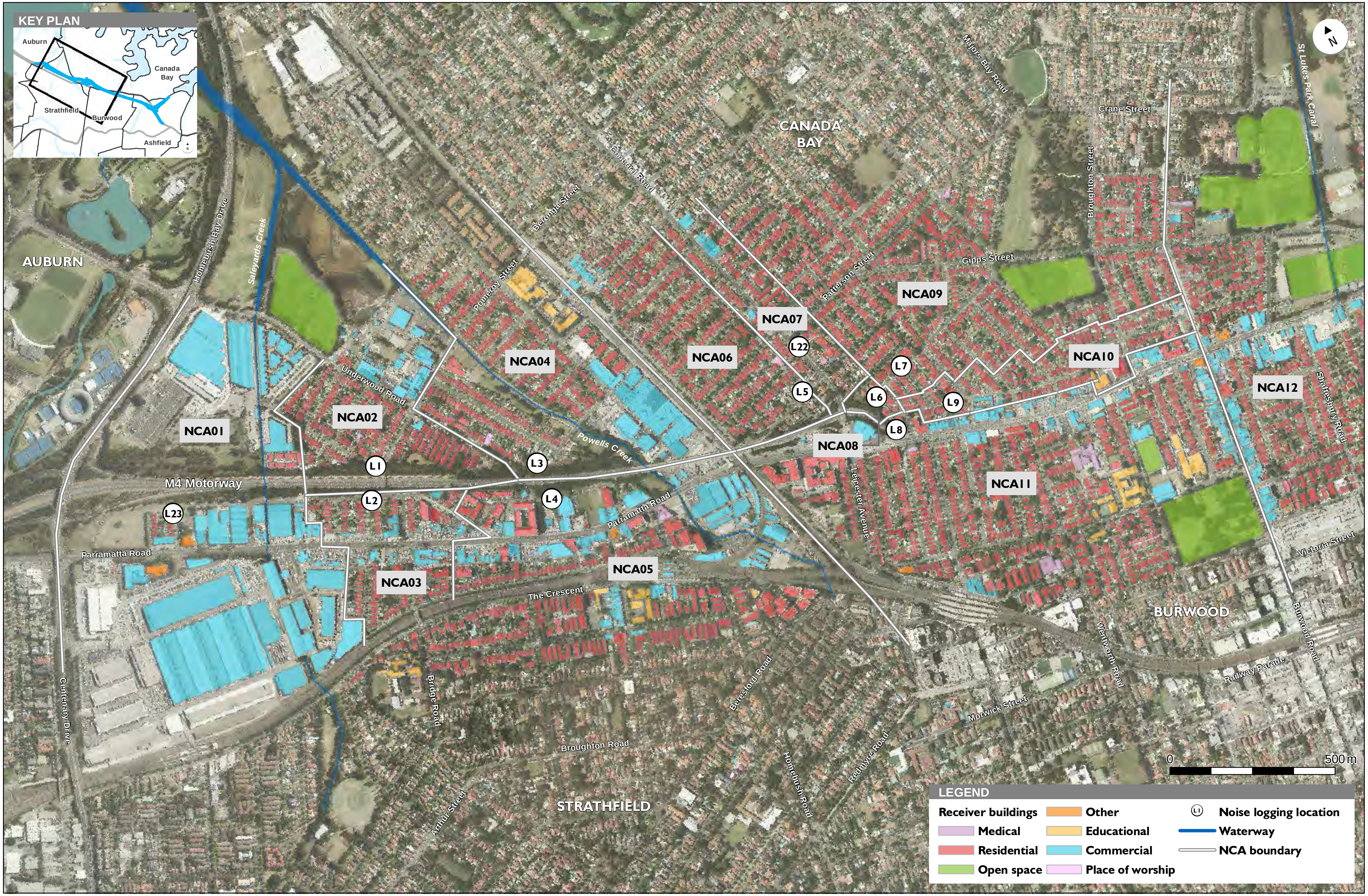

Figure 10.1 Noise catchment areas, sensitive receivers and logging locations - Map 1

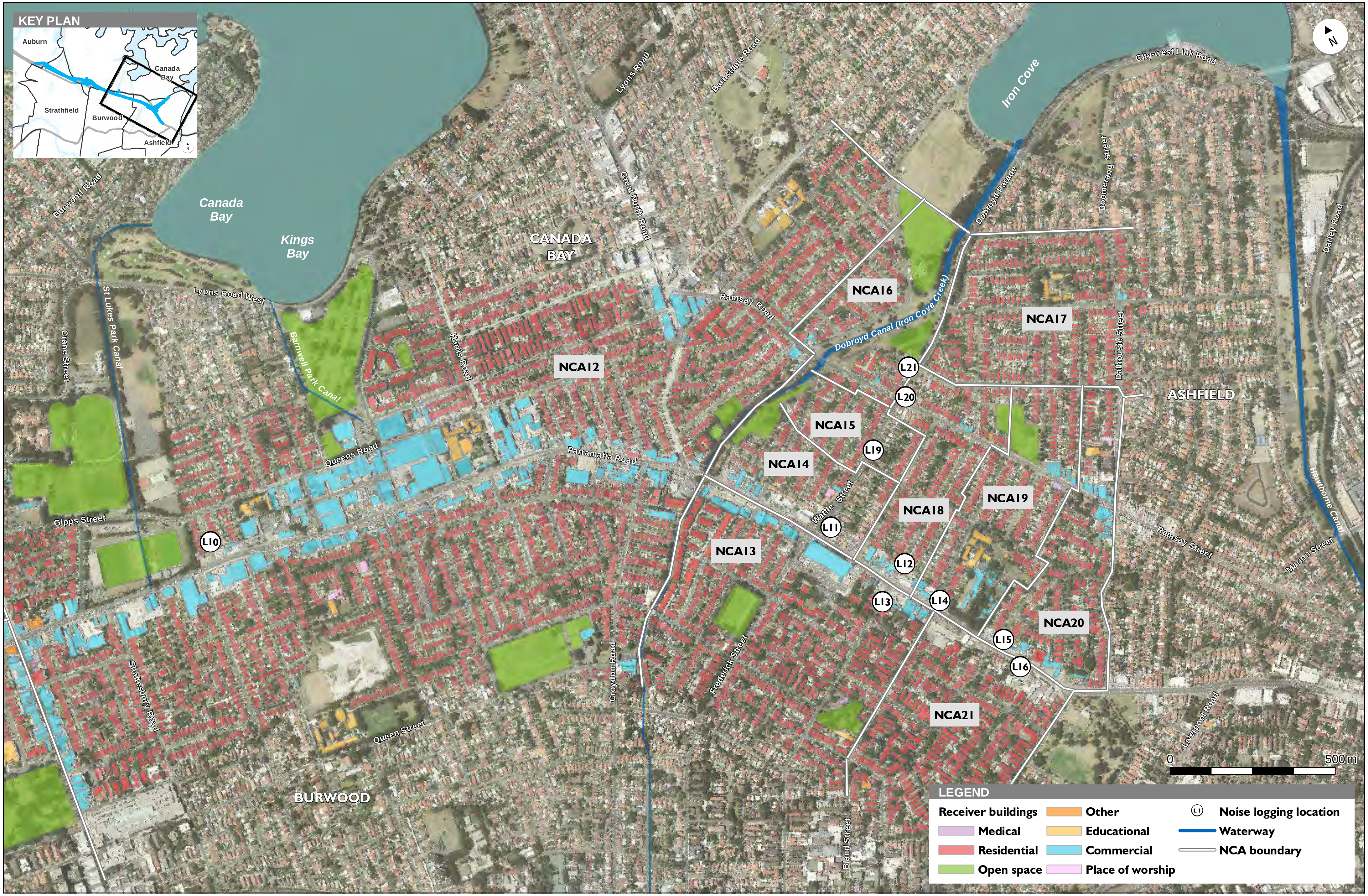

Figure 10.2 Noise catchment areas, sensitive receivers and logging locations - Map 2

10.1.3 Background noise monitoring

Unattended background noise monitoring was carried out at 23 locations between 26 March and 9 April 2014. Monitoring locations were selected to be representative of receivers and noise catchment areas that would potentially be affected by the project during construction or operation (or both). Noise monitoring locations are shown on **Figure 10.1** and described in detail in section 3.3 of the noise and vibration impact assessment in **Appendix I**. Background monitoring has been undertaken to:

- Determine the existing background noise levels across each noise catchment
- Establish construction and operational noise criteria to be applied to the assessment
- Calibrate the noise models used for the assessment.

Attended background noise monitoring was also undertaken at the unattended monitoring locations. Attended monitoring was undertaken over 15 minute sampling periods to determine the existing L_{Aeq} (the 'energy average noise level'), L_{A90} (the noise level exceeded for 90 per cent of the sample period) and other relevant statistical noise levels during the daytime, evening and night-time periods.

The results of monitoring were reviewed to exclude noise identified as extraneous and data affected by adverse weather conditions, to establish representative noise levels within each NCA.

10.1.4 Policy framework

The following guidelines have been used in the noise and vibration assessment:

- Construction noise:
  - *Interim Construction Noise Guideline* (ICNG) (DECC 2009)
  - *Construction Noise Strategy* (Transport for NSW 2012d)
- Construction vibration:
  - *Assessing Vibration: A Technical Guideline* (DEC 2006)
  - German Standard (DIN) 4150 Part 3-1999 *Structural vibration – Effects of vibration on structures*
  - British Standard (BS) 7385:Part 2-1993 *Evaluation and Measurement for Vibration in Buildings Part 2*
  - Australian Standard (AS) 2187: Part 2-2006 *Explosives − Storage and Use − Part 2: Use of Explosives*
  - *Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration* (Australian and New Zealand Environment Council 1990)
- Construction and operational traffic noise:
  - *NSW Road Noise Policy* (DECCW 2011) (RNP)
  - *Noise Criteria Guideline* (Roads and Maritime Services (Roads and Maritime) 2014b) (NCG)
  - *Noise Mitigation Guideline* (Roads and Maritime 2014d) (NMG)
- Noise from operational ancillary facilities:
  - *Industrial Noise Policy* (EPA 1999b) (INP)
- Sleep disturbance during construction and operation:
  - *NSW Road Noise Policy* (DECCW 2011)
  - *Preparing an Operational Noise and Vibration Assessment* (Roads and Maritime 2011c)
  - Practice Note 3 of the *Environmental Noise Management Manual* (Roads and Traffic Authority of NSW (RTA) 2001) (ENMM).

10.1.5 Noise modelling

Construction noise

Noise levels resulting from the construction of the project have been predicted at surrounding receiver locations the noise modelling software using SoundPLAN Version 7.1. The modelling includes the project design, local terrain, receiver buildings and structures.

In line with the requirements of the ICNG, all construction noise impacts have been based on a worst case assessment, which assumes that all modelled equipment would operate simultaneously. In fact, construction noise levels would be often lower than the predicted worst case scenario, as it would generally be unlikely that all equipment would operate simultaneously.

In addition, the worst case construction noise impacts would only be experienced at the nearest and most exposed receiver. Other receivers within each receiver area would generally experience lower noise levels compared to the most noise exposed location, as construction work would be undertaken at greater distances and may also be shielded from the noise source by other buildings. An indicative reduction in noise levels can be assumed as follows:

- A doubling of the distance between the source and receiver would provide a reduction in noise level of about six decibels (dBA)
- Buildings and other solid structures located between the construction noise source and sensitive receivers would act as barriers and would typically reduce noise levels by up to 15 dBA.

Operational road traffic noise

The operational noise assessment has been undertaken in accordance with the RNP (DECCW 2011) as interpreted by Roads and Maritime in the NCG (Roads and Maritime 2014b). The NCG provides a consistent approach to identifying road noise criteria for Roads and Maritime projects, while meeting the intention of the RNP. Practice Note 3 in the ENMM (RTA 2001) has been used for the assessment for sleep disturbance.

Road traffic noise levels have been calculated using SoundPLAN software, which implements the Calculation of Road Traffic Noise algorithm devised by the UK Department of Transport. With suitable corrections, this method has been shown to give accurate predictions of road traffic noise under Australian conditions.

The operational traffic noise assessment was based on the following scenarios, which are consistent with the scenarios modelled in the traffic and transport assessment (refer to **Chapter 8** (Traffic and transport)):

- 2021 ’No Build’: The forecast road traffic volumes at the nominal year of opening (2021) without the project and without any other WestConnex projects
- 2021 ‘Build’: The forecast road traffic volumes in 2021 including the project and the approved M4 Widening and King Georges Road Interchange Upgrade projects, but without any other WestConnex projects
- 2031 ‘No Build’: The forecast road traffic volumes 10 years after the nominal opening year assuming that the King Georges Road Interchange Upgrade and the M4 Widening projects are complete, but the remaining WestConnex projects, including the M4 East, are not built. Any increase in traffic is due to general traffic growth
- 2031 ‘Build’: The forecast road traffic volumes 10 years after the nominal opening year assuming all WestConnex projects are complete. This scenario also includes the Sydney Gateway and the Southern Extension.

The comparison between the 2021 ‘No Build’ and ’Build’ scenarios will indicate the potential for any noise issues at the start of the project, such as community reaction to significant changes in noise levels. The comparison for 2031 will indicate the potential for noise impacts in the longer term, once the project and all other WestConnex projects are well established and the surrounding road network has stabilised.

Operational ancillary facilities

Noise from operational ancillary facilities has been assessed in accordance with the INP (EPA 1999b). The operational ancillary facilities considered as part of the assessment include:

- In-tunnel jet fans at locations where below ground components of the project come to the surface (ie tunnel/ramp portals)
- The eastern and western ventilation buildings
- Fresh air supply facility at Cintra Park.

At this stage of the design, specific mechanical plant for other operational ancillary facilities has not been selected. Due to the variety of plant items anticipated to be required, it is not practicable to specify individual acoustic requirements for individual units where equipment has yet to be selected. The exact requirements for the plant systems depend on the design, operation during the daytime, evening and night-time periods and location, and would be considered during detailed design.

Maximum noise levels

A maximum noise level assessment was conducted in accordance with the procedure ‘Preparing an Operational Noise and Vibration Assessment’ (Roads and Maritime 2011c) using guidance contained in the RNP and Practice Note 3 of the ENMM.

It is noted that the RNP and ENMM both state that, while a maximum noise level assessment is required to be undertaken for new and upgraded road infrastructure projects, it should only be used as a tool to help prioritise and rank mitigation strategies, and should not be applied as a decisive criterion in itself.

The objective of the maximum noise level assessment was to determine whether maximum noise levels are likely to increase or decrease as a result of the project.

10.2 Existing environment

The existing noise environment across the study area varies; however, road noise is generally the primary contributor to background noise levels, largely due to the presence of major roads such as the M4, Parramatta Road, Concord Road and Wattle Street. The local road network also contributes to background noise levels, albeit to a lesser degree than major roads.

Other background noise sources in the vicinity of the project footprint are the Main North Rail Line (including diesel train services) and aircraft noise.

Land use in the vicinity of the project footprint predominantly consists of residential dwellings of varying densities; however, commercial and light industrial development is focused along Parramatta Road. Land use is discussed further in **Chapter 12** (Property and land use).

A range of noise sensitive receivers are located adjacent to the project corridor. All residences (including hotels, motels, hostels and serviced apartments) are considered to be sensitive receivers during both construction and operation. All commercial receivers are considered to be sensitive to construction noise and vibration impacts. Other receivers sensitive to noise and vibration during both construction and operation include educational institutions, child care centres, hospitals and medical centres, aged care facilities, places of worship and open space.

The results of background noise monitoring (both attended and unattended) are provided in **Table 10.2**.

Background noise levels are observed to be consistent with traffic flows on the surrounding network, with levels during the evening being similar (slightly less) than the day time period and then a more significant reduction in noise during the night-time period when traffic flows drop.

The results of the attended monitoring are considered to be generally consistent with the results of the unattended monitoring and assist in showing that existing noise levels are dominated by the adjacent road network.

Table 10.2 Background noise monitoring results

Noise monitoring location	Noise level (dBA)									
	Unattended monitoring results							Attended monitoring results		
	Rating background level (RBL) during ICNG defined time periods [1]			Rating background level (RBL) during RNP defined time periods [2]				Measured noise levels		
	Day RBL	Evening RBL	Night RBL	Day $L_{Aeq(15hr)}$	Night $L_{Aeq(9hr)}$	Daytime $L_{Aeq(1hr)}$	Night-time $L_{Aeq(1hr)}$	L_{A90}	L_{Aeq}	L_{Amax}
L1	53	52	46	58	55	61	59	53	58	80
L2	50	50	46	57	54	61	58	53	57	69
L3	50	49	43	55	52	59	56	52	59	79
L4	56	56	48	63	59	65	63	56	62	89
L5	53	52	46	66	62	68	67	54	65	82
L6	48	47	42	56	51	59	56	50	57	73
L7	41	41[4]	38	56	49	61	55	41	61	79
L8	55	54	47	64	62	66	65	58	67	80
L9	41	41[4]	40	57	50	59	55	42	54	70
L10	50	50	46	59	57	62	60	52	59	73
L11	58	58[4]	52	67	64	69	68	59	64	78
L12	46	46[4]	43	59	56	62	61	49	59	80
L13	46	46	38	60	56	64	61	51	60	73
L14	56	54	44	68	65	69	70	60	69	83
L15	54	52	41	66	63	67	68	53	66	79
L16	58	55	45	73	70	75	75	61	73	84
L18 [3]	58	55	44	71	69	74	72	60	72	98
L19	60	58	44	70	67	72	71	60	68	89
L20 [3]	56	53	43	67	64	69	68	57	66	85
L21	61	57	42	71	67	73	72	62	71	86
L22	53	53	49	59	57	62	60	54	58	79
L23	53	52	46	58	55	61	59	53	58	80

Note 1: ICNG governing periods – Day: 7.00 am to 6.00 pm Monday to Saturday, 8.00 am to 6.00 pm Sunday; Evening: 6.00 pm to 10.00 pm; Night: 10.00 pm to 7.00 am Monday to Saturday, 10.00 pm to 8.00 am Sunday.

Note 2: RNP assessment time periods – Day: 7.00 am to 10.00 pm; Night: 10.00 pm to 7.00 am (weekly data).

Note 3: Monitoring location near to building facade. Measured noise levels considered to represent facade affected noise levels which are up to 2.5 dBA higher than the equivalent free-field condition.

Note 4: Evening RBL reduced to equal daytime RBL in accordance with INP application notes

10.3 Assessment criteria

10.3.1 Construction noise

Construction noise from surface activities

Residential receivers

Noise management levels (NMLs) for residential receivers have been derived based on guidance contained within the ICNG. The approach to determining the NMLs is described in **Table 10.3**.

Table 10.3 Determination of NMLs for residential receivers

Time of day	NML $L_{Aeq(15minute)}$	How to apply
Standard hours: • Monday to Friday 7:00 am to 6:00 pm • Saturday 8:00 am to 1:00 pm • No work on Sundays or public holidays	RBL + 10 dBA	The noise affected level represents the point above which there may be some community reaction to noise. Where the predicted or measured $L_{Aeq(15minute)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
	Highly noise affected 75 dBA	The highly noise affected level represents the point above which there may be strong community reaction to noise. Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restructuring the hours that the very noisy activities can occur, taking into account: • Times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences) • If the community is prepared to accept a longer overall construction period in exchange for restrictions on the daily construction times.
Outside recommended standard hours	RBL + 5 dBA	A strong justification would typically be required for works outside the recommended standard hours. The proponent should apply all feasible and reasonable work practices to meet the noise affected level. Where all feasible and reasonable practices have been applied and noise is more than 5 dBA above the noise affected level, the proponent should negotiate with the community.

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

Project specific NMLs have been developed based on the methodology outlined in **Table 10.3** and the background noise levels (RBL) outlined in **Table 10.2**.

Table 10.4 outlines the project specific NMLs for each of the NCAs.

Table 10.4 Residential receiver NMLs for construction

NCA	Representative monitoring location	Standard hours noise affected level	Out of hours			Sleep disturbance
		Daytime period	Daytime period	Evening period	Night-time period	Night-time period
1	L23	63	58	58	54	64
2	L01	63	58	57	51	61
3	L02	60	55	55	51	61
4	L03	60	55	54	48	58
5	L04	66	61	61	53	63
6	L05	63	58	57	51	61
7	L22	71	66	62	47	57
8	L06	58	53	52	47	57
9	L07	51	46	46	43	53
10	L09	51	46	46	45	55
11	L08	65	60	59	52	62
12	L10	60	55	55	51	61
13	L13	56	51	51	43	53
14	L11	68	63	63	57	67
15	L19	68	63	60	49	59
16	L21	66	61	58	48	58
17	L21	66	61	58	48	58
18	L12	56	51	51	48	58
19	L14	66	61	59	49	59
20	L15	64	59	57	46	56
21	L16	68	63	60	50	60
East of limit of works	L18	57	52	52	44	54

Other sensitive land uses

NMLs for non-residential sensitive land uses are defined within the ICNG and are outlined in **Table 10.5**.

Table 10.5 Noise management levels for non-residential sensitive receivers

Land use	NML $L_{Aeq(15minute)}$ (applied when the property is in use)
Classrooms at schools and other education institutions	Internal noise level 45 dBA (55 dBA external level)
Hospital wards and operating theatres	Internal noise level 45 dBA
Places of worship	Internal noise level 45 dBA (55 dBA external level)
Active recreation areas (characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion)	External noise level 65 dBA
Passive recreation areas (characterised by contemplative activities that generate little noise and where benefits are compromised by external noise intrusion, eg reading, meditation)	External noise level 60 dBA
Community centres	Depends on the intended use of the centre. Refer to the recommended 'maximum' internal levels in AS 2107 for specific uses.

Land use	NML $L_{Aeq(15minute)}$ (applied when the property is in use)
Childcare centres[1]	Play areas • Internal noise level 55 dBA • External noise level 65 dBA Sleep areas • Internal noise level 40 dBA • External noise level 50 dBA

Note 1 No specific guideline noise levels are provided within the ICNG for childcare centres. Levels provided have been adopted for the purposes of this assessment.

Commercial and industrial premises

An external NML of 70 dBA $L_{Aeq(15minute)}$ has been adopted for commercial premises, while a NML of 75 dBA $L_{Aeq(15minute)}$ has been adopted for industrial premises.

Ground-borne noise from tunnelling by roadheader

Residential NMLs are outlined in the ICNG for ground-borne noise, which are applicable when ground-borne noise levels are higher than airborne construction noise levels. Ground-borne noise levels at residences are only provided for the evening and night-time periods, as the objective of these goals is to minimise impacts on amenity and sleep. The following ground-borne NMLs are applicable for residences:

- Evening: 40 dBA $L_{Aeq(15minute)}$
- Night-time: 35 dBA $L_{Aeq(15minute)}$.

The ICNG does not provide guidance in relation to acceptable ground-borne noise levels for commercial receivers. An internal NML of 60 dBA $L_{Aeq(15minute)}$ has been adopted in order to identify potential impacts.

Criteria for vibration from blasting are discussed in **section 10.3.2**.

Construction traffic noise

The ICNG does not provide specific guidance in relation to acceptable noise levels associated with construction traffic. For assessment purposes, guidance is taken from the RNP.

Construction traffic NMLs set at 2 dBA above existing road traffic noise levels are considered appropriate to identify the onset of potential noise impacts. In considering feasible and reasonable mitigation measures where the relevant noise increase is greater than 2 dBA, consideration would also be given to the actual noise levels associated with construction traffic and whether or not these levels comply with the following road traffic noise criteria in the RNP:

- 60 dBA LAeq(15hour) day and 55 dBA LAeq(9hour) night for existing freeway/arterial/sub-arterial roads
- 55 dBA LAeq(1hour) day and 50 dBA LAeq(1hour) night for existing local roads.

Sleep disturbance

This assessment has adopted an external sleep disturbance screening criterion of RBL plus 15 dBA, and a sleep disturbance NML of 55 dBA L_{AFmax} (the maximum fast time weighted noise level from road traffic occurring at a particular location) (internal). The latter equates to an external NML of 65 dBA L_{AFmax} when factoring in open windows.

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

10.3.2 Construction vibration

Vibration damage goals

BS 7385 Part 2-1993 sets guide values for vibration based on the lowest vibration levels above which damage has been credibly demonstrated. **Table 10.6** shows the recommended guideline limits for transient vibration to minimise risk of cosmetic damage to residential and industrial buildings.

Table 10.6 Transient vibration guide values – minimal risk of cosmetic damage

Type of building	Peak component particle velocity in frequency range of predominant pulse 4 Hertz (Hz) to 15 Hz	 15 Hz and above
Reinforced or framed structures. Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
Unreinforced or light framed structures. Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

Note that where continuous vibration gives rise to magnification of vibration by resonance (in specific conditions where the structure can readily store and transfer vibration energy), then the guide values in **Table 10.6** may need to be reduced by up to 50 per cent.

DIN 4150 outlines the safe vibration limits for short-term building vibration in relation to structure damage. These are described in **Table 10.7**.

Table 10.7 DIN 4150 structure damage – safe limits for short-term building vibration

Group	Type of structure	Peak particle velocity (mm/s) At foundation 1 Hz to 10 Hz	 10 Hz to 50 Hz	 50 Hz to 100 Hz[1]	 Plane of floor of uppermost storey All frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 at 10 Hz increasing to 40 at 50 Hz	40 at 50 Hz increasing to 50 at 100 Hz	40
2	Dwellings and buildings of similar design and/or use	5	5 at 10 Hz increasing to 15 at 50 Hz	15 at 50 Hz increasing to 20 at 100 Hz	15
3	Structures that, because of their particular sensitivity to vibration (structurally unsound), do not correspond to those listed in Lines 1 or 2	3	3 at 10 Hz increasing to 8 at 50 Hz	8 at 50 Hz increasing to 10 at 100 Hz	8

Project vibration goals for residential and commercial locations

For most sources of intermittent vibration during construction, such as rock breakers, piling rigs, vibratory rollers and excavators, the predominant vibration energy occurs at frequencies usually in the 10 Hertz to 100 Hertz range. On this basis a vibration damage screening level of 7.5 millimetres per second has been adopted for the purpose of assessing potential impacts from continuous vibration.

In the lower frequency region (below four Hertz), the guide values for building types are reduced, as a high displacement is associated with relatively low peak component particle velocity. To minimise risk of structural damage a guide value of 3.7 millimetres per second has been adopted.

Project vibration goals for heritage buildings

BS 7385 states that ‘a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive’.

Heritage buildings are to be considered on a case by case basis. Where a historic building is deemed, following inspection, to be sensitive to damage from vibration, the more conservative DIN 4150 superficial cosmetic damage criterion of 2.5 millimetres per second should be considered as a screening criterion. Where heritage buildings of a typical residential-type construction are not found to be structurally unsound, the DIN 4150 superficial cosmetic damage criterion of five millimetres per second may be more suitable as a screening criterion.

It should be noted that levels higher than these minimum figures for low frequencies may be quite 'safe', depending on the frequency content of the vibration.

Human comfort goals for construction vibration

For most construction activities that generate perceptible vibration in nearby buildings, the character of the vibration emissions is intermittent. *Assessing Vibration: A technical guideline* nominates preferred and maximum vibration goals for critical areas, residences and other sensitive receivers as shown in **Table 10.8**. The guideline indicates that a low probability of adverse comment or disturbance to building occupants would be expected at or below the preferred values.

The applicable human comfort vibration goal for intermittent vibration source is defined in terms of vibration dose values (VDVs), where the permissible vibration level corresponding to the VDV varies according to the duration of exposure.

Table 10.8 Preferred and maximum vibration dose values for intermittent vibration

Building type	Preferred vibration dose value ($m/s^{1.75}$)	Maximum vibration dose value ($m/s^{1.75}$)
Critical working areas (eg hospital operating theatres, precision laboratories)	0.10	0.20
Residential daytime	0.20	0.40
Residential night-time	0.13	0.26
Offices, schools, educational institutions and places of worship	0.40	0.80
Workshops	0.80	1.60

Note: Daytime is 7:00 am to 10:00 pm and night-time is 10:00 pm to 7:00 am

Recommended safe working distances for vibration intensive plant

Table 10.9 outlines the recommended safe work distances for specific construction plant. These distances are contained within Transport for NSW's *Construction Noise Strategy* (2012d). The recommended safe works distances discussed in **Table 10.9** have been developed to be consistent with BS 7385 and *Assessing Vibration: A technical guideline*. The aim of the recommendations is to minimise the likelihood of cosmetic damage to buildings and disturbance or annoyance to humans. The human response safe working distances are conservative, developed with reference to the more stringent objectives for continuous vibration for typical residential buildings.

Where it is not possible to achieve the distances outlined in **Table 10.9** during construction, due to engineering standards and design requirements, the contractor would undertake vibration monitoring of vibratory plant at the start of activities likely to have an impact, to establish appropriate site-specific working limits.

Table 10.9 Recommended safe working distance for vibration intensive plant

Plant item	Rating/ description	Safe working distance			
		Cosmetic damage			Human response[3]
		Residential and light commercial[1]	Group 2 (typical)[2]	Group 3 (Structurally unsound)[2]	
Vibratory roller	< 50 kN (typically 1-2t)	5 m	7 m	11 m	15 m to 20 m
	< 100 kN (typically 2-4t)	6 m	8 m	13 m	20 m
	< 200 kN (typically 4-6t)	12 m	16 m	15 m	40 m

Plant item	Rating/ description	Safe working distance			
		Cosmetic damage			Human response[3]
		Residential and light commercial[1]	Group 2 (typical)[2]	Group 3 (Structurally unsound)[2]	
	< 300 kN (typically 7-13t)	15 m	20 m	31 m	100 m
	> 300 kN (typically 13-18t)	20 m	26 m	40 m	100 m
	> 300 kN (typically > 18t)	25 m	33 m	50 m	100 m
Small hydraulic hammer	300 kg - 5 to 12t excavator	2 m	3 m	5 m	7 m
Medium hydraulic hammer	900 kg - 12 to 18t excavator	7 m	10 m	15 m	23 m
Large hydraulic hammer	1600 kg - 18 to 34t excavator	22 m	29 m	44 m	73 m
Vibratory pile driver	Sheet piles	2 m to 20 m	3 m	5 m	20 m
Pile boring	≤ 800 mm	2 m (nominal)	3 m	5 m	N/A
Jackhammer	Hand held	1 m (nominal)	2 m	3 m	Avoid contact with structure
Roadheader[4]	Tunnelling	2 m	3 m	5 m	7 m

Note 1: Criteria referenced from British Standard BS 7385 Part 2-1993 *Evaluation and measurement for vibration in buildings Part 2*

Note 2: Criteria referenced from DIN 4150 Structural Damage - Safe Limits for Short-term Building Vibration

Note 3: Criteria referenced from EPA's *Assessing Vibration: a technical guideline (*DEC 2006)

Note 4: Measurement from SLR database

Blasting

Blasting is proposed to be used on the project for part of the construction of the mainline tunnels. Blasting has been considered as an excavation method for the tunnels because the vibration caused by a single blast (airblast) is much shorter than the continuous vibration and ground-borne noise resulting from mechanical excavation equipment such as roadheaders.

Human comfort

Guidance in relation to acceptable overpressure and vibration from blasting is provided in the ICNG, which specifies that the assessment should be based on the levels in the *Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration* (Australian and New Zealand Environment Council (ANZEC) 1990), as follows:

- Airblast overpressure criteria for blasting:
  - Recommended maximum level of 115 dBA (linear peak). This may be exceeded on up to five per cent of the total number of blasts over a period of 12 months
  - A maximum level of 120 dBA (linear peak) should not be exceeded at any time
- Ground vibration criteria for blasting
  - Recommended maximum level of five millimetres per second (peak particle velocity). This may be exceeded on up to five per cent of the total number of blasts over a period of 12 months
  - A maximum level of 10 millimetres per second (peak particle velocity) should not be exceeded at any time.

These criteria relate to sensitive sites, which include houses and low rise residential buildings, theatres, schools and other similar buildings occupied by people.

The blast vibration criteria identified in ANZECC 1990 are considered conservative and were originally developed to protect communities exposed to long-term blasting operations such as at mining sites. For projects such as this, with a shorter duration of blasting of 12 months or less, a higher vibration criterion may be reasonable. For this project, the location of the blast moves along the alignment such that any one receiver is affected for only a short period of time.

Table J4.5(A) in Appendix J of AS2187 presents vibration limits designed to safeguard human comfort in relation to blasting that have been used by some authorities, as it defines clearer vibration limits which are dependent on the specific duration of the project. Based on the limitations of ANZECC 1990 and further guidance in AS2187, a human comfort vibration limit of 10 millimetres per second (peak particle velocity) for blasting operations lasting less than 12 months has been adopted for to this project.

Control of damage

In relation to damage from airblast, AS 2187 notes that from Australian and overseas research, damage (even of a cosmetic nature) has not been found to occur at airblast levels below 133 dBL.

It should be noted that BS 7385 states that ‘a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive’. Nominating appropriate criteria for heritage buildings generally requires site inspections; this would be confirmed during detailed design.

10.3.3 Operational noise

Road traffic noise

The operational road noise assessment was undertaken with guidance from the NCG. The NCG documents Roads and Maritime’s interpretation of the RNP, and provides a consistent approach to identifying road noise criteria for Roads and Maritime projects.

Although it is not mandatory to achieve the noise assessment criteria in the NCG, justification is required if it is not considered feasible or reasonable to achieve them.

Residential receivers

Residences may be assigned ‘new’, ‘redeveloped’, ‘transition zone’ or ‘relative increase criteria’, depending on how the project would influence noise levels. For each facade of the residence, the most stringent applicable criterion is used in the assessment.

Criteria are based on the type of road development by which a residence is affected. In some instances, residences may be exposed to noise from both new and redeveloped roads. In such instances, the proportion of noise from each road is used to establish ‘transition zone criteria’. A further check is made to prevent large increases in noise level using the ‘relative increase criteria’.

The project consists of multiple alternating new and redeveloped road segments, with transition zones at the following locations:

- Along the M4 between Homebush Bay Drive and Concord Road
- Concord Road interchange
- Wattle Street interchange
- Parramatta Road interchange.

The new road criteria apply where the road is in tunnel or has been substantially realigned outside the NCG tolerance band and/or existing grade. However, consideration can be given to whether a road has been substantially realigned for distances less than six times the existing lane width, using local context for guidance. This situation occurs in the vicinity of the Wattle Street and Parramatta Road interchanges, where the road would be realigned to a new location within the tolerance band but over the existing housing footprint.

Figure 10.3 and **Figure 10.4** show where the new and redeveloped road criteria apply.

Figure 10.3 Project road classifications for road traffic noise criteria – Map 1

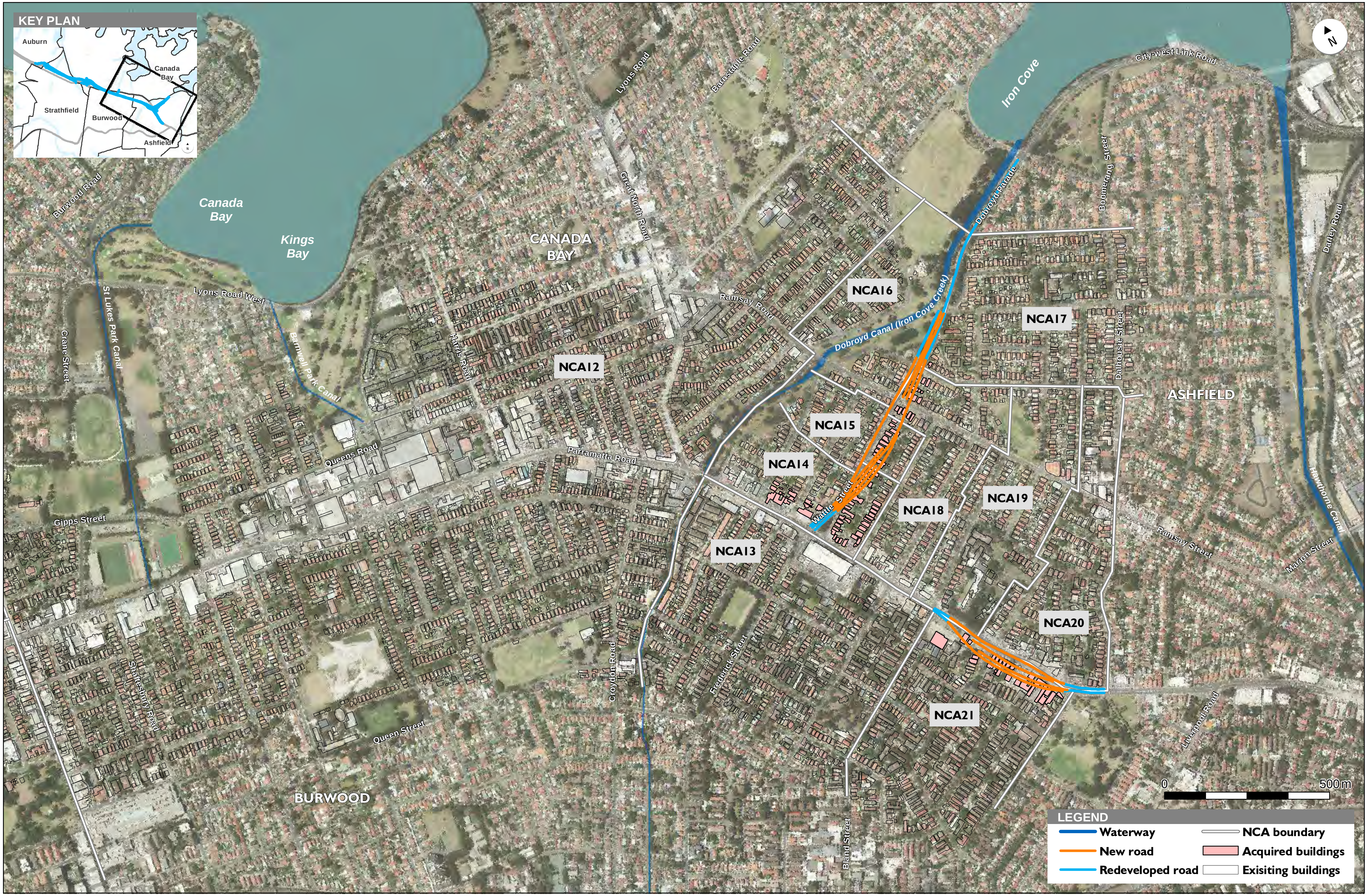

Figure 10.4 Project road classifications for road traffic noise criteria - Map 2

The criteria outlined in the NCG for residential land uses (including aged care facilities) are shown in **Table 10.10**.

Table 10.10 NCG road traffic noise assessment criteria for residential land uses

Road category	Type of project/land use	Assessment criteria (dBA)	
		Daytime (7.00 am – 10.00 pm)	Night-time (10.00 pm – 7.00 am)
Freeway/arterial/ sub-arterial road	1. Residential affected by noise from new freeway/arterial/sub-arterial road corridors	$L_{Aeq(15hour)}$ 55 (external)	$L_{Aeq(9hour)}$ 50 (external)
	2. Residential affected by noise from redevelopment of existing freeway/arterial/sub-arterial roads 3. Residential affected by additional traffic on existing freeways/arterial/sub-arterial roads generated by land use developments	$L_{Aeq(15hour)}$ 60 (external)	$L_{Aeq(9hour)}$ 55 (external)
	4. Existing residences affected by both new roads and the redevelopment of existing freeway/arterial/sub-arterial roads in a transition zone[1]	Between $L_{Aeq(15hour)}$ 55-60 (external)	Between $L_{Aeq(9hour)}$ 50-55 (external)
	5. Existing residences affected by increases in traffic noise of 12dBA or more from new freeway/arterial/sub-arterial roads[2]	Between $L_{Aeq(15hour)}$ 42-55 (external)	Between $L_{Aeq(9hour)}$ 42-50 (external)
	6. Existing residences affected by increases in traffic noise of 12dBA or more from redevelopment of existing freeway/arterial/sub-arterial roads[2]	Between $L_{Aeq(15hour)}$ 42-60 (external)	Between $L_{Aeq(9hour)}$ 42-55 (external)

Note 1: The criteria assigned to the entire residence depend on the proportion of noise coming from the new and redeveloped road. Please refer to Roads and Maritimes' NCG for further information.

Note 2: The criteria at each facade are determined from the existing traffic noise level plus 12dBA.

Other sensitive land uses

The criteria for other sensitive receivers are summarised in **Table 10.11**.

Table 10.11 NCG criteria for other sensitive land uses

Existing sensitive land use	Assessment criteria (dBA)		Additional considerations
	Daytime (7.00 am – 10.00 pm)	Night-time (10.00 pm – 7.00 am)	
School classrooms	$L_{Aeq(1hour)}$ 40 (internal)	-	In the case of buildings used for education or health care, noise level criteria for spaces other than classrooms and wards may be obtained by interpolation from the 'maximum' levels shown in Australian Standard 2107:2000.
Places of worship	$L_{Aeq(1hour)}$ 40 (internal)	$L_{Aeq(1hour)}$ 40 (internal)	The criteria are internal, ie the inside of a church. Areas outside the place of worship, such as a churchyard or cemetery, may also be a place of worship. Therefore, in determining appropriate criteria for such external areas, it should be established which activities in these areas may be affected by road traffic noise.

Existing sensitive land use	Assessment criteria (dBA) Daytime (7.00 am – 10.00 pm)	Night-time (10.00 pm – 7.00 am)	Additional considerations
Open space (active use)	$L_{Aeq(15hour)}$ 60 (external) when in use	–	Active recreation is characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion.
Open space (passive use)	$L_{Aeq(15hour)}$ 55 (external) when in use	–	Passive recreation is characterised by contemplative activities, eg playing chess or reading, that generate little noise and whose benefits are compromised by external noise intrusion.
Childcare facilities	Sleeping rooms $L_{Aeq(1hour)}$ 35 (internal) Indoor play areas $L_{Aeq(1hour)}$ 40 (internal) Outdoor play areas $L_{Aeq(1hour)}$ 55 (external)	–	Multi-purpose spaces, eg shared indoor play/sleeping rooms should meet the lower of the respective criteria. Measurements for sleeping rooms should be taken during designated sleeping times for the facility, or if these are not known, during the highest hourly traffic noise level during the opening hours of the facility.
Aged care facilities	-	-	Residential land use noise assessment criteria should be applied to these facilities (see **Table 10.10**).
Hospital wards	$L_{Aeq(1hour)}$ 35 (internal)	$L_{Aeq(1hour)}$ 35 (internal)	-

Sleep disturbance

The sleep disturbance criteria outlined in **section 10.3.1** also apply to operational road traffic noise.

Operational ancillary facilities criteria

The INP has two separate noise criteria: one to account for intrusive noise, and the other to protect the amenity of particular land uses. These criteria are to be met at the most affected boundary of each relevant property. The more stringent of these two criteria typically determines the project noise goals.

To provide for protection against intrusive noise, the INP states that the L_{Aeq} noise level of the source, measured over a period of 15 minutes, should not be more than five dBA above background noise level.

Table 10.12 outlines the project specific noise criteria for the operational ancillary facilities. The controlling criteria (ie most stringent) are shown in **bold** and would be used for the assessment of these facilities.

Table 10.12 Operational noise goals for operational ancillary facilities

Facility	Location	Operational noise goals (dBA) $L_{Aeq(15min)}$ intrusive	$L_{Aeq(Period)}$ amenity[1,2]	$L_{A1(60sec)}$ sleep disturbance screening level
Tunnel jet fans	Western mainline tunnel portals	51	**45**	61
	Concord Road ramp portals	51	**45** [3]	61
	Wattle Street southbound ramp portals	49	**45** [3]	59
	Wattle Street northbound ramp portals	49	**45** [3]	59

Facility	Location	Operational noise goals (dBA)		
		$L_{Aeq(15min)}$ intrusive	$L_{Aeq(Period)}$ amenity[1,2]	$L_{A1(60sec)}$ sleep disturbance screening level
	Parramatta Road ramp portals	46	**45** [4]	56
Ventilation facilities	Western ventilation facility	51	**45**	61
	Eastern ventilation facility	51	**45** [4]	61
	Fresh air supply facility at Cintra Park	48	**45** [4]	58

Note 1: Bold indicates the controlling design criteria (ie the lower of the intrusiveness and amenity criteria).

Note 2: Criteria are identified as controlling as noise source is continuous throughout the period.

Note 2: An urban night-time amenity noise level of 45 dBA has been applied for the amenity criterion at these locations. This is due to the noise logging locations being adjacent to the road which results in the measured L_{Aeq} noise levels not being representative of all receivers in the catchment.

Note 4: Locations adjacent to Parramatta Road where noise levels may decrease in the future due to reduced traffic volumes. An urban night-time amenity noise level of 45 dBA has therefore been applied for the amenity criterion at these locations.

Sleep disturbance

The sleep disturbance criterion is defined as the existing background noise levels (RBL) plus 15 dBA. The sleep disturbance screening criterion applies outside bedroom windows during the night-time period.

Specific sleep disturbance criteria for properties in the vicinity of operational ancillary facilities are outlined in **Table 10.12**.

10.4 Assessment of construction impacts

10.4.1 Construction activity noise

Although the construction timeframes show activities extending for relatively long durations over the construction phase, in practice, noise impacts from tunnelling operations and most above ground construction activities would be intermittent within these durations and would generally tend to move along the alignment such that impacts are experience at any given receiver for a far shorter duration. Activities associated with fixed sites, such as construction ancillary facilities and spoil handling and tunnelling support sites, would be restricted to the general locality of the site and would affect the same adjacent receivers for longer periods than the main road works.

The construction noise assessment assesses the potential impacts of the project during seven key construction scenarios:

- Demolition of buildings
- Work area establishment
- Temporary road and intersection modifications
- Construction ancillary facilities
- Tunnelling site activities
- Road works
- Ventilation facility construction.

For each scenario, the relevant noise management levels for each NCA are presented, along with a prediction of the extent (if any) to which the noise management level is exceeded for each relevant time period, measured as $L_{Aeq(15minute)}$, which is the ‘energy average noise level’ evaluated over a 15 minute period. Any exceedance is presented as a range, with the lower number representing the least noise intensive scenario and the higher number representing the most noise intensive scenario.

A prediction of the extent (if any) to which the $L_{A1(1minute)}$ levels (the typical ‘maximum noise level for an exceedance in the sleep disturbance screening criterion of RBL plus 15 dBA is also presented, where night-time works are proposed.

Acoustic shielding provided by property boundary fencing has not been included in the construction noise prediction methodology, as the effective acoustic properties of such fencing can vary significantly. The results presented below are therefore considered conservative, as boundary fencing may provide additional noise screening up to around 10 dBA depending on relative orientation of source and receiver. The assessment below also is considered conservative, as it assumes the simultaneous operation of equipment in proximity to receivers. This is therefore considered to be a worst case assessment.

The results of the assessment for each scenario are summarised in the following sections. Further detail is provided in section 10 of the noise and vibration impact assessment in **Appendix I**.

Demolition of buildings

The project involves demolition of buildings within the project footprint. This work would be undertaken during daytime hours only, including potentially outside standard hours on weekends, and would generally involve works at any one location being limited to about seven days per property.

Table 10.13 outlines the predicted exceedances of the noise management levels for residential receivers as a result of the demolition of buildings.

Table 10.13 Residential noise management level exceedances for the demolition of buildings

NCA	Noise management level (dBA)				Noise management level worst case exceedance ($L_{Aeq(15minute)}$ (dBA))				Maximum exceed. of $L_{A1(1min)}$
	Day	Day out of hours	Evening	Night	Day	Day out of hours	Evening	Night	
1	63	58	NA	NA	up to 2	NA	NA	NA	NA
2	63	58	NA	NA	up to 25	NA	NA	NA	NA
3	60	55	NA	NA	up to 13	NA	NA	NA	NA
4	60	55	NA	NA	over 25	NA	NA	NA	NA
5	66	61	NA	NA	up to 11	NA	NA	NA	NA
6	63	58	NA	NA	over 25	NA	NA	NA	NA
7	71	66	NA	NA	over 25	NA	NA	NA	NA
8	58	53	NA	NA	over 25	NA	NA	NA	NA
9	51	46	NA	NA	over 25	NA	NA	NA	NA
10	51	46	NA	NA	up to 17	NA	NA	NA	NA
11	65	60	NA	NA	up to 21	NA	NA	NA	NA
12	60	55	NA	NA	up to 8	NA	NA	NA	NA
13	56	51	NA	NA	over 25	NA	NA	NA	NA
14	68	63	NA	NA	over 25	NA	NA	NA	NA
15	68	63	NA	NA	up to 23	NA	NA	NA	NA
16	66	61	NA	NA	over 25	NA	NA	NA	NA
17	66	61	NA	NA	over 25	NA	NA	NA	NA
18	56	51	NA	NA	over 25	NA	NA	NA	NA
19	66	61	NA	NA	up to 10	NA	NA	NA	NA
20	64	59	NA	NA	up to 25	NA	NA	NA	NA
21	68	63	NA	NA	over 25	NA	NA	NA	NA
Receivers east of project	57	52	NA	NA	up to 11	NA	NA	NA	NA

Note: Results for evening, night-time and sleep disturbance are not applicable (NA), as work would not be carried out during these periods.

The demolition of buildings within the project footprint would result in significant noise impacts during the standard daytime hours, with exceedances of 25 dBA predicted. Exceedances outside standard hours, but still during daytime hours, would also be more than 25 dBA. These exceedances would largely be as a result of using high noise producing plant, such as rockbreakers, close to receivers. The use of such equipment would be limited and would not be required for the full duration of the work.

Other sensitive receivers are generally predicted to be subject to moderate exceedances (ie up to 15 dBA) of the NMLs during the standard daytime construction hours. Seven non-residential sensitive receivers would experience exceedances higher than 15 dBA:

- Place of worship adjacent to works along the M4 in NCA 4 – exceedances up to 25 dBA
- Place of worship adjacent to road works along Concord Road in NCA 6 – exceedances up to 23 dBA
- Place of worship adjacent to road works along Concord Road in NCA 7 – exceedances of more than 25 dBA
- Place of worship adjacent to road works on Wattle Street in NCA 14 – exceedances of more than 25 dBA
- Passive recreation area adjacent to road works on Wattle Street in NCA 16 – exceedances of up to 22 dBA
- Educational facility adjacent to road works at the Parramatta Road civil site (C10) in NCA 19 – exceedances of more than 25 dBA
- Childcare Centre adjacent to road works at the Parramatta Road civil site (C10) in NCA 20 – exceedances of more than 25 dBA.

Typically impacts at receivers are predicted to be negligible in the majority of the NCAs, indicating that the works only result in high impacts for a small proportion of the study area. Typically, NML exceedances in NCAs immediately adjacent to the works would be minor (less than 10 dBA). The exception to this is NCAs 8 and 15, which would experience high exceedances (over 20 dBA) and moderate exceedances (up to 20 dBA) respectively.

Overall these impacts would be short-term, as demolition of each building is likely to be limited to a period of no longer than seven days and would only be undertaken during daytime hours.

Work area establishment

The work area establishment scenario would be contained within the construction footprint, but would involve works directly adjacent to sensitive receivers in some locations. Work area establishment would be undertaken during daytime hours only including, potentially, outside standard hours on weekends.

Table 10.14 outlines the predicted exceedances of the noise management levels for residential properties during the work area establishment scenario.

Table 10.14 Residential noise management level exceedances for work area establishment

NCA	Noise management level (dBA)				Noise management level exceedance ($L_{Aeq(15minute)}$ (dBA))				Maximum exceed. of
	Day	Day out of hours	Evening	Night	Day	Day out of hours	Evening	Night	$L_{A1(1min)}$
1	63	58	NA	NA	over 25	over 25	NA	NA	NA
2	63	58	NA	NA	over 25	over 25	NA	NA	NA
3	60	55	NA	NA	up to 25	over 25	NA	NA	NA
4	60	55	NA	NA	over 25	over 25	NA	NA	NA
5	66	61	NA	NA	up to 24	over 25	NA	NA	NA
6	63	58	NA	NA	over 25	over 25	NA	NA	NA
7	71	66	NA	NA	up to 21	over 25	NA	NA	NA
8	58	53	NA	NA	over 25	over 25	NA	NA	NA
9	51	46	NA	NA	over 25	over 25	NA	NA	NA
10	51	46	NA	NA	up to 24	over 25	NA	NA	NA
11	65	60	NA	NA	up to 25	over 25	NA	NA	NA
12	60	55	NA	NA	over 25	over 25	NA	NA	NA
13	56	51	NA	NA	over 25	over 25	NA	NA	NA
14	68	63	NA	NA	up to 21	over 25	NA	NA	NA
15	68	63	NA	NA	up to 21	over 25	NA	NA	NA

NCA	Noise management level (dBA)				Noise management level exceedance ($L_{Aeq(15minute)}$ (dBA))				Maximum exceed. of $L_{A1(1min)}$
	Day	Day out of hours	Evening	Night	Day	Day out of hours	Evening	Night	
16	66	61	NA	NA	over 25	over 25	NA	NA	NA
17	66	61	NA	NA	over 25	over 25	NA	NA	NA
18	56	51	NA	NA	over 25	over 25	NA	NA	NA
19	66	61	NA	NA	up to 16	up to 21	NA	NA	NA
20	64	59	NA	NA	up to 23	over 25	NA	NA	NA
21	68	63	NA	NA	up to 25	over 25	NA	NA	NA
Receivers east of project	57	52	NA	NA	up to 10	up to 15	NA	NA	NA

Note: Results for evening, night-time and sleep disturbance are not applicable (NA) as work would not be carried out during these periods.

The worst case predicted exceedances of the noise management levels for work area establishment are generally between 20 dBA and 25 dBA during the standard daytime construction hours. Exceedances of the noise management levels are generally predicted to be more than 25 dBA during daytime out of hours works.

Other sensitive receivers are generally predicted to be subject to moderate exceedances of the NMLs (ie up to 15 dBA). Nine non-residential sensitive receivers would experience exceedances of more than 15 dBA during work area establishment:

- Place of worship adjacent to the Underwood Road civil and tunnel site (C3) in NCA 4 – exceedances over 25 dBA
- Place of worship near the Concord Road civil and tunnel site (C5) in NCA 6 – exceedances up to 22 dBA
- Place of worship adjacent to the Concord Road civil and tunnel site (C5) in NCA 7 – exceedances over 25 dBA
- Medical facilities adjacent to the Cintra Park tunnel site (C6) in NCA 12 – exceedances over 25 dBA
- Place of worship adjacent to the Northcote Street tunnel site (C7) and eastern ventilation facility site (C8) in NCA 14 – exceedances over 25 dBA
- Passive recreation area adjacent to the Wattle Street and Walker Avenue civil site (C9) in NCA 16 – exceedances over 25 dBA
- Educational facility adjacent to the Parramatta Road civil site (C10) in NCA 19 – exceedances over 25 dBA
- Childcare centre adjacent to the Parramatta Road civil site C10 in NCA 20 – exceedances over 25 dBA
- Active recreation area adjacent to the Parramatta Road civil site C10 in NCA 22 – exceedances up to 22 dBA.

Typically impacts at receivers are considered to be significantly less than the worst-case scenario outlined in **Table 10.14**. Typically exceedances of the NML during daytime hours would be minor (ie less than 10 dBA), however NCAs 8, 15 and 18 would have higher exceedances due to the size of the areas, meaning separation of receivers from the works is reduced. Out of hours works would typically be minor (ie up to 10dBA) to moderate (between 10 and 20 dBA), with the exception of NCAs 8 and 15 where impacts would be over 20 dBA due to the close proximity of the works. More detail on typical exceedances is provided in Table 33 in the noise and vibration assessment (**Appendix I**).

Work associated with construction ancillary facility establishment would generally be short-term. Impacts from the use of construction ancillary facilities during construction are discussed in the subsection below titled 'Construction ancillary facilities'.

Temporary road and intersection modifications

Work involving temporary road and intersection modifications may be required during out of hours periods, in order to minimise impacts on traffic and ensure the safety of construction workers.

Table 10.15 outlines the predicted exceedances of the noise management levels at residential properties for works associated with temporary road and intersection modifications.

Table 10.15 Residential noise management level exceedances for temporary road and intersection modifications

NCA	Noise management level (dBA)				Noise management level exceedance ($L_{Aeq(15minute)}$ (dBA))				Maximum exceed. of $L_{A1(1min)}$
	Day	Day out of hours	Evening	Night	Day	Day out of hours	Evening	Night	
1	63	58	58	54	-	-	-	-	-
2	63	58	57	51	-	-	-	-	-
3	60	55	55	51	-	-	-	-	-
4	60	55	54	48	-	-	-	-	-
5	66	61	61	53	-	-	-	-	-
6	63	58	57	51	-	-	up to 1	up to 7	up to 1
7	71	66	62	47	-	-	up to 2	up to 17	up to 11
8	58	53	52	47	-	-	up to 1	up to 6	-
9	51	46	48	43	up to 4	up to 9	up to 9	up to 12	up to 6
10	51	46	49	45	-	-	-	-	-
11	65	60	59	52	-	-	-	-	-
12	60	55	55	51	up to - 5	up to 10	up to 10	up to 14	up to 8
13	56	51	51	43	up to 2	up to 7	up to 7	up to 15	up to 9
14	68	63	64	57	up to 4	up to 9	up to 9	up to 15	up to 9
15	68	63	60	49	-	up to 2	up to 5	up to 16	up to 10
16	66	61	58	48	up to 14	up to 19	up to 22	over 25	over 25
17	66	61	58	48	up to 5	up to 10	up to 13	up to 23	up to 17
18	56	51	52	48	up to 12	up to 17	up to 17	up to 20	up to 14
19	66	61	59	49	-	-	-	-	-
20	64	59	57	46	-	up to 5	up to 7	up to 18	up to 12
21	68	63	60	50	up to 1	up to 6	up to 9	up to 19	up to 13
Receivers east of project	57	52	52	44	-	-	-	-	-

Noise impacts associated with temporary road and intersection modifications required as part of the project during standard daytime construction hours would generally only result in minor exceedances. The exception is in NCAs 16 and 18, where exceedances of up to 13 dBA and 17 dBA respectively are predicted. This is largely due to the proximity of the works to the receivers.

Where temporary road and intersection modifications are required to be undertaken at night, exceedances of the NML would be greater than 10 dBA in a number of NCAs, with exceedance of more than 25 dBA experienced within NCA 16.

Other sensitive receivers are generally predicted to be subject to moderate NML exceedances of up to 15 dBA when in use as a result of this construction scenario.

Typically impacts at receivers would be significantly less than the worst-case scenario outlined in **Table 10.15**. Typically exceedances are predicted to be negligible, with exceedances of up to one dBA predicted in NCA 8 only. This indicates that these works would only result in impacts on a small proportion of receivers which are located closest to the works. More detail on typical exceedances is provided in Table 35 in the noise and vibration assessment (**Appendix I**).

Work associated with temporary road and intersection modification would generally be short-term. Impacts from road construction work are discussed in the subsection below titled 'Road construction'.

Construction ancillary facilities

During construction, 10 construction ancillary facilities would operate to support construction activities. These facilities would be contained within the construction footprint, but would involve works located directly adjacent to sensitive receivers in some locations.

Table 10.16 outlines the predicted exceedances of the noise management levels for residential properties as a result of the operation of construction ancillary facilities.

Table 10.16 Residential noise management level exceedances for construction ancillary facilities

NCA	Noise management level (dBA)				Noise management level exceedance ($L_{Aeq(15minute)}$ (dBA))				Maximum exceed. of $L_{A1(1min)}$
	Day	Day out of hours	Evening	Night	Day	Day out of hours	Evening	Night	
1	63	58	58	54	up to 16	3–23	3–23	7–27	19
2	63	58	57	51	up to 21	15–35	16–36	22–42	34
3	60	55	55	51	up to 13	up to 18	up to 18	2–22	14
4	60	55	54	48	up to 20	15–35	16–36	22–42	34
5	66	61	61	53	up to 17	6–26	6–26	14–34	26
6	63	58	57	51	up to 16	5–25	6–26	12–32	24
7	71	66	62	47	-	up to 18	2–22	17–37	29
8	58	53	52	47	up to 24	24–44	25–45	30–50	42
9	51	46	48	43	up to 21	18–38	18–38	21–41	33
10	51	46	49	45	up to 15	5–25	5–25	6–26	18
11	65	60	59	52	up to 13	up to 20	1–21	8–28	20
12	60	55	55	51	up to 20	15–35	15–35	19–39	31
13	56	51	51	43	up to 23	33–53	33–53	36–56	48
14	68	63	64	57	up to 10	12–32	12–32	20–40	32
15	68	63	60	49	up to 10	up to 17	up to 20	11–31	23
16	66	61	58	48	up to 15	2–22	5–25	15–35	27
17	66	61	58	48	up to 14	20–40	23–43	33–53	45
18	56	51	52	48	over 25	1–21	1–21	7–27	19
19	66	61	59	49	up to 4	up to 14	up to 16	6–26	18
20	64	59	57	46	up to 9	up to 19	1–21	12–32	24
21	68	63	60	50	up to 16	20–40	23–43	33–53	45
Receivers east of project	57	52	52	44	-	up to 6	up to 6	up to 14	6

The operation of the construction facilities is predicted to result in exceedances of the NML of more than 10 dBA during the standard daytime hours at residential properties located immediately adjacent to the facilities. Where construction ancillary facilities are to be operated at night, exceedances of more than 20 dBA are predicted in a number of NCAs.

Other sensitive receivers are generally predicted to be subject to moderate exceedances (ie up to 10 dBA) of the NMLs during the standard daytime construction hours. Nine non-residential sensitive receivers would experience exceedances higher than 10 dBA during the use of construction ancillary facilities:

- Place of worship adjacent to the Underwood Road civil and tunnel site (C3) in NCA 4 – exceedances up to 20 dBA
- Place of worship adjacent to the Concord Road civil and tunnel site (C5) in NCA 7 – exceedances up to 17 dBA
- Medical facilities adjacent to the Cintra Park tunnel site (C6) in NCA 12 – exceedances up to 21 dBA
- Active recreation adjacent to the Cintra Park tunnel site (C6) in NCA 12 – exceedances up to 10 dBA

- Place of worship adjacent to the Northcote Street tunnel site (C7) and eastern ventilation facility site (C8) in NCA 14 – exceedances up to 17 dBA
- Passive recreation area adjacent to Wattle Street and Walker Avenue civil site (C9) in NCA 16 – exceedances over 25 dBA
- Educational facility adjacent to the Parramatta Road civil site (C10) in NCA 19 – exceedances up to 17 dBA
- Childcare centre adjacent to the Parramatta Road civil site (C10) in NCA 20 – exceedances up to 22 dBA.

Typically impacts at receivers are considered to be significantly less than the worst-case scenario outlined in **Table 10.16**. Typically exceedances are predicted to be negligible (eg 3 dBA at NCA 18 for the daytime), the exception to this is NCA 8 which would have levels of over 20 dBA. These exceedances are due to the proximity of NCA 8 to the Concord Road construction ancillary facility. More detail on typical exceedances is provided in Table 37 in the noise and vibration assessment (**Appendix I**).

As the compound facilities are at fixed locations, exceedances are considered to be potentially reduced through the implementation of mitigation measures outlined in **section 10.7**.

Road construction

The construction of new road works as part of the project would be undertaken within the construction footprint. This would be likely to involve out of hours works, to minimise impacts on traffic and reduce safety risks for construction workers.

Table 10.17 outlines the predicted exceedances of the NMLs for residential properties as a result of road construction work.

Table 10.17 Residential noise management level exceedance for road works

NCA	Noise management level (dBA)				Noise management level exceedance ($L_{Aeq(15minute)}$ (dBA))				Maximum exceed. of $L_{A1(1min)}$
	Day	Day out of hours	Evening	Night	Day	Day out of hours	Evening	Night	
1	63	58	58	54	over 25	over 25	over 25	over 25	over 25
2	63	58	57	51	over 25	over 25	over 25	over 25	over 25
3	60	55	55	51	over 25	over 25	over 25	over 25	over 25
4	60	55	54	48	over 25	over 25	over 25	over 25	over 25
5	66	61	61	53	up to 24	over 25	over 25	over 25	over 25
6	63	58	57	51	over 25	over 25	over 25	over 25	over 25
7	71	66	62	47	over 25	over 25	over 25	over 25	over 25
8	58	53	52	47	over 25	over 25	over 25	over 25	over 25
9	51	46	48	43	over 25	over 25	over 25	over 25	over 25
10	51	46	49	45	up to 18	up to 23	up to 23	up to 24	up to 17
11	65	60	59	52	over 25	over 25	over 25	over 25	over 25
12	60	55	55	51	up to 8	up to 13	up to 13	up to 17	up to 10
13	56	51	51	43	over 25	over 25	over 25	over 25	over 25
14	68	63	64	57	over 25	over 25	over 25	over 25	over 25
15	68	63	60	49	over 25	over 25	over 25	over 25	over 25
16	66	61	58	48	over 25	over 25	over 25	over 25	over 25
17	66	61	58	48	over 25	over 25	over 25	over 25	over 25
18	56	51	52	48	over 25	over 25	over 25	over 25	over 25
19	66	61	59	49	up to 22	over 25	over 25	over 25	over 25
20	64	59	57	46	over 25	over 25	over 25	over 25	over 25
21	68	63	60	50	over 25	over 25	over 25	over 25	over 25
Receivers east of project	57	52	52	44	up to 22	over 25	over 25	over 25	over 25

Daytime road construction works are predicted to result in exceedances of more than 10 dBA at residential properties that are highly exposed to the works. In some locations, works for new lanes would be located within 15 metres of residential properties. The maximum exceedance would generally be more than 25 dBA during the daytime and night-time periods.

Out of hours works are predicted to result in higher exceedances at all locations when compared to the predicted daytime levels, with exceedances generally being greater than 20 dBA.

Other sensitive receivers are generally predicted to be subject to moderate exceedances (ie up to 15 dBA) of the NMLs during the standard daytime construction hours. Nine non-residential sensitive receivers would experience exceedances higher than 15 dBA during road construction:

- Place of worship adjacent to works along the M4 in NCA 4 – exceedances up to 25 dBA
- Place of worship adjacent to road works along Concord Road in NCA 6 – exceedances up to 25 dBA
- Place of worship adjacent to road works along Concord Road in NCA 7 – exceedances of more than 25 dBA
- Place of worship adjacent to road works at the Parramatta Road and M4 intersection in NCA 11 – exceedances up to 19 dBA
- Place of worship adjacent to road works on Wattle Street in NCA 14 – exceedances of more than 25 dBA
- Passive recreation area adjacent to road works on Wattle Street in NCA 16 – exceedances of more than 25 dBA
- Educational facility adjacent to road works at the Parramatta Road civil site (C10) in NCA 19 – exceedances of more than 25 dBA
- Childcare Centre adjacent to road works at the Parramatta Road civil site (C10) in NCA 20 – exceedances of more than 25 dBA
- Active recreation area adjacent to road works at the Parramatta Road civil site (C10) in NCA 22 – exceedances of more than 25 dBA.

Typically impacts at receivers are considered to be significantly less than the worst-case scenario outlined in **Table 10.17**. Typically exceedances of the NML during daytime hours would be minor (ie less than 10 dBA), however NCAs 8, 15 and 18 would have higher exceedances due to the size of the areas, meaning separation of receivers from the works is reduced. Out of hours works would typically minor (ie up to 10dBA) to moderate (between 10 and 20 dBA), with the exception of NCAs 1, 8, 15 and 18 where impacts would be over 20 dBA due to the close proximity of the works. More detail on typical exceedances is provided in Table 39 in the noise and vibration assessment (**Appendix I**).

The implementation of mitigation measures discussed in **section 10.7** would assist in reducing the severity of the exceedances.

Tunnel construction ancillary facilities

Tunnelling would be carried out 24 hours a day, seven days a week. In order for this to occur, some above ground tunnel construction ancillary facilities would also be required to operate 24 hours a day, seven days a week.

Table 10.18 outlines the predicted exceedances of the NMLs for residential properties as a result of 24 hour tunnelling activities, including any above ground support activities.

Table 10.18 Residential noise management level exceedances for tunnel construction activities

NCA	Noise management level (dBA)				Noise management level exceedance ($L_{Aeq(15minute)}$ (dBA))				Maximum exceed. of $L_{A1(1min)}$
	Day	Day out of hours	Evening	Night	Day	Day out of hours	Evening	Night	
1	63	58	58	54	-	-	-	-	-
2	63	58	57	51	-	up to 1	up to 2	up to 8	up to 3

NCA	Noise management level (dBA)				Noise management level exceedance ($L_{Aeq(15minute)}$ (dBA))				Maximum exceed. of $L_{A1(1min)}$
	Day	Day out of hours	Evening	Night	Day	Day out of hours	Evening	Night	
3	60	55	55	51	-	up to 1	up to 1	up to 5	-
4	60	55	54	48	up to 19	up to 24	up to 25	over 25	over 25
5	66	61	61	53	-	up to 3	up to 3	up to 11	up to 6
6	63	58	57	51	up to 3	up to 8	up to 9	up to 15	up to 10
7	71	66	62	47	up to 7	up to 12	up to 16	over 25	over 25
8	58	53	52	47	over 25	over 25	over 25	over 25	over 25
9	51	46	48	43	over 25	over 25	over 25	over 25	over 25
10	51	46	49	45	up to 9	up to 14	up to 14	up to 15	up to 10
11	65	60	59	52	up to 2	up to 7	up to 8	up to 15	up to 10
12	60	55	55	51	up to 14	up to 19	up to 19	up to 23	up to 18
13	56	51	51	43	up to 10	up to 15	up to 15	up to 23	up to 18
14	68	63	64	57	up to 8	up to 13	up to 13	up to 19	up to 14
15	68	63	60	49	-	-	-	up to 8	up to 3
16	66	61	58	48	-	-	-	up to 2	-
17	66	61	58	48	-	-	-	-	-
18	56	51	52	48	up to 12	up to 17	up to 17	up to 20	up to 15
19	66	61	59	49	-	-	-	up to 3	-
20	64	59	57	46	-	-	-	-	-
21	68	63	60	50	-	-	-	up to 1	-
Receivers east of project	57	52	52	44	-	-	-	-	-

NMLs for residential properties located close to the tunnel construction ancillary facilities are predicted to be exceeded by more than 25 dBA during the night-time period. These exceedances would be restricted to residential properties directly adjacent to tunnelling sites. Where exceedances are expected, properties would be considered for construction mitigation.

Other sensitive receivers are generally predicted to be subject to moderate exceedances (ie up to 15 dBA) of the NMLs during the standard daytime construction hours. The church located on Concord Road adjacent to the project would however experience exceedances of the NMLs of up to 19 dBA.

Typically impacts at receivers are considered to be significantly less than the worst-case scenario outlined in **Table 10.18**. Typically exceedances of the NMLs would be negligible indicating that works only impact on a relatively small number of receivers. Typically NML exceedances in NCAs immediately adjacent to the tunnel sites would be minor (less than 10 dBA). The exception to this is in NCA 8 where exceedances would be moderate (ie up to 20 dBA). More detail on typical exceedances is provided in Table 41 in the noise and vibration assessment (**Appendix I**).

The implementation of mitigation measures discussed in **section 10.7** would assist in reducing the severity of the exceedances.

Ventilation facility construction

The project would include the construction of ventilation facilities.

Table 10.19 outlines the predicted exceedances of the NMLs for residential properties as a result of the construction of the ventilation facilities.

Table 10.19 Residential noise management level exceedances for ventilation facility construction

NCA	Noise management level (dBA)				Noise management level exceedance ($L_{Aeq(15minute)}$ (dBA))				Maximum exceed. of $L_{A1(1min)}$
	Day	Day out of hours	Evening	Night	Day	Day out of hours	Evening	Night	
1	63	58	58	54	-	-	-	-	-
2	63	58	57	51	up to 7	up to 12	up to 13	up to 19	up to 11
3	60	55	55	51	-	up to 4	up to 4	up to 8	-
4	60	55	54	48	up to 10	up to 15	up to 16	up to 22	up to 14
5	66	61	61	53	up to 7	up to 12	up to 12	up to 20	up to 12
6	63	58	57	51	-	-	-	-	-
7	71	66	62	47	-	-	-	-	-
8	58	53	52	47	-	-	-	-	-
9	51	46	48	43	-	-	-	-	-
10	51	46	49	45	-	-	-	-	-
11	65	60	59	52	-	-	-	-	-
12	60	55	55	51	up to 10	up to 15	up to 15	up to 19	up to 11
13	56	51	51	43	up to 1	up to 6	up to 6	up to 14	up to 6
14	68	63	64	57	-	up to 1	up to 1	up to 7	-
15	68	63	60	49	-	-	-	up to 10	up to 2
16	66	61	58	48	-	-	-	-	-
17	66	61	58	48	-	-	-	-	-
18	56	51	52	48	up to 10	up to 15	up to 15	up to 18	up to 10
19	66	61	59	49	-	-	-	up to 1	-
20	64	59	57	46	-	-	-	-	-
21	68	63	60	50	-	-	-	-	-
Receivers east of project	57	52	52	44	-	-	-	-	-

For works during standard daytime hours, minor worst case NML exceedances of less than 10 dBA are predicted at most potentially affected residential receivers. Predicted worst case noise impacts are higher for works undertaken outside standard daytime hours. Other sensitive receivers are generally predicted to be subject to moderate NML exceedances of up to 15 dBA when in use.

Typically impacts at receivers would be negligible, with only those closest to the works affected.

Sleep disturbance

Table 10.14 to **Table 10.19** identify that the $L_{A1(1minute)}$ levels exceed the sleep disturbance criteria for the worst case exceedance during all construction scenarios where works are proposed at night. These impacts would not be experienced within all NCAs. It is noted that the ICNG only requires the proposal to consider maximum noise levels where construction works are planned to extend over more than two consecutive nights.

Cumulative impacts of multiple scenarios

The prediction of cumulative noise levels from more than one construction scenario operating close to another scenario within the proposal area is a complex matter, given the number of sources and possible locations of a particular combination of construction works.

In practice, it is not always possible to specify the precise location of more than one works scenario for the same 15 minute period, and calculating the cumulative impacts based on all nearby works operating simultaneously on a worst case basis results in the assessment becoming overly conservative.

Since the works are anticipated to be of a similar nature, the effect of concurrent construction works is likely only to increase the number of 15 minute periods during construction when the predicted worst case noise impacts would be apparent. In practice, the noise levels would vary due to the fact that plant and equipment would move about the worksites and there would be times when some plant and equipment would not be operating.

Construction scenarios with the potential to generate cumulative impacts include activities at construction ancillary facilities and tunnelling sites. These facilities would include predominantly stationary noise sources which would operate on a day-to-day basis. The worst case impacts on the most potentially affected receivers from the combination of construction ancillary facilities and tunnelling sites operating concurrently are not anticipated to increase significantly beyond the individual scenario impacts. Cumulative noise impacts generated by concurrent operation of construction ancillary facilities and tunnel sites on the worst case construction noise levels are therefore concluded to be minor.

Highly noise affected residential receivers

Receivers are considered to be highly noise affected if noise levels from construction exceed 75 dBA L_{Aeq} during the daytime period.

Table 10.20 outlines the number of residential receivers that would be highly noise affected. The project would result in highly noise affected receivers within all but one NCA for at least one construction scenario. Mitigation measures would be implemented to reduce the number of highly noise affected residential receivers. There are no highly noise affected residential receivers in relation to the 'ventilation facility construction' scenario.

Table 10.20 Highly noise affected residential receivers

NCA	Highly noise affected residential receivers during each construction scenario					
	Work area establishment (daytime only)	Temporary road and intersection modifications	Construction work site (daytime only)	Road works	Tunnelling sites operations	Demolition of properties (daytime only)
1	7	-	2	14	-	-
2	43	-	9	41	-	5
3	14	-	-	33	-	-
4	22	-	7	18	1	30
5	8	-	1	8	-	1
6	21	-	6	27	-	23
7	11	-	-	19	2	19
8	8	-	6	7	1	8
9	15	-	-	23	2	22
10	-	-	-	-	-	-
11	10	-	1	7	-	5
12	15	-	3	-	-	-
13	5	-	4	4	-	10
14	26	-	3	19	2	35
15	34	-	11	39	-	38
16	15	1	6	18	-	13
17	21	-	5	49	-	14
18	19	-	4	31	-	34
19	3	-	-	7	-	1
20	11	-	-	28	-	11
21	38	-	20	43	-	52

Considerations to reduce construction noise levels

The ICNG acknowledges that it is inevitable that construction noise impacts will be associated with most projects. Accordingly, all 'feasible and reasonable' work practices (see **section 10.1** for definition) should be implemented during construction to minimise or remove any noise impacts.

A range of noise mitigation measures has been recommended as part of the noise and vibration assessment. The following sections outline these measures and, where feasible, the effectiveness of these measures.

Temporary acoustic hoarding

In the vicinity of stationary construction activities (ie construction ancillary facilities), acoustic hoarding/barriers around the perimeter of the site would be considered to reduce noise impacts. The installation of such hoarding typically reduces noise levels between five dBA and 10 dBA. As shown in **Table 10.21** the installation of hoardings would reduce the number of highly noise affected receivers by more than 60 per cent. These reductions are based on hoarding heights varying between 2.1 and 4.5 metres (refer to Table 42 of the noise and vibration assessment in **Appendix I** for specific heights).

Table 10.21 Reduction in highly noise affected receivers with acoustic hoarding

NCA	Highly noise affected receivers (no hoarding)	Highly noise affected receivers (with hoarding)
1	1	1
2	7	2
3	-	-
4	6	1
5	-	1
6	5	1
7	-	-
8	5	1
9	-	-
10	-	-
11	-	1
12	3	-
13	-	4
14	3	-
15	8	3
16	5	1
17	4	1
18	4	-
19	-	-
20	-	-
21	5	15
Receivers east of works limit	-	-
Total	**88**	**32**

Acoustic building enclosures at tunnelling sites

In order to sufficiently mitigate noise from 24 hour tunnel activities, a combination of acoustic hoarding and acoustic building enclosures may be required.

The installation of an acoustic shed around the tunnelling shaft and works areas, in combination with temporary acoustic hoarding at the site boundary, is predicted to significantly reduce NML exceedances from construction works undertaken within tunnelling sites and is expected to eliminate almost all highly noise affected receivers. Indicative NML exceedances with acoustic sheds in place have been predicted to reduce the worst-case NML exceedances by 10 dBA.

The detailed design of the tunnelling enclosures would be considered during the construction planning and work area establishment phases of the project. The position of nearby sensitive receivers would be considered when planning the site layout and designing the acoustic enclosure to ensure sufficient noise mitigation is achieved for all surrounding receivers.

Priority construction of noise barriers

The project requires the construction of noise barriers to minimise operational noise. The construction of these barriers as early in the construction period as possible would assist with further reducing noise levels on surrounding receivers in the following locations:

- North of the M4 between Homebush Bay Drive and Underwood Road
- South of the M4 between Homebush Bay Drive and Powell Street
- Surrounding the Concord Road civil and tunnel site
- East of the Northcote Street tunnel site
- South of Wattle Street between Parramatta Road and Waratah Street.

Construction methods and scheduling

Given the potential for high noise levels at residential receivers, adherence to daytime construction hours is recommended for excavation, demolition or rock breaking activities, and for activities concentrated in a single area (ie activities that do not move along the alignment, and do not require out of hours activities for safety reasons or to minimise disruption to road networks). An exception to this recommendation is provided for tunnelling works, which are proposed to operate continuously 24 hours a day, seven days a week to minimise the overall duration of construction and potential impacts on the local community. Additional mitigation measures outlined in **section 10.7.2** would also be implemented to reduce noise levels where possible.

10.4.2 Ground-borne noise

Ground-borne noise impacts have been predicted using a three-dimensional modal which factors in the receiver location and the position of the tunnel. **Figure 10.5** provides indicative ground-borne noise levels for tunnelling equipment based on past tunnelling projects within Sydney. This figure shows that ground-borne noise levels reduce as the distance from tunnelling activities increases.

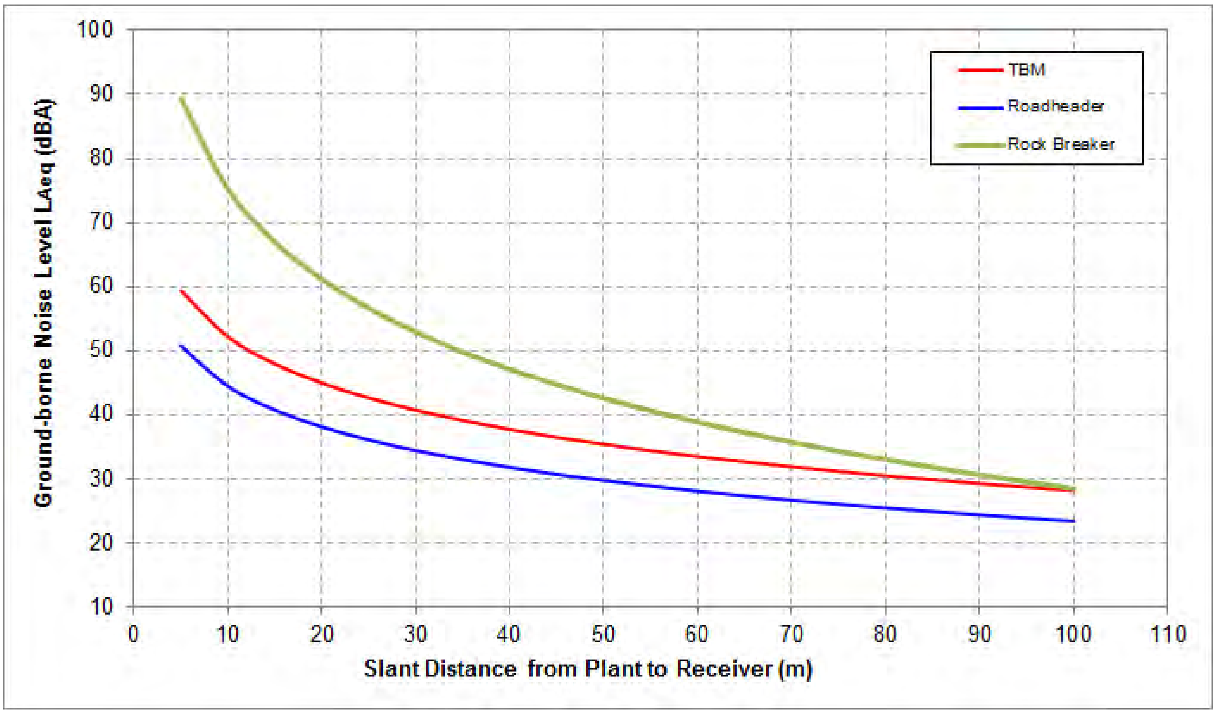

Figure 10.5 Indicative ground-borne noise levels from tunnel boring machines, roadheaders and rock breakers

It should be noted that tunnel boring machines (TBMs) are not proposed to be used for construction of the project.

Where the works are located more than 40 metres from sensitive receivers, ground-borne noise levels comply with the more stringent 35 dBA $L_{Aeq(15minute)}$ night-time criterion. Works are likely to be within 40 metres of tunnelling activities − and therefore exceedances of the criterion may be expected at the nearest receivers – at the following locations:

- In the vicinity of Concord Road at Concord and North Strathfield, where the access tunnels to the mainline tunnels are close to the surface. Receivers in this area would be subject to ground-borne levels of about 45 dBA $L_{Aeq(15minute)}$, which exceeds both the evening and night-time criteria
- Just east of Burwood Road at Burwood (tunnel section), where ground-borne noise levels of up to 37 dBA are predicted. This would result in an exceedance of the night time criterion
- In the vicinity of Frederick Street at Ashfield, where ground-borne noise levels of up to 43 dBA are predicted. This would result in an exceedance of the evening and night time criterion
- In the vicinity of Wattle Street at Haberfield, where the access tunnels to the mainline tunnels are close to the surface. Receivers in this area would be subject to ground-borne noise levels of about 53 dBA LAeq(15minute), which exceeds both the evening and night-time criteria.

Impacts would decrease with distance. Given that tunnelling would progressively move along the alignment at approximately 30 metres per week, it is anticipated that worst case ground-borne noise impacts would only be experienced at any one location for a relatively short period of time.

10.4.3 Construction traffic noise

Table 10.22 outlines the predicted traffic noise increases on roads affected by construction traffic. As shown in **Table 10.22**, construction traffic is generally unlikely to increase traffic noise levels by more than two dBA, which is the level above which additional noise would be noticeable. The exceptions to this are movements on Short Street East and Powell Street (both local roads), where noise levels may increase by more than two dBA. This increase would be noticeable, particularly at the Short Street East site.

Table 10.22 Construction traffic noise levels

Compound	Haulage route	Road	Predicted traffic noise increase (dBA) 1	
			Daytime	Night-time
Homebush Bay Drive civil site (C1) and Pomeroy Street civil site (C2)	Heavy vehicles – via existing M4 Light vehicles – via existing M4 and Pomeroy Street	M4	Less than 0.5	Less than 0.5
		Pomeroy Street	Less than 0.5	Less than 0.5
Underwood Road civil and tunnel site (C3)	Underwood Road and Short Street East	Underwood Road	Less than 0.5	Less than 0.5
		Short Street East	Greater than 2.0 [2]	Greater than 2.0 [2]
Powells Creek civil site (C4)	Heavy vehicles – Powell Street and Underwood Road Light vehicles – Powell Street and Parramatta Road	Powell Street	Greater than 2.0 [2]	n/a
		Underwood Road	Less than 0.5	
		Parramatta Road	Less than 0.5	
Concord Road civil and tunnel site (C5)	Heavy vehicles – Sydney Street (M4 off-ramp) and Concord Road Light vehicles – Alexandra Street and Ada Street	Sydney Street (M4 off-ramp)	Less than 0.5	1.8
		Concord Road	Less than 0.5	0.9
		Alexandra Street	Refer to note 3	
		Ada Street	Refer to note 3	

Compound	Haulage route	Road	Predicted traffic noise increase (dBA) 1	
			Daytime	Night-time
Cintra Park tunnel site (C6)	Heavy vehicles – Parramatta Road Light vehicles – Gipps Street	Parramatta Road	Less than 0.5	Less than 0.5
		Gipps Street	Less than 0.5	Less than 0.5
Northcote Street tunnel site (C7)	Parramatta Road and Wattle Street	Parramatta Road	Less than 0.5	Less than 0.5
		Wattle Street	Less than 0.5	Less than 0.5
Eastern ventilation facility site (C8)	Heavy vehicles – Parramatta Road and Wattle Street Light vehicles – Walker Avenue	Parramatta Road	Less than 0.5	n/a
		Wattle Street	Less than 0.5	
		Walker Avenue	Refer to note 3	
Wattle Street and Walker Avenue civil site (C9)	Wattle Street	Wattle Street	Less than 0.5	<0.5
Parramatta Road civil site (C10)	Heavy vehicles – Parramatta Road Light vehicles – Orpington Street	Parramatta Road	Less than 0.5	<0.5
		Orpington Street	Refer to note 3	

Note 1: Existing traffic noise levels based on traffic modelling undertaken by WDA and/or AADTs where available

Note 2: Estimate at the worst-affected receiver (ie with least existing road traffic noise exposure) based on the assumption that minimal heavy vehicles currently use these local roads. Existing traffic flows on this road are not currently available.

Note 3: As no heavy vehicles are proposed to use these roads, the contribution due to the proposed construction traffic (light vehicles only) is predicted to be lower than the nominated criteria for local roads, and below the existing noise level predicted from nearby major roads. Existing traffic flows on this road are not currently available.

In terms of sleep disturbance, construction traffic on arterial roads is unlikely to significantly increase the number of maximum noise events, given the relatively high existing traffic volumes on these roads.

Construction traffic on local roads may cause a noticeable increase in the number of maximum noise events. This would be the case particularly on Short Street East, where heavy vehicles associated with spoil removal and concrete delivery are proposed at night. Further assessment of night-time maximum noise events on local roads would be undertaken during detailed design, once the requirements for night-time local road access are finalised and more information is available with regard to likely night-time vehicle numbers on the proposed roads.

With appropriate attention to minimising noise through suitable driving, light vehicles are unlikely to exceed the sleep disturbance screening criteria.

10.4.4 Construction vibration

Table 10.23 outlines the number of buildings that are located within the safe work distances identified in **Table 10.9** for the highest vibration plant to be used on site (bored piling, jackhammer, rock anchor drill and rockbreaker).

Table 10.23 Buildings within safe working distance of highest vibration plant

NCA	Number of buildings within safe working distance			
	Cosmetic damage criteria			Human response criteria
	Residential and light commercial	Group 2 (typical buildings)	Group 3 (Structurally unsound)	
1	4	8	-	12
2	9	13	-	48
3	2	7	-	33
4	7	8	-	28
5	-	1	-	8
6	22	24	5	47
7	30	31	2	41
8	4	4	-	10
9	1	3	-	17
10	-	-	-	-
11	3	3	-	9
12	-	-	-	-
13	1	1	1	4
14	20	22	-	45
15	24	25	-	48
16	9	11	-	17
17	11	13	-	37
18	20	20	2	27
19	1	2	2	4
20	7	10	-	14
21	28	32	1	44
Total	**203**	**238**	**13**	**493**

Three properties within NCA 2 would also be within the minimum safe working distances for human response due to the use of roadheaders and rock anchor drill as part of tunnelling activities.

Cosmetic damage impacts

Up to 203 residential and light commercial buildings would be within the safe working distances for these building types, should a large rockbreaker be used along the edge of the construction footprint. Where possible, the positioning of vibration intensive equipment within the construction footprint would be reviewed during detailed design and construction.

Eleven heritage listed buildings would be within the safe working distance for structurally unsound buildings. Ten of these buildings are masonry constructions which are not likely to be structurally unsound; however, one timber building could be potentially structurally unsound. The construction type and structural integrity of all the listed heritage buildings would be investigated during detailed design by a suitably qualified structural engineer. This information would be used to verify the applicable vibration criteria and associated impacts.

This assessment only considered road works and tunnelling construction scenarios. Should any other scenarios require vibration intensive equipment, the safe work distances in **Table 10.9** would be used to determine the indicative safe working distances.

At locations where the predicted and/or measured vibration levels are greater than the nominated screening levels, a more detailed analysis of the building structure, vibration source, dominant frequencies and dynamic characteristics of the structure would be required to determine the applicable safe vibration level.

Human comfort impacts

A low risk of annoyance is predicted as a result of tunnelling works, as works would only likely be within the nominated safe working distance for three buildings within NCA 2, near the western tunnel portals.

Roadwork activities, however, would involve the use of a large rockbreaker which may result in a significant number of receivers (493) being within the nominated safe working distance for human comfort vibration.

The safe working distances identified in **Table 10.9** relate to continuous vibration and apply to residential receivers. For most construction activities, vibration emissions are intermittent in nature; for this reason, higher vibration levels occurring over shorter periods are permitted, as discussed in BS 6472-1.

Cumulative vibration impacts

Due to the intermittent nature of construction work, vibration impacts from multiple work scenarios would be unlikely to result in concurrent vibration peaks. Rather, they may increase the effective duration of the exposure to vibration. Vibration impacts due to multiple simultaneous works would therefore be managed in the same manner as for single works scenarios (dependent on the operating equipment).

10.4.5 Blasting

Blasting is proposed as an excavation technique because the vibration impacts from blasting are of a much shorter duration for nearby sensitive receivers compared to the duration of vibration impacts associated with mechanical excavation methods such as roadheaders or rockbreakers. Blasting would be restricted to the following hours:

- 9.00 am to 5.00 pm Monday to Friday
- 9.00 am to 1.00 pm Saturday
- No blasting on Sundays and public holidays.

Based on vibration site law developed from blasting of the northern section of the Sydney Harbour Tunnel and the typical 30 metres depth of the tunnel, the predicted vibration level for a maximum instantaneous charge of 10 kilograms is 12 millimetres per second. The measures blast emissions data indicates a dominant frequency of the vibration signal of around 20 Hertz at a distance of 30 metres.

The use of a maximum instantaneous charge of 10 kilograms would meet the cosmetic building damage guidelines (ie 26 millimetres per second); however, it would exceed the human comfort criteria (ie 10 millimetres per second). In order to achieve the criteria, a maximum instantaneous charge of seven kilograms would be required to be used.

Further investigations into predicted noise and vibration level would be undertaken following confirmation of the scope of blasting. Where levels are to exceed the criteria alternative methods (eg electronic detonation blasting and penetrating cone fracture) and quantities of material to be used in blasting would be reviewed during detailed design to ensure impacts are minimised.

Measures to mitigate the impacts of blasting are discussed in **section 10.7**.

10.5 Assessment of operational impacts

10.5.1 Road traffic noise assessment

Average noise levels

Operational traffic noise impacts as a result of the project have been assessed using the noise model developed for the project. The model has been used to assess noise levels at sensitive receivers for the nominal year of opening (2021) and 10 years after the nominal year of opening (2031).

Without mitigation

Noise predictions shown in **Table 10.24** indicate that, without the project, many receivers located in the vicinity of the project would be subject to significant noise impacts as a result of traffic on the existing road network without the implementation of operational noise mitigation.

As shown in **Table 10.24**, the project is predicted to result in an overall reduction in the number of receivers where exceedances of the noise criteria are experienced during both the daytime and night-time periods. This reduction is a result of reductions in the numbers of vehicles using some surface roads such as the existing M4 (east of the tunnel portals), Parramatta Road east of Concord Road, and Wattle Street north of Ramsay Street.

About 78 per cent of receivers modelled showed a reduction in noise levels. About 18 per cent experienced a minor increase of up to two dBA, which is generally considered to be unnoticeable for the average person. This relatively minor change in noise levels at the majority of receivers means that the requirement to provide mitigation is largely as a result of existing high noise levels.

Large reductions in noise levels (up to eight dBA) have been identified north of the existing M4, east of the tunnel portals, due to a reduction in the number of vehicles using the surface M4 between the western tunnel portal and Parramatta Road. The project would result in some large increases in noise levels (up to 16 dBA) in the vicinity of the Concord Road (NCAs 7, 8 and 9) and Wattle Street (NCAs 14 to 18) interchanges. These increases are the result of road infrastructure moving closer to some residences, in combination with the removal of other dwellings that would have provided some screening.

Table 10.24 Operational traffic noise without mitigation − exceedances of the noise criteria (all receivers)

NCA	2021 'do minimum'		2021 'do something'		2031 'do minimum'		2031 'do something'	
	Day	Night	Day	Night	Day	Night	Day	Night
1	55	51	54	55	54	55	68	66
2	34	28	13	10	37	33	34	30
3	46	23	44	27	45	27	58	48
4	19	2	16	0	19	3	18	1
5	96	75	54	45	98	76	66	54
6	33	31	13	12	35	33	16	16
7	71	71	78	78	71	72	78	78
8	1	1	-	-	1	1	-	-
9	72	74	71	75	73	74	71	76
10	14	14	2	-	14	17	2	-
11	170	168	131	127	175	181	137	136
12	77	71	70	67	89	73	75	68
13	142	140	135	129	144	142	136	131
14	11	18	16	18	11	22	20	20
15	21	24	29	32	24	27	32	32
16	40	52	46	54	41	53	41	51
17	38	38	43	39	39	40	43	40
18	35	38	37	38	35	38	38	41
19	67	55	65	54	68	56	65	54
20	46	35	43	31	58	43	58	39
21	117	117	144	144	117	120	144	145
Total	**1205**	**1126**	**1104**	**1035**	**1248**	**1186**	**1200**	**1126**

The receivers with predicted exceedances of the noise criteria have been subject to further analysis to determine the following:

- The residential receivers that are also subject to an increase in traffic noise of two dBA or more above the 'do minimum' scenario. These receivers would be eligible for further consideration of additional feasible and reasonable noise mitigation measures, in accordance with the NCG and NMG

- The residential receivers predicted to be acutely affected by traffic noise (a daytime noise level in excess of 65 dBA $L_{Aeq(15\text{-hour})}$ or a night-time noise level in excess of 60 dBA $L_{Aeq(9\text{-hour})}$). These receivers would be eligible for consideration of additional feasible and reasonable noise mitigation measures, in accordance with the NMG.

The outcome of this analysis was that 392 receivers/floors located on 301 properties would be eligible for consideration of feasible and reasonable noise mitigation measures, based on the following triggers:

- The predicted noise levels exceed the NCG controlling criterion and the noise level increase due to the project is greater than two dBA. A total of 76 receivers are triggered on this criterion alone
- The predicted noise level is five dBA or more above the criteria (exceeds the cumulative limit) and the receiver is significantly influenced by project road noise, regardless of the incremental impact of the project. A total of 33 receivers are triggered on this criterion alone
- If the noise level contribution from the road project is acute (daytime $L_{Aeq(15hour)}$ 65 dBA or higher, or night-time $L_{Aeq(9hour)}$ 60 dBA or higher) then it qualifies for consideration of noise mitigation even if noise levels are dominated by another road. No receivers are triggered on this criterion alone
- A total of 283 receivers are triggered by a mix of the above criteria.

Receivers/floors eligible for further consideration of noise mitigation are located across all the NCAs with the exception of NCA 8, which is largely to be acquired by the project. **Table 10.25** summarises the number of receivers that are eligible for further consideration of noise mitigation by NCA.

Table 10.25 Operational traffic noise – receivers eligible for further consideration of noise mitigation

NCA	Eligible for additional mitigation		Eligible for at-property treatment	
	Residential receiver floors (receiver lots)	Other receiver floors (receiver lots)	Residential receiver floors (receiver lots)	Other receiver floors (receiver lots)
1	53 (31)	0 (0)	22 (22)	0 (0)
2	20 (17)	1 (1)	4 (4)	1 (1)
3	31 (29)	4 (3)	26 (25)	4 (3)
4	0 (0)	5 (4)	0 (0)	5 (4)
5	11 (6)	3 (2)	11 (6)	3 (2)
6	10 (10)	1 (1)	10 (10)	1 (1)
7	68 (55)	2 (1)	68 (55)	2 (1)
8	0 (0)	0 (0)	0 (0)	0 (0)
9	2 (2)	0 (0)	1 (1)	0 (0)
10	0 (0)	0 (0)	0 (0)	0 (0)
11	14 (8)	0 (0)	14 (8)	0 (0)
12	0 (0)	0 (0)	0 (0)	0 (0)
13	0 (0)	4 (2)	0 (0)	4 (2)
14	16 (14)	1 (1)	9 (8)	1 (1)
15	28 (26)	0 (0)	18 (16)	0 (0)
16	15 (13)	2 (2)	15 (13)	2 (2)
17	32 (27)	0 (0)	25 (20)	0 (0)
18	13 (10)	0 (0)	8 (6)	0 (0)
19	1 (1)	1 (1)	1 (1)	1 (1)
20	15 (11)	2 (2)	15 (11)	2 (2)
21	37 (21)	0 (0)	37 (21)	0 (0)
TOTALS	**366 (281)**	**26 (20)**	**284 (227)**	**26 (20)**
	392 (301)		**310 (247)**	

Low noise pavement would be provided on new and modified surface sections of the M4 (as shown on **Figure 10.6** and **Figure 10.7**). Other roads have not been considered for low noise pavement due to low travel speeds. Providing low noise pavements would reduce noise levels such that 21 receivers (total floors) no longer require consideration of additional noise mitigation.

The remaining 371 receivers (total floors) at which noise levels are still above the criteria following the installation of low noise pavement would be considered for mitigation through noise barriers. A total of seven new and increased height barriers would be provided as part of the project (refer to **section 5.8.6** in **Chapter 5** (Project description)). These barriers are also shown on **Figure 10.6** and **Figure 10.7**. Modelling including the proposed noise barriers predicts that reductions in noise levels to below the noise criteria would be experienced at 61 receivers (total floors).

Following the installation of low noise pavement and noise barriers, a total of 310 receivers (total floors) would still require consideration for additional mitigation. These properties are shown in **Figure 10.6** and **Figure 10.7** and include 37 multi storey dwellings (over two storeys).

With mitigation

Table 10.26 indicates that the proposed mitigation measures that form part of the project (low noise pavement and noise barriers) would reduce the overall number of receivers that experience exceedances. The reduction in the number of receivers between the 2031 daytime and night-time periods, when compared to the do something scenario (with no mitigation), would be 122 (day) and 103 (night). There would be a slight increase (less than five) in the number of receivers over the criteria in the 'Build' scenario with mitigation compared to the 'Build' scenario without mitigation in NCA12 and NCA16. This is a result of marginal (less than 0.5 dBA) noise differences due to reflections from new noise barriers.

Table 10.26 Operational traffic noise with mitigation − exceedances of the noise criteria (all receivers)

NCA	2021 'do minimum'		2021 'do something'		2031 'do minimum'		2031 'do something'	
	Day	Night	Day	Night	Day	Night	Day	Night
1	55	51	11	11	54	55	29	29
2	34	28	2	2	37	33	5	5
3	46	23	37	22	45	27	48	41
4	19	2	16	0	19	3	16	1
5	96	75	54	45	98	76	66	54
6	33	31	13	12	35	33	16	16
7	71	71	77	77	71	72	77	78
8	1	1	-	-	1	1	-	-
9	72	74	70	74	73	74	70	75
10	14	14	2	-	14	17	2	-
11	170	168	131	127	175	181	136	135
12	77	71	72	67	89	73	76	68
13	142	140	135	129	144	142	136	131
14	11	18	9	8	11	22	10	13
15	21	24	17	22	24	27	20	22
16	40	52	47	57	41	53	45	54
17	38	38	28	31	39	40	26	30
18	35	38	34	35	35	38	34	33
19	67	55	65	54	68	56	65	54
20	46	35	43	31	58	43	57	39
21	117	117	144	144	117	120	144	145
Total	**1205**	**1126**	**1007**	**948**	**1248**	**1186**	**1078**	**1023**

Figure 10.6 Properties eligible for consideration of at-property treatment - Map 1

Figure 10.7 Properties eligible for consideration of at-property treatment - Map 2

Maximum noise levels

Table 10.27 outlines the maximum noise levels measured at each of the monitoring locations. Maximum noise levels typically range from 65 dBA to 85 dBA; however, higher maximums were observed adjacent to Parramatta Road, Wattle Street and Concord Road. Noise levels towards the upper end of the range presented in **Table 10.27** are likely to be from heavy vehicles passing the monitoring location.

Table 10.27 Operational traffic noise – maximum noise levels

Monitoring location	Total night-time events within the monitoring period	Measured maximum noise level (dBA L_{AFmax})	
		Range	Average
L1	62	65-79	72
L3	79	65-77	71
L5	500	69-96	75
L7	210	65-82	70
L9	164	65-82	70
L10	126	68-82	74
L12	181	66-83	73
L13	375	65-85	72
L15	147	74-90	77
L16	165	81-98	84
L18	291	70-86	75
L19	140	81-95	85
L20	366	77-97	83
L21	264	75-93	80
L22	447	74-99	82
L23	363	68-92	75

The maximum noise assessment carried out for the project indicates a potential increase in maximum noise levels in the following locations:

- South of the M4 adjacent to the new westbound M4 bridge, where the existing noise barrier section would not block line of sight to an elevated heavy vehicle exhausts on the new bridge. Typical increases of between 5 dBA and more than10 dBA are predicted. It is noted that some receivers are eligible for consideration of at property treatments in this catchment as part of the project
- North of the M4 adjacent to the new eastbound M4 bridge, where the operational noise barrier would be located to reduce the dominant L_{Aeq} noise source (the main carriageways), but would not provide screening from elevated heavy vehicle exhausts on the new bridge, Typical increases of between 2 dBA and more than10 dBA are predicted. It is noted that some receivers are eligible for consideration of at property treatments in this catchment as part of the project.
- South of the M4 adjacent to the new westbound on-ramp, at the adjacent multi-storey receiver on Powell Street. Typical increases of around 3 dBA are predicted. It is noted that receivers are not eligible for consideration of at property treatments in this catchment as part of the project.
- East of the new Concord Road interchange, where the new on- and off-ramps would be closer to receivers and elevated heavy vehicle exhausts would be above the proposed noise barrier height. Screening has also been reduced due to removal of the front row of buildings. Indicatively, typical increases of between 4 dBA and more than10 dBA are predicted. It is noted that some receivers are eligible for consideration of at property treatments in this catchment as part of the project.
- South of the Parramatta Road interchange, where screening would be reduced due to the removal of the front row of buildings, and the road alignment would be closer to receivers to the south. Typical increases of between 6 dBA and more than 10 dBA are predicted. It is noted that some receivers are eligible for consideration of at property treatments in this catchment as part of the project.

- South of Wattle Street, adjacent to access gaps in the proposed noise barriers, where the road would be closer to receivers. Typical increases of between 5 dBA and more than 10 dBA are predicted. It is noted that some receivers are eligible for consideration of at property treatments in this catchment as part of the project.

The proposed noise barrier designs would reduce the scale of maximum noise levels for receivers, mainly located north of the unchanged existing M4, and parts east of Wattle Street.

Some of the abovementioned receivers may experience an increase in magnitude of maximum noise levels due to changes in view to the road alignment. Detailed investigation of maximum noise levels would be undertaken during detailed design, including consideration of feasible and reasonable noise mitigation on the basis of maximum noise levels.

Noise and vibration impacts from operation of tunnels

During operation, properties located above the mainline tunnels would not experience any noise and vibration impacts as a result of vehicles within the tunnels.

10.5.2 Operational ancillary facilities

Table 10.28 outlines the predicted noise levels and maximum allowable sound power levels for the tunnel jet fans and ventilation facilities, respectively.

Table 10.28 Operational ancillary facilities noise levels

Facility	Location	Operational noise (dBA L_{Aeq})		Comments
		Controlling noise goal	Predicted noise level	
Tunnel jet fans	Western mainline tunnel portals	45	37	Complies with noise goal
	Concord Road ramp portals	51	44	Complies with noise goal
	Wattle Street southbound ramp portals	49	36	Complies with noise goal
	Wattle Street northbound ramp portals	49	41	Complies with noise goal
	Parramatta Road ramp portals	46	37	Complies with noise goal
Ventilation facilities	Western ventilation facility	45	Compliance at nearest receiver would require a maximum allowable sound power level at ventilation outlet of 81 dBA L_{WA}	
	Fresh air supply facility at Cintra Park	45	Compliance at nearest receiver would require a maximum allowable sound power level at ventilation outlet of 76 dBA L_{WA}	
	Eastern ventilation facility	45	Compliance at nearest receiver would require a maximum allowable sound power level at ventilation outlet of 84 dBA L_{WA}	

Predicted noise levels for the ventilation facilities have not been modelled. The design of the facilities and details of plant equipment would be confirmed during detailed design. Therefore, the assessment has provided the maximum allowable sound power levels for plant and equipment at the ventilation facilities in order to achieve compliance at the nearest receiver.

The predicted noise levels indicate that no exceedance of the criteria is anticipated any of the five jet fan locations.

Based on the predicted noise propagation from the ventilation outlets, the recommended maximum allowable sound power level at each ventilation outlet, in order to meet the nominated noise goal at the nearest receiver, is as follows:

- 81 dBA L_{WA} at the western ventilation facility

- 76 dBA L_{WA} at the fresh air supply facility at Cintra Park
- 84 dBA L_{WA} at the eastern ventilation facility.

10.6 Assessment of cumulative impacts

10.6.1 Construction

The M4 Widening project includes a construction compound on the southern side of the existing M4, east of Homebush Bay Drive, associated with the G-loop on-ramp works at Homebush Bay Drive. There is some potential for construction of the project to overlap with construction of the M4 Widening project, which is scheduled for completion in 2017. While it is anticipated that the frequency of potential construction noise impacts may increase during this overlapping period, there are no predicted increases in the worst-case construction noise impacts as presented in **section 10.4.1**, due to the distances between plant items (for either project) and the affected receivers.

No other WestConnex component projects in the vicinity of the project are considered likely to contribute to the predicted worst case cumulative construction noise impacts identified in **section 10.4.1**.

10.6.2 Operation

Operational cumulative impacts of the project as part of WestConnex have been assessed in **section 10.5**, as the modelled scenario for 2031 includes the operation of all components of WestConnex.

10.7 Management of impacts

10.7.1 Project design features that manage impacts

Construction

As described in section 6.5 of **Chapter 6** (Construction work), the project would include the erection of acoustic sheds at the Underwood Road tunnel site (C3), Concord Road tunnel site (C5), Cintra Park tunnel site (C6) and Northcote Street tunnel site (C7). These sheds would minimise the noise impacts resulting from the proposed 24 hour tunnelling activities at each of these sites. The exact nature of these sheds is not yet confirmed and would be further developed during detailed design.

Operation

As outlined in section 5.8.6 of **Chapter 5** (Project description), the project includes the construction of noise barriers to minimise road noise impacts, and provision of low noise pavement for new and modified sections of the existing M4. The location of noise barriers and low noise pavement is shown on **Figure 10.6** and **Figure 10.7**.

10.7.2 Environmental management measures

Environmental management measures relating to noise and vibration during construction and operation are provided in **Table 10.29**.

Table 10.29 Environmental management measures – noise and vibration

Impact	No.	Environmental management measure	Responsibility	Timing
Construction				
General	NV1	A Construction Noise and Vibration Management Plan will be prepared and implemented consistent with the requirements of the *Interim Construction Noise Guideline* (DECC 2009), and will include the following: • Identification of nearby residences and other sensitive land uses • Description of approved hours of work • Description and identification of all construction activities, including work areas, equipment and duration • Description of what work practices (generic and specific) will be applied to minimise noise and vibration • A complaints handling process • Noise and vibration monitoring procedures • Overview of community consultation required for identified high impact works.	Construction contractor	Pre-construction
Construction noise	NV2	Induction and training will be provided to relevant staff and subcontractors outlining their responsibilities with regard to noise.	Construction contractor	Construction
	NV3	Work will be undertaken during standard construction hours as far as feasible and reasonable.	Construction contractor	Construction
	NV4	Where feasible and reasonable, particularly noisy activities such as the use of impact piling rigs, road and concrete saws and rockbreakers, will be scheduled around times of high background noise to provide masking.	Construction contractor	Construction
	NV5	Noisy activities that cannot be undertaken during standard construction hours will be scheduled as early as possible during the evening and/or night-time periods.	Construction contractor	Construction
	NV6	Permanent noise barriers will be scheduled for completion as early as possible in order to minimise construction noise.	Construction contractor	Construction
	NV7	Property treatments identified for the operational phase of the project will be considered for installation before or early in the construction period, where they would improve noise levels.	Construction contractor	Construction

Impact	No.	Environmental management measure	Responsibility	Timing
	NV8	Acoustic sheds to be erected at the Underwood Road tunnel site (C3), Concord Road tunnel site (C5), Cintra Park tunnel site (C6), Northcote Street tunnel site (C7) and eastern ventilation facility site (C8) will be reviewed during construction planning to determine the attenuation level required.	Construction contractor	Pre-construction
	NV9	Temporary acoustic barriers (walls or hoarding) will be considered at all construction ancillary facility and work areas where feasible and reasonable. Recommended heights and locations of these barriers are provided in Table 42 of the noise and vibration assessment in **Appendix I**.	Construction contractor	Pre-construction
	NV10	Night works will be programmed to minimise the number of consecutive nights that work affects the same receivers, where feasible. This would not apply to civil and tunnel sites.	Construction contractor	Construction
	NV11	When working adjacent to schools, particularly noisy activities will be scheduled outside normal school hours, where practicable.	Construction contractor	Construction
	NV12	Works will be scheduled to avoid the coincidence of noisy plant working simultaneously close together and adjacent to sensitive receivers.	Construction contractor	Construction
	NV13	Equipment that is used intermittently will be shut down when not in use.	Construction contractor	Construction
	NV14	Where feasible and reasonable, heavy vehicle movements will be limited to daytime hours.	Construction contractor	Construction
	NV15	Where feasible and reasonable, the offset distance between noisy plant items and nearby noise sensitive receivers will be as large as possible.	Construction contractor	Construction
	NV16	Where feasible and reasonable, equipment with directional noise emissions will be oriented away from sensitive receivers.	Construction contractor	Construction
	NV17	Regular compliance checks on the noise emissions of all plant and machinery will be conducted.	Construction contractor	Construction
	NV18	Ongoing noise monitoring will be undertaken during construction at sensitive receivers during critical periods to identify and assist in managing high risk noise events.	Construction contractor	Construction
	NV19	Reversing of equipment will be minimised to prevent nuisance caused by reversing alarms. Use of non-tonal reversing alarms (‘quackers’) will be implemented to further reduce the nuisance caused by reversing alarms.	Construction contractor	Construction

Impact	No.	Environmental management measure	Responsibility	Timing
	NV20	Loading and unloading will be carried out away from sensitive receivers, where practicable.	Construction contractor	Construction
	NV21	Deliveries will be carried out during standard construction hours where feasible and reasonable.	Construction contractor	Construction
	NV22	Additional noise mitigation measures during out of hours works will be determined on a case-by-case basis using individual receiver predictions, and may consist of offers of alternative accommodation, monitoring, individual briefings, letter box drops, project specific respite offers, phone calls and specific notifications.	Construction contractor	Construction
	NV23	Alternative works methods, such as use of hydraulic or electric controlled units in place of diesel units, will be considered and implemented where feasible and reasonable.	Construction contractor	Construction
	NV24	Respite periods (eg one hour respite for every three hours of continuous construction activity) will be scheduled for high noise impact works where appropriate.	Construction contractor	Construction
Construction traffic noise	NV25	Truck drivers will be advised of designated vehicle routes, parking and queuing locations, acceptable delivery hours and other relevant practices (ie minimising the use of engine brakes, and no extended periods of engine idling).	Construction contractor	Construction
	NV26	Deliveries and spoil removal will be planned to avoid queuing of trucks around construction ancillary facilities.	Construction contractor	Construction
	NV27	As far as practicable, construction vehicle movements along local roads at night will be restricted to light vehicles only, subject to further investigation of potential night-time maximum noise levels during detailed design.	Construction contractor	Construction
	NV28	As far as practicable, heavy vehicle movements outside standard construction hours associated with tunnel support works (spoil removal, concrete delivery and other heavy vehicle movements) will be limited to access and egress directly to and from the arterial road network.	Construction contractor	Construction
	NV29	Spoil removal will be undertaken during the day as far as practicable.	Construction contractor	Construction

Impact	No.	Environmental management measure	Responsibility	Timing
Construction vibration	NV30	Before the start of tunnelling or other vibration intensive works at each site, condition surveys will be undertaken on properties and structures within the preferred project corridor (the zone on the surface equal to 50 metres from the outer edge of the tunnels) and within 50 metres of surface works.	Construction contractor	Construction
	NV31	The safe working distances will be complied with where feasible and reasonable. This will include the consideration of smaller equipment when working close to existing structures.	Construction contractor	Construction
	NV32	If vibration intensive works are required within the safe working distances, vibration monitoring or attended vibration trials will be undertaken at the outset of these works to ensure that levels are within relevant criteria.	Construction contractor	Construction
	NV33	Investigate the feasibility of rescheduling the hours of operation of major vibration generating plant and equipment to less sensitive times such as 9.00 am to 12.00 pm or 2.00 pm to 5.00 pm, if agreed by the community affected.	Construction contractor	Construction
	NV34	Investigations will be undertaken into all heritage items located within the safe working boundary to determine if these structures are structurally unsound, to assist with determining the applicable criteria for each item.	Construction contractor	Pre-construction
	NV35	Building condition surveys of potentially affected structures will be completed both before and after the works to identify existing damage and any damage due to the works.	Construction contractor	Pre-construction and post construction
Ground-bourne noise	NV36	Vibration intensive construction works will be confined to the less sensitive daytime period (9.00 am to 12.00 pm or 2.00 pm to 5.00 pm) as far as reasonably practicable.	Construction contractor	Construction
	NV37	A detailed ground-borne vibration assessment will be undertaken following further geotechnical investigations. This will include developing the vibration site law for the project.	Construction contractor	Construction
Blasting	NV38	Noise and vibration mitigation methods specific to blasting will be incorporated into the CNVMPs where required.	Construction contractor	Construction
	NV39	Blasting will be restricted to standard daytime hours (except where approved by the relevant authority).	Construction contractor	Construction

Impact	No.	Environmental management measure	Responsibility	Timing
	NV40	Site investigations will be conducted prior to production blasting to define suitable blast sizes to comply with project blasting noise and vibration criteria.	Construction contractor	Construction
	NV41	Dilapidation studies of nearby receiver buildings will be undertaken where the potential for exceedances of the blasting criteria is identified.	Construction contractor	Pre-construction
	NV42	Where the predicted levels exceed the noise or vibration criteria for blasting, alternative construction methods, such as penetrating cone fracture, will be utilised.	Construction contractor	Construction
Operational ventilation facility	NV44	Once plant items within the ventilation building are confirmed during detailed design, impacts will be assessed with consideration of the INP modifying factors. Where modifying factors are found to be applicable they will be added to the assessment, and compliance with the INP criteria checked at all receivers.	Construction contractor	Pre-construction
Consultation with impacted receivers	NV45	Community consultation protocols for sensitive receivers likely to be impacted by construction activities such as blasting, vibration and noise will be prepared and implemented.	Construction contractor	Pre-construction and construction
Operation				
Road noise impact	OpNV1	At locations where residual impacts remain after all feasible and reasonable approaches have been exhausted, noise mitigation in the form of acoustic treatment of existing individual dwellings will be considered.	Roads and Maritime	Operation
	OpNV2	Noise barriers will be refined during detailed design to maximise the number of receivers that receive a reduction in exceedances of noise criteria.	Construction contractor	Pre-construction
	OpNV3	Operational traffic noise will be monitored at sensitive receivers for between six months and one year after opening. If the traffic noise levels are above the predicted levels, consideration of additional feasible and reasonable mitigation measures will be undertaken.	Construction contractor	Operation
Operational ancillary facilities	OpNV4	Operational ancillary facilities will be designed to meet project specific noise criteria derived in accordance with the NSW Industrial Noise Policy.	Construction contractor	Pre-construction

At property acoustic treatment

Despite the provision of noise barriers, a number of receiver locations would continue to experience exceedances of the applicable noise assessment criteria. These receivers would be eligible for consideration of further mitigation in the form of at-property acoustic treatments for habitable rooms. For properties where applicable criteria are exceeded by up to 10 dBA, fresh air ventilation, sealing of wall vents and upgraded window and door seals (architectural treatment type 1) would generally be considered appropriate. Where applicable criteria are exceeded by more than 10 dBA additional upgrade of windows and doors may be considered (architectural treatment type 2).

A full list of receivers considered eligible for at-property acoustic treatments, based on the current design of the project, is included in the noise and vibration impact assessment in **Appendix I**. These receiver locations will be confirmed during the detailed design process.

11 Human health

This chapter outlines the potential human health impacts associated with the M4 East project (the project). A detailed human health assessment has been undertaken for the project and is included in **Appendix J**.

The Secretary of the Department of Planning and Environment has issued a set of environmental assessment requirements for the project; these are referred to as Secretary's Environmental Assessment Requirements (SEARs). **Table 11.1** sets out these requirements as they relate to human health, and identifies where they have been addressed in this environmental impact statement (EIS).

Table 11.1 Secretary's Environmental Assessment Requirements – human health

Secretary's Environmental Assessment Requirement	Where addressed in the EIS
An assessment of human health impacts with particular consideration of:	**Chapter 11** (this chapter)
• how the design of the proposal minimises adverse health impacts,	**Sections 11.3** and **11.4**
• human health impacts from the operation of the tunnel under a range of conditions, including worst case operating condition,	**Sections 11.3** and **11.4**
• human health risks and costs associated with the proposal, including those associated with air quality, noise and vibration, and social impacts, during the construction and operation of the proposal, and	**Sections 11.3** and **11.4**
• the Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards (enHealth, 2012) and Air Quality in and Around Traffic Tunnels (NHMRC 2008).	**Section 11.1**

11.1 Assessment methodology

The methodology is based on defining and assessing potential risks to human health from the construction and operation of the project. This assessment has focused on key impacts to air quality, noise and vibration and social changes.

11.1.1 Method of assessment

The methodology adopted for the human health risk assessment is in accordance with national and international guidance that is endorsed or accepted by Australian health and environmental authorities, and includes:

- *Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards: 2012* (enHealth 2012b)
- *Health Impact Assessment Guidelines* (enHealth 2001)
- *Australian Exposure Factors Guide*, EnHealth Council, 2012 (enHealth 2012a)
- B(8) *Guideline on Community Engagement and Risk Communication*, National Environment Protection (Assessment of Site Contamination) Measure, 1999 (National Environment Protection Council Schedule (NEPC) 1999 amended 2013a)
- National Environmental Protection (Air Toxics) Measure, *Impact Statement for the National Environment Protection (Air Toxics) Measure*, 2003 (NEPC 2003)

- *Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual* (Part F, Supplemental Guidance for Inhalation Risk Assessment), EPA-540-R-070-002, January 2009 (United States Environment Protection Agency (USEPA) 2009).

More specifically in relation to the assessment of health impacts associated with exposure to particulates, guidelines available from the NEPC, World Health Organisation (WHO) and the USEPA have been used as required.

This chapter considers the following issues in relation to the assessment of human health impacts:

- Existing conditions (in relation to air quality and noise)
- How the design of the project minimises adverse health impacts
- Human health risks and costs associated with the project, including those associated with air quality, noise and vibration, and social impacts, during the construction and operation of the proposal and estimation of short-term (acute) and long-term (chronic) impacts during construction and operation of the project
- Human health impacts, from within the tunnel and outside of the tunnel, from the operation of the tunnel under a range of conditions, including worst case operating condition.
- Consideration of cumulative impacts (including both the project and the possible future M4-M5 Link) and changes to exposure that are associated with the project.

Key tasks involved in this assessment include:

- A review of all available information and guidelines that relate to the project design
- Outcomes from relevant technical studies undertaken in relation to air quality, noise and vibration which include assessment methodology, criteria, project goals, survey results and analysis
- Identification of populations located in the vicinity of the project who may be exposed to impacts from the project
- A toxicity assessment to identify the adverse health effects and quantitative toxicity values or exposure-response relationships that are associated with the key pollutants identified and evaluated as part of this assessment
- A risk assessment that enabled a calculation of an increased annual risk and an increased incidence of the effect occurring within the population of concern, including qualitative and quantitative assessment as appropriate, and also considering the level of uncertainty associated with all aspects of the technical studies.

The detailed principles, methodology and limitations of the toxicity and risk assessment are provided in section 3 of **Appendix J**.

11.1.2 Study area

The mainline tunnel covers a distance of around five kilometres from Homebush in the west to Haberfield in the east. The population considered in this assessment includes those who live or work within the vicinity of the interchanges and the local road network. The suburbs (or part suburbs) considered are:

- Homebush
- Sydney Olympic Park
- Rookwood
- Ashfield
- Wareemba
- Five Dock
- Summer Hill
- North Strathfield
- Concord
- Strathfield
- Rodd Point
- Leichardt
- Burwood
- Concord West
- Lidcombe
- Haberfield
- Russell Lea
- Croyden
- Canada Bay

The assessment of potential impacts on the surrounding community, particularly in relation to air quality, has considered the location where maximum impacts from the project may occur.

In addition, impacts to community receivers in the wider area have been identified. Community receivers are locations in the local community where more sensitive members of the population, such as infants, young children, the elderly or those with existing health conditions or illnesses, may spend a significant period of time. These locations comprise hospitals, child care facilities, schools and aged care homes/facilities. **Table 11.2** lists the 38 specific community receptors included in the health risk assessment.

A further 10,000 individual receivers have been modelled in the streets/suburbs located close to the project. These individual receivers represent residential homes, workplaces or recreational areas located in the surrounding community. These receptors are referred to as residential, workplace and recreational receivers. The maximum impacts in all of the residential and workplace receivers have also been included in this assessment.

11.1.3 Field survey and analysis

Five air quality monitoring stations were established in the project area to support the development and assessment of the project. The monitoring stations were designed to supplement the existing NSW Office of Environment and Heritage and NSW Roads and Maritime Services stations, to establish representative data and to provide long-term air quality data in the vicinity of the project. Background air quality data relevant to the assessment of carbon monoxide, nitrogen dioxide and particulate matter was collated from these monitoring stations. Data analysis used an air dispersion model (GRAL) to predict changes in ambient air quality associated with a range of emissions scenarios for the operational years 2021 and 2031. The monitoring and modelling details are discussed in **Chapter 9** (Air quality).

Existing ambient noise was measured during a baseline survey early in 2014. Equipment was deployed to 23 locations for a 15 day period in March and April 2014. The background level calculated for use in the noise assessment relates to specific time periods in the *Interim Construction Noise Guideline* (NSW DECC 2009) and *Road noise policy guideline*. In addition, attended monitoring was undertaken at 16 locations to supplement this data. Noise during construction has been assessed using the CONCAWE model (within SoundPLAN 7.1). Operational noise impacts have been assessed for the years 2021 and 2031. The modelling has considered noise impacts in the community both with and without the construction of the project. Details of monitoring stations, noise criteria and modelling are discussed in **Chapter 10** (Noise and vibration).

Air quality monitoring locations and noise survey locations area shown on **Figure 11.1**.

11.2 Existing environment

11.2.1 Population profile

The composition of the populations located within the suburbs considered in this assessment (based on state suburb areas) are available from the Australian Bureau of Statistics for the census year 2011 and are summarised in Table 4.2 and Table 4.3 in **Appendix J**.

The suburbs of interest in the project are located in five local government areas: Auburn, Strathfield, Canada Bay, Burwood and Ashfield. The estimated population growths for these areas (based on information presented in Local District Health Profiles, NSW government) are:

- Strathfield: 22 per cent between 2011 and 2025
- Canada Bay: 69.1 per cent between 2011 and 2025
- Burwood: 27.9 per cent between 2011 and 2025
- Ashfield: 17.2 per cent between 2011 and 2025
- Bankstown: 11.5 per cent between 2015 and 2031.

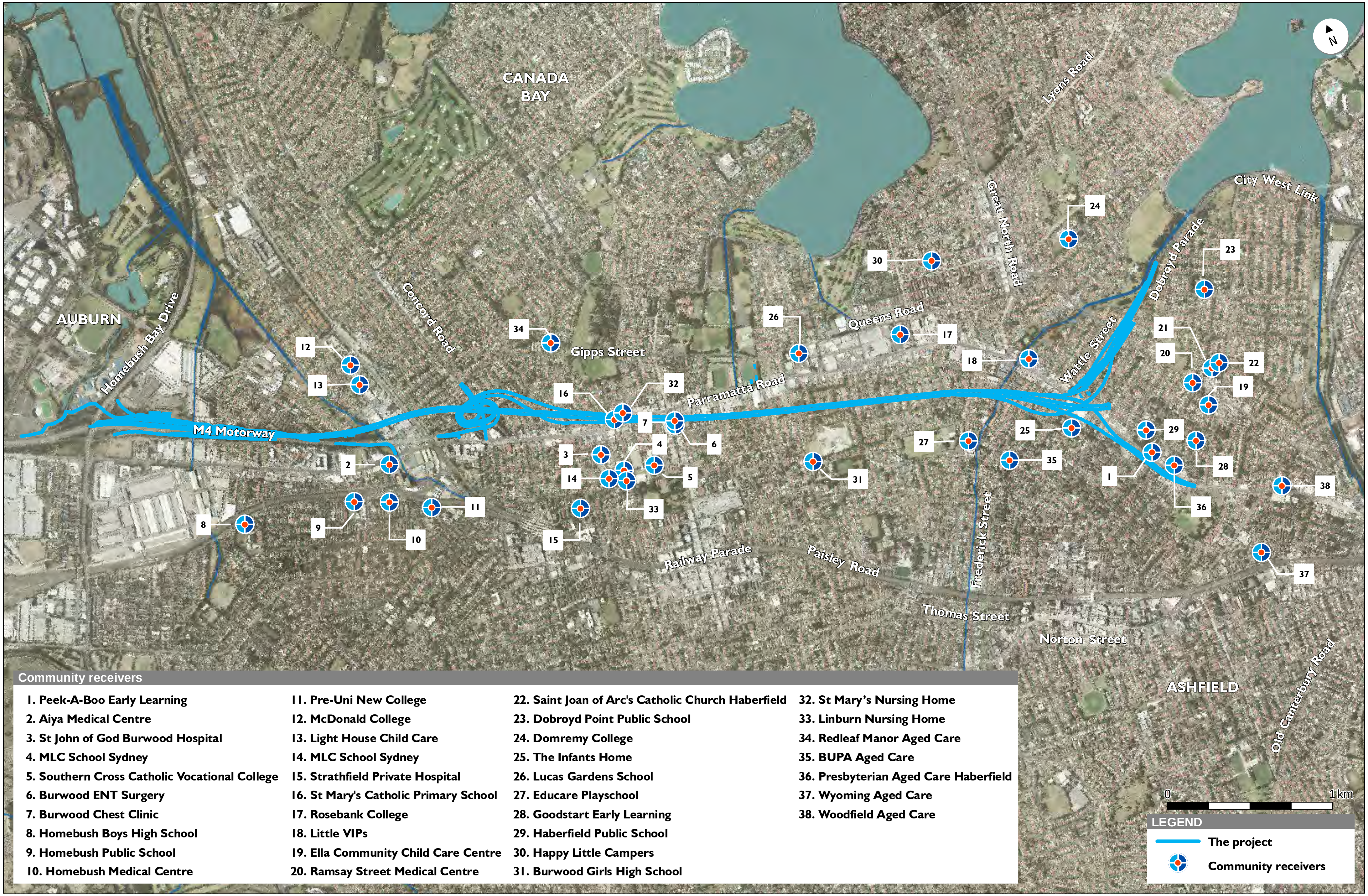

Figure 11.1 Community receivers evaluated in human health risk assessment

Appendix J section 4 provides a detailed description of the social characteristics and economic status of the five local government areas. **Table 11.2** presents a list of the sensitive receptors, termed community receptors included in this assessment. The locations of the receptors are shown on **Figure 11.1**.

Table 11.2 Community receptors included in health risk assessment

Community receptors	Type of receptor	Suburb
Peek-A-Boo Early Learning Centre	Childcare	Haberfield
Aiya Medical Centre	Medical	Homebush
St John of God Burwood Hospital	Medical	Burwood
MLC School Sydney	School	Burwood
Southern Cross Catholic Vocational College	School	Burwood
Burwood ENT Surgery	Medical	Burwood
Burwood Chest Clinic	Medical	Burwood
Homebush Boys High School	School	Strathfield
Homebush Public School	School	Strathfield
Homebush Medical Centre	Medical	Strathfield
Pre-Uni New College	School	Strathfield
McDonald College	School	North Strathfield
Light House Child Care	Childcare	North Strathfield
MLC School Sydney	School	Burwood
Strathfield Private Hospital	Medical	Strathfield
St Mary's Catholic Primary School	School	Concord
Rosebank College	School	Five Dock
Little VIPs	Childcare	Haberfield
Ella Community Child Care Centre	Childcare	Haberfield
Ramsay Street Medical Center	Medical	Haberfield
St. John of Arc Catholic Primary School	School	Haberfield
Saint Joan of Arc's Catholic Church Haberfield	Place of worship	Haberfield
Dobroyd Point Public School	School	Haberfield
Domremy College	School	Five Dock
The Infants Home	Childcare	Ashfield
Lucas Gardens School	School	Canada Bay
Educare Playschool	Childcare	Croydon
Goodstart Early Learning	Childcare	Haberfield
Haberfield Public School	School	Haberfield
Happy Little Campers	Childcare	Five Dock
Burwood Girls High School	School	Burwood
St Mary's Nursing Home	Aged care	Concord
Linburn Nursing Home	Aged care	Burwood
Redleaf Manor Aged Care	Aged care	Concord
BUPA Aged Care	Aged care	Ashfield
Presbyterian Aged Care Haberfield	Aged care	Haberfield
Wyoming Aged Care	Aged care	Summer Hill
Woodfield Aged Care	Aged care	Haberfield

11.2.2 Existing health of population

The health of the community is influenced by a complex range of interacting factors including age, socio-economic status, social capital, behaviours, beliefs and lifestyle, life experiences, country of origin, genetic predisposition and access to health and social care. Information in relation to health-related behaviours (that are linked to poorer health status and chronic disease including cardiovascular and respiratory diseases, cancer, and other conditions that account for much of the burden of morbidity and mortality in later life) are available for large health population areas in Sydney and NSW. This includes risky alcohol drinking, smoking, consumption of fruit and vegetables, being overweight and obese and adequate physical activity. A review of data from NSW Health (2015) generally indicates the:

- Population in the Sydney area have similar rates of risky alcohol drinking and smoking and similar intakes of recommended consumption of fruit and vegetables compared with NSW
- Population in the Sydney area have higher rates of adequate physical activity, and lower rates of overweight and obesity compared with NSW
- Local government areas of Ashfield, Burwood and Strathfield have similar rates for psychological distress compared with NSW and Canada Bay has slightly lower rates for psychological distress compared with NSW
- Rate of mortality for the indicators presented in the Sydney Area Health Service is slightly lower than but similar to that reported for NSW (indicators: cardiovascular disease, various lung conditions)
- Rate of hospitalisations for the indicators presented in the Sydney Area Health Service is slightly lower than but similar to that reported for NSW (indicators diabetes, cardiovascular disease, asthma (5–34 years) and various lung conditions (65+ years))
- Population in the local government areas, including the larger Sydney area, the health statistics (including mortality rates and hospitalisation rates for most of these categories) are generally lower than compared with a number of other health areas and the whole of NSW.

Appendix J section 4.5 provides further details on health related behaviours and health indicators for the project area.

11.2.3 Existing air quality

The project lies within an urbanised area of Sydney. In large urban areas there is usually a complex interaction of pollution sources, substantial concentration gradients, short-term meteorological conditions and local topography.

Air quality in the Sydney region has improved over the last few decades. The improvements have been attributed to initiatives to reduce emissions from industry, motor vehicles, businesses and residences. While levels of nitrogen dioxide, sulphur dioxide and carbon continue to be below national standards, levels of ozone and particles ($PM_{2,5}$ and PM_{10}) can occasionally exceed the standards. For these pollutants there are a large number of sources in the project area including other combustion sources (other than from the project), other local construction/earthworks and personal exposures (such as smoking) and risk taking behaviours that have the potential to affect the health of any population.

A full description of existing air quality is provided in **Chapter 9** (Air quality).

11.2.4 Existing noise and vibration

The results of the noise monitoring demonstrate that existing average maximum noise level events typically range from 65 to 85 dB(A) LAFmax at the monitoring locations along the project area. Locations immediately adjacent to Parramatta Road, Wattle Street and Concord Road were observed to have the higher existing maximum noise level events as a result of the relatively short setback and no screening from the road. Noise level events towards the upper end of the range are likely to be from heavy vehicles, with light vehicles tending towards the lower end of the range (if present).

A full description of the existing noise environment is provided in **Chapter 10** (Noise and vibration).

11.3 Assessment of construction impacts

11.3.1 Air quality

Chapter 9 (Air quality) has evaluated impacts to air that may occur during construction. The assessment considered impacts that may occur during tunnelling activities and surface works and involved a qualitative assessment approach. For almost all construction activities, significant impacts on receptors would be prevented through project design and effective mitigation measures. However, dust management measures may not be effective all of the time. In situations where the management measures are not fully effective, such impacts would be temporary and short-lived and are not considered to be of significance. A construction air quality management plan would be developed and implemented for all construction activities of the project.

11.3.2 Noise and vibration

As described in **Chapter 10** (Noise and vibration), a worst case assessment (excluding mitigation measures) has been used in accordance with the *Interim Construction Noise Guideline* (NSW DECC 2009a) for the assessment of construction noise. For each area assessed, the noise levels at the most affected receiver have been used to represent the whole area.

Construction noise

Noise impacts in excess of the criteria have been identified at a number of receivers during site establishment works, temporary road closures and intersection modifications, works within the various construction compounds, construction of surface roadways, tunnelling works, demolition of acquired structures and construction of fixed facilities. Hence a range of mitigation measures would be implemented to mitigate and manage impacts.

It is likely that the screening criterion for sleep disturbance would be exceeded for night works adjacent to residential receivers for most works scenarios. The level of noise predicted for the project is typical for construction works using noise intensive equipment in built up areas. Construction works would be undertaken during daytime hours wherever possible. Further consideration of the need for noise mitigation measures where works are required at night would be undertaken during detailed design.

Construction traffic

Potential increases in noise for sensitive receivers due to construction traffic have been assessed separately from the assessment of noise from other construction activities.

Heavy vehicles involved in construction would use the existing arterial road network (M4, Parramatta Road, Wattle Street and Concord Road). Access and use of local roads has been evaluated in **Chapter 10** (Noise and vibration). The assessment found that Short Street East and Powell Street in Homebush Bay were the most affected local roads proposed to carry heavy construction vehicles. Other local roads around the construction ancillary facilities would be much less affected.

Ground-borne noise

Detailed three-dimensional modelling has been undertaken for the project to predict potential elevated noise due to ground-borne noise. Ground-borne noise occurs when works are being undertaken under the ground surface or in some other fashion that results in the vibrations from noise moving through the ground rather than the air. This project involves tunnelling so many of the more significant noise activities would be present at depth (approximately 40 metres below ground level).

The modelling has addressed the worst case situation when the tunnelling is occurring immediately beneath a sensitive receiver. The tunnelling equipment would move at about 10 metres per day so would be directly underneath a sensitive receiver for a relatively short time (2–3 days).

The worst-case ground-borne noise levels are predicted to be compliant with the more stringent 35 dB(A) LAeq(15minute) night-time criterion at the majority of receivers which are potentially affected by ground-borne noise from tunnelling works.

At locations near interchanges where the tunnel rises to meet surface roads (Homebush Bay Drive, Concord Road, Wattle Street and Parramatta Road) some exceedance of the evening and night-time noise criteria may occur.

Vibration impacts

Some of the equipment which would be used in construction would have the potential to cause unacceptable levels of vibration.

Managing the potential for such vibration to actually cause discomfort or structural damage at sensitive receiver locations is based on ensuring suitable separation distances between the equipment and the receiver locations.

The assessment undertaken indicates a low risk of annoyance from the proposed tunnelling works using a roadheader with all receivers outside the nominated safe working distance except three receivers in NCA02 near the tunnel dives.

Assessment of the proposed roadworks using a large rock breaker may result in a significant number of receivers (just fewer than 500 residential receivers across the project) within the nominated safe working distance for human comfort vibration.

In relation to human comfort (response), the safe working distances relate to continuous vibration and apply to residential receivers. For most construction activities, vibration emissions would be intermittent in nature and for this reason, higher vibration levels, occurring over shorter periods are permitted.

Receivers adjacent to construction areas have been identified as likely to perceive vibration impacts at times during construction works. This is expected to be primarily due to works associated with rock breakers and other high vibration plant items such as heavy vibratory rollers. In practice vibration impacts from most construction activities would be intermittent within the duration of the proposal and generally tend to move along the alignment such that impacts at any given receiver are for a far shorter duration. The required locations for vibration intensive equipment would be reviewed during detailed design when more specific information is available.

Blasting impacts

Detailed analysis would be undertaken in the detailed design phase of the project to determine compliance with the relevant criteria. Blasting activities would only occur underground during standard daytime hours (except where approved by the relevant authority). These works would be managed such that the criteria are not exceeded. Building condition surveys would be required for nearby buildings where it is identified that there may be potential for exceedances of the vibration criteria related to blasting.

11.4 Assessment of operational impacts

11.4.1 Air quality

The assessment of impacts to air associated with the project has considered a range of scenarios that include the current situation and operation for the future years 2021 and 2031 with and without the project outside of the tunnel. This assessment has focused on key pollutants that are associated with vehicle emissions:

- Volatile organic compounds (VOCs)
- Polycyclic aromatic hydrocarbons (PAHs)
- Carbon monoxide (CO)
- Nitrogen dioxide (NO_2)
- Particulate matter ($PM_{2.5}$ and PM_{10}).

The assessment of changes in air quality relate to the discharge of air from within the tunnel to atmosphere via the two ventilation outlets located at the eastern and western ends of the tunnel.

There are in-tunnel air quality limits that are required to be met under all operational circumstances (except emergencies such as fire). The tunnel ventilation system and tunnel operational parameters are designed to ensure the in-tunnel concentration limits are not exceeded and limit the discharge of pollutants to the external air. Additional details on the assessment scenarios, locations of monitoring stations and the emission sources and limits considered are summarised in **Chapter 9** (Air quality).

Vehicle emissions

Emissions from vehicles using the tunnel have been estimated based on published emission factors relevant to vehicle fleets in the year 2020. These emissions have been assumed to remain the same for assessing impacts in 2021 and 2031. **Chapter 9** (Air Quality) describes the traffic mix and the emissions used in the air quality assessment scenarios. The mix of vehicles has been assumed to be the same for vehicles within the tunnel and for vehicles on surface roads.

Volatile organic compounds and polycyclic aromatic hydrocarbons

VOCs and PAHs are associated with emissions from vehicles using the tunnel and the local surface road network, with levels dependent on the mix of vehicles.

Most of the VOC emissions comprise a range of hydrocarbons. From a toxicity perspective the key volatile organic compounds that have been considered for the vehicle emissions are BTEX, 1,3-butadiene, acetaldehyde and formaldehyde (consistent with those identified and targeted in studies conducted in Australia on vehicle emissions (Department of Environment and Heritage 2003; EPA 2012).

The predicted (incremental) concentration of individual VOCs and PAHs associated with the project (based on the speciation as outlined above) have been reviewed against published peer-reviewed health based guidelines that are relevant to acute and chronic exposures (where relevant). The health based guidelines adopted (identified on the basis of guidance from enHealth 2012) are relevant to exposures, both acute and chronic, that may occur to all members of the general public (including sensitive individuals) with no existing adverse health effects. The proportion of each of the key VOCs considered are derived from the 2008 Air Emissions Inventory for the Greater Metropolitan Region in NSW (EPA 2012).

A summary of the speciation profile of VOCs for the different vehicle types considered in the project as well as the weighted mass fraction for these volatile organic compounds considered for the project is presented in **Appendix J**.

Table 11.3 and **Table 11.4** present a summary of the maximum predicted one-hour or annual average concentrations of VOCs and PAHs assessed on the basis of a threshold with comparison against acute and chronic health based guidelines. The table also presents a Hazard Index (HI) which is the ratio of the maximum predicted concentration to the guideline. Each individual HI is added up to obtain a total HI for all threshold VOCs and PAHs considered. The total HI is a sum of the potential hazards associated with all the threshold VOCs and PAHs together assuming the health effects are additive, and is evaluated as follows (enHealth 2012a):

- A total HI less than or equal to one means that all the maximum predicted concentrations are below the health based guidelines and there are no additive health impacts of concern
- A total HI greater than one means that the predicted concentrations (for at least one individual compound) are above the health based guidelines, or that there are at least a few individual VOCs and PAHs where the maximum predicted concentrations are close to the health based guidelines such that there is the potential for the presence of all these together (as a sum) to result in adverse health effects.

The values presented in the tables have been rounded to two significant figures for individual HI calculations and one significant figure for the total HI and total carcinogenic risk, reflecting the level of uncertainty in the calculations presented.

The following evaluation is based on the maximum predicted change (incremental) concentration in air for 2021, 2031 and the cumulative scenario as modelled in the Air Quality Assessment Report, **Appendix H**. Concentrations in all other areas of the surrounding community are lower than evaluated in this assessment. In most locations the change due to the project is a lowering of VOC and PAH concentrations in air (ie beneficial).

Table 11.3 Assessment of acute exposures to VOCs – maximum impacts in community associated with project

Key VOC	Maximum predicted 1-hour average concentration associated with project and calculated HI					
	2021		2031		Cumulative - 2031	
	Max concentration (µg/m^3)	HI	Max concentration (µg/m^3)	HI	Max concentration (µg/m^3)	HI
Total VOCs	**172**		**109**		**113**	
Toluene	14	0.0031	7.9	0.0017	9.0	0.0020
Xylenes	11	0.0052	6.6	0.0030	7.5	0.0034
1,3-Butadiene	1.9	0.0029	1.2	0.0018	1.2	0.0019
Formaldehyde	4.3	0.29	3.6	0.24	2.8	0.19
Acetaldehyde	2.2	0.0048	1.6	0.0035	1.5	0.0031
	Total HI	**0.3**		**0.2**		**0.2**

Table 11.4 Assessment of chronic exposures to VOCs and PAHs – maximum impacts in community associated with project

Key VOCs and PAHs	Maximum predicted annual average concentration associated with project and calculated HI					
	2021		2031		Cumulative - 2031	
	Max Concentration (µg/m^3)	HI	Max Concentration (µg/m^3)	HI	Max Concentration (µg/m^3)	HI
Total VOCs	**2.8**		**1.6**		**1.2**	
Toluene	0.17	0.000035	0.095	0.000019	0.075	0.000015
Xylenes	0.14	0.00065	0.079	0.00036	0.062	0.00028
1,3-Butadiene	0.027	0.090	0.015	0.050	0.012	0.039
Formaldehyde	0.12	0.036	0.073	0.022	0.052	0.016
Acetaldehyde	0.051	0.011	0.030	0.0067	0.022	0.0049
Total PAHs	**0.00084**		**0.00050**		**0.00038**	
Naphthalene	0.00055	2×10^{-4}	0.00033	1×10^{-4}	0.00025	8×10^{-5}
Acenaphthylene	0.000045	2×10^{-7}	0.000027	1×10^{-7}	0.000020	1×10^{-7}
Acenaphthene	0.000012	6×10^{-8}	0.0000069	3×10^{-8}	0.0000053	3×10^{-8}
Fluorene	0.000058	4×10^{-7}	0.000034	2×10^{-7}	0.000026	2×10^{-7}
Phenanthrene	0.000012	8×10^{-7}	0.000068	5×10^{-7}	0.000052	4×10^{-7}
Anthracene	0.0000093	9×10^{-8}	0.0000055	5×10^{-8}	0.0000041	4×10^{-8}
Fluoranthene	0.0000067	4×10^{-8}	0.0000040	3×10^{-8}	0.0000030	2×10^{-8}
Pyrene	0.000012	1×10^{-7}	0.0000069	7×10^{-8}	0.0000053	5×10^{-8}
	Total HI	**1**		**1**		**0.9**

Table 11.5 presents a summary of the calculated incremental lifetime carcinogenic risk associated with exposure to the maximum predicted concentrations of benzene and carcinogenic PAHs (as benzo(a)pyrene TEQ). The calculated risks are considered in conjunction with what are considered negligible, tolerable/acceptable and unacceptable risks as outlined in **Appendix J**.

Table 11.5 Assessment of incremental lifetime carcinogenic risk – maximum impacts in community associated with project

Key VOC	Maximum predicted 1-hour average concentration associated with project and calculated HI					
	2021		2031		Cumulative - 2031	
	Maximum concentration (µg/m^3)	ILCR	Maximum concentration (µg/m^3)	ILCR	Maximum concentration (µg/m^3)	ILCR
Benzene	0.10	3×10^{-7}	0.055	2×10^{-7}	0.043	1×10^{-7}
Benzo(a)pyrene TEQ	0.0000076	3×10^{-7}	0.0000045	2×10^{-7}	0.0000034	2×10^{-7}
Total carcinogenic risk		**6×10^{-7}**		**4×10^{-7}**		**3×10^{-7}**

For the assessment of acute exposures to VOCs (**Table 11.3**), the calculated HI associated with exposure to the maximum concentrations predicted is less than one for 2021, 2031 and the cumulative scenario. On this basis there are no acute risk issues in the local community associated with the project.

For the assessment of chronic exposures to VOCs and PAHs (**Table 11.4**), the calculated HI associated with exposure to the maximum concentrations predicted is less than or equal to one for 2021, 2031 and the cumulative scenario. For the assessment of lifetime cancer risks associated with the maximum change in benzene and carcinogenic PAHs (as benzo(a)pyrene TEQ) are all below 1x10-6 and are considered to be negligible. On this basis there are no chronic risk issues in the local community associated with the project. It is noted that the calculations undertaken for PAHs is based on a conservative estimate of the fraction of emissions from vehicles that comprises PAHs (as a percentage of total VOCs). The approach adopted is expected to overestimate concentrations of PAHs in air. Hence the calculations presented in **Table 11.4** are considered to be a conservative upper limit estimate.

Carbon monoxide

Adverse health effects of exposure to carbon monoxide are linked with carboxyhaemoglobin (COHb) in blood. Association between exposure to carbon monoxide and cardiovascular hospital admissions and mortality, especially in the elderly for cardiac failure, myocardial infarction and ischemic heart disease; and some birth outcomes (such as low birth weights) have been identified (NEPC 2010). Guidelines are available in Australia from NEPC and NSW EPA (OEH) that are based on the protection of adverse health effects associated with carbon monoxide. These guidelines consider exposures to carbon monoxide has considered ‘lowest observed adverse effect level’ and ‘no observed adverse effect level’.

A guideline level of carbon monoxide of nine parts per million by volume (ppmv) (or 10 milligrams per cubic metre or 10,000 micrograms per cubic metre) over an eight-hour period was considered to provide protection (for both acute and chronic health effects) for most members of the population. An additional 1.5 fold uncertainty factor to protect more susceptible groups in the population was included. On this basis the NEPC and the EPA guideline is protective of adverse health effects in all individuals, including sensitive individuals. The EPA has also established a guideline a one-hour average (30 milligrams per cubic metre) concentrations of carbon monoxide in ambient air based on criteria established by the WHO (WHO 2000a).

Table 11.6 presents a summary of the maximum predicted cumulative one-hour average and eight-hour average concentrations of carbon monoxide.

Table 11.6 Review of potential acute and chronic health impacts – carbon monoxide (CO)

Scenario	Maximum 1-hour average concentration of CO (mg/m^3) Without project	With project	Maximum 8-hour average concentration of CO (mg/m^3) Without project	With project
2021				
Maximum	8.5	7.9	5.8	5.4
2031				
Maximum	7.0	6.2	4.8	4.3
Cumulative				
Maximum	--	5.9	--	4.3
Relevant health based guideline	30		10	

All the concentrations of carbon monoxide presented in the **Table 11.6** are well below the relevant health based guidelines. Hence there are no adverse health effects expected in relation to exposures (acute and chronic) to carbon monoxide in the local area surrounding the project.

Nitrogen dioxide

Motor vehicles, along with industrial, commercial and residential (eg gas heating or cooking) combustion sources, are primary producers of nitrogen oxides, which include nitrogen dioxide. In Sydney, the OEH (2012) estimated that on-road vehicles account for about 62 per cent of emissions of nitrogen oxides, industrial facilities account for 12 per cent, other mobile sources account for about 22 per cent with the remainder from domestic/commercial sources.

Nitrogen dioxide is the only oxide of nitrogen that may be of concern to health (WHO 2000b). Nitrogen dioxide can cause inflammation of the respiratory system and increase susceptibility to respiratory infection. Exposure to elevated levels of nitrogen dioxide has also been associated with increased mortality, particularly related to respiratory disease, and with increased hospital admissions for asthma and heart disease patients (WHO 2013a). Asthmatics, the elderly and people with existing cardiovascular and respiratory disease are particularly susceptible to the effects of nitrogen dioxide. The health effects associated with exposure to nitrogen dioxide depend on the duration of exposure as well as the concentration.

Guidelines are available from the NSW EPA and NEPC which indicate acceptable concentrations of nitrogen dioxide. These guidelines are based on protection from adverse health effects following both short-term (acute) and longer-term (chronic) exposure for all members of the population including sensitive populations like asthmatics, children and the elderly.

Potential health effects associated with nitrogen dioxide consider both comparison with guidelines for cumulative exposure (acute and chronic) and an assessment of incremental impacts on health (associated with changes in air quality from the project).

Cumulative (total) nitrogen dioxide

The guideline for the assessment of acute (short-term) exposure is 246 micrograms per cubic metre (or 120 parts per billion by volume (ppbv)) and chronic (long-term or lifetime) exposures of 62 micrograms per cubic metre (or 30 ppbv) is protective of adverse health effects in all individuals, including sensitive individuals.

Table 11.7 presents a summary of the modelled scenarios for maximum predicted cumulative one-hour average concentration of nitrogen dioxide and the maximum predicted cumulative annual average concentration.

Table 11.7 Review of potential acute and chronic health impacts and maximum predicted cumulative annual average concentration – nitrogen dioxide (NO_2)

Location and scenario	Maximum 1-hour average concentration of NO_2 without project (μg/m^3) (acute)	Maximum 1-hour average concentration of NO_2 with project (μg/m^3) (acute)	Maximum annual average concentration of NO_2 (μg/m3) (chronic)
2021			
Maximum residential	375	307	34.4
Maximum commercial	360	286	32.6
2031			
Maximum residential	286	243	31.0
Maximum commercial	359	238	30.1
Health based guideline	**246**	**246**	**62**

The maximum cumulative concentrations of nitrogen dioxide for acute (short-term) exposure presented in **Table 11.7** are above the acute NEPC guideline of 246 micrograms per cubic metre. This is principally due to the contribution from surface roads that are predicted to exceed the short-term criteria in 2021 without the construction of the project. The maximum cumulative concentrations of nitrogen dioxide are shown to be lower or equivalent with construction of the project than for 2021 and 2031 without the project. Section 8.4.4 of Appendix H (Air quality impact assessment) provides contour figures showing the location of nitrogen dispersion.

All the concentrations of nitrogen dioxide presented in **Table 11.7** are below the chronic NEPC guideline of 62 micrograms per cubic metre. Hence, there are no adverse health effects expected in relation to chronic exposures to nitrogen dioxide in the local area surrounding the project.

Incremental nitrogen dioxide

Table 11.8 presents a summary of the health endpoints from the effects of short-term exposure of nitrogen dioxide, the β coefficient relevant to the calculation of a relative risk. These health endpoints have been evaluated in relation to changes in nitrogen dioxide concentrations in air associated with the project within the local community in 2021 and 2031. The coefficients adopted for the assessment of impacts on mortality and asthma emergency department admissions are derived from the detailed assessment undertaken for the current review of health impacts of air pollution undertaken by NEPC (Golder 2013) and are considered to be robust.

Table 11.8 Adopted exposure-responses relationships for assessment of changes in nitrogen dioxide concentrations

Health endpoint	Exposure period	Age group	Adopted β coefficient (as %) for 1 μg/m^3 increase in PM	Reference
Mortality, all causes (non-trauma)	Short-term	30+	0.00188 (0.19%)	Relationship derived for from modelling undertaken for 5 cities in Australia and 1 day lag. (EPHC 2010; Golder 2013)
Mortality, respiratory	Short-term	All ages*	0.00426 (0.43%)	Relationship derived for from modelling undertaken for 5 cities in Australia and 1 day lag. (EPHC 2010; Golder 2013)
Asthma emergency department admissions	Short-term	1–14 years	0.00115 (0.11%)	Relationship established from review conducted on Australian children (Sydney) for the period 1997 to 2001. (Golder 2013; Jalaludin et al. 2008)

β = regression/slope coefficient, or the slope of the exposure-response function which can also be expressed as the per cent change in response per 1 μg/m^3 increase in particulate matter exposure.

Table 11.9 presents the change in individual risk associated with changes in nitrogen dioxide at the maximum impacted residential and workplace receptors in the surrounding community, as well as the community receptors, for the operational years 2021 and 2031.

Table 11.9 Maximum calculated risks associated with short-term exposure to changes in nitrogen dioxide with operation of the project

Scenario and receptor	Maximum change in individual risk from short-term exposure to nitrogen dioxide for the following health endpoints		
	Mortality: all causes (ages 30+)	Mortality: respiratory (all ages)	Asthma emergence department admissions (1–14 years)
With the project 2021			
Maximum residential	2×10^{-6}	4×10^{-6}	2×10^{-5}
Maximum workplace	2×10^{-6}	4×10^{-6}	2×10^{-5}
Childcare centres	-4×10^{-7}	-8×10^{-7}	-5×10^{-6}
Hospitals	-7×10^{-7}	-1×10^{-6}	-9×10^{-6}
Schools	3×10^{-7}	7×10^{-7}	4×10^{-6}
Aged care	4×10^{-7}	9×10^{-7}	6×10^{-6}
With the project 2031			
Maximum residential	2×10^{-6}	4×10^{-6}	2×10^{-5}
Maximum workplace	2×10^{-6}	4×10^{-6}	2×10^{-5}
Childcare centres	-2×10^{-7}	-5×10^{-7}	-3×10^{-6}
Hospitals	-6×10^{-7}	-1×10^{-6}	-7×10^{-6}
Schools	5×10^{-7}	1×10^{-6}	7×10^{-6}
Aged care	4×10^{-7}	8×10^{-7}	5×10^{-6}

For this project, all maximum impacted locations lie in the range 2x10-6 to 3x10-5 and are considered to be tolerable/ acceptable. Risks at all community receptors vary from -5x10-5 to 7 x 10-6 with the majority of the calculated risks for community receptors calculated to be negative, indicating that the project is expected to result in a lower level of risk at these locations. Where an increase in risk was calculated at the community receptors, they are all considered to be tolerable/ acceptable.

It is noted that the maximum increase in short-term concentrations of nitrogen dioxide is less for the scenario where the operation of project is considered, when compared with the scenario where the tunnel is not operating (refer to **Table 11.7**). Where the tunnel is not operating the maximum increase in short-term nitrogen dioxide concentrations in the local community is higher (with maximum impacts at a different location) than evaluated above and would result in individual risks that are higher. This is due to higher impacts of nitrogen dioxide from a greater number of vehicles on surface roads (compared with a proportion of these vehicles using the project tunnel).

While the calculated risks associated with maximum impacts of nitrogen dioxide in the local community are considered to be tolerable, the risks are lower than would occur if the tunnel were not constructed.

Particulate matter

Particulate matter (PM) is a widespread air pollutant with a mixture of physical and chemical characteristics that vary by location (and source) and substance. Particulates can be derived from natural sources such as soil dust, pollen and moulds, and other sources that include combustion and industrial processes. Secondary particulate matter is formed via atmospheric reactions of primary gaseous emissions. The gases that are the most significant contributors to secondary particulates include nitrogen oxides, ammonia, sulfur oxides, and certain organic gases (derived from vehicle exhaust, combustion sources, agricultural, industrial and biogenic emissions).

Particulate matter has been linked to adverse health effects after both short-term exposure (days to weeks) and long-term exposure (months to years). The health effects associated with exposure to particulate matter vary widely (with the respiratory and cardiovascular systems most affected) and include mortality and morbidity effects. The potential for particulate matter to result in adverse health effects is dependent on the size and composition of the particulate matter.

The particle size addressed in this study relate to the particulates most commonly measured in the urban air environment studies:

- PM_{10} (particulate matter below 10 microns in diameter)
- $PM_{2.5}$ (particulate matter below 2.5 microns in diameter)

Table 11.10 presents a summary of the current NEPC and EPA air quality goals and guidelines for particulate matter.

Table 11.10 Ambient air quality goals for particulates

Pollutant	Averaging period	Criteria (µg/m³)	Reference
PM_{10}	24-hour	50 Maximum of 5 days exceedance per year	(DEC 2005b; NEPC 2003)
	Annual	30	(DEC 2005b)
$PM_{2.5}$	24-hour	25	Advisory reporting standards (NEPC 2003)
	Annual	8	

The assessment of changes in incidence of particular health indicators in the community results in the calculation of a change in the number of cases (of mortality, hospital or emergency department admissions) within the population evaluated. Where changes in air quality associated with this project are well below 10 cases per year they are considered to be within the normal variability of health statistics, and these changes would not be measurable in any health statistics for the area. For evaluating impacts form this project a 10 fold margin of safety has been included to determine what changes in incidence may be considered negligible within the study population. This means that changes in the population incidence of any health effect evaluated that is less than one case per year are considered negligible.

Calculated risks and population incidence – cumulative scenario

Table 11.11 presents the calculated individual risk associated with changes in $PM_{2.5}$ and PM_{10} concentrations at the maximum impacted receptor (regardless of land use), maximum impacted residential and workplace receptors, as well as the community receptors, for the cumulative scenario (ie WestConnex) during the year 2031. The change in $PM_{2.5}$ and PM_{10} concentration considered in the risk calculations are also included in the table.

Table 11.11 Calculated individual risk associated with changes in $PM_{2.5}$ and PM_{10} concentrations – cumulative scenario in 2031

Health endpoint	Maximum calculated change in individual risk for key locations in community						
	Maximum	Maximum residential	Maximum workplace	Childcare centres	Hospitals	Schools	Aged care
Change in annual average concentration							
$PM_{2.5}$ (µg/m³)	0.75	0.75	0.70	0.010	-0.22	0.057	0.00008
PM_{10} (µg/m³)	1.0	1.0	0.90	0.011	-0.43	0.16	0.10
Primary health indicators: $PM_{2.5}$							
Mortality all causes (long-term effects, ages 30+)	4×10^{-5}	4×10^{-5}	4×10^{-5}	6×10^{-7}	-1×10^{-5}	3×10^{-6}	2×10^{-7}

Health endpoint	Maximum calculated change in individual risk for key locations in community					
Cardiovascular hospitalisations (short-term effects, ages 65+)	5×10^{-5}	5×10^{-5}	5×10^{-5}	7×10^{-7}	-2×10^{-5}	4×10^{-6}	6×10^{-9}
Respiratory hospitalisations (short-term effects, ages 65+)	1×10^{-5}	1×10^{-5}	1×10^{-5}	2×10^{-7}	-3×10^{-6}	9×10^{-7}	1×10^{-9}
Secondary health indicators: $PM_{2.5}$							
Mortality all causes (short-term effects, all ages)	4×10^{-5}	4×10^{-5}	4×10^{-5}	6×10^{-7}	-1×10^{-5}	3×10^{-6}	2×10^{-7}
Mortality, cardiopulmonary (long-term effects, ages 30+)	5×10^{-5}	5×10^{-5}	5×10^{-5}	7×10^{-7}	-2×10^{-5}	4×10^{-6}	6×10^{-9}
Mortality, cardiovascular (short-term effects, all ages)	1×10^{-5}	1×10^{-5}	1×10^{-5}	2×10^{-7}	-3×10^{-6}	9×10^{-7}	1×10^{-9}
Mortality, respiratory (short-term effects, all ages)	4×10^{-5}	4×10^{-5}	4×10^{-5}	6×10^{-7}	-1×10^{-5}	3×10^{-6}	2×10^{-7}
Asthma emergency department hospitalisations (1–14 years)	5×10^{-5}	5×10^{-5}	5×10^{-5}	7×10^{-7}	-2×10^{-5}	4×10^{-6}	6×10^{-9}
Secondary health indicators: PM_{10}							
Mortality all causes (short-term effects, all ages)	3×10^{-6}	3×10^{-6}	2×10^{-6}	3×10^{-8}	-1×10^{-6}	5×10^{-7}	3×10^{-7}
Diesel particulate matter							
Lung cancer	1×10^{-5}	1×10^{-5}	1×10^{-5}	2×10^{-7}	-4×10^{-6}	1×10^{-6}	1×10^{-9}
Negligible risks	$< 1 \times 10^{-6}$						
Tolerable risks	$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$						
Unacceptable risks	$> 1 \times 10^{-4}$						

Negative value indicates that risks have decreased with operation of the project

Review of the calculated changes in risk indicates the following in relation to impacts associated with the operation of WestConnex in 2031:

- Most of the calculated individual risks are negative, meaning that the operation of WestConnex will result in lower levels of risk in the community
- There are no calculated individual risks that exceed 1×10^{-4} and hence there are no unacceptable risks identified in the community surrounding the project
- The calculated individual risks for the maximum impacted receptor and maximum impacted residential and workplace receptors are in the range 7×10^{-7} to 5x10-5 and are considered to range from negligible to tolerable/acceptable.

11.4.2 Assessment of regulatory worst case scenarios

An assessment of the regulatory worst case scenarios were undertaken assuming emissions from the tunnel ventilation outlets occur at the maximum discharge limits.

This may occur in the event of a breakdown or accident and may result in a short period of time where emissions from the tunnel ventilation facility are higher than during normal operations. Such situations are not planned and where they occur the duration of the event is not expected to last for longer than a few hours to less than a day. The scenarios considered in the AQAR assume that such an event may last for a 24-hour period.

The assumptions underpinning the all regulatory worst-case scenarios were very conservative, and resulted in contributions from project ventilation outlets that were much higher than those that could ever occur under any operational conditions in the tunnel.

In relation to impacts on health a worst-case situation results in short-term changes in air quality. Hence health effects identified and evaluated in this assessment that relate to changes in short-term concentrations of nitrogen dioxide and $PM_{2.5}$ require further assessment.

The assessment of short-term health impacts has utilised the methodology outlined in **Appendix A** of the Human Health Risk Assessment in **Appendix J**, with the parameters selected to be relevant to a one-hour or 24-hour exposure period (as relevant to each pollutant). The assessment has considered the following scenarios:

- Short-term change in air concentrations associated with maximum emissions from the ventilation outlets from the project tunnel
- Short-term changes in air concentrations associated with maximum emissions form the ventilation outlets for the project tunnel and the M4–M5 Link.

Risk calculations can be undertaken for the short-term change in air quality associated with each of these scenarios. How often these events occur during any one year may result in some contribution to the total annual individual risk calculated for the expected operation of the project. The frequency of a worst-case traffic scenario occurring is not known, hence for the purpose of this assessment some conservative assumptions have been adopted.

Table 11.12 presents the calculated change in individual risk associated with exposure to worst-case emissions of nitrogen dioxide. The table includes the assumptions adopted for the assessment.

Table 11.13 presents the calculated change in individual risk associated with exposure to worst-case emissions of $PM_{2.5}$. The table includes the assumptions adopted for the assessment.

Appendix H of the Human Health Risk Assessment in **Appendix J** presents the calculations undertaken to evaluate the above scenarios.

Table 11.12 Maximum calculated risks associated with short-term exposure changes in nitrogen dioxide concentrations – regulatory worst case

Scenario	Maximum change in individual risk for the following health endpoints		
	Mortality: All causes (ages 30+)	Mortality: Respiratory (all ages)	Asthma ED admissions (1–14 years)
The project			
Maximum annual risk – expected operations	$2x10^{-6}$	$4x10^{-6}$	$3x10^{-5}$
Increase in risk for 1 day of worst-case emissions (assuming event lasts for 8 hours)*	$9x10^{-9}$	$2x10^{-8}$	$1x10^{-7}$
Increase in risk assuming worst-case event occurs 1 day each week (52 days per year)*	$5x10^{-7}$	$1x10^{-6}$	$6x10^{-6}$
Maximum annual risk – expected conditions plus worst-case event**	$2x10^{-6}$	$5x10^{-6}$	$4x10^{-5}$
The project and M4–M5 Link (cumulative)			
Maximum annual risk – expected operations	$2x10^{-6}$	$4x10^{-6}$	$3x10^{-5}$
Increase in risk for 1 day of worst-case emissions (assuming event lasts for 8 hours)*	$2x10^{-8}$	$4x10^{-8}$	$2x10^{-7}$
Increase in risk assuming worst-case event occurs 1 day each week (52 days per year)*	$9x10^{-7}$	$2x10^{-6}$	$1x10^{-5}$
Maximum annual risk – expected conditions plus worst-case event**	$3x10^{-6}$	$6x10^{-6}$	$4x10^{-5}$
Negligible risks	$< 1x10^{-6}$		
Tolerable/acceptable risks	$\geq 1x10^{-6}$ and $\leq 1x10^{-4}$		
Unacceptable risks	$> 1x10^{-4}$		

* Assumes that the maximum predicted impact occurs at the same location for eight hours, and occurs at the same location (receptor) every day the worst-case event occurs. With changes in meteorology in the local area the one-hour maximum concentration is expected to change in concentration and location throughout any one day and over different days. Hence this assumption is conservative.

** Assumes the maximum annual average impact and maximum short-term change occur that the same location (receptor).

Table 11.13 Maximum calculated risks associated with short-term exposure changes in $PM_{2.5}$ concentrations – regulatory worst case

Scenario	Maximum change in individual risk for the following short-term health endpoints					
	Cardiovascular hospitalisations (65 years+)	Respiratory hospitalisations (65 years +)	Mortality all causes (all ages)	Mortality cardiovascular (all ages)	Mortality respiratory (all ages)	Asthma ED admissions (1–14 years)
The project						
Maximum annual risk – expected operations	3×10^{-5}	7×10^{-6}	2×10^{-6}	6×10^{-7}	4×10^{-7}	7×10^{-6}
Increase in risk for 1 day of worst-case emissions	3×10^{-7}	6×10^{-8}	2×10^{-8}	6×10^{-9}	4×10^{-9}	7×10^{-8}
Increase in risk assuming worst-case event occurs 1 day each week (52 days per year)*	1×10^{-5}	3×10^{-6}	1×10^{-6}	3×10^{-7}	2×10^{-7}	4×10^{-6}
Maximum annual risk – expected conditions plus worst-case event**	4×10^{-5}	1×10^{-5}	3×10^{-6}	9×10^{-7}	6×10^{-7}	1×10^{-5}
The project and M4–M5 Link (cumulative)						
Maximum annual risk – expected operations	4×10^{-5}	8×10^{-6}	2×10^{-6}	8×10^{-7}	5×10^{-7}	9×10^{-6}
Increase in risk for 1 day of worst-case emissions	6×10^{-7}	1×10^{-7}	4×10^{-8}	1×10^{-8}	8×10^{-9}	1×10^{-7}
Increase in risk assuming worst-case event occurs 1 day each week (52 days per year)*	3×10^{-5}	7×10^{-6}	2×10^{-6}	6×10^{-7}	4×10^{-7}	7×10^{-6}
Maximum annual risk – expected conditions plus worst-case event**	7×10^{-5}	1×10^{-5}	4×10^{-6}	1×10^{-6}	9×10^{-7}	2×10^{-5}
Negligible risks	$< 1 \times 10^{-6}$					
Tolerable/acceptable risks	$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$					
Unacceptable risks	$> 1 \times 10^{-4}$					

* Assumes that the maximum predicted impact occurs at the same location (receptor) every day the worst-case event occurs. With changes in meteorology in the local area the 24-hour maximum concentration is expected to change in concentration and location over different days. Hence this assumption is conservative.

** Assumes the maximum annual average impact and maximum short-term change occur that the same location (receptor).

Review of the maximum calculated changes in risk associated with short-term changes in nitrogen dioxide (**Table 11.12**) and $PM_{2.5}$ (**Table 11.13**) concentration under the worst-case scenarios evaluated indicates the following:

- The maximum change in short-term risk associated with worst-case scenarios occurring on any one day is negligible
- Where it is conservatively assumed that the worst-case scenario occurs one day each week (and the maximum changes impact the same receptor location every time), the maximum individual risk increases

- The total maximum individual risk does not exceed $1x10^{-4}$ and hence there are no unacceptable risks identified in the community surrounding the project
- The calculated maximum individual risks are in the range $6x10^{-7}$ to $7x10^{-5}$ and are considered to range from negligible to tolerable/acceptable.

On the basis of the above, emissions from the ventilation outlets during a worst-case scenario (such as a breakdown or accident) has the potential to increase individual risks, however the maximum individual risks (even where conservative assumptions are adopted) remain in the range of negligible to tolerable/acceptable.

11.4.3 Assessment of in-tunnel air quality impacts

In-tunnel air quality limits based on the conditions of approval for NorthConnex have been considered in this assessment, as presented in **Table 11.14**. These have been taken to be limits/criteria that are required to be met under all operational circumstances (except emergencies such as fire). The tunnel ventilation system and tunnel operational parameters have been designed to ensure the in-tunnel concentration limits are not exceeded.

Table 11.14 In-tunnel average limits along length of tunnel

Pollutant	Concentration limit	Averaging period
Carbon monoxide	87 ppm	Rolling 15-minute average
Carbon monoxide	50 ppm	Rolling 30-minute average
Carbon monoxide	200 ppm	Rolling 3-minute average
Nitrogen dioxide	0.5 ppm	Rolling 15-minute average

Consideration of visibility criteria in the design of the tunnel ventilation system is required due to the need for visibility levels that exceed the minimum vehicle stopping distance at the design speed. Visibility is reduced by the scattering and absorption of light by PM suspended in the air. The amount of light scattering or absorption is dependent upon the particle composition (dark particles, such as soot, are particularly effective), diameter (particles need to be larger than around 0.4 microns), and density.

Particles causing a loss of visibility also have an effect on human health, so monitoring visibility also provides the potential for an alternative assessment of the air quality and health risk within a tunnel. However, such an assessment is limited by the short duration of exposure in tunnels compared with the longer exposure times (24 hours and one year) for which the health effects of ambient particles have been established. Moreover, there is no safe minimum threshold for particles, and so visibility cannot reliably be used as a criterion for health risk (NHMRC 2008). Hence visibility limits within the tunnel have not been further evaluated.

Concentrations of pollutants in the tunnel are expected to vary depending on:

- Time of day – Pollutant concentrations within the tunnels have been estimated to vary by a factor of up to nine times (depending on the particular pollutant and location within the main alignment tunnels) from periods of low traffic to peak traffic
- Location within the main alignment tunnels – Concentrations of pollutants would gradually increase from the tunnel entrance to around the offtake to the ventilation outlets. The average exposure for a motorist would be around half of the maximum concentration within the tunnel.

The assessment of potential exposures that may occur in the tunnel has been undertaken with consideration of these factors. In addition the following has also been considered:

- The time spent within the tunnel would be limited, taking around four minutes to travel the full distance of the tunnel (when travelling at 80 kilometres per hour). During peak times the time of travel may be slightly longer depending on the speed of traffic flow in the tunnel. As the concentrations are not the same in all parts of the tunnel, with concentrations increasing with distance from the start, the amount of time exposed to the maximum concentration would be much lower (around one minute). The average exposure through the whole tunnel would be lower than, approximately half, the maximum (at the end of the tunnel)

- The concentration of pollutants within the vehicle itself, particularly where all windows are closed when inside the tunnel, as most vehicles have filters on the air intake. Where the air conditioning/ventilation in the car is set to recirculation this would limit the contribution of air derived from within the tunnel to the air within the vehicle. Measurements conducted by NSW Health in relation to the M5 East Tunnel (NSW Health 2003) identified that closing car windows and switching the ventilation to recirculation can reduce exposures by approximately 70–75 per cent for carbon monoxide and nitrogen dioxide, 80 per cent for fine particulates and 50 per cent for volatile organic compounds.

The predicted concentrations of in-tunnel pollutants are presented in **Chapter 9** (Air Quality) and in **Appendix H** and discussed in the following sections.

Carbon monoxide

The maximum one-hour average concentration of carbon monoxide in the tunnel is predicted to be approximately 9.5 ppm eastbound and 17.5 ppm westbound. These concentrations are lower than the health based guideline of 25 ppm (one-hour average) established by the WHO (WHO 2010) and 34 ppm established by the USEPA (NHMRC 2008). The concentrations are lower than PIARC in-tunnel limits (Longley 2014).

The NHMRC (2008) has published measured concentrations of carbon monoxide from a range of tunnels in Sydney and around the world. The measured concentrations come from a number of different studies where the averaging time for the collection of the data varies significantly. This makes it difficult to directly compare the range of reported concentrations with the concentrations predicted in this assessment (ie not comparing data reported over similar averaging/exposure periods). While noting this difficulty in comparing the data, the range of average concentrations of carbon monoxide have been reported from 6 to 44 milligrams per cubic metre (NHMRC 2008). The predicted hourly average concentration in the project tunnel is within the range reported in other tunnels.

- The tunnel is designed to meet in-tunnel limits for carbon monoxide. While actual concentrations in the tunnel are expected to be lower than these limits, where the limits are met the following can be noted:
  - The in-tunnel limit for carbon monoxide of 87 ppm as a 15-minute average is equivalent to the health based guideline of 90 ppm (15-minute average) established by the WHO (WHO 2010)
  - The in-tunnel limit for carbon monoxide of 50 ppm as a 30-minute average is the same as the health based guideline of 50 ppm (30-minute average) established by the WHO (WHO 2000a).

On the basis of the above, where the in-tunnel limits are met there are no health issues of concern related to in-tunnel exposures to carbon monoxide.

Nitrogen dioxide

In relation to the nitrogen dioxide concentrations predicted within the tunnel, the following is noted:

- The maximum concentrations in the tunnel vary throughout the day, with the maximum concentration predicted at any time of the day and at the lowest speed less than 0.8ppm. The average concentration in the tunnel is expected to be (at most) approximately 0.4 ppm, less than the in-tunnel limit

- The maximum in-tunnel concentrations estimated for travelling at 80 kilometres per hour through the tunnel varies from close to zero ppm at the start to approximately 0.45 ppm eastbound and 0.52 ppm westbound. These concentrations are lower than the in-tunnel limit of 0.5 ppm (set as a 15-minute average). Actual exposures will only occur for approximately four minutes at an average concentration of 0.2 to 0.25 ppm (with windows down). Lower concentrations of approximately 0.06 to 0.075 ppm may occur with windows up and ventilation on recirculation

- The NHMRC (2008) has published measured concentrations of nitrogen dioxide from a range of tunnels in Sydney and around the world. The measured concentrations come from a number of different studies where the averaging time for the collection of the data varies significantly. This makes it difficult to directly compare the range of reported concentrations with the concentrations predicted in this assessment (ie not comparing data reported over similar averaging/exposure periods). While noting this difficulty in comparing the data, the NHMRC (2008) have reported a range of average concentrations of nitrogen dioxide in tunnels that range from 0.05 to 0.3 ppm with levels up to 0.4 ppm reported during peak periods. These levels are based on data with averaging times that vary from 30 seconds during travel through a tunnel, six minute averages, to long term data with (unspecified averaging times). At the downstream end of a tunnel (where exposure is very short, ie minutes) levels up to 0.8 ppm have been reported
- There are very few studies that have evaluated health effects associated with very short duration exposures to nitrogen dioxide. A study conducted in Stockholm (Svartengren et al. 2000) involved exposing 20 adults with mild asthma to air quality inside a car in a tunnel for 30 minutes, where levels of nitrogen dioxide ranged from 0.1 to 0.24 ppm (noting exposure to particulate matter and other pollutants inside the tunnel occurred at the same time). The study showed an increase in bronchial response to allergens several hours after exposure for individuals with allergic asthma. These results are similar to other studies where individuals with mild asthma were exposed to 0.26 ppm nitrogen dioxide for 30 minutes (Barck et al. 2002; Strand et al. 1998), a range of concentrations from 0 to 0.53 ppm for 30 minutes (Bylin et al. 1988) or for 15 minutes on one day and then repeated twice in the following day (Barck et al. 2005), followed by an allergen inhalation challenge. None of the available studies have considered individuals with moderate or severe asthma. The data suggest that exposure to elevated concentrations of nitrogen dioxide in a congested tunnel is associated with an increased risk of adverse effects for those with asthma (NHMRC 2008)
- There are no guidelines in Australia for levels of nitrogen dioxide in tunnels. Guidelines for in-tunnel levels of nitrogen dioxide are available from Belgium (0.5 ppm for exposures <20 minutes), France (0.4 ppm for a 15 minute average exposure period), Norway (Norwegian Public Road Admiration (NPRA) guidelines of 0.75 ppm at the tunnel midpoint and 1.5 ppm at the tunnel ends, based on a 15-minute average), Hong Kong (one ppm as a five minute average) and New Zealand (one ppm as a 15 minute average) (Longley 2014). The PIARC has proposed a level of one ppm (as a threshold limit for healthy people). The average expected exposures, including the average during high traffic low speed situations are the same as or lower than the available short term (15–20 minute average) guidelines.

Particulate matter

There are no health based guidelines available for the assessment of short-duration exposures to PM within a tunnel. In-tunnel criteria relate to visibility (and safety in using the tunnel). It is expected that the concentration of PM within the tunnel will be higher than ambient air concentrations, and the concentration of PM will increase with increasing distance travelled through the tunnel. The in-tunnel concentrations for PM are taken to be PM_{10} concentrations. Concentrations of $PM_{2.5}$ will comprise a significant portion of the PM_{10} concentration.

The maximum concentration of PM_{10} in the tunnel ranges from approximately 0.05 to 0.6 milligrams per cubic metre. The average concentration in the tunnel may be approximately 0.025–0.3 milligrams per cubic metre. Motorists may be exposed to these levels where widows are open. The average exposure concentration is lower (ranging from 0.0075 to 0.09 milligrams per cubic metre) with windows closed and ventilation on recirculation

- Recent review (WHO 2013b) of available studies in relation to short-duration (less than 24-hour) exposures to particulates indicates the following:
  - Epidemiological and clinical studies have demonstrated that sub-daily exposures to elevated levels of particulate matter can lead to adverse physiological changes in the respiratory and cardiovascular system, in particular exacerbation of existing disease. This is generally consistent with the outcome of studies reviewed and considered by the USEPA (USEPA 2009)

- The studies available do not cover a range of exposure concentrations, nor do they adequately address other variables such as co-pollutants (gases) or repeated short-duration exposures
- The studies have not determined if a one-hour exposure would lead to a different response than a similar dose spread over 24-hours, or if an exposure-response can be determined
- Exposures that occur during the use of various transportation methods (such as in-vehicles) have been found to contribute to and affect 24-hour personal exposures.

The urban epidemiology studies (upon which exposure-response relationships are based and have been used in this assessment) utilise health data for adverse health effects from an urban population, where the urban population will have been exposed to ambient levels of particulate matter (as measured by air monitoring stations) as well as fluctuations that occur throughout the day during various daily activities including in-vehicle exposures (and others such as cooking).

These large urban studies have related health effects to regional ambient (urban) air concentrations. They have not measured daily (or longer term) personal exposures to particulate matter, but such fluctuations would occur within the population exposed and would be expected to be accounted for within the health data considered in the epidemiology studies. Specific health effects from the short duration variations in particulate exposures throughout any specific day cannot be determined from these studies. It is therefore important to consider if exposures to $PM_{2.5}$ in the project tunnel would be consistent with other tunnels or in-vehicle exposures (during commuting in an urban environment), where the following can be considered:

- Exposure to particulate matter within vehicles varies with the intensity of the traffic, the age of the vehicle the choice of ventilation used within the vehicle and the type of fuel used (Knibbs, de Dear & Morawska 2010). Levels of $PM_{2.5}$ reported in vehicles in Europe (European Topic Centre (ETC) 2013) vary from 0.022 to 0.085 milligrams per cubic metre for passenger cars and 0.026–0.13 milligrams per cubic metre for bus travel
- Levels of $PM_{2.5}$ that have been measured within cars while commuting in Sydney (where tunnel travel was not part of the study) range from 0.009 to 0.045 milligrams per cubic metre (NSW Health 2004)
- Keeping windows closed and switching ventilation to recirculation has been shown to reduce exposures inside the vehicle by up to 80 per cent (NSW Health 2003). While noting no guidelines are availability for very short duration exposures, this would further reduce exposure to motorists.

Overall assessment of in-tunnel impacts

The duration of exposure to vehicle emissions within the project tunnel is limited (minutes, rather than hours, only) and where guidelines are available for short duration exposures in tunnels, the likely exposure concentrations (representative of the average concentrations from start to end) are generally within or below these guidelines. Short-duration exposure guidelines are not available for nitrogen dioxide or particulate matter (assessed as $PM_{2.5}$). In relation to nitrogen dioxide, the published exposures studies suggest in situations of congested traffic (including delayed traffic in a tunnel) there is an increased risk of adverse health effects amongst individuals with asthma. Particulate matter exposures within the tunnel are estimated to be similar to those expected within other vehicle tunnels, are of limited duration (minutes). Particulate exposures vary throughout a day depending on the activities undertaken. Exposures that may occur within the tunnel are consistent with expected variability of exposure to PM throughout any day where a range of activities are undertaken.

For regular users of tunnels in Sydney, and regular commuters in heavy traffic, repeated short duration exposures to elevated concentrations of pollutants from vehicle emissions would contribute to a higher level of overall (daily) exposure and may be associated with increased risks for asthmatics. Drivers who regularly use tunnels or drive in congested traffic in Sydney can minimise exposure to vehicle emissions by keeping windows up and air conditioning on recirculation when in tunnels or heavy traffic conditions. Keeping windows closed and switching ventilation to recirculation has been shown to reduce exposures inside the vehicle by up to 80 per cent.

11.4.4 Noise and vibration

Environmental noise has been identified as a growing concern in urban areas because it has negative effects on quality of life and well-being and it has the potential for causing harmful physiological health effects. With increasingly urbanised societies impacts of noise have the potential to increase within the community. Noise energy does not accumulate either in the body or in the environment but it can have both short-term and long-term adverse effects on people. These health effects include (WHO 1999, 2011):

- Sleep disturbance (sleep fragmentation that can affect psychomotor performance, memory consolidation, creativity, risk-taking behaviour and risk of accidents)Annoyance
- Hearing impairment
- Interference with speech and other daily activities
- Children's school performance (through effects on memory and concentration)
- Cardiovascular health
- Possible effects on mental health (usually in the form of exacerbation of existing issues for vulnerable populations rather than direct effects)
- Possible tinnitis (which can also result in sleep disturbance, anxiety, depression, communication and listening problems, frustration, irritability, inability to work, reduced efficiency and a restricted participation in social life)
- Possible cognitive impairment in children (including deficits in long term memory and reading comprehension)
- Possible indirect effects such as impacts on the immune system.

Annoyance can be a major consideration because it reflects the community's dislike of noise and their concerns about the full range of potential negative effects and it affects the greatest number of people in the population.

The criteria developed for use in the assessment for control of noise come from policy documents developed by the NSW Government including the *NSW Industrial Noise Policy* (EPA 2000), the NSW *Interim Construction Noise Guideline* (DECCW 2009a), and the NSW Road Noise Policy (EPA 2011). Noise impacts during operation of the project have been assessed for the years 2021 and 2031. The modelling has considered noise impacts in the community both without the construction of the project and with the construction of the project. In relation to noise impacts from the operation of the project, the assessment identified the following:

- The project is predicted to result in an overall decrease in the number of receivers with an exceedance of the *Noise criteria guideline* (Roads and Maritime 2015) criteria across the project area as a whole. This is mainly due to areas where traffic is forecast to reduce as part of the project (such as the unmodified section of M4 east of the proposed portals, Parramatta Road east of Concord Road and Wattle Street north of Ramsay Street)
- The project is predicted to result in a reduction or minor (less than 2.0 dB(A)) increase in noise levels at the majority of receivers (approximately 96% of receivers). This magnitude of noise increase is generally considered to be unnoticeable
- Large reductions in noise (up to around -8 dB(A)) are identified north of the M4 east of the new portals where the project is forecast to significantly reduce traffic on the M4 carriageways
- Large increases in noise (up to around +16 dB(A) without mitigation) are identified near the Concord Road and Wattle Street interchanges where the project adds new lanes/ramps closer to receivers in combination with removing existing building screening due to property acquisitions.

For most of the project area noise levels will be similar or decrease where traffic that is now at the surface will be taken into the tunnels. For those locations where a surface interchange will be constructed, noise levels are likely to increase above current levels.

In urban areas particularly where noise is dominated by road traffic noise, access to outdoor green-space areas that are not (perceived to be) impacted by noise (eg where there is a quiet side of a specific property or there is access to a quiet green space areas close to the residential home) have been found to significantly improve well-being and lower levels of stress (Gidlöf-Gunnarsson & Öhrström 2007). Impacts on the use and enjoyment of outdoor areas due to increased noise may result in increased levels of stress at individual properties.

Where specific residents/properties do not take up the recommended architectural treatments to mitigate noise indoors there is the potential for noise levels at these properties to exceed the relevant guidelines/criteria. In these situations there is the potential for adverse health effects, particularly annoyance and sleep disturbance, to occur.

Community consultation will be an important part of the process in addressing noise impacts for the project as there are a number of individual homes where at-property treatment will be required to enable the noise criteria to be met, and minimise the potential for adverse health effects associated with the project but such treatments may have other effects which will also need to be managed/considered.

11.5 Assessment of social impacts on health

General

The World Health Organisation defines health as ‘a (dynamic) state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity’. Hence the assessment of health should include both the traditional/medical definition that focuses on illness and disease as well as the more broad social definition that includes the general health and wellbeing of a population.

The assessment of changes in air quality and noise on the health of the local community (presented in **Chapter 9** and **Chapter 10** respectively) addressed key aspects that have the potential to directly affect health.

There are, however a range of other impacts associated with the project that can affect the health and well-being of the community in a more indirect way. In addition, changes within a community that may be associated with the project may be differentially distributed. This may affect population groups that may be advantaged or disadvantaged based on age, gender, socioeconomic status, geographic location, cultural background, aboriginality, and current health status and existing disability. This aspect relates to the equity of the impacts in the local community.

This section has more specifically evaluated changes in the community that have the potential to indirectly affect the health and well-being of the community. In addition this section has provided a review of whether there are any impacts that are likely to be more significant in any section of the community, and if these areas may result in inequitable impacts on the health of the population.

This section refers to the social impact assessment which is summarised in **Chapter 14** (Social and economic) and included in **Appendix M**.

Changes in traffic

The study area currently comprises an urbanised area dominated by heavy traffic volumes on the M4, Parramatta Road and local roads. The project aims to redirect through vehicle movements off the surface road network into the tunnel. While this is intended to result in improvements in local traffic once completed, the project does involve some impacts to local traffic and access during construction.

Construction

A number of changes to local roads are proposed during the construction phase of works. While it is expected that access to all properties on the local roads will be maintained during the construction works, temporary closures or reduced capacity of some local roads may affect the movement of local traffic through the area.

Major construction works would be primarily accessed from Parramatta Road and the M4. Construction ancillary facilities would be located to provide the most direct access for heavy vehicles to and from arterial roads such as Parramatta Road, M4, Concord Road, Sydney Street and Wattle Street and to avoid or minimise use of local roads.

In addition a number of bus stops located at or near construction ancillary facilities at Underwood Road, Concord Road, Cintra Park and Parramatta Road will be relocated.

It is expected that during construction there will some impact to the local community as a result of increased travel times for vehicles, cyclists and bus passengers; reduced pedestrian roadside safety due to an increase in traffic; reduction in pedestrian and cyclist amenity.

These changes have the potential to result in increased levels of stress and anxiety in the local community. These impacts, however, are expected to occur during the period of construction only.

Operations

However once the project is complete it is expected to result in large reductions in vehicle delays along the corridor between Homebush Bay Drive in the west, and City West Link and Haberfield/Leichardt in the east. This is evident both within the new project tunnel which will ultimately provide connectivity to the M4–M5 Link, and also on the existing Parramatta Road despite the reduction in capacity due to the provision of kerbside bus lanes. The assessment has also identified benefits on the parallel route along Queens Road and Gipps Street. This improvement will enhance connectivity regionally.

Public transport

A limited number of bus routes currently use Parramatta Road within the study area of the project. However, Transport for NSW has identified the potential for a new high frequency bus route between Burwood and the CBD which would be provided following delivery of the project. The traffic study has also indicated that the project could deliver significant travel time savings for buses (between three and 15 minutes during peak periods) between Burwood and Chandos Street as a result of the project, with a dedicated bus lane provided east from Burwood on Parramatta Road.

Improvements in public transport availability and especially efficiency will have broad social benefits. The use of public transport includes incidental exercise (eg walking to and from bus or train stops) increasing the chance of travellers meeting recommended daily physical activity targets.

Pedestrian and cycle access

The existing pedestrian network is varied, with residential areas located off the main roadways providing good pedestrian facilities. Parramatta Road currently favours high volume traffic movements which impacts accessibility and travel times for pedestrians.

Some pedestrian footpaths will be closed during construction, however these closures will only affect one side of the road (allowing access to remain on the other side of the road). Where required safe alternate pedestrian access routes will be identified. Pedestrian access will be restored once construction is complete. Additional crossings will be provided at the off-ramp location on Concord Road and Powells Creek. In addition changes to signal timings due to changes in traffic volumes and distribution may lower the time taken to cross major intersections, potentially improving travel times and accessibility.

The existing cycle network comprises limited dedicated cycleways (targeted at leisure trips rather than commuter trips) and a mix of on-road options. There are significant gaps in north-south connections due to Parramatta Road and the M4. During construction, works will be undertaken to ensure that connectivity is maintained for cyclists. This will involve cycleway detours from the M4 onto local roads and other cycleways. Once the project is completed reduced traffic volumes would provide opportunities to improve cycling routes through the study area and these are being investigated as part of the Parramatta Road Urban Transformation Program.

Improved urban amenity and cycling infrastructure could likely attract more people to both recreational and commuter cycling, with consequent positive health benefits.

As discussed in **section 11.4.1**, the project will result in improved air quality (ie decrease in total pollutant concentrations) within much of the local community. The redistribution of surface traffic in the area will result in an increase in pollutants at some locations, however the risks to health posed by these changes range from negligible to tolerable/acceptable.

A review of the changes in air quality associated with the project has not identified impacts that significantly affect specific areas of disadvantage. In relation to changes in air quality impacts associated with the project, changes in $PM_{2.5}$ are of most relevance. The areas where increases in $PM_{2.5}$ concentrations are predicted are adjacent to existing roadways, where changes in traffic volumes associated with the project are predicted to result in a small increase in $PM_{2.5}$ exposure.

Suburbs in the study area that, based on the 2011 Census Data, are slightly more disadvantaged (in relation to the Socio-Economic Index for Areas (SEIFA)) include Homebush West and Burwood.

- In Homebush West there are some areas where the project will result in decreased $PM_{2.5}$ impacts, however there are few small areas where the project will result in increased $PM_{2.5}$ impacts. The increase only affects a small number of residential homes/buildings located in this area (located close to existing roadways) and there is no significant increase affecting the whole population. The calculated increase in risk associated with exposure to the increased concentrations of $PM_{2.5}$ in air at these locations (assessed in section 6) was considered to be tolerable/ acceptable.
- In Burwood there are areas located in the vicinity of Parramatta Road where the project will result in a decreased $PM_{2.5}$ impacts. There are no increases in $PM_{2.5}$ concentrations predicted in this area.

Other areas where small increases in $PM_{2.5}$ were predicted are located in the suburbs of Haberfield and Leichardt, which are both areas of low socioeconomic disadvantage.

Hence the changes in air quality associated with the project are not considered to adversely affect areas of lower socioeconomic disadvantage.

It is noted that in many urban areas housing prices are lower on main roadways. However, in the study area the median house prices are high, so the effect of changes in price based on proximity to main roads is not a significant factor. Some public housing is located in the study area, however these properties are mixed in with privately owned property such that there are no specific areas with higher populations of public housing tenants. Hence there are no social equity issues identified in relation to the change in air quality in the local community.

11.6 Changes in noise

As discussed in **section 11.4.2**, the project will result in lower noise levels in many areas with some areas, located close to new road infrastructure, experiencing an increase in noise. In addition where no mitigation measures are implemented the predicted change in noise levels associated with various construction activities are likely to result in adverse health impacts. These impacts include disturbance of sleep, reduced capacity for concentration, interference with speech and other activities and the loss of the use of outdoor space are all likely with potential for effects on cardiovascular health if the elevated noise at a particular location occurs for extended periods. Annoyance and increased stress levels will also occur. Consequently, significant mitigation of noise and vibration impacts is required to be implemented during the construction phase of the project to ensure there are no impacts on the health and wellbeing of the local community..

Road noise changes predicted for the project will require the implementation of mitigation measures (low noise pavement and some noise barriers) with some properties also requiring treatment to lower noise levels inside the home to a level where health impacts are minimised. For properties where noise treatment is identified, these measures are effective in minimising impacts of noise on health if they are taken up by the property owner and windows and doors are kept closed. Where this does not occur there is the potential for health impacts to occur as a result of increased road noise (particularly in the evening and at night). In addition, it is noted that for these properties comfortable use of outdoor areas may change (due to increased noise impacts) and affect the access and use of outdoor garden areas. Where alternate quiet outdoor areas are accessible, such impacts are not considered to be significant, however for some members of the community it may not be possible or practical to travel to other outdoor areas. Where this is the case the change in property use (as a result of noise impacts) may result in increased levels of stress and anxiety and decreased wellbeing.

Properties where noise mitigation measures are required for the operation of the project are primarily located adjacent to existing main roadways: the M4, Concord Road and Wattle Street. There are some properties that are not located adjacent to existing major roadways. A number of these properties are already affected by elevated levels of road noise and the mitigation measures proposed may reduce overall impacts of road noise at these locations. A review of the areas where noise impacts are predicted has not identified impacts that affect specific areas of disadvantage.

11.7 Changes in community

Changes in the urban environment have the potential to result in impacts to health, primarily due to increased levels of stress and anxiety associated with rapid changes in the community. In relation to this project, many of the changes relate to property acquisitions, access to community facilities, visual impacts and changes in community cohesion.

Property acquisitions and access

Assessment of the social impacts of property acquisitions presented in the SIA concluded that it is anticipated that the social impacts of relocating for many of the directly affected households would be a major short term impact. While for some, if they desire but are unable to relocate locally, the social impact may involve an extended recovery time.

The project would involve the acquisition of some community facilities (Strathfield Girl Guides Hall (to be relocated), Powells Creek/Arnotts Reserve, Zongde Buddhist Temple (to be relocated) and Concord Uniting Church (part acquisition only)).

During construction a loss of access to other facilities (Bill Boyce Reserve at Pomeroy Street, parts of Reg Coady Reserve at Wattle Street, vacant land located west of Powells Creek and Cintra Park Hockey Complex) would occur. Community access to these facilities and open space areas would be returned after construction is complete.

In relation to property acquisitions, the following can be noted from the SIA for specific areas within the community:

- Homebush area – residents living in the properties proposed to be acquired (on Ismay Avenue, Allen and Short streets and Underwood Road) are not considered to be vulnerable and hence the project is not expected to disproportionately disadvantage residents in this area
- Concord area – a number of the properties proposed to be acquired are in locations adjacent to existing major roadways (affected by existing noise and amenity impacts). Two of the properties are public housing properties. These tenants may be at a greater disadvantage and may be more vulnerable to health issues associated with relocation
- Cintra Park area – no residential properties will be acquired in this area. The only impacts relate to and use of Cintra Park stadium land and parking areas for construction activities. These impacts are temporary
- Wattle Street area – a large number of properties are proposed to be acquired (along Wattle Street, Parramatta Road, and include some adjoining properties in Wolseley, Northcote, Ramsay and Martin Streets and Walker Avenue). While these acquisition are not expected to disadvantage any particular group the project would have some impact on the cohesion of the local community
- Parramatta Road area – the properties proposed to be acquired in this area (primarily front the southern side of Parramatta Road and adjoining areas of Chandos Street) are at greater socio-economic disadvantage and may be more vulnerable to health issues associated with relocation.

Moving house is known to be a significant stressor that can have a negative short-term impact on the health of individuals. WDA is providing access for affected households to a counselling service (WestConnex Assist) to support them in negotiating the land acquisition process. This service provides short-term, results-focussed support to help people adapt to changes brought by the property acquisition process, and can also on-refer clients to other service providers as required. This service would assist in minimising health impacts associated with property acquisitions.

Visual changes

Changes in visual amenity are predicted to occur during construction for a number of residents where the property overlooks a construction ancillary facility or work site. Once completed, new road infrastructure (ramps and tunnel) would be landscaped to reduce long-term visual impacts of the project.

The project is located in a highly modified urban environment and does not involve clearing of remnant native vegetation. Small areas of planted vegetation would be removed with mitigation measures proposed to minimise indirect impacts.

Noise mitigation measures would result in the installation of noise barriers in some locations which would affect visual amenity. In addition, some properties would be located closer to new road infrastructure. These impacts are primarily along the M4 corridor in Homebush at the western and eastern ventilation facilities, and Concord Road, Parramatta Road and Wattle Street interchanges. Project design and landscaping plans aim to minimise visual intrusion of project elements and respect and respond to the existing character of these areas.

Changes to the amenity and of a street or suburb can negatively impact a sense of belonging and identity of its residents and consequently their community cohesion.

11.8 Assessment of cumulative impacts

Within an urban environment there is a wide range of complex factors (acting and interacting at different scales) that can affect health and wellbeing. This is conceptualised in **Appendix J** (presented by the International Council for Science and similar to that defined by the WHO) (International Council for Science (ICSU) 2011). The factors identified may result in either positive or negative impacts on health and wellbeing. It is noted that no single element or determinant acts in isolation. Health and wellbeing in the urban environment depends on the sum of the total interactions between many factors. Where negative impacts have been identified, these impacts are either short-term (during construction only) and/or appropriate mitigation or management measures have been identified which would minimise impacts on the community.

11.9 Management of impacts

Environmental management measures to minimise impacts to human health during construction and operation of the project are provided in **Table 11.15**. In addition, management measures are provided in the following sections:

- Transport and travel management measures: **section 8.6**
- Air quality management measures: **section 9.9** and **9.10**
- Noise impacts management measures: **section 10.7**
- Social impact management measures: **section 14.6**.

Table 11.15 Environmental management measures – human health

Impact	No.	Environmental management measure	Responsibility	Timing
Construction				
Moving house due to property acquisition	HH1	Provision of access for affected households to a counselling service, WestConnex Assist, to support them in negotiating the land acquisition process and relocation.	WDA	Pre-construction