11 Human health

A Technical working paper: Human health (**Appendix I**) has been prepared to assess the potential impacts of the project on human health. This chapter includes:

- An outline of the methodology used to undertake the human health assessment
- A summary of the existing environment as it relates to human health
- A description of the potential impacts of the project on human health during construction and operation
- Environmental management measures proposed to be implemented to minimise any potential impacts of the project on human health.

Table 11-1 sets out the Secretary's Environmental Assessment Requirements (SEARs) as they relate to human health, and where in the environmental impact statement (EIS) these have been addressed.

Table 11-1 SEARs – human health

SEARs	Where addressed
An assessment of human health impacts with particular consideration of:	
• how the design of the proposal minimises adverse health impacts,	**Section 11.3** and **Section 11.4**
• human health impacts from the operation of the tunnel under a range of conditions, including worst case operating condition, and	**Section 11.3** and **Section 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 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 11.3** and **Section 11.4** **Section 11.1**

11.1 Assessment methodology

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

11.1.1 Method of assessment

The human health risk assessment was carried out 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* (enHealth, 2012a)
- *Health Impact Assessment Guidelines* (enHealth, 2001)
- *Australian Exposure Factor Guidelines* (enHealth, 2012b)
- *Health Impact Assessment Guidelines* (Harris, 2007)
- *National Environment Protection Council (NEPC) Schedule B(8) Guideline on Community Consultation and Risk Communication, National Environment Protection (Assessment of Site Contamination) Measure* (NEPC, 2013)

- *NEPC National Environmental Protection (Air Toxics) Measure, Impact Statement for the National Environment Protection (Air Toxics) Measure* (NEPC, 2003)
- *United States Environment Protection Agency (USEPA) Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment)*, EPA-540-R-070-002 (USEPA, 2009).

More specifically in relation to the assessment of health impacts associated with exposure to particulates, additional guidelines available from the NEPC, World Health Organisation and 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 as well as social impacts during the construction and operation of the project, and an estimation of short-term (acute) and long-term (chronic) impacts during construction and operation of the project
- Human health impacts to users of the tunnel and external receivers from the operation of the tunnel under a range of conditions, including worst case operating condition
- Consideration of cumulative impacts, and changes to exposure that are associated with the project.

Key tasks involved in the human health risk assessment included:

- A review of available information and guidelines that relate to the project design
- Reviewing 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 that may be exposed to impacts from the project
- A toxicity assessment that enables a calculation of an increased annual risk and an increased incidence of a potential impact 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.
- A risk assessment that enabled a calculation of an increased annual risk and an increased incidence of a potential impact 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 the Technical working paper: Human health (**Appendix I)**.

11.1.2 Study area

The study area is centred on the project alignment and comprises an area that is about 11 kilometres by seven kilometres in size. The suburbs (or part suburbs) considered as part of the human health risk assessment included:

- Roselands
- Riverwood
- Narwee and Beverly Hills
- Lakemba and Wiley Park
- Hurstville
- Penshurst
- Canterbury
- Belmore
- Campsie and Clemton Park
- Kingsgrove North and Earlwood
- Kingsgrove South, Bexley North and Bardwell Park
- Bexley
- Arncliffe, Turrella and Bardwell Valley
- Rockdale and Banksia
- Wolli Creek
- Monterey, Brighton-Le-Sands and Kyeemagh
- Sydenham, Tempe and St Peters
- Marrickville
- Erskineville and Alexandria
- Newtown
- Botany
- Mascot.

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

Impacts to sensitive community receivers in suburbs close to the study area have also 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 45 specific community receivers included in the health risk assessment.

A further 46,200 individual receivers have been modelled in the streets / suburbs located in the study area. These individual receivers represent residential homes, workplaces or recreational areas located in the surrounding community. These receivers are referred to as residential, workplace and recreational (RWR) receivers. The RWR receivers include other community receivers located in the study area, not included in **Table 11-2**. The peak impacts on all of the RWR receivers have also been evaluated in this assessment.

Table 11-2 Community receivers included in health risk assessment

Receiver name	Type of receiver	Suburb
Active Kids Beverly Hills	Child care	Beverly Hills
Active Kids Narwee	Child care	Narwee
Beverly Hills North Public School	School	Beverly Hills
Beverly Hills Girls High School	School	Beverly Hills
Barfa Bear Child Care Centre	Child care	Beverly Hills
Regina Coeli Catholic Primary School	School	Beverly Hills
Footsteps Early Learning Centre	Child care	Beverly Hills
Footsteps Early Learning Centre OOSH School Care	Child care	Beverly Hills
McCallums Hill Public School	School	Roselands
Hurstville City Council Family Day Care Scheme	Child care	Hurstville
Kingsgrove North High School	School	Kingsgrove
Kingsgrove Early Childhood Health Centre	Health	Kingsgrove
Kingsgrove World Of Learning	Child care	Kingsgrove
Kingsgrove Day Hospital	Hospital	Kingsgrove
Kings Medical Clinic	Health	Kingsgrove
Kids Oasis Childcare Centre	Child care	Kingsgrove
Clemton Park Public School	School	Clemton Park
The Salvation Army Booth College	School	Bexley North
Alloa Nursing Home	Aged care	Arncliffe
Athelstane Public School	School	Arncliffe

Receiver name	Type of receiver	Suburb
Kinderoos Childcare Centre	Child care	Arncliffe
Ladybugs Day Care	Child care	Turrella
Macedonian Community Child Care Centre	Child care	Arncliffe
Arncliffe Public School	School	Arncliffe
Tempe High School	School	Tempe
Tillman Park Child Care Centre	Child care	Tempe
St Pius' Catholic Primary School	School	Enmore
Camdenville Public School	School	Newtown
Camdenville Public School Preschool	School	Newtown
St Peters Public School	School	St Peters
Sydney Park Childcare Centre	Child care	Alexandria
Sydney Park Childcare Centre	Child care	Alexandria
Lady Gowrie Child Centre	Child care	Erskineville
Active Kids Mascot	Child care	Mascot
Building Blocks Early Childhood Learning	Child care	Alexandria
Rosemore Aged Care	Aged care	Belmore
Fairmont Aged Care	Aged care	Bexley
Prestige Nursing Agency	Aged care	Varsity Lakes, Campsie
Lakemba Masonic Caring Centre	Aged care	Lakemba
Jenny-Lyn Aged Care Centre	Aged care	Brighton-Le-Sands
Menaville Nursing Home	Aged care	Rockdale
Chow Cho-Poon Nursing Home	Aged care	Earlwood
Moorefields Masonic Village	Aged care	Roselands
Glen Village	Aged care	Bardwell Valley
Macquarie Lodge Retirement Village	Aged care	Arncliffe

11.1.3 Field survey and analysis

Seven air quality monitoring stations were established in the study area to support the development and assessment of the project. The monitoring stations have been designed to supplement the existing Office of Environment and Heritage (OEH) and Roads and Maritime stations so that representative data can be established and long-term air quality data near the project can be provided. Background air quality data relevant to the assessment of carbon monoxide (CO), nitrogen dioxide (NO_2) 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. More detail regarding the air quality assessment is provided in **Chapter 10** (Air quality).

Existing ambient noise was measured at 27 locations (refer to the Technical working paper: Human health in (**Appendix I**) for locations) during four noise monitoring periods that were conducted in May / June 2014, December 2014, March 2015 and June 2015. The background noise levels established for use in the noise assessment relates to specific time periods in the *Interim Construction Noise Guideline* (DECC, 2009) and *Road Noise Policy Guideline* (DECCW, 2011).

Attended noise monitoring was also undertaken at a number of locations to supplement ambient noise monitoring. Construction noise was assessed using the CONCAWE model (within SoundPLAN 7.1). Operational noise impacts have been assessed for the years 2021 (representing the year of opening of the project) and 2031 (10 years after opening of the project). Operational noise modelling has considered noise impacts in the community both with and without the project. Details of noise monitoring stations, monitoring locations, noise criteria and modelling are discussed in **Chapter 12** (Noise and vibration).

11.2 Existing environment

11.2.1 Population profile

The composition of the populations located within the suburbs considered in this assessment are available from the Australian Bureau of Statistics for the census year 2011 and are summarised in Table 4.2 and Table 4.3 of the Technical working paper: Human health (**Appendix I**).

The suburbs included in the human health risk assessment are located in six local government areas; Canterbury, Hurstville, Rockdale, Marrickville, Sydney and Botany Bay. The estimated population growth from 2011 to 2013 in each of these local government areas is:

- Canterbury: 23.3 per cent growth in population, including a 26.4 per cent increase in the number of children aged under 15 years and a 62.9 per cent increase in the population aged 65 years and older
- Hurstville: 28.1 per cent growth in population, including a 31.7 per cent increase in the number of children aged under 15 years and 59.3 per cent increase in the population aged 65 years and older
- Rockdale: 30.7 per cent growth in population, including a 36.0 per cent increase in the number of children aged under 15 years and a 58.3 per cent increase in the population aged 65 years and older
- Marrickville: 19.8 per cent growth in population, including a 36.1 per cent increase in the number of children aged under 15 years and a 50.0 per cent increase in the population aged 65 years and older
- Sydney: 58.3 per cent growth in population, including a 95.8 per cent increase in the number of children aged under 15 years and a 136.5 per cent increase in the population aged 65 years and older
- Botany Bay: 43.2 per cent growth in population, including a 49.9 per cent increase in the number of children aged under 15 years and a 75.5 per cent increase in the population aged 65 years and older.

Section 4 of the Technical working paper: Human health (**Appendix I**) provides a detailed description of the social characteristics and economic status of the six local government areas relevant to the project. **Table 11-2** provides a list of the sensitive receivers, termed community receivers, included in this assessment. The locations of the social and economic receivers are shown on **Figure 11-1**.

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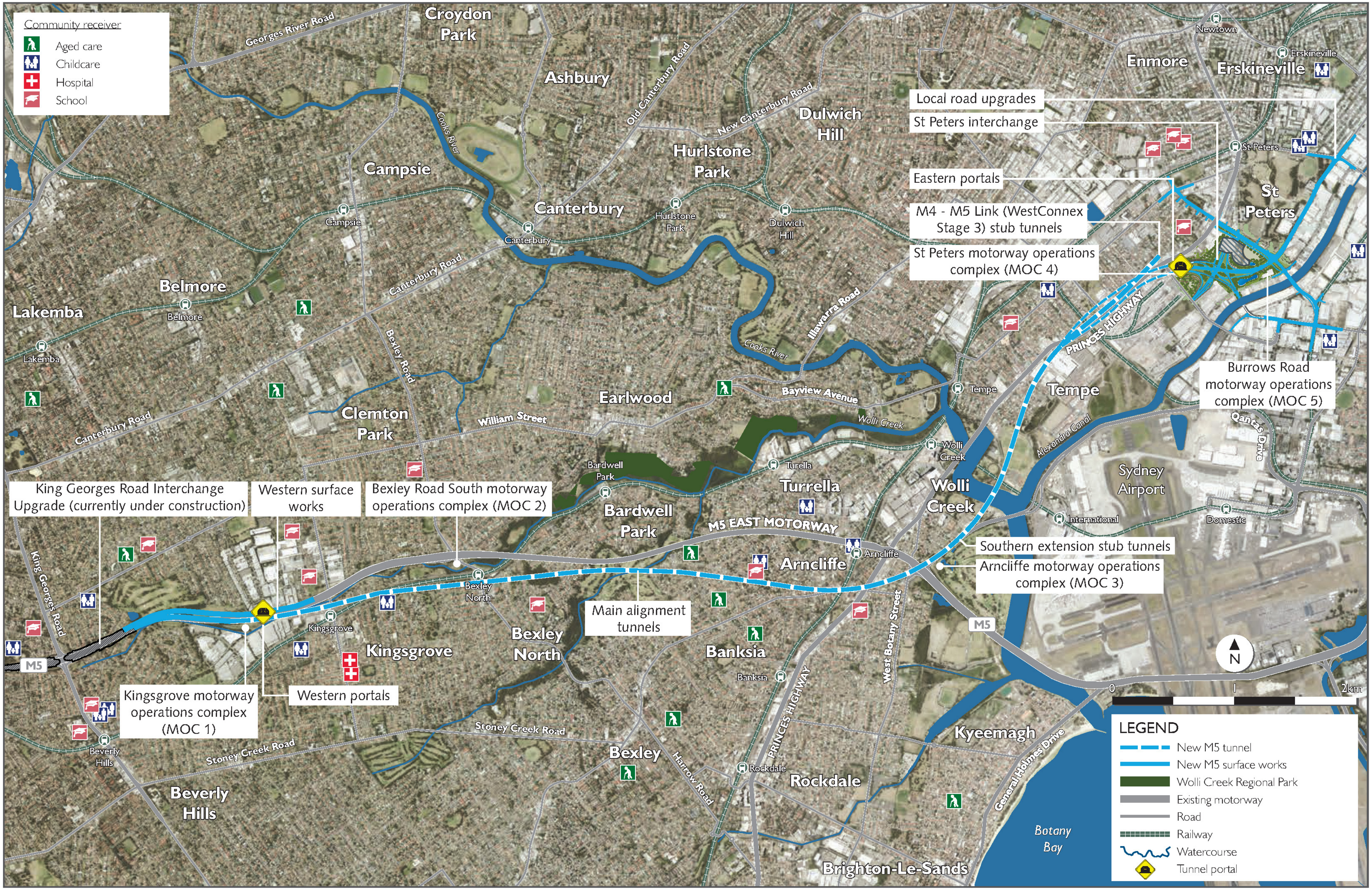

Figure 11-1 Community receivers evaluated in human health risk assessment

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11.2.2 Health of existing population

The health of the community within the study area 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.

The population of the study area is largely located within the Sydney Area Health Service and the South Eastern Sydney Area Health Service. The incidence of health-related behaviours in this area, compared with other health areas in NSW and the state of NSW (based on data from 2014) generally indicates that the population in the Sydney and South Eastern Sydney areas:

- Have similar rates of risky alcohol drinking and smoking and similar intakes of recommended consumption of fruit and vegetables compared with NSW
- Have higher rates of adequate physical activity and lower rates of being overweight and obese compared with NSW.

A review of the data obtained from Health Statistics New South Wales (refer Table 4.4 in the Technical working paper: Human health (**Appendix I**) generally indicates that for the population in the study area, the health statistics (including mortality rates and hospitalisation rates for most categories) are variable but generally similar to those reported in the larger area health services of Sydney and South Eastern Sydney, the wider Sydney metropolitan area and the whole of NSW.

Section 4.5 of the Technical working paper: Human health (**Appendix I**) provides further details on health related behaviours and health indicators for the study area.

11.2.3 Existing air quality

The project is situated 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 all affecting the quality of the air.

Air quality in the Sydney region has improved over the last few decades. The improvements have been attributed to initiatives which aim to reduce emissions from industry, motor vehicles, businesses and residences. While levels of NO_2, SO_2 and CO continue to be below national standards, levels of ozone and particulate matter ($PM_{2.5}$ and PM_{10}) can occasionally exceed the standards. For these pollutants there are a large number of sources in the study area including 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 near the project is provided in **Chapter 10** (Air quality).

11.2.4 Existing noise and vibration

The noise levels at attended monitoring locations showed a typical daily trend with lower noise levels during the night-time compared to the daytime and evening periods. This is characteristic of urban and suburban areas where the ambient noise environment is primarily influenced by road traffic.

The data is also consistent with observed traffic flows on the adjacent major roads which have a relatively small reduction in traffic volumes during the evening compared to the daytime period, and a more significant reduction in volumes during the night-time.

The measured noise levels have been used with consideration of the existing road traffic flows to calibrate the operational noise model and also to establish construction noise management levels for the project.

Background noise levels for construction have been established for the day (7am to 6pm, varying from 45 to 68 decibels (dB(A)), evening (6 to 10pm, varying from 43 to 67 dB(A)) and night-time (10pm to 7am, varying from 32 to 51 dB(A)) periods as rating background level (RBL) values determined on the basis adopted guidelines.

Background noise levels for operations have been established for the day (7am to 10pm varying from 54 to 73 dB(A)) as $L_{Aeq(15\ hour)}$ and night-time (10pm to 7am varying from 50 to 70 dB(A)) as $L_{Aeq(9\ hour)}$.

A full description of the existing noise environment is provided in **Chapter 12** (Noise and vibration).

11.3 Assessment of potential impacts

11.3.1 Construction

Air quality

Chapter 10 (Air quality) has considered impacts to air quality that may occur during construction as a result of tunnelling activities and surface works. The assessment of construction air quality was carried out using a qualitative assessment approach. For almost all construction activities, significant impacts to receivers would be avoided through project design and the implementation of effective mitigation measures. However, dust management measures may not be effective all of the time. In situations where the construction air quality management measures are not fully effective, impacts to receivers would be temporary and short-term and are not considered to be significant. A construction air quality management plan would be developed and implemented for all construction activities of the project (refer to **Chapter 10** (Air quality) for more information).

Noise and vibration

As described in **Chapter 12** (Noise and vibration), a worst case noise and vibration assessment (assuming no additional mitigation measures are implemented) was carried out in accordance with the *Interim Construction Noise Guidelines* (DECC, 2009). For each area assessed, the noise levels at the most affected receiver have been used to represent the whole area.

Construction noise

Potential construction noise which exceeds the applicable construction noise management levels have been identified at a number of receivers during site establishment works, road and intersection modifications (including traffic controls), works within the various construction compounds, construction of surface roadways and other local road works (as part of the local road upgrades), M5 East Motorway road widening and realignment (as part of the western surface works), construction of tunnel portals and interchanges, tunnelling works, demolition of existing structures and construction of fixed facilities. A range of mitigation measures (including temporary construction noise attenuation structures) have therefore been identified to mitigate and manage these potential impacts.

During construction it is likely that the screening criterion for sleep disturbance would be exceeded during some night time works adjacent to residential receivers for most works scenarios, with the greatest impact predicted during local road works and road works for the construction of toll infrastructure. The level of noise predicted for the project is typical for construction works using noise intensive equipment in urbanised areas. Where possible, construction works would be undertaken during the daytime. The need for additional noise mitigation measures for works during night time would be considered during detailed design works for the project.

Construction traffic

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

The majority of construction traffic flows would occur on major roads. Construction compound locations have been selected to minimise the use of local roads; however, construction vehicles may use local roads that do not form part of the construction compound vehicle routes to access construction areas (such as along local roads that are subject to construction activities). The construction traffic noise associated with access and use of local roads has been evaluated in **Chapter 12** (Noise and vibration). The assessment found that Wirega Avenue and West Botany Street (north of the M5 East Motorway) were the most affected local roads proposed to carry heavy construction vehicles. Other local roads around the temporary construction compounds would be less affected.

Ground-borne noise

Detailed three-dimensional modelling was undertaken for the project to predict potential elevated noise levels 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 vibrations being generated from noise moving through the ground rather than the air.

The three-dimensional modelling addressed the worst case scenario, where tunnelling occurs immediately beneath a sensitive receiver. The tunnelling equipment would move at about seven metres per day so would be directly underneath a sensitive receiver for a relatively short period of time (around five days for most receivers). However, tunnelling advance rates may reduce to between two and five meters a day around tunnel portals, which may increase the duration of exposure for sensitive receivers at these locations.

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

At some locations where the tunnel rises to meet surface roads (for example St Peters interchange) and where cross passages would be constructed (for example at Kingsgrove, Bardwell Park, Bexley North and St Peters), exceedances of evening noise criteria may occur. Some 369 receivers may also experience exceedances of the more stringent night-time criteria throughout the study area, including the suburbs of Kingsgrove, Bexley North, Bardwell Park, Tempe, and St Peters.

Vibration impacts

Some of the equipment which would be used during 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 construction plant and equipment and the sensitive receiver locations.

The vibration assessment undertaken indicates about 163 receivers would experience exceedances of the preferred night-time human comfort criteria during tunnelling works. The maximum night-time criteria are not anticipated to be exceeded.

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 as a result of 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 throughout the duration of construction 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

Blasting would be carried out along the length of the tunnel alignment during excavation and would be carefully planned to ensure blast limits are satisfied. Each blast event would be tailored to site conditions and site constraints at each blast location as tunnelling activities progress. Impacts resulting from blasting are largely dependent on the blast methodology. The size of the charge, space between charges and timing between charges results in a large variability in the vibration generated by a blast. This variability necessitates a specialised blast consultant to design blasts to ensure compliance with the applicable vibration criteria. Further detailed assessment and a blast trial process would be described in a Blast Management Strategy, which would be prepared during the detailed design of the project.

11.3.2 Operation

Air quality

The assessment of impacts to air quality associated with operation of the project has considered a range of scenarios that include the existing situation and operation for the future years 2021 and 2031; with and without the project, outside of the main alignment tunnels. The operational air quality assessment has focused on the following key pollutants associated with vehicle emissions:

- Volatile organic compounds (VOC)
- Polycyclic aromatic hydrocarbons (PAH)
- CO
- NO_2
- Particulate matter ($PM_{2.5}$ and PM_{10}).

Emissions associated with the operation of the tunnel relate to the discharge of air from within the tunnel to atmosphere via three ventilation facilities located at Kingsgrove (venting emissions from west-bound traffic), Arncliffe (venting emissions from east-bound traffic) and St Peters (venting emissions from east-bound traffic).

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 to limit the discharge of pollutants to the external environment. Additional details on the operational air quality assessment scenarios, locations of air quality monitoring stations and the emission sources and limits considered are provided in **Chapter 10** (Air quality).

Vehicle emissions

Emissions from vehicles using the main alignment tunnels have been estimated based on published emission factors relevant to vehicle fleets in the year 2020. These emissions factors have been assumed to remain the same for assessing impacts in 2021 and 2031. This is a conservative approach because it does not take into account improvement in fuel and vehicle efficiencies that are likely to occur over this period.

Volatile organic compounds and polycyclic aromatic hydrocarbons

VOCs and PAHs are associated with emissions from vehicles using the main alignment tunnels 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 VOCs that have been considered for the vehicle emissions are benzene, toluene, ethylbenzene, and xylenes (BTEX), 1,3-butadiene, acetaldehyde and formaldehyde (consistent with those identified and targeted in studies conducted in Australia on vehicle emissions (Department of the Environment, 2003; EPA, 2012b)).

The predicted (incremental) increase in concentration of individual VOCs and PAHs associated with the project (based on the speciation 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 (enHealth, 2012a) 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, 2012b).

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 the VOCs considered for the project is presented in the Technical working paper: Human health (**Appendix I**).

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 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:

- 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) in concentration in air for 2021, 2031 and the cumulative scenario as modelled as part of the air quality assessment (refer to **Appendix H**). Concentrations in all other areas of the surrounding community are lower than evaluated in this assessment. In most locations the project results in a lowering of VOCs and PAHs concentrations in air (ie a beneficial effect).

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.

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	
	Maximum concentration (µg/m^3)	HI	Maximum concentration (µg/m^3)	HI	Maximum concentration (µg/m^3)	HI
Total VOCs	**244**		**171**		**146**	
Toluene	19.5	0.0043	12.4	0.0028	11.7	0.0026
Xylenes	16.1	0.0073	10.2	0.0046	9.7	0.0044
1,3-Butadiene	2.8	0.0042	1.8	0.0027	1.7	0.0025
Formaldehyde	6.0	0.40	5.7	0.38	3.6	0.24
Acetaldehyde	3.2	0.0067	2.6	0.0055	1.9	0.0040
Total HI	**0.4**		**0.4**		**0.2**	

For the assessment of chronic exposures to VOCs and PAHs (**Table 11-4**), the calculated HI associated with exposure to the predicted maximum concentrations is less than or equal to one for 2021, 2031 and the cumulative scenario. The calculated lifetime cancer risks associated with the maximum change in benzene and carcinogenic PAHs (as benzo(a)pyrene Toxic Equivalence Quotient (TEQ)) are equal to 1×10^{-5} and are considered to be tolerable.

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	
	Maximum concentration (μg/m^3)	HI	Maximum concentration (μg/m^3)	HI	Maximum concentration (μg/m^3)	HI
Total VOCs	**6.3**		**4.8**		**5.5**	
Toluene	0.51	0.00010	0.35	0.000070	0.44	0.000088
Xylenes	0.42	0.0019	0.29	0.0013	0.36	0.0017
1,3-Butadiene	0.072	0.24	0.051	0.17	0.063	0.21
Formaldehyde	0.15	0.047	0.16	0.048	0.13	0.041
Acetaldehyde	0.082	0.0091	0.072	0.008	0.072	0.007
Total PAHs	**0.042**		**0.032**		**0.036**	
Naphthalene	0.027	9×10^{-3}	0.021	7×10^{-3}	0.024	8×10^{-3}
Acenaphthylene	0.0022	1×10^{-5}	0.0017	9×10^{-6}	0.0020	1×10^{-5}
Acenaphthene	0.00058	3×10^{-6}	0.00044	2×10^{-6}	0.00051	2×10^{-6}
Fluorene	0.0029	2×10^{-5}	0.0022	2×10^{-5}	0.0025	2×10^{-5}
Phenanthrene	0.0057	4×10^{-5}	0.0043	3×10^{-5}	0.0050	4×10^{-5}
Anthracene	0.00046	5×10^{-7}	0.00035	3×10^{-7}	0.00040	4×10^{-7}
Fluoranthene	0.00033	2×10^{-6}	0.00025	2×10^{-6}	0.00029	2×10^{-6}
Pyrene	0.00058	6×10^{-6}	0.00044	4×10^{-6}	0.00051	5×10^{-6}
Total HI	**0.3**		**0.2**		**0.3**	

Table 11-5 presents a summary of the calculated incremental lifetime carcinogenic risk (ILCR) 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 the risk assessment within the Technical working paper: Human health in **Appendix I**.

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	0.27	6×10^{-7}	0.19	5×10^{-7}	0.24	6×10^{-7}
Benzo(a)pyrene TEQ	0.00037	1×10^{-5}	0.00029	1×10^{-5}	0.00033	1×10^{-5}
Total carcinogenic risk	1×10^{-5}		1×10^{-5}		1×10^{-5}	

ILCR = incremental lifetime carcinogenic risk

The results shown in **Table 11-3**, **Table 11-4** and **Table 11-5** indicate that there would be no chronic health risk issues in the local community associated with the project. It is noted that the calculations undertaken for PAH are based on a conservative estimate of the fraction of emissions from vehicles that comprises PAH (as a percentage of total VOCs). The approach adopted is expected to overestimate concentrations of PAH in air. Hence the calculations presented are considered to be a conservative upper limit estimate.

Carbon monoxide

Adverse health effects of exposure to CO are linked with carboxyhaemoglobin (COHb) in blood. Association between exposure to CO and cardiovascular hospital admissions and mortality; especially in the elderly, for cardiac failure, myocardial infraction and ischemic heart disease as well as some birth outcomes (such as low birth weights) have been identified (NEPC, 2010). Guidelines are available in Australia from NEPC (NEPC, 2003) and the NSW EPA (OEH) that are based on the protection of adverse health effects associated with CO. These guidelines consider exposures to CO from a ‘lowest observed adverse effect level’ and ‘no observed adverse effect level’.

A guideline level of CO 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 more susceptible groups of individuals. The NSW EPA has also established a guideline one-hour average (30 milligrams per cubic metre) concentrations of CO 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 CO for the assessment years 2021 and 2031, both without and with the project.

Table 11-6 Review of potential acute and chronic health impacts – carbon monoxide

Scenario	Maximum 1-hour average concentration of carbon monoxide (mg/m^3)		Maximum 8-hour average concentration of carbon monoxide (mg/m^3)	
	Without project	With project	Without project	With project
2021				
Maximum	8.0	8.7	5.5	6.0
2031				
Maximum	7.7	8.5	5.3	5.8
Cumulative - 2031				
Maximum	--	7.8	--	5.4
Relevant health based guideline	30		10	

All the concentrations of CO presented in the above table are well below the relevant health based guidelines. Hence, there are no adverse health effects expected in relation to exposures (acute or chronic) to CO in the local area surrounding the project.

Nitrogen dioxide

Motor vehicles, along with industrial, commercial and residential (for example gas heating or cooking) combustion sources, are primary producers of nitrogen oxides, including NO_2. In Sydney, it was 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 (EPA, 2012b).

NO_2 is the only oxide of nitrogen that may be of concern to health (WHO 2000b). NO_2 can cause inflammation of the respiratory system and increase susceptibility to respiratory infection. Exposure to elevated levels of NO_2 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 NO_2. The health effects associated with exposure to NO_2 depend on the duration of exposure as well as the concentration.

Guidelines are available from the NSW EPA and NEPC (NEPC 2003) which indicate acceptable concentrations of NO_2. 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 NO_2 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 nitrogen dioxide

The guideline for the assessment of acute (short-term) exposure is 246 micrograms per cubic metre (µg/m^3) (or 120 parts per billion by volume (ppbv)) and chronic (long-term or lifetime) exposures of 62 µg/m^3 (or 30 ppbv) is protective of adverse health effects in all individuals, including sensitive individuals.

Table 11-7 presents a summary of the maximum predicted cumulative annual average concentration of NO_2 for the modelled scenarios.

Table 11-7 Review of potential acute health impacts – NO_2

Location and scenario	Maximum 1-hour average concentration of NO_2without the project (µg/m^3)	Maximum 1-hour average concentration of NO_2 with the project (µg/m^3)
2021		
Maximum residential	473	424
Maximum commercial	452	458
2031		
Maximum residential	477	383
Maximum commercial	388	331
Cumulative - 2031		
Maximum residential	--	312
Maximum commercial	--	298
Acute health based guideline	**246**	**246**

The maximum cumulative concentrations of NO_2 presented in the above table are above the acute NEPC guideline of 246 micrograms per cubic metre, principally due to the contribution of NO_2 from the surface roads that are predicted to exceed the short-term criteria even without the construction of the project.

The maximum cumulative concentrations of NO_2 are equal to or lower with operation of the project (particularly in 2031 and with consideration of all the WestConnex projects), which indicates that the project provides some benefit (ie an improvement) in lowering concentrations of NO_2 within the local community (compared with the situation where the project was not constructed).

To further address potential risks to human health that may be associated with localised changes in short-term exposures to NO_2 that relate to the project, incremental risk calculations have been undertaken and are presented in Section 6.8 of the Technical working paper: Human health in **Appendix I**.

Assessment of chronic exposures

The NEPC ambient air quality guideline for the assessment of chronic (long-term) exposures to NO_2 relates to the maximum predicted total (cumulative) annual average concentration in air.

The guideline of 62 µg/m^3 (or 30 ppbv) is based on a lowest-observed-adverse-effect level (LOAEL) of the order of 40–80 ppbv (around 75–150 µg/m^3) during early and middle childhood years. These exposures can lead to the development of recurrent upper and lower respiratory tract symptoms, such as recurrent 'colds', a productive cough and an increased incidence of respiratory infection with resultant absenteeism from school.

An uncertainty factor of two was applied to the LOAEL to account for susceptible people within the population resulting in a guideline of 20-40 ppbv (38–75 µg/m^3) (NEPC 1998). On this basis the NEPC (and OEH) chronic guideline is protective of adverse health effects in all individuals, including sensitive individuals.

Table 11-8 presents a summary of the maximum predicted cumulative annual average concentration of NO_2 for the modelled scenarios.

Table 11-8 Review of potential chronic health impacts – NO_2

Location and scenario	Maximum annual average concentration of NO_2 (µg/m^3) Without the project	With the project
2021		
Maximum residential	45.2	42.9
Maximum commercial	47.4	43.0
2031		
Maximum residential	39.4	39.8
Maximum commercial	43.4	38.9
Cumulative – 2031		
Maximum residential	--	36.5
Maximum commercial	--	36.8
Chronic health based guideline	**62**	

All the concentrations of NO_2 presented in **Table 11-8** are well below the chronic NEPC guideline of 62 µg/m^3. No adverse health effects are therefore expected in relation to chronic exposures to NO_2 in the local area surrounding the project.

The maximum concentrations of NO_2 are equal to or lower in the local community for the situation where the project (and all of the WestConnex projects) is operating. This indicates that that the operation of the project provides some benefit (ie an improvement) in lowering the concentrations of NO_2 in the local community.

<u>Incremental nitrogen dioxide</u>

Table 11-9 presents a summary of the health endpoints considered in this assessment, the β coefficient relevant to the calculation of a relative risk (refer to Appendix A in the Technical working paper: Human health (**Appendix I**) for details on the calculation of a β coefficient from published studies).

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 11-9 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 NO_2	Reference
Mortality, all causes (non-trauma)	Short-term	30+	0.00188 (0.19%)	Relationship derived from modelling undertaken for five cities in Australia and one day lag (EPHC 2010; Golder 2013)
Mortality, respiratory	Short-term	All ages*	0.00426 (0.43%)	Relationship derived from modelling undertaken for five cities in Australia and one 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)

* Relationships established for all ages, including young children and the elderly
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 11-10 presents the change in individual risk associated with changes in NO_2 at the maximum impacted receiver (regardless of the land use), the maximum impacts to residential and workplace receivers in the surrounding community, as well as the community receivers, for the operational years 2021 and 2031, including the cumulative scenario (refer to the Technical working paper: Human health (**Appendix I**) for the method of calculating individual risks).

The maximum impacted receiver was included and evaluated for potential exposures by residents to address future changes in land use that may occur during redevelopment. These calculations reflect the maximum population risk in the community from changes in NO_2 concentrations associated with the project. Risks for all other receivers (including other sensitive receivers) would be lower than the maximums presented.

For this project, all maximum impacted locations lie in the range $3x10^{-6}$ to $9x10^{-5}$ and are considered to be tolerable / acceptable. Risks at all community receivers vary from $-6x10^{-6}$ to $2x10^{-5}$ with a number of the calculated risks for community receivers 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 receivers, they are all considered to be tolerable / acceptable.

These conclusions remain unchanged where risks associated with cumulative impacts from the operation of all WestConnex projects are considered.

Table 11-10 Maximum calculated risks associated with short-term exposure to changes in NO_2 concentrations with operation of the project

Scenario and Receiver	Maximum change in individual risk from short-term exposure to NO_2 for the following health endpoints[(a)]		
	Mortality: All causes (ages 30+)	Mortality: Respiratory (all ages)	Asthma ED Admissions (1–14 years)
2021			
Maximum	6×10^{-6}	1×10^{-5}	8×10^{-5}
Maximum residential	5×10^{-6}	1×10^{-5}	6×10^{-5}
Maximum workplace	6×10^{-6}	1×10^{-5}	8×10^{-5}
Childcare centres	9×10^{-7}	2×10^{-6}	1×10^{-5}
Hospitals	7×10^{-7}	1×10^{-6}	9×10^{-6}
Schools	8×10^{-7}	2×10^{-6}	1×10^{-5}
Aged care	1×10^{-6}	3×10^{-6}	2×10^{-5}
2031			
Maximum	4×10^{-6}	9×10^{-6}	6×10^{-5}
Maximum residential	4×10^{-6}	7×10^{-6}	5×10^{-5}
Maximum workplace	4×10^{-6}	9×10^{-6}	6×10^{-5}
Childcare centres	5×10^{-7}	1×10^{-6}	6×10^{-6}
Hospitals	-5×10^{-7}	-1×10^{-6}	-6×10^{-6}
Schools	1×10^{-7}	2×10^{-6}	1×10^{-5}
Aged care	6×10^{-7}	1×10^{-6}	8×10^{-6}
Cumulative - 2031			
Maximum	7×10^{-6}	1×10^{-5}	9×10^{-5}
Maximum residential	3×10^{-6}	7×10^{-6}	4×10^{-5}
Maximum workplace	7×10^{-6}	1×10^{-5}	9×10^{-5}
Childcare centres	6×10^{-7}	1×10^{-6}	8×10^{-6}
Hospitals	-3×10^{-7}	-6×10^{-7}	-4×10^{-6}
Schools	9×10^{-7}	2×10^{-6}	1×10^{-5}
Aged care	5×10^{-7}	1×10^{-6}	6×10^{-6}
Negligible risks	$< 1 \times 10^{-6}$		
Tolerable/acceptable risks	$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$		
Unacceptable risks	$> 1 \times 10^{-4}$		

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

Particulate matter

Particulate matter is a widespread air pollutant with a mixture of physical and chemical characteristics that vary by location 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 the human health risk assessment relate to the particulates most commonly measured in the urban air environment studies, including

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

Table 11-11 presents a summary of the current NEPC and EPA air quality goals and guidelines for particulate matter.

Table 11-11 Ambient air quality goals for particulates

Pollutant	Averaging period	Criteria (µg/m^3)	Reference
PM_{10}	24-hour	50 Maximum of five days exceedance per year	(DEC 2005; NEPC 2003)
	Annual	30	(DEC 2005)
$PM_{2.5}$	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 from this project a ten-fold margin of safety was 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 evaluated health effect that are less than one case per year are considered negligible.

Calculated risks and population incidence – cumulative scenario

Table 11-12 presents the calculated individual risk associated with changes in $PM_{2.5}$ and PM_{10} concentrations at the maximum impacted receiver (regardless of land use), maximum impacted residential and workplace receivers, as well as community receivers, for the cumulative scenario (ie operation of the complete WestConnex program of works) in the year 2031. The change in $PM_{2.5}$ and PM_{10} concentration considered in the risk calculations are also included.

A review of the calculated changes in risk indicates the following in relation to impacts in the study area associated with the operation of WestConnex in 2031:

- Most of the calculated individual risks are in the range $2x10^{-7}$ to $1x10^{-4}$ and are considered to range from negligible to tolerable/acceptable
- As with the assessment of the New M5 in 2021 and 2031, where the cumulative impacts of the WestConnex program of works are considered, there are a number of locations where the project results in lower particulate matter concentrations and other locations where there are some increases in the particulate matter concentrations. This is due to the redistribution of traffic on surface roads in the area
- The greatest increases in $PM_{2.5}$ occur in existing commercial / industrial areas of St Peters, Alexandria and Tempe. In relation to residential areas, the greatest increases occur in the area of Rockdale (Bay Street) and Alexandria (Campbell Road adjacent to Sydney Park). Impacts associated with the Southern extension are based on a strategic concept only. Risks associated with the operation of the Southern extension are therefore indicative only, would be subject to further design, as well as separate planning and approval.

Table 11-12 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[(a)]						
	Maximum	Maximum residential	Maximum workplace	Childcare centres	Hospitals	Schools	Aged care
Change in annual average concentration							
$PM_{2.5}$ (µg/m^3)	1.9	0.87	1.9	0.18	-0.07	0.2	0.12
PM_{10} (µg/m^3)	3.0	1.3	3.0	0.23	0.016	0.37	0.14
Primary health indicators: $PM_{2.5}$							
Mortality all causes (long-term effects, ages 30+)	1 x 10^{-4}	5 x 10^{-5}	1 x 10^{-4}	1 x 10^{-5}	-4 x 10^{-6}	1 x 10^{-5}	7 x 10^{-6}
Cardiovascular hospitalisations (short-term effects, ages 65+)	1 x 10^{-4}	6 x 10^{-5}	1 x 10^{-4}	1 x 10^{-5}	-5 x 10^{-6}	1 x 10^{-5}	9 x 10^{-6}
Respiratory hospitalisations (short-term effects, ages 65+)	3 x 10^{-5}	1 x 10^{-5}	3 x 10^{-5}	3 x 10^{-6}	-1 x 10^{-6}	3 x 10^{-6}	2 x 10^{-6}
Secondary health indicators: $PM_{2.5}$							
Mortality all causes (short-term effects, all ages)	9 x 10^{-6}	4 x 10^{-6}	9 x 10^{-6}	9 x 10^{-7}	-3 x 10^{-7}	1 x 10^{-6}	6 x 10^{-7}
Mortality, cardiopulmonary (long-term effects, ages 30+)	1 x 10^{-4}	4 x 10^{-5}	1 x 10^{-4}	9 x 10^{-6}	-4 x 10^{-6}	1 x 10^{-5}	6 x 10^{-6}
Mortality, cardiovascular (short-term effects, all ages)	3 x 10^{-6}	1 x 10^{-6}	3 x 10^{-6}	3 x 10^{-7}	-1 x 10^{-7}	3 x 10^{-7}	2 x 10^{-7}
Mortality, respiratory (short-term effects, all ages)	2 x 10^{-6}	9 x 10^{-7}	2 x 10^{-6}	2 x 10^{-7}	-7 x 10^{-8}	2 x 10^{-7}	1 x 10^{-7}
Asthma emergency department hospitalisations (1–14 years)	3 x 10^{-5}	2 x 10^{-5}	3 x 10^{-5}	3 x 10^{-6}	-1 x 10^{-6}	4 x 10^{-6}	2 x 10^{-6}
Secondary health indicators: PM_{10}							
Mortality all causes (short-term effects, all ages)	9 x 10^{-6}	4 x 10^{-6}	6 x 10^{-6}	7 x 10^{-7}	5 x 10^{-8}	1 x 10^{-6}	4 x 10^{-7}
Diesel particulate matter							
Lung cancer	3 x 10^{-5}	1 x 10^{-5}	3 x 10^{-5}	2 x 10^{-6}	-1 x 10^{-6}	3 x 10^{-6}	2 x 10^{-6}
Negligible risks	$< 1 \times 10^{-6}$						
Tolerable risks	$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$						
Unacceptable risks	$> 1 \times 10^{-4}$						

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

Elevated Receivers

Further assessment of elevated receivers was undertaken in relation to potential health impacts at both 10 metres and 30 metres above the ground level, representative of potential exposures that may occur in multi-storey buildings.

Impacts that are derived from changes in emissions from surface roads are expected to decrease with height above the roadway. However, in areas closest to the ventilation outlets there is the potential for increased impacts with height.

The assessment of potential impacts at 10 metres and 30 metres height has focused on the worst-case scenario, being the 2031 cumulative case, associated with impacts from all components of the WestConnex program. The maximum change in $PM_{2.5}$ relevant to this scenario was evaluated, which does not relate to any existing multi storey building, rather the maximum value change anywhere in the study area.

Table 11-13 presents the calculated risks associated with the maximum predicted change in $PM_{2.5}$ concentrations at a height of 10 metres and 30 metres above ground level. Calculations are presented in Appendix F of the Technical working paper: Human health (**Appendix I**).

The calculations presented in **Table 11-13** indicate the following:

- At a height of 10 metres within the study area, the maximum change in $PM_{2.5}$ is lower than at ground level and results in risks that are considered to range from negligible to tolerable / acceptable
- At a height of 30 metres within the study area, the maximum change in $PM_{2.5}$ is significantly greater than at ground level and at 10 metres height, and results in risks that are considered to be unacceptable. Further review of the impacts predicted at 30 metres height indicates the following:
  - The impacts identified at 30 metres height are localised around the ventilation outlets, with the maximum increases more specifically located adjacent to the future Southern extension ventilation facility (not part of the New M5 project)
  - The maximum increase in $PM_{2.5}$ away from the immediate vicinity of the ventilation outlets is less than 0.8 µg/m^3 which is associated with small changes in risk that are considered to be tolerable / acceptable
  - There are currently no multi-storey buildings located close to the proposed ventilation facilities associated with the New M5 or the potential location of the future Southern extension ventilation facility, hence the maximum risks calculated are hypothetical at this stage
  - For the New M5, future development of land (including re-zoning) near the ventilation facilities that may involve multi-storey buildings would need to consider the air dispersion performance of the New M5 facilities. The future Southern extension and future M4-M5 Link ventilation facilities are subject to further design development and planning approvals. Any future EIS for these projects would as a minimum assess potential air quality impacts and human health risks associated with these projects, including potential impacts on elevated receivers.

Table 11-13 Calculated individual risk associated with changes in PM2.5 concentrations – cumulative scenario in 2031 for elevated receivers

Health Endpoint	Maximum calculated	
	10 m height	30 m height
Change in annual average concentration		
$PM_{2.5}$ (µg/m^3)	0.73	24.2
Primary health indicators: $PM_{2.5}$		
Mortality all causes (long-term effects, ages 30+)	4 x 10^{-5}	1 x 10^{-3}
Cardiovascular hospitalisations (short-term effects, ages 65+)	5 x 10^{-5}	2 x 10^{-3}
Respiratory hospitalisations (short-term effects, ages 65+)	1 x 10^{-5}	4 x 10^{-4}
Secondary health indicators: $PM_{2.5}$		
Mortality all causes (short-term effects, all ages)	4 x 10^{-6}	1 x 10^{-4}
Mortality, cardiopulmonary (long-term effects, ages 30+)	4 x 10^{-5}	1 x 10^{-3}
Mortality, cardiovascular (short-term effects, all ages)	1 x 10^{-6}	4 x 10^{-5}
Mortality, respiratory (short-term effects, all ages)	7 x 10^{-7}	2 x 10^{-5}
Asthma emergency department hospitalisations (1–14 years)	1 x 10^{-5}	4 x 10^{-4}
Negligible risks	< 1 x 10^{-6}	
Tolerable/acceptable risks	≥ 1 x 10^{-6} and ≤ 1 x 10^{-4}	
Unacceptable risks	> 1 x 10^{-4}	

Shaded cells indicate calculated risks that are considered unacceptable

Assessment of regulatory worst case scenario

Regulatory worst-case scenarios have been evaluated in the Technical working paper: Air Quality (**Appendix H**). These scenarios are based on the situation where emissions to air 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 Technical working paper: Air Quality (**Appendix H**) assume that such an event may last for a 24-hour period.

The assumptions underpinning the all regulatory worst-case scenarios were 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 human health, a worst-case scenario results in short-term changes in air quality. As a result, health effects identified and evaluated in this assessment that relate to changes in short-term concentrations of NO_2 and $PM_{2.5}$ require further assessment. The assessment of short-term human health impacts has utilised the methodology outlined in Appendix A of the Technical working paper: Human health (**Appendix I**) 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 from the ventilation outlets for the project tunnel and the future 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 11-14** presents the calculated change in individual risk associated with exposure to worst-case emissions of NO_2. The table includes the assumptions adopted for the assessment.

Table 11-15 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.

A review of the maximum calculated changes in risk associated with short-term changes in NO_2 (**Table 11-14**) and $PM_{2.5}$ (**Table 11-15**) 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 occurs at the same receiver location every time), the maximum individual risk increases
- The total maximum individual risk increases to but does not exceed $1x10^{-4}$ and hence there are no unacceptable human health risks identified in the community surrounding the project
- The calculated maximum individual risks are in the range of $1x10^{-6}$ to $1x10^{-4}$ 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) are considered to be tolerable / acceptable.

Table 11-14 Maximum calculated risks associated with short-term exposure changes in NO_2 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 (2021)	6×10^{-6}	1×10^{-5}	8×10^{-5}
Increase in risk for 1 day of worst-case emissions (assuming event lasts for 4 hours)*	1×10^{-8}	2×10^{-8}	2×10^{-7}
Increase in risk assuming worst-case event occurs 1 day each week (52 days per year)*	6×10^{-7}	1×10^{-6}	8×10^{-6}
Maximum annual risk – expected conditions plus worst-case event**	7×10^{-6}	1×10^{-5}	9×10^{-5}
The project and future M4–M5 Link (cumulative)			
Maximum annual risk – expected operations	7×10^{-6}	1×10^{-5}	9×10^{-5}
Increase in risk for 1 day of worst-case emissions (assuming event lasts for 4 hours)*	1×10^{-8}	3×10^{-8}	2×10^{-7}
Increase in risk assuming worst-case event occurs 1 day each week (52 days per year)*	7×10^{-7}	1×10^{-6}	9×10^{-6}
Maximum annual risk – expected conditions plus worst-case event**	8×10^{-6}	1×10^{-5}	1×10^{-4}
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 for four hours, and occurs at the same location (receiver) 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 (receiver).

Table 11-15 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	8×10^{-5}	2×10^{-5}	6×10^{-6}	2×10^{-6}	1×10^{-6}	2×10^{-5}
Increase in risk for 1 day of worst-case emissions	8×10^{-7}	2×10^{-7}	5×10^{-8}	2×10^{-8}	1×10^{-8}	2×10^{-7}
Increase in risk assuming worst-case event occurs 1 day each week (52 days per year)*	4×10^{-5}	9×10^{-6}	3×10^{-6}	8×10^{-7}	5×10^{-7}	1×10^{-5}
Maximum annual risk – expected conditions plus worst-case event**	1×10^{-4}	3×10^{-5}	9×10^{-6}	3×10^{-6}	1×10^{-6}	3×10^{-5}
The project and M4–M5 (cumulative)						
Maximum annual risk – expected operations***	6×10^{-5}	1×10^{-5}	4×10^{-6}	1×10^{-6}	9×10^{-7}	2×10^{-5}
Increase in risk for 1 day of worst-case emissions	9×10^{-7}	2×10^{-7}	6×10^{-8}	2×10^{-8}	1×10^{-8}	2×10^{-7}
Increase in risk assuming worst-case event occurs 1 day each week (52 days per year)*	5×10^{-5}	1×10^{-5}	3×10^{-6}	9×10^{-7}	6×10^{-7}	1×10^{-5}
Maximum annual risk – expected conditions plus worst-case event**	1×10^{-4}	2×10^{-5}	7×10^{-6}	2×10^{-6}	1×10^{-6}	3×10^{-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 (receiver) 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 (receiver)

*** Maximum change in risk for the cumulative scenario relates to the maximum change at a residential location. The maximum change predicted within the study area is predicted to occur in a commercial/industrial area that is located within the footprint of the proposed Southern extension and is not considered representative of a realistic community receiver for evaluating cumulative impacts (as the Southern extension would be constructed for the cumulative case)

Assessment of in-tunnel air quality impacts

The in-tunnel air quality was evaluated for the following reasons:

- To design and control ventilation systems - tunnel construction and operation has been designed with the aim to minimise the significant costs involved in providing active ventilation. As a result, systems are designed, constructed and operated to provide sufficient ventilation to maintain acceptable air quality in the main alignment tunnel, at reasonable cost (NHMRC, 2008)
- To manage in-tunnel exposure to air pollution
- To manage external air pollution.

In-tunnel air quality limits, based on the conditions of approval for NorthConnex, have been considered in the human health assessment and are presented in **Table 11-16**. 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 11-16 In-tunnel average limits along length of tunnel

Pollutant	Concentration limit	Averaging period
CO	87 ppm	Rolling 15-minute average
CO	50 ppm	Rolling 30-minute average
CO	200 ppm	Rolling 3-minute average
NO_2	0.5 ppm	Rolling 15-minute average

Another important consideration for tunnel ventilation design is visibility. 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 particulate matter 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 μm), and density.

Particles which result in a loss of visibility also have an effect on human health, and so monitoring visibility also provides the potential for an alternative assessment of the air quality and human health risk within a tunnel. However, such an assessment is limited by the short duration of exposure in tunnels compared with longer exposure times (24 hours and one year) for which the health effects of ambient particles have been established. Further, 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 main alignment tunnels have not been further evaluated.

Concentrations in the main alignment tunnels 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 10 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 and ventilation facilities - concentrations of pollutants would gradually increase from the tunnel entrance to the next offtake to a ventilation outlet. 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 main alignment tunnels was undertaken with consideration of these factors. In addition, the following has also been considered:

- The time spent within the main alignment tunnels would be limited, taking around six to seven 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. Concentrations are not the same in all parts of the tunnel, with concentrations increasing with distance from the start. As a result, 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 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 Motorway 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 CO and NO_2, 80 per cent for fine particulates and 50 per cent for VOCs.

The following provides further discussion on the range of concentrations predicted within the main alignment tunnels.

Carbon monoxide

The maximum one-hour average concentration of CO in the tunnel is predicted to be approximately 7 ppm eastbound, and 13 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 CO from a range of tunnels in Sydney and internationally. 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 the human health risk assessment (ie not comparing data reported over similar averaging / exposure periods). While noting this difficulty in comparing the data, a range of average concentrations of CO have been reported from six ppm to 38 ppm (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 CO. 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 CO 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 CO 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 CO.

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 1.0 ppm. The average concentration in the tunnel is expected to be (at most) approximately 0.5 ppm, equal to the in-tunnel limit
- The maximum in-tunnel concentrations of NO_2 estimated for travelling at 80 kilometres per hour through the tunnel varies from close to 0 ppm at the start to approximately 0.5 ppm both eastbound and westbound. These concentrations are equal to the in-tunnel limit of 0.5 ppm (set as a 15-minute average). Actual exposures would only occur for approximately six to seven minutes at an average concentration of approximately (but likely less than) 0.25 ppm (with windows down). Lower concentrations of approximately 0.06 ppm may occur with windows up and ventilation on recirculation
- The NHMRC (2008) has published measured concentrations of NO_2 from a range of tunnels in Sydney and internationally. 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 NO_2 in tunnels that range from 0.05 ppm 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 NO_2. 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 NO_2 ranged from 0.1 ppm 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 NO_2 for 30 minutes (Barck et al. 2002; Strand et al. 1998), a range of concentrations from zero ppm 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 NO_2 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 NO_2 in tunnels. Guidelines for in-tunnel levels of NO_2 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 (1 ppm as a five minute average) and New Zealand (1 ppm as a 15 minute average) (Longley, 2014). The PIARC has proposed a level of 1 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 particulate matter within a tunnel. In-tunnel criteria relate to visibility (and safety in using the tunnel). It is expected that the concentration of particulate matter within the tunnel would be higher than ambient air concentrations, and the concentration of particulate matter would increase with increasing distance travelled through the tunnel.

The maximum concentration of PM_{10} in the tunnel ranges from approximately 0.01 milligrams per cubic metre to 0.55 milligrams per cubic metre. The average concentration in the tunnel may be approximately 0.005 milligrams per cubic metre to 0.27 milligrams per cubic metre. Motorists may be exposed to these levels where widows are open. The average exposure concentration is lower (ranging from 0.001 to 0.05 milligrams per cubic metre) with windows closed and ventilation on recirculation

Recent review (WHO, 2013) 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 2009a)
- 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 would 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 human 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 human 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 (ETC 2013) vary from 0.022 to 0.085 milligrams per cubic metre for passenger cars and 0.026 to 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 NO_2 or particulate matter (assessed as $PM_{2.5}$). In relation to NO_2, 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 and 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 particulate matter 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.

Noise and vibration

Environmental noise was 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, the impacts of environmental noise has 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 could include:

- 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 tinnitus (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* (NSW, DECC 2009), the *NSW Interim Construction Noise Guideline* (NSW DECCW, 2011), and the N*SW Road Noise Policy* (NSW EPA, 2000).

Noise impacts during operation of the project have been assessed for the years 2021 and 2031. In relation to noise impacts from the operation of the project, the assessment identified the following:

- The project would alter traffic volumes on the existing M5 East Motorway and hence result in an appreciable reduction in noise levels between Beverly Hills and Kingsgrove
- In the western portion of the project, road traffic noise levels are predicted to exceed the adopted daytime criteria at 53 residential receivers and one school receiver, with one residential receiver identified for consideration of additional noise mitigation measures. Noise levels are predicted to exceed the adopted night-time criteria at 65 residential receivers, with one residential receiver identified for consideration of additional noise mitigation measures. The receiver identified for additional noise mitigation is located in Beverly Hills
- Around the St Peters interchange and local road upgrades traffic noise levels are predicted to exceed the adopted daytime criteria at 386 receivers, with 146 receivers (143 residential, 2 school receivers and one recreation area) identified for consideration of additional noise mitigation measures. Noise levels are predicted to exceed the adopted night-time criteria at 382 receivers, with 157 residential receivers identified for consideration of additional noise mitigation measures. The receivers identified for additional noise mitigation include residential homes in Alexandria and St Peters, St Peters Public School and parts of Sydney Park
- The redistribution of traffic on local roadways has the potential to impact on noise levels. The traffic noise assessment concluded that the changes in noise levels on parallel routes would be indiscernible.
- The maximum noise events are predicted to occur between 10pm and 12 midnight and after 6am in the Beverly Hills area. This is likely to be linked to increased heavy vehicle movements. In the St Peters area there are currently a number of maximum noise events and these are likely to increase over time as the percentage of heavy vehicles increases.
- Noise impacts from fixed facilities have also been assessed. The predicted noise levels demonstrate that during both normal traffic conditions and low speed traffic conditions the operational noise criteria would not be exceeded.

Mitigation measures have been considered to reduce noise levels in those locations where it would be above guidance values.

The hierarchy of noise mitigation is firstly to consider at-source noise mitigation measures such as road design and traffic management, then the use of quieter pavements. If these measures cannot be designed to meet the noise criteria, the use of 'in-corridor' mitigation measures would be considered, which are generally noise barriers and mounds. Finally, if the applicable noise criteria cannot be met by using a combination of all these methods, at-receiver mitigation measures can be considered such as architectural treatments and property boundary walls.

For properties where exceedances are up to 10 dB(A), fresh air ventilation, sealing of wall vents and upgraded window and door seals are generally considered appropriate (Architectural treatment type 1). Where exceedances are over 10 dB(A) additional upgrade of windows and doors may be considered (Architectural treatment type 2). One property in Bevery Hills and 157 properties in the Alexandria / St Peters area have been identified as being eligible for consideration of architectural treatments (of varying levels). The properties identified in the Alexandria / St Peters area that are eligible for consideration of noise mitigation are presented in Figure 5-1 to Figure 5-4 of the Technical working paper: Human health (**Appendix I**).

Contamination

The project includes a range of works that are in areas where contamination, derived from former uses of these areas, is known to be present. Contamination may be present as a result of the presence of former landfills, contaminated soil or contaminated groundwater. This includes St Peters interchange and the Arncliffe construction compound.

Intrusive leachate, ground gas, soil, fill and groundwater investigations would be undertaken in specific areas of environmental concern, as outlined in Technical working paper: Contamination (**Appendix O**).

Subject to the nature of the activities proposed to be carried out on the relevant properties, sampling activities would be undertaken prior to disturbance of these areas to minimise the potential for identifying unexpected finds with respect to contaminated land. The investigations would be undertaken in accordance with ASC NEPM (NEPC 1999 amended 2013) guidelines. These guidelines are risk-based guidelines, aimed at protecting the health of the community and workers who may be present on or adjacent to the site. The guidelines are designed to be protective of exposures that may occur as a result of direct contact as well as inhalation. The findings of the investigation would be used to inform appropriate remediation and management options (if required) for the project. Such measures would be protective of the health of all members of the public for both direct contact (where relevant) and inhalation exposures.

The Construction Environmental Management Plan (CEMP) would incorporate an unexpected finds procedure, which would be implemented to manage potentially contaminated materials that may be encountered in areas not identified in the Technical working paper: Contamination (**Appendix O**). The procedure would outline the process for the identification and assessment of potentially contaminated material in the event that previously unidentified contamination is discovered during construction or excavation activities. The procedure would include requirements for inspections and testing of suspected contamination by an appropriately qualified hygienist and/or contaminated lands consultant.

11.3.3 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 broader 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 10** (Air quality) and **Chapter 12** (Noise and vibration) 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. 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, socio-economic 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 specifically evaluates changes that have the potential to indirectly affect the health and well-being of the community. In addition, this section provides 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 15** (Social and economic).

Changes in traffic

The study area includes the local road network associated with the existing M5 East Motorway corridor and the area around the St Peters interchange and local road upgrades.

The existing M5 East Motorway corridor provides the main passenger, commercial and freight connection between South West Sydney and the Sydney CBD, Sydney Airport and Port Botany. It is the main east-west freight, commercial and passenger vehicle corridor in southern Sydney, and is of local and regional transport importance in terms of its function. It also connects to the Sydney orbital network and interstate transport routes. The corridor forms part of the AusLink National Land Transport Network (National Road Network) and the Sydney orbital network.

The M5 East Motorway corridor is subject to high levels of congestion, particularly during peak periods. In addition, arterial roads connecting to the M5 East Motorway, including King Georges Road, Canterbury Road, Stoney Creek Road, the Princes Highway and General Holmes Drive, are experiencing greater volumes of traffic than they were originally designed for, particularly heavy vehicle movements. The additional vehicles along these roads are causing underperformance of the M5 East Motorway by increasing congestion, travel time variability and a higher risk of crashes.

The area around the St Peters interchange and local road upgrades spans the Sydney, Marrickville and Botany local government areas. The key roads at this location include the Princes Highway, Campbell Street, Campbell Road, Euston Road, Bourke Road and Gardeners Road. Intersections along main roads in the area are currently congested and include a high percentage of heavy vehicles.

Construction

Changes to local roads are proposed during construction of the project. While it is expected that access to properties on the local roads would be maintained during construction, some permanent and temporary closures or reduced capacity of some local roads may affect the movement of local traffic through the area.

There are 14 construction compounds used during construction that may result in impacts to local traffic, property access, pedestrian and cyclists movements, and bus stop locations. More significant impacts associated with changes in road access are expected to occur around Arncliffe and St Peters. Some temporary road closures would be required along the M5 East Motorway at night to facilitate the installation, relocation and removal of traffic barriers, the installation of tolling infrastructure, and for works associated with the M5 East Motorway corridor integration works.

The project would result in the generation of additional heavy and light vehicle movements for the removal of spoil, generally along the M5 East Motorway and M5 South West Motorway, deliveries and other movements associated with construction activities. Construction traffic would use the existing motorway and arterial road network as much as possible to minimise impacts on local roads. Construction traffic has the potential to add to existing high levels of congestion in the area increasing traffic delays at some intersections.

It is expected that during construction there would be 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, as well as a 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

Once the project is complete it is expected to result in reductions in vehicle delays in a number of areas, including the M5 East Motorway. The project would result in changes to localised traffic volumes within the M5 East Motorway corridor due to traffic switching to the New M5 and other parallel arterial roads, such as Stoney Creek Road. It is expected that traffic switching to parallel arterial roads may be partly a result of the introduction of tolls onto the M5 East Motorway.

Changes to public transport and pedestrian cycle infrastructure

Public transport

No pedestrians or regular bus services use the existing M5 East Motorway corridor. Intercity and regional bus services which depart from the Sydney CBD use the M5 East Motorway and the M5 South West Motorway; however there are no operational bus stops along the M5 East Motorway.

The Sydney and Marrickville local government areas are serviced by four railway lines, with the closest railway stations located at St Peters and Mascot. The St Peters and Mascot area also has a comprehensive bus network which provides access to the surrounding activity and employment centres as well as the Sydney central business district.

The project would result in the temporary relocation of one bus stop (on Euston Road Alexandria) and the temporary closure of four bus stops, Princes Highway St Peters, two on Bourke Street Mascot and on Gardeners Road in Mascot). The bus stops that are temporarily relocated or closed would be reinstated at the completion of construction.

The bus stop on the southbound side of Canal Road near the intersection of the Princes Highway would be permanently relocated further south along Canal Road to accommodate construction vehicles accessing the Canal Road construction compound. The final location of this bus stop would be determined during detailed design and in consultation with Transport for NSW.

During construction, delays in local traffic would also affect bus travel times. Once the project is completed there would be some changes in bus travel times, with some routes taking additional time and other taking less time (refer to **Chapter 9** (Traffic and transport)).

The project would not impact on the operation of passenger rail services on the Sydney metropolitan rail network.

Pedestrian and Cycle Access

There is currently a network of cycle paths in the area, comprising a mixture of separated cycleways and on road paths in areas of low to medium traffic. Following the commencement of construction of the King Georges Road Interchange upgrade, cyclists can no longer use the M5 East Motorway between this interchange and Bexley Road. An alternative route is provided through the M5 Linear Park between King Georges Road and Bexley Road.

The major cycle path in the area is the Bourke Road cycleway, which provides a separated cycle path along Bourke Road between Gardeners Road and the Green Square railway station. Additional separated cycleways are located in Sydney Park, and these connect to on-road cycle paths on surrounding roads.

Construction of the project would require modifications to pedestrian and cycling facilities around the western surface works, Kingsgrove Road surface works and Bexley Road surface works. This includes realignment of existing pathways to maintain access during construction, temporary closure of some pathways with diversions in place during construction, removal of cyclists from the M5 East Motorway and diversion onto local/surrounding roads.

Roads and Maritime is proposing to widen Marsh Street to three lanes in each direction as part of the Airport West Precinct component of the WestConnex enabling works around Sydney Airport. As part of these works, a dedicated cycleway would be constructed along the westbound carriageway of Marsh Street. Signalised pedestrian crossing facilities are also proposed at the Flora Street / Marsh Street intersection as part of the Airport West Precinct works. Modifications to the Flora Street / Marsh Street intersection would integrate with the Airport West Precinct, and would be constructed in consultation with Roads and Maritime.

The local road upgrades would include new and upgraded pedestrian and cycle infrastructure. This infrastructure has been designed to maintain and enhance pedestrian and cyclist accessibility and connectivity, particularly around the St Peters interchange and Sydney Park. The most significant new infrastructure would be the construction of the Campbell Road pedestrian and cycle bridge which would provide connections between Sydney Park and Mascot. This would provide east-west connectivity across Alexandra Canal connecting the Bourke Road cycleway to St Peters at Unwins Bridge Road. A separated cycleway would also be constructed along Campbell Street. The upgrades to pedestrian and cycle infrastructure would provide for a safe cyclist and pedestrian environment by minimising the interface of cyclists and pedestrians with vehicular traffic, and would also provide a regional cycle connection between Mascot and Marrickville.

The shared path within Beverly Grove Park would be reinstated to the north and south to accommodate the western surface works and the Kingsgrove motorway operations complex. The realignment of this shared path would not restrict its use.

On-road cyclists may experience delays at intersections and increased travel times when accessing and using detours and changes in cycle routes. A strategy for the maintenance of pedestrian and cyclist access during construction would be provided as part of the Construction Traffic Management and Safety Plan(s) for the project.

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

Changes in air quality

The project would 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 would result in an increase in pollutants at some locations. The calculated 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 (refer to Figure 6.4 in the Technical working paper: Human health in (**Appendix I**) for the distribution of changes in $PM_{2.5}$ concentrations in the community).

In relation to changes in air quality impacts associated with the operation of 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. Some of the roadways where increases are predicted are roads that are likely to be used by traffic avoiding the tolling of the M5 East Motorway and these roads run through existing residential areas.

An increase in $PM_{2.5}$ is predicted on Campbell Road in Alexandria adjacent to Sydney Park. While the risks associated with changes in $PM_{2.5}$ concentrations in air are considered to be tolerable / acceptable, properties at this location have also been identified as homes that may require treatment to mitigate increases in noise associated with the operation of the project. While it is not possible to quantify the cumulative risk to health from air quality and noise sources, it is important that measures identified for the effective mitigation of noise are implemented in these areas.

Suburbs in the human health risk assessment study area that, based on the 2011 Census Data, are slightly more disadvantaged (in relation to the Socio-Economic Index for Areas (SEIFA)) include Lakemba, Wiley Park, Punchbowl/Canterbury, Campsie, Hurstville and Arncliffe. Lakemba, Wiley Park and Campsie in particular are noted to have high unemployment and lower household incomes when compared with other suburbs in the study area and Sydney. Some of the predicted increases in $PM_{2.5}$ relate to roadways that run along the boundary of Hurstville and Lakemba. Some roadways that run through Lakemba and Campsie are predicted to have a small decrease on $PM_{2.5}$ concentrations. Within Arncliffe both small increases and small decreases in $PM_{2.5}$ are predicted in some areas. For most of these suburbs, however, there is no predicted change in air quality as a result of the project.

Overall, the changes in air quality associated with the project are not considered to adversely affect areas of socio-economic disadvantage.

The median house prices in the human health risk assessment study area are variable, however in most areas they are consistent with the Sydney average. 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.

Changes in noise

The project would result in lower noise levels in many areas, with only some areas located close to new road infrastructure experiencing an increase in noise. 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 may include disturbance of sleep, reduced capacity for concentration, interference with speech and other activities, and the loss of the use of outdoor space. These impacts may have potential for effects on cardiovascular health if the elevated noise at a particular location occurs for extended periods. Annoyance and increased stress levels would also occur. Consequently, mitigation of noise and vibration impacts would be implemented during construction of the project to avoid or minimise potential impacts on the health and wellbeing of the local community.

Predicted changes in road noise as a result of the project would 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.

Noise levels were predicted at every façade of every building within 600 metres of the project. The use of each receiver was identified through a visual inspection. The receiver was assessed against the EPA’s Road Noise Policy (RNP) criteria, which was specifically developed to minimise adverse health impacts for affected receivers. Where exceedances of criteria were identified, noise mitigation was clearly identified and committed to in accordance with the Roads and Maritime Noise Criteria Guideline and Noise Management Guideline to ensure that adequate noise mitigation is provided to those receivers affected.

The EPA’s RNP criterion for residential receivers represents an external noise criterion. The impact of open windows does not impact the noise criteria for this type of sensitive receivers. For other types of sensitive noise receivers (such as schools, hospitals and child care), an internal noise criterion applies which is measured from the centre of the habitable room that has the greatest exposure to road noise with open windows.

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. 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-time).

In addition, it is noted that for these properties, comfortable use of outdoor areas may change due to increased noise impacts and may affect the access and use of outdoor garden areas. Where alternative quite outdoor areas are accessible such impacts would not 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 in the Alexandria / St Peters area. Most of these properties are not located adjacent to existing major roadways.

The location of properties where noise mitigation is required is generally in an area of low socio-economic disadvantage. It is noted however that some of the individual properties impacted include public housing.

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

The design of the project has been developed to minimise the need for surface property acquisition and impacts on other residential and open space areas. There would, however, be a number of property acquisitions as well as other temporary and permanent impacts on land use associated with the project.

Impacts during construction would include full and partial acquisitions, temporary alterations or disruptions, temporary occupation of land and the settlement of the ground surface as a result of tunnelling. The surface works for the project would impact 159 properties, of which 109 properties are not owned by Roads and Maritime or other NSW Government agencies, and would require acquisition or temporary occupation of the land for project works at the surface.

In relation to impacts to publicly accessible areas, the following areas are expected to be affected:

- M5 Linear Park – the majority of the M5 Linear Park is owned by Roads and Maritime with the remainder owned by Canterbury City Council. Around 10.7 hectares of the M5 Linear Park would be permanently impacted by the project with around 2.6 hectares temporarily impacted. Land required temporarily for construction would be returned to recreational purposes following the completion of construction
- Kogarah Golf Course – The project would occupy a portion of the Kogarah Golf Course during construction and operation. The construction footprint has been minimised so that nine holes would remain open during construction and reduce impacts on the recreation value of the land. The footprint of the permanent facilities has been restricted and appropriately sited to minimise impacts to the future use or development potential of the golf course site
- Sydney Park - currently used for public recreation. Around 0.2 hectares of City of Sydney land adjacent to the road corridor within Sydney Park would be permanently acquired, which represents around 0.56 per cent of the total area of Sydney Park. An additional 0.55 hectares would be temporarily occupied or leased for construction purposes from City of Sydney and returned to recreational uses following the completion of construction
- May Street Reserve - this would be partially impacted by the upgrade of Campbell Street and the intersection of Unwins Bridge Road / Campbell Street / May Street / Bedwin Road. Part of the park is owned by Roads and Maritime with around 0.015 hectares owned by Marrickville Council that would be acquired. Around 0.06 hectares of land not required for the project would be landscaped to reconfigure the May Street Reserve
- Camdenville Park - around 1.1 hectares of Camdenville Park would be impacted as a result of the widened road and works associated with the existing drainage basin. Land not required for road infrastructure (around 0.86 hectares) would be leased or temporarily acquired from Marrickville Council
- Existing industrial areas (including areas used for the Commercial Road construction compound and areas in Mascot) that would be acquired. Residual industrial / commercial land, being land in excess of operational requirements, would be rehabilitated at the end of the construction period and returned for permissible uses under land use zoning provisions.

The construction and / or operation of the project has the potential to restrict local access and connectivity between the various land uses around the surface components of the project. Restrictions are most likely to occur at the western surface works, St Peters interchange and local roads upgrades and include the following:

- The western surface works would be located within a linear infrastructure corridor, which already contains the M5 East Motorway. The main impacts of the project on connectivity of land would be along the corridor during construction. This would largely be a result of roadworks and local road upgrades requiring temporary diversion of existing pedestrian and cyclist facilities. At the completion of construction, the pedestrian and cycle paths would be reinstated. As a result the project is unlikely to generate connectivity impacts at the western surface works during operation

- The project has the potential to restrict access and connectivity around the St Peters interchange and local road upgrades during construction. The project has been designed to enhance pedestrian and cyclist access around the St Peters interchange and would connect with existing cycle and pedestrian paths to Sydney Park via a bridge over Campbell Road
- In eastern parts of the project, new areas of open space would be created around the St Peters interchange. A master plan solution was developed, encompassing the entire interchange site and ensuring its integration with surrounding areas. The majority of the open space to be provided by the master plan would be completed as part of the project. The project would extend the parklands of Sydney Park further south, providing much needed open space for a growing population. Featuring landscape mounds, the design of the interchange parklands would continue the features of Sydney Park. This space would be accessed from shared paths in the east connecting to Sydney Park or via a dedicated entrance at the corner of Canal Road and Princes Highway
- The project would provide the following improved and upgraded connectivity for cyclists and pedestrians:
  - In the western reaches of the project, the existing M5 Linear Park shared path would be updated to provide a three metre wide surface for the majority of its length. This would be complemented by new landscaping along the length of the Linear Park
  - In the east of the project a number of amendments along local roads would provide the opportunity to improve pedestrian and cyclist connectivity around the St Peters interchange. Bridges over the Alexandra Canal would also provide new connections between Mascot, Alexandria and St Peters. These connections would increase access for a growing residential population to Sydney Park and the additional parklands to be created as part of the project
  - Pedestrian access to Sydney Park and the open space created by the project would also be improved
- The property adjustments required for the local road upgrades consist typically of driveway adjustments / extensions to suit the realignment of Euston Road, Campbell Street / Campbell Road and Gardeners Road. Where the works have an impact on a structure such as a residential or commercial building, the entire property has been acquired in most instances. The exception is along Euston Road and Gardeners Road at St Peters where the partial demolition of buildings would be required on some properties. At these locations, access would be modified but maintained during construction.

The operational surface footprint of the project has been generally located along existing roads, and within existing infrastructure corridors so that the new infrastructure would generally be consistent with the surrounding land use.

Closure of the former Alexandria Landfill site as part of the project, would result in a positive land use change by re-using the site as the St Peters interchange. The redevelopment of this site would also enhance pedestrian and cycle path connectivity between Sydney's south and Sydney Park as well as providing an opportunity to create additional public open space.

The project has the potential to affect development patterns in the area as a result of changes in traffic congestion and desirability of different areas for residential and commercial use. Urban development has the potential to result in increased levels of stress and anxiety within the existing community.

Moving house is known to be a significant stressor that can have a negative short-term impact on the health of individuals. Sydney Motorway Corporation, on behalf of Roads and Maritime is providing access for affected households to a counselling service, WestConnex Assist, to support them in negotiating the land acquisition process.

WestConnex Assist was established to provide support to people facing significant change as a result of the project. WestConnex Assist provides independent and confidential phone or face-to-face counselling, across a range of locations and a diverse team of professionals, including psychologists, social workers and qualified counsellors can be matched to the needs of each individual.

Roads and Maritime is also providing an independent service to vulnerable households, such as the elderly and those suffering an illness, to help assist with their relocation. This service aims to provide assistance with tasks such as finding a new property (either to rent or purchase), arranging removalists, service connections (electricity, gas etc.), attending appointments with solicitors and other tasks associated with relocating.

These services will assist in minimising health impacts associated with property acquisitions.

Visual changes

The existing environment of the study area contains a mixed level of visual amenity. This is due to a variety of factors, most significantly the fact that road and rail transport corridors already exist through much of the study area. Furthermore, there are few iconic views available within the study area, and some sections of the study area (such as the existing Alexandria landfill) do not currently provide a high level of visual amenity.

Changes in visual amenity are predicted to occur during construction for a number of residents where the property overlooks a construction compound or work site. In addition, the quality of the view for recreational users in a number of areas would be impacted by the construction works. There is the potential for moderate to high impacts to residents as a result of the use of night lighting at the Kingsgrove North construction compound, Bexley Road North construction compound, Bexley Road East construction compound and the Campbell Road construction compound.

Once completed there would be a range of new road infrastructure that includes ventilation facilities, ramps, tunnel facilities and noise barriers. The areas where new infrastructure and facilities would be present include the Kingsgrove motorway operations complex, M5 Motorway corridor, Bexley North, Bexley Road South motorway operations complex, Arncliffe motorway operations complex, St Peters interchange and motorway complex, and the Burrows Road Motorway Control Complex.

Visual impacts during construction would be managed through the use of landscaping. Designs for temporary noise barriers and hoarding would include painted surfaces and project information, prompt removal of graffiti, use of toned colours and materials on acoustic sheds, use of cut-off and directed lighting to minimise light spill and minimising visual impacts of construction works by maximising separation distances to residential areas.

Visual impacts associated with the operation of the project would be managed through the use of a range of measures that include appropriate building designs for the local areas, landscaping, use of appropriate fencing materials in parks and public spaces, and the use of lighting designs to minimise light spill into surrounding areas.

Changes to noise barriers to minimise visual amenity impacts (such as heights and construction materials) would be undertaken in consultation with specialist noise consultants to ensure the effectiveness of the noise mitigation measures remain. It is important for the protection of human health that the integrity and effectiveness of the noise mitigation measures adopted remains unchanged.

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

The M5 East Motorway, arterial roads and the local road network are currently used by emergency services to travel to and from call-outs. Construction of the project may require temporary traffic diversions, road occupation, temporary road closures and alternative property access arrangements.

The Construction Traffic Management Plan(s) for the project would be developed in consultation with relevant emergency services, ensuring that procedures are in place to maintain safe, priority access for emergency vehicles through construction zones. Additionally, local emergency services would be periodically updated on the staging and progress of construction works.

The project would not impact access to health or emergency services.

11.3.4 Assessment of cumulative impacts

Within an urban environment there are a wide range of complex factors (acting and interacting at different scales) that can affect human health and wellbeing. This is conceptualised in the Technical working paper: Human health (**Appendix I**). 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.

11.4 Environmental management measures

Environmental management measures to minimise impacts to human health during construction and operation of the project are provided in **Table 11-17**. Additional management measures to avoid or minimise impacts to human health are provided in the following chapters:

- Transport and travel management measures - **Chapter 9** (Traffic and transport)
- Air quality management measures - **Chapter 10** (Air quality)
- Noise and vibration impact management measures - **Chapter 12** (Noise and vibration)
- Social impact management measures - **Chapter 15** (Social and economic)

Table 11-17 Environmental management measures – human health

Impact	No.	Environmental management measure	Timing
Construction			
Moving house as a result of property acquisition	HH1	Affected households would be provided access to a free counselling service; WestConnex Assist, to support them in the land acquisition process and relocation.	Pre-construction

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