Barangaroo Ferry Hub

Environmental Impact Statement

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Appendix E Technical Paper: Noise and Vibration Impact Assessment

global environmental solutions

Barangaroo Ferry Hub

Construction and Operational

Noise and Vibration Impact Assessment

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Transport for NSW
c/o RPS Australia Asia Pacific
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Barangaroo Ferry Hub

Construction and Operational

Noise and Vibration Impact Assessment

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1 INTRODUCTION

1.1 Project Summary

Transport for NSW (TfNSW) is seeking approval for the Barangaroo Ferry Hub. The approval is sought under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

A State Significant Infrastructure (SSI) Application and Supporting Document (Version 1.4, dated 30 September 2014) were lodged with the Department of Planning and Environment (DP&E) requesting the Secretary's Environmental Assessment Requirements (SEARs) for the Barangaroo Ferry Hub proposal.

The documents outlined in the SSI Application have identified the need for a new ferry terminal within the Sydney Central Business District (CBD), and more specifically, at Barangaroo. The proposed Barangaroo Ferry Hub would play a key role in:

- Addressing the unique transport needs of the Barangaroo redevelopment project
- Enabling growth in ferry patronage
- Providing convenient access to the western parts of the CBD for ferry passengers
- Relieving capacity constraints at Circular Quay.

The project comprises construction and operation of three ferry wharves to be constructed in two stages (two wharves by 2016 and the third wharf as demand necessitates). It would incorporate waterside components of the Barangaroo Ferry Hub and ancillary landside facilities such as ticket vending machines and wayfinding signage

1.2 Report Objectives

SLR Consulting Australia Pty Ltd (SLR) has been engaged by RPS Australia Asia Pacific on behalf of TfNSW to perform a noise and vibration assessment of the potential impacts resulting from the construction and operation of the Barangaroo Ferry Hub.

This report presents the results of background noise monitoring undertaken in the locality of the proposed works from which appropriate operational noise objectives and construction noise management levels have been determined. Noise levels have been predicted to the nearest noise sensitive receivers surrounding the project site from activities associated with the construction and operation of the Barangaroo Ferry Hub and assessed for potential impacts. This report also provides recommended management measures to mitigate the potential construction noise and vibration, and operational noise impacts arising from the proposed ferry hub.

This report will form part of the Environmental Impact Statement (EIS) which provides an assessment of the Concept Proposal for the project.

1.3 Relevant Guidelines

The noise and vibration guidelines for the proposed construction and operation are based on the publications managed by the Environment Protection Authority[1] (EPA).

SLR recognises that there is currently no specific guideline to oversee the noise emission associated with the operation of a ferry terminal in NSW. As such, the following acoustical guidelines are discussed and referenced in order to develop project specific noise objectives.

- *Rail Infrastructure Noise Guideline* (RING), *EPA 2013*[i]
- *Road Noise Policy* (RNP), *DECCW 2011*[ii]
- *Industrial Noise Policy* (INP) (DECCW, 2000)[iii]
- The guidelines applicable to the construction assessment include:
- Construction Noise – *Interim Construction Noise Guideline* (ICNG), DECC 2009[iv]
- Construction Noise – *Construction Noise Strateg*y, Transport for NSW[v]
- Construction Vibration (human comfort) – *Assessing Vibration - a technical guideline,* DEC 2006[vi]
- Construction Vibration (Structural) – Australian Standard AS 2187: Part 2-2006 *Explosives - Storage and Use - Part 2: Use of Explosives*[vii]
- Construction Vibration (Structural) – British Standard BS 7385 Part 2-1993 *Evaluation and measurement for vibration in buildings Part 2*.[viii]
- The following additional guidelines and standards are also referenced in this study:
- Noise measurement procedure – AS 1055:1997 *Acoustics – Description and Measurement of Environmental Noise*[ix]
- Acoustic instrumentation – AS IEC 61672.1-2004 *Electroacoustics - Sound Level Meters, Part 1: Specifications*[x]

1.4 Terminology

Specific acoustic terminology is used within this report. An explanation of common terms is included as **Appendix A**.

[1] Noise and Vibration guidelines are available at the following web address: http://www.environment.nsw.gov.au/noise

2 PROJECT DESCRIPTION

2.1 Concept Proposal

The proposal comprises the construction and operation of a ferry hub and would include:

- Establishment of construction work area and a temporary construction compound.
- Construction of three new ferry wharves and ancillary landside ferry facilities
- Potential demolition of the King Street Wharf wave baffle
- Site clean-up and opening of the new wharves
- Operation of three wharves including ferry layover, pump out facilities and minor maintenance activities
- Landside ancillary facilities comprising of wayfinding signage and ticketing
- Eventual decommissioning and removal of the public transport elements of King Street Wharf such as ticket machines and signage.

Initially, two wharves would be constructed. When demand necessitates, the third ferry wharf would be constructed.

Figure 1 illustrates indicative key proposal features of the ferry wharves.

Figure 1 Indicative Barangaroo Ferry Hub key proposal features

Note : Image provided by RPS, 19 November 2014

2.2 Proposed Ferry Hub Operation

The Barangaroo Ferry Hub would include three operating ferry wharves catering for most vessel classes (with the exception of the larger Manly Freshwater Ferries). The wharves would operate primarily to service Sydney Ferries rather than commercial vessels which would continue to use the King Street Wharf facilities.

The vessel classes which are expected to provide the majority of services to Barangaroo Ferry Hub and their passenger capacity, are detailed below in **Table 1**. The passenger numbers presented are used to estimate the patronage at the terminal for operational assessment purposes.

Table 1 Barangaroo Ferry Hub Vessel Classes

Vessel Class	Passenger Capacity[1]
First Fleet	393
RiverCat	230
Harbourcat	150
Captain Cook Charter	198[2]

Note 1: "Sydney Ferries Fleet Facts", http://www.transport.nsw.gov.au/content/sydney-ferries-fleet-facts, Transport for NSW. 2012-01-20. Retrieved 20 October 2014

Note 2: "Two More 24m Ferries Enter Service On Sydney Harbour", http://www.incatcrowther.com/display_news.php?id=165, INCAT Crowther. 2014-08-12. Retrieved 20 October 2014

At the year of opening (2016), the Barangaroo Ferry Hub is expected to have patronage of up to eight vessels per hour during weekday peak periods and up to 14 vessels per hour all day Saturday and Sunday. Patronage throughout is expected to increase, requiring up to 14 vessels per hour for both weekday peak and weekend services by year 2026.

The third wharf would be constructed in the future when the demand for ferry services necessitates. It is assumed that once the third wharf becomes operational the average operation per wharf remain unchanged (i.e. a period of time after year 2026).

The following table, **Table 2**, details the proposed operation frequency of ferries at the Barangaroo Ferry Hub.

Table 2 Barangaroo Ferry Hub Proposed Operation Frequency

	2016 (Year of opening) / Hour		2026 (10 years after opening) / Hour		2026 / Hour [2]	
	2 wharves	**Average per wharf[1]**	**2 wharves**	**Average per wharf**	**3 wharves**	**Average per wharf**
Monday to Friday Peak periods[3] (AM/PM)	8 vessels	4 vessels	14 vessels	7 vessels	21 vessels	7 vessels
Saturdays, Sundays and Public Holidays All day	14 vessels	7 vessels	14 vessels	7 vessels	21 vessels	7 vessels

Note 1: The two wharf breakdown of vessel frequency has been applied to the third wharf for future scenario (i.e. year 2026).

Note 2: The predicted number of vessels is based on the operation of two wharves as detailed in SSI Application supporting document version 1.4 dated 30 September, Section 4.2.2 pp 29. These are indicative numbers only as the third wharf would only be constructed in the future when the demand for ferry services necessitates.

Note 3: AM and PM peak periods are anticipated to have a comparable intensity of operations

Indicative vessel movements and the likely manoeuvring requirements for vessels arriving and departing the wharves are shown in **Figure 2**.

Figure 2 Indicative Vessel Movements

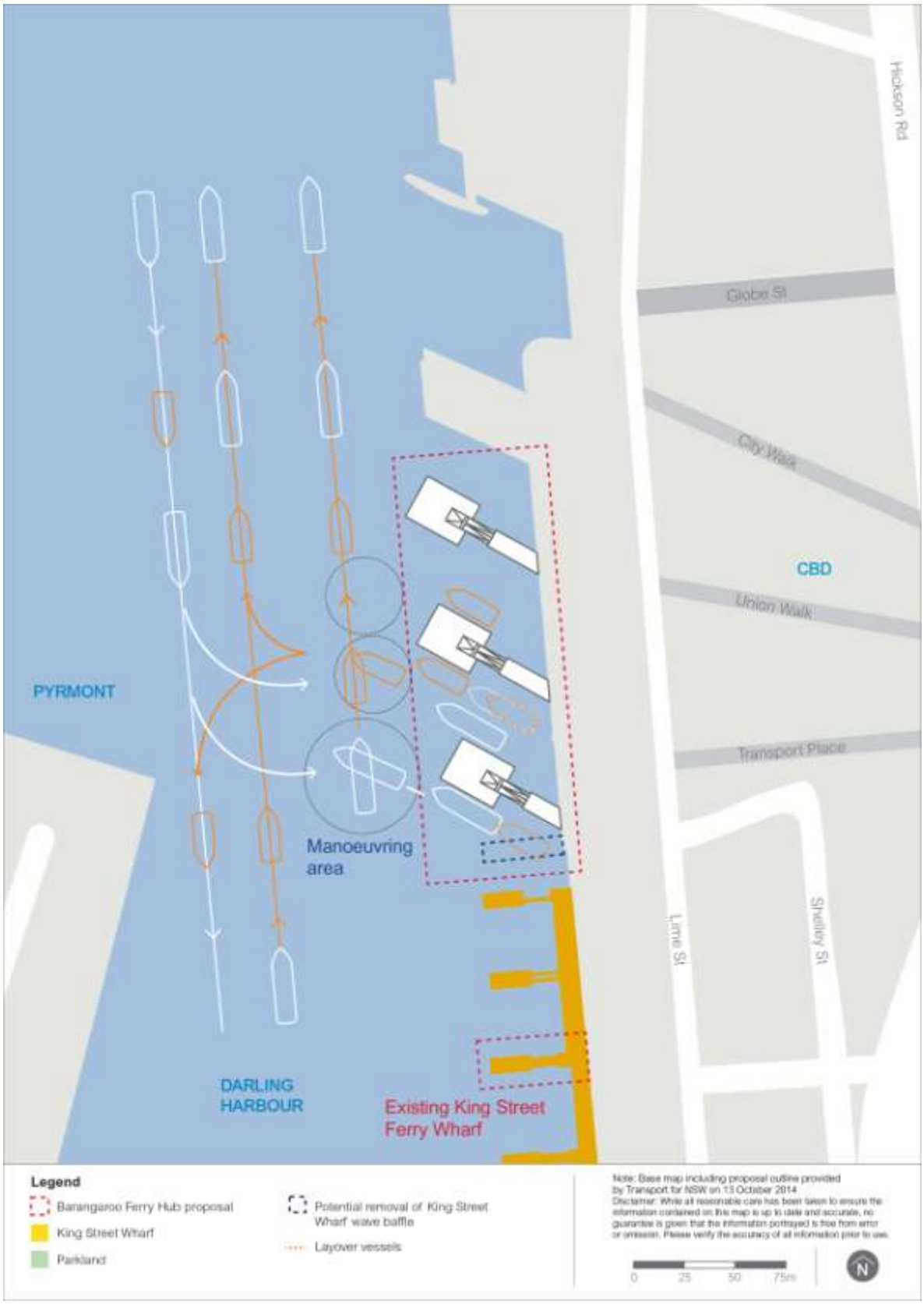


Image provided by RPS, 20 November 2014

2.2.1 Operating Hours

The proposed operating hours of the Barangaroo Ferry Hub are detailed below in **Table 3**.

Table 3 Proposed Barangaroo Ferry Hub Operating Hours

Day	Operating Hours
Monday to Friday	5:00 am – 12:00 am midnight
Saturday, Sunday and Public Holidays	7:00 am – 12:00 am midnight

It is anticipated that the Barangaroo Ferry Hub may be required to operate outside of the above hours during special events such as New Year's Eve, Vivid and Australia Day. However, the likely extension of hours would be covered in the predicted maximum capacity night-time noise assessment of this report (i.e. between 10:00 pm and 7:00 am weekdays and 10:00 pm to 8:00 am on weekends and public holidays as described in the RNP) and therefore does not require an additional assessment.

2.2.2 Wharf Operations

The southern side of each wharf would provide a single berth for daytime layover, subject to timetable requirements. Overnight, up to three vessels may be in layover on each wharf. During layover minor vessel maintenance (e.g. cleaning, minor repairs and daily sewerage pump-out) may be undertaken. Ferries would run on shore power during layover.

For the purpose of this assessment it is anticipated that maintenance activities would occur in the night-time assessment period; after the last scheduled service (end of shift) between 12:00 am midnight and 1:00 am.

Noise sources considered for the operation of Barangaroo Ferry Hub include, but are not limited to, the following:

Operational[2]

- Ferry noise (engine, propeller noise, horns/warning devices[3] and impact noise of ferries against pontoons during docking);
- PA systems; and
- Passenger noise.

Maintenance (on vessels[4] and on wharves)

- Sewerage pump-out; and
- Cleaning.
  - High pressure water cleaning of wharf facilities around three times weekly
  - High pressure water blasting on tidal stairs or ladders would occur once monthly.

[2] Layover of ferries would run on shore power and are not expected to generate additional noise.

[3] Alarms or emergency alerts would only be used during emergencies and are highly audible by design (other than occasional testing which would not be audible. It should be noted that noise level of the alert systems cannot be lowered without compromising safety.

[4] All substantial vessel repairs would be undertaken off-site (e.g. at Balmain Shipyard). Minor repairs at the terminal would be carried out internally within the ferries or the terminal (e.g. changing light bulbs, minor repairs within the noise-insulated engine room). These minor repairs are considered to be a non-event as any resulting noise would be negligible.

2.3 Proposed Ferry Hub Construction

It is proposed that the construction of Barangaroo Ferry Hub would be carried out in two stages. Initially, two wharves would be constructed. When demand necessitates, the third ferry wharf would be constructed.

The majority of construction for the project involves waterside elements including the three wharves and associated piles. Ancillary facilities such as ticket vending machines and wayfinding signage would be constructed on land.

2.3.1 Site Establishment

- Installation of hoarding along the foreshore;
- Installing silt curtains within the waterway;
- Installing temporary construction compound (around 420 sqm) on the Barangaroo Development foreshore;
- The majority of construction plant, equipment, material and personnel would be transported via Sydney Harbour (on boat and/or barge); and

2.3.2 Construction of New Wharves and Ancillary Facilities

- The majority of wharf components such as piles, pontoon, gangway and ancillary facilities would be constructed off site and transported via Sydney Harbour (on boat and/or barge);
- Installation of piles (combination of screwing, vibrating and hammering techniques would be used). One pile would be installed at any one time with no concurrent piling work anticipated;
- Concrete works – filling piles and link structure; and
- Intricate lifting and placement - installation of gangway, rooves and some of the ancillary facilities. The pontoon would be floated into place and secured to piles.

It is anticipated that specific components of work (piling and intricate lifts) may need to be undertaken out-of-hours (i.e. during the evening and night-time periods) to achieve calm environmental conditions (e.g. still water and minimal wind) and ensure that barges used for the piling can remain still for the piles to be installed accurately and safely. Out-of-hours works (OOHWs) would be limited to the early stages of construction (piling and intricate lifts) and a relatively minor portion of the overall construction program.

A 130 m wide navigation channel would be maintained for safety and to minimise disturbance to vessel movements travelling to and from Darling Harbour.

Installation of Piles

The construction of piled foundation systems in bedrock (up to 30 piles per wharf) and indicative duration of works are detailed in **Table 4**.

Table 4 Proposed Piling Installation

Activity reference No	Activities	Approximate duration of works per pile	Applicable Assessment Time Period
1	Pitching of pile	3 hours	Calm water conditions which may involve night-time/ early morning
2	Vibrating hammer	1 hour	
3	Pile drilling	3 hours	
4	Pile hammering	30 minutes with diesel hammer or 1 hour with hydraulic hammer	
5	Finishing - cutting, welding and plugging of piles with concrete	Cutting – 1 hour Concrete works – 1.5 hours Concreting transition (link) structure up to 1 month / wharf	Standard working hours

Note: Installation of piles for the first two wharves would be completed in activities one to four. Then the finishing process (Activity Five) would likely to occur for a number of piles at once.

Pontoon

The floating pontoon structure would be built and assembled as one structure off site. The complete structure would then be towed to site for final positioning.

Mooring of Barges

Initially, barges would be self-anchoring or with a jack-up mechanism, if jack-up barge is used. As piles are progressively installed, the barges could use the piles as mooring points.

The majority of waterside works would be undertaken using plant and equipment mounted on barges.

Throughout the construction:

- Limited materials would be stored on site;
- Barge mounted cranes would be used for materials handling; and
- Land materials handling are considered to be minor in comparison to waterside works.

2.3.3 Potential Demolition (King Street Wharf Wave Baffle)

- Removal of timber decking, supporting timber girders and underlying wash barrier steel substructure; and
- Pile extraction (vibratory hammer)
    - In case of failed extraction, the piles would be cut at seabed level using underwater equipment.

2.3.4 Site Clean-up and Opening for Operation

Site clean-up and restoration; and

Removal of hoarding and fencing.

2.3.5 Construction Duration and Proposed Hours

At this stage, it is anticipated that construction works for the initial two wharves would take approximately 12 months. It is anticipated that the third wharf would be constructed much later after the opening of the first two wharves when demand necessitates. It is TfNSW's policy to undertake a consistency review at the time of carrying out future works to ensure the assessment carried out in the EIS and this report remain appropriate.

The proposed construction hours are assumed to follow the *Interim Construction Noise Guideline* (ICNG) recommended standard hours of construction being 7:00 am to 6:00 pm Monday to Friday and 8:00 am to 1:00 pm Saturday with no work occurring on Sundays or public holidays. Emergency works may however occur on a 24/7 basis.

However, there are two types of activities wich are anticipated to require calm water conditions for construction accuracy and safety of workers. These are intricate lifts by barge crane and the piling works. If the calm conditions do not occur during ICNG recommended standard hours of construction, the intricate lifts and piling activities would have to be carried out outside those recommended standard hours of construction.

A summary of indicative night works for piling drilling and intricate lifts based on similar wharves projects is detailed in **Table 5**.

Table 5 Summary of Indicative Out-of-Hours Works (OOHWs)

Activities	Time period
Pile Drilling	
Setup for drilling	12:00 am to 1:00 am
Drilling of piles	1:00 am to 6:00 am
Pack up	6:00 am to 7:00 am
Pile Hammering	
Setup for hammering	4:00 am to 5:00 am
Hammering of piles	5:00 am to 7:00 am
Intricate Lifting	
Intricate Lifting and placement	12:00 am to 7:00 am
	11:00 pm to 7:00 am

2.3.6 Construction Source Sound Power Levels

Typical L_{Aeq} sound power levels (SWLs) for equipment assumed in the assessment are presented in **Table 30**.

In accordance with the ICNG, activities identified as being particularly annoying attract a 5 dB “annoyance penalty”. Activities and associated plant operations which contain potential tonal, impulsive, intermittent and/or low frequency noise characteristics would typically be identified as being annoying. The SLR database of sound power levels for construction equipment accounts for this “annoyance penalty”.

3 DESCRIPTION OF THE EXISTING ENVIRONMENT

3.1 Project Area and Sensitive Receivers

The proposed Barangaroo Ferry Hub would be located on the southwestern boundary of Barangaroo South (currently under construction). The surrounding area is a combination of dense residential and commercial receivers. Existing ferry services use King Stret Ferry Wharf, which is in close proximity to the proposed site.

The surrounding area has been divided into Noise Catchment Areas (NCAs) which reflect the changing land uses and ambient noise environments adjacent to the Barangaroo Ferry Hub and are detailed in **Table 6**. The location of the various NCAs and sensitive receivers are indicated in **Figure 3.**

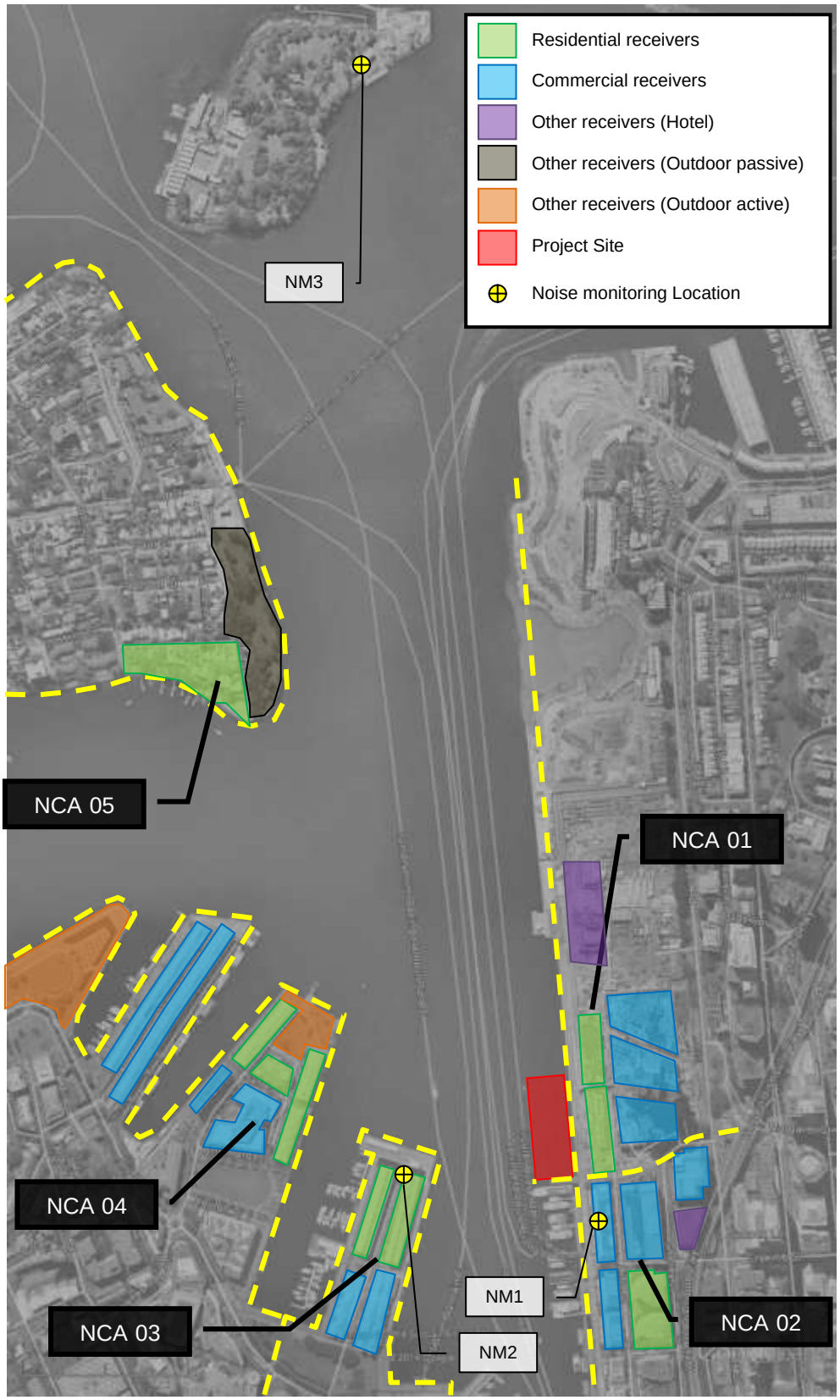
The nearest receivers potentially affected by the project are identified below in **Figure 3**.

Table 6 Noise Catchment Areas and Surrounding Land Uses

NCA	Distance (m) to Works[1]	Description
NCA-01	60	Future residential and commercial receivers east of site, future hotel north east of site
NCA-02	116	Commercial, residential receivers and hotel southeast of site
NCA-03	200	Residential receivers at the end of Wharf 10 west of the site and commercial receivers southwest of site
NCA-04	332	Open space, residential receivers at the end of the Darling Island Road west of site, commercial receivers southwest and Jones Bay Wharf
NCA-05	743	Balmain East Headland residential receivers and open space northwest of site

Note 1: Approximate minimum horizontal offset distance from the nearest receiver building facade (receiver of any type) to the centre of the Barangaroo Ferry Hub project (i.e. centre of wharf 2).

Figure 3 Barangaroo Ferry Hub Project Location and Surroundings



3.1.1 Barangaroo Development

The development site was previously operating as a cruise liner terminal. Currently, the Barangaroo South development (including Barangaroo residential buildings R8 and R9 of NCA-01) is in construction and the residences are likely to be occupied from September 2015. Therefore theses residences are likely to be occupied during construction and operation of Barangaroo Ferry Hub.

3.2 Identification of Noise and Vibration Sensitive Receivers in the Project Area

The sensitivity of receivers to noise and vibration is dependent upon the occupancy type and the nature of the activities being performed within the affected premises. Sensitivity to noise is a subjective response varying for different individuals and can depend on the existing noise environment.

For the purpose of this assessment, receivers potentially sensitive to noise and vibration have been categorised as:

- Residential;
- Commercial;
- Other receivers (e.g. Hotels); and
- Other (such as passive or active recreation areas, etc).

Sensitive receivers located within each NCA are illustrated in **Figure 3**. Residential receivers are detailed in **Table 7.**

Non-residential sensitive receivers which have the potential to be affected by noise and vibration from the proposal are detailed in **Table 8**.

Table 7 Nearest Residential Receivers

NCA	Address	Description	Receiver Type	Horizontal Distance (m)[1]
NCA-01	Barangaroo South Residential Apartments R8	Future Development	Residential	67
NCA-01	Barangaroo South Residential Apartments R9	Future Development	Residential	61
NCA-02	23 Shelley Street	Portside Tower	Residential	252
NCA-03	56 Pirrama Road, Pyrmont (East)	Wharf 8	Residential	210
NCA-03	56 Pirrama Road, Pyrmont (West)	Wharf 9	Residential	237
NCA-04	8 Wharf Crescent, Pyrmont	Darling Island Apartments Block 3	Residential	332
NCA-04	3 Darling Island Rd, Pyrmont	Darling Island Apartments Block 1	Residential	372
NCA-04	3 Darling Island Rd, Pyrmont	Darling Island Apartments Block 2	Residential	390
NCA-05	21 Edward Street, Balmain East (Edward Street, Balmain East Little Edward Street, Balmain East William Street, Balmain East)	Balmain East Headland Residents	Residential	735

Note 1: Approximate horizontal offset distance from the nearest point of the receiver building to the centre of the works (i.e. centre of wharf 2) for the project.

Table 8 Other Non-Residential Noise and Vibration Sensitive Receivers

NCA	Address	Description	Receiver Type	Horizontal Distance (m)[1]
NCA-01	Crown Tower Hotel	Future Development	Hotel	238
NCA-01	Barangaroo South International Tower 1 (IT1), C3	Future Development	Commercial	148
NCA-01	Barangaroo South International Tower 2 (IT2), C4	Future Development	Commercial	96
NCA-01	Barangaroo South International Tower 3 (IT3), C5	Future Development	Commercial	106
NCA-02	10-12 Shelley Street, Sydney	KPMG Australia, American Express	Commercial	190
NCA-02	22 Shelley Street, Sydney	Hotel Ibis	Hotel	225
NCA-02	1 Shelley Street, Sydney	Macquarie Private Wealth, Brookfield Multiplex	Commercial	149
NCA-02	5-15 Lime Street, Sydney	King Street Wharf (Restaurants and bars)	Commercial	130
NCA-02	25 Lime Street, Sydney	King Street Wharf (Restaurants and bars)	Commercial	250
NCA-03	Wharf 7/58 Pirrama Road, Pyrmont	Sydney Heritage Fleet	Commercial	317
NCA-03	Wharf 10 Pirrama Road, Pyrmont	Sydney Wharf Marina	Commercial	354
NCA-04	Darling Island Road, Pyrmont	Ballarat Park	Open space (Outdoor active)	321
NCA-04	1 Darling Island Road, Pyrmont	Fairfax Media	Commercial	384
NCA-04	26-32 Pirrama Road, Jones Bay Wharf	Doltone House	Commercial	516
NCA-04	38-42 Pirrama Road, Jones Bay Wharf	Channel 7	Commercial	465
NCA-04	Pirrama Road, Pyrmont	Pirrama Park	Open space (Outdoor active)	659
NCA-05	Edward Street, Balmain East	Illoura Reserve	Open space (Outdoor passive)	700

Note 1: Approximate horizontal offset distance from the nearest point of the receiver building to the centre of the works (i.e. centre of wharf 2) for the project.

3.3 Existing Acoustic Environment

In order to establish the existing ambient noise environment at the surrounding residences, SLR conducted noise monitoring at representative Location NM2 and obtained noise monitoring data from our database at locations NM1[5] and NM3[6] as shown in **Figure 3**.

Photographs of the noise monitoring equipment at NM1 and NM2 are provided below in **Figure 4**.

5 Noise data at NM1 was taken from SLR noise database.

6 Noise data at NM3 was taken from SLR noise database.

Figure 4 Unattended Noise Monitoring Equipment Deployed On-site

NM1) Level 3, 5 Lime Street looking southwest towards existing King Street Wharf

NM2) Ground Floor northern side of Wharf 8, 56A Pirrama Road, looking east towards the Barangaroo Development

Note: Photograph of NM3 is not available

3.4 Noise Monitoring Location

The locations for noise monitoring were chosen as being presentative of the sensitive receivers surrounding the Barangaroo Ferry Hub development.

The monitoring location NM1 was chosen as being representative of current receivers on King Street Wharf and the future receivers R8 and R9 of the Barangaroo South development (NCA-01 and NCA-02) due to the similarity in noise environment, and land usage (mixed residential and commercial).

Monitoring location NM2 was chosen as being representative of NCA-03 and NCA-04, as the location contains primarily residential receivers and commercial (general office) land use which are likely to have lower ambient noise levels than location NM1.

Monitoring location NM3 at Goat Island was chosen as being representative of the adjacent residential receivers in NCA-05.

3.5 Methodology for Unattended Noise Monitoring

The noise loggers continuously measured noise levels in 15 minute sampling periods in order to determine the existing L_{Aeq}, L_{A90} and other relevant statistical noise levels during the daytime, evening and night-time periods.

The equipment was set up with microphones at 1.5 m above the ground level. All microphones were fitted with wind shields.

All noise measurement instrumentation used in the surveys was designed to comply with the requirements of Australian Standard AS IEC 61672.1-2004 *Electroacoustics - Sound level meters, Part 1: Specifications* and carried appropriate and have current National Association of Testing Authorities (NATA) calibration certificates. The calibration of the loggers was checked both before and after each measurement survey and the variation in calibration at all locations was found to be within acceptable limits at all times.

The results of the noise monitoring have been processed to exclude noise identified as extraneous and/or data affected by adverse weather conditions (i.e. wind or rain) so as to establish representative noise levels in the area at the residences.

Details of noise monitoring and instrumentation are outlined in **Table 9**.

Table 9 Unattended Noise Monitoring Summary

Noise Monitoring ID	Relevant NCAs	Address	Comments	Instrument and Serial Number	Monitoring Period
NM1[1]	NCA-01 NCA-02	5-15 Lime Street, Sydney	On level 3 balcony of building	SVAN 957 SN: 20675	24 April 2013 to 30 April 2013
NM2	NCA-03 NCA-04	56A Pirrama Road, Pyrmont (Wharf 8)	Northern boundary of building vicinity	SVAN 957 SN: 23243	26 August 2014 to 9 September 2014
NM3[1]	NCA-05	Goat Island	The roof of the disused Port Emergency Services building located on the eastern side of the island	SVAN 957 SN: 23815	18 January 2013 to 4 February 2013

Note 1: Noise monitoring data of NM1 and NM3 were taken from SLR's database.

3.6 Unattended Noise Monitoring Results

The results of the unattended ambient noise surveys are summarised in **Table 10** as the Rating Background Level (RBL)[7] noise levels for the ICNG daytime, evening and night-time periods. By analysing the monitoring data, RBLs were obtained. These data provide the basis for setting construction NMLs.

The results of this unattended noise monitoring are provided in **Table 10** below. The 24 hour daily noise levels (at NM2 only) are presented graphically in **Appendix B**.

Table 10 Measured Ambient Noise Levels

Location	Noise Level - dBA re 20 µPa					
	RBL, L_{A90}			$L_{Aeq(period)}$		
	Daytime[2]	Evening[2]	Night-time[2]	Daytime[2]	Evening[2]	Night-time[2]
NM1[1]	52	59	46	61	66	70 (52)[3]
NM2	51	46	41	56	52	47
NM3[1]	49	49	41	55	56	49

Note 1: Noise monitoring data of NM1 and NM3 were taken from SLR's database.

Note 2: ICNG Governing Periods – Day: 7.00 am to 6.00 pm Monday to Saturday, 8.00 am to 6.00 pm Sunday; Evening: 6.00 pm to 10.00 pm; Night: 10.00 pm to 7.00 am Monday to Saturday, 10.00 pm to 8.00 am Sunday.

Note 3: Existing ambient noise levels excluding weekend bar operations on ground floor

[7] As defined by the INP – *"the overall single-figure background level representing each assessment period (day/evening/night) over the whole monitoring period (as opposed to over each 24-hour period used for the assessment background level). The rating background level is the level used for assessment purposes".* The measured RBLs are used to define the construction NMLs as in accordance with the ICNG.

The higher evening and night-time noise levels measured at NM1 are due to the operation of commercial premises on the ground floor below the monitoring location. Based on the noise monitoring data, the higher noise levels in the evening and night-time periods occurred on up to four out of seven days of the total survey duration. This discrepancy in the diurnal trend is considered characteristic of this particular land use and would likely be similar to Barangaroo South development once completed.[8]

The noise levels at NM2 display a typical diurnal trend with lower noise levels during the night-time than during the daytime and evening periods. This is characteristic of urban areas where the ambient noise environment is dominated by 'urban hum' (i.e. the aggregate sound of many unidentifiable sources - primarily road traffic).

The marginally higher evening noise levels measured at NM3 are likely due to the combination of sources with the traffic peak after 6 pm as the monitoring location is exposed to the waterways and has direct line of sight to the north of the CBD. This discrepancy in the diurnal trend is considered characteristic of this particular land use and would likely be similar to the Balmain East Headland foreshore residents.

The noise logging results are considered representative of the area and suitable for the determination of operational noise levels and construction noise management levels to the nearest residential receivers.

3.7 Operator Attended Noise Measurements – Vessel Operation

Noise surveys of the ferry activity at existing wharves at Cockatoo Island and Circular Quay were carried out on 25 August 2014 between the hours of 7:30 am and 3:00 pm.

The equipment utilised for the attended noise surveys comprised of a Brüel & Kjaer Type 2250 Class 1 sound level meter, fitted with a microphone wind shield.

The acoustic instrumentation used during the noise monitoring survey was designed to comply with the requirements of AS IEC 61672.1 2004: *Electroacoustics-Sound level meters-Specifications* and carried appropriate and current NATA (or manufacturer) calibration certificates.

Calibration was checked prior to and subsequent to the noise survey. The drift in microphone calibration was within the acceptable level of ±0.5 dBA at all times.

The activities of 15 different vessels were measured including during idling, reverse thrust and accelerating to and from the wharf. A complete list of ferry measurements is detailed in **Appendix C**.

[8] Barangaroo South planning documentation indicates café, dining, retail and/or bar usage of ground floor levels of buildings R8 and R9. This is a similar mix to the King Street Wharf ground floor, and indicates monitoring data NM1 is likely to be applicable to these future Barangaroo South buildings.

4 OPERATIONAL NOISE ASSESSMENT METHODOLOGY

4.1 Introduction

Improvement of transportation is a key objective of the NSW Government. It includes improved public transport and increased frequency of services to support the growing community of Barangaroo and the CBD.

Notwithstanding, adverse effects on residents living alongside marine based transport terminals can occur from the exposure to increased vessel traffic, extended operating hours and existing development along transport routes that were not designed to mitigate these particular noise sources. Introduction to the new noise sources associated with the ferry terminal operation may potentially disturb sleep, causing stress, annoyance and interference with the daily activities of the surrounding noise sensitive receivers. These impacts need to be managed to protect the amenity and wellbeing of those local communities living near the proposed developments.

Ferry operations can be inherently noisy due to the safety requirements and types of vessel used. Relatively high noise levels may still occur even after all feasible and reasonable means of mitigating the noise have been applied.

A range of initiatives is required in order to address and control the new noise sources associated with tge subject marine operations, including limiting noise from future vessels and providing avenues for relief for those acutely affected by noise from operations of the ferry hub.

As the introduction of Barangaroo Ferry Hub would likely be classified as the introduction of new noise sources within an existing industrial environment, there is opportunity to address the specific noise sources and introduce control to the potential noise emissions associated with the operations of the Barangaroo Ferry Hub.

Within NSW, noise from industrial facilities and similar commercial operations are assessed against specific guidelines for fixed continuous noise sources. Additionally, guidelines exist for road traffic noise, rail noise and aircraft operations that enable developments to be designed for noise compliance.

SLR acknowledges that currently:

There is no existing framework available to assess the acoustical implications of marine based transport noise including ferry terminal operations.

As such, this section of the report reviews and outlines existing policies and design levels, and derives appropriate noise objectives to assess the potential noise emission from the proposed Barangaroo Ferry Hub.

The following guidelines are discussed within this section:

- Rail Infrastructure Noise Guideline (RING);
- NSW Industrial Noise Policy (INP); and
- Road Noise Policy (RNP)

4.2 Comparison of Current NSW Guidelines

4.2.1 Rail Infrastructure Noise Guideline (RING)

The RING is used to assess the noise and vibration impacts of new and upgraded rail infrastructure projects on sensitive receivers such as residential land uses. The noise trigger levels are separated into the following categories;

- Heavy rail development:
    - New rail line development
    - Redevelopment of existing rail line; and
- Light rail development

Ferry operations at Barangaroo Ferry Hub are considered to share similar characteristics to the light rail operations (on the basis of frequency, capacity and activity) rather than heavy rail which operates at higher speeds and has a higher carrying capacity than light rail.

The relevant airborne light-rail noise trigger levels for residential land uses are presented in **Table 11**.

Table 11 Airborne Light Rail Noise Triggers for Residential Land Use

Sensitive Land Use	Noise Trigger Level (dBA)	
	Daytime 7:00 am to 10:00 pm	**Night-time 10:00 pm to 7:00 am**
Residential	60 $L_{Aeq(15hour)}$ and 80 L_{Amax}	50 $L_{Aeq(9hour)}$ and 80 L_{Amax}

Note: L_{Amax} refers to the maximum noise level not exceeded for 95 per cent of rail pass-by events and is measured using the 'fast' response setting on a sound level meter.

The RING requires noise to be assessed for the proposed year of opening as well as for a future design year, typically ten years after opening.

The RING noise triggers for non-residential sensitive receptors are applicable when the building or premise is in use. A summary of trigger levels for non-residential receivers is outlined in **Table 12**. All noise trigger levels are external levels except where otherwise stated. Sensitive receptors in the subset proposal area (other than residential) are listed in **Table 6**. Commercial receptors are not considered sensitive to operational airborne noise impacts.

Table 12 Airborne Rail Noise Triggers for Non-Residential Land Use

Sensitive Land Use	Noise Trigger Level (dBA), when in use	
	Daytime 7:00 am to 10:00 pm	**Night-time 10:00 pm to 7:00 am**
Open space – passive use (e.g. parkland, bush reserves)	60 $L_{Aeq(15hour)}$ external	65 $L_{Aeq(9hour)}$ and 80 L_{Amax}

Note: L_{Amax} refers to the maximum noise level not exceeded for 95 per cent of rail pass-by events and is measured using the 'fast' response setting on a sound level meter.

It should be noted that the noise trigger levels stipulated in the RING are assessed over 15 hour and 9 hour periods for daytime and night-time respectively.

4.2.2 NSW Industrial Noise Policy (INP)

The NSW EPA's INP provides criteria for the assessment of noise impacts associated with industrial activities. It aims to balance the need for industrial activity with the desire for quiet within the community. The guided levels are designed to protect at least 90 per cent of the population living in the vicinity of the industrial noise sources for at least 90 per cent of the time.

The INP's objectives are:

- To establish noise criteria that would protect the community from excessive noise
- To preserve the amenity for specific land uses
- To use the criteria for deriving project specific land uses
- To promote uniform methods to estimate and measure noise impacts, including a procedure for evaluating meteorological effects

Implementation is achieved by ensuring:

- That noise from any single source does not intrude greatly above the prevailing background noise level in the short term. This is known as the intrusive noise criterion; and that
- The background noise level does not exceed the level appropriate for the particular locality and land use. This is known as the amenity criterion[9].

It should be noted that the INP criteria relate specifically to industrial-type noise sources and do not include transport corridors (road, rail and air), community noise or construction noise. However, it is often referenced by Councils and local governments as a planning tool to address potential noise impacts from proposed noise generating facilities which are generally continuous in nature (e.g. mechanical plant from commercial premises).

Intrusiveness Criterion

For assessing intrusiveness, the background noise generally needs to be measured. The intrusiveness criterion essentially means that the equivalent continuous noise level (L_{Aeq}) of the source should not be more than 5 dBA above the existing ambient (background) L_{A90} noise level (or RBL), measured during the different periods of the day (daytime, evening and night-time) at the boundary of the nearest sensitive receivers.

It should be noted that the noise criterion for intrusiveness is assessed over 15 minutes, $L_{Aeq(15minute)}$ of any time periods of the day.

Amenity Criterion

The amenity criterion is based on land use and associated activities (and their sensitivity to noise emission).

The "Amenity" noise goal seeks to place a control on noise emissions according to how existing industrial/commercial-related noise levels compare to the recommended noise levels for the type of area involved (i.e. rural, suburban, urban and urban/industrial interface).

The resulting amenity noise level placed upon emissions of a new facility then depends upon whether existing industrial/commercial-related $L_{Aeq(period)}$ noise levels are lower or higher than the recommended amenity level.

It is necessary that the cumulative effect of noise from industrial sources be considered in assessing the impacts. The existing noise level from industry is measured and compared with the amenity level. If it approaches the amenity level, then noise levels from new industrial-type noise sources need to be designed so that the cumulative effect does not produce total noise levels that would significantly exceed the criterion.

[9] The amenity criterion is based on land use and associated activities (and their sensitivity to noise emission). The cumulative effect of noise from sources (such as industrial) needs to be considered in assessing the impact against the amenity criterion.

Conversely, where the existing noise level from industrial noise sources is close to the acceptable noise level, the noise level from any other sources must be controlled to preserve the amenity of an area.

The INP provides recommended acceptable noise levels for residents located in “Rural”, “Suburban”, “Urban” and “Urban/Industrial” interface. The recommended acceptable and maximum levels are reproduced in **Table 13**.

Table 13 Amenity Criteria - Recommended L_{Aeq} Noise Levels from Industrial Noise Sources

Type of Receiver	Indicative Noise Amenity Area	Time of Day[1,2]	Recommended L_{Aeq} Noise Level[3]	
			Acceptable	Recommended Maximum
Residence	Rural	Day	50 dBA	55 dBA
		Evening	45 dBA	50 dBA
		Night	40 dBA	45 dBA
	Suburban	Day	55 dBA	60 dBA
		Evening	45 dBA	50 dBA
		Night	40 dBA	45 dBA
	Urban	Day	60 dBA	65 dBA
		Evening	50 dBA	55 dBA
		Night	45 dBA	50 dBA
	Urban/Industrial Interface - for existing situations only	Day	65 dBA	70 dBA
		Evening	55 dBA	60 dBA
		Night	50 dBA	55 dBA

Note 1: For Monday to Saturday, Daytime 0700 hours - 1800 hours; Evening 1800 hours - 2200 hours; Night-time 2200 hours - 0700 hours.

Note 2: On Sundays and Public Holidays, Daytime 0800 hours - 1800 hours; Evening 1800 hours - 2200 hours; Night-time 2200 hours - 0800 hours.

Note 3: The L_{Aeq} index corresponds to the level of noise equivalent to the energy average of noise levels occurring over a measurement period.

Port activities have been conducted at Barangaroo (previously known as Darling Harbour East) and the surrounding foreshore since the mid 1820s and since the nineteenth century area has been (as currently constructed prior to the approval of when the Barangaroo Concept Plan in 2007) used as wharves and shipping infrastructure[10].

The ongoing use of the wharf and foreshore for marine transport is not considered a new use, but rather another layer of port activity and therefore the urban/industrial interface indicative noise amenity area applies. It is noted that the INP and INP Application Notes provide guidance on when to apply the urban/industrial interface amenity category and refer to 'existing' plant on 'existing' sites. The continued ongoing use of the port is consequently considered an existing use.

The urban/industrial interface recommended noise levels would apply to those receivers in the immediate area surrounding the existing industry, in this instance the adjacent foreshores of Barangaroo South (including King Street Wharf, Pyrmont Bay, and Jones Bay receivers). For urban/industrial interface the recommended acceptable noise level is 50 dBA during the night-time period, 55 dBA during the evening and 65 dBA during the day.

The urban recommended noise levels would apply to receivers in Balmain East (at NCA-05).

It is essential to note that in some instances where the recommended maximum noise level cannot be achieved (even with implementation of all feasible and reasonable mitigation), the proposed development is considered to have a large adverse noise impact. The INP provides guidance with respect to such development as follows:

10 "Discover Barangaroo – History", http://www.barangaroo.com/discover-barangaroo/history.aspx, Barangaroo Delivery Authority. 2013. Retrieved 20 October 2014

"Where the proposed development exceeds the recommended maximum noise levels in Table 2.1 (Amenity Criteria)*, substantial benefits in other areas, including a high degree of social worth, would need to be demonstrated."*

Sleep Disturbance

It is envisaged that the proposed Barangaroo Ferry Hub would operate during the night-time period (i.e. 5:00 am to 7:00 am and 10:00 pm to 12:00 am midnight on weekdays, and 7:00 am to 8:00 am and 10:00 pm to 12:00 am midnight weekends and public holidays). Maintenance, layover and cleaning would also be undertaken during the night-time period. Therefore the potential for sleep disturbance has to be considered.

The current approach to assessing potential sleep disturbance is to apply an initial screening level of "L_{Amax} or L_{A1} = background plus 15 dB" (as described in the Application Notes to the INP), and to undertake further analysis if the screening criterion cannot be achieved. The sleep disturbance screening criterion applies outside bedroom windows during the night-time period.

4.2.3 Road Noise Policy (RNP)

The characteristics of ferry terminal operations are considered to share similarities with those of the local road – metropolitan, described by the RNP as "characteristically having low or intermittent traffic flows".

The RNP assessment criteria for residences adjacent to such projects are summarised in **Table 14.**

Table 14 RNP Criteria – Residential

Road Category	Type of Project/Land Use	Assessment Criteria (dBA)	
		Daytime (7 am – 10 pm)	**Night-time (10 pm – 7 am)**
Local Roads	4. Existing residences affected by noise from new local road corridors	$L_{Aeq(1hour)}$ 55 (external)	$L_{Aeq(1hour)}$ 50 (external)

It should be noted that the noise criteria for local roads are assessed over 1 hour period, $L_{Aeq(1hour)}$ to take into account of the peak hour traffic.

Sleep Disturbance

Guidance for the assessment of sleep disturbance given in the RNP is reproduced as follows:

Triggers for, and effects of sleep disturbance from, exposure to intermittent noise such as noise from road traffic are still being studied. There appears to be insufficient evidence to set new indicators for potential sleep disturbance due to road traffic noise. The NSW Roads and Traffic Authority's Practice Note 3 (NSW Roads and Traffic Authority 2008) outlines a protocol for assessing and reporting on maximum noise levels and the potential for sleep disturbance.

The procedure for assessing the potential for sleep disturbance, detailed within *Practice Note III* of the RMS *Environmental Noise Management Manual* (ENMM), is to perform an L_{AFmax} – $L_{Aeq(1hr)}$ calculation on individual vehicle passby noise measurements. A maximum noise level event is then defined as a passby for which the night-time L_{AFmax} – $L_{Aeq(1hr)}$ difference is greater than 15 dB.

With regard to the reaction to potential sleep disturbance events, the RNP gives the following guidance:

> *From the research on sleep disturbance to date it can be concluded that:*
>
> - *maximum internal noise levels below 50–55 dB(A) are unlikely to awaken people from sleep*
> - *one or two noise events per night, with maximum internal noise levels of 65–70 dB(A), are not likely to affect health and wellbeing significantly.*

It is generally accepted that internal noise levels in a dwelling with the windows open are 10 dB lower than external noise levels. Based on this conservative minimum attenuation of 10 dB, the first conclusion above suggests that short term external noises of 60 dBA to 65 dBA are unlikely to cause awakening reactions.

The second conclusion suggests that one or two noise events per night with maximum external noise levels of 75 dBA to 80 dBA are not likely to affect health and wellbeing significantly.

4.3 Summary of NSW Noise Guidelines

The noise design levels presented in RING, NSW INP and RNP are summarised below in **Table 15**.

Table 15 NSW's Noise Design Levels for Residential Receivers

Guidelines	Time period	Assessment Location	Descriptor	Levels, dBA
Rail Infrastructure Noise Guideline	Daytime[1]	1 m from nearest affected facade	$L_{Aeq(15hour)}$	60
			L_{Amax}	80
	Night-time[1]	1 m from nearest affected facade	$L_{Aeq(9hour)}$	50
			L_{Amax}	80
Industrial Noise Policy (Intrusive)	Daytime[2] 7:00 am to 6:00 pm	At receiver's boundary	$L_{Aeq(15minute)}$	Daytime RBL + 5 dB
	Evening 6:00 pm to 10:00 pm	At receiver's boundary	$L_{Aeq(15minute)}$	Evening RBL + 5 dB
	Night-time[2] 10:00 pm to 7:00 am	At receiver's boundary	$L_{Aeq(15minute)}$	Night-time RBL + 5 dB
Industrial Noise Policy (Amenity, Urban/Industrial Interface)	Daytime[2] 7:00 am to 6:00 pm	At receiver's boundary	$L_{Aeq(period)}$	65 dBA to 70 dBA
	Evening 6:00 pm to 10:00 pm	At receiver's boundary	$L_{Aeq(period)}$	55 dBA to 60 dBA
	Night-time[2] 10:00 pm to 7:00 am	At receiver's boundary	$L_{Aeq(period)}$	50 dBA to 55 dBA
Industrial Noise Policy (Sleep disturbance)	Night-time[2] 10:00 pm to 7:00 am	Outside nearest affected bedroom	L_{Amax} or L_{A1}	Night-time RBL + 15 dB
Road Noise Policy	Daytime[1]	1 m from nearest affected facade	$L_{Aeq(1hour)}$	55
	Night-time[1]	1 m from nearest affected facade	$L_{Aeq(1hour)}$	50
		Outside nearest affected bedroom facade	L_{Amax}	75 dBA to 80 dBA

Note 1: Assessment time periods are 7:00 am to 10:00 pm for daytime and 10:00 pm to 7:00 am for night-time.

Note 2: Time period shown are applicable to Monday to Saturday only. Sundays and public holidays daytime period is between 8:00 am to 6:00 pm and night-time period is between 10:00 pm to 8:00 am.

Sensitive land uses other than residential such as businesses and open areas would require the determination separate proposal specific noise goals. For such receivers, the external to internal building noise reduction would be estimated and the internal L_{Aeq} noise levels from operations compared to the 'recommended' internal levels presented in AS/NZS 2107:2000 Acoustics – *Recommended design sound levels and reverberation times for building interiors*.

4.4 Discussion of NSW Noise Guidelines

For any proposed future noise-generating developments, the noise guidelines outlined in **Section 4.2** above would generally be considered as planning objectives. These are unlikely to be the limiting or mandatory limits for the development. The determination of acceptability for a noise generating development is not determined solely on the basis of compliance. Several other factors have to be considered in the determination for suitability. These factors include economic consequences, environmental effects and the social worth of the development. The various noise guidelines assist in determining consent/licence conditions as they provide information on the likely effect of any environmental noise associated with the development.

In principle, human response to noise within the community varies subjectively. There is a proportion within a community that is very sensitive to noise, those who are less sensitive to the same noise source, and majority of the population that lies anywhere in between the two bounds of the impact. The NSW INP states the following in relation to the variation of noise sensitive receivers within the population:

> *"This noise-sensitive sector of the population will react, often strongly, to intruding noises that are barely audible within the overall noise environment, or will have an expectation of very low environmental noise levels. On the other hand, there are those within the community who find living in noisy environments, such as near major industry, on main roads or under aircraft flight paths, an acceptable situation. The bulk of the population lies within these two extremes, being unaffected by low levels of noise and being prepared to accept levels of noise that are commensurate with living in an urban, industrialised society."*

Generally, the development of noise guidelines (e.g. as outlined within this document) have been adopted in order to safeguard at least 90 per cent of the population living in the vicinity of the noise sources under consideration (i.e. rail, road, aircraft and industrial noise) from the adverse effect of noise for at least 90 per cent of the time. In the event that the designed noise levels are achieved, it is anticipated that most people would be unlikely to consider the resultant noise levels excessive. However, where the designed noise levels cannot be achieved, it does not necessary mean that the persons affected by the noise would find the noise unacceptable.

As discussed in **Section 4.2.2**, the ongoing use of the subject wharf and foreshore for marine transport is not considered a new use, but rather another aspect of port activity and therefore the Barangaroo Ferry Hub would be considered as an addition to exiting industry interface. The existence of Darling Harbour East and the surrounding foreshore has been established since the mid 1820 and it is likely that it may have been in existence before the surrounding noise sensitive developments (excluding the Barangaroo development currently under construction) and before any noise control legislation was introduced. The range of mitigation options available for such sites may therefore be either extremely limited or costly.

It should also, be noted that the requirement to reduce noise emissions from existing sites should be weighed against the wider economic, social and environmental considerations. The project-specific noise levels should not be applied as mandatory noise limits. The noise levels should be considered as the initial target levels to drive the process of assessing all feasible and reasonable noise control measures. Achievable noise goals should then be derived as a result from applying all feasible and reasonable noise control measures. Further, sites with limited mitigation measures due to specific requirements and restrictions, the achievable noise limits may sometimes be above the project-specific noise levels.

4.5 Barangaroo Ferry Hub Operational Noise Objective

In order to determine the suitable operational noise objective for the project consideration to the following items in addition to the factors discussed in **Section 4.4**, (with acoustical significance) has been taken into account:

Noise characteristics of the vessel:

- Usage of warning system; and
- Engine noise and noise from manoeuvring pattern

Operation characteristics:

- Intermittent characteristics of ferry movements;
- Definite peak periods of vessel traffic can be expected on weekdays;
- Operates partly into the early mornings (before 7:00 am on Monday to Saturday and 8:00 am on Sundays), into night-time period (between 10:00 pm and 12:00 am midnight) and extended hours during special events.

The proposed operational noise objectives for the Barangaroo Ferry Hub, given in **Table 16** and **Table 17**, have been derived with guidance from the three documents reviewed in **Section 4.2** to take into account the acoustical characteristics (such as vessel traffic and source characteristics) of the ferry terminal operation.

The characteristics of road traffic noise is considered to be inconsistent with ferry traffic and therefore the overall L_{Aeq} design levels are not included in the process of establishing noise objective for the project.

For the purpose of this assessment, it is conservatively assumed that all buildings have openable windows. The internal noise levels are then assumed to be 10 dB lower than external noise levels when windows are open, and up to 25 dB lower than external noise levels with windows closed.

Table 16 Barangaroo Ferry Hub Operational Noise Objective for Residential and Non-residential Land Use

Time period	Receiver Type	Assessment Location	Descriptor	Assessment period	Noise Level, dBA	Source	Comments
Residential Land Use							
Day time[1]	Residential	1 m from nearest affected facade	LAeq(1hour)	1 hour	60	RING	To address potential noise from daytime operation.
			LAmax	Within 1 hour period	80	RING	To address potential noise from maximum noise events due to the operation (i.e. horn/ alert usage).
Night-time[1]	Residential		LAeq(1hour)	1 hour	50	RING	To address potential noise from night-time operation.
			LAmax	Within 1 hour period	80	RING	To address potential noise from maximum noise events due to the operation (i.e. horn/ alert usage).
Night-time	Residential	1 m from nearest affected facade	LAmax		Night-time RBL + 15 dB	INP (Sleep disturbance)	To identify potential sleep disturbance
Other Land Use[3]							
When in use	Hotels	Internal	LAeq[2]	Within 1 hour period	Internal noise level 35 dBA[4]	INP	To address potential noise from the operation
When in use	Commercial	at the most affected occupied point on the premises	LAeq[2]	Within 1 hour period	70 (external)[5]	INP	
When in use	Passive Recreational area	at the most-affected point within 50 m of the area boundary	LAeq[2]	Within 1 hour period	50 (external)[5]	INP	
When in use	Active Recreational area	at the most-affected point within 50 m of the area boundary	LAeq[2]	Within 1 hour period	55 (external) [5]	INP	

Note 1: Assessment time periods are 7:00 am to 10:00 pm for daytime and 10:00 pm to 7:00 am for night-time.

Note 2: The LAeq noise level for a specific period represents the LAeq level calculated or measured over the applicable day, evening and night period (i.e. LAeq(period)) except when otherwise stated.

Note 3: The noise levels are designed to be at acceptable noise levels detailed INP to ensure the proposed development does not give rise to the cumulative noise of other waterways operation.

Note 4: Based on recommended internal noise levels from AS2107:2000

Note 5: The external noise levels should be assessed at the most affected occupied point on the premises.

4.6 Project Specific Operational Noise Levels

Based on the noise objectives outlined above in **Table 16**, the processed results of the unattended noise monitoring were used to determine project specific noise objectives and noise screening levels for operation of Barangaroo Ferry Hub. These levels are presented in **Table 17**.

It should be noted that these design objectives are nominated for the purpose of indicating the potential operational noise implications from the proposed development and are not intended to be use as controlling noise levels.

Table 17 Project Specific Operational Noise Objective for Sensitive Receivers Surrounding Barangaroo Ferry Hub

NCA Receiver Types	NM ID	Receiver Type	Operational Noise Objective				
			Daytime Period[1]		Night-time Period[1]		
			LAeq (1hour)	LAmax	LAeq (1hour)	LAmax	Sleep Disturbance LAmax
NCA01-RES	NM1	Residential	60	80	50	80	61
NCA01-COM		Commercial	70	N/A	70	N/A	N/A
NCA01-OHO		Other (Hotel) [2]	35[1]	N/A	35[1]	N/A	N/A
NCA02-RES	NM1	Residential[2]	60	80	50	80	61
NCA02-COM		Commercial	70	N/A	70	N/A	N/A
NCA02-OHO		Other (Hotel) [2]	35[1]	N/A	35[1]	N/A	N/A
NCA03-RES	NM2	Residential	60	80	50	80	56
NCA03-COM		Commercial	70	N/A	70	N/A	N/A
NCA04-RES	NM2	Residential	60	80	50	80	56
NCA04-COM		Commercial	70	N/A	70	N/A	N/A
NCA04-OoA		Other (Outdoor Active)[3]	55	N/A	N/A	N/A	N/A
NCA05-RES	NM3	Residential	60	80	50	80	56
NCA05-OoP		Other (Outdoor Passive) [3]	50	N/A	N/A	N/A	N/A

Note 1: Assessment time periods are 7:00 am to 10:00 pm for daytime and 10:00 pm to 7:00 am for night-time.

Note 2: Residential receivers include single dwelling, hotels, hostels and apartments

Note 3: Only assessed when in use

A noise assessment at residential receivers based on an established noise guideline (INP) is also provided for comparison. The project-specific noise criteria are detailed in **Table 18**.

Table 18 Summary of Project Specific Noise Criteria (INP)

NCA Receiver Type[1]	NM ID	Time Period	Measured RBL (L_{A90}) , dBA	INP Assessment Criteria	
				Intrusive Criteria	Amenity Criteria
				LAeq(15minute)	LAeq(period)
NCA01-RES	NM1	Daytime	52	57	65
		Evening	59[2]	57	55
		Night-time	46	51	50
NCA02-RES	NM1	Daytime	52	57	65
		Evening	59[2]	57	55
		Night-time	46	51	50
NCA03-RES	NM2	Daytime	51	56	65
		Evening	46	51	55
		Night-time	41	46	50
NCA04-RES	NM2	Daytime	51	56	65
		Evening	46	51	55
		Night-time	41	46	50
NCA05-RES	NM3	Daytime	49	54	60
		Evening	49	54	50
		Night-time	41	46	45

Note 1: 'RES' refers to residential receivers only (ie apartments and single dwellings)

Note 2: Where the evening background noise level of evening period is higher than the measured daytime noise level, the lower measured level of daytime would be used. (INP Application notes of Section 3.1)

5 OPERATIONAL NOISE ASSESSMENT

5.1 Operational Scenario

Based on the information contained in the SSI Application supporting document (version 1.4 dated 30 September 2014) and on our understanding of the project (year 2026 forecasts for operations), operational scenarios were developed on a worst-case basis.

It is anticipated that the Barangaroo Ferry Hub may be required to operate outside of the above hours during special events such as New Year's Eve, Vivid and Australia Day. The likely extension of hours is covered in the night-time noise assessment of Scenario 1 (Peak Periods) outlined below.

Peak Periods

The peak periods observed from the Circular Quay timetable[11] during weekday are between 7:00 am to 9:00 am (morning peak period) and 5:00 pm to 7:00 pm (evening peak period). The ferry traffic on the weekend was observed to be similar to the weekday peak periods (i.e. constant throughout the day with no specific peak).

Within a given one hour period, patron numbers awaiting embarkation is assumed to be 50 per wharf (i.e. a third of Harbourcat capacity per wharf, with passengers across three wharves) engaged in conversation at casual vocal effort.

It should be noted that peak period assessment is based on an assumed worst-case operation and is unlikely the typical operation expected at Barangaroo Ferry Hub.

Off-peak Period

The off-peak period ferry movements have been estimated to be half of the daytime/evening peak periods.

Within a given one hour period, patron numbers awaiting embarkation is assumed to be 25 per wharf (i.e. a third of Harbourcat capacity per wharf, with passengers across three wharves) engaged in conversation at a casual vocal effort.

Maintenance

Maintenance such as sewerage pump-out (assumed occurred daily) on each wharf and water blasting at the wharves (monthly) are carried out after last vessel service.

These scenarios are considered to be representative of the noisiest activities and are detailed in **Section 2.2** and replicated below.

5.2 Modelling of Barangaroo Ferry Hub Operational Scenarios

Scenario 1: Year 2026 forecasts for operations - maximum ferry movements across all three wharves.

- Total of 21 vessels per hour (entering and exiting)
- Passengers across three wharves, engaged in conversation, and a
- Total of three PA system – one per wharf.

[11] Observations made from review of current timetables (F3 Parramatta River and F4 Darling Harbour), dated 20 October 2013.

- http://www.transportnsw.info/resources/documents/timetables/F3-parramatta-river.pdf
- http://www.transportnsw.info/resources/documents/timetables/F4-darling-harbour.pdf

Scenario 2: Year 2026 forecasts for operations – off-peak ferry movements (50% reduced capacity) across three wharves.

- Total of 10 vessels per hour (entering and exiting)
- Passengers across three wharves, engaged in conversation, and
- Total of three PA system – one per wharf.

Scenario 3: Night-time cleaning activities without ferry movement

- High pressure water cleaning – one per wharf on both wharves occurring concurrently, and
- Sewage pump-out – two across two wharves assumed to occur concurrently.

5.3 Operational Ferry Noise Levels

Sound Power Levels (SWLs) derived from the measured ferry activities (**Appendix C**) are shown in **Table 19**. The SWLs are maximum noise emission levels of ferries that are expected to be used on this project during operation.

Table 19 Sound Power Level of Ferry Terminal Activities

Ferry Terminal Activities	SWL, dBA	Duty Factor (time operating per 15 minute period)
Accelerating	98	2 minutes
Reverse Thrust	93	1 minute
Idling	92	5 minutes
Horn	118	5 seconds
PA system	73	5 minutes
Passenger noise – casual vocal effort	60	10 minutes
Water pump (high pressure water)	110	5 minutes
Sewage pump	72	10 minutes

The duty factor represents the likely amount of time that a particular activity would be undertaken in any 15 minute period. This takes into account of the fact that in a 15 minute period one ferry operation may involve, for example, acceleration to the terminal for 1 minute, then berthing for 30 seconds using reverse thrust, idling for 5 minutes as the passengers embark the ferry, sounding the horn for 5 seconds before departing the terminal and accelerating to the next destination for 1 minute (i.e. all the activities would not be operating simultaneously at the same wharf).

5.4 Operational Assessment of the Ferry Wharf

Operational noise levels have been predicted at the nearest noise sensitive receivers using the CONCAWE prediction methodology within the SoundPLAN noise modelling software.

The calculation of noise levels would inevitably depend on the number of vessel movements, the duration of operation at any one time and their precise location relative to the receiver of interest. In practice, the noise levels would vary due to the fact that the vessels would move along their planned routes and would not all be operating concurrently.

Note that in the absence of operating schedules, the operational scenario has been derived based on the forecast operation of the terminal for a worst case situation (i.e. during peak hours with all three wharves in use within a one hour period).

In the absence of an existing framework for noise emissions from commuter ferry operations, an assessment has also been undertaken against the project-specific noise criteria specified in the INP.

5.4.1 Assessment against Project Specific Noise Objectives

The predicted noise levels for the operation during the peak period scenario are detailed in **Table 20** and are compared to the project specific noise objective detailed in **Table 17**.

Table 20 Predicted Operational Noise Levels (Noise Objectives)

Scenario	NCA	Receiver Type	Worst-case Predicted Noise Level (dBA)		Operational Noise Objective					Exceedance		
					Daytime		Night-time			Daytime	Night-time	
			LAeq (1hour)	LAmax	LAeq (1hour)	LAmax	LAeq (1hour)	LAmax	Sleep Disturbance LAmax	LAeq(1hour) / LAmax	LAeq(1hour) / LAmax	Sleep Disturbance LAmax
Sc1 – Peak Period Ferry Movements 2026[4]	NCA-01	Residential	Up to 53	Up to 72	60	80	50	80	61	- / -	Up to 3 / -	Up to 11
		Commercial	45-50	67-69	70	N/A	70	N/A	N/A	- / N/A	- / N/A	N/A
		Other (Hotel)[3]	Up to 49 (24)	Up to 63 (38)	35[2]	N/A	35[2]	N/A	N/A	- / -	- / -	N/A
	NCA-02	Residential	<30	42-42	60	80	50	80	61	- / -	- / -	-
		Commercial	44-51	65-71	70	N/A	70	N/A	N/A	- / N/A	- / N/A	N/A
		Other (Hotel) [3]	Up to 42 (17)	Up to 62 (37)	35[2]	N/A	35[2]	N/A	N/A	- / -	- / -	N/A
	NCA-03	Residential	50-53	64-66	60	80	50	80	56	- / -	Up to 3/ -	8-10
		Commercial	38-45	53-62	70	N/A	70	N/A	N/A	- / N/A	- / N/A	N/A
	NCA-04	Residential	46-49	59-61	60	80	50	80	56	- / -	- / -	3-5
		Commercial	33-44	41-58	70	N/A	70	N/A	N/A	- / N/A	- / N/A	N/A
		Other (Outdoor Active) [1]	33-50	35-62	55	N/A	N/A	N/A	N/A	- / N/A	- / N/A	N/A
	NCA-05	Residential	38-41	50-52	60	80	50	80	56	- / -	- / -	-
		Other (Outdoor Passive) [1]	38-42	48-53	50	N/A	N/A	N/A	N/A	- / N/A	- / N/A	N/A

Scenario	NCA	Receiver Type	Worst-case Predicted Noise Level (dBA)		Operational Noise Objective					Exceedance		
					Daytime		Night-time			Daytime	Night-time	
			LAeq (1hour)	LAmax	LAeq (1hour)	LAmax	LAeq (1hour)	LAmax	Sleep Disturbance LAmax	LAeq(1hour) / LAmax	LAeq(1hour) / LAmax	Sleep Disturbance LAmax
Sc2 – Off-Peak Period Ferry Movements 2026	NCA-01	Residential	Up to 50	Up to 72	60	80	50	80	61	- / -	- / -	Up to 11
		Commercial	42-47	67-69	70	N/A	70	N/A	N/A	- / N/A	- / N/A	N/A
		Other (Hotel) [3]	Up to 46 (21)	Up to 63 (38)	35[2]	N/A	35[2]	N/A	N/A	- / -	- / -	N/A
	NCA-02	Residential	<30	42-42	60	80	50	80	61	- / -	- / -	-
		Commercial	41-48	65-71	70	N/A	70	N/A	N/A	- / N/A	- / N/A	N/A
		Other (Hotel) [3]	Up to 39 (14)	Up to 62 (37)	35[2]	N/A	35[2]	N/A	N/A	- / -	- / -	N/A
	NCA-03	Residential	47-50	64-66	60	80	50	80	56	- / -	- / -	8-10
		Commercial	35-42	53-62	70	N/A	70	N/A	N/A	- / N/A	- / N/A	N/A
	NCA-04	Residential	43-46	59-61	60	80	50	80	56	- / -	- / -	3-5
		Commercial	30-41	41-58	70	N/A	70	N/A	N/A	- / N/A	- / N/A	N/A
		Other (Outdoor Active) [1]	30-47	35-62	55	N/A	N/A	N/A	N/A	- / N/A	- / N/A	N/A
	NCA-05	Residential	35-38	50-52	60	80	50	80	56	- / -	- / -	-
		Other (Outdoor Passive) [1]	35-39	48-53	50	N/A	N/A	N/A	N/A	- / N/A	- / N/A	N/A

Scenario	NCA	Receiver Type	Worst-case Predicted Noise Level (dBA)		Operational Noise Objective					Exceedance		
					Daytime		Night-time			Daytime	Night-time	
			LAeq (1hour)	LAmax	LAeq (1hour)	LAmax	LAeq (1hour)	LAmax	Sleep Disturbance LAmax	LAeq(1hour) / LAmax	LAeq(1hour) / LAmax	Sleep Disturbance LAmax
Sc3 – Maintenance Works	NCA-01	Residential	64-66	69-70	60	80	50	80	61	4-6 / -	14-16 / -	8-9
		Commercial	56-60	60-63	70	N/A	70	N/A	N/A	- / N/A	- / N/A	N/A
		Other (Hotel) [3]	Up to 49 (24)	Up to 53 (28)	35[2]	N/A	35[2]	N/A	N/A	- / -	- / -	N/A
	NCA-02	Residential	<30	<30	60	80	50	80	61	- / -	- / -	-
		Commercial	46-56	50-61	70	N/A	70	N/A	N/A	- / N/A	- / N/A	N/A
		Other (Hotel) [3]	Up to 43 (18)	Up to 48 (23)	35[2]	N/A	35[2]	N/A	N/A	- / -	- / -	N/A
	NCA-03	Residential	50-52	53-55	60	80	50	80	56	- / -	Up to 2 / -	-
		Commercial	32-48	34-51	70	N/A	70	N/A	N/A	- / N/A	- / N/A	N/A
	NCA-04	Residential	46-49	49-52	60	80	50	80	56	- / -	- / -	-
		Commercial	<30-44	30-48	70	N/A	70	N/A	N/A	- / N/A	- / N/A	N/A
		Other (Outdoor Active) [1]	<30-49	<30-52	55	N/A	N/A	N/A	N/A	- / N/A	- / N/A	N/A
	NCA-05	Residential	38-40	41-42	60	80	50	80	56	- / -	- / -	-
		Other (Outdoor Passive)[1]	37-41	39-43	50	N/A	N/A	N/A	N/A	- / N/A	- / N/A	N/A

Note 1: Only assessed when in use

Note 2: The Hotel NML is an internal noise level.

Note 3: Hotel predicted internal noise levels are shown in brackets for comparison with the NML. The predicted noise levels are based on 6.38 mm laminate glazing, and a window area of $2m^2$ per Hotel suite.

Note 4: Assumed operational in all periods daytime and night-time representing typical peak periods and during special events

5.4.2 Assessment against Project-Specific Noise Criteria (INP)

The predicted noise levels for the operation during the peak period scenario are detailed in **Table 21** and are compared to the project-specific noise criteria detailed in **Table 18**.

Table 21 Predicted Operational Noise Levels (INP)

Scenario	NCA	Worst-case Predicted Noise Level (dBA)			INP Noise Criteria						Exceedance					
					Intrusive Criteria			Amenity Criteria			Intrusive Criteria			Amenity Criteria		
		LAeq (15minute)	LAeq (Day and Evening)	LAeq (Night)	Daytime[1]	Evening[1]	Night-time[1]	Daytime[1]	Evening[1]	Night-time[1]	Daytime[1]	Evening[1]	Night-time[1]	Daytime[1]	Evening[1]	Night-time[1]
Sc1 – Peak Period Ferry Movements 2026[2]	NCA01-RES	53	53	49-50	57	57	51	65	55	50	-	-	Up to 2	-	-	-
	NCA02-RES	<30	<30	<30	57	57	51	65	55	50	-	-	-	-	-	-
	NCA03-RES	50-53	50-53	47-49	56	51	46	65	55	50	-	1-2	4-7	-	-	-
	NCA04-RES	46-49	46-49	42-46	56	51	46	65	55	50	-	-	Up to 3	-	-	-
	NCA05-RES	38-41	38-41	35-37	54	54	46	60	50	45	-	-	-	-	-	-
Sc2 – Off-Peak Period Ferry Movements 2026	NCA01-RES	Up to 50	Up to 50	46-47	57	57	51	65	55	50	-	-	-	-	-	-
	NCA02-RES	<30	<30	<30	57	57	51	65	55	50	-	-	-	-	-	-
	NCA03-RES	47-50	47-50	44-46	56	51	46	65	55	50	-	-	1-4	-	-	-
	NCA04-RES	43-46	43-46	39-43	56	51	46	65	55	50	-	-	-	-	-	-
	NCA05-RES	35-38	35-38	32-34	54	54	46	60	50	45	-	-	-	-	-	-

Scenario	NCA	Worst-case Predicted Noise Level (dBA)			INP Noise Criteria						Exceedance					
					Intrusive Criteria			Amenity Criteria			Intrusive Criteria			Amenity Criteria		
		LAeq (15minute)	LAeq (Day and Evening)	LAeq (Night)	Daytime[1]	Evening[1]	Night-time[1]	Daytime[1]	Evening[1]	Night-time[1]	Daytime[1]	Evening[1]	Night-time[1]	Daytime[1]	Evening[1]	Night-time[1]
Sc3 – Maintenance Works	NCA01-RES	64-66	64-66	61-62	57	57	51	65	55	50	7-9	7-9	13-15	Up to 1	9-11	11-12
	NCA02-RES	<30	<30	<30	57	57	51	65	55	50	-	-	-	-	-	-
	NCA03-RES	Up to 50	50-52	47-49	56	51	46	65	55	50	-	Up to 1	Up to 4	-	-	-
	NCA04-RES	46-49	46-49	42-45	56	51	46	65	55	50	-	-	Up to 3	-	-	-
	NCA05-RES	38-40	38-40	35-36	54	54	46	60	50	45	-	-	-	-	-	-

Note1 : INP assessment Periods –
Day: 7.00 am to 6.00 pm Monday to Saturday, 8.00 am to 6.00 pm Sunday;
Evening: 6.00 pm to 10.00 pm;
Night: 10.00 pm to 7.00 am Monday to Saturday, 10.00 pm to 8.00 am Sunday.

Note 2: Assumed operational in all periods daytime, evening and night-time representing typical peak periods and during special events

5.5 Discussion of Results

5.5.1 Barangaroo Operational Noise Objectives Assessment

Operational noise levels have been predicted at the nearest receiver locations to the proposed Barangaroo Ferry Hub. The resultant daytime and night-time $L_{Aeq(1hour)}$ and L_{Amax} noise level predictions, are presented in **Table 20** for the proposed operational scenarios and compared with the Barangaroo Operational Noise Objectives.

Scenario 1 and Scenario 2

The noise levels of vessel movements for Scenario 1 and Scenario 2 are predicted to comply with the daytime noise objectives (both $L_{Aeq(1hour)}$ and L_{Amax}).

An exceedance of up to 3 dB in the night-time of Scenario 1 has been predicted at residential receivers in NCA-01 and NCA-03 due to the proximity of the proposed route. The predicted noise levels of Scenario 2 show compliance with the night-time noise objectives.

Scenario 3

The noise levels of maintenance works (Scenario 3) are predicted to exceed the noise objectives by 6 dB and 16 dB at NCA-01 in the daytime and night-time respectively. The predicted noise levels also indicate an exceedance of up to 2 dB during the night-time period at NCA-03.

The exceedance for Scenario 3 is due to the use of use of high pressure water cleaning equipment and the close proximity to the receivers.

Sleep Disturbance

Exceedances of the sleep disturbance screening criteria of up to 11 dB, 10 dB and 5 dB (predicted L_{Amax} noise levels of 72 dB, 66 dB and 61 dB) are predicted in Scenario 1 and Scenario 2 for residential receivers at NCA-01, NCA-03 and NCA-04 respectively. This is likely due to the use of warning horns.

Exceedances of the sleep disturbance screening criteria of up to 9 dB (predicted L_{Amax} noise level of 70 dB) are predicted in Scenario 3 for residential receivers at NCA-01. This is likely due to the use of high pressure water cleaning equipment.

As discussed in **Section 4.2.3**, maximum internal noise levels below 50 dBA to 55 dBA are unlikely to cause sleep arousal. On this basis, the predicted short-term external noise levels of between 60 dBA to 65 dBA at residential receivers in NCA-02, NCA-04 and NCA-05 are unlikely to cause awakening reactions. A 1 dB variation in noise level would not be audible and thus the short-term external noise level predicted at for Scenario 1 and Scenario 2 at NCA-03 would be unlikely to cause sleep disturbance to the residential receivers in this noise catchment.

Maximum noise levels of up to 72 dBA for Scenario 1 and Scenario 2, and 70 dB for Scenario 3 are predicted at the receivers in NCA-01. The RNP suggests that one or two noise events per night with maximum external noise levels of 75 dBA to 80 dBA are not likely to affect health and wellbeing significantly. While the night-time vessel movements would likely decrease in the night-time periods (5:00 am to 7:00 am and 10:00 pm to 12:00 am midnight), the maximum noise level due to horn usage is unlikely to decrease. On this basis, the predicted noise levels show sleep disturbance at receivers in NCA-01.

5.5.2 INP Project-Specific Noise Criteria Assessment

Operational noise levels have been predicted at the nearest receiver locations to the proposed Barangaroo Ferry Hub. The resultant daytime, evening and night-time $L_{Aeq(15minute)}$ and $L_{Aeq(period)}$ noise level predictions, are presented in **Table 21** for the proposed operational scenarios and compared with the relevant INP assessment criteria.

Scenario 1 and Scenario 2

The predicted noise levels of Scenario 1 and Scenario 2 show compliance with the nominated daytime, evening and night-time amenity noise criteria.

Exceedances of up to 7 dB in the night-time intrusive criteria of Scenario 1 have been predicted at residential receivers in NCA-01, NCA-03 and NCA-04 due to the proximity of the proposed route.

Exceedances of up to 4 dB in the nigh-time intrusive criteria of Scenario 2 have been predicted at residential receivers in NCA-03 due to the proximity of the proposed route.

Scenario 3

Exceedances of up to 15 dB and 12 dB of the nominated night-time intrusive and amenity criteria have been predicted for maintenance works (Scenario 3) at residential receivers in NCA-01.

Exceedances of up to 6 dB and 3 dB of the nominated night-time intrusive criteria have been predicted for maintenance works (Scenario 3) at residential receivers in NCA-03 and NCA-04.

The exceedance for Scenario 3 is due to the use of use of high pressure water cleaning equipment and the close proximity to the receivers.

Sleep Disturbance

Method of assessing sleep disturbance is addressed in the assessment of Barangaroo Operational Noise Objectives. As such, the exceedances detailed in **Section 5.5.1** are expected to be the same.

5.6 Operational Noise Assessment Summary and Recommendations

5.6.1 Scenario 1 and Scenario 2

The information presented in **Table 20** and **Table 21** indicates that, due to the close vicinity of the wharves and ferry routes, residents in NCA-01 and NCA-02 (and NCA-03 for INP assessment) may experience exceedances of noise levels the night-time noise objective (and INP criterion) for the Scenario 1 and Scenario 2. Notwithstanding, the measured night-time ambient noise level at NM1 (excluding the bar operations) was 52 dBA. A noise level 1 dB above the measured ambient noise level due to ferry operations would unlikely to be noticeable and would have the same characteristics as the surrounding noise environment.

An exceedance of sleep disturbance screening criterion up to 11 dB suggests residential receivers would be impacted by the use of warning horns. TfNSW will investigate different horn noise specifications and operating procedures to address this impact and will implement feasible and reasonable measures identified during this investigation.

5.6.2 Scenario 3

The information presented in **Table 20** and **Table 21** indicates that exceedances of noise levels the daytime and night-time noise objective (and all periods of INP intrusive and amenity criteria) may be experienced by the residential receivers in NCA-01 (NCA-03 and NCA-04 in INP assessment) due to the use of high pressure water cleaning equipment at close proximity to the receivers.

Where feasible and reasonable, maintenance involving use of such equipment should consider the following:

- Limiting the number of equipment to one machinery at any given time
- Activity should be carried out (were feasible) during the daytime where higher ambient noise is expected and thus lower the degree of impact experienced by the receivers.

6 CONSTRUCTION NOISE AND VIBRATION ASSESSMENT METHODOLOGY

6.1 Construction Noise Management Levels

The NSW EPA *Interim Construction Noise Guideline* (ICNG) requires proposal specific Noise Management Levels (NMLs) to be established for noise affected receptors. In the event construction noise levels are predicted to be above the NMLs, all feasible and reasonable work practices are investigated to minimise noise emissions.

Having investigated all feasible and reasonable work practices, if construction noise levels are still predicted to exceed the NMLs then the potential noise impacts would be managed via site specific construction noise management plans, to be prepared in the detailed design phase.

6.1.1 Residential Receivers

The ICNG provides an approach for determining $L_{Aeq(15minute)}$ NMLs at residential receptors surrounding the project site with application of the measured $L_{A90(15minute)}$ background noise levels, as described in **Table 22**.

Table 22 Determination of NMLs for Residential Receptors

Time of Day	NML $L_{Aeq(15minute)}$	How to apply
Standard Hours Monday to Friday 7:00 am to 6:00 pm Saturday 8:00 am to 1:00 pm No work on Sundays or public holidays	RBL + 10 dBA	The noise affected level represents the point above which there may be some community reaction to noise. Where the predicted or measured LAeq(15minute) 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 75 dBA	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 restructuring the hours that the very noisy activities can occur, taking into account: Times identified by the community when they are less sensitive to noise (such as before and after school for works near schools or mid-morning or mid-afternoon for works near residences. If the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.

Time of Day	NML $L_{Aeq(15minute)}$	How to apply
Outside recommended standard hours	RBL + 5 dBA	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 practice have been applied and noise is more than 5 dB above the noise affected level, the proponent should negotiate with the community.

Note 1: Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5 m above ground level. If the property boundary is more than 30 m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 m of the residence. Noise levels may be higher at upper floors of the noise affected residence.

Note 2: The RBL is the overall single-figure background noise level measured in each relevant assessment period (during or outside the recommended standard hours). The term RBL is described in detail in the NSW Industrial Noise Policy.

Adopting the measured background noise levels in **Table 10**, the residential NMLs derived for the Concept Proposal are detailed in **Table 23**.

Table 23 Residential Receptor NMLs in Concept Proposal for Construction

NCA Receiver Type[1]	NM ID	Receiver Type	Standard Construction (RBL +10dBA)	OOHWs (RBL +5dBA)			Sleep Disturbance Screening (RBL+15)
			Daytime Period	Daytime Period	Evening Period	Night-time Period	
NCA01-RES	NM1	Residential	62	57	57[1]	51	61
NCA02-RES	NM1	Residential	62	57	57[1]	51	61
NCA03-RES	NM2	Residential	61	56	51	46	56
NCA04-RES	NM2	Residential	61	56	51	46	56
NCA05-RES	NM3	Residential	59	54	54	46	56

Note 1: Where the evening background noise level of evening period is higher than the measured daytime noise level, the lower measured level of daytime would be used. (INP Application Notes of Section 3.1)

Where construction would be undertaken during the night-time period the potential for sleep disturbance should be assessed. The current approach to identifying potential sleep disturbance impacts is to set a screening criterion 15 dB above the RBL during the night-time period (10:00 pm to 7:00 am).

The term 'screening criterion' indicates a noise level that is intended as a guide to identify the likelihood of sleep disturbance. It is not a firm criteria to be met, however where the screening level is met sleep disturbance is not likely. When the screening criterion is not met, a more detailed analysis is required.

The detailed analysis should assess the maximum noise level or $L_{A1(1minute)}$, the extent that the maximum noise level exceeds the background noise level and the number of times any exceedance occurs during the night-time period.

The RNP which contains a section on sleep disturbance that includes a summary of current literature, concludes that:

- Maximum internal noise levels below 50 dBA to 55 dBA are unlikely to cause awakening reactions

- One or two events per night, with maximum internal noise levels of 65 dBA to 70 dBA (i.e. Approximate to 75 dBA to 80 dBA external noise levels), are not likely to affect health and wellbeing significantly.

6.1.2 Other Sensitive Land Uses

The proposal specific $L_{Aeq(15minute)}$ NMLs for other non-residential noise sensitive receptors from the ICNG are provided in **Table 24**.

Table 24 Noise Management Levels for Other Sensitive Receptors

Land Use	NML $L_{Aeq(15minute)}$ (Applied when the property is in use)
Active recreation areas (characterised by sporting activities and activities which genera their own noise or focus for participants, making them less sensitive to external noise intrusion)	External noise level 65 dBA[2]
Passive recreation areas (characterised by contemplative activities that generate little noise and where benefits are compromised by external noise intrusion, e.g. reading, meditation)	External noise level 60 dBA[2]
Hotels	Internal noise level 35 dBA[1]
Commercial and Offices	External noise level 70 dBA[2]

Note 1: Based on recommended internal noise levels from AS2107:2000

Note 2: The external noise levels should be assessed at the most affected occupied point on the premises.

6.1.3 Construction Traffic Noise

It is proposed that the majority of the wharf components such as the piles, pontoon, gangway and ancillary facilities would be transported to the project site via Sydney Harbour (on boat and/or barge).

For this reason road traffic noise generated by construction activity is not anticipated to be the controlling factor for these proposed works and therefore further assessment is not warranted.

6.2 Ground-borne Construction Noise

Ground-borne noise results from the transmission of vibration rather than the direct transmission of noise through the air. Ground-borne (or regenerated) construction noise is usually present on tunnelling projects when vibration from activities such as rockbreaking, road heading, rotary cutting, tunnel boring and rock drilling/sawing can be transmitted through the ground and into the habitable areas of nearby buildings. Ground-borne noise occurs when this vibration in the ground and/or building elements is regenerated as audible noise within areas of occupancy inside the building.

The ICNG defines internal ground-borne noise goals for residential receivers of 40 dBA $L_{Aeq(15minute)}$ during the evening (6:00 pm to 10:00 pm) and 35 dBA $L_{Aeq(15minute)}$ during the night-time (10:00 pm to 7:00 am). The goals are only applicable when ground-borne noise levels are higher than airborne noise levels

The nature of the works (surface works with minimal screening effects and transient vibration from piling activities) means that ground-borne noise impacts are expected to be negligible. This is because the airborne noise emissions in most circumstances are much higher than ground-borne noise levels. For this reason ground-borne noise is not anticipated to be the controlling factor for these proposed works and therefore further assessment is not warranted.

6.3 Vibration Impact Assessment Criteria

6.3.1 Structural Damage Criteria

Most commonly specified "safe" structural vibration limits are designed to minimise the risk of threshold or cosmetic surface cracks, and are set well below the levels that have the potential to cause damage to the main structure.

6.3.2 British Standard 7385: Part 2 - 1993

In terms of the most recent relevant vibration damage criteria, Australian Standard AS 2187.2 - 2006 "*Explosives - Storage and Use - Use of Explosives*" recommends the frequency dependent guideline values and assessment methods given in BS 7385 Part 2-1993 *"Evaluation and measurement for vibration in buildings Part 2*" be used as they are "applicable to Australian conditions".

The standard sets guide values for building vibration based on the lowest vibration levels above which damage has been credibly demonstrated. These levels are judged to give a minimal risk of vibration induced damage, where minimal risk for a named effect is usually taken as a 95% probability of no effect.

Sources of vibration that are considered in the standard include demolition, blasting (carried out during mineral extraction or construction excavation), piling, ground treatments (e.g. compaction), construction equipment, tunnelling, road and rail traffic and industrial machinery.

The recommended limits (guide values) for transient vibration to ensure minimal risk of cosmetic damage to residential and industrial buildings are presented numerically in **Table 25** and graphically in **Figure 5**.

Table 25 Transient Vibration Guide Values - Minimal Risk of Cosmetic Damage

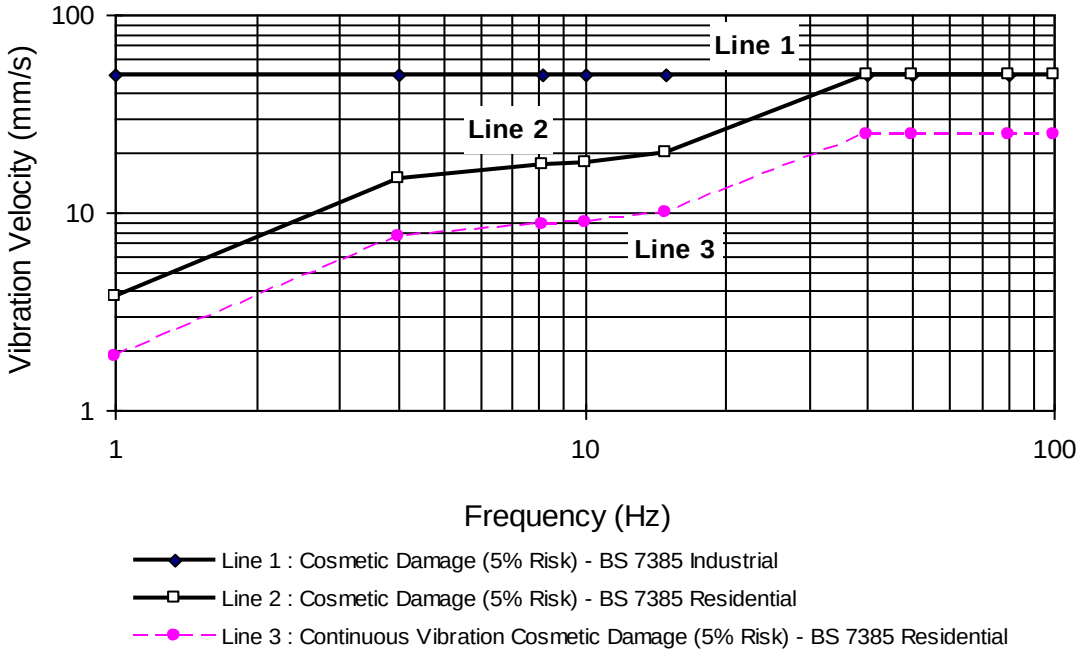
Line	Type of Building	Peak Component Particle Velocity in Frequency Range of Predominant Pulse	
		4 Hz to 15 Hz	15 Hz and Above
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

The standard states that the guide values in **Table 25** relate predominantly to transient vibration which does not give rise to resonant responses in structures and low-rise buildings.

Where the dynamic loading caused by continuous vibration is such as to give rise to dynamic magnification due to resonance, especially at the lower frequencies where lower guide values apply, then the guide values in **Table 25** may need to be reduced by up to 50%.

The activity associated with the wharf construction is transient in nature and will therefore be covered by the criteria given in **Table 25** above.

Figure 5 Graph of Transient Vibration Guide Values for Cosmetic Damage



In the lower frequency region where strains associated with a given vibration velocity magnitude are higher, the guide values for building types corresponding to Line 2 are reduced. Below a frequency of 4 Hz where a high displacement is associated with the relatively low peak component particle velocity value, a maximum displacement of 0.6 mm (zero to peak) is recommended. This displacement is equivalent to a vibration velocity of 3.7 mm/s at 1 Hz.

The standard goes on to state that minor damage is possible at vibration magnitudes which are greater than twice those given in **Table 25**, and major damage to a building structure may occur at values greater than four (4) times the tabulated values.

Fatigue considerations are also addressed in the standard and it is concluded that unless calculation indicates that the magnitude and number of load reversals is significant (in respect of the fatigue life of building materials) then the guide values in **Table 25** should not be reduced for fatigue considerations.

In order to assess the likelihood of cosmetic damage due to vibration, AS2187 specifies that vibration measured should be undertaken at the base of the building and the highest of the orthogonal vibration components (transverse, longitudinal and vertical directions) should be compared with the criteria curves presented in **Table 25**.

It is noteworthy that in addition to the guide values nominated in **Table 25**, the standard states that:

> *"Some data suggests that the probability of damage tends towards zero at 12.5 mm/s peak component particle velocity. This is not inconsistent with an extensive review of the case history information available in the UK."*

Also that:

> *"A building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive."*

6.4 Human Comfort Vibration Criteria

6.4.1 General Discussion on Human Perception to Vibration

Humans are far more sensitive to vibration than is commonly realised. They can detect vibration levels which are well below those causing any risk of damage to a building or its contents.

The actual perception of motion or vibration may not, in itself, be disturbing or annoying. An individual's response to that perception, and whether the vibration is "normal" or "abnormal", depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as "normal" in a car, bus or train is considerably higher than what is perceived as "normal" in a shop, office or dwelling.

Human tactile perception of random motion, as distinct from human comfort considerations, was investigated by Diekmann and subsequently updated in German Standard DIN 4150 Part 2 1975. On this basis, the resulting degrees of perception for humans are suggested by the vibration level categories given in **Table 26**.

Table 26 Peak Vibration Levels and Human Perception of Motion

Approximate Vibration Level	Degree of Perception
0.10 mm/s	Not felt
0.15 mm/s	Threshold of perception
0.35 mm/s	Barely noticeable
1 mm/s	Noticeable
2.2 mm/s	Easily noticeable
6 mm/s	Strongly noticeable
14 mm/s	Very strongly noticeable

Note: These approximate vibration levels (in floors of building) are for vibration having a frequency content in the range of 8 Hz to 80 Hz.

Table 26 suggests that people will just be able to feel floor vibration at levels of about 0.15 mm/s and that the motion becomes "noticeable" at a level of approximately 1 mm/s.

6.4.2 Human Comfort Criteria for Intermittent Vibration

Guidance in relation to assessing potential disturbance from ground-borne vibration is set out in British Standard 6472-1992 "Evaluation of Human Exposure to Vibration in Buildings (1 Hz to 80 Hz)". This standard has recently been revised and the current Standard is dated 2008. This 1992 version of the standard is however still recommended for use by the EPA[12].

BS 6472 includes detailed guidance on the use of Vibration Dose Values (VDVs) which allow an assessment of the severity of intermittent vibration to be carried out. This analysis and assessment procedure is most relevant to the character of the vibration generated during construction works.

Table 27 shows the range of satisfactory vibration dose values for which various degrees of adverse comment may be expected in residential premises and office buildings. The most stringent of which are the levels of building vibration associated with a "low probability of adverse comment" from occupants.

[12] For information on the implication of the changes made in the 2008 version of BS 6472, please refer to the paper "Implications of updating the vibration assessment methodology of BS6472 from the 1992 to the revised 2008 version" by M. Allan, D. Duschlbauer, M. Harrison published in the August 2010 edition of Acoustics Australia (Vol 38 No 2).

Table 27 Vibration Dose Values (m/s$^{1.75}$) above which Various Degrees of Adverse Comment May Be Expected in Residential Buildings, Offices

Location	Low Probability of Adverse Comment	Adverse Comment Possible	Adverse Comment Probable
Residential buildings 16 hour day	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
Offices 16 hour day	0.4 to 0.8	0.8 to 1.6	1.6 to 3.2

Situations exist where motion magnitudes above the dose levels given in BS 6472 can be acceptable, particularly for temporary disturbances and infrequent events of short-term duration (e.g. construction project).

When short-term works such as piling, demolition or compaction give rise to impulsive vibrations, it should be borne in mind that undue restriction on vibration levels can significantly prolong these operations and result in greater annoyance.

In certain circumstances, the use of higher magnitudes of acceptability may be considered, e.g. for projects having social worth or broader community benefits or in view of the economic or practical feasibility of reducing vibration to the recommended levels. In such cases, best management practices should be employed to reduce levels as far as practical.

7 CONSTRUCTION NOISE AND VIBRATION IMPACT ASSESSMENT

7.1 Demolition and Construction Scenarios and Corresponding Equipment

In order to assess the potential noise and vibration impacts during demolition and construction works, a number of scenarios comprising typical plant and equipment frequently used on similar sites have been developed based on the drawings provided by the client and our understanding of the project. These scenarios are considered to be representative of the noisiest activities described in **Section 2.3** and are summarised below in **Table 28**.

Table 28 Construction Modelling Scenarios

Scenario ID	Activity	Approximate duration of works at any locality[1]
Installation of piles[1]		Up to 2 months in total
Scenario 1[2]	Pile drilling	Up to 3 hrs per pile
Scenario 2[2]	Impact piling	Up to 1 hr per pile
Scenario 3[4]	Pile finishing - reinforced concrete and trimming of piles	Up to 2 hrs
Lifting works[1]		Up to 4 weeks in total
Scenario 4[3]	Intricate lifts / pile pitching	Up to a half day per gangway and up to 4 days per roof
Demolition works		Up to 2 months in total
Scenario 5[4]	Potential demolition of King Street Wharf wave baffle	Up to 1 month
Scenario 6[4]	Pile extraction	Up to 1 month
Construction		
Scenario 7[4]	Landside construction - ancillary and landside ferry facilities	Up to 8 weeks

Note 1: There are likely to be between 21 piles for each wharf (or up to 29 piles in the event where fender piles are required)
Note 2: May be carried out in the early mornings and/or night-time periods
Note 3: May be carried out in the night-time period
Note 4: Likely to be carried out within the daytime standard construction hours

The plant and equipment likely to be operating in each scenario outlined above are presented in **Table 29**.

Table 29 Construction Scenarios and Corresponding Equipment

Equipment	Scenarios						
	Installation of piles			*Intricate Lifts*	*Demolition works*		*Construction*
	Sc1	Sc2	Sc3 [2]	Sc4	Sc5 [2]	Sc6 [2]	Sc7 [2]
Barge	2	2	2	3	2	2	1
Boat	1	1	1	1	1	1	1
Chain saw					1		
Compressor	1	1	1	1	1	1	1
Concrete pump			1				
Concrete truck			1				
Crane (35 tonnes, barge mounted)	1	1	1	1	1	1	1
Excavator					1		
Generator	1	1	1	1	1	1	1
Hand tools	1	1		1	1	1	1
Light vehicles					2		3
Lighting tower[1]	2	2		2			
Piling Rig (Bored, barge mounted)	1			.			
Piling Rig (Impact, barge mounted) [3]		1					
Piling Rig (Vibratory, barge mounted)[3]						1	
Small Grinder and drill/ power hand tools	1		1		1	1	1
Water pump (high pressure water)					1		1

Note1: Lighting towers are only used during evening and night-time works
Note 2: Works are likely to be carried out within the daytime standard construction hours
Note 3: The operation of the plant has been identify to be of impulsive characteristic

7.2 Demolition and Construction Equipment Source Noise Levels

Typical maximum Sound Power Levels (SWLs) of construction plant are shown in **Table 30**. Those SWLs are maximum noise emission levels of plant that are expected to be used on this project in typical operation.

Table 30 Sound Power Levels of Equipment

Plant Item	SWL (maximum $L_{Aeq(15minute)}$)	Duty Factor (minutes operating per 15 minute period)
Barge	100	5
Boat	90	15
Chain saw	108	5
Compressor	95	15
Concrete pump	106	5
Concrete truck	106	5
Crane (35 tonnes, barge mounted)	100	15
Excavator	96	15
Generator	101	15
Hand tools	94	5
Light vehicles	101	5
Lighting tower	77	15
Piling Rig (Bored, barge mounted)	111	5
Piling Rig (Impact, barge mounted)[1]	128	12
Piling Rig (Vibratory, barge mounted) [1]	116	5
Small Grinder and drill/ power hand tools	98	5
Water pump (high pressure water)	110	5

Note 1 : The SWLs include a 5 dB penalty to account for the impulsive nature of the source.

In accordance with the ICNG, activities identified as being particularly annoying attract a 5 dBA "annoyance penalty". Activities and associated plant operations which contain potential tonal, impulsive, intermittent and/or low frequency noise characteristics would typically be identified as being annoying. The SLR database of SWLs for construction equipment accounts for this "annoyance penalty".

The duty factor represents the likely amount of time that a particular piece of equipment would be operating in any 15 minute period. This takes account of the fact that in a 15 minute period one operation may use, for example, the chainsaw for 5 minutes, then a grinder for 5 minutes and then hand tools for another 5 minutes (i.e. all the equipment would not be used simultaneously).

7.3 Construction and Demolition Noise Assessment

Demolition and construction noise levels have been predicted at the nearest noise sensitive receivers using the CONCAWE prediction methodology within SoundPLAN noise modelling software. The calculated noise levels would inevitably depend on the number and type of plant items and equipment operating at any one time and their precise location relative to the receiver of interest. In practice, the noise levels would vary due to the fact that plant and equipment would move about the worksites and would not all be operating concurrently. In some cases, reductions in noise levels would occur when plant are located behind hoardings or even other items of equipment.

Note that in the absence of a detailed construction schedule, the scenarios one, two, three and four are assumed to be undertaken independently of each other. For the possibility of 2 scenarios (or more) operating simultaneously, the maximum predicted noise levels given in **Table 31** would increase.

For assessment purposes, it has been assumed that Scenario 3, Scenario 5, Scenario 6 and Scenario 7 would occur during daytime standard construction hours. night-time

A review of the SLR construction noise source database and experience on previous construction projects indicates that 8 dBA could be added to the predicted $L_{Aeq(15minute)}$ noise levels in order to give a conservative estimate of the $L_{A1(60second)}$ noise emission levels.

The predicted noise levels for each work scenario are detailed in **Table 31** and are compared to the NMLs for the standard hours and OOHWs.

Table 31 Demolition and Construction Predicted Noise Levels

Scenario	NCA	Receiver Type	Noise Level – $L_{Aeq(15minute)}$ (dBA)								Noise Level – $L_{A1(60second)}$ (dBA)		
			Worst-case Predicted[5]	NML				Exceedance				Worst-case Predicted	Screening Crit.	Exceedance
				Day	OOHW Day	OOHW Eve	OOHW Night	Day	OOHW Day	OOHW Eve	OOHW Night		(RBL+15 dBA)	
Sc1 – Pile Drilling[1]	NCA-01	Residential[5]	62-70	62	57	57	51	Up to 5	5-10	5-10	11-19	70-78	61	9-17
		Commercial	57-63	70	70	70	70	-	-	-	-	65-71	N/A	N/A
		Other (Hotel)[7]	Up to 51 (26)	35[6]	35[6]	35[6]	35[6]	-	-	-	-	Up to 59 (34)	N/A	N/A
	NCA-02	Residential	Up to 32	62	57	57	51	-	-	-	-	Up to 40	61	-
		Commercial	57-69	70	70	70	70	-	-	-	-	65-77	N/A	N/A
		Other (Hotel) [7]	Up to 55 (30)	35[6]	35[6]	35[6]	35[6]	-	-	-	-	Up to 63 (38)	N/A	N/A
	NCA-03	Residential	55-56	61	56	51	46	-	-	4-5	9-10	63-64	56	7-8
		Commercial	44-51	70	70	70	70	-	-	-	-	52-59	N/A	N/A
	NCA-04	Residential	48-52	61	56	51	46	-	-	Up to 1	2-6	56-60	56	Up to 4
		Commercial	31-49	70	70	70	70	-	-	-	-	39-57	N/A	N/A
		Other (Outdoor Active)	24-52	65	65	65	65	-	-	-	-	32-60	N/A	N/A
	NCA-05	Residential	41-42	59	54	54	46	-	-	-	-	49-50	56	-
		Other (Outdoor Passive)	38-43	60	60	60	60	-	-	-	-	46-51	N/A	N/A
Sc2 – Impact Piling[1]	NCA-01	Residential[5]	80-88[4]	62	57	57	51	18-26	23-31	23-31	29-37	88-96	61	27-35
		Commercial	75-81	70	70	70	70	5-11	5-11	5-11	5-11	83-89	N/A	N/A
		Other (Hotel) [7]	Up to 69 (44)	35[6]	35[6]	35[6]	35[6]	Up to 9	Up to 9	Up to 9	Up to 9	Up to 77 (52)	N/A	N/A
	NCA-02	Residential	Up to 50	62	57	57	51	-	-	-	-	Up to 58	61	-
		Commercial	75-87	70	70	70	70	5-17	5-17	5-17	5-17	83-95	N/A	N/A
		Other (Hotel) [7]	Up to 73 (48)	35[6]	35[6]	35[6]	35[6]	Up to 13	Up to 13	Up to 13	Up to 13	Up to 81 (56)	N/A	N/A

Scenario	NCA	Receiver Type	Noise Level – $L_{Aeq(15minute)}$ (dBA)								Noise Level – $L_{A1(60second)}$ (dBA)		
			Worst-case Predicted[5]	NML				Exceedance				Worst-case Predicted	Screening Crit. (RBL+15 dBA)	Exceedance
				Day	OOHW Day	OOHW Eve	OOHW Night	Day	OOHW Day	OOHW Eve	OOHW Night			
	NCA-03	Residential	73-74	61	56	51	46	12-13	17-18	22-23	27-28	81-82	56	25-26
		Commercial	62-70	70	70	70	70	-	-	-	-	70-78	N/A	N/A
	NCA-04	Residential	67-70	61	56	51	46	6-9	11-14	16-19	21-24	75-78	56	19-22
		Commercial	49-67	70	70	70	70	-	-	-	-	57-75	N/A	N/A
		Other (Outdoor Active)	43-70	65	65	65	65	Up to 5	Up to 5	Up to 5	Up to 5	51-78	N/A	N/A
	NCA-05	Residential	59-60	59	54	54	46	Up to 1	5-6	5-6	13-14	67-68	56	11-12
		Other (Outdoor Passive)	57-61	60	60	60	60	Up to 1	Up to 1	Up to 1	Up to 1	65-69	N/A	N/A
Sc3 – Pile Finishing[1]	NCA-01	Residential[5]	66-68	62	57	57	51	4-6	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Commercial	54-60	70	70	70	70	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Other (Hotel) [7]	Up to 48 (23)	35[6]	35[6]	35[6]	35[6]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
	NCA-02	Residential	Up to 29	62	57	57	51	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Commercial	53-66	70	70	70	70	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Other (Hotel) [7]	Up to 51 (26)	35[6]	35[6]	35[6]	35[6]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
	NCA-03	Residential	51-53	61	56	51	46	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Commercial	41-48	70	70	70	70	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
	NCA-04	Residential	45-48	61	56	51	46	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Commercial	28-45	70	70	70	70	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Other (Outdoor Active)	21-48	65	65	65	65	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
	NCA-05	Residential	37-38	59	54	54	46	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Other (Outdoor Passive)	35-39	60	60	60	60	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]

Scenario	NCA	Receiver Type	Noise Level – $L_{Aeq(15minute)}$ (dBA)								Noise Level – $L_{A1(60second)}$ (dBA)		
			Worst-case Predicted[5]	NML				Exceedance				Worst-case Predicted	Screening Crit. (RBL+15 dBA)	Exceedance
				Day	OOHW Day	OOHW Eve	OOHW Night	Day	OOHW Day	OOHW Eve	OOHW Night			
Sc4 – Intricate Lifts[1]	NCA-01	Residential[5]	59-67	62	57	57	51	Up to 5	2-10	2-10	8-16	67-75	61	6-14
		Commercial	54-63	70	70	70	70	-	-	-	-	62-71	N/A	N/A
		Other (Hotel) [7]	Up to 48 (23)	35[6]	35[6]	35[6]	35[6]	-	-	-	-	Up to 56 (31)	N/A	N/A
	NCA-02	Residential	Up to 29	62	57	57	51	-	-	-	-	Up to 37	61	-
		Commercial	54-66	70	70	70	70	-	-	-	-	62-74	N/A	N/A
		Other (Hotel) [7]	Up to 52 (27)	35[6]	35[6]	35[6]	35[6]	-	-	-	-	Up to 60 (35)	N/A	N/A
	NCA-03	Residential	51-53	61	56	51	46	-	-	Up to 2	5-7	59-61	56	3-5
		Commercial	41-48	70	70	70	70	-	-	-	-	49-56	N/A	N/A
	NCA-04	Residential	45-49	61	56	51	46	-	-	-	Up to 3	53-57	56	Up to 1
		Commercial	28-46	70	70	70	70	-	-	-	-	36-54	N/A	N/A
		Other (Outdoor Active)	21-48	65	65	65	65	-	-	-	-	29-56	N/A	N/A
	NCA-05	Residential	38-39	59	54	54	46	-	-	-	-	46-47	56	-
		Other (Outdoor Passive)	35-40	60	60	60	60	-	-	-	-	43-48	N/A	N/A
Sc5 – Demolition of Baffle[3]	NCA-01	Residential[5]	63-71	62	N/A[3]	N/A[3]	N/A[3]	1-9	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Commercial	58-64	70	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Other (Hotel) [7]	Up to 52 (27)	35[6]	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
	NCA-02	Residential	Up to 33	62	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Commercial	58-70	70	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Other (Hotel) [7]	Up to 56 (31)	35[6]	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
	NCA-03	Residential	56-57	61	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Commercial	45-53	70	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
	NCA-04	Residential	50-53	61	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]

Scenario	NCA	Receiver Type	Noise Level – LAeq(15minute) (dBA)								Noise Level – LA1(60second) (dBA)		
			Worst-case Predicted[5]	NML				Exceedance			Worst-case Predicted	Screening Crit. (RBL+15 dBA)	Exceedance
				Day	OOHW Day	OOHW Eve	OOHW Night	Day	OOHW Day	OOHW Eve	OOHW Night			
		Commercial	32-50	70	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Other (Outdoor Active)	26-53	65	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
	NCA-05	Residential	42-43	59	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Other (Outdoor Passive)	40-44	60	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
Sc6 – Pile Extraction[3]	NCA-01	Residential[5]	66-73	62	N/A[3]	N/A[3]	N/A[3]	4-9	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Commercial	60-67	70	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Other (Hotel) [7]	Up to 55 (30)	35[6]	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
	NCA-02	Residential	Up to 35	62	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Commercial	60-72	70	N/A[3]	N/A[3]	N/A[3]	Up to 2	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Other (Hotel) [7]	Up to 58 (33)	35[6]	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
	NCA-03	Residential	58-59	61	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Commercial	47-55	70	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
	NCA-04	Residential	52-55	61	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Commercial	34-52	70	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Other (Outdoor Active)	28-55	65	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
	NCA-05	Residential	44-45	59	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Other (Outdoor Passive)	42-46	60	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
Sc7 – Landside Construction[3]	NCA-01	Residential[5]	70-73	62	N/A[3]	N/A[3]	N/A[3]	8-11	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Commercial[2]	58-68	70	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Other (Hotel) [7]	Up to 52 (27)	35[6]	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]

Scenario	NCA	Receiver Type	Noise Level – $L_{Aeq(15minute)}$ (dBA)								Noise Level – $L_{A1(60second)}$ (dBA)		
			Worst-case Predicted[5]	NML				Exceedance			Worst-case Predicted	Screening Crit. (RBL+15 dBA)	Exceedance
				Day	OOHW Day	OOHW Eve	OOHW Night	Day	OOHW Day	OOHW Eve	OOHW Night			
	NCA-02	Residential	Up to 32	62	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Commercial[2]	57-70	70	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Other (Hotel) [7]	Up to 53 (28)	35[6]	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
	NCA-03	Residential	54-55	61	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Commercial[2]	45-52	70	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
	NCA-04	Residential	48-51	61	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Commercial[2]	31-48	70	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Other (Outdoor Active)[2]	25-52	65	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
	NCA-05	Residential	40-41	59	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
		Other (Outdoor Passive)[2]	38-42	60	N/A[3]	N/A[3]	N/A[3]	-	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]

Note 1: Scenarios that may occur during OOHWs (Evening or Night-time)

Note 2: Only assessed when in use

Note 3: N/A Scenarios likely to happen during standard hours only

Note 4: Residential receivers in NCA-01 are predicted to be Highly Noise Affected (i.e. predicted noise level above 75 dBA) during Scenario 2 Impact Piling works.

Note 5: Residential receivers in NCA-01 are currently under construction and are expected to complete in late 2015

Note 6: The Hotel NML is an internal noise level.

Note 7: Hotel predicted internal noise levels are shown in brackets for comparison with the NML. The predicted noise levels are based on 6.38 mm laminate glazing, and a window area of $2m^2$ per Hotel suite.

7.4 Summary of Predicted Construction Noise Exceedances

In order to simplify the data presented in **Table 31**, a classification relating to the extent of the potential noise exceedance has been adopted for use and is described below:

- Low Impact - 0 dBA to 9 dBA
- Moderate Impact - 10 dBA to 25 dBA
- High Impact - >25 dBA

7.5 Discussion of Predicted Construction Noise Exceedances

Pile installation

Due to the nature of the nature of piling works and close proximity to the receptors, impact piling will affect all NCAs. The predicted noise levels detailed in **Table 31** show high NML exceedances during impact piling works are predicted at residential receptors:

- Up to 37 dB at NCA-01 during standard construction hours and OOHWs;
- Up to 28 dB at NCA-03 during night-time OOHWs.

Commercial and other receivers (i.e. hotel receptors) are predicted to be subject to moderate NML exceedances over 17dB and 13 dB respectively.

The predicted noise levels detailed in **Table 31** show moderate NML exceedances during pile drilling works are predicted at residential receptors:

- Up to 19 dB at NCA-01 during OOHWs;
- Up to 10 dB at NCA-03 during night-time OOHWs.

Commercial and other receivers (i.e. hotel receptors) are predicted to comply with NML during pile drilling works.

It should be noted that high impact activities such as impact piling are likely to be of short duration (e.g. up to 1 hour per pile with hydraulic plant or 30 mins with diesel plant.

Intricate lifts

Due to the close vicinity of the works to receivers, the predicted noise levels indicate moderate exceedances of the NMLs at residential receptors in NCA-01 of up to 5 dB and 16 dB during standard construction hours and OOHWs respectively.

Demolition works

Low exceedances of the NMLs at residential receptors in NCA-01 of up to 9 dB are predicted during standard construction hours.

Landside construction

Moderate exceedances of the NMLs at residential receptors in NCA-01 of up to 11 dB are predicted during standard construction hours.

7.5.1 Sleep Disturbance

It is noted that the ICNG would require the proposal to consider maximum noise levels where construction works are planned to extend over more than two consecutive nights.

The assessment of maximum noise impacts presented in **Table 31** (potential sleep disturbance) has been quantified based on preliminary construction methodology. Results of the assessment indicated that sleep disturbance is likely to occur with the use of high noise activities such as impact piling (Scenario 3).

It is anticipated that the finalised requirements for OOHWs would be determined at a later design stage.

7.6 Demolition and Construction Vibration Assessment

7.6.1 Ground-borne Vibration (Safe Working Distances)

As a guide, safe working distances for typical items of vibration intensive plant are listed in **Table 32**. The safe working distances are quoted for both "Cosmetic Damage" (refer British Standard BS 7385) and "Human Comfort" (refer British Standard BS 6472-1).

Table 32 Recommended Safe Working Distances for Vibration Intensive Plant

Plant Item	Rating/Description	Safe Working Distance[2]	
		Cosmetic Damage (BS 7385)	Human Response (BS 6472)
Piling rig (impact)[1]	(assumed similar to 900 kg hydraulic hammer)	7 m	23 m
Vibratory Pile Driver	Used briefly to remove small number of steel piles (<5min each)	2 m to 20 m	20 m
Piling rig (screw)	≤ 800 mm	2 m (nominal)	N/A

Note: 1. Vibration levels generated from piling rigs are very much site dependant and are influenced by variables such as pile diameter, hammer weight, and rock type. The vibration levels used here are assumed to be similar to a medium sized hydraulic hammer (900kg). Vibration levels from the piling rigs MUST be verified on site at the commencement of piling activities, the ground vibration attenuation at the site confirmed and the safe working distances verified.

2. More stringent safe working distances may apply to heritage or other sensitive structures than are nominated above.

The safe working distances presented in **Table 32** are indicative and would vary depending on the particular item of plant and local geotechnical conditions. They apply to cosmetic damage of typical buildings under typical geotechnical conditions. The safe working distances would be verified at the commencement of the works by confirming the ground vibration attenuation levels of the site.

In relation to human comfort (response), the safe working distances in **Table 32** relate to continuous vibration and apply to **residential** receivers. For most construction activities, vibration emissions are intermittent in nature and for this reason, higher vibration levels, occurring over shorter periods are allowed, as discussed in BS 6472-1.

The levels of vibration produced by piling are expected to be below the minor structural damage criterion at the nearest buildings. Notwithstanding, a review of vibration impacts is recommended after the capacity of the vibration generating construction equipment is known and all potentially affected buildings are identified and offset distances determined.

7.6.2 Summary of Vibration Impacts

The levels of vibration produced by demolition and construction activities are expected to be below the minor structural damage criterion. It should be noted that Vibration is highly unlikely to be an issue for this project due to setback distance, vibratory pads on the new residential buildings of Barangaroo South development.

Notwithstanding, a review of vibration impacts is recommended after the capacity of the vibration generating construction equipment is known and all potentially affected buildings are identified and offset distances determined.

7.7 Recommended Construction Noise and Vibration Mitigation and Management Measures

The predicted construction noise levels presented in **Table 31** indicate that the adjacent residents may experience daytime noise levels above 75 dBA during noise intensive activities due to the close vicinity of the works.

The ICNG and the TfNSW *Construction Noise Strategy,* (TfNSW, 2012) describe strategies for construction noise mitigation and control that are applicable to this proposal. The strategies are designed to minimise, to the fullest extent practicable, noise during construction.

7.7.1 Restriction of Construction Hours

Where reasonable and feasible, preference would be given to scheduling construction works within the standard construction hours of:

- Monday to Friday 7:00 am to 6:00 pm.
- Saturday 8:00 am to 1:00 pm.

Due to the nature of the project evening and night work may also be required to ensure suitable conditions for installation of piles and intricate lifts over the water. The conditions where construction works related to roadways would be required outside of standard hours are outlined in TfNSW *Construction Noise Strategy* as follows:

- Temporary road closures and other measures are required by the Police and other regulatory authorities for the safe delivery of material/ equipment.
- Works have the potential to disrupt commuter services and road networks.
- Works are required to be completed to maintain health and safety, avoid loss of life or injury and to prevent environmental damage.

While most equipment and materials would be transported via water rather than road for this project, the above principles would still apply.

Special Weather Condition Requirements

The construction of piles and intricate lifting works would require specific weather conditions, such as calmer water evening or night-time period or during the night-time/daytime shoulder period for example (5:00 am to 7:00 am, etc). This is necessary to ensure the safety of the workers, businesses, residents and pedestrians, and to enable accurate installation of wharf components to ensure a safe and quality final product.

Where OOHWs are proposed, site specific Construction Noise and Vibration Management Plans (CNVMPs) would be developed in the detailed design phase. The CNVMPs would provide a detailed assessment of potential noise levels and site specific measures to control potential noise impacts and minimise the potential for disturbance at affected receptors. A range of feasible and reasonable construction noise mitigation measures that could be considered is provided in **Section 7.7.3**.

7.7.2 Restriction of Construction Noise Levels

The ICNG acknowledges that due to the nature of construction activities it is inevitable there would be some noise from construction sites. The NMLs identified in this report have been applied to prescribe measures for the control of potential construction noise impacts at sensitive receptors. Where exceedances of the NMLs have been predicted during the daytime (standard construction hours), receptors are considered to be noise affected.

The proponent should apply all feasible and reasonable work practices to meet the NMLs and inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels, duration of noise generating construction works, and the contact details for the proposal.

Receptors are considered to be highly noise affected if noise levels from construction exceed 75 dBA L_{Aeq}. Due to the close vicinity of the works, the assessment of construction noise has identified worst case construction works that would result in noise levels above 75 dBA during noise intensive activities at immediately adjacent residences during the majority of the works scenarios.

Consequently, site-specific CNVMPs should be developed in the detailed design phase when more information is available on the schedule for the works and the equipment to be used. The proponent and construction contractor(s) should schedule work to provide respite periods from the noisiest activities, and communicate with the impacted residents by clearly explaining the duration and noise level of the works.

A potential approach would be to schedule a respite period of one hour for every three hours of continuous construction activity, or scheduling high noise generating works to less sensitive times of 9:00 am to 12:00 pm or 2:00 pm to 5:00 pm.

Where OOHWs are required, these would be predicted to result in significant exceedances of the NMLs. The proponent should identify all feasible and reasonable work practices in the CNVMPs to reduce potential noise impacts. Where all feasible and reasonable practices have been applied and noise would be more than 5 dB above the noise affected level, the proponent should negotiate with the community to determine the schedule for the works or provide respite to occupants where sleep disturbance is likely to occur.

7.7.3 Construction Noise Mitigation Measures

Based on the assessment of construction noise impacts in this report a range of noise mitigation measures have been recommended to reduce and control potential construction noise impacts.

The construction noise mitigation measures are recommended to, where feasible and reasonable, minimise potential for disturbance at receptors, preserve the acoustic amenity of the surrounding environment and aim to control noise levels within the construction NMLs.

Construction Environmental Management Plan

A Construction Environmental Management Plan (CEMP) would be prepared during the detailed design phase and implemented through all construction activities. A CNVMP would be included in the CEMP to provide the framework and mechanisms for the management and mitigation of all potential noise and vibration impacts from the construction works.

Given the degree of construction noise level predictions it is recommended that a CNVMP be prepared which should as a minimum include:

- Identification of nearby residences and sensitive land uses.
- Determination of NMLs and the prediction of noise levels.
- Description of approved hours of work and what work would be undertaken.
- Restrictions on the hours of construction for specific works
- Description of what work practices would be applied to minimise noise.
- Description of the complaints handling process.
- Description of monitoring that is required.

Construction Noise Mitigation

The reasonableness of the identified feasible mitigation measures would be considered during the construction planning and site establishment phases of the proposal as well as in the development of CNVMPs. In general, mitigation measures that should be considered are summarised as follows:

- For construction concentrated in a single area, such as at pile installation works, temporary localised acoustic barriers around the source (i.e. pile driver shroud[13]) coupled with temporary acoustic fencing/barriers around the site perimeter should be considered where feasible and reasonable in order to mitigate off-site noise levels. Noise walls are effective for receptors at or near ground level and localised barriers would provide additional attenuation for receptors at higher elevations or overlooking the sites.
- Given the potentially high noise levels at residential receptors, adherence to daytime construction hours is recommended where feasible and practicable for the installation of piling, demolition activities and for activities concentrated in a single area (i.e. activities that do not move away from one area of receptors) provided that they do not require OOHWs for safety reasons.
- Night works should be programmed in order to minimise the number of consecutive nights work impacting the same receptors.
- Avoiding the coincidence of noisy plant operating simultaneously close together and adjacent to sensitive receptors would result in reduced noise emissions impacts.
- Equipment which is used intermittently is to be shut down when not in use. Plant items such as barge/s or concrete trucks should be turned off when parked, positioned or otherwise not in use.
- Where possible, the offset distance between noisy plant items and nearby noise sensitive receptors should be as great as possible (e.g. away from residential receptors).
- Where possible, equipment with directional noise emissions should be oriented away from sensitive receptors.
- Regular compliance checks on the noise emissions of all plant and machinery used for the proposal would indicate whether noise emissions from plant items are higher than predicted. This would also identify defective silencing equipment on the items of plant and equipment.
- Ongoing noise monitoring during construction works at sensitive receptors during critical periods in order to identify and assist in managing high risk noise events.
- Regular identification of noisy activities and the adoption of improvement techniques.
- Where possible, heavy vehicle movements should be limited to daytime hours (e.g. deliveries).
- Reversing of equipment should be minimised so as to prevent nuisance caused by reversing alarms. For example, by arranging for one-way site traffic routes.
- Where feasible and practicable, broadband audible alarms should be used on vehicles and elevating work platforms used on site.
- Loading and unloading should be carried out away from sensitive receptors, where practical.
- Regular reinforcement (such as at toolbox talks) of the need to minimise noise.
- Where feasible and practicable, avoid or limit the use of portable radios, public address systems or other methods of site communication that may unnecessarily impact upon nearby residents.

Additional Noise Mitigation Measures

Additional noise mitigation measures to be explored in the CNVMPs in the event of predicted exceedances of the noise goals (particularly during OOHWs) are described in the TfNSW *Construction Noise Strategy*. This strategy includes the definition of the level of noise impact which triggers consideration of each additional mitigation measure (reproduced in **Table 33** of this report).

[13] Example of supplier of localised noise barrier such as Echo Barrier (http://www.echobarrier.com/product-range/h2-standard-acoustic-fencing/)

The additional mitigation measures described in the *Construction Noise Strategy* are summarised below, with discussion of their potential applicability to the subject works. The objective of these additional noise mitigation measures is to engage, inform and provide project-specific information to the community, recognising that advanced warning of potential disruptions can assist in reducing the impact.

- **Periodic Notifications** – Periodic notifications include regular newsletters, letterbox drops or advertisements in local papers to provide an overview of current and upcoming works and other topics of interest.
- **Website** – The project website would form a resource for members of the community to seek further information, including noise and vibration management plans and current and upcoming construction activities.
- **Project Info-line and Construction Response Line** – TfNSW operate a Construction Response Line and Project Info-line. These numbers provide a dedicated 24 hour contact point for any complaints regarding construction works and for any project enquiries. All complaints require a verbal response within 2 hours. All enquiries require a verbal response within 24 hours during standard construction hours, or on the next working day during OOHWs (unless the enquirer agrees otherwise).
- **Email Distribution List** – An email distribution list would be used to disseminate project information to interested stakeholders.
- **Signage** – Signage on construction sites would be provided to notify stakeholders of project details and project emergency or enquiry information.
- **Specific Notifications (SN)** – Specific notifications would be letterbox dropped or hand distributed to the nearby residences and other sensitive receptors no later than seven days ahead of construction activities that are likely to exceed the noise objectives. This form of communication is used to support periodic notifications or to advertise unscheduled works.
- **Phone Calls (PC)** – Phone calls may be made to identified/affected stakeholders within seven days of the proposed work. For these works, considering the large numbers of receptors, phone calls are not considered a reasonable mitigation measure in all cases, but could be used to inform specific receptors, if requested (after notification of the works as above).
- **Individual Briefings (IB)** – Individual briefings may be used to inform stakeholders about the impacts of high noise activities and mitigation measures that will be implemented. Communications representatives from the contractor would visit identified stakeholders at least 48 hours ahead of potentially disturbing construction activities. For these works, considering the large numbers of potentially affected receptors, individual briefings may not be considered a reasonable mitigation measure in all cases but could be used for specific receptors, if requested (after notification of the works as above).
- **Monitoring (M)** – Ongoing noise monitoring during construction works at sensitive receptors during critical periods would be used to identify and assist in managing high risk noise events. Monitoring of noise would also be undertaken in response to complaints. All noise monitoring would be carried out by an appropriately trained person in the measurement and assessment of construction noise and vibration who is familiar with the requirements of the relevant standards and procedures.
- **Project Specific Respite Offer (RO)** – Residents subjected to lengthy periods of noise and/or vibration may be eligible for a project specific respite offer. The purpose of such an offer is to provide residents with respite from an ongoing impact. An example of a respite offer might be pre-purchased movie tickets. The provision of this measure would be determined on a case-by-case basis.

Project specific respite offers are unlikely to be reasonable and feasible in the vicinity of the project area. This is partly due to the impracticability of providing respite offers to large numbers of people during the proposed night-time works but also reflects the fact that the existing night-time noise environment in the Barangaroo precinct means that facades of residential buildings would generally provide a high level of noise attenuation.

- **Alternative Accommodation (AA)** – As described in the TfNSW *Construction Noise Strategy*, provision of alternative accommodation for residents would be considered in the event that highly intrusive noise impacts are predicted during the night-time period (between 10:00 pm and 7:00 am). However, as this project is likely to require night-time works, provision of alternative accommodation in all cases may not always be reasonable or feasible.

Offers of alternative accommodation to residents are also unlikely to be reasonable and feasible for multistorey residential receivers in NCA-01, NCA-02, NCA-03 and NCA-04. Due to the impracticability of providing alternative accommodation to large numbers of people during the proposed night-time works. Further, residential buildings within the Barangaroo South development (R8 and R9 buildings) have design features with doubled glazing, and with bedrooms located to the east (rear) of the units. These factors would reduce the noise impact on residents.

Table 33 Additional Mitigation Measures Matrix – Airborne Construction Noise

Time Period		**Mitigation Measure**			
		$L_{Aeq(15minute)}$ Noise Level above Background (RBL)			
		0 to 10 dBA	**10 to 20 dBA**	**20 to 30 dBA**	**>30 dBA**
		Noticeable	**Clearly Audible**	**Moderately Intrusive**	**Highly Intrusive**
Standard	Mon-Fri (7am - 6pm)	-	-	LB, M	LB, M
	Sat (8am - 1pm)				
	Sun/Pub Hol. (Nil)				
OOHW Period 1	Mon-Fri (6pm - 10pm)	-	LB	M, LB	M, IB, LB, RO, PC, SN
	Sat (7am - 8am) and (1pm - 10pm)				
	Sun/Pub Hol. (8am - 6pm)				
OOHW Period 2	Mon-Fri (10pm - 7am)	LB	M, LB	M, IB, LB, PC, SN	AA, M, IB, LB, PC, SN
	Sat (10pm - 8am)				
	Sun/Pub Hol. (6pm - 7am)				

Note: The following abbreviations are used: Alternative accommodation (AA), Monitoring (M), Individual briefings (IB), Letter box drops (LB), Project specific respite offer (RO), Phone calls (PC), Specific notifications (SN).

7.7.4 Other Noise Mitigation Considerations

Commercial Receptors

For other sensitive receptors that operate outside standard construction hours, for example commercial receptors (restaurants) on King Street Wharves which could operate up to 3:00 am, it is recommended that the proponent communicates with the affected premises in order to clearly explain the timing, duration and likely noise level of the works. Reasonable and feasible noise mitigation options and measures should be developed in consultation with the receptor.

Source Noise Controls

Where reasonable and practical, noisy plant or processes should be replaced by less noisy alternatives.

Works requiring particular weather conditions such as piling and intricate lifts are the most likely activities that the contractor may want to do at night. Where feasible and practical, alternative method such as using a jack-up barge to enable the works to be carried out within standard construction hours should be considered as one of the mitigation options.

7.8 Typical Noise Mitigation Strategy

A summary of typical noise benefit from the project noise mitigation measures (refer to **Section 7.7**) is presented in **Table 34**.

Table 34 Summary of Typical Noise Mitigation Strategy

Construction Noise Mitigation Measures	Potential Noise Reduction
Schedule construction works within the standard construction hours were practical	No reduction during standard construction hours Eliminates OOHWs noise impacts
Schedule respite periods as required during construction For example: • one hour for every three hours of continuous construction activity • minimise the number of consecutive nights work impacting the same receivers	N/a
Were feasible, schedule high noise generating works to less sensitive times of 9:00 am to 12:00 pm or 2:00 pm to 5:00 pm	N/a
Temporary acoustic fencing/barriers	Typically around 5 dB to 10 dB
Portable localised temporary screens	Up to around 15 dB
Install operational architectural property treatments	N/a
Avoid the coincidence of noisy plant working simultaneously close together	Up to 3 dB for halving the number of similarly dominant plant items working together
Shut down equipment when not in use	Negligible reduction in comparison to worst-case predictions, however eliminates noise source during less noise intensive works
Maximise the offset distance between noisy plant items and nearby noise sensitive receivers	Approximately 6 dB reduction per doubling of offset distance
Regular compliance checks on the noise emissions	N/a
Ongoing noise monitoring during construction	N/a
Loading and unloading should be carried out away from sensitive receivers	Approximately 6 dB reduction per doubling of offset distance

8 SUMMARY OF IMPACTS AND MITIGATION

8.1 Operational Noise of Barangaroo Ferry Hub

The operational noise objectives for the subject project have been developed from existing guidelines for noise assessments within NSW, as discussed in **Section 4**. These noise objectives are based on a combination of guidelines in particular those that apply to light rail, noting the similarity between the intermittent nature the light rail and ferry transportation.

The operational noise assessment of the Barangaroo Ferry Hub has been undertaken with guidance for feasible and reasonable noise mitigation measures taken from RING, RNP and INP.

Operational noise levels associated with the project have been predicted using a three-dimensional noise model. Noise levels predictions and potential exceedances of nominated assessment objectives have been identified and reported.

In relation to the assessment against the proposed Barangaroo operational noise objectives, the following observations were made:

- Exceedances of up to 3 dB during the night-time have been predicted for Scenario 1 at NCA-01 and NA-03 due to the proximity of the proposed ferry route.
- The noise levels of vessel movements for Scenario 2 are predicted to comply with the daytime and night-time noise objectives (both $L_{Aeq(1hour)}$ and L_{Amax} descriptors).
- Exceedances of L_{Amax} of up to 11 dB, 10 dB and 5 dB of the sleep disturbance screening criteria have been predicted for Scenario 1 and Scenario 2 at NCA-01, NCA-03 and NCA-03 respectively due to use of warning horns and high pressure water cleaning equipment.
- Exceedances of $L_{Aeq(1hour)}$ up to 6 dB and 16 dB of the $L_{Aeq(1hour)}$ daytime and night-time criterion respectively at NCA-01; and up to 2 dB at NCA-02 during the night-time have been predicted for Scenario 3 due to use of high pressure water cleaning equipment. However, this activity would likely to occur once per month only.

An assessment against the nominated INP noise criteria was also carried out for comparison with the Barangaroo operational noise objectives presented in **Table 16**. For the assessment against the INP noise criteria, the following observations were made:

- Exceedances of up to 2 dB of the evening intrusive criteria and exceedances of up to 2 dB, 7 dB and 3 dB of the night-time intrusive criteria have been predicted for Scenario 1 at NCA-01, NCA-03 and NCA-04 respectively due to proximity of the proposed ferry route. The predicted noise levels for Scenario 1 show compliance during all periods of the day with the amenity criteria.
- Exceedances of up to 4 dB of the night-time intrusive criteria have been predicted for Scenario 2 at NCA-03 due to proximity of the proposed ferry route. The predicted noise levels for Scenario 2 show compliance during all periods of the day with the amenity criteria.
- Exceedances of the sleep disturbance screening criteria are expected to be the same as detailed in the assessment against Barangaroo operational noise objectives
- Exceedances of the project specific intrusive criteria by up to 9 dB at NCA-01 and by up to 1 dB at NCA-03 during the daytime and evening respectively. Exceedances of the night-time intrusive criteria of 15 dB, 4 dB and 3 dB have been predicted at NCA-01, NCA03 and NCA04 for Scenario 3. Exceedances of 1 dB, 11 dB and 12 dB of the daytime, evening and night-time amenity criteria respectively have been predicted at NCA-01 for Scenario 3 due to use of high pressure water cleaning equipment. However, this activity would likely to occur once per month only.

The predicted $L_{Aeq(15minute)}$ noise levels indicate exceedances of the INP based project specific noise criteria at more NCAs than the assessment against the proposed Barangaroo operational noise objectives outlined in **Section 4.5** due to the site specific background noise levels used in establishing the INP based noise criteria. The reason for the exceedances with the assessment against INP based noise criteria was, as with the Barangaroo operational noise objective assessment, due to the proximity of the proposed ferry route and use of high pressure water cleaning equipment. However, compliance with the INP amenity criteria (Urban/Industrial Interface) at all NCAs have been predicted for Scenario 1 and Scenario 2.

Feasible and reasonable noise mitigation measures have been recommended for the operation of the project in **Section 5.6** of this report.

8.2 Construction Noise and Vibration

The approach taken in this assessment has been to assess the noise impacts of representative construction activities at set time periods, to inform the potentially impacted residential receivers of the scheduling of the works and to minimise the noise and vibration impacts on sensitive receptors, where practicable.

Consistent with the requirements of the ICNG, the construction noise impacts are based on a realistic worst-case assessment. For most activities, it is expected that the construction noise levels would be lower than have been (conservatively) predicted in this report.

Due to the close proximity of residential and other noise sensitive receivers surrounding Barangaroo Ferry Hub, pile installation works have the potential to result in high noise impacts.

Where possible, works would be completed during standard daytime construction hours. However, the nature of the project means that evening and night-time work is likely to be required. OOHWs are proposed for intricate lifts, pile drilling and impact piling in order to ensure accuracy and safe working conditions. Feasible and reasonable noise mitigation measures have been recommended in accordance with the TfNSW *Construction Noise Strategy* for the construction of the project in **Section 7.7.3** of this report.

A CNVMP would be developed to document all necessary measures to manage and mitigate potential noise and vibration levels during standard daytime and OOHWs during the detailed design phase of the project.

9 REFERENCES

[i] Rail Infrastructure Noise Guideline, NSW, EPA, 2013
[ii] *Road Noise Policy*, NSW, DECCW, 2011
[iii] Industrial Noise Policy, NSW, DECCW, 2000
[iv] Interim Construction Noise Guideline, DECC, 2009
[v] Construction Noise Strategy, TfNSW, 2012
[vi] Assessing Vibration: a technical guideline, DEC, 2006
[vii] AS 2187: Part 2-2006 Explosives – Storage and use – Part 2: Use of Explosives, Standards Australia 2006
[viii] BS 7385 Part 2-1993 Evaluation and measurement for vibration in buildings Part 2, BSI, 1993
[ix] AS 1055:1997 Acoustics – Description and Measurement of Environmental Noise
[x] AS IEC 61672.1-2004 Electroacoustics - Sound Level Meters, Part 1: Specifications

Acoustic Terminology

1 Sound Level or Noise Level

The terms 'sound' and 'noise' are almost interchangeable, except that in common usage 'noise' is often used to refer to unwanted sound.

Sound (or noise) consists of minute fluctuations in atmospheric pressure capable of evoking the sense of hearing. The human ear responds to changes in sound pressure over a very wide range. The loudest sound pressure to which the human ear responds is ten million times greater than the softest. The decibel (abbreviated as dB) scale reduces this ratio to a more manageable size by the use of logarithms.

The symbols SPL, L or L_P are commonly used to represent Sound Pressure Level. The symbol L_A represents A-weighted Sound Pressure Level. The standard reference unit for Sound Pressure Levels expressed in decibels is 2×10^{-5} Pa.

2 'A' Weighted Sound Pressure Level

The overall level of a sound is usually expressed in terms of dBA, which is measured using a sound level meter with an 'A-weighting' filter. This is an electronic filter having a frequency response corresponding approximately to that of human hearing.

People's hearing is most sensitive to sounds at mid frequencies (500 Hz to 4000 Hz), and less sensitive at lower and higher frequencies. Thus, the level of a sound in dBA is a good measure of the loudness of that sound. Different sources having the same dBA level generally sound about equally loud.

A change of 1 dBA or 2 dBA in the level of a sound is difficult for most people to detect, whilst a 3 dBA to 5 dBA change corresponds to a small but noticeable change in loudness. A 10 dBA change corresponds to an approximate doubling or halving in loudness. The table below lists examples of typical noise levels

Sound Pressure Level (dBA)	Typical Source	Subjective Evaluation
130	Threshold of pain	Intolerable
120	Heavy rock concert	Extremely noisy
110	Grinding on steel	
100	Loud car horn at 3 m	Very noisy
90	Construction site with pneumatic hammering	
80	Kerbside of busy street	Loud
70	Loud radio or television	
60	Department store	Moderate to quiet
50	General Office	
40	Inside private office	Quiet to very quiet
30	Inside bedroom	
20	Recording studio	Almost silent

Other weightings (eg B, C and D) are less commonly used than A-weighting. Sound Levels measured without any weighting are referred to as 'linear', and the units are expressed as dB(lin) or dB.

3 Sound Power Level

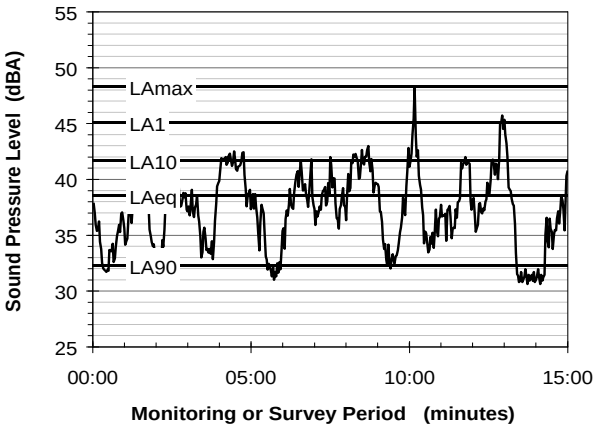
The Sound Power of a source is the rate at which it emits acoustic energy. As with Sound Pressure Levels, Sound Power Levels are expressed in decibel units (dB or dBA), but may be identified by the symbols SWL or L_W, or by the reference unit 10^{-12} W.

The relationship between Sound Power and Sound Pressure may be likened to an electric radiator, which is characterised by a power rating, but has an effect on the surrounding environment that can be measured in terms of a different parameter, temperature.

4 Statistical Noise Levels

Sounds that vary in level over time, such as road traffic noise and most community noise, are commonly described in terms of the statistical exceedance levels L_{AN}, where L_{AN} is the A-weighted sound pressure level exceeded for N% of a given measurement period. For example, the L_{A1} is the noise level exceeded for 1% of the time, L_{A10} the noise exceeded for 10% of the time, and so on.

The following figure presents a hypothetical 15 minute noise survey, illustrating various common statistical indices of interest.



Of particular relevance, are:

L_{A1} The noise level exceeded for 1% of the 15 minute interval.

L_{A10} The noise level exceed for 10% of the 15 minute interval. This is commonly referred to as the average maximum noise level.

L_{A90} The noise level exceeded for 90% of the sample period. This noise level is described as the average minimum background sound level (in the absence of the source under consideration), or simply the background level.

L_{Aeq} The A-weighted equivalent noise level (basically the average noise level). It is defined as the steady sound level that contains the same amount of acoustical energy as the corresponding time-varying sound.

When dealing with numerous days of statistical noise data, it is sometimes necessary to define the typical noise levels at a given monitoring location for a particular time of day. A standardised method is available for determining these representative levels.

This method produces a level representing the 'repeatable minimum' L_{A90} noise level over the daytime and night-time measurement periods, as required by the EPA. In addition the method produces mean or 'average' levels representative of the other descriptors (L_{Aeq}, L_{A10}, etc).

5 Tonality

Tonal noise contains one or more prominent tones (ie distinct frequency components), and is normally regarded as more offensive than 'broad band' noise.

6 Impulsiveness

An impulsive noise is characterised by one or more short sharp peaks in the time domain, such as occurs during hammering.

7 Frequency Analysis

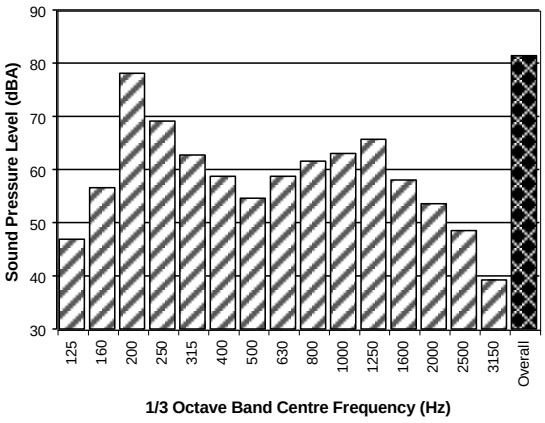
Frequency analysis is the process used to examine the tones (or frequency components) which make up the overall noise or vibration signal. This analysis was traditionally carried out using analogue electronic filters, but is now normally carried out using Fast Fourier Transform (FFT) analysers.

The units for frequency are Hertz (Hz), which represent the number of cycles per second.

Frequency analysis can be in:

- Octave bands (where the centre frequency and width of each band is double the previous band)
- 1/3 octave bands (3 bands in each octave band)
- Narrow band (where the spectrum is divided into 400 or more bands of equal width)

The following figure shows a 1/3 octave band frequency analysis where the noise is dominated by the 200 Hz band. Note that the indicated level of each individual band is less than the overall level, which is the logarithmic sum of the bands.



8 Vibration

Vibration may be defined as cyclic or transient motion. This motion can be measured in terms of its displacement, velocity or acceleration. Most assessments of human response to vibration or the risk of damage to buildings use measurements of vibration velocity. These may be expressed in terms of 'peak' velocity or 'rms' velocity.

The former is the maximum instantaneous velocity, without any averaging, and is sometimes referred to as 'peak particle velocity', or PPV. The latter incorporates 'root mean squared' averaging over some defined time period.

Vibration measurements may be carried out in a single axis or alternatively as triaxial measurements. Where triaxial measurements are used, the axes are commonly designated vertical, longitudinal (aligned toward the source) and transverse.

The common units for velocity are millimetres per second (mm/s). As with noise, decibel units can also be used, in which case the reference level should always be stated. A vibration level V, expressed in mm/s can be converted to decibels by the formula 20 log (V/V_o), where V_o is the reference level (10^{-9} m/s). Care is required in this regard, as other reference levels may be used by some organizations.

9 Human Perception of Vibration

People are able to 'feel' vibration at levels lower than those required to cause even superficial damage to the most susceptible classes of building (even though they may not be disturbed by the motion). An individual's perception of motion or response to vibration depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as 'normal' in a car, bus or train is considerably higher than what is perceived as 'normal' in a shop, office or dwelling.

10 Over-Pressure

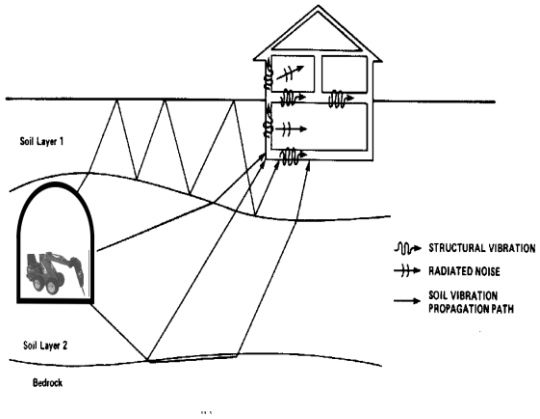
The term 'over-pressure' is used to describe the air pressure pulse emitted during blasting or similar events. The peak level of an event is normally measured using a microphone in the same manner as linear noise (ie unweighted), at frequencies both in and below the audible range.

11 Ground-borne Noise, Structure-borne Noise and Regenerated Noise

Noise that propagates through a structure as vibration and is radiated by vibrating wall and floor surfaces is termed 'structure-borne noise', 'ground-borne noise' or 'regenerated noise'. This noise originates as vibration and propagates between the source and receiver through the ground and/or building structural elements, rather than through the air.

Typical sources of ground-borne or structure-borne noise include tunnelling works, underground railways, excavation plant (eg rockbreakers), and building services plant (eg fans, compressors and generators).

The following figure presents the various paths by which vibration and ground-borne noise may be transmitted between a source and receiver for construction activities occurring within a tunnel.



The term 'regenerated noise' is also used in other instances where energy is converted to noise away from the primary source. One example would be a fan blowing air through a discharge grill. The fan is the energy source and primary noise source. Additional noise may be created by the aerodynamic effect of the discharge grill in the airstream. This secondary noise is referred to as regenerated noise

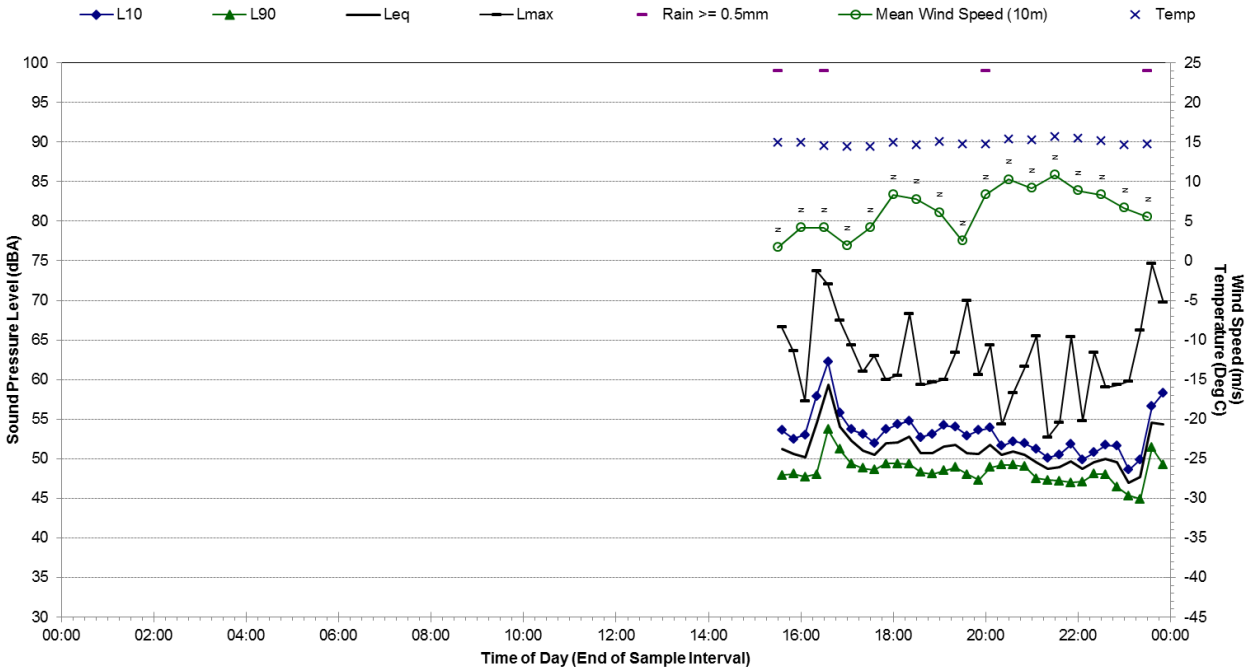
Appendix B

Report 610.14047

Ambient Noise Monitoring

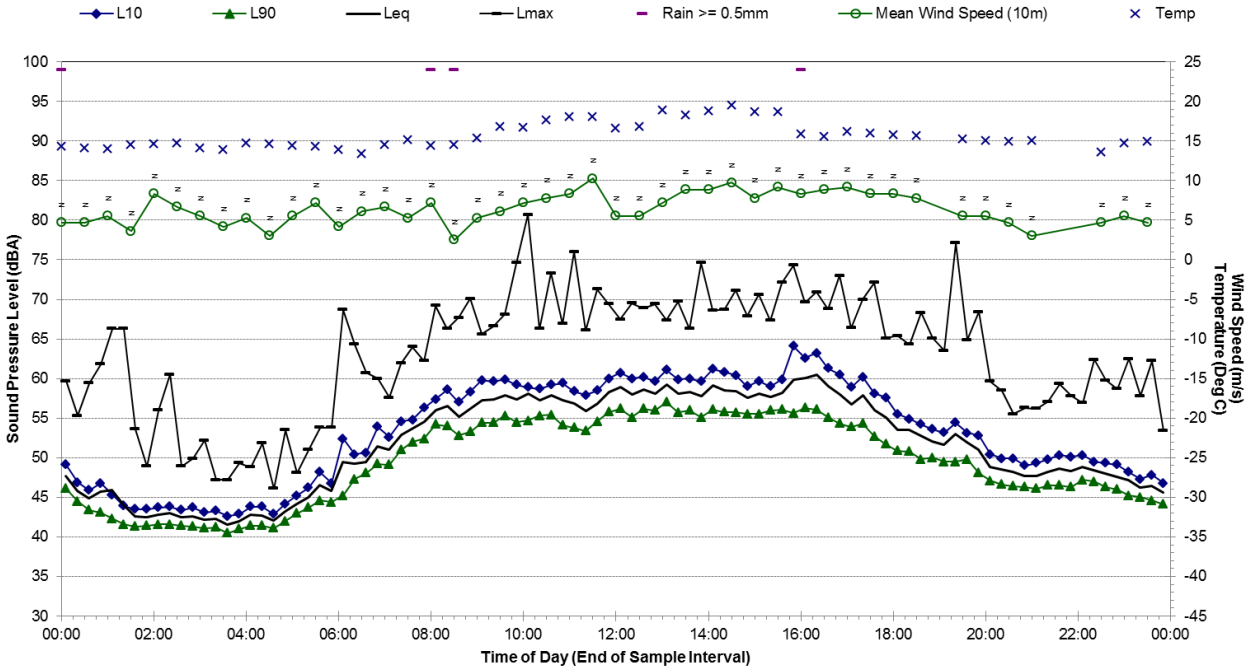
Statistical Ambient Noise Levels

NM2 - 56A Pirrama Road, Pyrmont - Tuesday, 26 August 2014



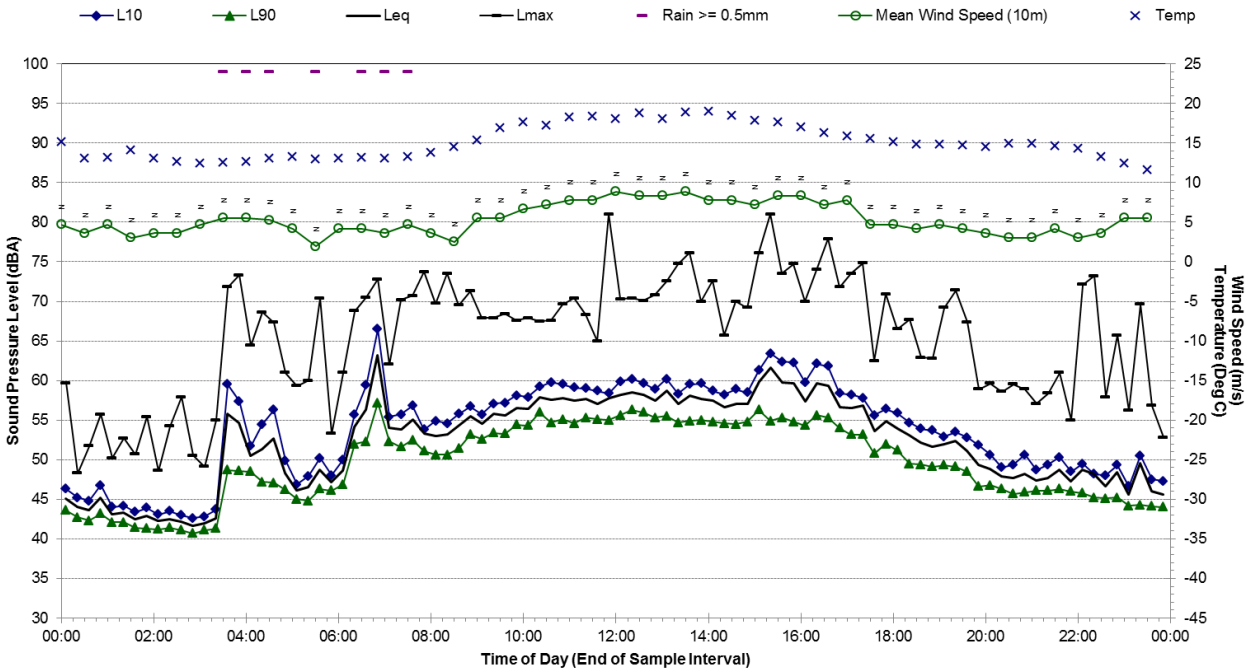
Statistical Ambient Noise Levels

NM2 - 56A Pirrama Road, Pyrmont - Wednesday, 27 August 2014



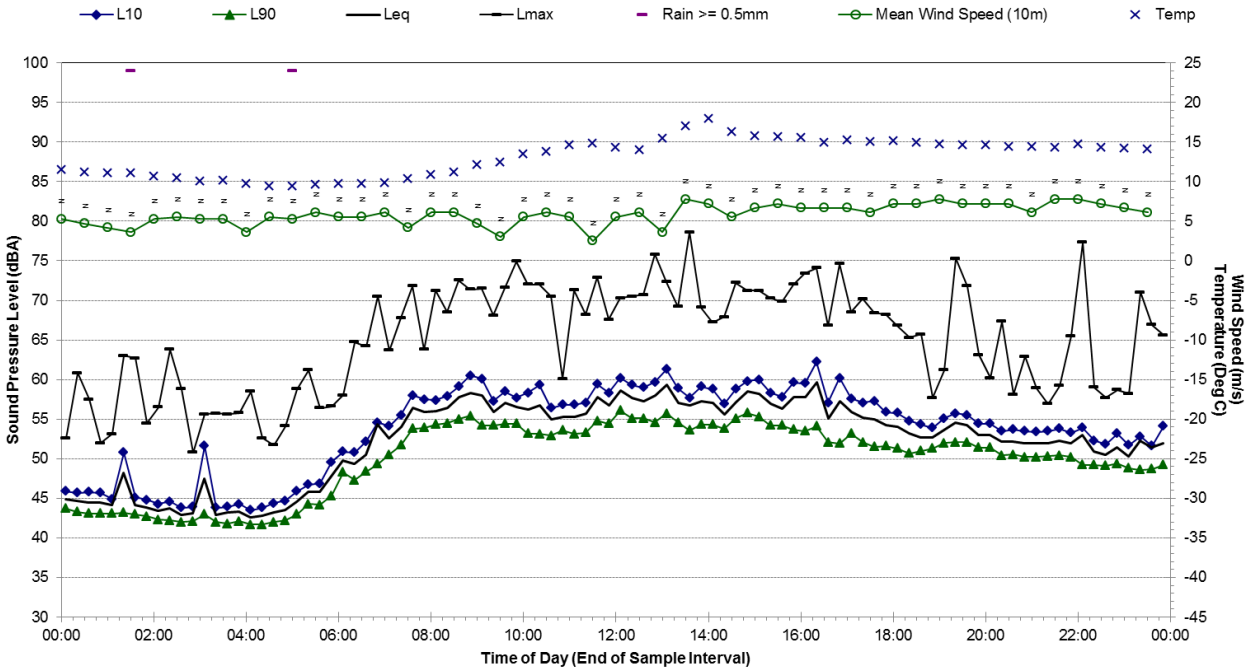
Statistical Ambient Noise Levels

NM2 - 56A Pirrama Road, Pyrmont - Thursday, 28 August 2014



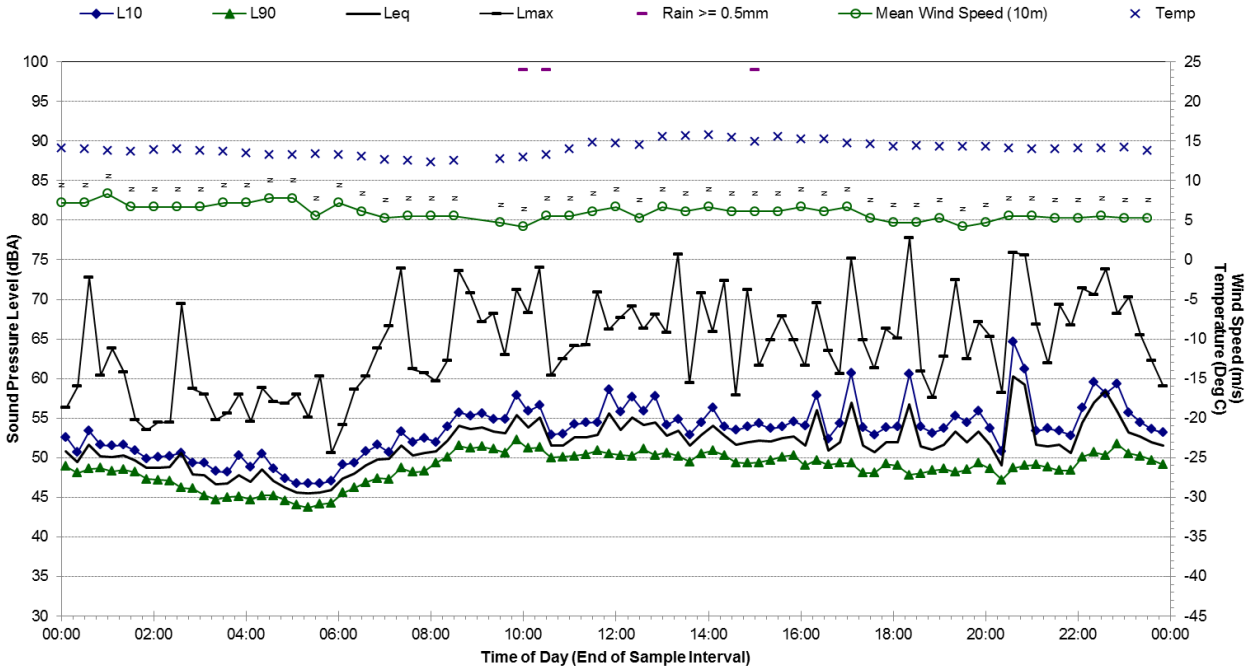
Statistical Ambient Noise Levels

NM2 - 56A Pirrama Road, Pyrmont - Friday, 29 August 2014



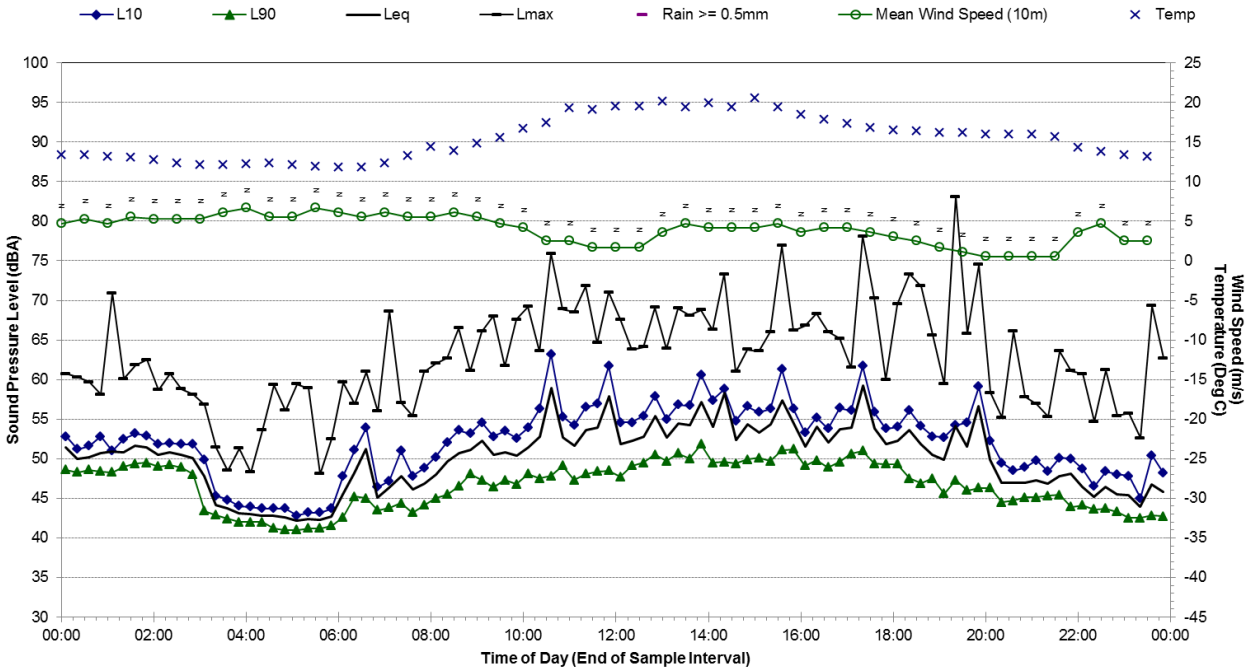
Statistical Ambient Noise Levels

NM2 - 56A Pirrama Road, Pyrmont - Saturday, 30 August 2014



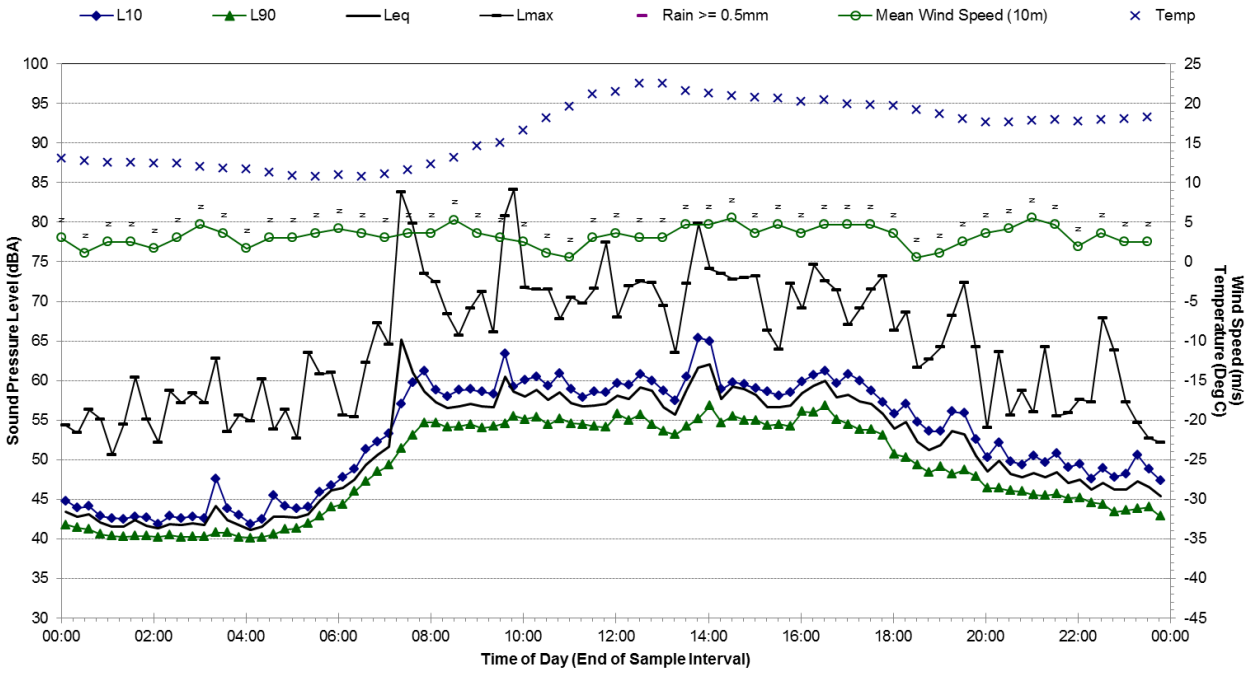
Statistical Ambient Noise Levels

NM2 - 56A Pirrama Road, Pyrmont - Sunday, 31 August 2014



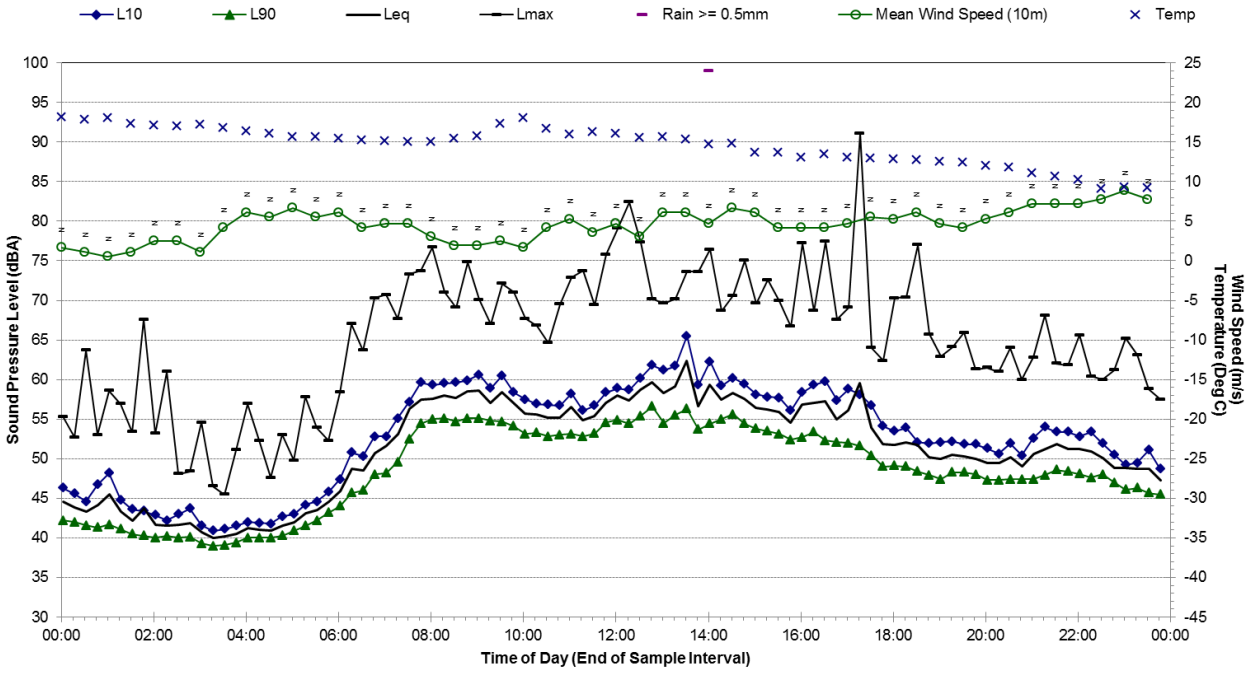
Statistical Ambient Noise Levels

NM2 - 56A Pirrama Road, Pyrmont - Monday, 1 September 2014



Statistical Ambient Noise Levels

NM2 - 56A Pirrama Road, Pyrmont - Tuesday, 2 September 2014



Statistical Ambient Noise Levels

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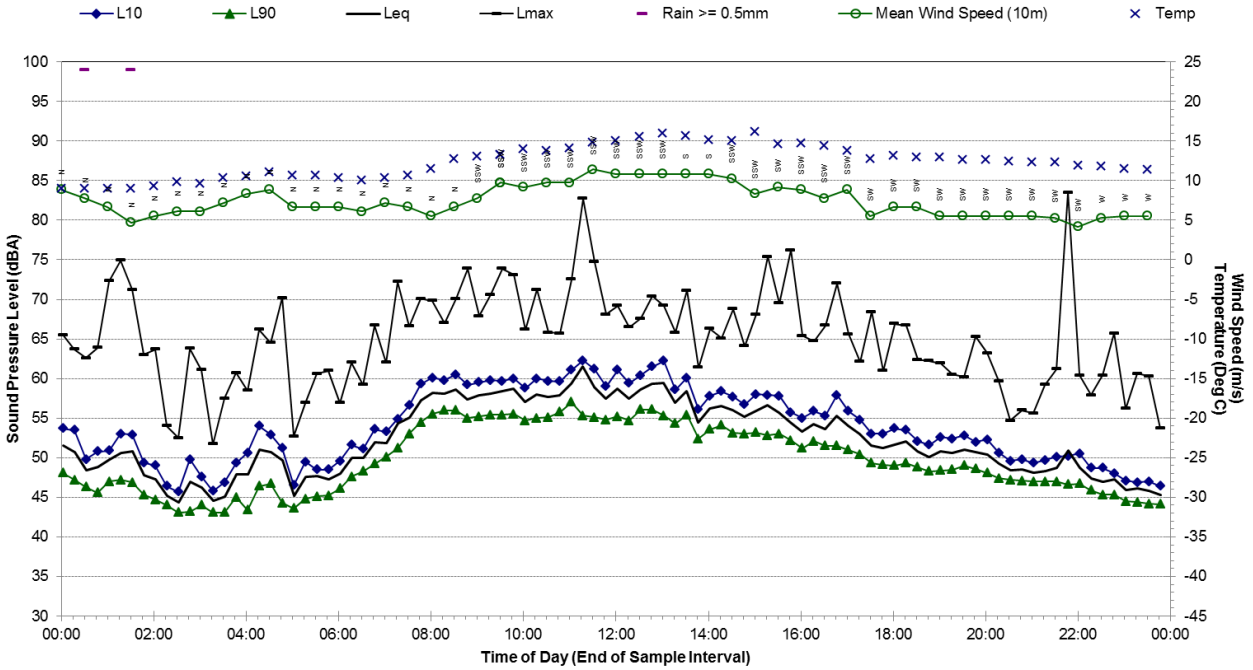

Statistical Ambient Noise Levels

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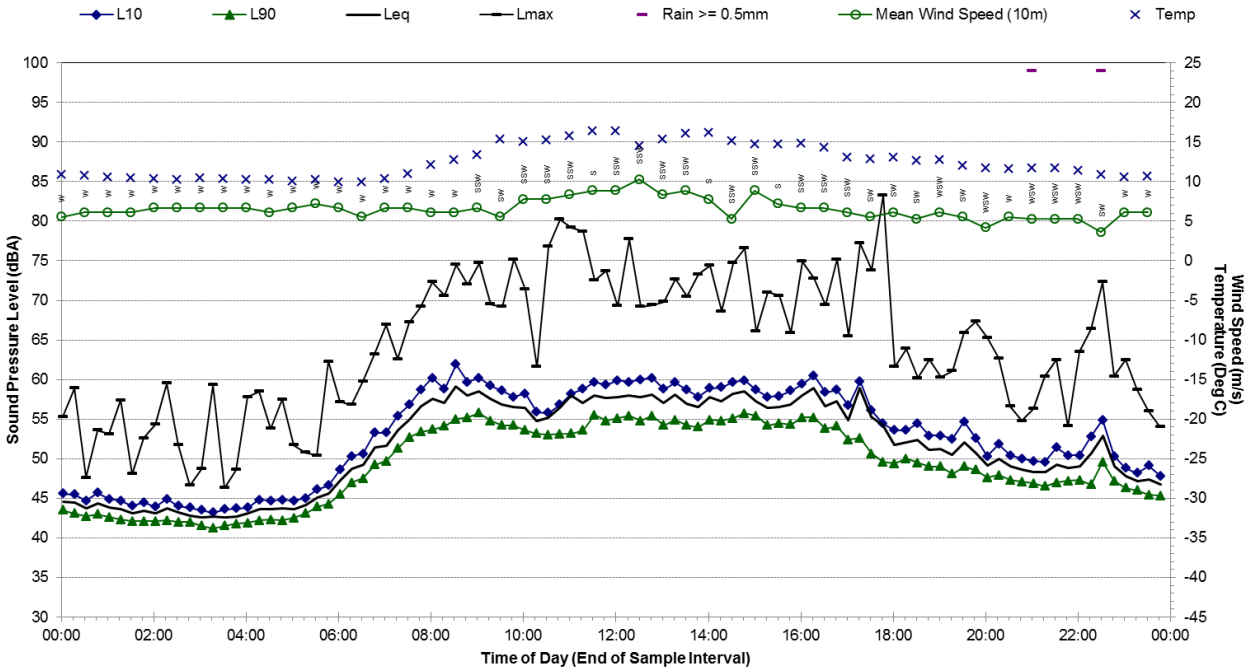

Statistical Ambient Noise Levels

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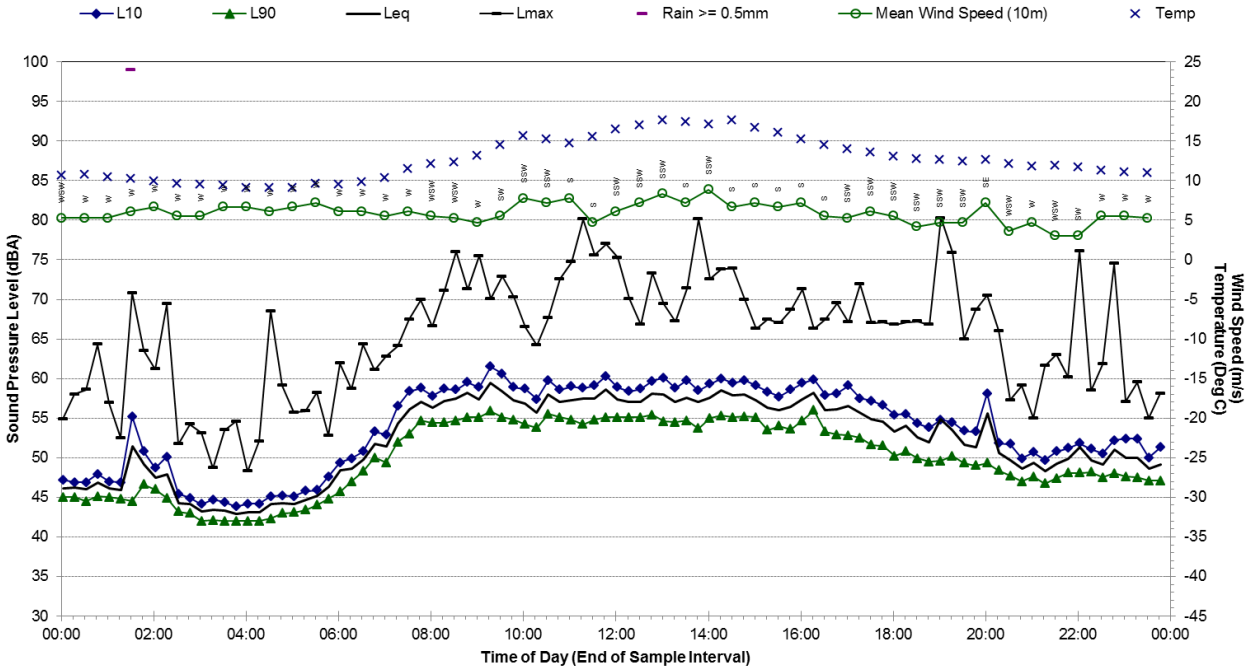

Statistical Ambient Noise Levels

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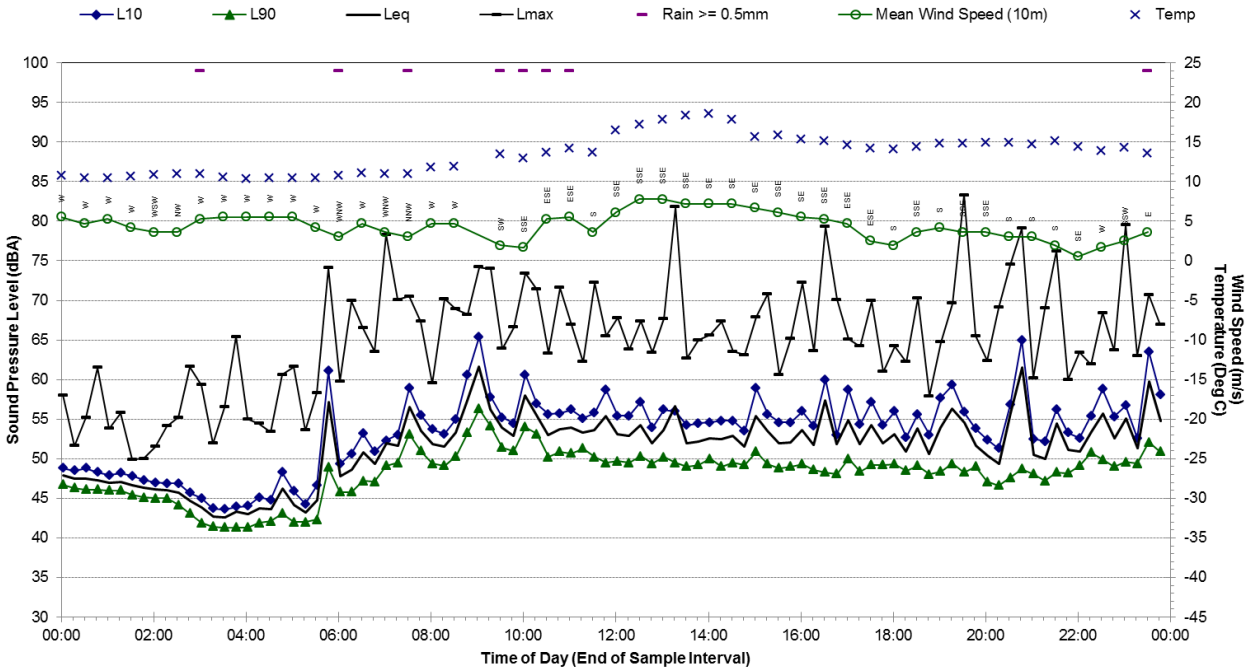

Statistical Ambient Noise Levels

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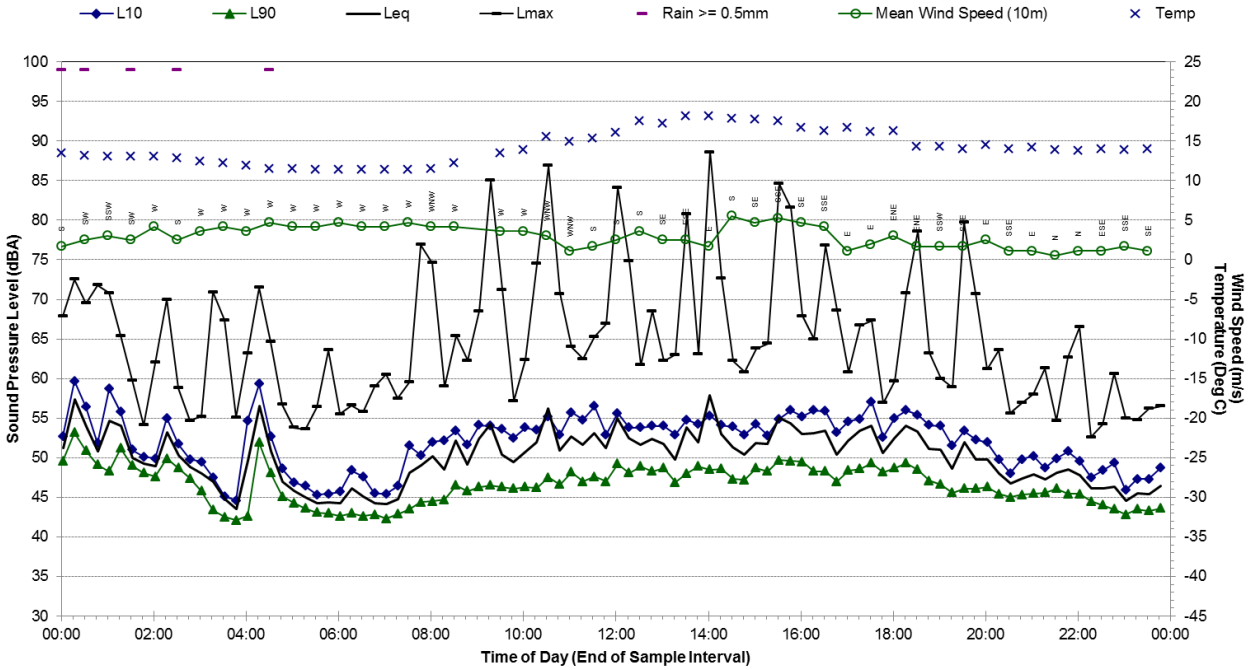

Statistical Ambient Noise Levels

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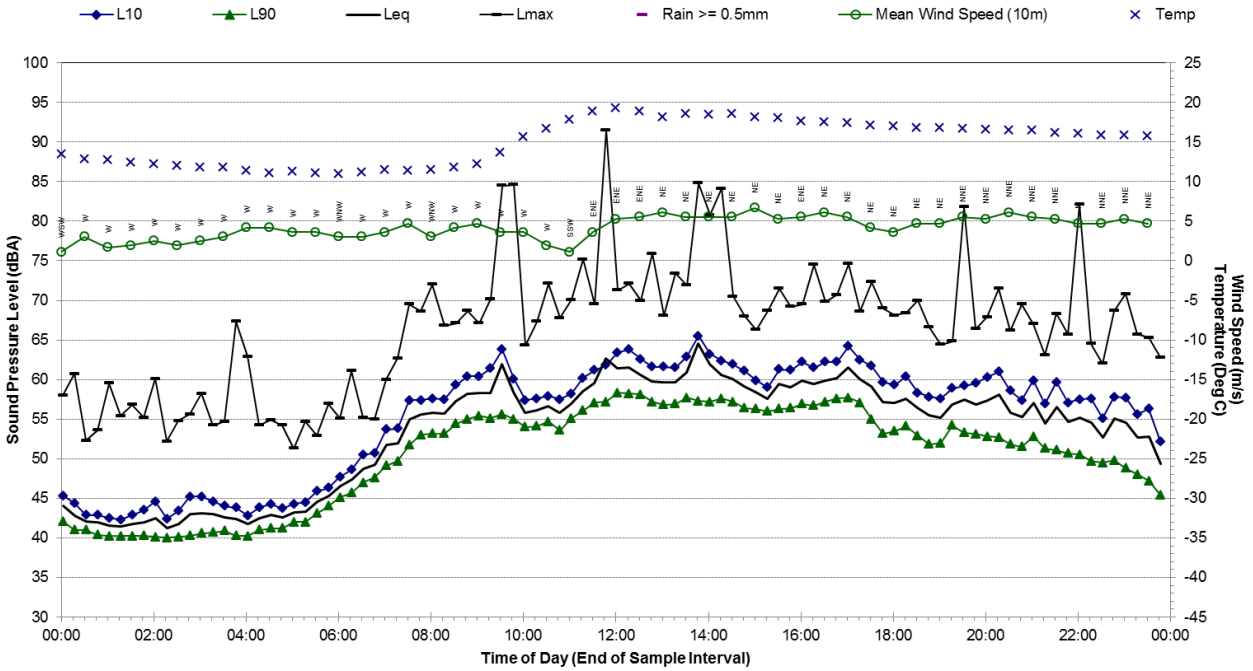
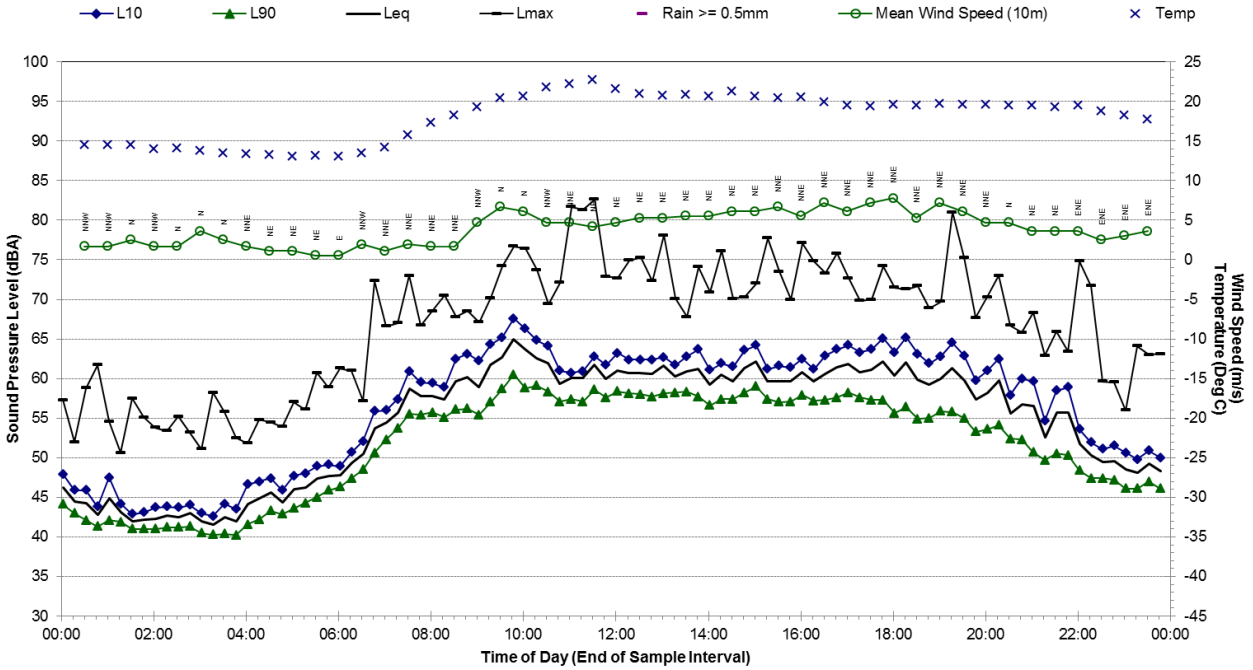


Statistical Ambient Noise Levels

NM2 - 56A Pirrama Road, Pyrmont - Tuesday, 9 September 2014



Statistical Ambient Noise Levels

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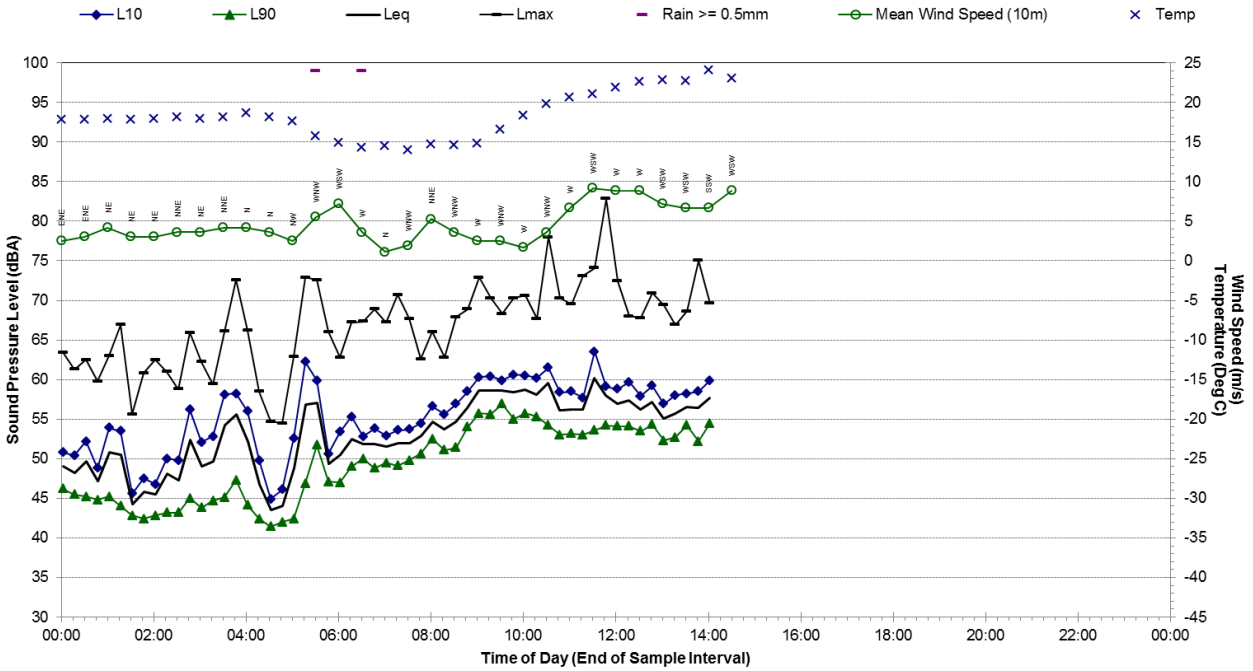
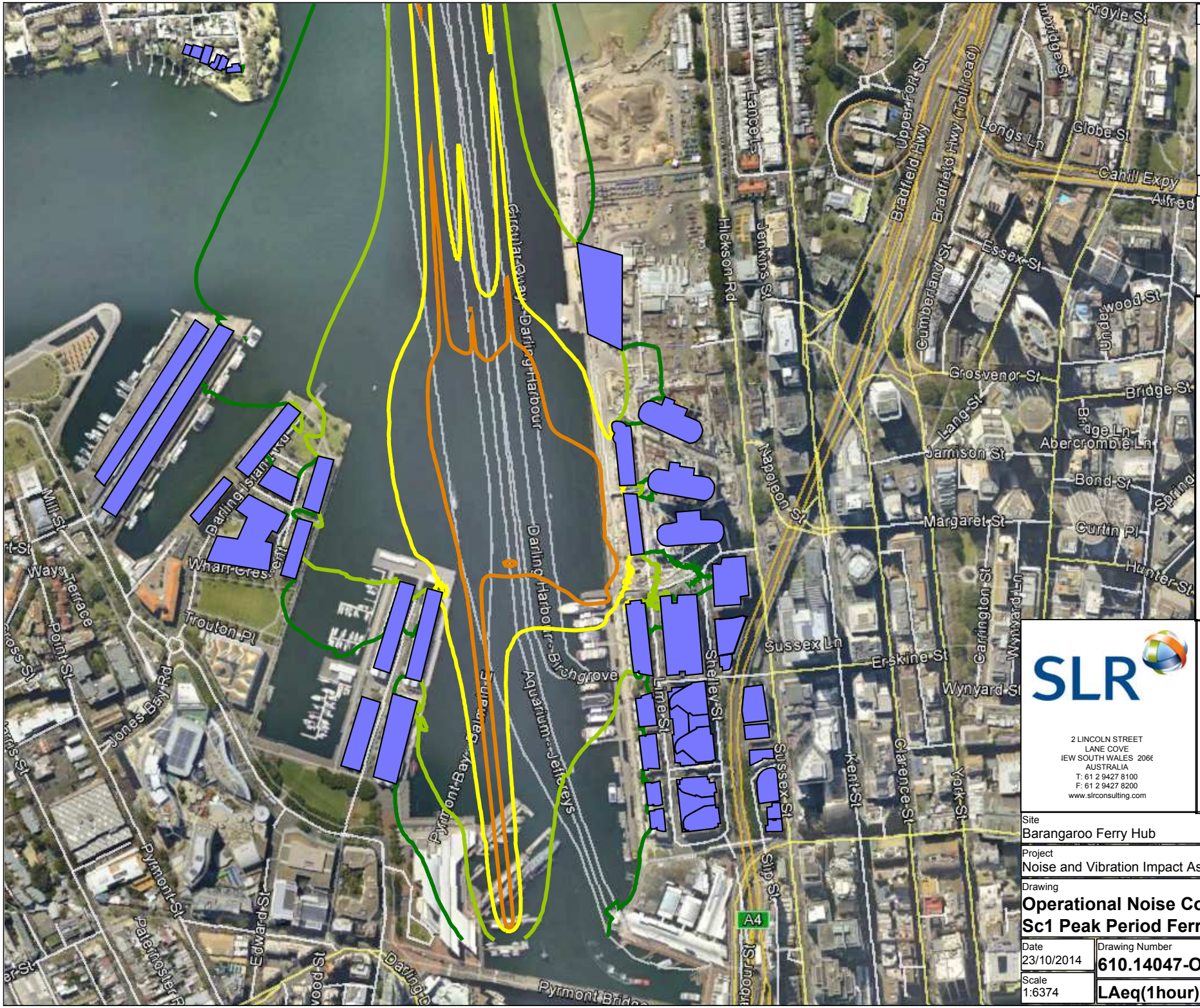


Noise Measurement of Ferry Activities

Fleet Name	Class	Measurement Location	Activity	L_{Aeq}	L_{Amax}
-	River Cat	Cockatoo Island	Engine/ Accelerating	63	69
Pam Burridge	HarbourCat	Cockatoo Island	Approaching / Reverse thrust	62	67
Pam Burridge	HarbourCat	Cockatoo Island	Reverse thrust	68	70
Pam Burridge	HarbourCat	Cockatoo Island	Accelerating	72	77
Mary Reiby	Captain Cook charter	Cockatoo Island	Engine	60	69
Mary Reiby	Captain Cook charter	Cockatoo Island	Accelerating	70	77
Golden Grove	First Fleet	Cockatoo Island	Reverse thrust / docking	61	70
Golden Grove	First Fleet	Cockatoo Island	Engine only	54	57
Golden Grove	First Fleet	Cockatoo Island	Reverse thrust / accelerating	64	71
Marjorie Jackson	RiverCat	Cockatoo Island	Reverse thrust	61	66
Marjorie Jackson	RiverCat	Cockatoo Island	Reverse thrust / accelerating	67	72
Marlene Mathews	RiverCat	Cockatoo Island	Accelerating	69	74
Shane Gould	RiverCat	Cockatoo Island	Reverse thrust	65	75
Shane Gould	RiverCat	Cockatoo Island	Reverse thrust / accelerating	71	75
Pam Burridge	HarbourCat	Cockatoo Island	Reverse thrust	60	67
Pam Burridge	HarbourCat	Cockatoo Island	Idling engine	57	63
Pam Burridge	HarbourCat	Cockatoo Island	Accelerating	68	74
Supply Sydney	First Fleet	Cockatoo Island	Idling engine	59	62
Supply Sydney	First Fleet	Cockatoo Island	Accelerating	66	70
Berry Cuthbert	River Cat	Cockatoo Island	Reverse thrust	63	73
Berry Cuthbert	River Cat	Cockatoo Island	Accelerating	68	72
Dawn Fraser	RiverCat	Cockatoo Island	Reverse thrust	60	65
Dawn Fraser	RiverCat	Cockatoo Island	Accelerating	69	73
Evonne Goolagong	RiverCat	Cockatoo Island	Reverse thrust	65	72
Evonne Goolagong	RiverCat	Cockatoo Island	Idling engine	66	71
Evonne Goolagong	RiverCat	Cockatoo Island	Accelerating	70	74
Shane Gould	RiverCat	Cockatoo Island	Idling engine	64	68
Shane Gould	RiverCat	Cockatoo Island	Reverse thrust / accelerating	68	74
Sirius	First Fleet	Cockatoo Island	Reverse thrust	63	67
Sirius	First Fleet	Cockatoo Island	Idling engine	61	65
Sirius	First Fleet	Cockatoo Island	Reverse thrust	61	72
Sirius	First Fleet	Cockatoo Island	Accelerating	63	66
Marlene Mathews	RiverCat	Cockatoo Island	Reverse thrust	64	69
Marlene Mathews	RiverCat	Cockatoo Island	Idling engine	66	76
Marlene Mathews	RiverCat	Cockatoo Island	accelerating	69	73
Marjorie Jackson	RiverCat	Cockatoo Island	reverse thrust	62	63
Marjorie Jackson	RiverCat	Cockatoo Island	Idling engine	63	69
Marjorie Jackson	RiverCat	Cockatoo Island	accelerating	69	74
Alexander	First Fleet	Circular Quay	Horns	-	73
Scarborough	First Fleet	Circular Quay	Horns	-	75

Predicted Operational Noise Contour Maps



LEGEND

Modelled Buildings

NOTES

Noise Levels
LAeq(1hour)
dBA

40
45
50
55

SLR

2 LINCOLN STREET
LANE COVE
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N

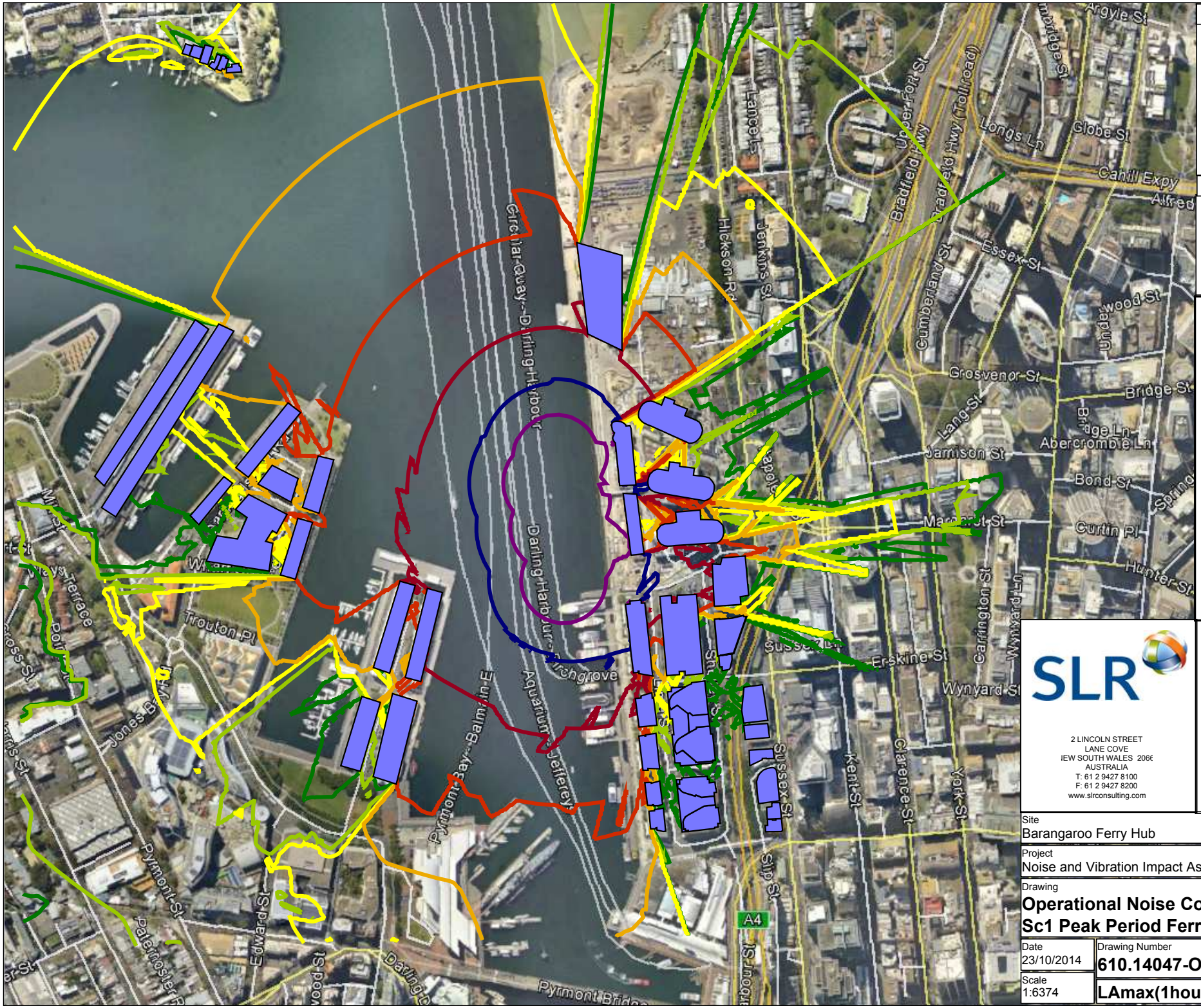
1:6374
0 30 60 120 180 240 m

Site
Barangaroo Ferry Hub

Project
Noise and Vibration Impact Assessment

Drawing
Operational Noise Contours
Sc1 Peak Period Ferry Movements 2026

Date	Drawing Number	Revision
23/10/2014	**610.14047-OPS_01A**	**0**
Scale 1:6374	**LAeq(1hour)**	



LEGEND

Modelled Buildings

NOTES

Noise Levels
LAmax(1hour)
dBA

40
45
50
55
60
65
70
75

SLR

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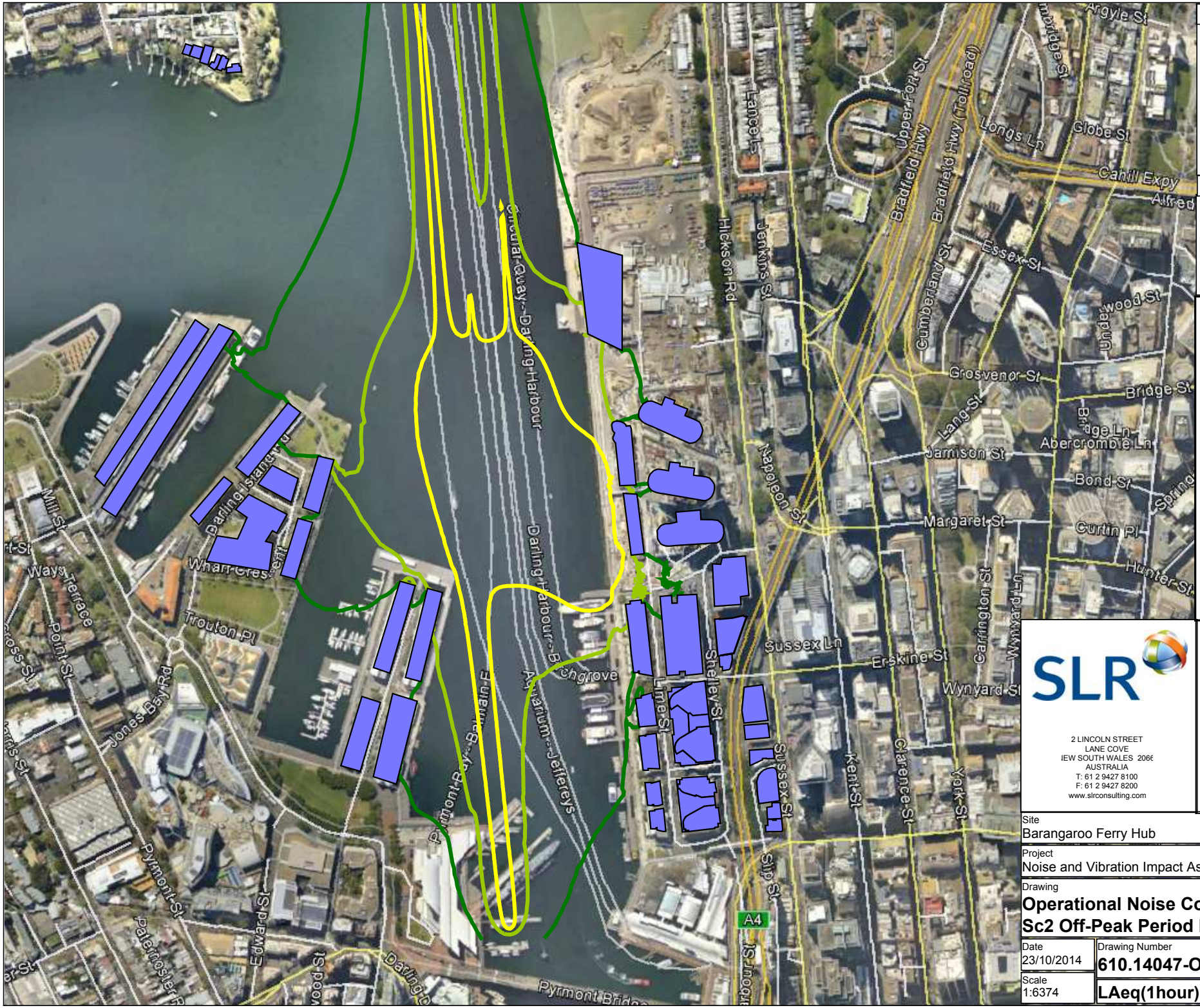
1:6374
0 30 60 120 180 240 m

Site
Barangaroo Ferry Hub

Project
Noise and Vibration Impact Assessment

Drawing
Operational Noise Contours
Sc1 Peak Period Ferry Movements 2026

Date	Drawing Number	Revision
23/10/2014	**610.14047-OPS_01B**	**0**
Scale 1:6374	**LAmax(1hour)**	



LEGEND

Modelled Buildings

NOTES

Noise Levels
LAeq(1hour)
dBA

40
45
50

SLR

2 LINCOLN STREET
LANE COVE
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1:6374
0 30 60 120 180 240 m

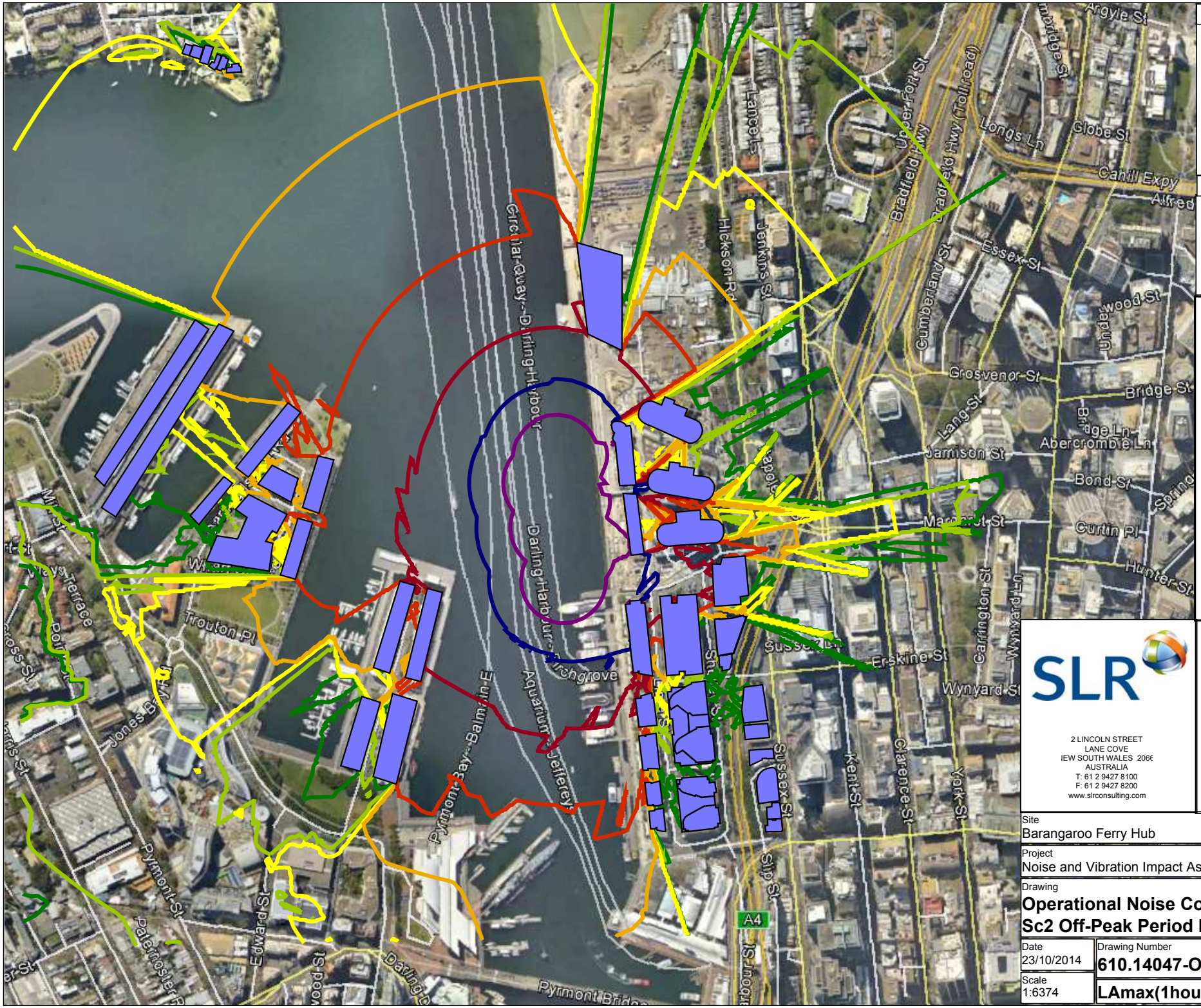
Site
Barangaroo Ferry Hub

Project
Noise and Vibration Impact Assessment

Drawing
Operational Noise Contours
Sc2 Off-Peak Period Ferry Movements 2026

Date	Drawing Number	Revision
23/10/2014	610.14047-OPS_02A	0

Scale	
1:6374	LAeq(1hour)



LEGEND

Modelled Buildings

NOTES

Noise Levels
LAmax(1hour)
dBA

40
45
50
55
60
65
70
75

SLR

2 LINCOLN STREET
LANE COVE
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1:6374
0 30 60 120 180 240 m

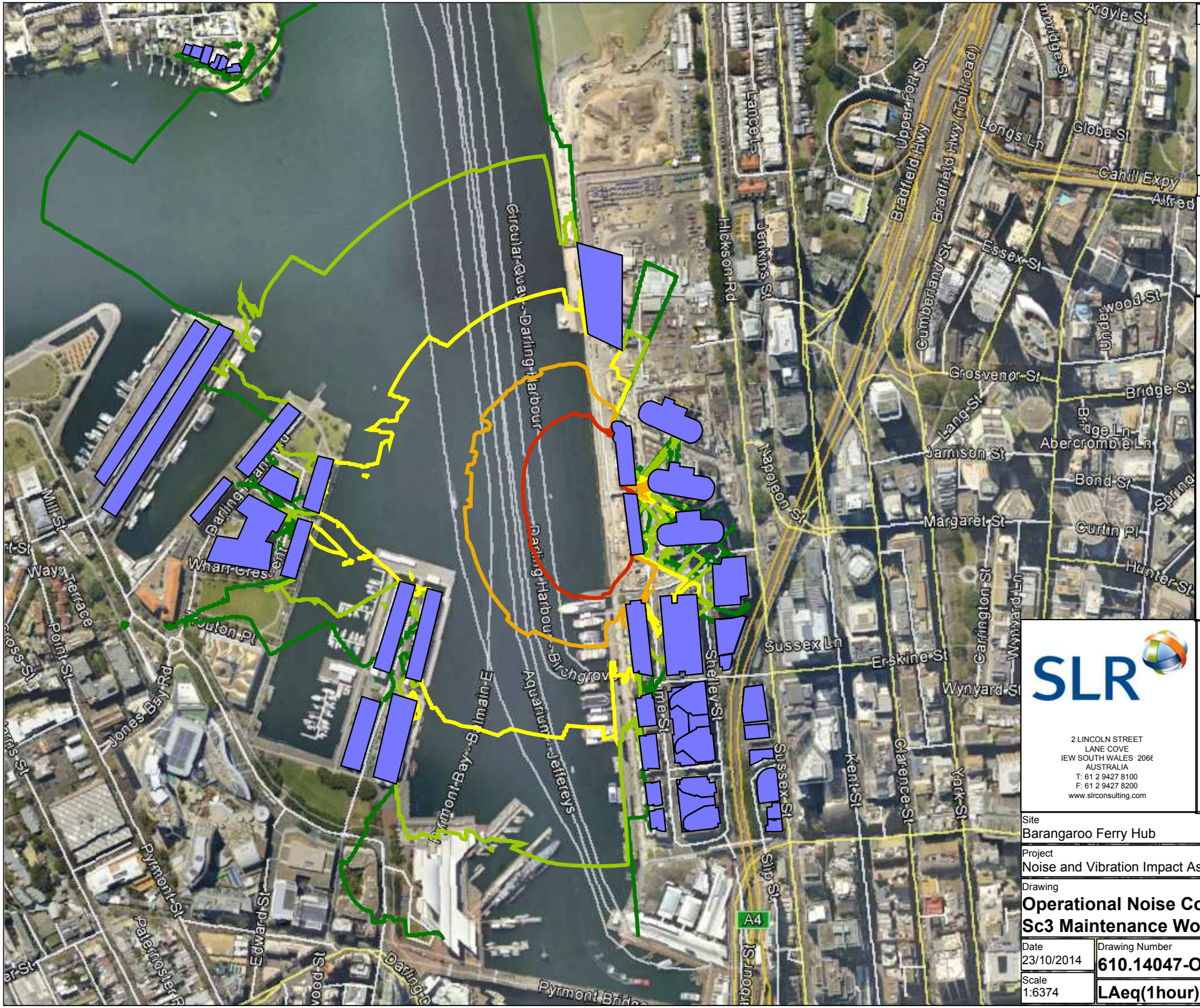
Site
Barangaroo Ferry Hub

Project
Noise and Vibration Impact Assessment

Drawing
Operational Noise Contours
Sc2 Off-Peak Period Ferry Movements 2026

Date	Drawing Number	Revision
23/10/2014	610.14047-OPS_02B	0

Scale	
1:6374	LAmax(1hour)



LEGEND

Modelled Buildings

NOTES

Noise Levels
LAeq(1hour)
dBA

40
45
50
55
60

SLR

2 LINCOLN STREET
LANE COVE
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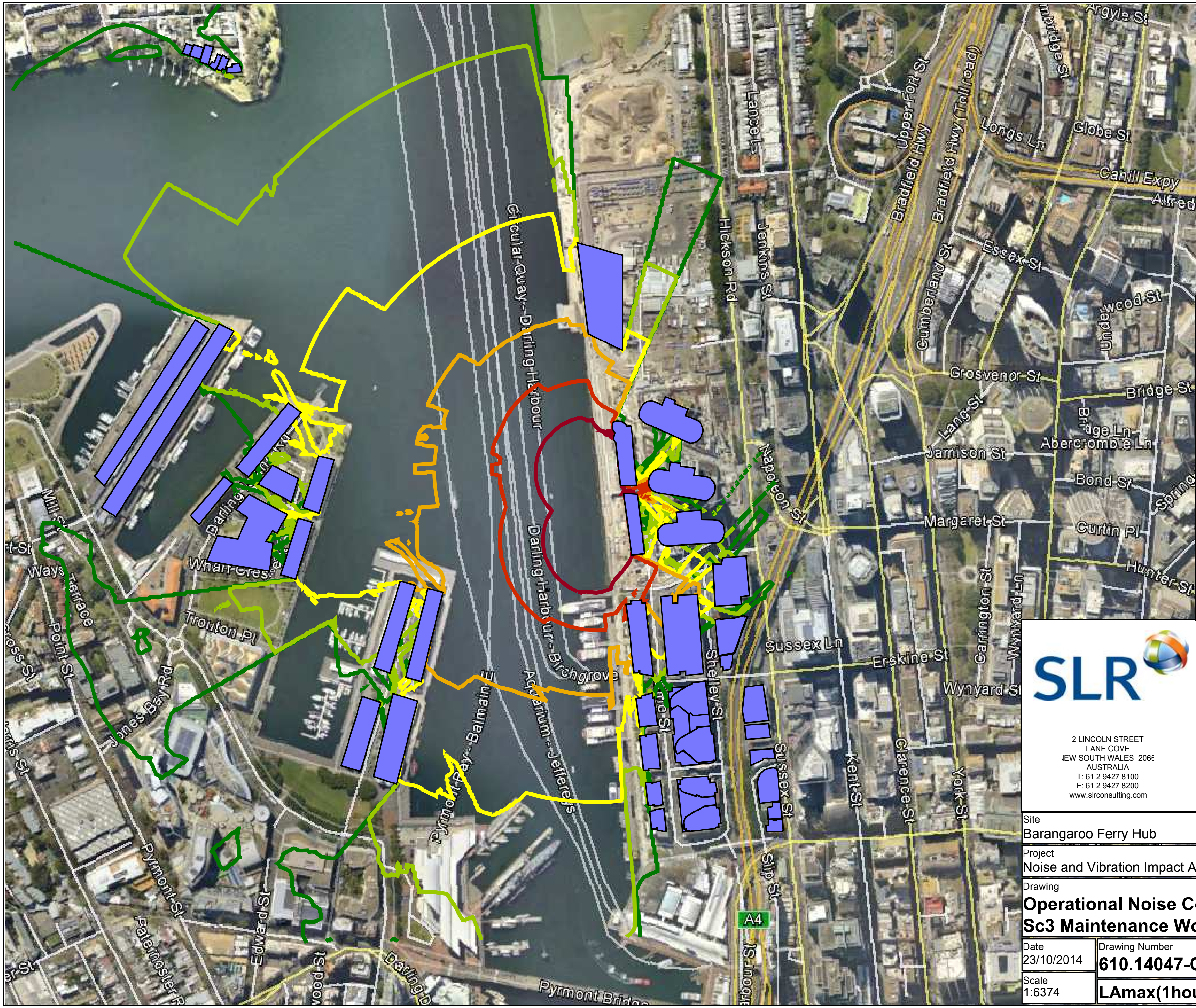
1:6374
0 30 60 120 180 240 m

Site
Barangaroo Ferry Hub

Project
Noise and Vibration Impact Assessment

Drawing
Operational Noise Contours
Sc3 Maintenance Works

Date	Drawing Number	Revision
23/10/2014	**610.14047-OPS_03A**	**0**
Scale 1:6374	**LAeq(1hour)**	



LEGEND

Modelled Buildings

NOTES

Noise Levels
LAmax(1hour)
dBA

40
45
50
55
60
65

SLR

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1:6374
0 30 60 120 180 240 m

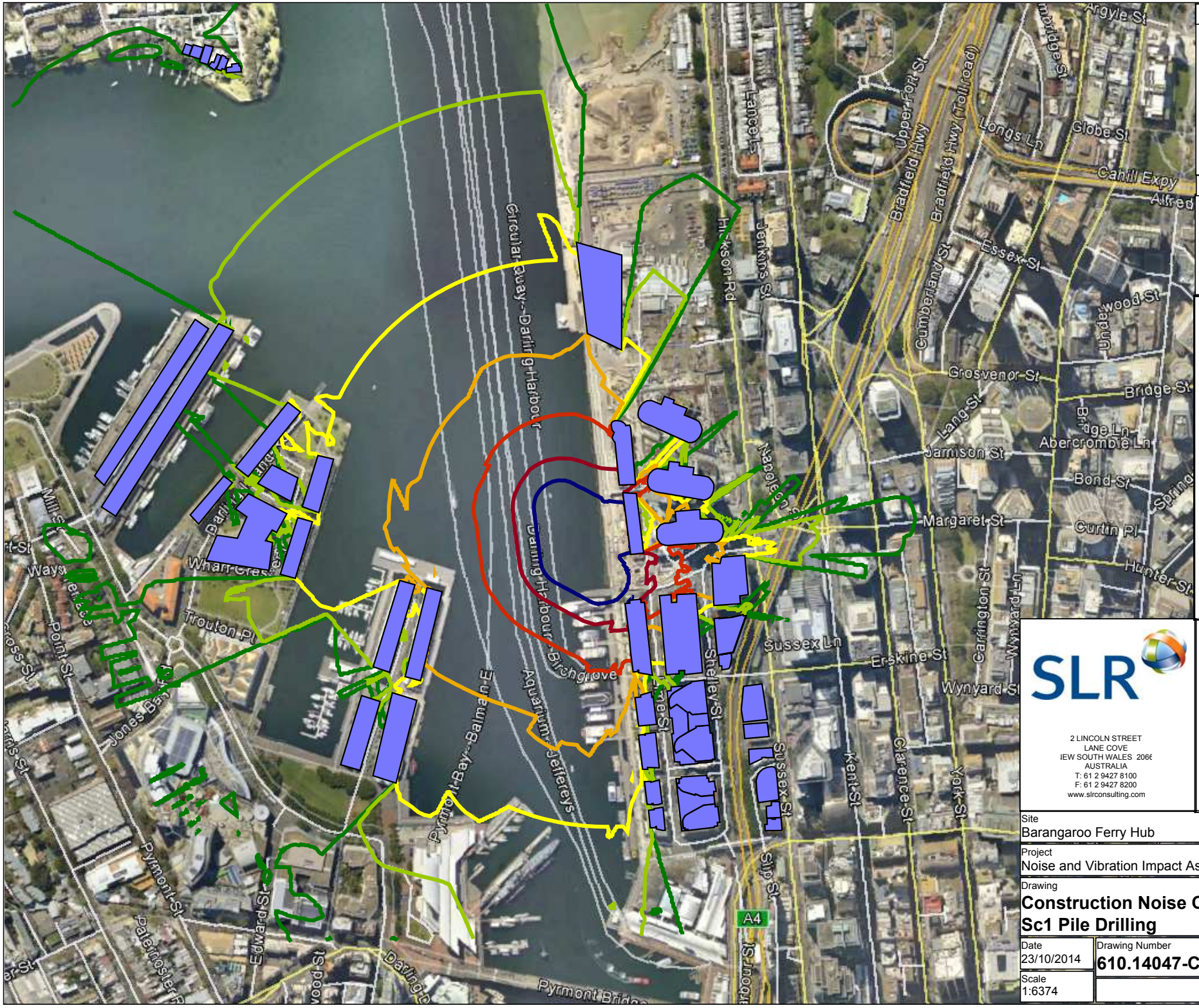
Site
Barangaroo Ferry Hub

Project
Noise and Vibration Impact Assessment

Drawing
Operational Noise Contours
Sc3 Maintenance Works

Date	Drawing Number	Revision
23/10/2014	**610.14047-OPS_03B**	**0**
Scale 1:6374	**LAmax(1hour)**	

Predicted Construction Noise Contour Maps



LEGEND

Modelled Buildings

NOTES

Noise Levels
LAeq(15minute)
dBA

40
45
50
55
60
65
70

SLR

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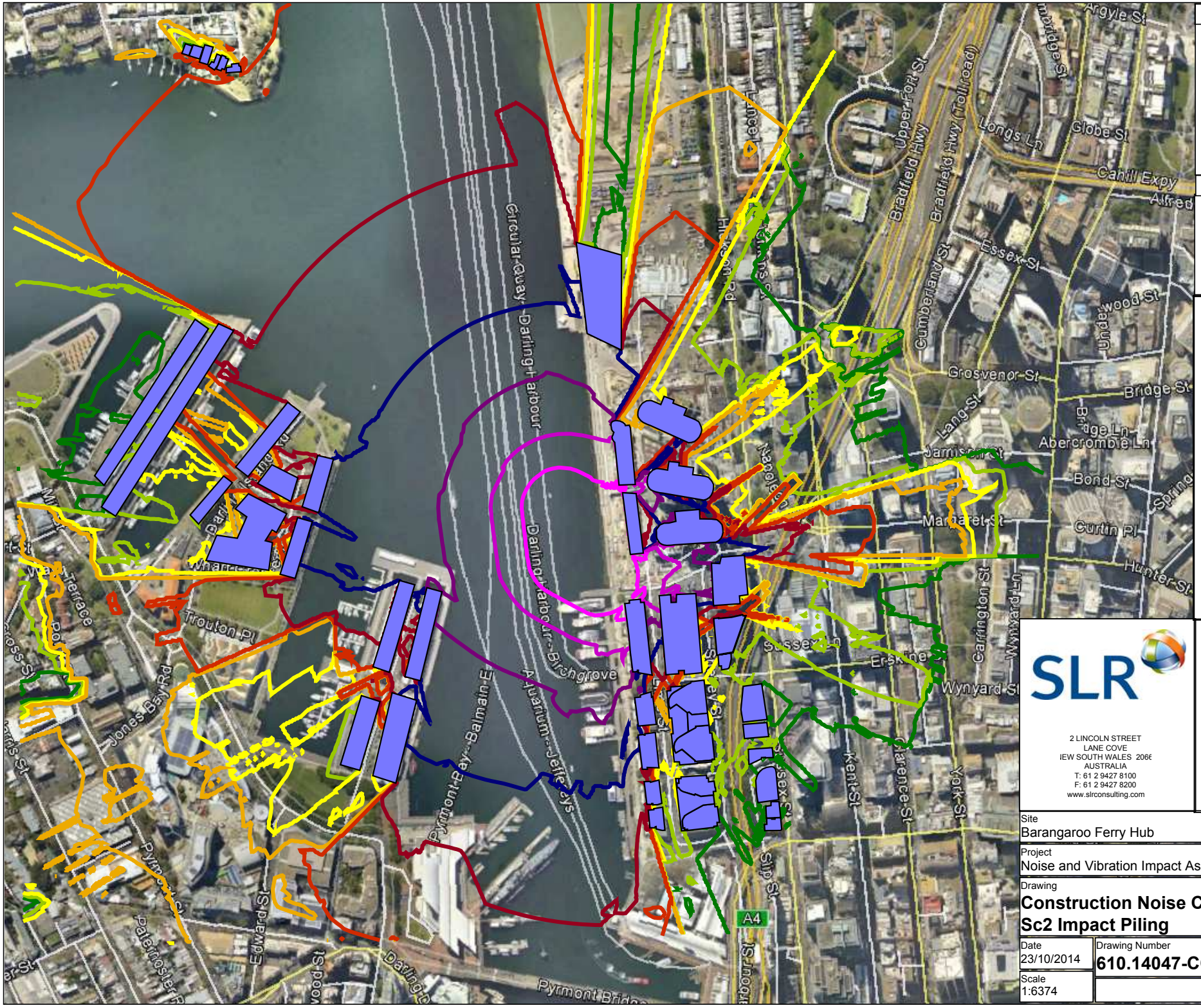
1:6374
0 30 60 120 180 240
m

Site
Barangaroo Ferry Hub

Project
Noise and Vibration Impact Assessment

Drawing
Construction Noise Contours
Sc1 Pile Drilling

Date	Drawing Number	Revision
23/10/2014	**610.14047-CON_01**	**0**
Scale 1:6374		



LEGEND

Modelled Buildings

NOTES

Noise Levels
LAeq(15minute)
dBA

40
45
50
55
60
65
70
75
80
85

SLR

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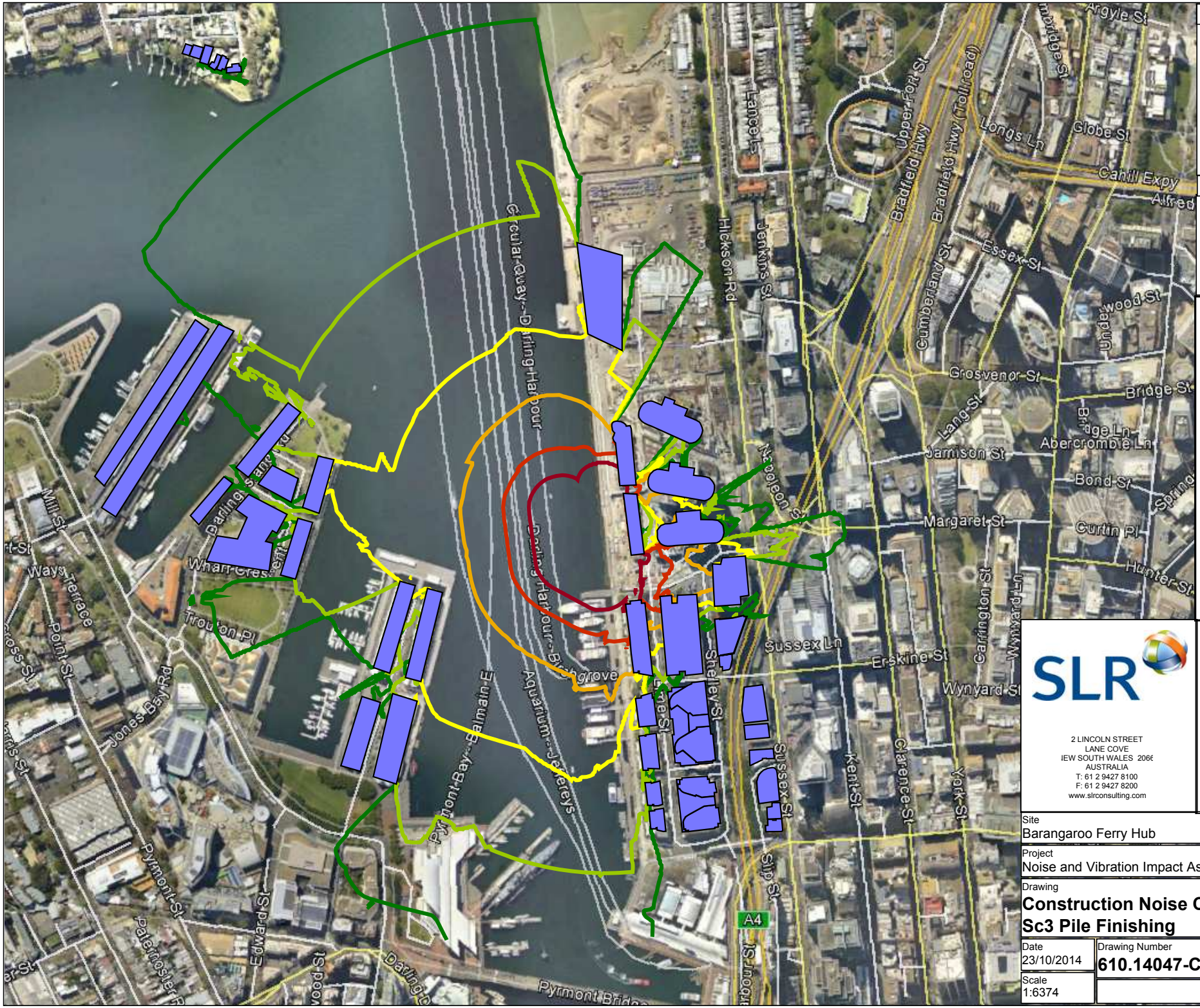
1:6374
0 30 60 120 180 240 m

Site
Barangaroo Ferry Hub

Project
Noise and Vibration Impact Assessment

Drawing
Construction Noise Contours
Sc2 Impact Piling

Date	Drawing Number	Revision
23/10/2014	**610.14047-CON_02**	**0**
Scale 1:6374		



LEGEND

Modelled Buildings

NOTES

Noise Levels
LAeq(15minute)
dBA

40
45
50
55
60
65

SLR

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1:6374
0 30 60 120 180 240 m

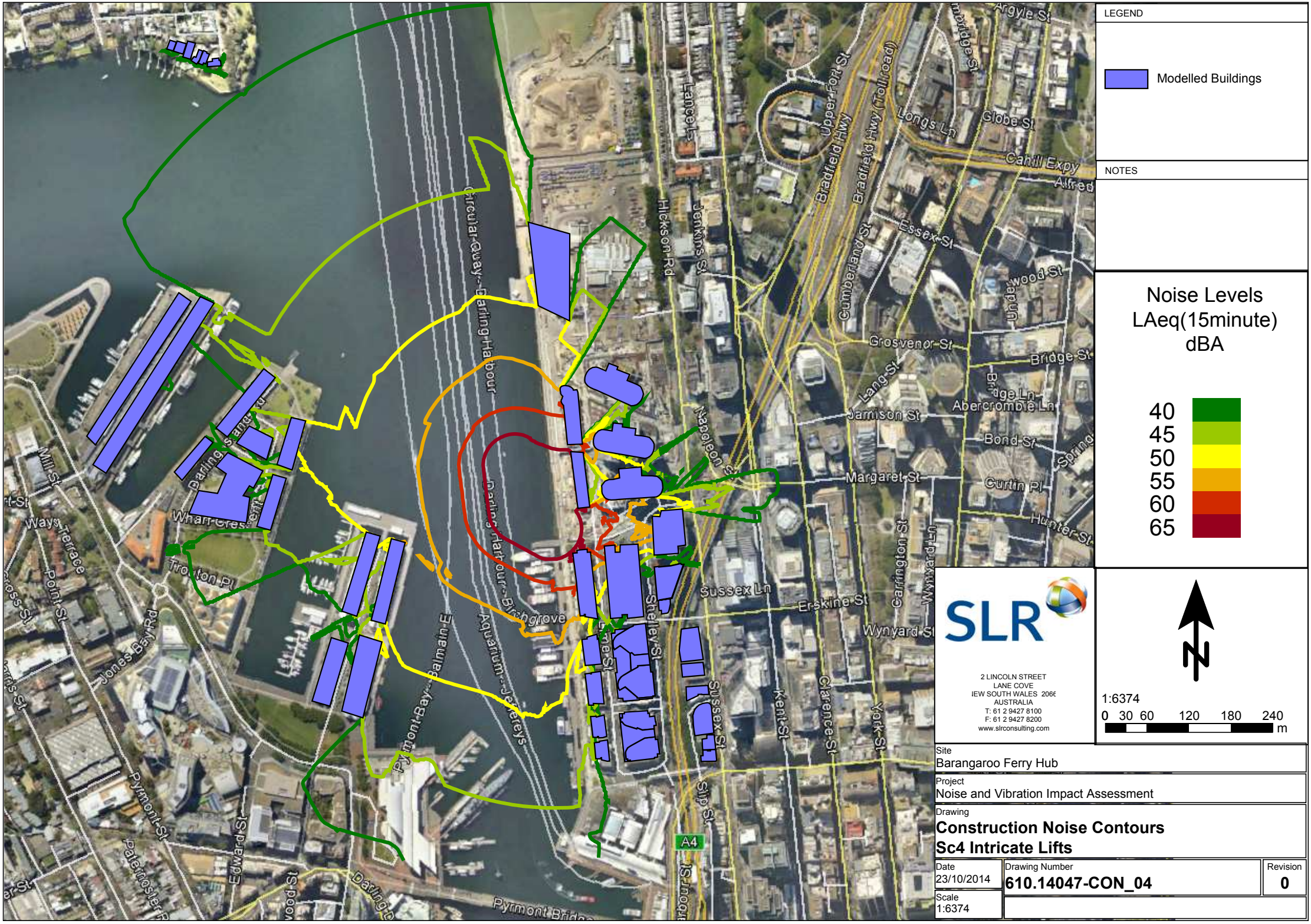
Site
Barangaroo Ferry Hub

Project
Noise and Vibration Impact Assessment

Drawing
Construction Noise Contours
Sc3 Pile Finishing

Date	Drawing Number	Revision
23/10/2014	**610.14047-CON_03**	**0**

Scale
1:6374


LEGEND
Modelled Buildings
NOTES
Noise Levels
LAeq(15minute)
dBA
40
45
50
55
60
65
Argyle St
Lancelot
Bradfield Hwy (Upper)
Bradfield Hwy (Trollroad)
Longs Ln
Globe St
Cahill Expy
Alfred
Hickson Rd
Jenkins St
Essex St
Cumberland St
Grosvenor St
Bridge St
Lang St
Jamison St
Abercrombie Ln
Bond St
Margaret St
Curtin Pl
Hunter St
Napoleon St
Circular Quay - Darling Harbour
Darling Harbour - Birchgrove
Aquarium - Jetreys
Darling Island
Wharf Cres
Mill St
Ways Terrace
Point St
Jones Bay Rd
Trouton Pl
Sussex Ln
Erskine St
Wynyard St
Carrington St
Shelley St
Sussex St
Kent St
Clarence St
York St
Slip St
Pymont Bridge
Pymont St
Edward St
Palmerston
Darling
A4
SLR
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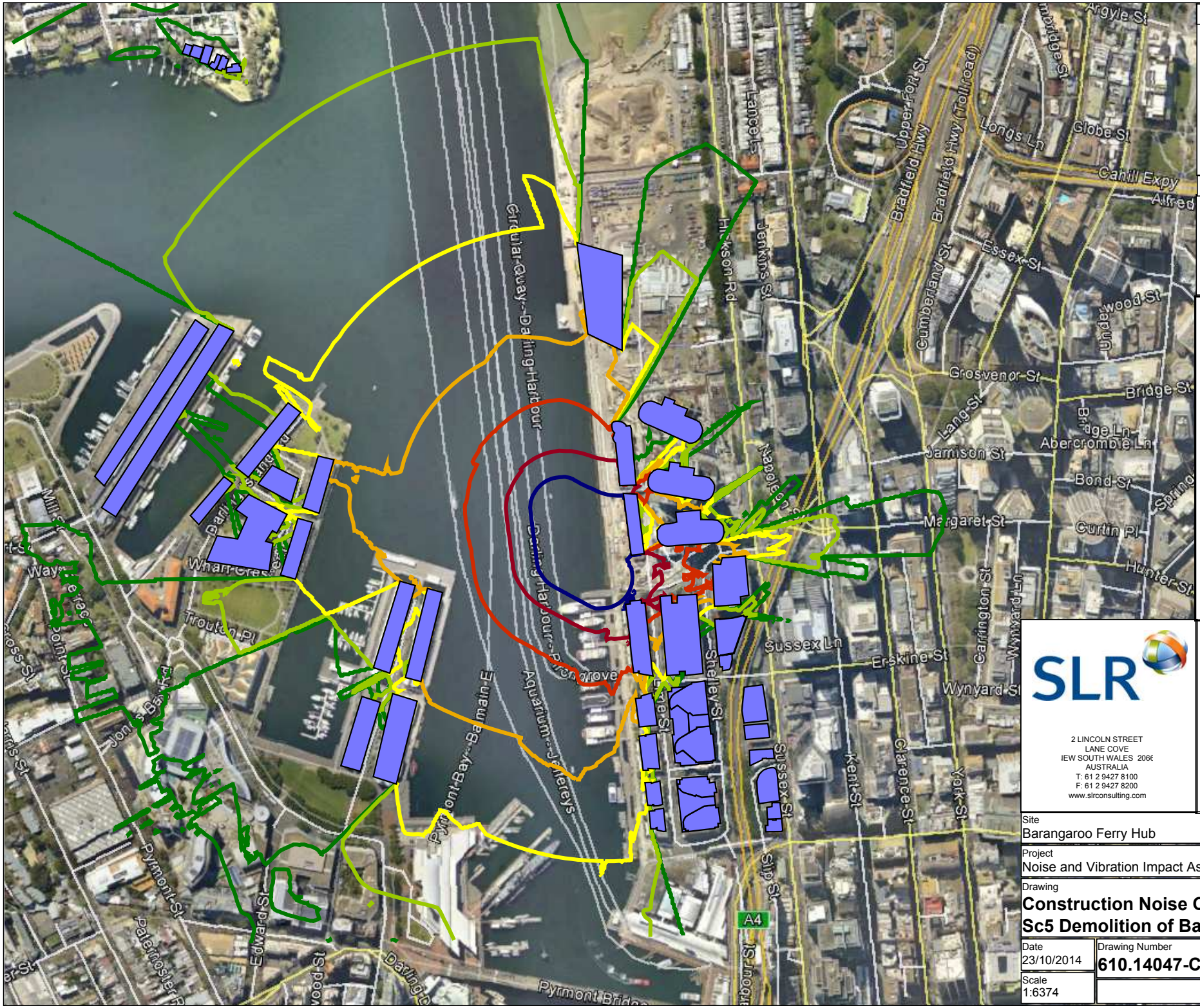
N
1:6374
0 30 60 120 180 240
m
Site
Barangaroo Ferry Hub
Project
Noise and Vibration Impact Assessment
Drawing
Construction Noise Contours
Sc4 Intricate Lifts
Date
23/10/2014
Drawing Number
610.14047-CON_04
Revision
0
Scale
1:6374


LEGEND
Modelled Buildings
NOTES
Noise Levels
LAeq(15minute)
dBA
40
45
50
55
60
65
70
Circular Quay
Darling Harbour
Pyrmont Bay
Aquarium
Jones Bay
Wharf
Pyrmont Bridge
Sussex St
Kent St
Clarence St
York St
Erskine St
Wynyard St
Margaret St
Bond St
Hunter St
Curtin Pl
Jamison St
Grosvenor St
Bridge St
Lang St
Abercrombie Ln
Cumberland St
Bradfield Hwy (Tollroad)
Upper Fort St
Argyle St
Globe St
Cahill Expy
Essex St
Jenkins St
Hickson Rd
Napoleon St
Shelley St
Slip St
Pyrmont St
Edward St
Harris St
Trouton Pl
Wharf Cres
A4
SLR
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LANE COVE
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F: 61 2 9427 8200
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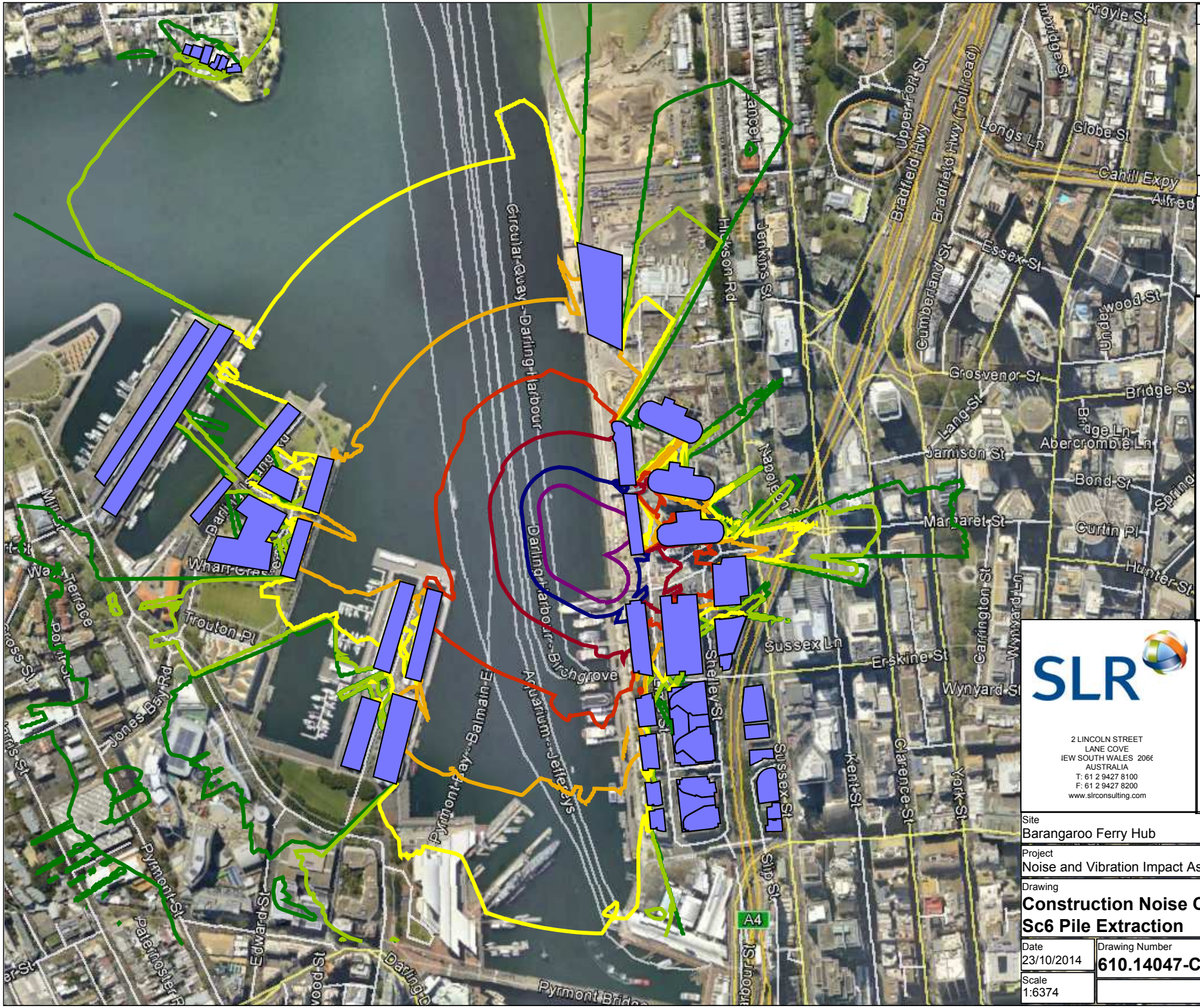
N
1:6374
0 30 60 120 180 240
m
Site
Barangaroo Ferry Hub
Project
Noise and Vibration Impact Assessment
Drawing
Construction Noise Contours
Sc5 Demolition of Baffle
Date
23/10/2014
Drawing Number
610.14047-CON_05
Revision
0
Scale
1:6374



LEGEND

Modelled Buildings

NOTES

Noise Levels
LAeq(15minute)
dBA

40
45
50
55
60
65
70
75

SLR

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LANE COVE
NEW SOUTH WALES 2066
AUSTRALIA
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N

1:6374
0 30 60 120 180 240 m

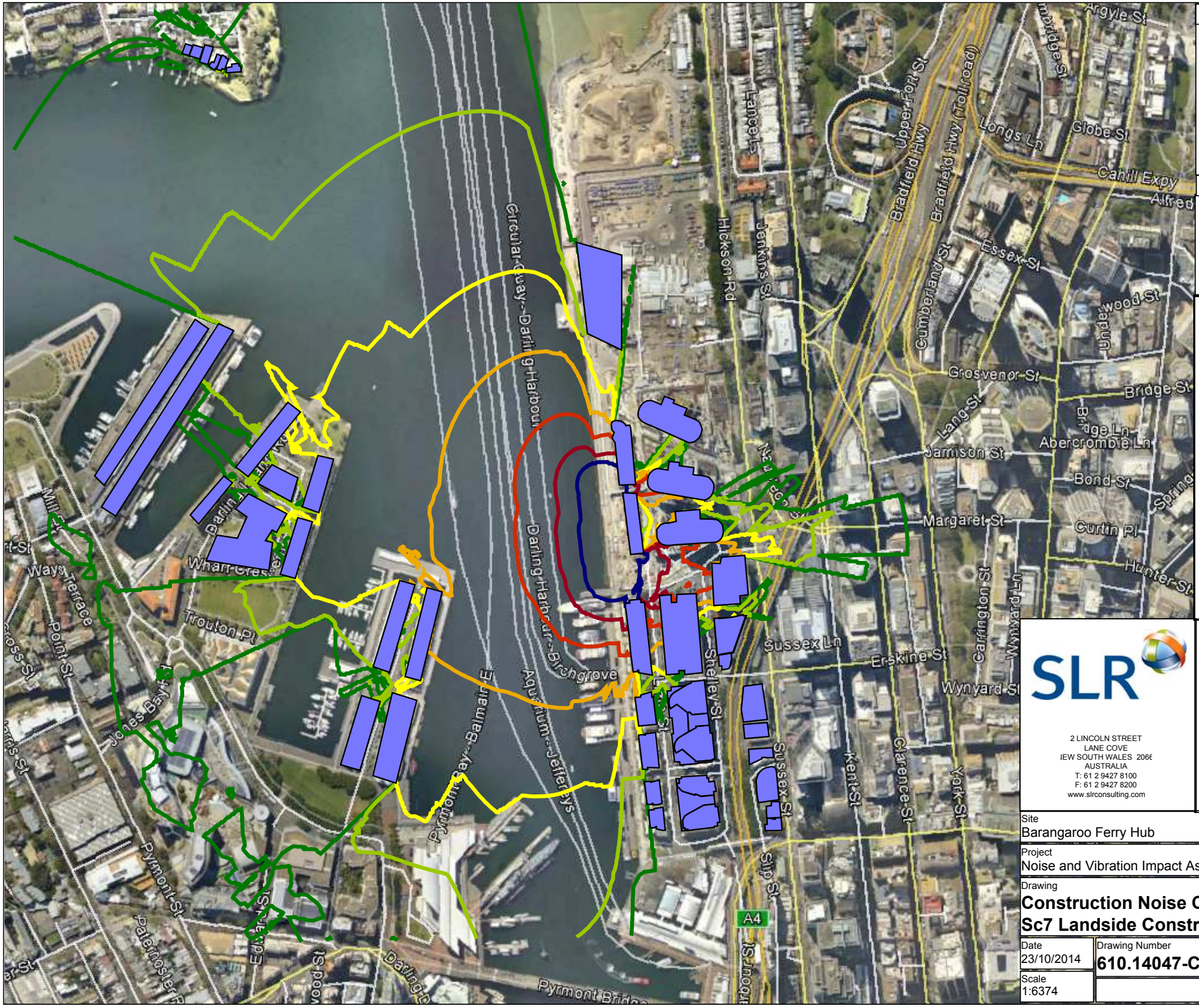
Site
Barangaroo Ferry Hub

Project
Noise and Vibration Impact Assessment

Drawing
Construction Noise Contours
Sc6 Pile Extraction

Date	Drawing Number	Revision
23/10/2014	**610.14047-CON_06**	**0**

Scale
1:6374



LEGEND

Modelled Buildings

NOTES

Noise Levels
LAeq(15minute)
dBA

40
45
50
55
60
65
70

SLR

2 LINCOLN STREET
LANE COVE
NEW SOUTH WALES 2066
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N

1:6374
0 30 60 120 180 240 m

Site
Barangaroo Ferry Hub

Project
Noise and Vibration Impact Assessment

Drawing
Construction Noise Contours
Sc7 Landside Construction

Date	Drawing Number	Revision
23/10/2014	**610.14047-CON_07**	**0**

Scale
1:6374