NSW GOVERNMENT

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 10

Construction noise and vibration

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10 Construction noise and vibration

This chapter considers the potential noise and vibration impacts from the construction of the project and identifies management measures to minimise these impacts. Potential noise and vibration impacts associated with the operation of the project are included in Chapter 11 (Operational noise and vibration).

A detailed noise and vibration assessment has been carried out for the project and is included in Appendix G (Technical working paper: Noise and vibration). The impacts associated with underwater noise are considered in Chapter 13 (Human health) and Chapter 19 (Biodiversity).

The Secretary's environmental assessment requirements as they relate to construction noise and vibration and where in the environmental impact statement these have been addressed, are detailed in Table 10-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to construction noise and vibration are included in Section 10.7.

Table 10-1 Secretary's environmental assessment requirements – construction noise and vibration

Secretary s requirement	Where addressed in EIS
Noise and Vibration – Amenity	
1. The Proponent must assess construction and operational noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must take into consideration and address the redistribution of traffic (including on local feeder roads) and operational plant and equipment, and must include consideration of impacts to sensitive receivers and include consideration of sleep disturbance and, as relevant, the characteristics of noise and vibration (for example, low frequency noise).	Relevant NSW noise and vibration guidelines used in the assessment are discussed in **Section 10.4.** Impacts from redistribution of traffic (including on local feeder roads) and operational plant and equipment are documented in **Chapter 11** (Operational noise and vibration).
2. An assessment of construction noise and vibration impacts which must address: a. the nature of construction activities (including transport, tonal or impulsive noise–generating works and the removal of operational noise barriers, as relevant);	The nature of construction activities and potential noise and vibration impacts are outlined in **Section 10.6,** while additional detail is provided in **Appendix G** (Technical working paper: Noise and vibration).
b. the intensity and duration of noise and vibration impacts (both air and ground borne). This must include consideration of extended construction impacts associated with ancillary facilities (and the like) and construction fatigue;	The intensity and duration of potential noise and vibration impacts are described in **Section 10.6**, however further detail is provided within **Appendix G** (Technical Working Paper: Noise and vibration).

Secretary s requirement	Where addressed in EIS
	Environmental management measures related to construction fatigue are in **Section 10.7**. Construction fatigue is also discussed in **Chapter 27** (Cumulative impacts).
c. the identification of receivers, existing and likely, during the construction period;	**Section 10.5** outlines the identification of receivers, both existing and likely, while **Section 10.6** outlines potential impacts on such receivers.
d. the nature, sensitivity and impact to receivers;	**Section 10.5** and **Section 10.6** present information on the nature, sensitivity and impact on receivers, however further detail is provided within **Appendix G** (Technical Working Paper: Noise and vibration).
e. the need to balance timely conclusion of noise and vibration–generating works with periods of receiver respite, and other factors that may influence the timing and duration of construction activities (such as traffic management);	Information regarding the need to balance timely conclusion of noise and vibration-generating works with periods of receiver respite, and other factors that may influence the timing and duration of construction activities (such as traffic management) is outlined **Section 10.6** as well as within **Appendix G** (Technical Working Paper: Noise and vibration).
f. the potential for works outside standard construction hours, including predicted levels, exceedances, number of potentially affected receivers, and justification for the activity in terms of the Interim Construction Noise Guideline (DECCW, 2009);	**Section 10.6** as well as **Appendix G** (Technical Working Paper: Noise and vibration) present details on the potential (and parameters) for works outside of standard construction hours.
g. a cumulative noise and vibration assessment inclusive of impacts from the project (including concurrent project construction activities);	**Section 10.6** as well as Appendix G (Technical working paper: Noise and vibration) present details on the cumulative noise and vibration assessment inclusive of impacts from the project (including concurrent project construction activities).
h. a cumulative noise and vibration assessment of the impacts from the project and the construction of other relevant development in the vicinity of the proposal;	**Section 10.6** as well as **Appendix G** (Technical working paper: Noise and vibration) presents detail on the cumulative noise and vibration assessment of impacts from the project and the construction of other relevant development in the vicinity of the proposal. **Chapter 27** (Cumulative impacts) assesses the cumulative construction noise and other relevant developments in the vicinity of the proposal.
i. details and analysis of the effectiveness of mitigation measures to adequately manage identified impacts, including	**Section 10.6** and **Appendix G** (Technical working paper: Noise and vibration) present details and analysis of the effectiveness of

Secretary s requirement	Where addressed in EIS
cumulative impacts as identified in (g) and (h) and a clear identification of residual noise and vibration following application of mitigation measures; and	mitigation measures (as outlined in **Section 10.9**).
j. a description of how community preferences have been taken into account in the design of mitigation measures and consider tailored mitigation, management and communication strategies for vulnerable community members.	**Appendix E** (Technical working paper: Community consultation framework) presents details of how community preferences would be taken into account in the design of mitigation measures and commitments to tailored mitigation, management and communication strategies for vulnerable community members.
3. The Proponent must demonstrate that blast impacts are capable of complying with the current guidelines, if blasting is required.	**Section 10.4** and **Section 10.6** outline how blast impacts are capable of complying with respect to relevant guidelines. Further detail is provided within **Appendix G** (Technical Working Paper: Noise and vibration).
Noise and Vibration – Structural	
1. The Proponent must assess construction and operation noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to the structural integrity and heritage significance of items (including Aboriginal places and items of environmental heritage).	**Section 10.6** as well as **Appendix G** (Technical working paper: Noise and vibration) presents details on the assessment of construction and operation noise and vibration impacts in respect to relevant NSW noise and vibration guidelines as well as the consideration of impacts on the structural integrity of buildings and heritage significance items. **Chapter 11** (Operational noise and vibration) presents information with respect to the operational phase. **Chapter 14** (Non-Aboriginal heritage) presents an assessment of impacts to items of significance as a result of vibration. **Chapter 15** (Aboriginal cultural heritage) provides an assessment of impacts to items of significance as a result of vibration.
2. The Proponent must demonstrate that blast impacts are capable of complying with the current guidelines, if blasting is required.	**Section 10.3** and **Section 10.6** outlines how blast impacts are capable of complying with respect to relevant guidelines. Further detail is provided within **Appendix G** (Technical Working Paper: Noise and vibration).

10.1 Acoustic terminology

Common acoustic terms used throughout this chapter and Chapter 11 (Operational noise and vibration) are explained in Table 10-2.

Table 10-2 Acoustic terminology

Term	Definition
Ambient noise	The all-encompassing noise associated within a given environment at a given time, usually composed of sound from all sources near and far.
dB(A)	dB(A) stands for A-weighted decibel, a unit used to measure noise. A summary of noise levels in the context of comparable activities is shown in Figure 10-1 to assist in the interpretation of the noise levels presented in this chapter. In terms of sound perception, a change of 1 dB(A) or 2 dB(A) in the sound pressure level is difficult for most people to detect. A 3 dB(A) to 5 dB(A) change corresponds to a small but noticeable change in loudness. An increase in sound level of 10 dB(A) is perceived as a doubling of loudness. However, individuals may perceive the same sound differently since many factors can influence an individual's response, including: • The specific characteristics of the noise (eg frequency, intensity, duration of the noise event) • Time of day noise events occur • Individual sensitivities and lifestyle • Reaction to an unfamiliar sound • Understanding of whether the noise is avoidable and the notions of fairness.
L_{A90}	L_{A90} is the level of noise exceeded for 90 per cent of the time. The bottom 10 per cent of the sample is the L_{A90} noise level expressed in units of dB(A).
$L_{Aeq(period)}$	$L_{Aeq(period)}$ is the A-weighted equivalent noise level. It is the summation of noise events and integrated over a period of time.
L_{Amax}	L_{Amax} is the maximum A-weighted sound pressure level measured over a given period.
Noise catchment area (NCA)	Noise catchment area is an area where noise and vibration sensitive receivers have similar acoustic environment. Refer to Section 10.3.1 for more information on NCAs.
Rating background level (RBL)	Rating background level is the background noise level in the absence of proposed construction activities. This parameter represents the average minimum noise level during the daytime, evening and night time periods and is used to set the $L_{Aeq(15\ minute)}$ noise management levels for residential receivers.

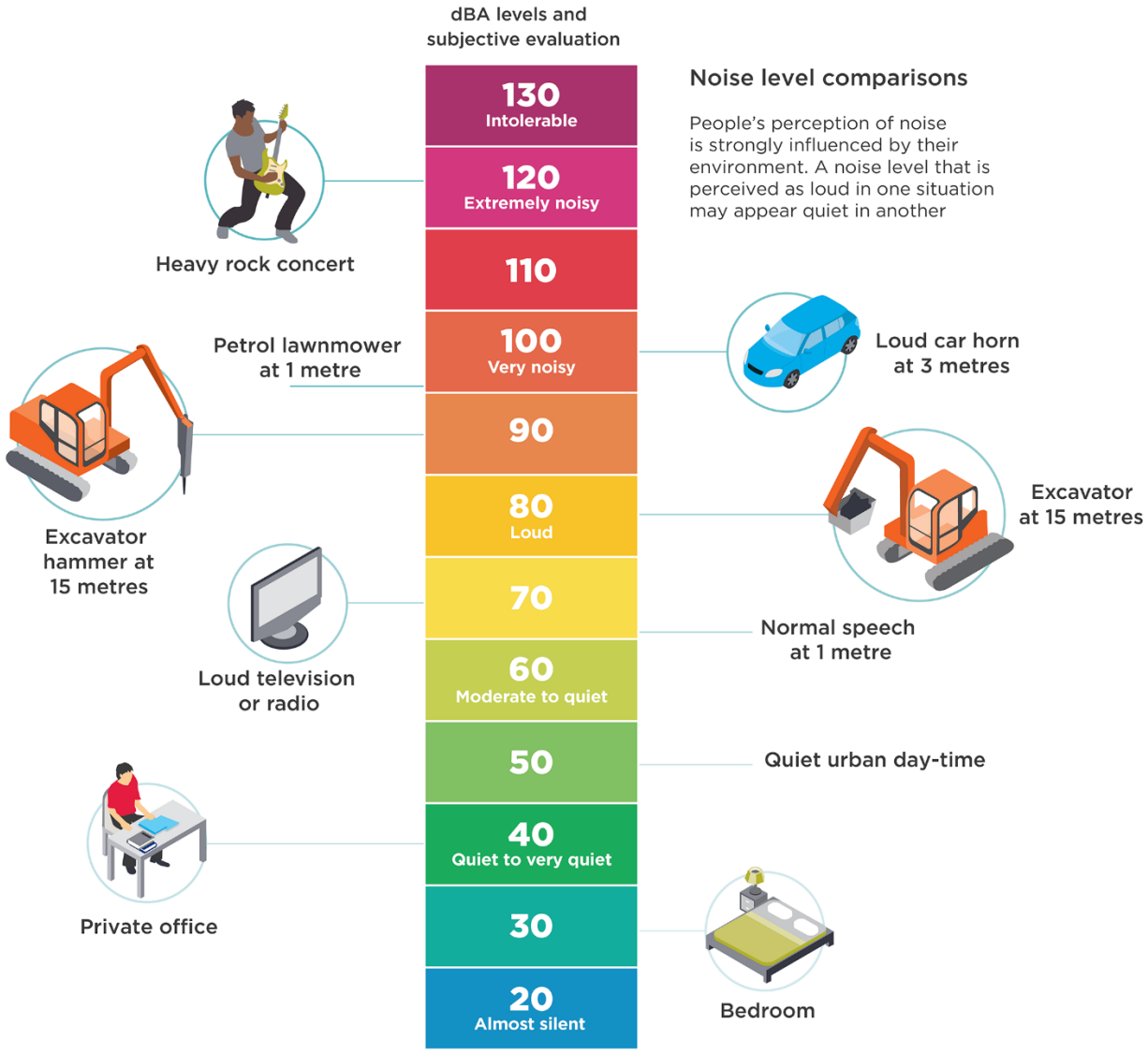


Figure 10-1 Noise level comparison

10.2 Legislative and policy framework

Construction noise and vibration from State significant infrastructure projects is regulated by the Department of Planning, Industry and Environment through project approval requirements under the *Environmental Planning and Assessment Act 1979* and by the NSW Environment Protection Authority through environment protection licences issued under the *Protection of the Environment Operations Act 1997*. In addition, the Protection of the Environment Operations (Noise Control) Regulation 2017 includes controls on noise from motor vehicles and marine vessels, while the *Heavy Vehicle (Vehicle Standards) National Regulation (NSW)* includes controls on noise from heavy vehicles.

The *Interim Construction Noise Guideline* (DECC, 2009a) provides guidance on assessing and managing construction noise, and to assist setting conditions in approvals and licences. The guideline covers noise and ground-borne noise impacts (including construction traffic within the construction footprint) and identifies noise management levels that guide the need to apply reasonable and feasible mitigation and management measures to minimise noise impacts. For construction vibration, *Assessing Vibration: a technical guideline* (DECC, 2006) provides guidance on managing the risk of vibration impacts on human comfort.

The *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a) integrates and adapts, for Transport for NSW projects, the direction and guidance provided by several other policies, guidelines and standards, including the *Interim Construction Noise Guideline* (DECC, 2009a), *Assessing Vibration: a technical guideline* (DECC, 2006), and Australian criteria for blasting (AS 2187.2 2006 (Standards Australia, 2006)). The *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a) is the key document providing guidance for the assessment and mitigation of construction noise and vibration on this project. It is supported by the *NSW Road Noise Policy* (DECCW, 2011), which addresses construction road traffic noise impacts (on public roads) and sleep disturbance, and the *Noise Criteria Guideline* (Roads and Maritime Services, 2015f), which provides an assessment process for construction traffic noise impacts.

10.3 Assessment methodology

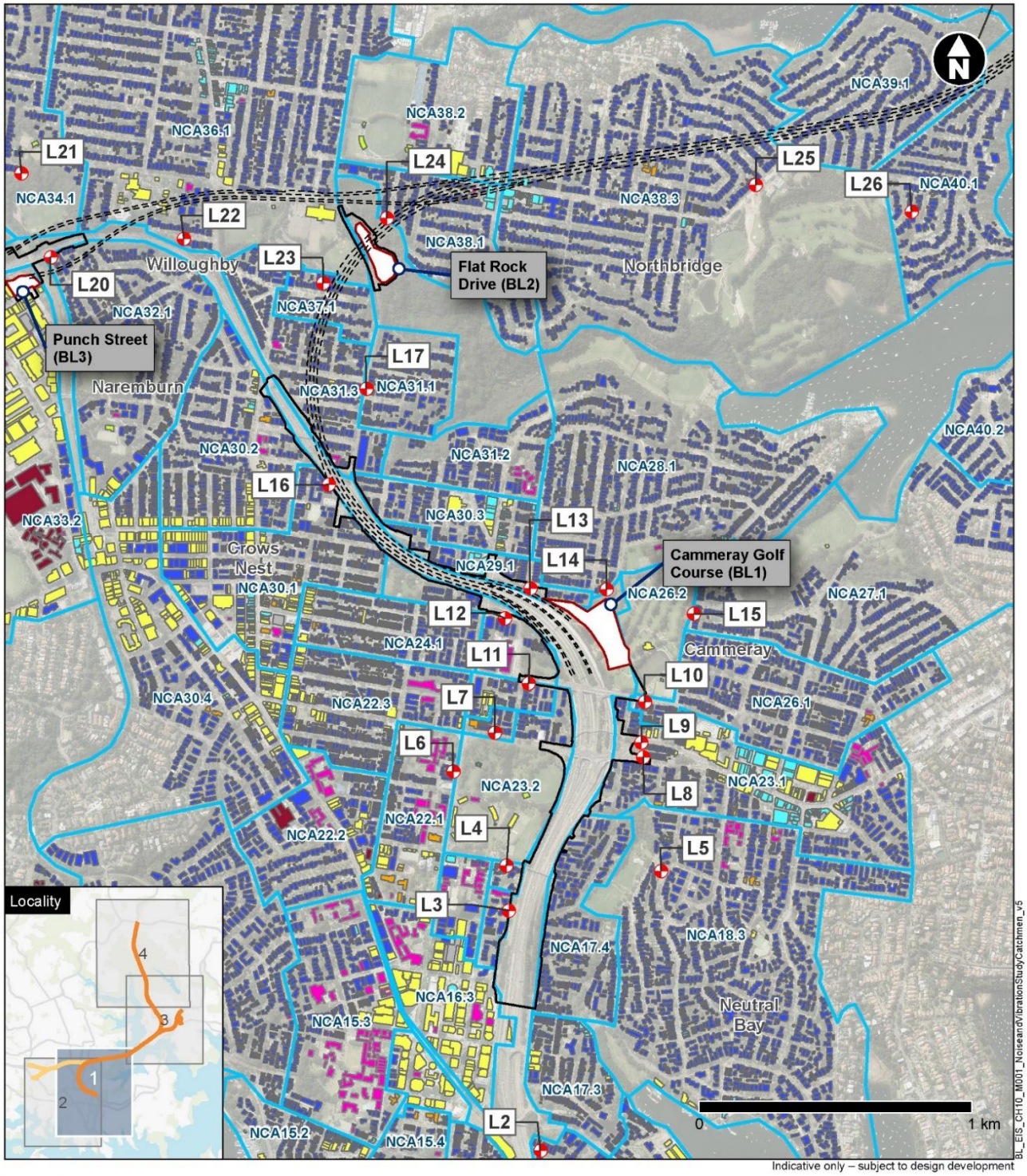
10.3.1 Noise sensitive receivers and noise catchment areas

The location and type of noise sensitive receivers near temporary construction support sites, construction sites and haulage routes were identified using a combination of aerial photography and visual inspections. These noise sensitive receivers were then grouped into noise catchment areas (NCAs) along the project alignment, being areas of similar acoustic environments. The noise catchment areas are shown in Figure 10-2 to Figure 10-5.

10.3.2 Background noise monitoring

Noise monitoring was carried out at 47 locations between June 2017 and April 2019 to establish existing background and existing traffic noise levels within the noise catchment areas. The noise monitoring locations are shown in Figure 10-2 to Figure 10-5. Noise monitoring carried out from 2017 is considered representative of the 2020 noise environment and is applicable for the purposes of the construction and operational noise assessment.

Further details of the noise monitoring are provided in Section 2 and Annexure C of Appendix G (Technical working paper: Noise and vibration).



Legend

- Construction footprint
- Construction support site boundary
- Tunnel section

Noise assessment features

- Noise monitoring location
- Noise catchment area (NCA)

Receiver type

- Commercial/industrial
- Mixed use
- Non receiver building
- Educational/childcare
- Medical
- Place of worship
- Recreational - active
- Recreational - passive
- Residential

Figure 10-2 Noise catchment areas and monitoring locations (map 1)

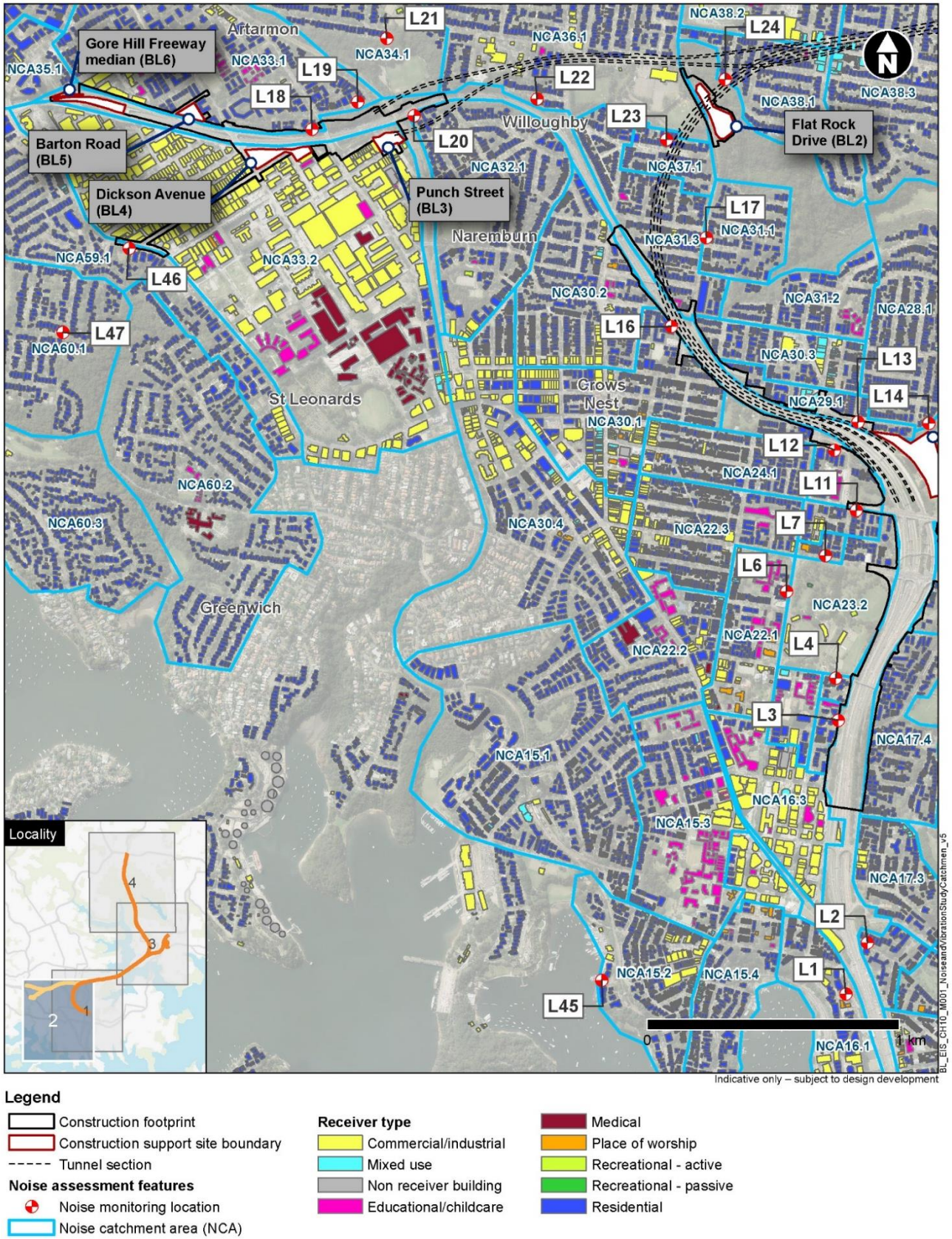


Figure 10-3 Noise catchment areas and monitoring locations (map 2)

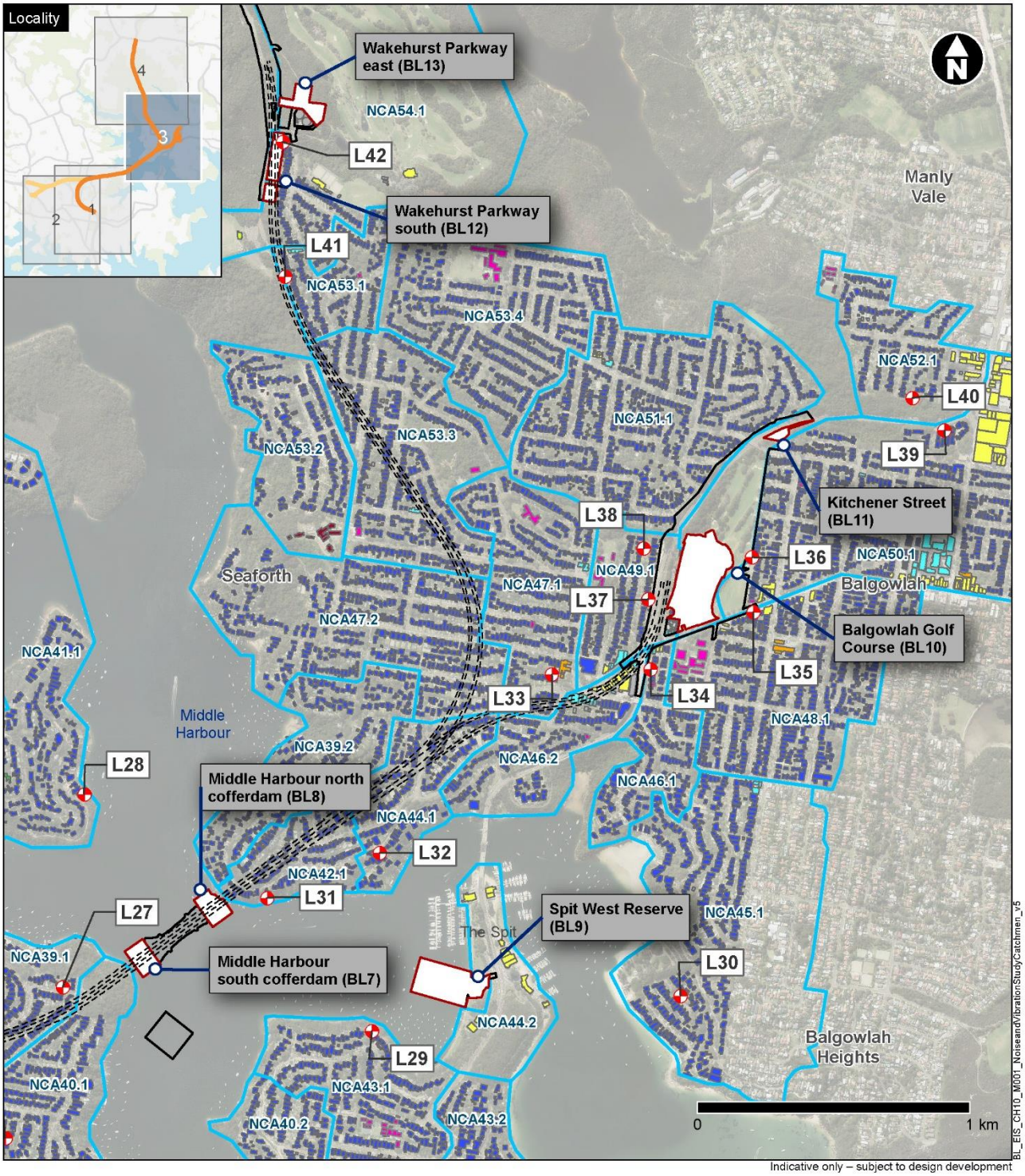


Figure 10-4 Noise catchment areas and monitoring locations (map 3)

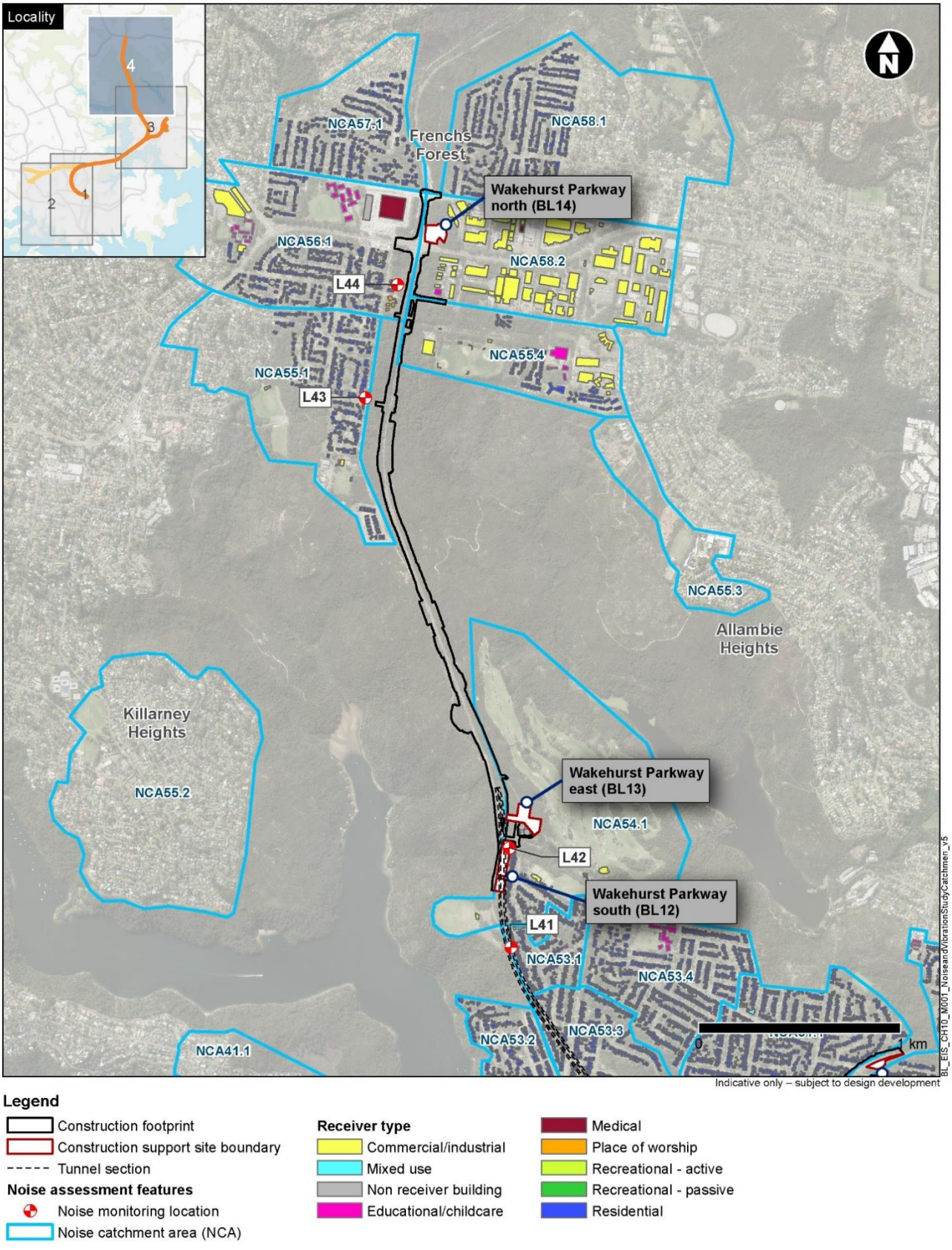


Figure 10-5 Noise catchment areas and monitoring locations (map 4)

10.3.3 Construction noise and vibration assessment

The construction noise and vibration assessment for the project considered the potential impacts associated with airborne noise, ground-borne noise and vibration, and included the following key steps:

- Identification of potentially affected noise and vibration sensitive receivers for each construction area and temporary construction support site
- Determination of noise and vibration objectives for residential and non-residential receivers
- Identification of indicative construction stages/scenarios including locations, working hours and the plant and equipment to be used
- Identification of other nearby construction projects that might also contribute noise levels in areas affected by the project if construction activities occur at the same time (cumulative noise impacts)
- Prediction of construction airborne noise, ground-borne noise, construction traffic noise and vibration impacts for the identified construction stages/scenarios
- Identification of environmental management measures to be implemented to avoid, minimise and mitigate noise and vibration impacts during construction.

For the prediction of airborne noise impacts from temporary construction support sites, consideration was given to realistic worst case construction activities as required by the *Interim Construction Noise Guideline* (DECC, 2009a). The realistic worst case scenario is conservative because it assumes all equipment expected to be used at a given site would be operating simultaneously, at a worst case intensity, and with a worst case orientation during a 15 minute period and at the closest possible location to an affected sensitive receiver. While the realistic worst case scenario might occur, noise levels at any one location would typically vary throughout construction as different plant and equipment is used and the activities move around the works area. Therefore, actual construction noise levels most of the time are likely to be lower than modelled within Appendix G (Technical working paper: Noise and vibration) and presented in this chapter.

For the prediction of airborne noise impacts from surface road works outside temporary construction support sites (eg surface road works in the Warringah Freeway, Gore Hill Freeway Connection surface road works, Balgowlah surface road works and surface road works associated with the connection and realignment and upgrade of the Wakehurst Parkway), consideration was given to both realistic typical and worst case construction noise impact scenarios. The realistic worst case scenarios are used to predict worst case noise impacts in terms of magnitude and distribution that might be expected from a given activity. As stated above, however, this might only occur part of the time and potentially for short durations. The typical impact scenarios were developed to represent the impacts from noise intensive construction activities when the loudest plant and equipment items (eg rock hammers or road saws) are not being used. These scenarios are likely to be more reflective of typical noise impacts that would more commonly occur during a particular construction activity. Figure 10-6 provides an example of how both typical and worst case noise scenarios could occur in a given period of time. The example provided is for utility modification works occurring at night.

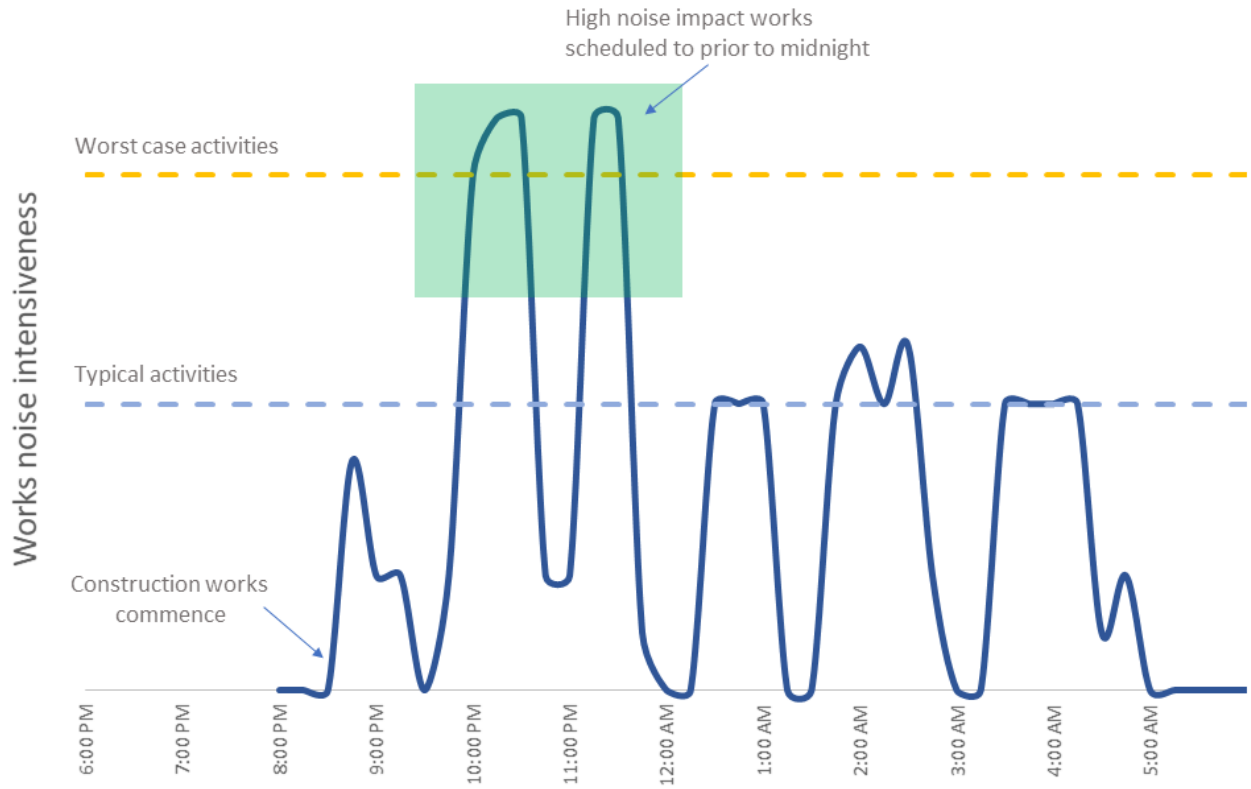


Figure 10-6 Example of noise intensiveness for typical and worst case construction noise impact scenarios

10.4 Assessment objectives and criteria

The construction noise and vibration assessment objectives and criteria applied to the project are summarised in the following sections and consider recommendations provided in the guidelines, policies and standards discussed in Section 10.2.

10.4.1 Airborne noise

Residential receivers

The noise management levels for residential receivers set in accordance with the *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a) are provided in Table 10-3. Construction noise impacts on residential receivers are assessed using these noise management levels, set with reference to time of day and background noise (Rating Background Level (RBL)). The RBL for each location was determined based on the quietest period of the day, evening or night assessment period in accordance with the *Noise Policy for Industry* (NSW EPA, 2017a). Where noise levels are above the noise management level, reasonable and feasible noise mitigation needs to be considered. Reasonable and feasible noise mitigation includes site specific measures for noise management, mitigation and treatment measures such as construction noise barriers, acoustic sheds, acoustic enclosures, and restricted construction hours and activities.

There is also a highly noise affected level for construction, above which further mitigation needs to be considered, such as additional consultation and notification, additional respite periods, and alternative accommodation.

Table 10-3 Noise management levels at residential receivers

Time of day	Applicable noise management level ($L_{Aeq\ (15\ minute)}$)[1]
Recommended standard construction hours: Monday to Friday 7am to 6pm Saturday 8am to 1pm No work on Sundays or public holidays	Noise affected RBL + 10 dB(A)[2]
	Highly noise affected 75 dB(A)
Outside recommended standard construction hours	Noise affected RBL + 5 dB (A)

Note 1: $L_{Aeq(15\ minute)}$ is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a period of 15 minutes

Note 2: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities.

As discussed in Chapter 6 (Construction works), recent planning approval conditions for State significant infrastructure projects have included an extension to standard construction hours on Saturdays, allowing certain activities to be carried out until 6pm. This approval condition has been provided on other major infrastructure projects such as Sydney Gateway, M6 Motorway (Stage 1) and WestConnex M4-M5 Link. Should the project construction contractor elect to use this additional allowance on Saturdays, site specific construction noise and vibration impact statements prepared for the project (refer to Section 10.7) would assess any associated noise impacts, and appropriate noise mitigation measures would be adopted accordingly.

Non-residential receivers

The noise management levels for non-residential receivers set in accordance with the *Interim Construction Noise Guideline* (DECC, 2009a) are provided in Table 10-4. These levels apply only during hours when the non-residential premises are being used.

The difference between an internal noise level and the external noise level is assumed to be 10 dB(A), which provides a conservative assumption that windows are open for ventilation. Buildings where windows are fixed or cannot otherwise be opened may achieve a greater noise level performance.

Table 10-4 Noise management levels at other noise sensitive land uses

Land use	Where objective applies	Noise management level $L_{Aeq\ (15\ minute)}$[1]
Classrooms at schools, and other educational institutions	Internal noise level	45 dB(A)[2]
Hospital wards and operating theatres	Internal noise level	45 dB(A)
Places of worship	Internal noise level	45 dB(A)
Childcare centre	External noise level	50 dB(A)
Active recreation areas (eg sports fields/activities which generate their own noise and are generally less sensitive to external noise)	External noise level	65 dB(A)
Passive recreation areas (eg area used for low intensity and low noise producing activities which could be impacted by external noise such as reading or meditation)	External noise level	60 dB(A)

Land use	Where objective applies	Noise management level $L_{Aeq\ (15\ minute)}$[1]
Community centres	Depends on the intended use of the centre	Refer to the 'maximum' internal levels in AS2107 for specific uses
Commercial premises (including offices and retail outlets)	External noise level	70 dB(A)
Industrial premises	External noise level	75 dB(A)
Special noise and/or vibration sensitive (eg laboratories, recording studios)	Depends on the intended use	Refer to the 'maximum' internal levels in AS2107 for specific uses.

Note 1: $L_{Aeq(15\ minute)}$ is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a period of 15 minutes
Note 2: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities.

Sleep disturbance criterion

A night time sleep disturbance 'screening criterion' noise goal of RBL + 15 dB(A) is used to identify the receivers where there is potential for sleep disturbance.

Where the sleep disturbance screening criterion is exceeded, further assessment is conducted to determine whether the 'awakening reaction' level of L_{Amax} 65 dB(A) would be exceeded and the likely number of these events. The awakening reaction level is the level above which sleep disturbance is considered likely.

Definition of 'feasible and reasonable'

As defined by the *Noise Policy for Industry* (NSW EPA, 2017a) a feasible mitigation measure is one that can be engineered and is practical to build and/or implement given project constraints such as safety, maintenance and reliability requirements and may also include options such as amending operational practices. Selecting reasonable measures from those that are feasible involves judging whether the overall noise benefits outweigh the overall adverse social, economic and environmental effects, including the cost of the mitigation measure. Noise impacts, noise mitigation benefits, cost effectiveness of noise mitigation and community views are considered when making this judgement.

10.4.2 Construction traffic noise

For locations within the construction footprint, where noise levels would increase by more than 2 dB(A) due to maximum construction traffic volumes or a temporary detour due to a road closure, further assessment was completed as per the *Noise Criteria Guideline* (Roads and Maritime, 2015f).

10.4.3 Ground-borne noise

Ground-borne noise is generated by vibration transmitted through the ground into a structure and is more likely to be noticeable during the evening and night periods, when masking by airborne noise is less likely. Ground-borne noise objectives set in accordance with the *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a) are provided in Table 10-5.

Table 10-5 Ground-borne noise objectives

Receiver type	Ground borne noise objectives ($L_{Aeq(15\ minute)}$)[1]
Residential (day – 7am to 6pm)	Not applicable
Residential (evening – 6pm to 10pm)	40 dB(A)[2] internal
Residential (night – 10pm to 7am)	35 dB(A) internal
Hospital wards and operating theatres	45 dB(A)
Childcare centres	40 dB(A)
Classrooms at schools and other educational institutions	45 dB(A)
Places of worship	45 dB(A)
Community centre	45 dB(A)
Commercial premises (including offices)	50 dB(A)
Commercial premises (including retail outlets)	55 dB(A)
Other noise-sensitive receivers	Refer to the 'maximum' internal levels in AS/NZS 2107 for specific uses

Note 1: $L_{Aeq(15\ minute)}$ is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a period of 15 minutes
Note 2: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities.

10.4.4 Vibration

For assessment purposes, a conservative vibration damage screening level for structurally sound structures of 7.5 mm/s (peak particle velocity) has been adopted to identify where further investigation is required. For structures where the screening level is predicted to be exceeded, a more detailed analysis of the building structure, vibration source, dominant frequencies and dynamic characteristics of the structure would be done during further construction planning to determine the applicable safe vibration level and approach to construction near the structure.

A conservative vibration damage screening level of 2.5 mm/s has also been adopted for heritage items. Where vibration at any heritage structure is predicted to exceed the screening level, the structure would be investigated during further construction planning to determine the susceptibility of the structure to vibration-induced damage. A site-specific construction approach would be developed to minimise the potential for damage and implemented during vibration intensive activities in the vicinity as required.

The recommended minimum working distances for construction plant in Table 10-6 consider both human comfort and impacts to structures and are referenced from the *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a), British Standard *BS 7385 Part 2–1993 Evaluation and measurement for vibration in buildings Part 2* (British Standards Institution, 1993), German Standard *DIN 4150: Part 3–1999 Structural vibration – Effects of vibration on structures* (German Institute for Standardisation, 1999) and the United States Department of Transportation *Federal Transit Administration Noise and Vibration manual* (FTA, 2018).

Where specified construction plant and equipment is used at greater distances from receiver locations than the specified safe working distance, there is negligible risk of structural damage or impacts to human comfort outside of the construction site. Where vibration intensive activities are required within the recommended minimum working distances, more detailed consideration of potential vibration impacts and the construction approach would occur during further design development and construction planning.

Table 10-6 Recommended minimum working distances for vibration intensive plant and equipment

Plant and equipment	Rating description	Minimum working distance in metres		
		Potential for cosmetic damage impacts		Potential for human response impacts[3] (outside construction site)
		Structurally sound[1] (eg residential and light commercial)	Structurally unsound[2] (eg unsound heritage structures)	
Vibratory roller	< 50kN (typically 1-2t)	5	11	15-20
	< 100kN (typically 2-4t)	6	13	20
	< 200kN (typically 4-6t)	12	15	40
	< 300kN (typically 7-13t)	15	31	100
	> 300kN (typically 13-18t)	20	40	100
	> 300kN (typically >18t)	25	50	100
Compactor	32t (non-vibratory)	15	30	40
Bulldozer	70t bulldozer with ripper	2	10	20
Excavators	< 30t (travelling/digging)	10	15	15
Small hydraulic hammer	300kg on 5-12t excavator	2	5	7
Medium hydraulic hammer	900kg on 12-18t excavator	7	15	23
Large hydraulic hammer	1600kg on 18-34t excavator	22	30	73
Vibratory pile driver	Sheet piles	2-20	5-30	20-50
Impact piling hammer	Typical driven pile[4]	20	30	110
	338kJ per stroke (23t hammer with 1.5m stroke)	70	140	330
Pile boring	≤800mm	2	5	N/A
Jackhammer	Hand held	1	3	5
Roadheader	Tunnelling	5	5	10
Rock drilling	Tunnelling	5	5	10
Hydraulic hammer	Tunnelling (35t excavator benching with large rock–hammer)	10	20	50
Truck traffic	On uneven construction haul roads	5	10	20

Plant and equipment	Rating description	Minimum working distance in metres		
		Potential for cosmetic damage impacts		Potential for human response impacts[3] (outside construction site)
		Structurally sound[1] (eg residential and light commercial)	Structurally unsound[2] (eg unsound heritage structures)	
Blasting operations	Over irregular surfaces	To be determined during test blasts to establish appropriate propagation characteristics for the site and increase the accuracy of blasting predictions		

Note 1: Criteria referenced from British Standard BS 7385 Part 2–1993 Evaluation and measurement for vibration in buildings Part 2 (British Standards Institution, 1993)
Note 2: Criteria referenced from German Standard DIN 4150 Structural Damage – Safe Limits for Short–term Building Vibration (including heritage items) (German Institute for Standardisation, 1999)
Note 3: Criteria referenced from Assessing Vibration: a technical guideline (DECC, 2006)
Note 4: Referenced to a 'typical' pile driver (impact) taken from US Department of Transportation Federal Transit Administration Noise and Vibration manual (FTA, 2018).

10.4.5 Blasting noise and vibration management levels

Underground blasting may be used for discrete elements of subsurface excavation. Controlled blasting has also been identified as an alternative to rock hammering in deep cut areas along the Wakehurst Parkway.

Criteria from AS 2187.2-2006 *Explosives - Storage and use - Part 2 Use of explosives* (Standards Australia, 2006) have been adopted for the project, including recommended limits for structural damage and human comfort, blasting operation hours, and underwater pressure. This is considered to be the appropriate blasting criteria for linear civil construction projects and has been included as a condition of approval on all stages of the WestConnex program of works. The limits for structural damage and human comfort presented in AS 2187.2-2006 are similar to those presented in the *Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration* (ANZEC, 1990) for long term projects, but AS 2187.2-2006 provides further guidance for consideration of the duration of blasting within a project where only a small amount of blasting is required or blasting may occur for less than one year.

10.5 Existing noise environment

The existing acoustic environment of the construction footprint and surrounds varies. The areas surrounding the construction footprint are mostly residential, except for clusters of commercial and industrial receivers around Artarmon and Frenchs Forest.

The acoustic environment in these residential areas is mostly influenced by noise from major roads. Traffic volumes on these major roads, and resulting noise levels, are generally highest in the morning between 7am and 9am, and lowest between 2am and 3am. Traffic noise on major roads during periods of high traffic volumes is generally continuous, rather than intermittent.

Noise generated by commercial and industrial areas influences the acoustic environment and contributes to higher ambient noise levels in some locations, masking road traffic noise.

The results of the noise monitoring for background and ambient traffic noise levels for the project are provided in Table 10-7. The location of noise monitoring surveys and noise catchment areas are shown on Figure 10-2 to Figure 10-5. The background noise levels are typical of urbanised environments with daytime background noise levels ranging from 36 dB(A)(L_{A90}) to 73 dB(A)(L_{A90}), and in most cases several decibels quieter during the evening period. Night time background noise levels are variable, from around 27 dB(A)(L_{A90}) to 55 dB(A)(L_{A90}) depending on the proximity of

receiver locations to 24 hour noise sources such as major transport corridors and industrial developments.

A comparison of noise levels to various activities is show in Figure 10-1 to assist in the interpretation of the noise levels presented in this chapter.

Table 10-7 Background and ambient traffic noise monitoring

Suburb	NCA	Noise monitoring location	Rating background level (dB(A))[1](LA90)[2] Day (7am to 6pm)	Rating background level (dB(A))[1](LA90)[2] Evening (6pm to 10pm)	Rating background level (dB(A))[1](LA90)[2] Night (10pm to 7am)	Existing road noise level (dB(A)) Day (7am to 10pm) (LAeq(15 hour))[3]	Existing road noise level (dB(A)) Night (10pm to 7am) (LAeq(9 hour))[4]
Milsons Point	16.1	Location L1	60	60	50	–	–
McMahons Point	15.2	Location L45	42	41	38	–	–
Kirribilli	17.2	Location L2	55	54	45	62	58
North Sydney	19.1	Location L3	73	71	55	79	74
	20.1	Location L4	52	52	45	60	54
	22.1	Location L6	52	47	36	67	61
Neutral Bay	18.3	Location L5	54	52	43	–	–
	23.1	Location L8	61	54	44	71	68
	23.1	Location L9	58	54	44	74	70
Cremorne	27.1	Location L15	49	48	39	–	–
Cammeray	26.1	Location L10	58	54	41	71	65
	21.1	Location L11	56	52	37	70	64
	25.1	Location L12	58	55	43	64	59
	29.1	Location L13	64	63	47	70	66
	28.1	Location L14	47	45	37	–	–
Crows Nest	21.1	Location L7	53	49	41	70	66
	30.1	Location L16	58	56	38	65	60

Suburb	NCA	Noise monitoring location	Rating background level (dB(A))[1](L_{A90})[2] Day (7am to 6pm)	Rating background level (dB(A))[1](L_{A90})[2] Evening (6pm to 10pm)	Rating background level (dB(A))[1](L_{A90})[2] Night (10pm to 7am)	Existing road noise level (dB(A)) Day (7am to 10pm) ($L_{Aeq(15\ hour)}$)[3]	Existing road noise level (dB(A)) Night (10pm to 7am) ($L_{Aeq(9\ hour)}$)[4]
Naremburn	31.1	Location L17	56	49	37	73	67
	32.1	Location L20	59	55	40	65	61
	37.1	Location L23	45	44	34	–	–
Artarmon	33.1	Location L18	67	63	46	74	69
	33.1	Location L19	55	53	40	61	57
	34.1	Location L21	44	44	37	–	–
Greenwich	59.1	Location L46	60	55	40	72	66
Lane Cove	60.1	Location L47	39	37	31	–	–
Willoughby	36.1	Location L22	50	48	38	–	–
Northbridge	38.1	Location L24	52	48	37	–	–
	38.3	Location L25	43	40	36	–	–
	40.1	Location L26	37	37	33	–	–
	39.1	Location L27	37	34	28	–	–
Castlecrag	41.1	Location L28	36	32	27	–	–
Mosman	43.1	Location L29	45	43	36	–	–
Clontarf	45.1	Location L30	40	38	33	–	–

Suburb	NCA	Noise monitoring location	Rating background level (dB(A))[1](L_{A90})[2] Day (7am to 6pm)	Rating background level (dB(A))[1](L_{A90})[2] Evening (6pm to 10pm)	Rating background level (dB(A))[1](L_{A90})[2] Night (10pm to 7am)	Existing road noise level (dB(A)) Day (7am to 10pm) ($L_{Aeq(15\ hour)}$)[3]	Existing road noise level (dB(A)) Night (10pm to 7am) ($L_{Aeq(9\ hour)}$)[4]
Seaforth	42.1	Location L31	42	38	36	–	–
	44.1	Location L32	50	49	40	–	–
	47.1	Location L33	43	39	30	–	–
	49.1	Location L37	45	42	31	56	51
	49.1	Location L38	43	40	33	54	49
	53.1	Location L41	48	39	28	68	61
	54.1	Location L42	45	39	29	55	50
Balgowlah	46.1	Location L34	58	54	37	67	64
	48.1	Location L35	55	50	32	73	71
	50.1	Location L36	47	45	35	55	52
	50.1	Location L39	47	45	30	55	51
Manly Vale	52.1	Location L40	49	45	36	61	56
Frenchs Forest	55.1	Location L43[5]	46	40	30	58	50
	56.1	Location L44[5]	53	48	34	–	–

Note 1: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 2: L_{A90} is the level of noise exceeded for 90 per cent of the time. The bottom 10 per cent of the sample is the L_{A90} noise level expressed in units of dB(A)
Note 3: $L_{Aeq(15\ hour)}$ is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a 15 hour period (7am to 10pm).
Note 4: $L_{Aeq(9\ hour)}$ is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a 9 hour period (10pm to 7am)
Note 5: Adopted from the Northern Beaches Hospital, Connectivity and Network Enhancements, Stage 2 project EIS (Roads and Maritime Services, 2015a). See Appendix G (Technical working paper: Noise and vibration) for further detail.

10.6 Assessment of potential impacts

10.6.1 Overview

This section provides an assessment of the potential noise and vibration impacts associated with the construction work areas and temporary construction support sites for the project.

For each area or site the key outcomes of the assessment for construction airborne noise, ground-borne noise (where relevant), road traffic noise and construction vibration are presented.

10.6.2 Mainline and ramp tunnelling ground-borne noise, vibration and blasting impacts

Ground-borne noise impacts

Ground-borne L_{Aeq} noise levels have been calculated for receiver buildings located above the mainline tunnels, and above tunnel on and off ramps to the mainline tunnels.

The number of buildings potentially exposed to ground-borne noise above the noise management levels during roadheader tunnelling and other subsurface activities are provided in Table 10-8. The number of buildings reported are based on the peak noise levels that a receiver building would be exposed to when the roadheader is at its closest point to the property.

The results show the following:

- Up to 107 residential receivers could experience ground-borne noise levels between 35 and 40 dB(A) from roadheader tunnelling, which would exceed the night time ground-borne noise management levels, but not the evening ground-borne noise management levels. The majority of these residential receivers are within Seaforth. However, exceedances of this magnitude are very small and unlikely to result in significant amenity impacts to affected sensitive receivers
- Other sensitive receiver buildings and commercial and industrial buildings are not predicted to experience ground-borne noise levels above their relevant ground-borne noise management level.

Ground-borne noise from excavation with roadheaders along the majority of the tunnel alignment would be audible only while the roadheader is directly beneath a particular sensitive receiver. Depending on the location of the receiver and the distance to the tunnel excavation location, ground-borne noise could be audible for a number of weeks as the tunnelling approaches and then moves away. Variation in ground-borne noise with the progression of works is illustrated in Figure 10-7. It is noted, however, that affected sensitive receivers might experience ground-borne noise on multiple occasions associated with excavation of each tunnel tube, and other subsurface excavations such as ventilation shafts, cross passages and niches for tunnel operational infrastructure.

Rock hammers are proposed to be used for clearing the bench of the tunnel and would follow behind the roadheader. Rock hammers might also be required for other subsurface excavations, such as niches and trenches for tunnel operational infrastructure. Table 10-8 shows there are more receivers that could be impacted during rock hammering than roadheader tunnelling. However, rock hammering work has more scope to be programmed outside evening and night time periods where feasible and reasonable to avoid ground-borne noise impacts during those more sensitive periods. Where rock hammers are required to carry out subsurface excavations that leaves exposed rock that needs ground support, there is potential that some rock hammering might be required outside standard construction hours. Such occurrences are not anticipated to the required frequently.

Where rock hammers are required to be used for subsurface excavations outside standard construction hours, a large number of residential receivers could experience ground-borne noise levels that exceed either the night time ground-borne noise management level of 35 dB(A) or the evening ground-borne noise management level of 40 dB(A) as provided in Table 10-8.

The predictions for the use of rock hammers in the tunnel show the following:

- Up to 531 residential receivers could be exposed to ground-borne noise levels above 45 dB(A). The potentially affected residential receivers are mainly within Seaforth and in particular NCA 53.3 (north of Frenchs Forest Road)
- Eight other sensitive receiver buildings could be ground-borne noise affected (ie above ground-borne noise management level)
- 16 commercial buildings could be ground-borne noise affected during rock hammer tunnelling activities.

Table 10-8 Sensitive receiver buildings potentially affected by ground-borne noise from roadheader rock hammer tunnelling

Suburb	NCA	Roadheader tunnelling					Rock hammer tunnelling				
		Residential receivers			Other sensitive receivers	Commercial /industrial receivers	Residential receivers			Other sensitive receivers	Commercial /industrial receivers
		> 35 to ≤ 40 dB(A)[1]	> 40 to ≤ 45 dB(A)	>45 dB(A)			> 35 to ≤ 40 dB(A)	> 40 to ≤ 45 dB(A)	>45 dB(A)		
North Sydney	23.2	–	–	–	–	–	–	1	–	–	–
Neutral Bay	23.1	–	–	–	–	–	–	–	–	–	–
Crows Nest	24.1	–	–	–	–	–	2	–	–	–	–
	30.1	–	–	–	–	–	28	28	18	1	–
Cammeray	25.1	5	–	–	–	–	11	13	29	–	–
	28.1	–	–	–	–	–	3	5	1	–	–
	29.1	3	–	–	–	–	13	18	32	–	–
	30.3	–	–	–	–	–	15	11	1	1	–
	31.2	–	–	–	–	–	–	–	–	–	–
Cremorne	26.1	–	–	–	–	–	–	–	–	–	–
Naremburn	30.2	–	–	–	–	–	2	–	–	–	–
	31.1	–	–	–	–	–	–	–	–	–	–
	31.3	–	–	–	–	–	111	13	2	1	–
	32.1	15	–	–	–	–	11	8	28	–	–
	37.1	–	–	–	–	–	32	19	–	–	–

Suburb	NCA	Roadheader tunnelling					Rock hammer tunnelling				
		Residential receivers			Other sensitive receivers	Commercial /industrial receivers	Residential receivers			Other sensitive receivers	Commercial /industrial receivers
		> 35 to ≤ 40 dB(A)[1]	> 40 to ≤ 45 dB(A)	>45 dB(A)			> 35 to ≤ 40 dB(A)	> 40 to ≤ 45 dB(A)	>45 dB(A)		
Artarmon	33.1	–	–	–	–	–	2	1	–	–	–
	33.2	–	–	–	–	–	–	–	–	–	–
	34.1	–	–	–	–	–	-	–	–	–	–
Willoughby	36.1	1	–	–	–	–	40	29	47	2	1
Northbridge	38.1	–	–	–	–	–	0	4	–	–	–
	38.2	–	–	–	–	–	–	–	–	–	–
	38.3	–	–	–	–	–	25	–	–	–	–
	39.1	–	–	–	–	–	60	6	–	–	–
	40.1	–	–	–	–	–	15	11	–	–	–
Seaforth	39.2	–	–	–	–	–	17	4	1	–	–
	42.1	–	–	–	–	–	24	59	7	–	–
	44.1	–	–	–	–	–	14	54	40	–	–
	46.2	–	–	–	–	–	19	9	32	–	13
	47.1	–	–	–	–	–	21	3	21	2	–
	47.2	–	–	–	–	–	61	37	6	–	–
	49.1	3	-	–	–	–	16	15	27	-	–
	53.1	26	–	–	–	–	2	9	44	–	–
	53.2	–	–	–	–	–	8	5	5	–	–

Suburb	NCA	Roadheader tunnelling					Rock hammer tunnelling				
		Residential receivers			Other sensitive receivers	Commercial /industrial receivers	Residential receivers			Other sensitive receivers	Commercial /industrial receivers
		> 35 to ≤ 40 dB(A)[1]	> 40 to ≤ 45 dB(A)	>45 dB(A)			> 35 to ≤ 40 dB(A)	> 40 to ≤ 45 dB(A)	>45 dB(A)		
	53.3	42	–	–	–	–	36	44	151	1	–
	54.1	12	–	–	–	–	6	6	33	–	–
Clontarf	46.1	–	–	–	–	-	4	7	6	-	2
Balgowlah	48.1	–	–	–	–	–	–	–	–	–	–
	50.1	–	–	–	–	–	–	–	–	–	–
North Balgowlah	51.1	–	–	–	–	–	–	–	–	–	–
		107	**0**	**0**	**0**	**0**	**638**	**419**	**531**	**8**	**16**

Note 1: dB(A) stands for A-weighted decibel, a unit used to measure noise.

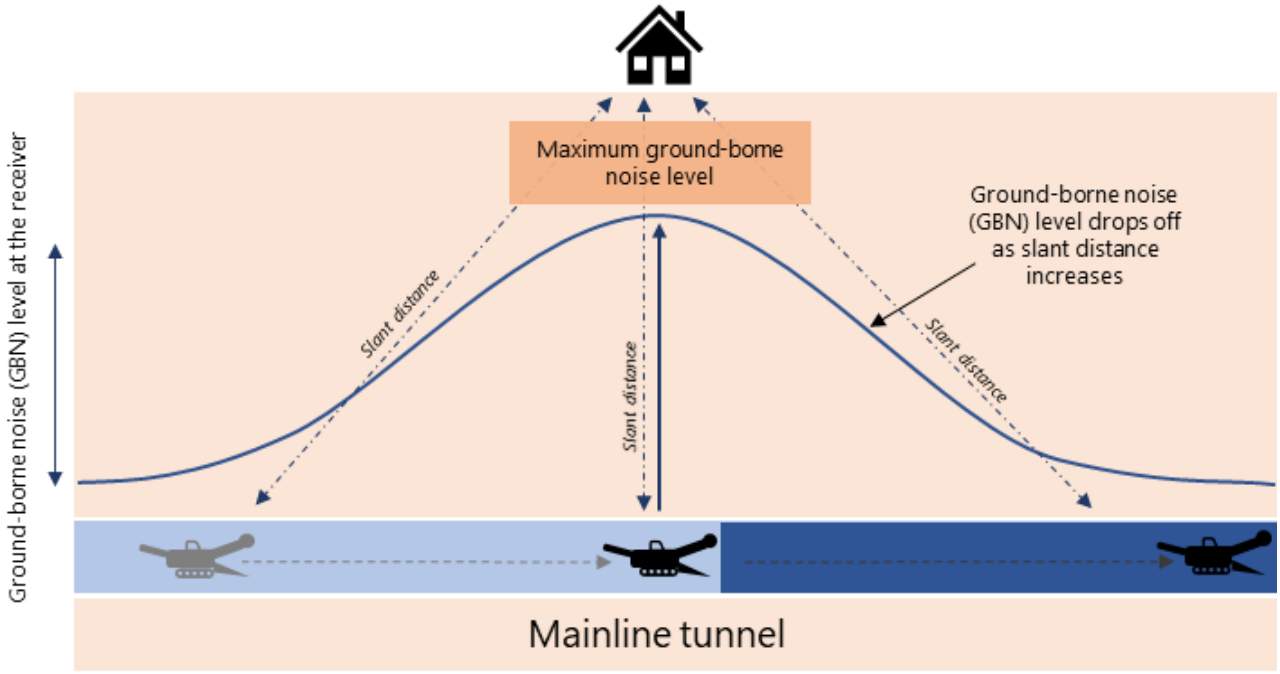


Figure 10-7 Indicative ground-borne noise impacts as tunnelling progresses

Vibration impacts

The number of receiver buildings exceeding the construction vibration screening levels from mainline and ramp tunnelling works is provided in Table 10-9. Vibration impacts from the operation of roadheaders are predicted to be below the vibration limits for human comfort at all receivers. One heritage listed receiver in NCA 33.1 (Artarmon Park potential archaeological deposit (PAD) (45-6-3362)) is located within the minimum working distance for vibration limits for cosmetic damage (unsound structure).

Up to 440 receiver buildings are predicted to be exposed to construction vibration levels above the human comfort criteria (refer to Section 10.4.4) from the operation of rock hammers during tunnelling. For these receivers, standard and additional mitigation measures from the *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a) would be implemented, which might include respite. It is noted that vibration is perceived by humans well below levels that could cause property damage.

Vibration levels during rock hammering at two heritage items located in NCA 26.2 (Cammeray Park (including golf course) and NCA 33.1 (Artarmon Park PAD (45-6-3362)) would potentially exceed the vibration screening criterion for cosmetic damage (unsound structure). Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 14 (Non-Aboriginal heritage) and Chapter 15 (Aboriginal heritage) for details on the heritage items potentially impacted. Identified heritage items would be further investigated to determine the susceptibility of the items to damage from vibration and to identify appropriate mitigation and management measures as required.

Table 10-9 Number of receiver buildings exceeding construction vibration screening criteria from mainline tunnel construction

Suburb	Noise catchment area	Number of receiver buildings affected by mainline tunnelling	
		Roadheaders	Rock hammers
Risk of structural or cosmetic damage			
	All	–	–
Heritage items requiring further investigation			
Cammeray	26.2	–	1
Artarmon	33.1	1	1
Total heritage items requiring further assessment		**1**	**2**
Buildings with screening level above risk of human comfort			
Cammeray	25.1	–	22
	29.1	–	16
Crows Nest	30.1	–	8
Naremburn	32.1	–	27
Artarmon	33.2	–	1
Willoughby	36.1	–	41
Seaforth	42.1	–	6
	44.1	–	31
	46.2		35
	47.1	–	22
	47.2	-	4
	49.1	–	25
	53.1	–	36
	53.2	–	3
	53.3	–	124
	54.1	–	32
Clontarf	46.1	-	7
Total buildings with screening level above risk of human comfort		**0**	**440**

Impacts from blasting

Blasting may be occasionally required during mainline tunnelling or excavation works.

There are two main impacts from blasting:

- Overpressure travelling as an airwave causing a vibration response in structures such as buildings
- Ground vibration transmitted through the ground that surrounds the blast.

Overpressure and ground vibration have the potential to cause discomfort or annoyance to sensitive receivers near the blast area. At high levels, overpressure and ground vibration have the potential to cause structural damage to building structures.

Blasting might, however, avoid the need to carry out vibration intensive activities, such as excavation with rock hammers, for long durations, thereby avoiding the associated amenity issues due to noise and vibrations. Blasting can, therefore, provide a lower impact alternative to traditional excavation methods. Blasting has been carried out safely and in compliance with the relevant criteria on other recent tunnelling projects in Sydney.

Where blasting is proposed during construction planning, potential overpressure and ground vibration impacts from blasting would be managed through site and blast specific assessments. Overpressure and vibration would be predicted during blast design, which would include test blasts to establish and develop site rules and confirm appropriate blast charges and configurations to ensure the objectives and criteria identified in AS 2187.2-2006 *Explosives – Storage and use – Part 2 Use of explosives* (Standards Australia, 2006) are achieved. All blasting and associated activities would be carried out in a manner that would not generate unacceptable noise and vibration impacts or pose a significant risk to nearby structures and sensitive receivers in accordance with the environmental management measures outlined in Section 10.7.

Controlled blasting proposed for Wakehurst Parkway surface road works is discussed in Section 10.6.15.

10.6.3 Warringah Freeway surface road works

Construction works summary

The following works would be required to connect Beaches Link to the Warringah Freeway:

- Construction of Beaches Link cut and cover portal structures and completion of associated ramps and works to tie-in to surface roads
- Upgrade drainage infrastructure at the connection to the Warringah Freeway.

During the works the Cammeray Golf Course construction support site (BL1) would be the main support site. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-10 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels during a typical and realistic worst case construction noise intensive work scenario.

As noted previously, for the prediction of airborne noise impacts from construction sites, consideration was given to realistic worst case construction activities as required by the *Interim Construction Noise Guideline* (DECC, 2009a). While the noise levels for the realistic worst case might occur at a sensitive receivers during the works, noise levels associated with the typical scenario would occur more frequently.

No receivers are predicted to be highly noise affected (ie predicted noise levels greater than 75 dB(A)) during typical works, however up to six residential receiver buildings in NCAs 23.2 and 25.1 (within Cammeray, on the western side of the Warringah Freeway) are predicted to be highly noise affected during worst case works when rock hammers are operating for the portal (northbound) construction works.

During standard working hours:

- No receivers are predicted to exceed the noise management level during typical works
- Up to 18 residential receiver buildings are predicted to experience noise levels of up to 20 dB(A) above the noise management level during worst case works.

During cut and cover portal structures works at night:

- Up to 148 residential receiver buildings are predicted to experience noise levels greater than the noise management level during paving and asphalting road works activities
- Up to 1917 receiver buildings would experience noise levels greater than the noise management level during worst case works.

The most likely source of potential sleep disturbance would be from airbrakes or metal rattling during night construction works. The predicted maximum noise levels show exceedances of the sleep disturbance screening levels as follows:

- During typical works, operations such as airbrakes may exceed the sleep disturbance screening level at up to 65 receiver buildings. Noise levels may exceed the awakening reaction levels at up to eight receiver buildings, with the highest number of exceedances occurring in NCAs 23.2, 24.1 and 25.1 (within Cammeray and Crows Nest, on the western side of the Warringah Freeway)
- During the worst case construction activities, up to 692 receiver buildings may exceed the sleep disturbance screening level. Noise levels may exceed the awakening reaction level at up to 46 receiver buildings.

Construction noise levels at non-residential receivers are not predicted to exceed the noise management levels during typical construction works.

For worst case activities, noise management level exceedances may occur at the following non-residential receivers:

- One childcare receiver with buildings located in NCA 28.1 (KU Cammeray Preschool)
- One educational receiver with buildings located in NCA 25.1 (ANZAC Park Public School)
- One recreational receiver in NCA 25.1 (ANZAC Park).

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-10 Number of residential receiver buildings over the noise management levels during Warringah Freeway surface road works (typical and realistic worst case scenarios)

Stage activity	Scenario	Highly noise affected >75 dB(A)[3] L_{Aeq}[1]		Day (standard construction hours) L_{Aeq}			Day (out of hours) L_{Aeq}				Evening L_{Aeq}				Night L_{Aeq}				Sleep disturbance L_{Amax}[2]	
		Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Portal structures/ramps (northbound)	Typical	0	0	0	0	0	6	0	0	0	2	4	0	0	113	29	6	0	65	8
	Worst case	6	6	16	2	0	180	16	2	0	266	39	6	0	1146	710	54	7	692	46
Portal structures/ramps (southbound)	Typical	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	10	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted “equivalent noise level”. It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

Depending on the detailed construction methodologies and programs, works on Warringah Freeway associated with both the Beaches Link and Gore Hill Freeway Connection project and Western Harbour Tunnel and Warringah Freeway Upgrade might be required at the same time in close proximity. Elevated noise levels from both projects might affect the same sensitive receivers. If this occurs, those receivers might experience amenity impacts over extended durations (construction fatigue). Also, works outside standard construction hours might be scheduled for both projects so that affected receivers do not get appropriate respite. In order to avoid these cumulative impacts, the project would consider and manage construction activities with consideration of amenity of the affected receivers, and would coordinate works outside standard construction hours with the Western Harbour Tunnel and Warringah Freeway Upgrade works where feasible and reasonable to provide affected revivers with appropriate respite Cumulative airborne construction noise impacts would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Construction traffic noise

Changes in traffic movements due to alterations made to existing traffic arrangements to facilitate the construction of the project, and construction vehicle movements associated with the Warringah Freeway surface road works are unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Construction ground-borne noise

Ground-borne noise levels have the potential to be generated by vibration intensive works at the surface road works. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers.

Construction vibration

Vibration intensive activities such as rock hammering could be required as part of the Warringah Freeway surface road works. Table 10-11 shows the number of properties that fall within the minimum working distances for the Warringah Freeway surface road works, two of which are identified heritage items (Cammeray Park (including Golf Course) and Northern Suburbs Ocean Outfall Sewer). The locations of the properties and heritage items are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7. Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 14 (Non-Aboriginal heritage) for details on the heritage items potentially impacted.

Table 10-11 Number of receiver buildings within minimum working distances for vibration intensive work – Warringah Freeway surface road works

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage item[1]	Sound structure	
24.1	–	–	2
23.2	–	1	1
25.1	–	6	19
26.2	2	–	–
29.1	–	–	2

Note 1: Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

10.6.4 Cammeray Golf Course (BL1)

Construction works summary

The Cammeray Golf Course construction support site (BL1) is located within the north-west portion of the Cammeray Golf Course. This site will have been previously utilised by the Western Harbour Tunnel and Warringah Freeway Upgrade project. This site would then be used for the construction and fitout of the project's motorway facilities at the Warringah Freeway and would provide tunnel and construction support for the Beaches Link component of the project. Works associated with the establishment, use and demobilisation of the site would occur over three years. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-12 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels.

Two receivers are predicted to be highly noise affected (ie predicted noise levels greater than 75 dB(A)) during decline piling works. Additionally, during standard construction hours, up to 157 receiver buildings in NCA 29.1 (within Cammeray, on the eastern side of the Warringah Freeway) are predicted to experience noise levels above the noise management level during these works.

Receiver buildings within NCA 28.1 (within Cammeray, on the eastern side of the Warringah Freeway) are expected to be noise affected during standard construction hours throughout most of the construction works at this temporary construction support site. However, construction noise in only expected to be above the daytime noise management level by about 3 dB(A) for the majority of works.

Up to eight receiver buildings in NCA 24.1 (within Crows Nest, on the western side of the Warringah Freeway) and NCAs 26.1 and 28.1 (within Cammeray and Cremorne, on the eastern side of the Warringah Freeway) are predicted to experience noise levels above the noise management level during the night period. This would occur during construction of the cut and cover portals, trough structures, and tunnels, and also during tunnel fitout. Exceedances would be largely due to truck movements as they enter and move along the internal roads within the site to the acoustic shed.

Maximum noise levels at night could exceed the sleep disturbance screening level at up to 69 receiver buildings. However, no receivers are predicted to be exposed to maximum noise levels above the awakening reaction level.

For non-residential receivers:

- Up to six receivers are predicted to experience noise levels above the noise management level during access decline piling works. A childcare receiver located in NCA 28.1 (KU Cammeray Preschool) is predicted to experience noise levels above the noise management level by 12 dB(A) during access decline piling and 6 dB(A) during site rehabilitation
- One educational sensitive receiver in NCA 25.1 (ANZAC Park Public School) is up to 2 dB(A) above the noise management level during access decline piling
- Three recreational receivers including the Cammeray Golf Course, Cammeray Playing Field and the Green Park Tennis Courts are predicted to be noise affected. Only the Cammeray Golf Course is predicted to be noise affected by more than 2 dB(A) above the noise management level during any stage of construction.

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-12 Number of residential receiver buildings over the noise management levels during construction at Cammeray Golf Course construction support site (BL1) (realistic worst case scenario)

Stage activity	Highly noise affected >75 dB(A)[3] (L_{Aeq}[1])		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Site establishment	0	–	7	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Decline, shed and ventilation excavation and construction	2	–	156	8	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Civil works and tunnel construction	0	0	4	0	0	0	0	0	0	0	0	0	0	8	0	0	0	68	0
Civil works and tunnel fitout and permanent facilities construction	0	0	2	0	0	0	0	0	0	0	0	0	0	7	0	0	0	69	0
Civil works and permanent facilities fitout	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	69	0
Site rehabilitation	0	–	10	3	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

There is potential for cumulative increases of construction noise from concurrent use of Cammeray Golf Course construction support site (BL1) and works associated with the final stages of the Western Harbour Tunnel and Warringah Freeway Upgrade project. Sensitive receivers in the vicinity have the potential to experience elevated noise levels over extended durations due to the use of the adjacent areas for temporary construction support sites by both projects. There is also potential for increased disturbance associated with works outside standard construction hours that these temporary construction support sites would support.

Site specific mitigation measures would be developed for Cammeray Golf Course construction support site (BL1) with the aim of ensuring that relevant noise management levels are met, minimising the potential for construction fatigue. Works outside standard construction hours, and the associated use of Cammeray Golf Course construction support site (BL1) and the temporary construction support sites associated with the Western Harbour Tunnel and Warringah Freeway Upgrade project, would be coordinated where feasible and reasonable to provide the affected receivers with appropriate respite.

Cumulative airborne construction noise impacts would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Construction traffic noise

Changes in traffic movements due to alterations made to existing traffic arrangements to facilitate the construction of the project, and construction vehicle movements associated with the Cammeray Golf Course construction support site (BL1) are unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Night time heavy vehicle movements from this site would be limited to four trucks per night. Since the number of truck movements generated by the site is not significant compared to existing heavy vehicle numbers on the Warringah Freeway, the number of maximum noise events that could disturb sleep are not likely to substantially increase. Additionally, all heavy vehicle haulage access to this construction site during tunnel construction and some civil works, would be directly to and from the Warringah Freeway, which would assist in managing potential noise impacts to nearby residential receivers.

Construction ground-borne noise

For the construction of the tunnel access decline and ventilation tunnels between the temporary construction support site at Cammeray Golf Course (BL1) and the mainline tunnel alignment, ground-borne noise levels are predicted to be below the ground-borne noise management level.

Ground-borne noise may also be generated by vibration intensive works within the temporary construction support site. However, throughout the construction works associated with the temporary construction support site it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby residential receivers.

Construction vibration

The major activities at Cammeray Golf Course construction support site (BL1) that would include vibration intensive works would include piling associated with access decline excavations and acoustic shed installation, and ventilation tunnel construction, where rock hammers and piling rigs may be needed. Table 10-13 shows one heritage item in NCA 26.2 (Cammeray Park (including Golf Course)) is predicted to be within the minimum working distances for major vibration generating activities. Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 14 (Non-Aboriginal heritage) for further details on the heritage item potentially impacted.

Two receiver buildings within NCA 26.2 (Cammeray) may also be exposed to vibration levels above the human response screening level. The locations of these properties are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). The risk of annoyance is considered low with duration of rock hammering limited to works associated with the surface level decline construction and acoustic shed construction.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-13 Number of receiver buildings within minimum working distances for vibration intensive work – Cammeray Golf Course construction support site (BL1)

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage item[1]	Sound structure	
26.2	1	–	2

Note 1: Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

10.6.5 Gore Hill Freeway Connection surface road works

Construction works summary

The following works would be required as part of the Gore Hill Freeway Connection surface road works:

- Upgrade and reconfiguration of the Gore Hill Freeway between the T1 North Shore and Western rail line and T9 Northern rail corridor and the Pacific Highway
- Modifications to the Reserve Road and Hampden Road bridges
- Construction of Beaches Link ramps and cut and cover tunnel access structures
- Widening of Reserve Road between the Gore Hill Freeway and Dickson Avenue
- Modification of the Dickson Avenue and Reserve Road intersection to allow for the Beaches Link off ramp
- Upgrades to existing roads around the Gore Hill Freeway to integrate the project with the surrounding road network
- Upgrade of the Dickson Avenue and Pacific Highway intersection
- New and upgraded pedestrian and cyclist infrastructure
- Other operational ancillary facilities, including surface drainage and utility modification works, signage and lighting, CCTV and other traffic management systems, environmental controls and landscape treatments.

The Gore Hill Freeway Connection surface road works also includes the use of the following temporary construction support sites:

- Dickson Avenue site (BL4)
- Barton Road site (BL5)
- Gore Hill Freeway median site (BL5).

The works would take about four years. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-14 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels during typical and realistic worst case construction noise intensive work scenarios.

One residential receiver building in NCA 59.1 (Greenwich) is predicted to experience noise levels greater than 75 dB(A) during typical works at the intersection of Pacific Highway and Dickson Avenue during bus stop relocation, pavement and road modification works. This would occur when works are carried out near the receiver when road saws are in use. Up to eight residential receiver buildings are predicted to experience noise levels greater than 75 dB(A) during worst case works during standard construction hours, which include the use of rock hammers during utility modification works.

For the Gore Hill Freeway Connection surface road works during standard construction hours:

- For typical surface road works, up to eight residential receiver buildings within any one major works area are predicted to exceed the daytime noise management level, however the exceedances would be below 10 dB(A). Notwithstanding, receivers closest to the Gore Hill Freeway would experience existing traffic noise levels above the noise management level. For typical works at temporary construction support sites, no receivers are predicted to exceed the noise management level
- For worst case surface road works, up to 131 residential receiver buildings are predicted to exceed the noise management level. However, the majority of exceedances would be below 10 dB(A) and would occur only during the use of rock hammers or during concrete saw cutting for utility modification works. For worst case works at temporary construction support sites, no receivers are predicted to exceed the noise management level.

Outside standard construction hours:

- For typical surface road works at night time, up to 112 residential receiver buildings are predicted to exceed the noise management level from any one major works area during typical works. For typical works at temporary construction support sites at night time, up to 42 receivers are predicted to exceed the noise management level
- For worst case surface road works, up to 1453 noise affected residential receiver buildings are predicted to exceed the noise management level from any one major works area. The key noise generating activities would be utility modification works, and the use of excavators with rock hammers or concrete saws and pavement/road modifications. When these noise intensive activities are not occurring, the number of potentially noise affected receiver buildings are reduced to only 10 to 20 per cent of the worst case total
- For worst case works at temporary construction support sites at night time, up to 33 residential receiver buildings are predicted to exceed the noise management level for the Dickson Avenue construction support site (BL4), up to 27 residential receiver buildings are predicted to exceed the noise management level for the Barton Road construction support site (BL5) and up to 45 receivers are predicted to exceed the noise management level for the Gore Hill Freeway median temporary construction support site (BL6). The majority of these exceedances would be below 5 dB(A).

The most likely source of potential sleep disturbance from night construction works would be from the use of pneumatic hammers (including rock hammers) or saws during utility modification or road pavement work, or from air brakes from truck movements on site. The predicted maximum noise levels show exceedances of the sleep disturbance screening level across all areas with night construction works for both typical and worst case construction activities as follows:

- Up to 63 receiver buildings are predicted to be above the sleep disturbance screening level during typical construction works
- Up to 19 residential receiver buildings have potential to exceed the awakening reaction level during typical construction works

- Up to 454 receiver buildings are predicted to be above the sleep disturbance screening level during worst case construction activities, with only up to 46 residential receiver buildings have potential to exceed the awakening reaction level during worst case construction work.

For the prediction of airborne noise impacts from construction sites, consideration was given to realistic worst case construction activities as required by the *Interim Construction Noise Guideline* (DECC, 2009a). While the noise levels for the realistic worst case might occur at a sensitive receivers during the works, noise levels associated with the typical scenario occur more frequently.

Noise management level exceedances may occur at the following non-residential receivers:

- Six childcare receivers in NCAs 33.1 and 33.2 (within Artarmon both south and north of the Gore Hill Freeway), three of which are predicted to exceed the noise management level by more than 20 dB(A) during worst case works
- Up to a 5 dB(A) increase at two educational receivers (Artarmon Public School and Thrive Learning Centre, Artarmon) in NCA 33.1 and 33.2 for typical and worst case construction works
- One place of worship in NCA 33.1 (St Basil's Anglican Church, Artarmon) for worst case construction works only
- One recreational receiver in NCA 59.1 (Coronation Viewpoint, Greenwich) for typical and worst case construction works and up to 17 dB(A) at recreational parks nearby works at Dickson Avenue and the Pacific Highway
- Up to 27 commercial and industrial receivers in NCAs 33.1 and 33.2 ((within Artarmon both south and north of the Gore Hill Freeway) for typical and worst case construction works.

Three childcare centres (Butterflies Early Learning Childcare Centre, Willoughby/Lane Cove Family Day Care and Innovative Early Learning Artarmon) and one commercial receiver are predicted to exceed the noise management level as a result of activities within the temporary construction support sites. However, due to existing ambient noise levels, it is likely that internal spaces are sufficiently acoustically treated to protect internal spaces from construction noise.

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-14 Number of residential receiver buildings over the noise management levels during Gore Hill Freeway Connection surface road works (typical and realistic worst case scenarios)

Works area	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Gore Hill Freeway median (BL6)	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	63	7
	Worst case	0	0	0	0	0	0	0	0	0	0	0	0	0	37	8	0	0	117	12
Barton Road (BL5)	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	9	5	0	0	30	9
	Worst case	0	0	1	0	0	1	0	0	0	3	0	0	0	13	13	1	0	40	14
Dickson Avenue (BL4)	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	9	7	0	0	28	9
	Worst case	0	0	0	0	0	0	0	0	0	0	0	0	0	17	16	0	0	43	16
Gore Hill Freeway eastbound lanes west of Reserve Road	Typical	0	0	3	0	0	2	3	0	0	4	3	0	0	48	18	5	0	30	10
	Worst case	3	3	7	3	0	10	7	3	0	25	8	3	0	192	147	18	5	158	36
Gore Hill Freeway eastbound lanes between Reserve Road and Hampden Road	Typical	0	0	8	0	0	5	8	0	0	6	9	1	0	23	19	9	4	27	19
	Worst case	8	8	12	8	0	13	12	8	0	24	10	9	1	343	100	19	13	126	37

Works area	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Gore Hill Freeway eastbound lanes west of Hampden Road	Typical	0	0	1	0	0	0	1	0	0	4	1	0	0	43	33	1	0	40	5
	Worst case	1	1	15	1	0	74	15	1	0	88	20	1	0	883	280	33	1	397	37
Gore Hill Freeway westbound lanes and off ramp west of Hampden Road	Typical	0	0	2	0	0	6	2	0	0	3	6	0	0	18	24	8	0	28	9
	Worst case	2	2	13	2	0	19	13	2	0	17	16	6	0	460	118	24	8	141	32
Gore Hill Freeway westbound lanes and off ramp east of Hampden Road	Typical	0	0	1	0	0	0	1	0	0	1	1	0	0	66	45	1	0	63	2
	Worst case	1	1	19	1	0	124	19	1	0	128	34	1	0	1059	348	45	1	454	46
Modifications to Reserve Road bridge and ramps	Typical	0	0	7	0	0	6	7	0	0	7	9	1	0	36	15	10	3	21	17
	Worst case	7	7	13	7	0	8	13	7	0	17	11	9	1	619	81	15	13	105	33
Beaches Link eastbound portal cut and cover and on ramp	Typical	0	–	1	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	20	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Works area	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Beaches Link westbound southern portal cut and cover and off ramp west of Hampden Road	Typical	0	0	0	0	0	6	0	0	0	6	1	0	0	27	26	6	0	31	7
	Worst case	0	0	14	0	0	23	14	0	0	19	23	1	0	892	158	26	6	243	35
Beaches Link westbound southern portal cut and cover and off ramp east of Hampden Road	Typical	0	0	0	0	0	0	0	0	0	1	0	0	0	50	24	0	0	34	1
	Worst case	0	0	12	0	0	85	12	0	0	98	15	0	0	817	240	24	0	336	29
Motorway Control Centre construction and tunnel support	Typical	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	10	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Beaches Link westbound northern portal cut and cover and off ramp to Reserve Road	Typical	0	0	0	0	0	0	0	0	0	1	0	0	0	66	23	0	0	37	1
	Worst case	0	0	31	0	0	106	14	0	0	115	18	0	0	978	293	23	0	384	28
Pacific Highway east bus stop relocation, pavement and road modification works	Typical	0	1	1	0	0	5	1	0	0	8	1	1	0	60	15	2	1	8	4
	Worst case	1	2	2	1	0	117	20	1	0	224	47	1	1	677	364	15	3	86	9

Works area	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Pacific Highway west pavement and road modification works	Typical	0	–	2	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	3	–	98	2	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted “equivalent noise level”. It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities.
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

There is potential for cumulative increases of construction noise from the Gore Hill Freeway Connection surface road works and the construction of the Warringah Freeway Upgrade component of the Western Harbour Tunnel and Warringah Freeway Upgrade project, which includes the use of a temporary construction support site at Waltham Street at Artarmon. Sensitive receivers in NCAs 32.1, 33.1 and 36.1 (residential areas of Naremburn, Artarmon and Willoughby in proximity to the surface works areas) have the potential to experience elevated noise levels over extended durations due to the use of the adjacent areas for temporary construction support sites by both projects. There is also potential for increased disturbance associated with works outside standard construction hours associated with the Gore Hill Freeway Connection surface road works and the Warringah Freeway Upgrade.

Site specific mitigation measures would be developed for the Gore Hill Freeway Connection surface road works with the aim of ensuring that relevant noise management levels are met, minimising the potential for construction fatigue. Works outside standard construction hours would be coordinated with the Warringah Freeway Upgrade where feasible and reasonable to provide the affected receivers with appropriate respite.

There is also potential for construction fatigue from the Gore Hill Freeway Connection surface road works and the Sydney Metro City & Southwest (Chatswood to Sydenham) project. This is due to works associated with the Artarmon substation site as part of the Sydney Metro City & Southwest (Chatswood to Sydenham) project and proximity to the project. Notwithstanding, given there would be a twelve month break between the commencement of construction at the Gore Hill Freeway Connection surface road works and the completion of works for the Artarmon substation site, the risk of construction is considered minor and would be managed Cumulative airborne construction noise impacts would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Construction traffic noise

Changes in traffic movements due to alterations made to existing traffic arrangements to facilitate the construction of the project, and construction vehicle movements associated with the Gore Hill Freeway Connection surface road works and temporary construction support sites are unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible. However, temporary construction support sites that have heavy vehicle movements during the night period have the potential to exceed the sleep disturbance screening levels and awakening reaction levels from air brake releases or metal bangs associated with the loads being carried.

Construction ground-borne noise

Ground-borne noise levels have the potential to be generated by vibration intensive works at the surface road works and associated temporary construction support sites. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers.

Construction vibration

Table 10-15 shows 16 and 84 receiver buildings fall within the minimum working distances for cosmetic damage (sound structures) and human response, respectively. The locations of these properties are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). One heritage item within the minimum working distances is a potential archaeological deposit (Artarmon Park PAD (45-6-3362)). It is within the minimum working distance for cosmetic damage (unsound structures), assuming that vibration intensive plant such as a large rock hammer would be used. Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 15 (Aboriginal heritage) for details on this potential impacted heritage item.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-15 Number of receiver buildings within minimum working distances for vibration intensive work – Gore Hill Freeway Connection surface road works

Location	NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
		Cosmetic damage		Human response
		Heritage item	Sound Structure	
Gore Hill Freeway eastbound lanes including Epping Road and Pacific Highway on ramps	33.1	–	15	38
	33.2	–	–	32
	35.1	–	1	14
Gore Hill Freeway westbound lanes including the Epping Road and Pacific Highway off ramp	33.1	–	–	8
	33.2	–	1	38
Modifications to Reserve Road bridge and ramps	33.1	–	4	19
	33.2	–	4	25
Beaches Link eastbound portal cut and cover tunnel and on ramp	33.1	1[1]	–	4
Beaches Link westbound southern portal cut and cover tunnel and off ramp to Reserve Road	33.1	1[1]	–	3
	33.2	–	9	43
Beaches Link westbound northern portal cut and cover and off ramp to Reserve Road	33.2	–	2	17
Intersection of Pacific Highway and Dickson Avenue modification works and bus stop relocation	33.2	–	6	18
	59.1	–	3	11

Note 1: Artarmon Park PAD (45-6-3362).

10.6.6 Flat Rock Drive (BL2)

Construction works summary

The Flat Rock Drive construction support site (BL2) is proposed in Flat Rock Reserve, Northbridge, on the eastern side of Flat Rock Drive, opposite to the Bicentennial Reserve Baseball Diamond. The site would support tunnelling. Works associated with the establishment, use and demobilisation of the site would occur over about five years. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-16 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels.

During standard construction hours three residential receiver buildings in NCAs 36.1, 37.1 and 38.1 (within Willoughby, Naremburn and Northbridge respectively) are predicted to experience noise levels greater than 75 dB(A) during early works and site establishment. An additional

residential receiver building would be highly noise affected (greater than 75 dB(A)) during road widening works.

During standard construction hours, up to 174 residential receiver buildings in NCAs 36.1, 37.1 and 38.1 (within Willoughby, Naremburn and Northbridge respectively) are predicted to experience noise levels greater than the relevant noise management level. These exceedances are predicted during utility modification, vegetation clearing, access decline excavation and road modification works.

During night time works, noise levels are predicted to be below the noise management levels except during short-term works associated with the road widening and modification of Flat Rock Drive. Up to 698 residential receiver buildings across several NCAs are predicted to exceed noise management levels during these works. The majority of the exceedances (88 per cent) would be less than 15 dB(A).

Maximum noise levels at night could exceed the sleep disturbance screening level at up to 555 receiver buildings across several NCAs from the short-term road works. Twenty-six of these receivers are predicted to be exposed to maximum noise levels above the awakening reaction level. Predicted noise levels are intended to be conservative and represent realistic worst case impacts during the project. Night time works would be minimised to reduce potential impacts where possible. Additionally, the number of heavy vehicle movements during night time periods generated by the site is not substantial compared to existing traffic numbers on Flat Rock Drive.

For non-residential receivers:

- A commercial receiver in NCA 36.1 (within Willoughby, west of Flat Rock Drive) is predicted to experience noise levels above the noise management level during site establishment works and road widening works
- Two childcare receivers in within NCA 36.1 (Tree of Life Early Learning School – Willoughby and Koala Cottage) and one within NCA 30.2 (Catholic Care Naremburn Family Centre) are predicted to experience noise levels above the noise management level during early works
- Five recreational receivers in NCAs 31.1 (Dawson Playground), 36.1 (Bicentennial reserve including Willoughby basketball and netball courts and the Flat Rock Baseball Diamond) and 38.2 (Shore playing fields) are predicted to experience noise levels above the noise management levels during the majority of the construction activities.

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-16 Number of residential receiver buildings over the noise management levels during construction at Flat Rock Drive construction support site (BL2) (realistic worst case scenario)

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Early works	1	–	143	31	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Establish site	2	–	108	25	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Road widening	1	1	118	27	1	98	33	3	1	103	69	4	1	305	309	79	5	555	26
Piling for access decline and shed	0	–	23	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Access decline construction	0	–	57	8	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Acoustic shed construction	0	–	15	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tunnelling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	143	0
Tunnel fitout	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	143	0
Site rehabilitation	0	–	28	1	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

There is potential for cumulative increases of construction noise from concurrent use of Flat Rock Drive construction support site (BL2) and works associated with the final stages of the Western Harbour Tunnel and Warringah Freeway Upgrade project. Sensitive receivers in the vicinity have the potential to experience elevated noise levels over extended durations due to the use of Flat Rock Drive construction support site (BL2) and temporary construction support sites and surface works associated with the Western Harbour Tunnel and Warringah Freeway Upgrade project. There is also potential for increased disturbance associated with works outside standard construction hours carried by both projects.

Site specific mitigation measures would be developed for Flat Rock Drive construction support site (BL2) with the aim of ensuring that relevant noise management levels are met, minimising the potential for construction fatigue. Works outside standard construction hours, and the associated use of Flat Rock Drive construction support site (BL2) and the temporary construction support sites surface works associated with the Western Harbour Tunnel and Warringah Freeway Upgrade project, would be coordinated where feasible and reasonable to provide the affected receivers with appropriate respite.

Cumulative airborne construction noise impacts would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Construction traffic noise

Changes in traffic movements due to alterations made to existing traffic arrangements to facilitate the construction of the project, and construction vehicle movements associated with the Flat Rock Drive construction support site (BL2) are predicted to increase road traffic noise levels by less than 2 dB(A). Changes of this magnitude are not typically noticeable and are considered to be a minor impact.

Night time heavy vehicle movements to and from this site would be limited to one vehicle per hour (no more than five trucks in total). Since the number of night truck movements generated by the site is insignificant compared to existing heavy vehicle numbers on Flat Rock Drive, the number of maximum noise events that could disturb sleep are not likely to substantially increase.

Construction ground-borne noise

Ground-borne noise could result from the excavation of the tunnel access decline between the Flat Rock Drive construction support site (BL2) and the tunnel alignment. However, due to the terrain and the depth of the tunnel access decline and the resulting slant distances to nearby occupied receiver buildings, no receiver buildings (occupied buildings) are predicted to experience ground-borne noise above the relevant noise management levels from access decline tunnel construction.

Construction vibration

For the Flat Rock Drive construction support site (BL2), the major work stages that may include vibration intensive works are site establishment, road widening, construction of the access decline and acoustic shed, and tunnelling. The results included in Table 10-17 indicate:

- Two buildings within NCAs 36.1 (Willoughby) and 37.1 (Naremburn) west of Flat Rock Drive have been identified within the minimum working distance for cosmetic damage (sound structures)
- One heritage item in NCA 37.1 (Flat Rock Creek PAD (45-6-3361)) is predicted to be within the minimum working distances for cosmetic damage (unsound structures)
- Up to eleven properties may be exposed to vibration levels above the human response screening level (ie residents may feel vibration) from rock hammering during early works and site establishment works.

The locations of these properties are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). The most vibration intensive activity at this site is likely to be construction of the tunnel access decline and the use of rock hammers for utility modification during early and site establishment works. Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 15 (Aboriginal heritage) for further details on the potentially impacted heritage item.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-17 Number of receiver buildings within minimum working distances for vibration intensive work – Flat Rock Drive construction support site (BL2)

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage item[1]	Sound structure	
36.1	–	1	3
37.1	1	1	4
38.1	–	–	4

Note 1: Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

10.6.7 Punch Street (BL3)

Construction works summary

The Punch Street construction support site (BL3) is proposed within the Artarmon industrial area, adjacent to the rail corridor on the southern side of the Gore Hill Freeway. The site would be a tunnel support and project management site and would be used for the construction of the Gore Hill Freeway Connection and the ramp tunnels for Beaches Link. Works associated with the establishment, use and demobilisation of the site would occur over about three years and nine months. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-18 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels.

No receiver buildings are predicted to experience noise levels greater than 75 dB(A).

During standard construction hours, up to 97 residential receiver buildings in NCAs 33.1, 34.1 and 36.1 (within Artarmon and Willoughby, north of Gore Hill Freeway) are predicted to experience noise levels above the noise management level. These exceedances are predicted during early works, site establishment works and construction of the acoustic shed.

During out of hours works, noise levels are predicted to be below the noise management levels.

Maximum noise levels at night could exceed the sleep disturbance screening level at up to 107 receiver buildings from tunnelling support works. Three of these receivers are predicted to be exposed to maximum noise levels above the awakening reaction level.

For non-residential receivers:

- Up to 12 commercial buildings in NCA 33.2 (within the Artarmon industrial area) are predicted to experience noise levels above the noise management level during early works, site establishment and the construction of the acoustic shed

- Two childcare receivers in NCA 33.2 (Creative Acorn Early Learning Centre and Butterflies Early Learning Childcare Centre) and one in NCA 36.1 (Tree of Life Early Learning School – Willoughby) are predicted to experience noise levels above the noise management level during site establishment and the construction of the acoustic shed
- One educational receiver in NCA 33.1 (Artarmon Public School) is predicted to experience noise levels above the noise management level during site establishment and the construction of the acoustic shed.

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-18 Number of residential receiver buildings over the noise management levels during construction at Punch Street construction support site (BL3) (realistic worst case noise)

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside of standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Early works	0	–	2	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Establish site	0	–	97	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Surface level access decline excavation and acoustic shed construction	0	–	38	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tunnelling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	107	3
Tunnel fitout	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	107	3
Build operational motorway facilities	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Site rehabilitation	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

There is potential for cumulative increases of construction noise from the Punch Street construction support site (BL3) and the construction of the Warringah Freeway Upgrade component of the Western Harbour Tunnel and Warringah Freeway Upgrade project. There is also potential for increased disturbance associated with works outside standard construction hours associated with the Punch Street construction support site (BL3) and the Warringah Freeway Upgrade. Cumulative construction noise increases are likely to occur rarely at shared receivers between both projects, if noise generating activities associated with both projects need to occur simultaneously.

Site specific mitigation measures would be developed for the Punch Street construction support site (BL3) with the aim of ensuring that relevant noise management levels are met, minimising the potential for construction fatigue. Works outside standard construction hours would be coordinated with the Warringah Freeway Upgrade where feasible and reasonable to provide the affected receivers with appropriate respite.

Cumulative airborne construction noise impacts would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Construction traffic noise

Construction vehicle movements associated with the Punch Street construction support site (BL3) are unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Over the entire night time period there would be six vehicles (12 movements) typically accessing the temporary construction support site. Since the number of truck movements generated by the site is not significant compared to existing heavy vehicle numbers on Gore Hill Freeway, the number of maximum noise events that could disturb sleep are not likely to substantially increase. Additionally, direct access would be provided from the site to the Gore Hill Freeway as the Gore Hill Freeway Connection works progresses, minimising use of local roads.

Construction ground-borne noise

For the construction of the tunnel access decline between the Punch Street construction support site (BL3) and the tunnel alignment, ground-borne noise levels are predicted to be between 35 and 40 dB(A) at seven receivers located in NCA 32.1 (within Naremburn, east of the T1 North Shore and Western rail line and T9 Northern rail corridor). These exceedances have the potential to exceed the night time ground-borne noise management level.

Construction vibration

Table 10-19 shows six and 25 receiver buildings fall within the minimum working distances for cosmetic damage (sound structures) and human response respectively. The majority of the receiver buildings are located within the Artarmon industrial area with further detail presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). The most vibration intensive activity at this site is likely to be the use of a large rock hammer during site establishment stages.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-19 Number of receiver buildings within minimum working distances for vibration intensive work – Punch Street construction support site (BL3)

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage structure	Sound structure	
Early works, establish site, build decline and shed			
32.1	–	–	3
33.2	–	6	22

10.6.8 Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8)

Construction works summary

The Middle Harbour south (BL7) and Middle Harbour north (BL8) construction support sites would be located at each end of the Middle Harbour crossing and within the harbour at Northbridge to the south and Seaforth to the north. The cofferdams would facilitate construction of the interface structures between the driven mainline tunnels and the immersed tube tunnel units. Works associated with the establishment, use and demobilisation of these temporary construction support sites would occur over about four years. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-20 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels from the Middle Harbour south cofferdam (BL7) and the Middle Harbour north cofferdam (BL8) construction support sites as well as construction activities associated with the installation of the immersed tube tunnel.

Up to 10 residential receiver buildings in NCAs 39.2 and 42.1 (within Seaforth) are predicted to be highly noise affected experiencing noise levels greater than 75 dB(A) during impact piling (also known as hammer piling) for the installation of the Middle Harbour north cofferdam. To ensure appropriate respite is provided to sensitive receivers in the vicinity, impact piling in any given week would be carried out over no more than either a two hour period each work day or over a 6 hour period on a single work day. Impact piling is expected to be completed over a 12 month period.

During standard construction hours, up to 1075 residential receiver buildings across NCAs either side of the crossing of Middle Harbour are predicted to experience noise levels greater than the noise management level. However, the majority of receivers (82 per cent) would experience exceedances of less than 10 dB(A). The majority of noise affected receivers would result from the installation of the Middle Harbour north and south cofferdams, cofferdam excavation works and immersed tube tunnel foundation works.

Immersion of tube tunnel units would require activities outside standard construction hours as a typical immersion process for one immersed tube tunnel unit would take 24 to 48 hours. Once started, it is not possible to halt the installation process at the end of a daytime work shift. During this time, up to 295 residential receiver buildings in NCAs 39.1, 39.2, 40.1, 40.2, 41.1 and 42.1 (within Northbridge, Castlecrag and Seaforth) are predicted to experience noise levels that exceed noise management levels. However, the majority of the exceedances (66 per cent) would be less than 5 dB(A). It is expected that the six tunnel tube units would be immersed at intervals over a six to nine month period, providing affected sensitive receivers with respite in between individual tube immersions.

Maximum noise levels at night could exceed the sleep disturbance screening level at up to 224 receiver buildings across several NCAs either side of the crossing of Middle Harbour from the immersion of tube tunnel units. Thirteen of these receivers are predicted to be exposed to maximum noise levels above the awakening reaction level.

One commercial receiver (Northbridge Sailing Club) within NCA 39.1 is predicted to be noise affected during construction of the Middle Harbour south cofferdam and piling for the foundations for immersed tube tunnel. Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-20 Number of residential receiver buildings over the noise management levels during construction at Middle Harbour (realistic worst case noise intensity scenario)

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20bB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25 dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25 dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25 dB(A)	Screening	Awakening
Build Middle Harbour north cofferdam	10	–	794	175	17	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Build Middle Harbour south cofferdam	0	–	882	185	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Dewater cofferdams	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Excavate cofferdams	1	0	200	15	7	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pile moorings	0	–	110	14	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cast Interface structures	0	–	54	3	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Remove cofferdams	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prepare foundations	0	–	50	6	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pile foundations	0	–	555	206	14	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Immerse tunnel units	0	0	23	0	0	65	23	0	0	94	56	1	0	195	93	7	0	224	13

Note 1: L_{Aeq} is the A-weighted “equivalent noise level”. It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

The Middle Harbour south (BL7) and Middle Harbour north (BL8) construction support sites would be sufficiently far removed from locations where activities associated with other major projects would be occurring that cumulative impacts are unlikely.

Impact piling associated with cofferdam construction and immersed tunnel tube support piles has the potential to generate significant noise levels and impacts. Impact piling in any given week would, however, be carried out over no more than either a two hour period each work day or a six hour period on a single work day. Also, once these noise intensive activities are completed, the remaining activities in this locality would be less noise intensive and would have a lower potential to cause amenity impacts. Hence the potential for construction fatigue due to extended duration noise impacts is considered to be low.

All works outside standard construction hours associated with the project occurring around Middle Harbour, including the use of the Spit West Reserve construction support site (BL9), would be managed to ensure that affected receivers are provided with appropriate respite.

No cumulative airborne construction noise impacts are anticipated associated with these temporary construction support sites.

Construction traffic noise

The crossing of Middle Harbour would be accessed by barges, usually from the Spit West Reserve construction support site (BL9) and there would therefore be no direct construction road traffic impacts associated with the Middle Harbour south (BL7) and Middle Harbour north (BL8) construction support sites. It is expected that noise from barge movements would not cause substantial amenity or sleep disturbance impacts.

Construction ground-borne noise

While there is some potential for ground-borne noise from vibration intensive activities, associated airborne noise is expected to dominate noise emitted from the Middle Harbour south (BL7) and Middle Harbour north (BL8) construction support sites. Airborne noise levels would typically be greater than ground-borne noise levels at the nearby residential receivers. No vibration intensive activities are proposed at either temporary construction support site outside standard construction hours. Therefore, no amenity impacts outside standard construction hours due to ground-borne noise are anticipated.

Construction vibration

Table 10-21 shows six heritage items in NCAs 40.1 and 39.1 (Clive Park and Tidal Pool, Clive Park one (Northbridge), Clive Park two (Northbridge, Cicada Pupa Cave), Clive Park four (Northbridge),Clive Park 8 (Shelter Midden WILL 170) and Clive Park (Midden WILL 169)) and one heritage item within NCA 42.1 (Harbour foreshore) are predicted to be within the minimum working distances for major vibration generating activities. Up to 148 buildings within Northbridge and Seaforth may be exposed to vibration levels above the human response screening level. The locations of these properties are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). The most vibration intensive activity at this site are likely to be impact piling and vibratory piling for the installation of the Middle Harbour south (BL7) and Middle Harbour north (BL8) cofferdams, cofferdam excavation works and immersed tube tunnel foundation works. Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 14 (Non-Aboriginal heritage) and Chapter 15 (Aboriginal heritage) for details on the heritage items potentially impacted.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

A number of underwater maritime heritage items are located in proximity to the Middle Harbour crossing and may experience potential direct or indirect impacts from construction works. These

items are not specifically addressed in Appendix G (Technical working paper: Noise and vibration), as both the submerged nature of these heritage items and that they are generally not building structures that require structural integrity for any specific purpose means that the standards and limits for managing structural damage are not directly applicable. For further information on impacts from construction works on these items including the potential for vibration impacts, refer to Appendix K (Technical working paper: Maritime heritage).

Table 10-21 Number of receiver buildings within minimum working distances for vibration intensive work – Middle Harbour construction support sites

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage item[1]	Sound structure	
39.1	1	–	19
39.2	–	2	51
40.1	5	–	17
42.1	1	6	61

Note 1: Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

10.6.9 Spit West Reserve (BL9)

Construction works summary

The Spit West Reserve construction support site (BL9) is located in the water west of Spit West Reserve, with a small adjoining land-based site. The proposed construction works at the site would include a temporary floating immersed tube tunnel casting facility that would be connected to Spit West Reserve by two temporary fixed jetties. The casting facility would provide space for two immersed tube tunnel units to be cast concurrently. Works associated with the establishment, use and demobilisation of this temporary construction support site would occur over about four years and six months. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-22 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels.

No receivers are predicted to be highly noise affected (ie predicted noise levels greater than 75 dB(A)).

During standard construction hours, up to 131 residential receiver buildings in NCAs 39.2, 40.2, 42.1, 43.1 and 43.2 (within Mosman and Seaforth) are predicted to experience noise levels above the noise management levels, mostly during early works and the construction of the temporary wharf and office building. During other stages, noise impacts would be less, with up to 52 receiver buildings noise affected.

Due to construction limitations of concrete pours associated with the casting of the tunnel units, these activities may be required to extend outside standard construction hours. If concrete pours extend into the evening period up to 171 residential receiver buildings are predicted to be noise affected by 1 to 5 dB(A) with an additional 48 residential receiver buildings noise affected by 6 to 15 dB(A).

Immersion of tube tunnel units would be supported from the Spit West Reserve construction support site (BL9) and would be required during out of hours of work as a typical immersion process for one immersed tube tunnel unit would take 24 to 48 hours. During this time, up to 79 residential receiver buildings across various NCAs surrounding the temporary construction support

site are predicted to exceed noise management levels, however the majority of the exceedances (80 per cent) would be less than 5 dB(A).

Maximum noise levels at night could exceed the sleep disturbance screening level at up to 132 receiver buildings across several NCAs from the immersion of tube tunnel units. None of these receivers are predicted to be exposed to maximum noise levels above the awakening reaction level.

For non-residential receivers:

- Five commercial receivers located in NCA 44.2 (within The Spit area of Mosman) are predicted to experience noise levels above the noise management level during early works by less than 10 dB(A)
- Up to two recreational receivers located in NCA 44.2 (Spit West Reserve and Pearl Bay Reserve) are predicted to experience noise levels above the noise management level at various construction work stages by less than 20 dB(A).

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-22 Number of residential receiver buildings over the noise management levels during construction at Spit West Reserve construction support site (BL9) (realistic worst case scenario)

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Early works	0	–	131	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Establish site	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Construct office and wharf	0	–	52	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Support dredging, pile installation and cofferdam/ interface structure works	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cast and fitout tunnel units	0	0	11	0	0	92	11	0	0	171	48	0	0	0	0	0	0	0	0
Support tunnel unit immersion	0	0	0	0	0	0	0	0	0	10	0	0	0	66	13	0	0	132	0
Site rehabilitation	0	–	45	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

The Spit West Reserve construction support site (BL9) would be sufficiently far removed from locations where activities associated with other major projects would be occurring that cumulative impacts are unlikely.

The predicted noise levels generated by the temporary construction support site are unlikely to result in significant amenity impacts for sensitive receivers in the vicinity. The use of the site is therefore unlikely to result in construction fatigue due to extended duration noise impacts is considered to be low.

All works outside standard construction hours associated with the project occurring around Middle Harbour, including the use of the Spit West Reserve construction support site (BL9), would be coordinated managed to ensure that affected receivers are provided with appropriate respite.

No cumulative airborne construction noise impacts are anticipated associated with this temporary construction support site.

Construction traffic noise

While the Spit West Reserve construction support site (BL9) would be accessed outside standard construction hours to support tunnel tube construction and immersion, the volume of construction vehicle movements are likely to be low compared to existing volumes on Spit Road. Therefore, construction vehicle movements are unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Heavy vehicle movements are expected during the evening period however no night time heavy vehicle movements would occur at this site. Road traffic related sleep disturbance impacts are not expected to occur.

Construction ground-borne noise

Ground-borne noise may be generated by vibration intensive works within the Spit West Reserve construction support site (BL9). Given the closest building to the site is around 60 metres away, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers. No vibration intensive activities are proposed at this temporary construction support site outside standard construction hours. Therefore, no amenity impacts outside standard construction hours due to ground-borne noise are anticipated.

Construction vibration

The most vibration intensive activities at this site are likely to be screw pile driving during wharf building works and the use of rock hammers during establishment works. There are no receiver buildings within the minimum working distances for major vibration generating activities. However, occupants of up to two commercial properties in NCA 44.2 (within The Spit area of Mosman) may be exposed to vibration levels above the human response screening level during early works and the construction of the office and wharf should rock hammers and screw pile driving be used.

A number of underwater maritime heritage items are located in proximity to the Spit West Reserve construction support site (BL9) and may experience potential direct or indirect impacts from construction works. These items are not specifically addressed in Appendix G (Technical working paper: Noise and vibration), as both the submerged nature of these heritage items and that they are generally not building structures that require structural integrity for any specific purpose means that the standards and limits for managing structural damage are not directly applicable. For further information on impacts from construction works on these items including the potential for vibration impacts, refer to Appendix K (Technical working paper: Maritime heritage).

10.6.10 Balgowlah Golf Course (BL10)

Construction works summary

The Balgowlah Golf Course construction support site (BL10) would be located partially within Balgowlah Golf Course and on privately owned lots on Dudley Street. This would be a tunnel support site and project management site. It would also be used for the construction of Beaches Link tunnel connection to Burnt Bridge Creek Deviation and surface works, construction of operational facilities and the development of new and improved open space and recreation facilities and support of the construction of the immersed tube tunnels at the Spit West Reserve construction support site (BL9). Works associated with the establishment, use and demobilisation of this temporary construction support site would occur over about five years. Staged construction of the open space and recreation facilities would be delivered progressively and continue for another year after the main construction works have been completed. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-23 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels.

During standard construction hours, up to 1004 residential receiver buildings in NCAs 47.1, 48.1, 49.1, 50.1 and 51.1 (within Seaforth, Balgowlah and North Balgowlah) are predicted to experience noise levels greater than the noise management level. This would be mostly during site establishment works. The majority of receivers would experience exceedances of less than 10 dB(A). Other activities for which construction noise could affect a number of nearby residential receivers are bulk earthworks, access decline construction and construction of the new recreation facilities.

During standard construction hours two residential receiver buildings within NCA 49.1 (within Seaforth, west of Burnt Bridge Creek Deviation) also have the potential to experience noise levels greater than 75 dB(A) during site establishment works while excavators with rock hammers, chainsaws and mulchers are in use.

During night road works for road and intersection modifications, up to 548 residential receiver buildings are predicted to experience noise levels above the relevant noise management levels. The majority of receivers (96 per cent) are predicted to experience exceedances of less than 15 dB(A).

Maximum noise levels at night could exceed the sleep disturbance screening level at up to 267 receiver buildings across several NCAs surrounding the Balgowlah Golf Course construction support site (BL10) during night road works. Eleven of these receivers are predicted to be exposed to maximum noise levels above the awakening reaction level.

During night time tunnelling and tunnel fitout works, occasional night time concrete truck movements could result in the high instantaneous noise impacts during arrival or departure. Up to 136 receiver buildings are predicted to potentially be exposed to maximum noise levels above the sleep disturbance screening level. No receivers are predicted to exceed the awakening reaction level.

A number of non-residential receivers could be noise affected during establishment and use of this temporary construction support site. Up to 32 non-residential receivers could experience noise level that exceed the relevant noise management levels during site establishment. The identified receivers include:

- Up to two childcare receivers located in NCAs 47.1 (Peacock Street Long Day Care and Seaforth Infants School) are predicted to be would be noise affected by up to 10 dB(A) above the noise management level and one receiver located in in NCA 50.1 (Balgowlah Kinder Haven) is predicted to experience noise levels above the noise management level during various project stages by up to 21 dB(A)

- Up to three educational receivers located in NCAs 48.1 (Northern Beaches Secondary College – Balgowlah Boys Campus), 49.1 (Seaforth Public School) and 50.1 (Punchinello Kindergarten) are predicted to experience noise levels above the noise management level during various project stages by up to 16 dB(A). Multiple buildings at Northern Beaches Secondary College Balgowlah Boys (NCA 48.1) and Seaforth Public School (NCA 49.1) may potentially be impacted.
- One recreational receiver (Balgowlah Oval) is predicted to experience noise levels above the noise management level by up to 14 dB(A)
- Up to three place of worship receivers located in NCAs 47.1 (Seaforth Anglican Church and Seaforth Baptist Church) and 48.1 (The Catholic Community of North Harbour) are predicted to experience noise levels above the noise management level during site rehabilitation by up to 7 dB(A).

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-23 Number of residential receiver buildings over the noise management levels during construction at Balgowlah Golf Course construction support site (BL10) (realistic worst case scenario)

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Early works	0	–	299	21	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Establish site	2	–	863	137	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Road/intersection modification	0	0	3	0	0	16	3	0	0	26	10	0	0	388	136	21	3	256	11
Bulk earthworks	0	–	188	1	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Build access decline	0	–	332	12	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Establish construction facilities	0	–	10	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Piling for acoustic shed	0	–	35	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Build acoustic shed	0	–	6	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Balgowlah road surface support works	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	136	0
Tunnelling	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	136	0
Tunnel fitout	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117	0

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Concrete batching	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117	0
Golf course north works	0	0	208	9	0	0	0	0	0	0	0	0	0	0	0	0	0	136	0
Build operational facilities	0	–	14	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Remove acoustic shed	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Decommission site	0	–	5	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Construct new oval	0	–	70	2	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Construct new field	0	–	34	9	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted “equivalent noise level”. It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

The Balgowlah Golf Course construction support site (BL10) would be sufficiently far removed from locations where activities associated with other major projects would be occurring that cumulative impacts are unlikely.

While the temporary construction support site would be in use for an extended duration, the majority of the activities that would onsite would not be noise intensive. Site specific mitigation measures would be developed for Balgowlah Golf Course construction support site (BL10) with the aim of ensuring that relevant noise management levels are met during site use, minimising the potential for construction fatigue.

The use of the temporary construction support site outside standard construction hours would typically be to support the Balgowlah surface road works described in Section 10.6.11. The use of Balgowlah Golf Course construction support site (BL10) and the Balgowlah surface road works would be coordinated to ensure that affected receivers in the vicinity are provided with appropriate respite.

No cumulative airborne construction noise impacts are anticipated associated with this temporary construction support site.

Construction traffic noise

Changes in traffic movements due to alterations made to existing traffic arrangements to facilitate the construction of the project, and construction vehicle movements associated with the Balgowlah Golf Course construction support site (BL10) are unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Since the number of night period truck movements generated by the site is small compared to existing heavy vehicle numbers on Sydney Road and Burnt Bridge Creek Deviation, the number of maximum noise events that could disturb sleep are not likely to substantially increase.

Construction ground-borne noise

For the construction of the tunnel access decline between the Balgowlah Golf Course construction support site (BL10) and the ramp tunnel alignment, ground-borne noise levels are predicted to be between 35 and 40 dB(A) at four receivers located in NCA 49.1 (within Balgowlah, east of Burnt Bridge Creek Deviation), with one receiver potentially experiencing ground-borne noise levels above 40 dB(A). During the construction of the ventilation tunnel and shaft, one residential receiver building within NCA 49.1 (in Seaforth, west of Burnt Bridge Creek Deviation) is predicted to be impacted by ground-borne noise levels above 35 dB(A). Both the tunnel access decline and the ventilation tunnel are not located directly below any residential receivers, limiting the potential ground-borne noise impacts.

Construction vibration

Table 10-24 shows 37 and 198 receiver buildings fall within the minimum working distances for cosmetic damage (sound structures) and human response respectively. The majority of these receiver buildings are within NCA 50.1 (in Balgowlah, east of Balgowlah Golf Course) with further detail on other properties provided in Annexure L of Appendix G (Technical working paper: Noise and vibration). The most vibration intensive activity at this site is likely to be construction of the tunnel access decline and the use of rock hammers for site establishment and excavation works. The risk of annoyance at this site is considered low as piling, earth compaction works and rock hammering would occur for a limited duration only.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-24 Number of receiver buildings within minimum working distances for vibration intensive work – Balgowlah Golf Course construction support site (BL10)

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage item	Sound structure	
46.1	–	–	4
48.1	–	1	30
49.1	–	10	37
50.1	–	26	101
51.1	–	–	26

10.6.11 Balgowlah surface road works

Construction works summary

The Balgowlah surface road works are located on and adjacent to the Burnt Bridge Creek Deviation, on the border between Seaforth and Balgowlah. The works would connect the Beaches Link tunnel to Burnt Bridge Creek Deviation, and include works required to properly integrate this new connection into the existing network. Works associated with the establishment, use and demobilisation of this temporary construction support site would occur over about three years and three months.

The Balgowlah surface road works also includes the use of Kitchener Street construction support site (BL11).

Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-25 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels during typical and realistic worst case construction noise intensive work scenarios.

During standard construction hours, no residential receiver buildings are predicted to experience noise levels greater than 75 dB(A) during typical works. However, up to 25 residential receiver buildings are predicted to experience noise levels greater than 75 dB(A) during worst case works, such as during the use of rock hammers during excavations of rock or utility modification works.

During standard construction hours:

- The highest predicted noise levels occur for receivers directly adjacent to the works or in close proximity in NCAs 46.1, 48.1, 49.1, 50.1 and 51.1 in Seaforth, Clontarf, Balgowlah and North Balgowlah,
- For typical surface road works, up to 127 residential receiver buildings are predicted to exceed the noise management level. For typical works at the Kitchener Street construction support site (BL11), up to 100 receivers are predicted to exceed the noise management level
- For worst case construction, up to 912 residential receiver buildings are predicted to exceed the noise management level. The highest predicted noise levels occur are associated with excavation or utility modification works when equipment such as road saws or rock hammers are in use. For worst case works at the Kitchener Street construction support site, up to 117 receivers are predicted to exceed the noise management level during oversized deliveries to the site, with most exceedances less than 10 dB(A).

Outside standard construction hours, the key noise generating activities associated with the Balgowlah surface road works would be installation of traffic management controls to facilitate traffic switches, resurfacing works along Burnt Bridge Creek Deviation, support and deliveries for the cut and cover portal construction works, and intersection and road works in the areas where the new access road would connect to the Burnt Bridge Creek Deviation and Sydney Road (activities that cannot take place during standard construction hours to avoid significant traffic disruption in the network):

- For typical surface works during the night time period, up to 2318 residential receiver buildings are predicted to exceed the noise management level. No noise management level exceedances are expected at the Kitchener Street construction support site since the site would operate typically during standard working hours only
- For worst case construction works, up to 4059 residential receiver buildings are predicted to exceed the noise management level at night time.
- During works outside standard construction hours up to nine receivers could be highly noise affected (ie greater than 75 dB(A)) when plant and equipment are close to a receiver building.

For the prediction of airborne noise impacts from construction sites, consideration was given to realistic worst case construction activities as required by the *Interim Construction Noise Guideline* (DECC, 2009a). While the noise levels for the realistic worst case might occur at a sensitive receiver during the works, noise levels associated with the typical scenario occur more frequently.

The most likely source of potential sleep disturbance from night construction works would be from the use of rock hammers or concrete saws during utility modification works. The predicted maximum noise levels show exceedances of the sleep disturbance screening level across all areas with night construction works for both typical and worst case construction activities as follows:

- During typical surface works up to 718 buildings are predicted to exceed the sleep disturbance screening level with up to 97 residential receiver buildings have potential to exceed the awakening reaction level during typical construction works
- During worst case surface works up to 1097 buildings are predicted to exceed the sleep disturbance screening level. However only up to 148 residential receiver buildings have potential to exceed the awakening reaction level during worst case construction work.

Noise management level exceedances may occur at the following non-residential receivers:

- Up to two childcare centres in NCA 47.1 (Peacock Street Long Day Care and Seaforth Infants School) and one childcare receiver in NCA 50.1 (Balgowlah Kinder Haven) are predicted to be noise affected
- Up to two commercial receivers on Sydney Road in NCA 46.1 and two commercial receivers on Sydney Road in NCA 48.1 are predicted to be noise affected
- Up to four schools located in NCAs 46.1 (Northside Preschool), 48.1 (Northern Beaches Secondary College – Balgowlah Boys Campus), 49.1 (Seaforth Public School) and 50.1 (Punchinello Kindergarten) are predicted to be above the noise management level during various stages of the works, two of which are predicted to more than 10 dB(A) above the noise management level
- Up to 5 dB(A) above the noise management level is predicted at two places of worship in NCA 47.1 (Seaforth Anglican Church and Seaforth Baptist Church), and one places of worship in NCA 48.1 (The Catholic Community of North Harbour)
- Up to 7 dB(A) above the noise management level at the Balgowlah Scout Hall when the works are at the closest location.

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-25 Number of residential receiver buildings over the noise management levels during Balgowlah surface road works (typical and realistic worst case scenarios)

Works area	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Existing road corridor (southbound)	Typical	0	0	116	11	0	35	11	0	0	49	31	0	0	259	147	24	0	718	97
	Worst case	20	0	730	158	24	97	57	1	0	163	88	6	0	573	450	79	5	1097	148
Existing road corridor (northbound)	Typical	0	1	104	15	1	218	161	32	1	364	251	64	3	984	1059	212	63	654	99
	Worst case	25	9	624	148	24	604	376	89	14	762	642	139	24	1458	1807	657	137	994	153
Trough works	Typical	0	0	52	1	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	0	464	45	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cut and cover portal works	Typical	0	0	37	1	0	43	22	0	0	99	37	1	0	780	434	30	1	196	7
	Worst case	0	0	401	29	0	54	24	0	0	134	42	1	0	857	509	37	2	455	22
Access road	Typical	0	0	11	1	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	0	225	17	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Works area	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Access road intersection at Burnt Bridge Creek Deviation	Typical	0	0	5	0	0	22	5	0	0	50	14	1	0	622	191	8	0	90	3
	Worst case	0	0	99	5	0	449	99	5	0	682	282	15	1	1217	1590	220	8	939	27
Sydney Road roadworks	Typical	1	1	8	1	0	11	8	1	0	25	12	4	0	1523	1940	264	41	935	85
	Worst case	6	6	53	8	1	394	53	8	1	797	217	13	4	1523	1940	264	41	935	85
Kitchener Street construction support site (BL11)	Typical	0	0	94	6	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	0	109	8	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

The Balgowlah surface road works would be sufficiently far removed from locations where activities associated with other major projects would be occurring that cumulative impacts are unlikely.

While these road works would occur over an extended duration and would generate significant noise levels at times, the majority of the activities that would onsite would not result in significant amenity impacts for nearby receivers, limiting the potential for construction fatigue.

Balgowlah Golf Course construction support site (BL10) would generally support any outside standard construction hours work for the Balgowlah surface road works instead of the Kitchener Street construction support site (BL11). The use of Balgowlah Golf Course construction support site (BL10) and the Balgowlah surface road works would be coordinated to ensure that affected receivers in the vicinity are provided with appropriate respite.

No cumulative airborne construction noise impacts are anticipated associated with the Balgowlah surface road work.

Construction traffic noise

Changes in traffic movements due to alterations made to existing traffic arrangements to facilitate construction, and heavy vehicle movements associated with the Balgowlah surface road works between work areas via the Burnt Bridge Creek Deviation, Sydney Road or from the Balgowlah Golf Course construction support site (BL10), are unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Reduced speed limit during traffic switching arrangements along the Balgowlah surface road works is likely to reduce road traffic noise levels at residential receiver buildings in NCA 50.1 (within Balgowlah, east of the Balgowlah Golf Course).

Construction ground-borne noise

Ground-borne noise levels have the potential to be generated by vibration intensive works during surface road works. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers.

Construction vibration

Table 10-26 shows up to 44 receiver buildings would be within minimum working distances for cosmetic damage (sound structures). Up to 197 receiver buildings would be within minimum working distance for human response. The locations of these properties are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). The most vibration intensive activity at this site is likely to be the use of rock hammers for surface road works.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-26 Number of receiver buildings within minimum working distances for vibration intensive work – Balgowlah connection surface road works

Location	NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
		Cosmetic damage		Human response
		Heritage item	Sound structure	
Existing road corridor (southbound)	46.1	–	–	8
	49.1	–	1	40
	50.1	–	–	7
	51.1	–	1	50
Existing road corridor (northbound)	46.1	–	–	6
	49.1	–	19	51
	50.1	–	–	3
	51.1	–	17	75
Trough works	49.1	–	–	16
Cut and cover portal works	49.1	–	–	16
Access road	48.1	–	–	7
	49.1	–	–	2
	50.1	–	–	2
	51.1	–	–	3
Access road intersection at Burnt Bridge Creek Deviation	49.1	–	–	3
	51.1	–	–	4
Sydney Road roadworks	48.1	–	8	31
	49.1	–	–	3
	50.1	–	–	5

10.6.12 Wakehurst Parkway south (BL12)

Construction works summary

The Wakehurst Parkway south construction support site (BL12) is located on the eastern side of Wakehurst Parkway between just south of Judith Street and Kirkwood Street at Seaforth. Construction works at the site would support the upgrade of Wakehurst Parkway and also the construction of the cut and cover tunnel connection and motorway facilities at Wakehurst Parkway. Works associated with the establishment, use and demobilisation of this temporary construction support site would occur over about four years and nine months. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-27 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels.

Up to 18 residential receiver buildings are predicted to experience noise levels greater than 75 dB(A) during standard construction hours when rock hammers, chainsaws and mulchers are in use as part of the site establishment and early works.

During standard construction hours, up to 54 residential receiver buildings in NCAs 53.1 and 54.1 (within Seaforth) are predicted to experience noise levels above the noise management level during site establishment, early works, and site restoration works. The majority of receivers (56 per cent) would experience increases of less than 10 dB(A).

No works outside standard working hours are proposed at this temporary construction support site.

For non-residential receivers, up to two recreational receivers located at Seaforth Oval in NCA 54.1 (within Seaforth) are predicted to experience noise levels above the noise management level during site establishment and early works by up to 11 dB(A).

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-27 Number of residential receiver buildings over the noise management levels during construction at Wakehurst Parkway south construction support site (BL12) (realistic worst case scenario)

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Early works	9	–	15	19	9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Establish site	18	–	30	6	18	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Support surface works	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Support cut and cover and motorway facilities	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Site rehabilitation	0	–	6	17	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted “equivalent noise level”. It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

The Wakehurst Parkway south construction support site (BL12) would be sufficiently far removed from locations where activities associated with other major projects would be occurring that cumulative impacts are unlikely.

While the temporary construction support site would be in use for an extended duration, the majority of the activities that would onsite would not be noise intensive. Site specific mitigation measures would be developed for this temporary construction support site with the aim of ensuring that relevant noise management levels are met during site use, minimising the potential for construction fatigue.

The use of Wakehurst Parkway south construction support site (BL12) outside standard construction hours would typically be to support the Wakehurst Parkway surface road works. The use of the temporary construction support site and the Wakehurst Parkway surface road works would be coordinated to ensure that affected receivers in the vicinity are provided with appropriate respite.

No cumulative airborne construction noise impacts are anticipated associated with this temporary construction support site.

Construction traffic noise

Construction traffic associated with the Wakehurst Parkway south construction support site (BL12) is unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

No night time heavy vehicle movements would occur to or from this site. Road traffic related sleep disturbance impacts are not expected to occur.

Construction ground-borne noise

Ground-borne noise may be generated by vibration intensive works within the Wakehurst Parkway south construction support site (BL12). However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers.

Construction vibration

Table 10-28 shows two heritage structures in NCA 54.1 (Bantry Bay Water Pumping Station and the Bantry Bay Reservoir) are predicted to be within the minimum working distances for major vibration generating activities. Up to 27 receiver buildings within NCA 54.1 (Seaforth) may be exposed to vibration above the human response screening level during early works. The locations of these properties are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). The most vibration intensive activity at this site is likely to be rock hammers for utility modification works. Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 14 (Non-Aboriginal heritage) for further details on the heritage items potentially impacted.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/ or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-28 Number of receiver buildings within minimum working distances for vibration intensive work – Wakehurst Parkway south construction support site (BL12)

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage items[1]	Sound structure	
54.1	2	21	27

Note 1: Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

10.6.13 Wakehurst Parkway east (BL13)

Construction works summary

The Wakehurst Parkway east construction support site (BL13) is located on the eastern side of Wakehurst Parkway, on land surrounding Sydney Water's Bantry Bay Reservoir site, adjacent to the Wakehurst Parkway Golf Course. This would be a tunnel support site and project management site. The site would be used for the construction of Beaches Link tunnel connection to Wakehurst Parkway, to support the construction of the ramp tunnels for the Beaches Link component of the project. Works associated with the establishment, use and demobilisation of this temporary construction support site would occur over about four years and six months. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-29 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels.

No receiver buildings are predicted to experience noise levels greater than 75 dB(A).

During standard construction hours, up to two residential receiver buildings in NCAs 54.1 (located on Kirkwood Street, Seaforth) are predicted to experience noise levels above the noise management level during early works and site establishment.

During night time works, noise levels are predicted to exceed noise management levels during site establishment works at up to 63 residential receiver buildings in NCAs 53.1 and 54.1 (within Seaforth). A high proportion of receivers (about 67 per cent) would experience exceedances of less than 5 dB(A).

Maximum noise levels at night could exceed the sleep disturbance screening level at up to 35 receiver buildings due to site establishment and tunnelling support works. None of these receivers are predicted to be exposed to maximum noise levels above the awakening reaction level.

No non-residential receivers are predicted to experience noise levels above the noise management levels.

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-29 Number of residential receiver buildings over the noise management levels during construction at Wakehurst Parkway east construction support site (BL13) (realistic worst case scenario)

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Early works	0	–	1	1	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Establish site	0	0	2	0	0	1	1	0	0	8	2	0	0	42	19	2	0	35	0
Establish facilities	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Piling for access decline and acoustic shed	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Build acoustic shed	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tunnelling	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	8	0
Tunnel fitout	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	8	0
Remove acoustic shed	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Site rehabilitation	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities.
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

The Wakehurst Parkway east construction support site (BL13) would be sufficiently far removed from locations where activities associated with other major projects would be occurring that cumulative impacts are unlikely.

While the temporary construction support site would be in use for an extended duration, the majority of the activities that would occur onsite would not be noise intensive. Site specific mitigation measures would be developed for this temporary construction support site with the aim of ensuring that relevant noise management levels are met during site use, particularly outside standard construction hours, minimising the potential for construction fatigue.

No cumulative airborne construction noise impacts are anticipated associated with this temporary construction support site.

Construction traffic noise

Construction traffic associated with the Wakehurst Parkway east construction support site (BL13) is unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Over the entire night time period there would be eight heavy vehicle movements (four vehicles). Since the number of night truck movements generated by the site is not significant compared to existing heavy vehicle numbers on Wakehurst Parkway, the number of maximum noise events that could disturb sleep are not likely to substantially increase.

Construction ground-borne noise

Ground-borne noise would be generated from the construction of the tunnel access decline between the temporary construction support site and mainline tunnel and by vibration intensive works within the temporary construction support site. No sensitive receivers are predicted experience ground-borne noise levels above the noise management level.

Construction vibration

Table 10-30 shows two heritage structures in NCA 54.1 (Bantry Bay Water Pumping Station and the Bantry Bay Reservoir) are predicted to be within the minimum working distances for major vibration generating activities. The most vibration intensive activity at this site is likely to be construction of the tunnel access decline, construction of the acoustic shed and the use of rock hammers for utility modification during early works. Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 14 (Non-Aboriginal heritage) for further details on the heritage items potentially impacted.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-30 Number of receiver buildings within minimum working distances for vibration intensive work – Wakehurst Parkway east construction support site (BL13)

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage item[1]	Sound structure	
54.1	2	–	-

Note 1: Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

10.6.14 Wakehurst Parkway north (BL14)

Construction works summary

The Wakehurst Parkway north construction support site (BL14) is located on the north east corner of Wakehurst Parkway and Warringah Road at Frenchs Forest. Construction works at the site would be related to the Wakehurst Parkway surface road works, minor intersection works at Wakehurst Parkway/Warringah Road and Wakehurst Parkway/Frenchs Forest Road and construction of the permanent tunnel support facilities. The site would also support the construction and operation of a temporary concrete batching plant. Works associated with the establishment, use and demobilisation of this temporary construction support site would occur over about five years. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-31 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels.

No receivers are expected to experience noise levels greater than 75 dB(A).

During standard construction hours, up to 31 residential receiver buildings in NCAs 56.1 and 57.1 (within Frenchs Forest, south and north of Warringah Road, west of Wakehurst Parkway) are predicted to experience noise levels above the noise management level during early works. All receivers are predicted to experience noise exceedances of less than 10 dB(A).

During night time support for the Wakehurst Parkway road surface works, no noise management level exceedances are predicted.

Maximum noise levels could exceed the sleep disturbance screening level at up to 161 receiver buildings from truck deliveries at night during surface activities. No receivers are expected to receive noise above the awakening reaction level.

Noise management level exceedances may occur at the following non–residential receivers:

- Three commercial receivers located in NCA 58.2 (within Frenchs Forest, east of Wakehurst Parkway)
- One childcare receiver located in NCA 58.2 (Kindalin Early Childhood Learning Centre)
- One educational receiver located in NCA 57.1 (The Forest High School)
- One recreational receiver in NCA 56.1 (Brick Pit Reserve)
- Four place of worship receivers in NCA 56.1
- One other sensitive receiver in NCA 56.1 (Northern Beaches Hospital).

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-31 Number of residential receiver buildings over the noise management levels during construction at Wakehurst Parkway north construction support site (BL14) (realistic worst case scenario)

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Early works	0	0	31	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Establish site	0	0	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Surface activities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	161	0
Build maintenance facility	0	0	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Site rehabilitation	0	0	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

The Wakehurst Parkway north construction support site (BL14) would be sufficiently far removed from locations where activities associated with other major projects would be occurring that cumulative impacts are unlikely. Also, the temporary construction support site would be in a location where the most affected receivers are not particularly noise sensitive.

The use of Wakehurst Parkway north construction support site (BL14) outside standard construction hours would typically be to support the Wakehurst Parkway surface road works. The use of the temporary construction support site and the Wakehurst Parkway surface road works would be coordinated to ensure that affected receivers in the vicinity are provided with appropriate respite.

No cumulative airborne construction noise impacts are anticipated associated with this temporary construction support site.

Construction traffic noise

Construction traffic associated with the Wakehurst Parkway east construction support site (BL13) is unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Night time heavy vehicle movements from this site would be limited to one vehicle per hour, which is not a substantial number when compared to existing heavy vehicle movements on Warringah Road and Wakehurst Parkway. Nearby receivers are not likely to notice the increase in the number of maximum noise events caused by the additional truck movements generated by the site.

Sleep disturbance impacts from construction traffic are not likely to occur.

Construction ground-borne noise

Ground-borne noise levels have the potential to be generated during early works, where rock hammering may be needed for utilities adjustments. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers.

Construction vibration

Table 10-32 shows two receiver buildings in NCA 58.2 (within Frenchs Forest, east of Wakehurst Parkway) are predicted to be within the minimum human response working distances for major vibration generating activities. The locations of these properties are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). The most vibration intensive activity at this site is likely to be use of rock hammers for utility modifications.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-32 Number of receiver buildings within minimum working distances for vibration intensive work – Wakehurst Parkway north construction support site (BL14)

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage item	Sound structure	
58.2	–	–	2

10.6.15 Wakehurst Parkway surface road works

Construction works summary

The Wakehurst Parkway connection and upgrade is located on the Wakehurst Parkway, between Killarney Heights and Frenchs Forest. Works would include on and off ramps along with tunnel portals, ventilation facility and widening and upgrading of the Wakehurst Parkway through to Warringah Road. Works associated with the establishment, use and demobilisation of this temporary construction support site would take about three years and nine months. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-33 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels during realistic worst case and typical construction noise intensive work scenario.

During standard construction hours one residential receiver building is predicted to experience noise levels greater than 75 dB(A) when works take place nearby for the Warringah Road and Wakehurst Parkway intersection. Up to five residential receiver buildings are predicted to experience noise levels greater than 75 dB(A) when works take place in the southern section of the Wakehurst Parkway surface road works at Seaforth.

During standard construction hours:

- For typical surface road works, there would be no exceedances greater than 20 dB(A).
- The highest noise impacts during typical surface road works would likely be during clearing and grubbing activities associated with the southern and central sections of Wakehurst Parkway. Daytime noise management levels for the southern section could be exceeded at up 15 residential receiver buildings, with six receivers by greater than 10 dB(A). For the central section, daytime noise management levels could be exceeded at up 20 residential receiver buildings. However, all exceedance levels would be less than 10 dB(A). Two receiver buildings would be exceeded in the northern area.
- For worst case surface road works, up to 21 residential receiver buildings could experience noise levels that exceed the relevant noise management levels during bulk earthworks for the cut and cover portal, with four receivers by greater than 10 dB(A).
- The highest worst case noise impacts during surface road works would likely be during paving and asphalting, when daytime noise management levels could be exceeded at up to 15 receiver buildings in the northern area, 77 in the central and 34 in the southern area along Wakehurst Parkway. Noise levels are predicted to be greater than 20 dB(A) above the daytime noise management level at up to five of those receiver buildings where noise levels could be considered highly intrusive. However, noise levels are not predicted to be more than 20 dB(A) above the daytime noise management level at any receiver buildings during typical construction work.

Outside standard construction hours:

- Around the Warringah Road and Wakehurst Parkway intersection, up to 431 receiver buildings could experience noise levels that exceed the noise management levels during typical works. Up to 886 receiver buildings are predicted to be noise affected during worst case works
- For oversized lifting works in the northern section of the Wakehurst Parkway surface road works area, up to 199 receiver buildings are predicted to exceed the noise management levels during typical works. Up to 249 receiver buildings are predicted to be noise affected during worst case works

- For the central and southern sections of the Wakehurst Parkway surface road works area, up to 77 and 33 receiver buildings respectively could experience noise levels that exceed the noise management levels during typical works. Up to 139 and 59 receiver buildings respectively are predicted to be noise affected during worst case works
- For the cut and cover portals and works associated with the ventilation outlet and motorway facilities, up to 91 receiver buildings could experience noise levels that exceed the noise management levels during typical works. Up to 168 receiver buildings are predicted to be noise affected during worst case works.

For the prediction of airborne noise impacts from construction sites, consideration was given to realistic worst case construction activities as required by the *Interim Construction Noise Guideline* (DECC, 2009a). While the noise levels for the realistic worst case might occur at a sensitive receiver during the works, noise levels associated with the typical scenario occur more frequently.

The most likely source of potential sleep disturbance from night construction works would be from the use of rock hammers or concrete saws during utility modification works. The predicted maximum noise levels show exceedances of the sleep disturbance screening level across all areas with night construction works for both typical and worst case construction activities as follows:

- During typical construction works up to 86 receiver buildings would exceed the sleep disturbance screening levels, with up to 11 residential receiver buildings have the potential to experience noise levels in excess of the awakening reaction level during typical construction works
- During periods of worst case works up to 115 receiver buildings above the sleep disturbance screening level, with up to 16 residential receiver buildings have the potential to experience noise levels in excess of the awakening reaction level during worst case construction work.

Noise management level exceedances may occur at the following non-residential receivers:

- Two commercial receivers located in NCA 58.2 for worst case construction works
- Up to one childcare receiver located in NCA 58.2 (Kindalin Early Childhood Learning Centre) for typical construction works, and up to two childcare receivers located in NCAs 55.1 (Little Bloomers Early Learning Centre) and 58.2 (Kindalin Early Childhood Learning Centre) for worst case construction works
- Two recreational receivers in NCAs 55.1 and 56.1 during the Warringah Road and Wakehurst Parkway intersection upgrade works and three recreational areas/facilities in NCAs 54.1, 55.1, and 55.4 during surface works along the Wakehurst Parkway
- One place of worship receiver in NCA 56.1 (Frenchs Forest Anglican Church)
- When works are closest to the Northern Beaches Hospital, construction noise levels are predicted to exceed the noise management level by up to 5 dB(A) during typical works, or 16 dB(A) during worst case construction works
- Two other sensitive receivers (community centres) in NCA 55.1.

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-33 Number of residential receiver buildings over the noise management levels during Wakehurst Parkway surface road works (typical and realistic worst case scenarios)

Work activity	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Warringah Road/ Wakehurst Parkway works area																				
Surface road works	Typical	0	0	3	1	0	9	3	1	0	32	15	1	0	288	188	24	1	76	7
	Worst case	1	0	44	4	1	29	12	1	0	80	43	4	1	455	374	51	6	115	16
Wakehurst Parkway road upgrade (north) works area																				
Clearing and grubbing	Typical	0	–	2	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	4	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Surface road works	Typical	0	0	0	0	0	3	1	0	0	14	4	0	0	138	48	13	0	36	4
	Worst case	0	0	14	1	0	2	2	0	0	18	4	0	0	171	63	14	1	57	7
Concrete barriers and traffic controls	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	14	7	0	0	36	4
	Worst case	0	0	0	0	0	1	0	0	0	3	1	0	0	35	22	4	0	57	7
	Typical	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Work activity	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Road furniture installation/ modification	Worst case	0	–	4	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Work activity	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Wakehurst Parkway road upgrade (centre) works area																				
Clearing and grubbing	Typical	0	–	20	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	51	1	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Surface road works	Typical	0	–	4	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	67	10	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Concrete barriers and traffic controls	Typical	0	0	0	0	0	0	0	0	0	10	0	0	0	30	47	0	0	86	2
	Worst case	0	0	0	0	0	10	0	0	0	37	15	0	0	51	73	15	0	103	15
Road furniture installation/ modification	Typical	0	–	1	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	37	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Work activity	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Wakehurst Parkway road upgrade (south) works area																				
Clearing and grubbing works	Typical	0	–	9	6	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	1	–	13	9	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Surface road works	Typical	0	–	8	5	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	5	–	21	8	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Concrete barriers and traffic controls	Typical	0	0	5	0	0	2	5	0	0	4	8	1	0	12	14	7	0	26	11
	Worst case	0	0	8	1	0	4	8	1	0	10	8	5	0	22	24	8	5	31	13
Road furniture installation/ modification	Typical	0	–	8	3	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	12	7	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Work activity	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1 10 dB(A)	11 20 dB(A)	>20dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	1 5 dB(A)	6 15 dB(A)	16 25 dB(A)	>25dB(A)	Screening	Awakening
Tunnel portals – cut and cover works area																				
Piling – Bored	Typical	0	–	3	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	11	3	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Bulk earthwork	Typical	0	0	11	3	0	2	4	0	0	11	8	2	0	55	21	6	0	18	3
	Worst case	0	0	17	4	0	13	6	0	0	14	17	4	0	86	63	15	4	21	4
Oversized lifting works	Typical	0	0	4	0	0	6	4	0	0	9	10	2	0	56	25	8	2	18	3
	Worst case	0	0	5	0	0	7	5	0	0	9	11	2	0	57	30	10	2	21	4
Deliveries	Typical	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Concrete pours	Typical	0	–	6	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	10	2	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

The Wakehurst Parkway surface road works would be sufficiently far removed from locations where activities associated with other major projects would be occurring that cumulative impacts are unlikely.

While these road works would occur over an extended duration and would generate significant noise levels at times, the majority of the activities that would onsite would not result in significant amenity impacts for nearby receivers due to the distances between the receiver and the work locations. The risk of construction fatigue due to elevated construction noise levels over an extended duration is therefore low.

Wakehurst Parkway south and north construction support sites (BL12 and BL14) would generally support any outside standard construction hours work for the Wakehurst Parkway surface road works. The use of Wakehurst Parkway south and north construction support site (BL12 and BL14) and the Wakehurst Parkway surface road works would be coordinated to ensure that affected receivers in the vicinity are provided with appropriate respite, minimising potential amenity impacts.

No cumulative airborne construction noise impacts are anticipated associated with the Wakehurst Parkway surface road work.

Construction traffic noise

Construction traffic associated with the Wakehurst Parkway connection is unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is barely perceptible.

Two heavy vehicles per hour are expected to be required during the standard hours works typically associated with the road works upgrade and the operation of the support sites such as the Wakehurst Parkway south (BL12) or Wakehurst Parkway north (BL14). There would be additional heavy vehicle movements associated with the concrete batch plant at Wakehurst Parkway north construction support site (BL14) which could be a maximum of three heavy vehicles per hour. No vehicle movements other than oversized deliveries are expected to be required outside standard construction hours.

Construction ground-borne noise

Ground-borne noise levels have the potential to be generated by vibration intensive works at the surface road works and associated temporary construction support sites. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers.

Construction vibration

Table 10-34 shows four heritage items located in NCAs 54.1 (Frenchs Bullocks Track, Frenchs Forest; Bantry Bay; Wakehurst Parkway (45-6-0662) and Rock engraving (Garigal National Park) (45-6-2940)) and 55.1 (Bantry Bay Aboriginal Engraving Site (45-6-0655)) are predicted to be within the minimum working distances for major vibration generating activities. Up to 27 sensitive receiver buildings are identified within the minimum working distance for human response from the Wakehurst Parkway surface road works. The locations of these properties are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). The most vibration intensive activity at this site is likely to be use of large rock hammers for the cut and cover portal works. Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 14 (Non-Aboriginal heritage) and Chapter 15 (Aboriginal heritage) for further details on the heritage items potentially impacted.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-34 Number of receiver buildings within minimum working distances for vibration intensive work – Wakehurst Parkway surface road works

Location	NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
		Cosmetic damage		Human response
		Heritage item[1]	Sound structure	
Warringah Road/Wakehurst Parkway	57.1	–	–	2
	58.1	–	–	1
Road length upgrade	54.1	3	–	9
	55.1	1	–	6
	56.1	–	–	9
Cut and cover portals and ventilation facility	54.1	1	–	–

Note 1: Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

Controlled blasting

Controlled blasting has been identified as an alternative to rock hammering in deep cuts areas along the Wakehurst Parkway. While rock hammering may be still required for secondary breakage and/or trimming walls, controlled blasting has the potential to significantly reduce noise exposure period compared to traditional rock hammering excavation, which might have to occur over very long periods of time.

If controlled blasting is carried out, it would be planned to comply with overpressure noise and ground vibration management levels discussed in Section 10.4.5 and environmental management measures included in Chapter 19 (Biodiversity) regarding the Large-eared Pied Bat (*Chalinolobus dwyeri*). Refer to Appendix G (Technical working paper: Noise and vibration) and Appendix S (Technical working paper: Biodiversity development assessment report) for further detail.

10.6.16 Other construction activities

Local area works

Local area and utility connection works, such as service and utility identification works, electricity, sewer, communications and other utility adjustments, and local road integration works, may be needed as part of establishing temporary construction support sites. While some locations where local area work would be required are known and have been assessed as part of the relevant compound or surface road work area, other requirements are still being investigated or are unknown. They could, therefore, be required outside of areas specifically assessed in this document. These works are typically very short duration and are similar to works regularly carried out by utilities providers and road maintenance crews across Greater Sydney.

Around the temporary construction support sites, residences are typically set back by about ten metres from the nearest road. Table 10-35 shows predicted typical noise levels that would be expected at ten metres from local area works. The predictions account for distance attenuation and some localised shielding (such as temporary noise barriers) and are expected to be conservative (over-predict) as they do not account for other effects such as ground absorption and terrain effects.

Table 10-35 Assessment local area works noise at the nearest receiver building

Item	Utilities modification		Pavement modification		Paving or asphalting		Linemarking	
	Typical	Worst case	Typical	Worst case	Typical	Worst case	Typical	Worst case
Distance to the highly noise affected level (m)	13	43	13	42	12	42	12	17
$L_{Aeq(15\ minute)}$[1] noise level at 10 m (dB(A))[2]	77	88	77	87	76	87	77	80

Note 1: $L_{Aeq(15\ minute)}$ is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a period of 15 minutes

Note 2: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities

The results presented in Table 10-35 show that receiver buildings have the potential to be highly noise affected during local areas works, depending on the activity, the plant and equipment in use and the proximity of the works to the affected receivers. In most noise catchment areas, with a standard construction hours noise management level of 55 dB(A) or more, noise from local area works at the closest receivers would typically exceed the noise management level by about 20 dB(A) and in the worst case up to 33 dB(A).

Outside standard construction hours, noise from local area works at the closest receivers would typically exceed the night time noise management level by about 35dB(A) and in the worst case up to about 50 dB(A). This is based on a noise management level in most noise catchment areas of 40 dB(A) or more.

Local area works would typically consist of short duration (up to one week at any location) and would be managed in accordance with guidance *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a).

Truck marshalling areas

Spoil haulage trucks would likely require marshalling areas to be used when delays are experienced at the tunnel sites. The locations of these staging areas would be selected during development of the detailed construction methodology.

Where required, truck marshalling locations would be selected away from residential receivers and the site layout would take advantage of on-site or adjacent non-receiver structures to maximise acoustic shielding to nearby noise sensitive receivers.

All drivers would be required to comply with a Heavy Vehicle Code of Conduct, which would include noise management methods such as limiting idling and compression braking, and traffic management practises to minimise noise emissions from vehicles entering and leaving the site.

10.7 Environmental management measures

Environmental management measures for potential noise and vibration impacts during construction are outlined in Table 10-36. Additional measures to address cumulative impacts are included in Chapter 27 (Cumulative impacts).

Table 10-36 Environmental management measures – construction noise and vibration

Ref	Phase	Impact	Environmental management measure	Location
CNV1	Pre-construction and construction	Construction noise and vibration impacts	A Construction Noise and Vibration Plan will be developed for the project. This plan will: a) Identify relevant criteria and management levels in relation to noise and vibration b) Identify noise and vibration sensitive receivers and features in the vicinity of the project c) Include standard and additional mitigation from the *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016) and detail how and when these will be applied in the project d) Describe the approach that will be adopted for carrying out location and activity specific construction noise and vibration impact assessments to assist with designing and selecting of the appropriate mitigation and management measures e) Include protocols that will be adopted to manage works required outside standard construction hours f) Detail the methodology and approach for managing construction noise impacts g) Detail the process for managing construction vibration, including for heritage structures, considering all types of vibration generating works, including blasting h) Outline the approach for identifying and managing potential cumulative impacts, including ensuring appropriate respite for works outside standard construction hours i) Outline the procedures and approach for noise and vibration monitoring to be carried out to confirm construction noise and vibration levels in relation to noise and vibration management levels j) Detail how construction noise impacts from concurrent or consecutive nearby construction works associated with the project will be managed where feasible and reasonable.	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			The Construction Noise and Vibration Management Plan will be implemented for the duration of construction of the project.	
CNV2	Pre-construction	Construction noise and vibration impacts	Detailed location and activity specific construction noise and vibration impact statements will be prepared and implemented to cover: • Construction support sites • Works outside standard construction hours • Works with the potential to result in highly noise affected residential receivers (ie exposed to noise levels that exceed 75 dB(A)) • Works with the potential to exceed relevant human response and cosmetic damage criteria for vibration • Subsurface tunnelling activities. The statements will consider the proposed site layouts and noise generating activities that will occur, identify potentially impacted sensitive receivers and assess predicted noise and vibration levels against the relevant criteria and management levels, and specify the feasible and reasonable mitigation and management measures that will be implemented in accordance with the requirements of the *Interim Construction Noise Guideline* (DECC, 2009) and the *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016).	BL/GHF
CNV3	Construction	Construction noise and vibration impacts during out of hours work	An out of hours works protocol will be developed for the construction of the project. The protocol will include: a) Details of works required outside standard construction hours justifications of why the works are required outside standard construction hours b) The noise and vibration impact assessment processes that will be followed to identify potentially affected receivers and clarify potential impacts c) Mitigation and management measures that are to be considered and implemented where appropriate to manage potential impacts	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			associated with works outside standard construction hours d) Details of the approval process (internal and external) for works proposed outside standard construction hours. The protocol will be prepared in consultation with Department of Planning, Industry and Environment and the NSW Environment Protection Authority. The project protocol will be implemented during the duration of the construction of the project.	
CNV4	Construction	Construction noise and vibration impacts during out of hours work	For works outside standard construction hours on and adjacent to major roadways, the elevated existing ambient and background noise levels during the following shoulder periods will be investigated and confirmed: • Shoulder period (night-day) – between 5.00am and 7.00am • Shoulder period (evening-night) – between 10.00pm and 12.00am. Where appropriate, these shoulder periods will be utilised where feasible and reasonable to minimise potential amenity impacts associated with project activities outside standard construction hours.	BL/GHF
CNV5	Construction	Construction noise and vibration impacts	Construction noise and vibration impacts will be monitored periodically throughout all stages of the construction support site to ensure that: a) Noise and vibration levels are consistent with the predictions detailed in the relevant construction noise and vibration impact statements b) Noise and vibration impacts are being appropriately managed c) Mitigation measures are effective.	BL/GHF
CNV6	Construction	Construction noise impacts	Where feasible and reasonable, unless compliance with the relevant traffic noise criteria can be achieved, or alternative arrangements have been agreed with affected receivers, construction vehicle movements will not occur on local roads beyond those required for direct access to construction sites.	BL/GHF
CNV7	Construction	Construction vibration impacts	Vibration generating activities will be managed through the establishment of	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			minimum working distances to achieve vibration screening levels. Where vibration levels are predicted to exceed the screening levels, a more detailed assessment of the impacted structure will be carried out to assess the susceptibility of the structure to damage from vibration due to the project. Appropriate mitigation and management measures, such as equipment substitution and alternative methods, will be identified and implemented to avoid damage. Attended vibration monitoring will be carried out during vibration intensive activities in the vicinity to ensure vibration levels remain below appropriate limits for that structure. For heritage items, the more detailed assessment will specifically consider the heritage values of the structure in consultation with a heritage specialist to ensure sensitive heritage fabric is adequately monitored and managed. Pre-construction building structure condition surveys will be carried out in accordance with environmental management measure SG7. Any building and/or structure damage from vibration caused by the project would be repaired at no cost to the owner.	
CNV8	Construction	Construction ground–borne noise impacts	Where ground-borne levels are predicted to exceed the relevant noise management levels, alternative construction techniques and equipment that are likely to generate less ground-borne noise will be investigated and used where feasible and reasonable.	BL/GHF
CNV9	Construction	Construction impacts from surface road works	Mitigation measures will be implemented for surface road works, local area and utility works, where construction activities are predicted to exceed noise management levels at receivers. Where feasible and reasonable, the approaches that will be used include: a) Carrying out works during the daytime period when near residential receivers b) Selection of plant and equipment to minimise noise and vibration impacts c) Management of plant and equipment to minimise the generation of noise and vibration impacts	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			d) Community consultation, engagement and notification e) Detailed programming and respite protocols f) Where out of hours works are required, programming the noisiest activities to occur during the less sensitive time periods g) Out of hours works protocols h) Limiting timing of noise intensive work i) Use of portable noise barriers around particularly noisy equipment such as concrete saws and rock hammers in cases where it will effectively reduce noise levels at nearby receivers j) Management of construction traffic to minimise movements during the night periods along local roads k) Establishing minimum vibration working distances for vibration intensive works l) Vibration and blasting trials and/or monitoring along with building condition surveys Construction support sites that support surface road works will be designed to ensure that primary noise sources are located as far as possible from the nearby noise sensitive receivers, with solid structures (shed, containers, barriers, etc) placed between the noise sensitive receiver where feasible and reasonable to maximise acoustic shielding and block the line of site between the source and the receiver.	
CNV10	Construction	Construction impacts from surface road works	Where feasible and reasonable, noise barriers proposed as part of the project to address road traffic noise will be implemented as early as possible to attenuate construction noise.	BL/GHF
CNV11	Construction	Increased road traffic noise levels due to noise barrier removal	Where it is necessary to relocate or remove existing noise barriers to facilitate construction of new road infrastructure, the new noise barriers will be installed before removing the existing barriers where feasible and reasonable. Where it is not possible to install the new barriers before removing the existing barriers, the duration between removing the existing and installing the new barriers will be minimised. Temporary noise barriers will	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			be installed to ensure that road traffic noise levels do not increase by more than 2 dB(A) at the affected residential receiver buildings, where feasible and reasonable.	
CNV12	Construction	Construction blasting impacts	Any blasting and associated activities will be carried out in a manner that does not generate unacceptable overpressure and vibration impacts or pose a significant risk of impact to structures and sensitive receivers (including threatened fauna and fauna habitat adjacent Wakehurst Parkway). Prior to any blasting all potentially affected sensitive receivers and features in the vicinity would be identified. Appropriate tests will be carried out at each proposed blasting location to develop site-specific laws that take into account relevant factors such as underlying geology and separation distance to sensitive receivers and features to determine appropriate charge sizes and blasting design to ensure compliance with relevant vibration and overpressure criteria. All blasting will be carried out in accordance with the specific-laws. Monitoring will occur to determine compliance with the relevant criteria, and the site-specific laws will be adjusted as required based on the monitoring results to ensure ongoing compliance. The potentially affected community will be kept informed about proposed blasting activities.	BL/GHF
CNV13	Construction	Cumulative construction noise impacts and construction fatigue	Construction noise from concurrent and consecutive major projects in the vicinity of work locations associated with the project will be managed to minimise cumulative construction noise impacts. Where feasible and reasonable the approaches that will be used include: a) Considering the potential for cumulative impacts due to other major projects in the locality during development of the detailed construction methodology. The construction methodology will be developed to minimise overall noise impacts and the need for respite for receivers potentially affected by cumulative impacts wherever feasible and reasonable	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			b) Consulting with other major projects in the vicinity with the aim of coordinating work between the different projects that will affect the same area to ensure that affected receivers get appropriate respite from high noise impact activities and works outside standard construction hours c) Implementing additional feasible and reasonable source mitigation for cumulative construction activities, where programming is not practical to avoid cumulative noise impacts d) Community consultation to seek feedback on and identify key noise and vibration issues relevant to the local community so that current and future works can be managed to limit cumulative impacts.	
CNV14	Construction	Impact piling	In any given week, impact piling will be carried out over no more than either: • a two hour period each work day or • a six hour period on a single work day.	BL

Note 1: BL = Beaches Link, GHF = Gore Hill Freeway Connection