented on other mixed-use precincts, and typically involves noise sensitive development to incorporate a level of acoustic mitigation to respond to the future environment, which enables greater opportunity and certainty for future operations. Critically, however, is determining the appropriate balance between the level of activation and the mitigation requirements and amenity outcomes for noise sensitive development, which should be determined prior to the first detailed DA. This should include a relatively comprehensive assessment of proposed activation.

These considerations are also critical within mixed-use buildings. For example, the siting of event spaces hub within the Power Station building should be carefully planned from the outset to ensure the operational requirements of each use are appropriately factored into the spatial arrangement, design and construction of the uses.

3 Conclusion

This acoustic report provides a high-level review of the draft Masterplan with consideration of potential impacts from the surrounding environment, impacts from the proposed uses and within Bays West Stage 1.

While a detailed quantitative assessment has not been carried out, the following observations and recommendations are made:

Environmental noise and vibration exposure and influence on land-use

- The site is exposed to moderate to high levels of existing environmental noise, from road traffic (south and west), and port vessel and landside noise (northeast and east).
- The level and character of noise exposure is expected to have reasonable impact on the proposed residential uses, warranting high levels of building sound insulation and compromised external amenity. As these sources impact a large area of the site, and from different directions, siting and orientation of buildings is not expected to provide significant benefit.
- A preliminary quantitative assessment has been carried out of road traffic and port noise to inform the suitability of residential land use. This indicated that external amenity would generally be low, and technical compliance with internal criteria may be feasible, however very high sound insulation performance is required and alternative ventilation would be required.
- Given the likely 5+ year period before new mixed-use development will be assessed, combined with the changing environmental circumstances, it is recommended that detailed acoustic testing is undertaken prior to future development applications being submitted.
- Commercial, retail, recreational and entertainment uses, while also potentially impacted by road and port noise, may still require moderate to high levels of sound insulation to provide acceptable internal occupant amenity. Cultural spaces such as theatres may warrant higher levels of sound attenuation, and their siting should have due regard for intermittent or low frequency noise from port activities, which may warrant higher levels of sound attenuation.
- The opportunity to integrate mitigation into the works being carried out for Westconnex is recommended to be investigated, particularly noise from Victoria Road and ANZAC Bridge to the southern entry and WBPS Plaza. Road traffic noise mitigation would likely only be beneficial if incorporated at the elevated position of the road. Detailed assessment would be required to evaluate whether any options could provide reasonable benefit to the site.

Sydney Metro West

- The design targets for noise and vibration emission from the Metro West station and rail operations should include all potential uses within the site. Both station noise and rail vibration are most feasibly addressed by mitigating at the source rather than through the design of the future buildings. Detailed criteria should be developed in consultation with Sydney Metro.

Potential impacts from the development

- It is considered that potential noise and vibration impact from Bays West Stage 1 on surrounding land use can be readily managed.
- Given the limited extent of noise sensitive receivers near the site, and the otherwise high background and ambient noise levels in the area, the site offers significant opportunity to create a highly activated area during the day, evening and night through the proposed range of cultural, community and recreational uses.
- The types of uses within Bays West will likely have the greatest influence of the level of activation. The inclusion of sensitive uses, that typical warrant higher levels of outdoor amenity, such as residential and educational development, are likely to introduce greater constraints or require more considered assessment of noise impacts.
- A comprehensive assessment of proposed indoor and outdoor uses should be carried out prior to the first detailed Development Application and should ideally inform site specific development design considerations so that future uses can be appropriately planned and design for the future acoustic environment.
- Detailed planning is also recommended where uses of varied intensity and sensitivity are proposed in the same building. Mixed-use buildings must be carefully planned from the outset to minimise potential constraints or conflict.

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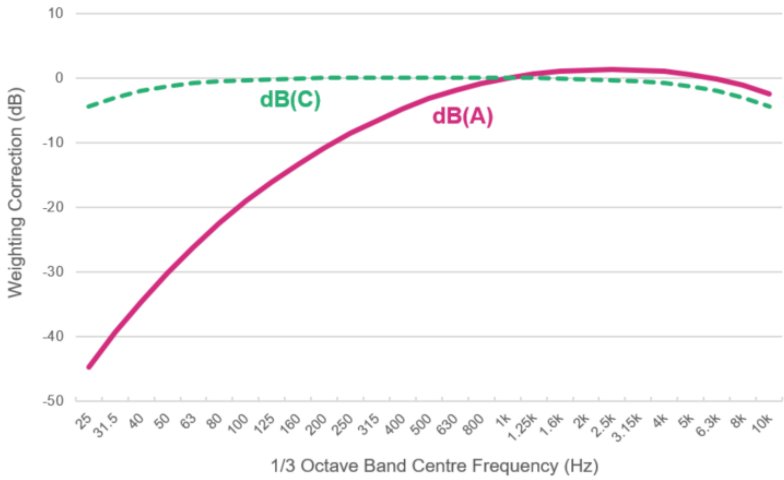
Appendix A

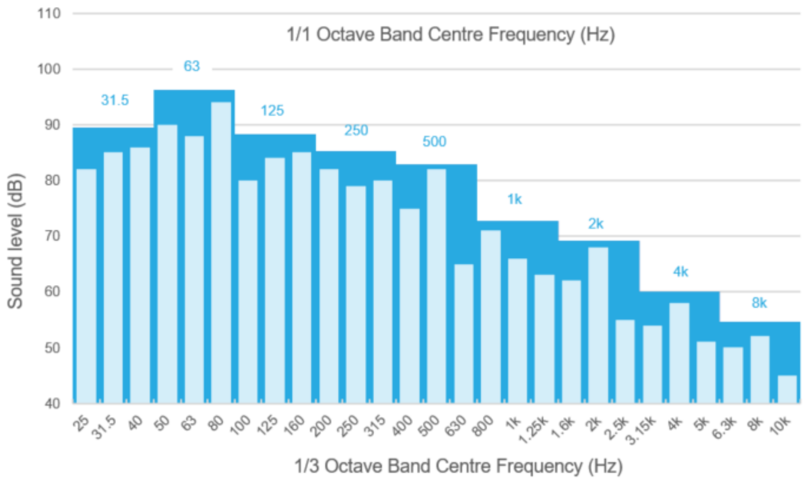
Acoustic Glossary

Term	Definition
Ambient noise level	The ambient noise level is the overall noise level measured at a location from multiple noise sources. When assessing noise from a particular development, the ambient noise level is defined as the remaining noise level in the absence of the specific noise source being investigated. For example, if a fan located on a building is being investigated, the ambient noise level is the noise level from all other sources without the fan operating, such as traffic, birds, people talking and other noise from other buildings.
Background noise level	The background noise level is the noise level that is generally present at a location at all or most times. Although the background noise may change over the course of a day, over shorter time periods (e.g. 15 minutes) the background noise is almost-constant. Examples of background noise sources include steady traffic (e.g. motorways or arterial roads), constant mechanical or electrical plant and some natural noise sources such as wind, foliage, water and insects. **Assessment Background Level (ABL):** A single-number figure used to characterise the background noise levels from a single day of a noise survey. ABL is derived from the measured noise levels for the day, evening or night time period of a single day of background measurements. The ABL is calculated to be the tenth percentile of the background L_{A90} noise levels – i.e. the measured background noise is above the ABL 90% of the time. **Rating Background Level (RBL / min$L_{A90,1hour}$):** A single-number figure used to characterise the background noise levels from a complete noise survey. The RBL for a day, evening or night time period for the overall survey is calculated from the individual Assessment Background Levels (ABL) for each day of the measurement period, and is numerically equal to the median (middle value) of the ABL values for the days in the noise survey.
Decibel (dB)	The logarithmic scale used to measure sound and vibration. Human hearing is not linear and involves hearing over a large range of sound pressures, which would be challenging to present on a linear scale. A logarithmic scale allows all sound levels to be expressed based on how loud they are relative to a reference sound (typically 20 µPa, which is the approximate human threshold of hearing). For sound in other media (e.g. underwater noise) a different reference level (1 µPa) is used instead. An increase of approximately 10 dB corresponds to a subjective doubling of the loudness of a noise. The minimum increase or decrease in noise level that can be noticed is typically 2 to 3 dB.
dB weighting curves	The frequency of a sound affects its perceived loudness and human hearing is less sensitive at low and very high frequencies. When seeking to represent the summation of sound pressure levels across the frequency range of human hearing into a single number, weighting is typically applied. Most commonly, A-weighting, denoted as dB(A), is used for environmental noise assessment. This is often supplemented by the linear or C-weighting curves, where there is the potential for excess low-frequency sound at higher sound pressure levels.

Term	Definition
	
dB(A)	dB(A) denotes a single-number sound pressure level that includes a frequency weighting ('A-weighting') to reflect the subjective loudness of the sound level. The frequency of a sound affects its perceived loudness. Human hearing is less sensitive at low and very high frequencies, and so the A-weighting is used to account for this effect. An A-weighted decibel level is written as dB(A). Some typical dB(A) levels are shown below.

Sound Pressure Level dB(A)	Example
130	Human threshold of pain
120	Jet aircraft take-off at 100 m
110	Chain saw at 1 m
100	Inside nightclub
90	Heavy trucks at 5 m
80	Kerbside of busy street
70	Loud stereo in living room
60	Office or restaurant with people present
50	Domestic fan heater at 1m
40	Living room (without TV, stereo, etc)
30	Background noise in a theatre
20	Remote rural area on still night
10	Acoustic laboratory test chamber
0	Threshold of hearing

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'. The unit of frequency is the hertz (Hz), which is identical to cycles per second. A thousand Hz is generally denoted as kHz. Human hearing ranges approximately from 20 Hz to 20 kHz. While single weighted sound pressure levels simplify the assessment and evaluation of sound levels, frequency analysis is often undertaken. 'Octave

Term	Definition
	bands', either 1/1 or 1/3 octave bands are most commonly utilised and are referred to by the nominal centre frequency of the band (e.g. 31.5 Hz), while being the summation of all frequencies between a defined lower and upper frequency. 
$L_{1(period)}$	The sound level exceeded for 1% of the measurement period. For example, 65 $dBL_{A1,1min}$ indicates that the A-weighted sound level would not exceed 65 dB for more than 0.6 seconds in the 1-minute measurement period.
$L_{10(period)}$	The sound level exceeded for 10% of the measurement period, or alternatively, the sound levels would be lower for 90% of the time. The L_{10} is often defined as the 'average maximum' sound levels, as in AS1055-1978 with the advent of statistical sound level meters.
$L_{90(period)}$	The sound level exceeded for 90% of the measurement period. The L_{90} is often defined as the 'average minimum' or 'background' noise level for a period of measurement. For example, 45 $dBL_{A90,15min}$ indicates that the sound level is higher than 45 dB(A) for 90% of the 15-minute measurement period.
$L_{eq(period)}$	The equivalent ('eq') continuous sound level, used to describe the level of a time-varying sound or vibration measurement. The L_{eq} is often defined as the 'average' level, and mathematically, is the energy-average level over a measurement period – i.e. the level of a constant sound that contains the same sound energy as the measured sound.
L_{max}	The L_{max} is the 'absolute maximum' level of a sound or vibration recorded over the measurement period. As the L_{max} is often caused by an instantaneous event, it can vary significantly between measurements.
Peak Particle Velocity (PPV)	The highest velocity of a particle (such as part of a building structure) as it vibrates. PPV is commonly used as a vibration criteria, and is often interpreted as a PPV based on the L_{max} or $L_{max,spec}$ index.
Sound Power and Sound Pressure	The sound power level (L_w) of a source is a measure of the total acoustic power radiated by a source. The sound pressure level (L_p) varies as a function of the environment and distance from a source. 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.

Term	Definition
Sound Reduction Index (R)	A measure of the sound level loss through a material for a particular frequency band. Sound reduction index is sometimes also referred to as **transmission loss.** It is a property of the component, unlike the sound level difference, which is affected by the common area between the rooms and the acoustics of the receiving room. R is the ratio (expressed in decibels) of the sound energy transmitted through the building element to the sound energy incident on the building element for a particular frequency band. The **weighted sound reduction index**, R_w, is a single figure description of sound reduction index across multiple frequency bands and is defined in BS EN ISO 717-1: 1997. R_w values are calculated from measurements in an acoustic laboratory. Note however that R_w is only calculated over a frequency range from 100 Hz to 3.15 kHz and hence sound outside of this range is excluded from calculation of R_w – particularly low frequency (bass) sound below 100 Hz. Sound insulation ratings derived from site measurements are referred to as **apparent sound reduction index** (R'_w) ratings.
Spectrum Adaptation Terms (C and C_{tr})	C and C_{tr} denote a spectrum adaptation (in dB) that are added to the R_w or D_w value of a partition to adjust for different sound characteristics. C is used to measure the performance of a partition for medium to high-frequency sound sources, such as speech. C_{tr} is used to measure the performance of a partition for low-frequency sound sources such as road traffic. The values of C and C_{tr} are dependent on the construction of the partition and are usually negative quantities, they typically increase the R_w requirement of a partition. For example, for a partition with an R_w of 56 dB and C_{tr} -6 dB, the R_w+C_{tr} is only 50 dB. The overall performance of the partition is quoted as the sum of the R_w value and the spectrum adaptation terms, e.g. D_w+C 55 dB; R_w+C_{tr} 60 dB.
Structureborne noise	The transmission of noise energy as vibration of building elements. The energy may then be re-radiated as airborne noise. Structureborne noise is controlled by structural discontinuities, i.e. expansion joints and floating floors.
Vibration	Waves in a solid material are called 'vibration', as opposed to similar waves in air, which are called 'sound' or 'noise'. If vibration levels are high enough, they can be felt; usually vibration levels must be much higher to cause structural damage. A vibrating structure (e.g. a wall) can cause airborne noise to be radiated, even if the vibration itself is too low to be felt. Structureborne vibration limits are sometimes set to control the noise level in a space. Vibration levels can be described using measurements of displacement, velocity and acceleration. Velocity and acceleration are commonly used for structureborne noise and human comfort. Vibration is described using either metric units (such as mm, mm/s and mm/s^2) or else using a decibel scale.