Consultants in Acoustics, Vibration & Structural Dynamics
email: sydney@renzotonin.com.au
website: www.renzotonin.com.au

BARANGAROO SOUTH 1A - RESIDENTIAL R8 & R9

OPERATIONAL & CONSTRUCTION NOISE AND VIBRATION REPORT

TF854-01F02 (REV 4) O&CNVA REPORT

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Prepared for:

Lend Lease Project Management & Construction (Australia) Pty Ltd
Level 4, The Bond
30 Hickson Rd, Millers Point
Sydney NSW 2000

Attention: Mr Gerard Graham

Sydney **(Head Office)**
Renzo Tonin & Associates (NSW) Pty Ltd
ABN 29 117 462 861
1/418A Elizabeth St., SURRY HILLS, NSW 2010
PO Box 877 STRAWBERRY HILLS, NSW 2012
Ph (02) 8218 0500 Fax (02) 8218 0501

Melbourne
Brisbane
Gold Coast
Kuwait

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1 INTRODUCTION

Renzo Tonin & Associates (hereon referred to as RT&A) has been engaged by Lend Lease Project Management & Construction (Australia) Pty td to prepare an operational and construction noise & vibration report for two (2) residential buildings located at Barangaroo. This report supports a Project Application (MP11_0002) submitted to the Minister for Planning pursuant to Part 3A of the Environmental Planning and Assessment Act 1979 (EP&A Act). The Application seeks approval for construction of two residential flat buildings (known as Buildings R8 and R9) and associated works at Barangaroo South as described in the Overview of Proposed Development section of this report.

This report utilises the results of long-term noise monitoring results presented within Wilkinson Murray's (WM) document "Barangaroo South, Commercial Building C5 Operational Noise Assessment, October 2011" (hereon referred to as WM C5 Operational Noise Assessment) to represent the existing background and ambient noise environment at potentially affected residential properties near the site.

This report generally sets out the assessment procedures and criteria relevant to the development in relation to:

- Noise emission from the site such as mechanical services,
- Noise onto the site from existing sources such as traffic, and
- Construction noise involved in building R8 and R9.

The work documented in this report was carried out in accordance with the Renzo Tonin & Associates Quality Assurance System, which is based on Australian Standard / NZS ISO 9001.

2 PROJECT DESCRIPTION

2.1 Overview of Proposed Development

The R8 and R9 Project Application seeks approval for the construction and use of two residential flat buildings comprising 161 apartments, ground floor retail, allocation of car parking spaces from the Bulk Excavation and Basement Car Parking Project Application, and the construction of the surrounding ancillary temporary public domain and landscaping.

2.2 Site Location

Barangaroo is located on the north western edge of the Sydney Central Business District, bounded by Sydney Harbour to the west and north, the historic precinct of Millers Point (for the northern half), The Rocks and the Sydney Harbour Bridge approach to the east; and bounded to the south by a range of new development dominated by large CBD commercial tenants.

The Barangaroo site has been divided into three distinct redevelopment areas (from north to south) – the Headland Park, Barangaroo Central and Barangaroo South.

The R8 and R9 Project Application Site area is located within Barangaroo South as shown in Figure 1. The Project Application Site extends over land generally known and identified in the approved Concept Plan as Block X.

2.3 Acoustic Assessment Requirements

This section presents the relevant legislation applicable to the assessment and refers to the Noise and Vibration legislation, guidelines and standards.

2.3.1 Director General's Recommendations

The Director General's Requirements issued by the Department of Planning and Infrastructure for R8 & R9 specifically require:

1. *Address potential noise impacts, in particular during the construction and operation of the development and appropriate mitigation measures.*
2. *The Environmental Assessment should include an assessment of noise and vibration impacts, prepared in consultation with DECCW. All feasible and reasonable noise impact mitigation measures should be implemented. The assessment should be prepared in accordance with the NSW government's Interim Construction Noise Guideline, Industrial Noise Policy and Application Notes, Environmental Criteria for Road Traffic Noise and Assessing Vibration: A Technical Guide, as appropriate, available at: http://www.environment.nsw.gov.au/noise/*

2.3.2 Guidelines

- British Standard 7385: Part 2 "Evaluation and measurement of vibration in buildings";
- German standard DIN 4150 - Part 3 - "Structural vibration in buildings - Effects on Structures";
- NSW Assessing Vibration – A Technical Guideline (AVTG, DECC 2006);
- NSW OEH (ex DECCW) Environmental Criteria for Road Traffic Noise (ECRTN), 1999;
- NSW Industrial Noise Policy (INP, EPA 2000);
- NSW Interim Construction Noise Guideline (ICNG, DECC 2009); and
- City of Sydney Council DCP – Specifically relating to Acoustic Privacy not addressed in the above documents.

2.3.3 Background Documents

- Wilkinson Murray (Sydney) Pty Ltd, Barangaroo South, Commercial Building C5 Operational Noise Assessment, October 2011; and
- Wilkinson Murray (Sydney) Pty Ltd, Barangaroo South, Construction of Commercial Building C5 Planning Application Construction Noise & Vibration Assessment, October 2011.

3 EXISTING NOISE ENVIRONMENT & NEAREST SENSTIVE RECEIVERS

Noise impacts at the residential premises are assessed against noise goals established from the existing noise environment of the area without the subject development in operation or under construction. Appendix B of the NSW DECCW's Industrial Noise Policy (INP) presents two methods of determining the background noise levels of an area being '*B1 – Long-term background noise method*' and '*B2 – Short-term background noise method*'. For the subject assessment, long-term noise monitoring was utilised to establish the existing acoustic environment.

3.1 Existing Noise Environment

Existing noise data is used for setting noise criteria for future noise generation from the site, including construction and operational noise.

Background noise varies over the course of any 24 hour period, typically from a minimum at 3am in the morning to a maximum during morning and afternoon traffic peak hours. Therefore, the NSW EPA requires that the level of background and ambient noise be assessed separately for the daytime, evening and night-time periods when noise from a site or facility is assessed. These periods are defined as follows:

- **Day** is defined as 7:00am to 6:00pm, Monday to Saturday and 8:00am to 6:00pm Sundays & Public Holidays.
- **Evening** is defined as 6:00pm to 10:00pm, Monday to Sunday & Public Holidays.
- **Night** is defined as 10:00pm to 7:00am, Monday to Saturday and 10:00pm to 8:00am Sundays & Public Holidays.

Appendix B of the NSW DECCW Industrial Noise Policy (INP) presents two methods of determining the existing noise levels of an area being '*B1 – Long-term background noise method*' and '*B2 – Short-term background noise method*'.

As presented in the WM C5 Operational Noise Assessment, long-term unattended monitoring was undertaken at eight (8) monitoring locations. The noise monitoring locations in Table 1 and Figure 1 were respectively reproduced from Table 2-2 and Figure 2-1 of the WM C5 Operational Noise Assessment.

Table 1 – Long-term Noise Monitoring Locations

Monitoring Location ID	Monitoring Location	Monitoring Period in 2010	Company
L1	Level 4, The Bond 30-38 Hickson Rd	14 April to 29 April	ARUP
L2	Middle of South Barangaroo Site	14 April to 29 April	ARUP
L3	South East of site adjacent to Sussex St	14 April to 29 April	ARUP
L4	South of site adjacent to King Street Wharf	14 April to 29 April	ARUP

Monitoring Location ID	Monitoring Location	Monitoring Period in 2010	Company
L5	3 High Street, Millers Point	31 August – 9 September	WM
L6	18 Merriman Street, Dawes Point	31 August – 6 September	WM
L7	25 Edward Street, Balmain East	31 August – 9 September	WM
L8	Adjacent to 3 Darling Island Rd, Darling Island	31 August – 9 September	WM

For the purpose of this assessment the monitoring data in Table 2 was reproduced from Table 2-3 of the WM C5 Operational Noise Assessment.

Table 2 –Measured Existing Background (L_{A90}) & Ambient (L_{Aeq}) Noise Levels

Monitoring Location ID	L_{A90} Background Noise Levels				L_{Aeq} Ambient Noise Levels			
	Day	Evening	Night	Saturday	Day	Evening	Night	Saturday
L1 - 30-38 Hickson Rd	53	53	49	51	62	61	57	60
L2 – Middle of Site	52	50	45	50	56	54	50	56
L3 - Sussex St	60	59	49	57	67	66	62	66
L4 - King Street Wharf	52	60	46	48	60	62	60	60
L5 – 3 High St	47	44	41	45*	58	55	51	55
L6 – 18 Merriman St	46	44	40	46*	58	55	50	56
L7 – 25 Edward St	49	45	40	46*	67	51	47	56
L8 - Darling Island	47	44	39	50*	54	49	46	56

Notes: Day is defined as 7:00am to 6:00pm, Monday to Saturday; 8:00am to 6:00pm Sundays & Public Holidays.
Evening is defined as 6:00pm to 10:00pm, Monday to Sunday & Public Holidays.
Night is defined as 10:00pm to 7:00am, Monday to Saturday; 10:00pm to 8:00am Sundays & Public Holidays.
** Determined from the afternoon on Saturday, 4 September as the morning was affected by rain.*

It is not specified in the WM C5 Operational Noise Assessment how RBLs were determined, but typically noise data is analysed to determine an assessment background level (ABL) for each day, evening and night period in each 24 hour period of noise monitoring, and based on the median of individual ABLs an overall single Rating Background Level (RBL) for the day, evening and night period is determined over the entire monitoring period in accordance with the NSW 'Industrial Noise Policy' (INP).

Appendix A of this report presents a description of acoustic terms.

3.2 Nearest Sensitive Receivers

The nearest potentially affected receivers to buildings R8 and R9 are presented in Table 3.

Figure 1 presents the site and surrounds of the study area and location of the proposed R8 and R9 buildings, along with the nearest affected receivers.

Table 3 – Nearest Receivers

Receiver ID	Receiver Location	Distance from Site (Approx. m)
	Residential Receivers	
R1	High Street, Millers Point	350
R2	38 Hickson Rd, Millers Point	180
R3	Sydney Wharf Apartments, Pirrama Road, Pyrmont	240
R4	Darling Island Apartments, Darling Island Rd and Wharf Cr, Darling Island	370
R5	Edward St, Balmain East	670
R6	Dawes Point	670
	Commercial Receivers	
C1	Aon Australia, Napoleon St	175
C2	Symantec, Napoleon St	175
C3	KMPG (American Express), Cnr of Sussex and Shelley St	80
C4	Lime St, (King Street Wharf)	40
C5	Temporary Cruise Terminal	330
C6	30 Hickson St, Millers Point	230
	Heritage Receivers	
H1	Former Grafton Bond Store, Hickson Rd, Millers Point	155
H2	The Sussex Hotel, 20-26 Sussex St, Sydney	155

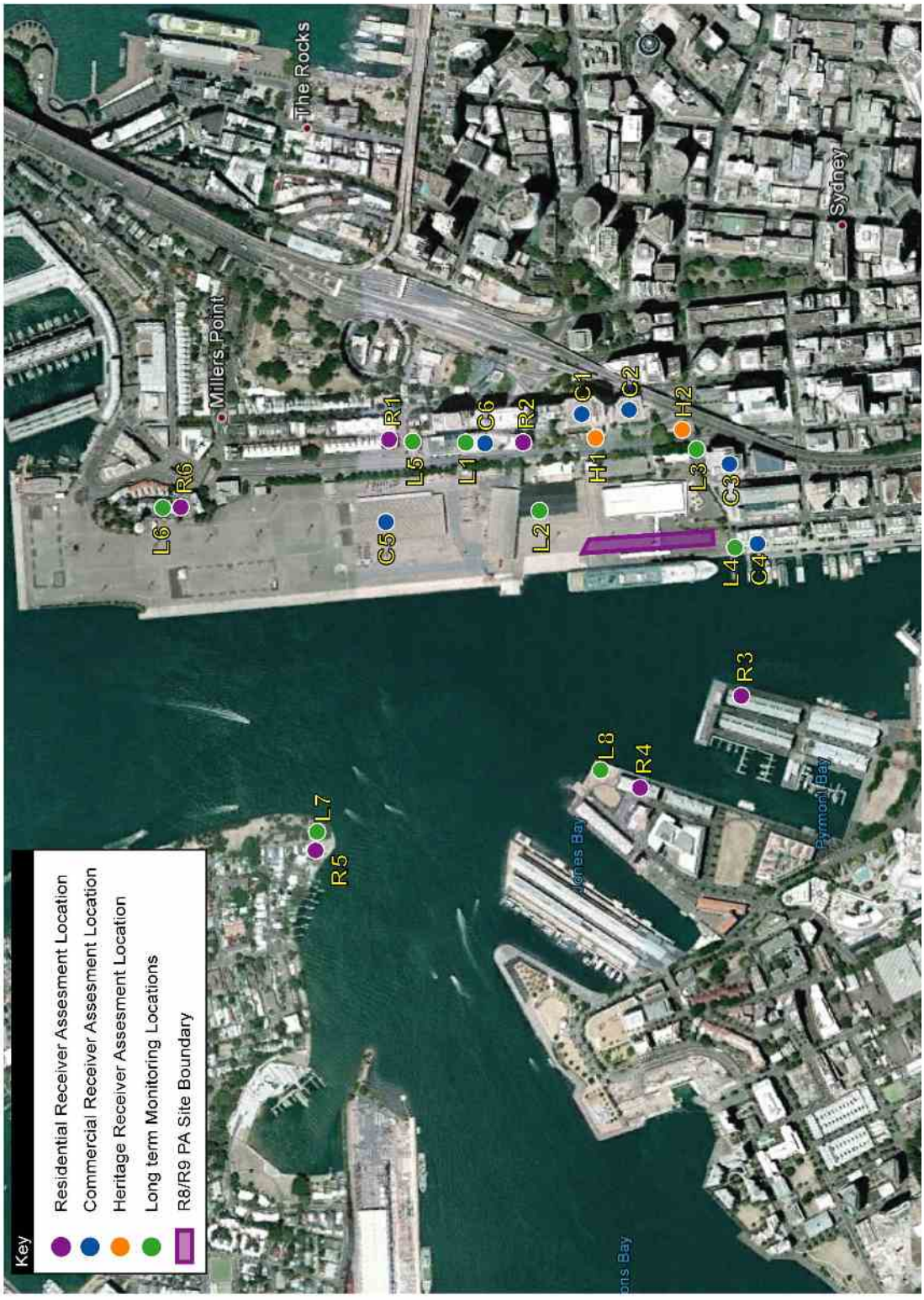


Figure 1 – Locality Map showing Site and Surrounds

4 OPERATIONAL NOISE AND VIBRATION

Operational noise from the proposed R8 and R9 buildings will be from mechanical plant located predominantly on the rooftop of the development. It is noted that retail uses are proposed on the ground floor; however these will be subject to separate Applications for their specific uses.

4.1 Operational Noise Criteria

Noise impact from the general operation of the proposed R8 and R9 buildings is to be assessed against the NSW Industrial Noise Policy (INP). The assessment procedure in terms of the INP has two components:

- Controlling intrusive noise impacts in the short term for residences
- Maintaining noise level amenity for particular land uses for residences and other land uses.

In accordance with the INP, noise impact should be assessed in terms of both intrusiveness and amenity. Based on the background and ambient noise monitoring carried out at the nearest affected residential locations, the industrial noise criteria are:

Table 4 – Project Specific Industrial Noise Criteria

Receiver ID	Representative Monitoring Location ID	Intrusiveness Criteria $L_{Aeq,15min}$			Amenity Criteria[1] $L_{Aeq,\ period}$		
		Day	Evening	Night	Day	Evening	Night
R1	L5	52	49	46	60	50	45
R2	L1	58	58	54	60	50	45
R3	L8	52	49	44	60	50	45
R4	L8	52	49	44	60	50	45
R5	L7	54	50	45	55	45	40
R6	L6	51	49	45	60	50	45
C1	-	-	-	-	65 (when in use)		
C2	-	-	-	-	65 (when in use)		
C3	-	-	-	-	65 (when in use)		
C4	-	-	-	-	65 (when in use)		
C5	-	-	-	-	65 (when in use)		
C6	-	-	-	-	65 (when in use)		
H1	-	-	-	-	65 (when in use)		
H2	-	-	-	-	65 (when in use)		

Notes: Residential locations has been categorised as 'Urban', except at R5 (Balmain East) which has been categorised as 'Suburban'. Given that the existing noise environment is not influenced by existing industry, the Amenity Criteria have not been modified in accordance with Table 2.2, NSW INP.

Ambient noise monitoring results not relevant for determination of commercial receiver criteria.

The INP amenity criterion requires assessment of total industrial noise emission/impact. In the case of a large development site such as Barangaroo, the cumulative impact of the development needs to be considered to the surrounding receivers. This aspect has been

addressed within the previously approved commercial development at Barangaroo, which considered potential noise from the R8 and R9 residential buildings.

4.1.1 Sleep Disturbance Noise Criteria (EPA)

Noise emanating from site operations after 10:00pm and before 7:00am should also be assessed for its potential to creating sleep disturbance. The INP does not address the issue of sleep disturbance, however a number of other publications produced by the EPA make the general observation that a person's sleep can be significantly disrupted by noise and provide guidance on this matter.

Guidance for assessing sleep disturbance resulting from short-duration high-level noises which occur between 10:00pm and 7:00am is taken from the EPA (ex OEH) policy with respect to sleep disturbance. The policy states that a sleep disturbance criterion of $L_{A1(1min)} \leq L_{A90(15min)} + 15dB(A)$, should be used as a first step 'guide' as it is 'not ideal' and 'where it is not met, a more detailed analysis is required'. That detailed analysis includes a reference to the research material contained in the NSW 'Environmental Criteria for Road Traffic Noise' (ECRTN) in the assessment of the subject proposal.

With regard to the project proposal, as noise emission from the site is to be predominantly mechanical plant, which does not typically produce peak noise events and is steady state in nature, sleep disturbance impact from the operation of the development is not expected. On this basis, no further assessment or consideration of sleep disturbance has been addressed in this report.

4.2 Operational Noise Assessment and Recommendations

Detailed specifications of mechanical services equipment that would otherwise allow an acoustic assessment of noise emission from the site are not available for this Application report. In line with the approvals for other development within Barangaroo, and not unlike other similar development within the City of Sydney area, detailed assessment of operational noise emission should form a conditional requirement of the development, to be satisfied prior to the issue of the construction certificate.

It is noted that the acoustic objectives of the INP will also be desired within the Barangaroo site so that the noise amenity of the future R8 and R9 residential development is protected. Therefore the nearest most sensitive receptors to operational noise from the development will be the residential occupancies of the subject buildings, and will be the determining locations for the acoustic design. By satisfying the relevant criteria at the subject site, compliance should readily be achieved at surrounding noise sensitive receptors. Notwithstanding, the cumulative noise emission from the Barangaroo site will be addressed during the detailed design phase.

Mechanical plant such as rooftop exhausts, air-conditioning and refrigeration associated with the development should be assessed at the time of detailed design and selection, having regard to nearby residential and commercial properties surrounding the development, and to future development within Barangaroo South. Any noise emissions from building services associated

with R8 and R9 shall be acoustically treated, where necessary, to comply with relevant Government policies. Although at this stage details of mechanical plant have not been finalised, the following in-principle noise management measures are provided for mechanical plant servicing the proposed development.

- Acoustic assessment of mechanical services equipment will need to be undertaken during the detail design and equipment selection phase of the development to ensure that they shall not either singularly or in total emit noise levels which exceed the noise limits;
- As noise control treatment can affect the performance of the mechanical services system, it is recommend that consultation with an acoustic consultant be made during the initial phase of detailed mechanical services system design in order to reduce the need for revision of mechanical plant and noise control treatment;
- Mechanical plant noise emission can be controllable by appropriate mechanical system design and implementation of common engineering methods that may include any of the following:
    - strategic positioning of plant away from sensitive neighbouring premises, maximising the intervening shielding between the plant and sensitive neighbouring premises,
    - commercially available silencers or acoustic attenuators for air discharge and air intakes of plant;
    - acoustically lined and lagged ductwork;
    - acoustic screens and barriers between plant and sensitive neighbouring premises; and/or
    - partially-enclosed or fully-enclosed acoustic enclosures over plant.
- Mechanical plant shall have their noise specifications and their proposed locations checked prior to their installation on site; and
- Fans shall be mounted on vibration isolators and balanced in accordance with Australian Standard 2625 "Rotating and Reciprocating Machinery – Mechanical Vibration".

4.3 Road Traffic Noise Assessment

An assessment of road traffic noise is considered in respect of the potential for additional traffic generated by the development. The majority of vehicular movements associated with the residential development will be by via the basement car park which was approved under a separate application. Further assessment or consideration of noise generated by vehicular movements associated with the residential building R8 and R9 has not been undertaken. As the basement is common across the adjacent commercial sites, a holistic noise assessment would in any case be required.

5 NOISE IMPACT UPON RESIDENTIAL DEVELOPMENT

Noise impact upon the residential buildings R8 and R9 is an important consideration in terms of the amenity for occupants of the buildings. Whilst the Director General's requirements do not outline any relevant criteria or guidelines with regard to noise impact upon the development, reference has been made to the City of Sydney Council's DCP, which provides objectives and criteria for internal noise levels within residential occupancies.

In addition to the DCP, the residential building must comply with the BCA which sets out requirements for sound insulation between tenancies. Both items do not affect the operational impact of the development on the surrounding area and therefore detailed assessment has not been carried out at this application stage. Whilst, acoustic design of these aspects will be addressed during the design development phase, the design objectives and expected outcomes are discussed below.

5.1 DCP Acoustic Privacy

OBJECTIVES

a) Achieve and maintain minimum standards of acoustic privacy in residential dwellings; and

b) Ensure acoustic impacts on surrounding uses are mitigated in noise generating developments.

PROVISIONS

1. An acoustic assessment, prepared by a specialist with qualifications and experience necessary to render them eligible as a full member of the Australian Acoustical Society (AAS), Institution of Engineers Australia (IEA), or the Australian Association of Acoustical Consultants (AAAC), is to be submitted with all development applications. The assessment is to address, at a minimum:

a) impacts on acoustic privacy of proposed residential uses from any surrounding noise sources such as road traffic and commercial and retail uses;

b) impacts on acoustic privacy of surrounding residential uses from any proposed commercial and retail uses; and

c) the impact of the development on the surrounding area, through mechanical services, earthworks, excavation and construction phases of development.

Note: Development adjacent to a road that may have daily vehicle movements of more than 40,000 vehicles, the development proposal must also comply with State Environmental Planning Policy (Infrastructure) 2007.

2. Where possible, noise is to be attenuated at its source, with applications demonstrating that proposed attenuation measures:

a) have the consent of relevant parties associated with that noise source; and
b) will endure for the life of the development proposal.

3. Dwellings are to be constructed so that in a naturally ventilated situation the repeatable maximum $L_{Aeq\ (1\ hour)}$ level does not exceed:

a) for closed windows and doors:

i. in bedrooms between 10pm and 7am, 35dB; and
ii. in main living area at any time, 45dB.

b) for open windows and doors:

i. in bedrooms between 10pm and 7am, 45dB; and
ii. in main living area at any time, 55dB.

4. Where natural ventilation of a room cannot be achieved, the repeatable maximum $L_{Aeq\ (1hour)}$ level when doors and windows are shut and mechanical ventilation/ air conditioning is operating in a dwelling it is not to exceed:

a) in bedrooms between 10pm and 7am, 38dB; and
b) in main living area at any time, 48dB.
c) These levels are to include the combined measured level of noise from both external sources and the ventilation system operating normally.

5. To limit the transmission of noise to and between dwellings, all floors are to have a weighted standardised impact sound pressure level (L'nT ,w) less than or equal to 55 where the floor separates a habitable room and another habitable room, bathroom, toilet, laundry, kitchen, plant room, stairway, public corridor, hallway and the like.
6. The overall design and layout of dwellings is to include, where appropriate:

a) a limit on window size and number where oriented towards an intrusive noise source;
b) seals at entry doors, to reduce noise transmission from common corridors or outside the building;
c) minimisation of the number of party (shared) walls with other dwelling units;
d) using storage, circulation zones, and non-habitable rooms within a dwelling to buffer noise from external sources;
e) double or acoustic glazing;
f) operable screens to balconies; and
g) continuous walls to ground level courtyards, where there would be no conflict with streetscape, security or other amenity requirements.

5.2 Internal Sound Insulation between Tenancies

As a minimum requirement, walls and floors shall comply with the National Construction Code (NCA) 2012. In addition, consideration is given to the City of Sydney Council's Development

Control Plan sets out more onerous requirements for floor impact. It is recommended that the DCP requirements are also met for the design.

5.3 Future Ambient Noise Levels

The noise environment to which the residential development will be situated will differ once the site has been developed. Whilst marine activities may be similar, increased pedestrian activity, mechanical plant and hospitality venues are expected to increase noise in the area. The extent to which this future activity impacts the residential buildings R8 and R9 is dependent upon the siting and design of the other noise generating development/sources and the patterns of pedestrian movement in the area. Noise levels are also expected to vary at the different facades of the R8 and R9 building due to their orientation to these activities. Noise emission from mechanical plant serving the commercial towers C3, C4 and C5 should be designed to achieve acceptable external noise amenity at the residential receptor locations of the R8 and R9 buildings.

Notwithstanding the above, investigations carried out by Wilkinson Murray determined the following estimated ambient noise levels for the Barangaroo site, being based on measurements carried out at East Circular Quay, Darling Walk and Harbourside.

Table 5 – Estimated Future Ambient Noise Levels at Barangaroo South Precinct

Location	$L_{Aeq,\ period}$			$L_{A1,\ period}$		
	Day	Evening	Night	Day	Evening	Night
Barangaroo South	62	60	56	70	65	60

5.4 Acoustic Assessment Requirements for Noise Intrusion

Whilst further assessment of the future ambient noise environment is required, based on the estimated noise levels above, the internal noise goals for the residential apartments can be readily address through specification of the building envelope design. For apartment buildings, this is typically isolated to the glazing specification, and in this case is likely to be limited to single laminated glazing. It is noted that a more substantial glazing specification is likely to be required in order to meet the thermal requirements, which can provide greater acoustic performance than that required to meet the internal noise levels. The internal noise amenity requirements can be therefore readily addressed by the design.

6 CONSTRUCTION NOISE & VIBRATION

6.1 Projected Program & Schedule

Construction of R8 and R9 is expected to occur from December 2013 to June 2015, and therefore in accordance with the NSW *Interim Construction Noise Guideline* (ICNG) a quantitative noise assessment should be carried out.

6.2 Construction Noise Guideline

Construction activities related to the development of the site should be managed and assessed in accordance with the NSW *ICNG*. This document is currently issued as an interim guideline, and is being referred to as the NSW standard policy for assessing construction noise on new projects.

The key components of the ICNG that can be incorporated into this assessment include:

1. Use of L_{Aeq} as the descriptor for measuring and assessing construction noise

In recent years NSW noise policies including the Industrial Noise Policy (INP) and the Environmental Criteria for Road Traffic Noise (ECRTN) have moved to the primary use of L_{Aeq} over any other descriptor. As an energy average, L_{Aeq} provides ease of use when measuring or calculating noise levels since a full statistical analysis is not required as when using, for example, the L_{A10} descriptor. Consistent with the latest guideline (ICNG) the use of L_{Aeq} as the key descriptor for measuring and assessing construction noise is to be used.

2. Application of feasible and reasonable noise mitigation measures

As stated in the ICNG, a noise mitigation measure is feasible if it is capable of being put into practice, and is practical to build given the project constraints. Selecting reasonable mitigation measures from those that are feasible involves making a judgement to determine whether the overall noise benefit outweighs the overall social, economic and environmental effects, including the cost of the measure. In other words the suitability of noise mitigation to each site needs to be considered.

3. Quantitative and qualitative assessment

The ICNG provides two methods for assessment of construction noise, being either a quantitative or a qualitative assessment. A quantitative assessment is recommended for major construction projects of significant duration, and involves the measurement and prediction of noise levels, and assessment against set criteria.

A qualitative assessment is recommended for small projects with a short-term duration where works are not likely to affect an individual or sensitive land use for more than three weeks in total. It focuses on minimising noise disturbance through the implementation of feasible and reasonable work practices, and community notification.

4. Management Levels

Residences

Table 6 below (reproduced from Table 2 of the ICNG) sets out the noise management levels and how they are to be applied. The rating background level (RBL) is used when determining the management level. The RBL is the overall single-figure background noise level measured in each relevant assessment period (during or outside the recommended standard hours).

Table 6 – Noise at Residences Using Quantitative Assessment

Time of Day	Management Level $L_{Aeq\ (15\ min)}$*	How to Apply
Recommended standard hours: Monday to Friday 7:00am to 6:00pm Saturdays 8:00am to 1:00pm	Noise affected RBL + 10dB(A)	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.
	Highly noise affected 75dB(A)	The highly noise affected level represents the point above which there may be strong community reaction to noise. ▪ Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: 1. times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences 2. if the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours	Noise affected RBL + 5dB(A)	▪ 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 5dB(A) above the noise affected level, the proponent should negotiate with the community. ▪ For guidance on negotiating agreements see section 7.2.2.

** Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5m 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.*

^ City of Sydney Standard Construction Hours

Commercial and Industrial Premises

The process of defining management levels for commercial and industrial premises is separated into three categories as follow;

- Industrial premises: external $L_{Aeq\ (15\ min)}$ 75 dB(A)
- Offices, retail outlets: external $L_{Aeq\ (15\ min)}$ 70 dB(A)
- Other businesses that may be very sensitive to noise, where the noise level is project specific.

The recommended 'maximum' internal noise levels in AS/NZS 2107:2000 'Acoustics – Recommended design sound levels and reverberation times for building interiors' may be referenced to assist in the determination of relevant noise levels for other noise-sensitive businesses.

6.3 Construction Hours

Construction of residential buildings R8 and R9 are to be consistent with the ICNG standard hours on weekdays (Monday to Friday), being between 7:00am to 6:00pm. However, consistent with the currently approved construction works at Barangaroo, Saturday work is proposed to be extended beyond the ICNG hours to 7:00am to 5:00pm. These proposed hours are consistent with the City of Sydney Councils Category 1 hours and therefore considered equivalent to the ICNGs standard hours in their application to the City of Sydney CBD zone.

The City of Sydney policy specifies a criteria of up to background + 10dB(A) for Category 1 hours, being consistent with the ICNG noise affected goals. It is noted that with the exception of Darling Island, the noise monitoring results for all residential receiver locations revealed that the ambient L_{Aeq} noise level on the Saturday was at least background + 10dB(A). In the case of the Darling Island location, the Saturday L_{Aeq} during the proposed construction period is only 1dB(A) lower than the established noise affected target. On this basis the proposed Saturday construction hours have been assessed against the standard ICNG goals.

6.4 Construction Noise Goals

Table 7 below sets out the construction noise goals relevant for the various receiver locations.

Table 7 – Construction Noise Criteria, dB(A)

Receiver ID	Receiver Location	Representative Monitoring Location ID	Standard Construction Hours*		
			Day RBL	Noise Affected	Highly Noise Affected
R1	High Street, Millers Point	L5	47	57	75
R2	38 Hickson Rd, Millers Point	L1	53	63	75
R3	Sydney Wharf Apartments, Pirrama Road, Pyrmont	L8	47	57	75
R4	Darling Island Apartments, Darling Island Rd and Wharf Cr, Darling Island		47	57	75
R5	Edward St, Balmain East	L7	49	59	75
R6	Dawes Point	L6	46	56	75
C1	Aon Australia, Napoleon St	L3	60	70	75
C2	Symantec, Napoleon St	L3	60	70	75

Receiver ID	Receiver Location	Representative Monitoring Location ID	Standard Construction Hours*		
			Day RBL	Noise Affected	Highly Noise Affected
C3	KMPG (American Express), Cnr of Sussex and Shelley St	L3	60	70	75
C4	Lime St, (King Street Wharf)	L4	52	70	75
C5	Temporary Cruise Terminal	L2	52	70	75
C6	30 Hickson St, Millers Point	L1	53	70	75
H1	Former Grafton Bond Store, Hickson Rd, Millers Point	L3	60	70	75
H2	The Sussex Hotel, 20-26 Sussex St, Sydney	L3	60	70	75

*Note: * Standard Construction hours are 7:00am to 6:00pm Monday to Friday and 7:00am to 5:00pm Saturday.*

6.5 Construction Vibration Guidelines

6.5.1 Disturbance to Buildings Occupants

For disturbance to human occupants of buildings, we refer to DECC's 'Assessing Vibration; a technical guideline', published in February 2006. This document provides criteria which are based on the British Standard BS 6472-1992, 'Evaluation of human exposure to vibration in buildings (1-80Hz)'. Vibration sources are defined as Continuous, Impulsive or Intermittent. Table 8 below provides a definition and examples of each type of vibration.

Table 8 – Types of Vibration

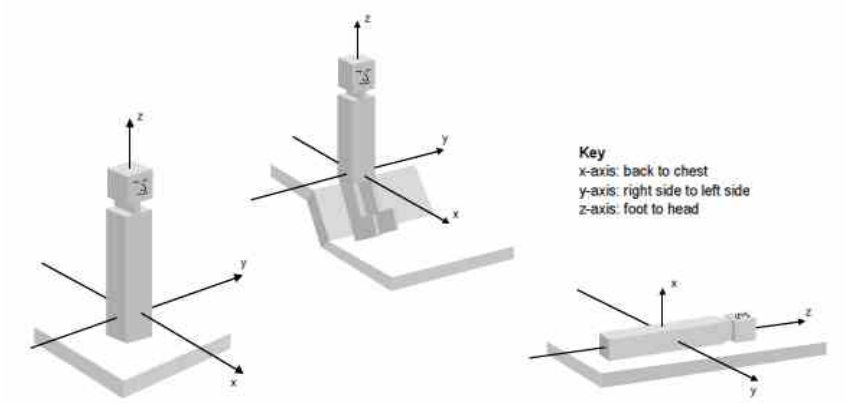
Type of Vibration	Definition	Examples
Continuous vibration	Continues uninterrupted for a defined period (usually throughout the day-time and/or night-time)	Machinery, steady road traffic, continuous construction activity (such as tunnel boring machinery).
Impulsive vibration	A rapid build-up to a peak followed by a damped decay that may or may not involve several cycles of vibration (depending on frequency and damping). It can also consist of a sudden application of several cycles at approximately the same amplitude, providing that the duration is short, typically less than 2 seconds	Infrequent: Activities that create up to 3 distinct vibration events in an assessment period, e.g. occasional dropping of heavy equipment, occasional loading and unloading.
Intermittent vibration	Can be defined as interrupted periods of continuous or repeated periods of impulsive vibration that varies significantly in magnitude	Trains, nearby intermittent construction activity, passing heavy vehicles, forging machines, impact pile driving, jack hammers. Where the number of vibration events in an assessment period is three or fewer, this would be assessed against impulsive vibration criteria.

Source: Assessing Vibration; a technical guideline, Dept Environment & Climate Change 2006

The criteria are to be applied to a single weighted root mean square (rms) acceleration source level in each orthogonal axis. Section 2.3 of the guideline states: 'Evidence from research suggests that there are summation effects for vibrations at different frequencies. Therefore, for evaluation of vibration in relation to annoyance and comfort, overall weighted rms acceleration values of the vibration in each orthogonal axis are preferred (BS 6472).'

When applying the criteria, it is important to note that vibration may enter the body along different orthogonal axes, i.e. x-axis (back to chest), y-axis (right side to left side) or z-axis (foot to head). The three axes are referenced to the human body. Thus, vibration measured in the horizontal plane should be compared with x- and y-axis criteria if the concern is for people in an upright position, or with the y- and z- axis criteria if the concern is for people in the lateral position.

Figure 2 – Orthogonal Axes for Human Exposure to Vibration



Source: Assessing Vibration; a technical guideline, Dept Environment & Climate Change 2006 p4

Preferred and maximum values for continuous and impulsive vibration are defined in Table 2.2 of the guideline and are reproduced below. In this assessment, commercial premises are included in the 'Offices, schools, educational institutions and places of worship' category of Table 9 below.

Table 9 – Preferred and Maximum Levels for Human Comfort

Location	Assessment period[1]	Preferred values		Maximum values	
		z-axis	x- and y-axis	z-axis	x- and y-axis
Continuous vibration[3] (Weighted RMS Acceleration, m/s^2, 1-80Hz)					
Critical areas[2]	Day or night time	0.005	0.0036	0.010	0.0072
Residences	Daytime	0.010	0.0071	0.020	0.014
	Night time	0.007	0.005	0.014	0.010
Offices, schools, educational institutions and places of worship	Day- or night time	0.020	0.014	0.040	0.028
Workshops	Day- or nighttime	0.04	0.029	0.080	0.058
Impulsive vibration[3] (Weighted RMS Acceleration, m/s^2, 1-80Hz)					
Critical areas[2]	Day or night-time	0.005	0.0036	0.010	0.0072
Residences	Daytime	0.30	0.21	0.60	0.42
	Night-time	0.10	0.071	0.20	0.14
Offices, schools, educational institutions and places of worship	Day- or night-time	0.64	0.46	1.28	0.92

Location	Assessment period[1]	Preferred values		Maximum values	
		z-axis	x- and y-axis	z-axis	x- and y-axis
Workshops	Day or night-time	0.64	0.46	1.28	0.92
Intermittent vibration[4] (Vibration Dose Values, VDV, $m/s^{1.75}$, 1-80Hz)					
Critical areas[2]	Day or night-time	0.10		0.20	
Residences	Daytime	0.20		0.40	
	Night-time	0.13		0.26	
Offices, schools, educational institutions and places of worship	Day- or night-time	0.40		1.60	
Workshops	Day or night-time	0.80		1.60	

Notes:
1. *Daytime is 7.00 am to 10.00 pm and night-time is 10.00pm to 7.00 am*
2. *Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. There may be cases where sensitive equipment or delicate tasks require more stringent criteria than the human comfort criteria specify above. Stipulation of such criteria is outside the scope of their policy and other guidance documents (e.g. relevant standards) should be referred to. Source: BS 6472-1992*
3. *For continuous and impulsive vibration the preferred and maximum values are weighted acceleration rms values (m/s^2)*
4. *For intermittent vibration the preferred and maximum values are vibration dose values (VDVs), based on the weighted acceleration values ($m/s^{1.75}$)*

Intermittent vibration is assessed using vibration dose values (VDVs). The VDV method is a fourth power approach which is more sensitive to peaks in the acceleration waveform and makes corrections to the criteria based on the duration of the source's operation. The VDV can be calculated using the overall weighted rms acceleration of the vibrating source in each orthogonal axis and the total period during which the vibration may occur. Weighting curves are provided in each orthogonal axis in the guideline. Preferred and maximum VDV values are defined in Table 2.4 of the guideline and are reproduced below.

Table 10 – Acceptable Vibration Dose Values for Intermittent Vibration ($m/s^{1.75}$)

Location	Daytime[1]		Night-time[1]	
	Preferred Values	Maximum Values	Preferred Values	Maximum Values
Critical areas[2]	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
Workshops	0.80	1.60	0.80	1.60

Notes:
1. *Daytime is 7.00 am to 10.00 pm and night-time is 10.00pm to 7.00 am*
2. *Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. These criteria are only indicative, and there may be a need to assess intermittent values against the continuous or impulsive criteria for critical areas. Source: BS 6472-1992*

6.5.2 Structural Damage to Buildings

Currently there is no existing Australian Standard for assessment of structural building damage caused by vibration energy. Therefore, reference is made to both the British and German standards below which are relevant to the assessment of structural damage.

6.5.2.1 British Standard

British Standard 7385: Part 2 "Evaluation and measurement of vibration in buildings", can be used as a guide to assess the likelihood of building damage from ground vibration. BS 7385 suggests levels at which 'cosmetic', 'minor' and 'major' categories of damage might occur.

BS 7385 recommends that the peak particle velocity is used to quantify vibration and specifies damage criteria for frequencies within the range 4Hz to 250Hz, which is the range usually encountered in buildings. At frequencies below 4Hz, a maximum displacement value is recommended. The levels from the standard are given below in Table 11.

Table 11 – BS 7385 Structural Damage Criteria

Group	Type of Structure	Peak Component Particle Velocity, mm/s		
		4Hz to 15Hz	15Hz to 40Hz	40Hz and Above
1	Reinforced or framed structures Industrial and heavy commercial buildings		50	
2	Un-reinforced or light framed structures Residential or light commercial type buildings	15 to 20	20 to 50	50

The peak vibration limits set for minimal risk of 'cosmetic' damage are: 15mm/s for un-reinforced or light framed structures, for example residential or light commercial buildings (Group 2; increasing as the frequency content of the vibration increases) and 50mm/s for reinforced or framed structures, for example industrial and heavy commercial buildings (Group 1; constant across all frequencies). 'Minor' damage is considered possible at vibration magnitudes which are twice those given and 'major' damage to a building structure may occur at levels greater than four times those values. These values relate to transient vibrations and to low rise buildings. Continuous vibration can give rise to dynamic magnifications due to resonances and may need to be reduced by up to 50%.

The levels set by this standard are considered 'safe limits' up to which no damage due to vibration effects has been observed for certain particular types of buildings. Damage comprises minor non-structural effects such as hairline cracks on drywall surfaces, hairline cracks in mortar joints and cement render, enlargement of existing cracks and separation of partitions or intermediate walls from load bearing walls. This standard states that it considers sources of vibration including blasting, demolition, piling, ground treatments, compaction, construction equipment, tunnelling, road and rail traffic and industrial machinery.

As stated in the standard, it sets guide values for building vibration based on the lowest levels above which damage has been credibly demonstrated. That is, it gives guidance on the levels of vibration above which building structures could be damaged.

6.5.2.2 German Standard

The German standard DIN 4150 – Part 3 – "Structural vibration in buildings – Effects on Structures", also provides recommended maximum levels of vibration that reduce the likelihood

of building damage caused by vibration. This standard too, presents recommended maximum limits over a range of frequencies measured in any direction at the foundation or in the plane of the uppermost floor.

The minimum 'safe limit' of vibration at low frequencies for commercial and industrial buildings is 20mm/s. For dwellings, it is 5mm/s and for particularly sensitive structures (e.g. historical with preservation orders etc.), it is 3mm/s. These limits increase as the frequency content of the vibration increases.

The criteria are presented in Table 12 below and are generally recognised to be conservative.

Table 12 – DIN 4150-3 Structural Damage Criteria

Group	Type of Structure	Vibration Velocity, mm/s			
		At Foundation and at Frequency of			Plane of Floor Uppermost Storey
		1Hz to 10Hz	10Hz to 50Hz	50Hz to 100Hz	All Frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or use	5	5 to 15	15 to 20	15
3	Structures that because of their particular sensitivity to vibration, do not correspond to those listed in Group 1 or 2 and have intrinsic value (e.g. buildings under a preservation order)	3	3 to 8	8 to 10	8

6.6 Construction Noise & Vibration Activities & Sources

6.6.1 Proposed Construction Activities

Whilst some additional bored piling activities are required for the R8 and R9 development, the primary construction activity for R8 and R9 is the general tower construction. This will entail, the primary concrete pours and structural work. As the development progresses, works will be contained to internal fit-out and finishing which will generate minimal noise emission to the surrounding area, in particular once the facade is complete.

Construction of R8 and R9 will coincide with the construction of other commercial buildings within Barangaroo South, so a quantitative assessment has also been undertaken to address cumulative impacts.

6.6.2 Construction Noise Sources

The following table lists construction plant and equipment likely to be used by the contractor to carry out the necessary construction work for R8 and R9. It is noted that the noise level data presented assumes all plant operating continuously and concurrently. The noise level

predictions based on these noise levels are therefore considered higher than that expected when plant equipment operates intermittently or individually.

Table 13 – Typical Construction Equipment & Sound Power Levels, dB(A)

Plant Item	Plant Description	Sound Power Levels (re: 10^{-12} Watts)	
		Typical L_{10} (Mid-Point)	Typical L_{eq} (Mid-Point)
	Piling		
1	Bored Piling Rig	114	111
	Tower Construction		
2	Truck (>20tonne)	106	103
3	Cherry Picker	105	102
4	2 x Concrete Truck	109	106
5	2 x Concrete Pump	105	102
6	2 x Concrete Vibrator	103	100
7	Light commercial vehicles (e.g. 4WD)	103	100
8	4 x Silenced Air Compressor	98	95
9	2 x Tower Crane	113	110
10	2 x Forklifts	94	91
	TOTAL SOUND POWER FOR INDICATIVE PURPOSES		116

Notes: The sound power data within the column marked "Typical L_{eq} (Mid-Point)" has been used in this study to calculate typical noise levels at the nominated assessment locations.

The sound power levels for the majority of activities presented in the above table are based on maximum levels given in Table D2 of Australian Standard 2436 – 1981 "Guide to Noise Control on Construction, Maintenance and Demolition Sites", DECCW's Interim 'Construction Noise Guideline', information from past projects and information held in our library files.

6.6.3 Construction Vibration Sources

Typical vibration levels from construction equipment most likely to cause significant vibration are summarised below. The information was sourced from a variety of reference materials available in the Renzo Tonin & Associates library.

Table 14 – Typical Ground Vibration Generated by Construction Plant

Activity	Typical Ground Vibration
Excavators / Bulldozers	Typical ground vibration from excavators and bulldozers range from 1mm/s to 2mm/s at distances of approximately 5m and at distances greater than 20m, vibration levels are usually below 0.2mm/s.
Compactor	Compactors typically generate 20mm/s at distances of approximately 5m, 2mm/s at distances of 15m. At distances greater than 30m, vibration are usually below 0.3mm/s.
Vibratory rollers	Ground vibration caused by vibratory rollers can range up to 1.5mm/s at distances of 25m. The highest levels of vibration usually occur as the roller is brought to rest and the frequency of the centrifugal forces passes through resonance with the natural frequency of the roller/ground/structure. Machinery should therefore not be brought to rest when in the vicinity of susceptible buildings, especially dwellings. Higher levels could occur at closer distances, however, no damage would be expected for any building at distances greater than approximately 12m (for a medium to heavy roller).

Activity	Typical Ground Vibration
Truck traffic	Typical vibration from heavy trucks passing over normal (smooth) road surfaces generate relatively low vibration levels in the range of 0.01 - 0.2mm/s at the footings of buildings located 10 - 20m from a roadway. Very large surface irregularities can cause levels up to five to ten times higher. In general, ground vibration from trucks is usually imperceptible in nearby buildings. The rattling of windows and other loose fittings that is sometimes reported is more likely to be caused by airborne acoustic excitation from very low frequency (infrasonic) noise radiated by truck exhausts and truck bodies. While this may cause concern to the occupants, the phenomenon is no different from the rattling caused by wind or people walking or jumping on the floor and fears of structural damage or even accelerated ageing are usually unfounded.

Based on the items above, and considering the distance to the vibration sensitive receptors, vibration generated from the construction of the residential towers is not expected to cause damage or adverse human response. On this basis, no further assessment or consideration of mitigation measures has been set out within this report.

6.7 Construction Noise Level Predictions

Noise levels at any given receiver resulting from construction would vary dependent upon the location of the receiver with respect to the construction site, shielding from intervening topography and structures, the type of and duration of operation being undertaken as well as the number of items of equipment and their locations.

Noise predictions for construction activity associated with R8 and R9 have been carried out for the total of all plant listed in Table 13 operating concurrently, and are presented in Table 15 below. As construction of R8 and R9 is to coincide with the construction of the Basement and C3, C4 and C5 tower construction, these activities form the basis of the cumulative scenario presented in Table 15.

Table 15 –Noise Predictions, dB(A)

Receiver ID	Receiver Location	Predicted L_{Aeq} Noise Levels			Noise Targets Standard Hours*	
		R8 & R9 All Plant	Basement & C3, C4 & C5	Cumulative	Noise Affected	Highly Noise Affected
R1	High St, Millers Point	54	56	**58**	57	75
R2	38 Hickson Rd, Millers Point	60	73	**73**	63	75
R3	Sydney Wharf Apartments, Pirrama Road, Pyrmont	57	58	**61**	57	75
R4	Darling Island Apartments, Darling Island Rd and Wharf Cr, Darling Island	54	57	**59**	57	75
R5	Edward St, Balmain East	48	52	54	59	75
R6	Dawes Point	48	52	54	56	75
C1	Aon Australia, Napoleon St	60	67	68	70	75
C2	Symantec, Napoleon St	60	68	68	70	75
C3	KMPG (American Express), Cnr of Sussex and Shelley St	67	70	**72**	70	75
C4	Lime St, (King Street Wharf)	69	67	**71**	70	75
C5	Temporary Cruise Terminal	55	59	60	70	75

C6	30 Hickson St, Millers Point	58	64	65	70	75
H1	Former Grafton Bond Store, Hickson Rd, Millers Point	61	70	70	70	75
H2	The Sussex Hotel, 20-26 Sussex St, Sydney	61	68	69	70	75

*Note: * Standard Construction hours are 7:00am to 6:00pm Monday to Friday and 7:00am to 5:00pm Saturday.*

Noise impacts during the construction of R8 and R9 have been predicted and compared to the construction noise targets for the standard hours of construction. Noise from R8 and R9 construction activities alone are predicted to comply with the 'noise affected' targets at all residential, commercial and heritage listed receivers. However cumulative impacts from all Barangaroo South construction activities were predicted to exceed the noise affected targets at the following locations:

- R1 - High St, Millers Point
- R2 - 38 Hickson Rd, Millers Point
- R3 - Sydney Wharf Apartments, Pirrama Road, Pyrmont
- R4 - Darling Island Apartments, Darling Island Rd and Wharf Cr, Darling Island
- C3 - KMPG (American Express), Cnr of Sussex and Shelley St
- C4 - Lime St, (King Street Wharf)

It is noted that at all of the above locations are predicted to comply with the highly affected targets.

It is noted that the noise predictions do not consider any acoustic shielding that may be provided by either the R8 and R9 or commercial tower structures. Therefore acoustic shielding, and thus a reduction in noise emission will result as the development progresses, particularly for receivers to the east and west of the site. Notwithstanding, consideration of the noise management measures, outlined in Section 6.8, should be considered to minimise noise impact during construction activities.

6.8 Cumulative Construction Noise Impacts

Further to the application assessment by NSW Department of Planning & Infrastructure, it has been requested that the potential for cumulative construction noise impact from other surrounding sites to Barangaroo South be addressed [DP&I letter, MP 11_0002].

6.8.1 Headland Park

The cumulative impact of R8/R9 construction works when combined with the other Barangaroo South and Headland Park works has been considered. The nearest receptors with the potential for cumulative impact with respect to these works are those located in Balmain. As outlined in the C5 Construction Noise and Vibration assessment (S 5.4, p. 33), noise from Barangaroo South works (excluding R8/R9) was more than 10dB(A) below the predicted noise level from the Headland Park works. Based on the predicted noise levels set out in Table 15 of this report, with the inclusion of works from R8/R9, construction noise from Barangaroo South is still more

than 10dB(A) below the Headland Park construction works and therefore will not result in any cumulative increase in noise at the nearest most potentially affected receivers.

6.8.2 Basement Car Park Project

The construction of the basement car park Stage 1b will be largely complete when Buildings C3, C4 and C5 are constructed, particularly by the time that works for the R8 and R9 buildings commence. The only area of the basement excavation works expected to coincide with the R8/R9 construction work is that being undertaken within the Declaration Area of the Barangaroo site (i.e. within Block 4). It is noted that the cumulative noise impact of basement construction work was included in the noise predictions set out in Table 15, and whilst they related more specifically to the Stage 1b works, noise emission associated with the residual portion of basement car park will be consistent with that already included in the assessment. On this basis, no additional cumulative impact beyond that presented in this report is considered to occur as result of the residual basement car park works.

6.8.3 Wynyard Walk

At the time of preparing this Noise and Vibration Assessment information with regard to the schedule and detail of works beyond the REF for the Wynyard Walk and Pedestrian Improvement works were not available and therefore not included in the assessment. However, the pedestrian improvements works are to be completed by the end of November 2012 and therefore not relevant to the cumulative impact assessment.

By reference to the REF of the Wynyard Walk, only Stage 7 works, being the reconfiguration of Shelley Street and construction of the Sussex St bridge is considered to have a potential cumulative impact with the nearest receptors to Barangaroo South. The nearest affected receptors are identified to be commercial premises located on Shelley St. However there is insufficient detail and no predictions presented in the REF to allow a cumulative impact assessment to be carried out. Notwithstanding, as Stage 7 works are to occur towards the end of the Wynyard Walk program, which coincides with the projected end of R8/R9 construction works, it is expected that construction noise from the Baragaroo South development will have progressed beyond the noisier earthworks and structures construction and therefore any cumulative impact is expected to be negligible.

6.8.4 Barangaroo Central Waterfront Promenade and Interim Public Domain SSD

The Barangaroo Central Waterfront Promenade works are to provide the public domain with the predominant works involving paving and minimal structures work. Currently there is no application submitted for the approval of these works however it is expected that equipment and activities associated with these works will be of lower intensity when compared with the remaining Barangaroo South basement and building construction works. On this basis, works associated with the Baragaroo Central Promenade are not expected to result in any cumulative noise and vibration impact to the nearest receptors to the site.

6.9 Construction Noise & Vibration Mitigation

The following recommendations provide in-principle noise control solutions to reduce construction noise and vibration impacts to residential receivers. Where actual construction activities differ from those assessed in this report, more detailed design of noise control measures may be required once specific items of plant and construction methods have been chosen and assessed on site.

The advice provided here is in respect of acoustics only. Supplementary professional advice may need to be sought in respect of fire ratings, structural design, buildability, fitness for purpose and the like.

Implementation of noise control measures, such as those suggested in Australian Standard 2436-2010 "Guide to Noise Control on Construction, Demolition and Maintenance Sites", are expected to reduce predicted construction noise levels. Reference to Australian Standard 2436-2010, Appendix C, Table C1 suggests possible remedies and alternatives to reduce noise emission levels from typical construction equipment. Table C2 in Appendix C presents typical examples of noise reductions achievable after treatment of various noise sources. Table C3 in Appendix C presents the relative effectiveness of various forms of noise control treatment.

Table 16 below sets out noise control methods, practical examples and expected noise reductions according to AS2436 and according to Renzo Tonin & Associates' opinion based on experience with past projects.

Table 16 – Relative Effectiveness of Various Forms of Noise Control, dB(A)

Noise Control Method	Practical Examples	Typical noise reduction possible in practice		Maximum noise reduction possible in practice	
		AS 2436	Renzo Tonin & Assoc.	AS 2436	Renzo Tonin & Assoc.
Distance	Doubling of distance between source and receiver	6	6	6	6
Screening	Acoustic barriers such as earth mounds, temporary or permanent noise barriers	5 to 10	5 to 10	20	20
Acoustic Enclosures	Engine casing lagged with acoustic insulation and plywood	5 to 10	5 to 10	15	15
Engine Silencing	Residential class mufflers	15 to 25	10 to 20	50	30
Substitution by alternative process	Use electric motors in preference to diesel or petrol	-	15 to 25	-	40

The Renzo Tonin & Associates' listed noise reductions are conservatively low and should be referred to in preference to those of AS2436, for this assessment.

Table 17 below summarises these options and the methods described above and should be employed, where considered reasonable and feasible.

Table 17 – Construction Noise and Vibration Management Options

Construction Noise and Vibration Management Options	
Source controls	
Time constraints	Limit work to the approved standard hours. Consider implementing respite periods with low noise/vibration-producing construction activities.
Scheduling	Perform noisy work during less sensitive time periods.
Equipment restrictions	Select low-noise plant and equipment. Ensure equipment has quality mufflers installed.
Emission restrictions	Establish stringent noise emission limits for specified plant and equipment. Implement noise monitoring audit program to ensure equipment remains within specified limits.
Substitute methods	Use quieter and less vibration emitting construction methods where possible. For example, when piling is required, bored piles rather than impact-driven piles will minimise noise and vibration impacts. Similarly, diaphragm wall construction techniques, in lieu of sheet piling, will have significant noise and vibration reduction benefits.
Limit equipment on site	Only have necessary equipment on site.
Limit activity duration	Where possible, concentrate noisy activities at one location and move to another as quickly as possible. Any equipment not in use for extended periods during construction work should be switched off.
Equipment Location	Noisy plant and equipment should be located as far as possible from noise sensitive areas, optimising attenuation effects from topography, natural and purpose built barriers and materials stockpiles. In regard to the subject site, it is recommended to locate any fixed plant equipment as far as practicable from Location C4 (Lime St), so as to reduce potential noise impact. This would include the location of the tower cranes. Locating equipment on the eastern side of the building, including the primary external lift during general construction is considered beneficial in terms of limiting noise impact upon residential receivers at Darling Point and Balmain.
Site access	Vehicle movements outside construction hours, including loading and unloading operations, should be minimised and avoided where possible.
Equipment maintenance	Ensure equipment is well maintained and fitted with adequately maintained silencers which meet the design specifications.
Reduced equipment power	Use only necessary size and power.
Quieter work practices	For example, implement worksite induction training, educating staff on noise sensitive issues and the need to make as little noise as possible.
Reversing alarms	Consider alternatives, such as manually adjustable or ambient noise sensitive types ("smart" reversing alarms) and closed circuit TV systems. Alternative site management strategies can be developed, in accordance with the Occupational Health and Safety Plan, with the concurrence of the Occupational Health and Safety Officer.
Path controls	
Noise barriers	It is noted that hoarding is to be installed at the site boundary and has been recommended to be maintained throughout the construction phase of all Barangaroo South development. Locate equipment to take advantage of the noise barriers provided by existing site features and structures.
Enclosures	Install noise-control kits for noisy mobile equipment and shrouds around stationary plant, as necessary.
Increased distance	Locate noisy plant as far away from noise-sensitive receptors as possible. As noted, it is recommended to locate the tower cranes and other fixed plant equipment as far as practicable from location C4 (Lime St).

Construction Noise and Vibration Management Options	
Receptor controls	
Consultation	Community consultation, information, participation and complaint responses are essential aspects of all construction noise management programs. They typically involve: • A community information program before construction and/or high risk activities is commenced. This usually involves a leaflet distribution and direct discussions and negotiations with affected residents, explaining the type, time and duration of expected noise emissions. • The involvement of affected residents in the development of acceptable noise management strategies. • A nominated community liaison officer with a contact telephone number. • A complaints hotline. • Timely responses to complaints, providing information on planned actions and progress towards the resolution of concerns.
Noise / Vibration Monitoring	Noise and vibration compliance monitoring for all major equipment and activities on site should be undertaken.

7 CONCLUSION

Renzo Tonin & Associates have completed an operation and construction noise and vibration assessment of the proposed R8 and R9 buildings in accordance with the Director General's Requirements (DGRs). From our assessment the items relevant to noise and vibration from or onto the site were identified as;

- Noise emission from the site such as mechanical services,
- Noise onto the site from existing sources such as traffic, commercial operation and marine activity, and
- Construction noise involved in building R8 and R9 including the cumulative impact with other Barangaroo South construction activities. .

The noise criteria and assessment methodology with regard to operational noise emission from mechanical services equipment has been established in accordance with the NSW Industrial Noise policy, however detailed noise assessment cannot be carried out until the design development stage, when the required equipment details are available. It is expected that such an assessment would be a conditional requirement of the development, to be satisfied prior to the construction certificate, being in line with the approvals already granted for the Barangaroo site. It is noted that as operational noise emission will consider impact upon residential receivers within the development itself, it is expected that by satisfying the noise objectives at the nearest receivers of R8 and R9, that the relevant criteria will be readily satisfied at the more distant surrounding development.

Noise onto the development was reviewed and considered with regard to the City of Sydney Development Control Plan in the absence of any relevant criteria or guidelines referenced in the DGR's. The criteria can be addressed through the acoustic design of the building envelope, which will be carried out during the design development phase. A preliminary review was carried out for this Project Application stage from which it was determined that the internal criteria should be readily achieved.

Construction noise and vibration was also assessed against the relevant policies, Standards and guidelines outlined in the DGRs. Impact from vibration was not found to be significant due to the nature of general construction works and distance to nearby vibration sensitive receiver locations. Noise emission from R8 and R9 construction activities was found to comply with the NSW ICNG 'noise affected' targets at all but one location, however the cumulative noise impact of all construction works within Barangaroo South was predicted to exceed the targets. Accordingly, discussion regarding construction noise mitigation and management options has been presented within the report. The mitigation and management options would be subject to further development and incorporation into a detailed site management plan.

APPENDIX A - GLOSSARY OF ACOUSTIC TERMS

The following is a brief description of the technical terms used to describe noise to assist in understanding the technical issues presented.

Adverse Weather — Weather effects that enhance noise (that is, wind and temperature inversions) that occur at a site for a significant period of time (that is, wind occurring more than 30% of the time in any assessment period in any season and/or temperature inversions occurring more than 30% of the nights in winter).

Ambient Noise — The all-encompassing noise associated within a given environment at a given time, usually composed of sound from all sources near and far.

Assessment Period — The period in a day over which assessments are made.

Assessment Point — A point at which noise measurements are taken or estimated. A point at which noise measurements are taken or estimated.

Background Noise — Background noise is the term used to describe the underlying level of noise present in the ambient noise, measured in the absence of the noise under investigation, when extraneous noise is removed. It is described as the average of the minimum noise levels measured on a sound level meter and is measured statistically as the A-weighted noise level exceeded for ninety percent of a sample period. This is represented as the $\mathbf{L_{90}}$ noise level (see below).

Decibel [dB] — The units that sound is measured in. The following are examples of the decibel readings of every day sounds:

0dB The faintest sound we can hear

30dB A quiet library or in a quiet location in the country

45dB Typical office space. Ambience in the city at night

60dB Martin Place at lunch time

70dB The sound of a car passing on the street

80dB Loud music played at home

90dB The sound of a truck passing on the street

100dB The sound of a rock band

115dB Limit of sound permitted in industry

120dB Deafening

dB(A): A-weighted decibels The ear is not as effective in hearing low frequency sounds as it is hearing high frequency sounds. That is, low frequency sounds of the same dB level are not heard as loud as high frequency sounds. The sound level meter replicates the human response of the ear by using an electronic filter which is called the "A" filter. A sound level measured with this filter switched on is denoted as dB(A). Practically all noise is measured using the A filter.

Frequency Frequency is synonymous to pitch. Sounds have a pitch which is particular to the nature of the sound generator. For example, the sound of a tiny bell has a high pitch and the sound of a bass drum has a low pitch. Frequency or pitch can be measured on a scale in units of Hertz or Hz.

Impulsive noise Having a high peak of short duration or a sequence of such peaks. A sequence of impulses in rapid succession is termed repetitive impulsive noise.

Intermittent noise The level suddenly drops to that of the background noise several times during the period of observation. The time during which the noise remains at levels different from that of the ambient is one second or more.

L_{max} The maximum sound pressure level measured over a given period.

L_{min} The minimum sound pressure level measured over a given period.

L_1 The sound pressure level that is exceeded for 1% of the time for which the given sound is measured.

L_{10} The sound pressure level that is exceeded for 10% of the time for which the given sound is measured.

L_{90} The level of noise exceeded for 90% of the time. The bottom 10% of the sample is the L_{90} noise level expressed in units of dB(A).

L_{eq} The "equivalent noise level" is the summation of noise events and integrated over a selected period of time. The L_{Aeq} is the 'A-

	weighted' L_{eq}.
Reflection	Sound wave changed in direction of propagation due to a solid object obscuring its path.
SEL	Sound Exposure Level (SEL) is the constant sound level which, if maintained for a period of 1 second would have the same acoustic energy as the measured noise event. SEL noise measurements are useful as they can be converted to obtain Leq sound levels over any period of time and can be used for predicting noise at various locations.
Sound	A fluctuation of air pressure which is propagated as a wave through air.
Sound Absorption	The ability of a material to absorb sound energy through its conversion into thermal energy.
Sound Level Meter	An instrument consisting of a microphone, amplifier and indicating device, having a declared performance and designed to measure sound pressure levels.
Sound Pressure Level	The level of noise, usually expressed in decibels, as measured by a standard sound level meter with a microphone.
Sound Power Level	Ten times the logarithm to the base 10 of the ratio of the sound power of the source to the reference sound power.
Tonal noise	Containing a prominent frequency and characterised by a definite pitch.