10 Health, safety and hazards

This chapter identifies potential hazards that could pose a risk to human health, the surrounding community or the human environment and outlines measures to avoid, mitigate or manage those risks. The construction and operation of the project has the potential to create a number of environmental hazards. This chapter is informed by **Appendix F** (Human health technical report) which provides greater detail of the human health risk assessment and results.

Table 10-1 sets out the SEARs relevant to health safety and hazards, and identifies where the requirements have been addressed in this EIS.

Table 10-1 SEARs - Health, safety and hazards

Assessment requirements	Where addressed
3. Health and Safety	
1. The Proponent must assess the potential health impacts from the construction and operation of the project. The assessment must:	
(a) describe the current known health status of the potentially affected population;	Section 10.2.
(b) describe how the design of the proposal minimises adverse health impacts and maximises health benefits;	Section 3.3 of Appendix F (Human health technical report).
(c) assess human health impacts from the operation and use of the tunnel under a range of conditions, including worst case operating conditions and the potential length of existing and committed future motorway tunnels in Sydney;	Section 10.4.1.
(d) human health risks and costs associated with the construction and operation of the proposal, including those associated with air quality, groundwater quality, odours, noise and vibration (including residual noise following application of mitigation measures), construction fatigue and social impacts (including from acquisitions) on the adjacent and surrounding areas, as well as opportunity costs (such as those from social infrastructure and active transport impacts) during the construction and operation of the proposal;	Section 10.3 and section 10.4. Chapter 9 (Air quality), Chapter 11 (Noise and vibration), Chapter 15 (Social and economic), and Chapter 17 (Geology and groundwater).
(e) include both incremental changes in exposure from existing background pollutant levels and the impacts of project specific pollutant levels at the location of the most exposed receivers and other sensitive receptors (including public open space areas, sportsgrounds, child care centres, schools, hospitals and aged care facilities);	Section 10.3.1 and section 10.4.2.
(f) assess the likely risks of the project to public safety, paying particular attention to pedestrian safety, subsidence risks, flood risks and the handling and use of dangerous goods;	Section 10.3.4 and 10.4.5 Chapters 8, 13, 14
(g) assess the opportunities for health improvement;	Section 10.3 and section 10.4 and Appendix F (Human health technical report).
(h) assess the distribution of the health risks and benefits;	Section 10.4.6
(i) include a cumulative human health impact assessment inclusive of in-tunnel users, local and regional impacts due to the operation of and potential continuous travel through existing and committed future motorway tunnels and surface road	Section 10.4.1 and section 10.4.2
17. Hazards	
The Proponent must describe the process for assessing the risk of emissions from ventilation facilities on aircraft operations taking into consideration the requirements of the *Airports Act 1996* (Commonwealth) and the Airport Regulations 1997.	Section 10.4.5.

10.1 Assessment approach

10.1.1 Human health risk assessment

The assessment approach for the human health risk assessment is detailed in **Appendix F** (Human health technical report). The assessment is informed by the air quality impact assessment and noise and vibration assessment undertaken for the project. The assessment approach for these assessments is outlined in **Chapter 9** (Air quality) and **Chapter 11** (Noise and vibration).

The assessment approach is in accordance with national and international guidance that is endorsed or accepted by Australian health and environmental authorities, and includes, but is not limited to:

- Air Quality in and Around Traffic Tunnels (National Health and Medical Research Council (NHMRC) 2008)
- *Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards: 2012* (enHealth 2012b)
- *Health Impact Assessment Guidelines* (enHealth 2001)
- *Health Impact Assessment: A Practical Guide* (NSW Health 2007)
- *Australian Exposure Factors Guide* (enHealth 2012a)
- *Schedule B8 Guideline on Community Engagement and Risk Communication (National Environment Protection Council Schedule (NEPC) 1999* amended 2013a)
- *National Environmental Protection (Air Toxics) Measure, Impact Statement for the National Environment Protection (Air Toxics) Measure* (NEPC 2003)
- *Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment) (United States Environmental Protection Agency* (USEPA) 2009b)

In addition, the following have been considered:

- *Methodology for Valuing the Health Impacts of Changes in Particle Emissions* (NSW EPA 2013)
- NSW Health, Building Better Health, Health considerations for urban development and renewal in the Sydney Local health District (LHD) (NSW Health, 2016)
- Air Quality in and Around Traffic Tunnels (National Health and Medical Research Council (NHMRC), 2008)
- NSW Health, Healthy Urban Development Checklist, A guide for health services when commenting on development policies, plans and proposals, 2009
- *State Environmental Planning Policy No. 33* (SEPP 33) – Hazardous and Offensive Development (NSW).

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

- Existing conditions (in relation to air quality and noise) (refer to **section 10.2.4**)
- Human health risks and costs associated with the project, including those associated with air quality, noise and vibration, groundwater, contamination, and social impacts, during the construction and operation of the project and estimation of short-term (acute) and long-term (chronic) impacts during construction and operation of the project
- Human health impacts on users of the tunnels and external receptors of air and noise emissions from the operation of the tunnels under a range of conditions, including a worst case operating condition
- Consideration of cumulative impacts resulting from the project and other related projects comprising the New M5 and M4M5 Link projects.

The detailed principles, methodology and limitations of the toxicity and risk assessment, as well as how the design of the project minimises adverse health impacts are provided in **Appendix F** (Human health technical report).

During community consultation undertaken prior to the EIS, some members of the community raised concern over the effect of air quality impacts on individuals with respiratory diseases such as asthma.

The potential for the project to result in respiratory effects for individuals is discussed in **section 10.4.1** and **section 10.4.2** of this chapter.

Study area

The study area, illustrated in **Figure 10-1**, identifies the area over which impacts to air quality has been considered (referred to as GRAL domain, as discussed in **Chapter 9** (Air quality)).

The operational modelling considered meteorology relevant to a larger area (red box, or GRAMM (Graz Mesoscale Model) domain, on **Figure 10-1**) that includes the study area, local terrain, and project-specific emission sources.

A smaller area, within this larger area, has been considered for the assessment of noise, soil and vibration impacts.

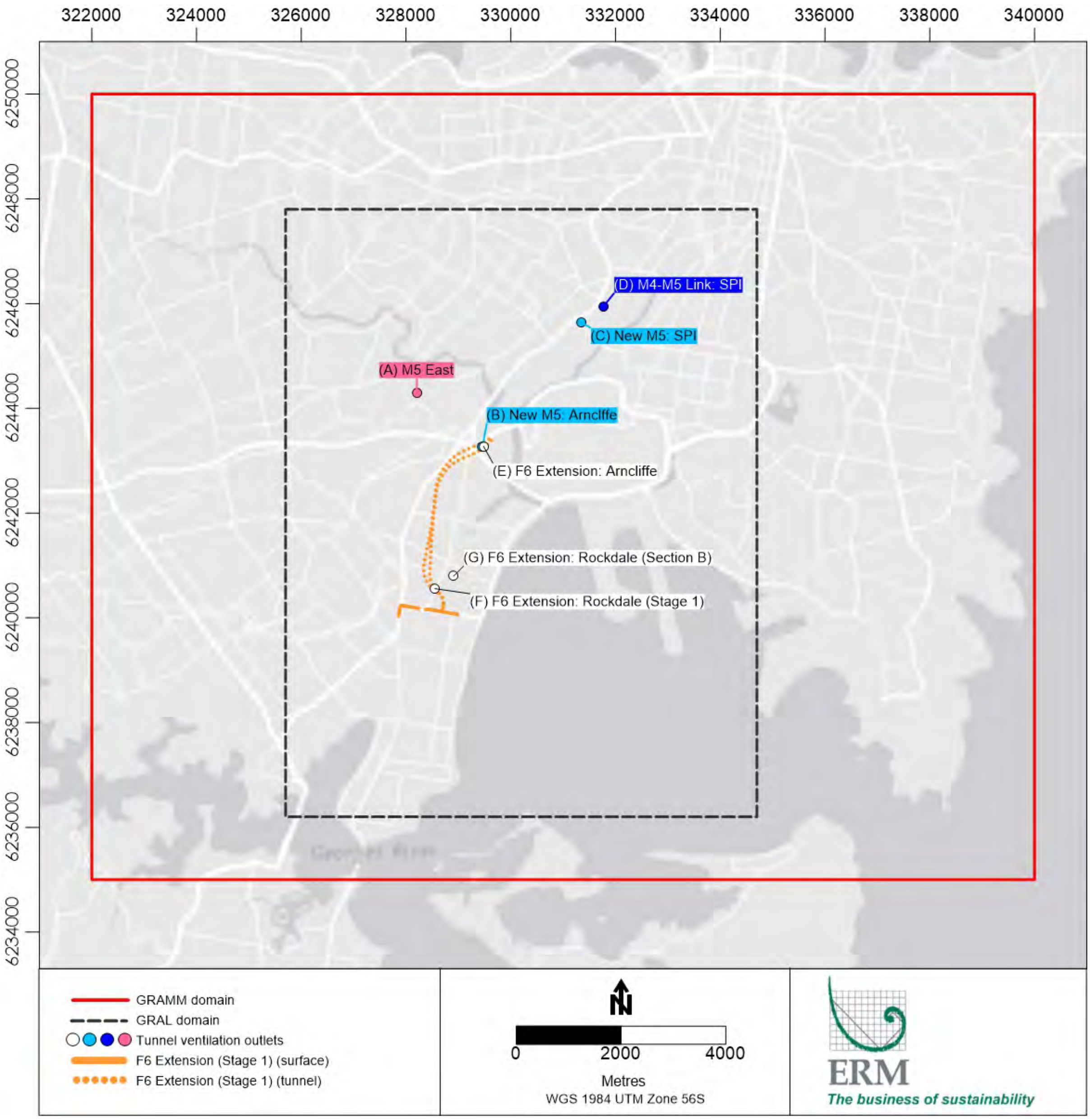

Figure 10-1 Air quality health impact assessment study area (ERM, 2018)

10.1.2 Assessment of other hazards and risks

A qualitative assessment of potential hazards and risks was undertaken for the project. The assessment identified potential hazards and risks based on those experienced on other recent NSW tunnelling projects.

10.2 Existing environment

Relevant information on the existing health aspects of the population has been obtained from the Australian Bureau of Statistics (ABS) Census 2011, information relevant to local government areas (LGAs) and health districts (in particular South Eastern Sydney and Sydney LHDs (LHD)). In some cases, where local data was lacking, information has been obtained (or compared with) data from larger populations areas of Sydney and/or NSW.

The population considered includes those who live or work within the vicinity of the construction ancillary facilities, surface works and intersection upgrades, ventilation facilities and the surrounding road network.

The study area covers several suburbs across the Bayside, City of Sydney, Inner West, Canterbury – Bankstown and Georges River LGAs.

10.2.1 Sensitive receptors

Sensitive community receptors are locations in the local community where more sensitive members of the population, such as infants and young children, the elderly or those with existing health conditions or illnesses, may spend a significant period of time. These locations include medical facilities, child care facilities, educational facilities and aged care homes/facilities.

Table 10-2 presents a list of the key community receptors included in the air quality assessment, for which a more detailed quantitative assessment of health impacts has been undertaken, compared to the remainder of the 17,509 receptor locations assessed for air quality (refer to **Chapter 9** (Air quality)). It is noted that these 30 locations are representative only and are not intended to comprise an exhaustive list of community receptors in the study area. The location of the 30 selected sensitive or community receptors is shown in **Figure 10-2**.

In addition to these community receptors, 17,509 individual receptors (residential, workplace and recreational (RWR) receptors also shown in **Figure 10-2**) have been modelled in the suburbs located in the study area. These individual RWR receptor locations represent a range of land uses including residential, commercial or recreational (open space) areas in the surrounding community, as detailed in **Table 10-3**. The RWR include all other community receptors located in the study area, not just those included in **Table 10-2**.

Table 10-2 Community receptors included in health risk assessment

	Receptor name	Type of receptor	Suburb	LGA
CR1	St Finbar's Primary School	Primary School	Sans Souci	Georges River
CR2	St George Christian School Infants	Primary School	Sans Souci	Georges River
CR3	Ramsgate Public School	Primary School	Ramsgate Beach	Bayside
CR4	Estia Health	Community Home	Kogarah	Bayside
CR5	Wesley Hospital Kogarah	General Hospital	Kogarah	Georges River
CR6	St George School	Special School	Kogarah	Bayside
CR7	St George Hospital	General Hospital	Kogarah	Georges River
CR8	Brighton-Le-Sands Public School	Primary School	Brighton Le-Sands	Bayside
CR9	Kogarah Public School	Primary School	Kogarah	Georges River
CR10	St George Girls High School	High School	Kogarah	Georges River
CR11	St Thomas More's Catholic School	Primary School	Brighton Le-Sands	Bayside
CR12	Jenny-Lyn Nursing Home	Community Home	Brighton Le-Sands	Bayside
CR13	Huntingdon Gardens Aged Care Facility	Community Home	Bexley	Bayside
CR14	Rockdale Public School	Primary School	Rockdale	Bayside
CR15	Scalabrini Village Nursing Home-Bexley	Community Home	Bexley	Bayside
CR16	Rockdale Nursing Home	Community Home	Rockdale	Bayside
CR17	Arncliffe Public School	Primary School	Arncliffe	Bayside

	Receptor name	Type of receptor	Suburb	LGA
CR18	Athelstane Public School	Primary School	Arncliffe	Bayside
CR19	Al Zahra College	Combined Primary-Secondary School	Arncliffe	Bayside
CR20	Cairnsfoot School	Special School	Brighton Le-Sands	Bayside
CR21	Undercliffe Public School	Primary School	Earlwood	Canterbury-Bankstown
CR22	Ferncourt Public School	Primary School	Marrickville	Inner West
CR23	Tempe High School	High School	Tempe	Inner West
CR24	St Peters Public School	Primary School	St Peters	Inner West
CR25	St Pius' Catholic Primary School	Primary School	Enmore	Inner West
CR26	Frobel Alexandria Early Learning Centre	Child Care Centre	Alexandria	Sydney
CR27	Little Learning School - Alexandria	Child Care Centre	Alexandria	Sydney
CR28	Active Kids Mascot	Child Care Centre	Mascot	Bayside
CR29	Mascot Public School	Primary School	Mascot	Bayside
CR30	Hippos Friends	Child Care Centre	Botany	Bayside

Table 10-3 Summary of RWR receptor types

Receptor type	Number	% of total
Aged care	32	0.18%
Child care / pre-school	21	0.12%
Commercial	1,359	7.77%
Community	3	0.02%
Further education	4	0.02%
Hospital	7	0.04%
Industrial	355	2.03%
Mixed use	617	3.52%
Other	445	2.54%
Park / sport / recreation	174	0.99%
Residential	14,408	82.28%
School	84	0.48%
Total	17,509	100.00%[1]

1 Total of receptor types does not add up to exactly 100 per cent due to rounding.

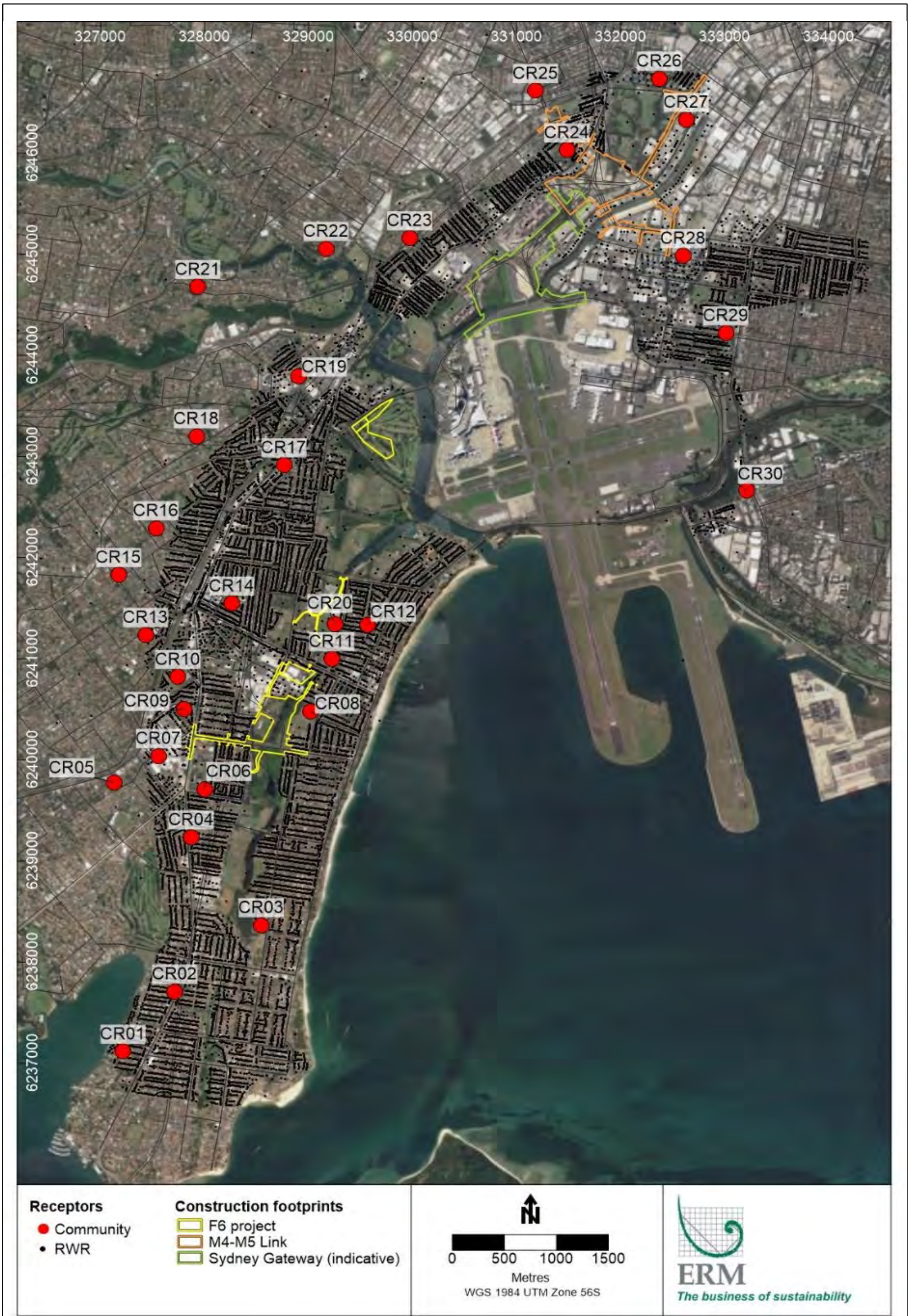

Figure 10-2 Community receptors and RWR receptors evaluated in health impact assessment

10.2.2 Demographic profile

The population within the study area consists of residents and workers as well as those attending educational and child care facilities, medical facilities and recreational areas. The composition of the populations located within the study area is expected to be generally consistent with statistics for the larger individual suburbs that are wholly or partially included in the study area.

Population statistics for the LGAs are available from the ABS for the Census year 2016 and are summarised in **Table 10-4**. For the purpose of comparison, the population statistics presented also include the statistics for larger statistical population groups in the area (defined by the ABS SA4) and the larger statistical areas of Greater Sydney and the rest of the NSW (excluding Greater Sydney) (as defined by the ABS).

Table 10-4 Summary of demographic statistics in the study area

Location	Total population		% Population of key age groups					
	Male	Female	0 4	5 19	20 64	65+	1–14[1]	30+[1]
Local government areas								
Botany[2]	23,229	23,420	6.2	16.5	64.3	13.0	15.7	59.8
Rockdale[2]	54,079	55,325	6.1	14.8	63.8	15.3	14.6	61.5
Sydney	107,852	100,530	3.3	7.4	81.0	8.2	5.9	57.6
Inner West	88,736	93,302	5.9	13.2	68.7	12.2	14.1	63.8
Canterbury – Bankstown	172,327	173,977	7.2	19.6	59.2	13.9	19.2	58.4
Georges River	71,755	75,086	5.8	17.0	61.8	15.3	15.7	60.8
Larger local statistical areas (SA4 – includes local government areas)								
Sydney – City and Inner South	161,061	154,483	4.1	9.6	76.9	9.4	8.6	58.9
Sydney – Inner West	142,436	150,867	5.9	14.5	66.1	13.5	14.6	61.9
Sydney – Inner South West	282,753	288,670	6.7	18.1	60.7	14.6	17.5	59.6
Statistical areas of Sydney and NSW								
Greater Sydney	2,376,766	2,447,221	6.4	18.2	61.4	13.9	17.4	60.4
Rest of NSW (excluding Greater Sydney)	1,301,717	1,341,813	5.8	18.5	55.1	20.6	17.3	64.6

Ref: Australian Bureau of Statistics, Census Data 2016
SA = statistical area
[1] Age groups specifically relevant to the characterisation of risk
[2] (Now amalgamated and known as Bayside Council)

When comparing the statistics of the study area to that of Greater Sydney:

- Sydney – City and Inner South have a lower proportion of children (0-19 years), a higher proportion of working aged individuals and a lower proportion of individuals aged over 65 years
- Sydney – Inner West have a slightly lower proportion of children and slightly higher proportion of working age individuals
- At a local government area level:
  - Sydney has a lower proportion of young children (0-4 years)
  - Botany, Rockdale, Sydney, Inner West, and Georges River have a lower proportion, while Canterbury-Bankstown have a higher proportion of children (5-19 years)
  - Canterbury-Bankstown have a lower proportion while Botany, Rockdale, Sydney and Inner West, have a higher proportion of working age individuals
  - Sydney and Inner West have a lower proportion while Rockdale and Georges River have a higher proportion of individuals aged over 65 years.

The estimated population growth from 2011 to 2036 for the relevant LGAs are (NSW Planning & Environment 2016) are shown in **Figure 10-3**.

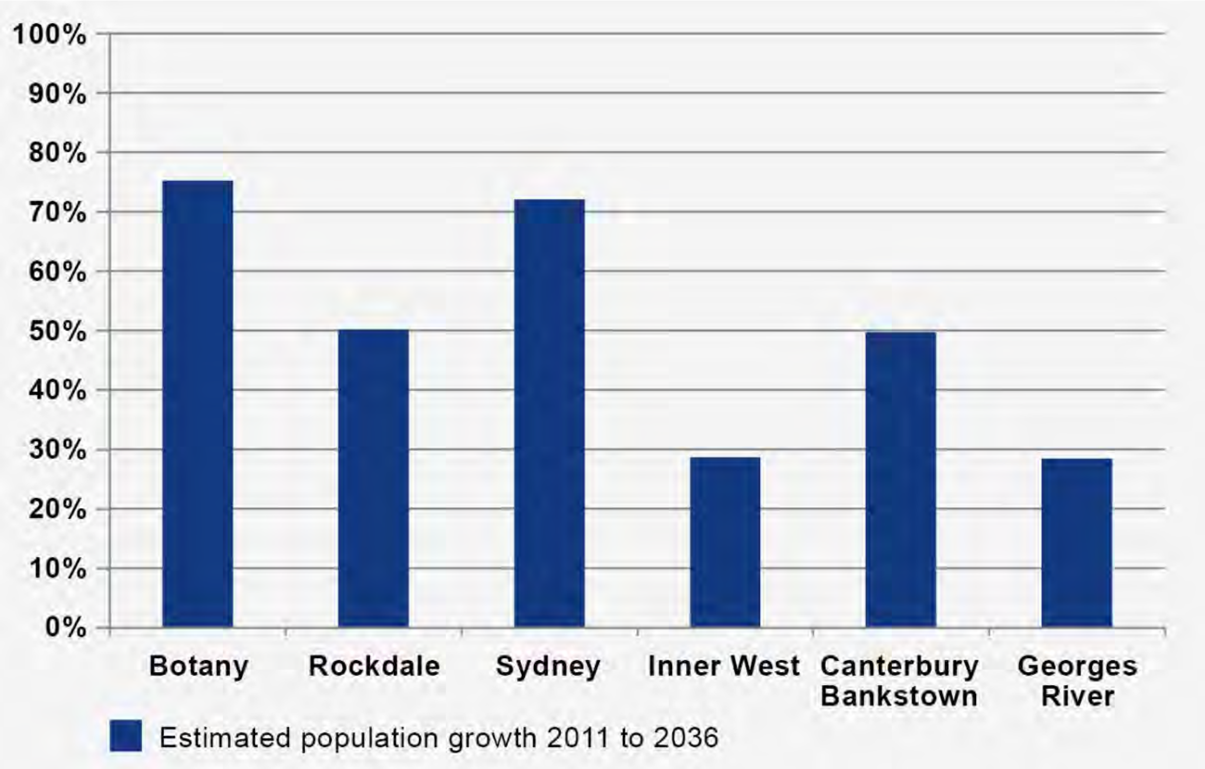

Figure 10-3 Estimated population growth from 2011 to 2036

Table 10-5 presents a summary of a selected range of demographic measures (including income) relevant to the population of interest with comparison to statistical areas of Greater Sydney and the rest of NSW (excluding Greater Sydney).

Table 10-5 Selected income demographics of population of interest

Location	Median age	Median household income ($/week)	Median mortgage repayment ($/month)	Median rent ($/week)	Average household size (persons)	Unemployment rate (%)
Local government areas						
Botany #	35	1,626	2,400	460	2.7	5.6
Rockdale #	35	1,575	2,167	460	2.7	6.2
Sydney	32	1,926	2,499	565	2.0	6.0
Inner West	36	2,048	2,600	480	2.4	4.8
Canterbury – Bankstown	35	1,298	2,000	380	3.0	8.2
Georges River	37	1,654	2,167	450	2.9	6.5
Larger local statistical areas (SA4 – includes local government areas)						
Sydney - City and Inner South	33	1,894	2,500	550	2.2	5.7
Sydney – Inner West	36	1,964	2,500	500	2.6	5.5
Sydney – Inner South West	35	1,431	2,167	415	2.9	7.4
Statistical areas of Sydney and NSW						
Greater Sydney	36	1,750	2,167	440	2.8	6.0
Rest of NSW (excluding Greater Sydney)	43	1,168	1,590	270	2.4	6.6

The social and income demographics of an area have some influence on the health of the existing population. As shown in **Table 10-5**, when comparing the populations of the study area to that of Greater Sydney:

- Botany, Rockdale, Canterbury-Bankstown and Georges River have a lower median income, while Sydney, and Inner West have a higher median income
- Botany, Sydney and Inner West have higher, while Canterbury-Bankstown has lower monthly mortgage repayments
- Sydney has higher and Canterbury-Bankstown has lower median weekly rental costs
- Sydney and Inner West have a smaller average household size
- Canterbury-Bankstown has higher and Inner West has lower unemployment rates.

10.2.3 Existing health of population

General

Full details of the existing health of the population and the assessment undertaken is provided in **Appendix F** (Human health technical report).

When considering the health of a local community there are a large number of factors to consider. The health of the community is influenced by a complex range of interacting factors including age, socio-economic status, social networks, behaviours, beliefs and lifestyle, life experiences, country of origin, genetic predisposition and access to health and social care. Hence, while it is possible to review existing health statistics for the local areas surrounding the project, it is not possible or appropriate to be able to identify a causal source, particularly individual or localised sources.

The project is located across the South Eastern Sydney LHD and Sydney LHD. Not all of the health data is available for all of these areas.

The assessment presented in the human health impact assessment (refer to **Appendix F** (Human health technical report) has focused on key pollutants that are associated with construction and combustion sources (e.g. from vehicles), including volatile organic compounds, polycyclic aromatic hydrocarbons, carbon monoxide, nitrogen dioxide and particulate matter (namely $PM_{2.5}$ and PM_{10}). For these pollutants, there are a large number of sources in the study area including other combustion sources (wood-fired heating, domestic cooking, industrial emissions), non-combustion sources including other local construction works. Other aspects that affect the health of an individual include personal exposures (such as smoking) and risk taking behaviours.

Health related behaviours

Information in relation to health related behaviours that are linked to poorer health status and chronic disease, such as cardiovascular and respiratory diseases, cancer, is available for the larger populations within the LHDs in Sydney and NSW. These behaviours include risky alcohol drinking, smoking, consumption of fruit and vegetables, being overweight or obese, and adequate physical activity. The incidence of these health-related behaviours in the South Eastern and Sydney LHDs, compared with other districts in NSW, and the state of NSW (based on NSW Health data from 2015 and 2016) is provided in **Appendix F** (Human health technical report).

Review of this data indicates the population in the South Eastern Sydney and Sydney LHDs (that include the study area) have lower rates of physical inactivity and of being overweight and obese compared with NSW.

Health indicators

Appendix F (Human health technical report) provides the rates of the key mortality indicators (such as cardiovascular disease, lung cancer and chronic obstructive pulmonary disease (COPD), hospitalisations and mental health indicators for the study area compared to Greater Sydney and NSW as a whole.

The data indicates that the rate of mortality indicators in the South Eastern Sydney and Sydney LHDs are significantly lower than the NSW average, except for lung cancer for the Sydney LHD which was around the same as the NSW average.

The rate of hospitalisations for the key mortality indicators in the South Eastern Sydney and Sydney LHDs is significantly lower than NSW as whole, with the exception of cardiovascular disease hospitalisations in South Eastern Sydney, which is similar to the rate for NSW.

In relation to mental health, data from NSW Health indicates the following for adults:

- The rate of high or very high psychological distress reported in 2015 in the Sydney LHD (13.9 per cent) is a little higher, and South Eastern Sydney LHDs (9.3 per cent) a little lower than the state average (11.8 per cent), however none were significantly different
- The rate of high or very high psychological distress in Sydney LHD has varied between 10 and 15 per cent between 2003 and 2015 while in the South Eastern Sydney LHD, the rate has declined from around 14 per cent in 2003 to less than 10 per cent in 2015.

Details on specific health indicators relevant to the quantification of exposure to nitrogen dioxide and particulate matter for the study area are provided in **Appendix F** (Human health technical report). This includes data on mortality and hospitalisations due to respiratory diseases such as asthma. A review of this data generally indicates that for the population in study area, the health statistics (including mortality rates and hospitalisation rates for most of these categories) are variable but generally similar to those reported in the larger LHDs of South Eastern Sydney, Sydney and the wider Sydney metropolitan area and slightly lower than the whole of NSW.

10.2.4 Existing air quality environment

Full details of the existing air quality environment and assessment undertaken is provided in **Appendix E** (Air quality technical report).

The project lies within an urbanised area of Sydney and hence it is important that the background air quality considered is representative of existing conditions in the local area. A summary of the assessment of background air quality is presented in **Chapter 9** (Air quality) and detailed in **Appendix E** (Air quality technical report).

The following is noted for the human health assessment in relation to background air quality:

- Carbon monoxide: background air concentrations (as one hour and eight hour averages) were below the current air quality guidelines both at any of the background air monitoring stations. A general downward trend in background air concentrations was observed.
- Nitrogen dioxide: background air concentrations (as one hour and annual averages) were below the current air quality guidelines both at all background air monitoring stations and at roadside monitoring locations. The concentration of nitrogen dioxide has been observed to be generally stable to trending downward over time.
- Ozone: background air concentrations (as one hour and four hour averages) exceeded the current air quality guidelines on a few occasions. The most number of times a station exceeded the guideline per year was eighteen, with many of the stations not exceeding more than 5 times per year. Annual ozone concentrations were stable between 2004 and 2016.
- PM_{10}: background concentrations of PM_{10} (as an annual average) were below the current air quality guidelines. However, there were exceedances of the 24 hour average criterion, most notably in the warm and dry year 2009
- $PM_{2.5}$: Long term measurement of annual $PM_{2.5}$ concentrations has only occurred at three OEH stations Chullora, Earlwood and Liverpool. Concentrations at these stations showed a broadly similar pattern, with a systematic reduction between 2004 and 2012 being followed by a substantial increase in 2013. The main reason for the increase was a change in the measurement method (as the reporting of $PM_{2.5}$ in air varies depending on the type of equipment used). The increases meant that background $PM_{2.5}$ concentrations in the study area during 2014 and 2015 were already very close to or above the annual average criterion of eight micrograms per cubic metre. There have been a number of exceedances of the 24 hour average criterion of 25 micrograms per cubic metre
- Air toxics: A number of measurement campaigns have been undertaken to determine the levels of air toxics around Sydney. All have found the concentrations remain low and under the respective Air Toxic NEPM investigation levels.

10.2.5 Existing noise environment

The study area for the noise assessment (refer to **Chapter 11** (Noise and vibration) includes a mixture of residential development, commercial and industrial properties, and major roads and railway lines.

Noise sensitive receptors

Throughout the study area, receptors which are potentially sensitive to noise and vibration include residential dwellings, schools, community centres, recreation areas, hospitals, libraries, commercial and industrial properties and places of worship.

A list of the noise sensitive receptors identified within the study area (excluding residential receptors) is provided in **Appendix G** (Noise and vibration technical report).

Existing noise levels

The results of the unattended ambient noise surveys undertaken in June 2015 (as part of the New M5 Motorway project) and November/December 2017 and February 2018 (specifically for this project) are provided in **Appendix G** (Noise and vibration technical report).

The background noise levels derived from monitoring indicate that the existing noise environment at the measurement locations is typical of major transport corridors in suburban/urban areas. In these locations daytime and evening background levels are generally high due to heavy and continuous traffic flows, with night time levels tending to decrease as a result of a reduction in these flows.

For the assessment of noise and vibration impacts, a range of guidelines and criteria have been adopted for the assessment.

The *Interim Construction Noise Guideline* (ICNG)[1] has been adopted for the assessment of noise during construction works. These guidelines require that noise impacts from the project be predicted at sensitive receptors. These noise levels are then compared with the project specific criteria, referred to as management levels, which are based on an increase above background levels. Where an exceedance occurs, the guidelines require that the proponent must apply all feasible and reasonable work practices to minimise impacts.

Intermittent vibration has been evaluated on the basis of the NSW EPA guideline *Assessing Vibration: A Technical Guideline*[2].

Operational noise impacts have been evaluated on the basis of the *NSW Road Noise Policy*[3], with additional guidance and criteria provided within Roads and Maritime's *Noise Criteria Guideline*[4] (NCG) and *Noise Mitigation Guideline* (NMG)[5].

[1] NSW DECC, 2009. *Interim Construction Noise Guideline.*
[2] NSW DEC, 2006. *Assessing Vibration: ATechnical Guideline.*
[3] NSW DECCW, 2011. *NSW Road Noise Policy.*
[4] NSW Roads and Maritime 2015. *Noise Criteria Guideline.*
[5] NSW Roads and Maritime 2015. *Noise Mitigation Guideline.*

10.3 Potential impacts – construction

During construction, the following hazards may be associated with the project:

- Potential hazards resulting from accidental releases or improper handling and storage of dangerous goods and hazardous substances within construction ancillary facilities
- Potential hazards resulting from release of hazardous substances from vehicles transporting them to and from the construction ancillary facilities in the event of an accident
- Potential safety hazards, such as dangers to construction workers, road users and the community, associated with the potential risk of tunnel collapse, tunnel fires or explosions, rock falls at cuttings and mobile plant (including plant overturning and plant collisions with workers or other plant)
- Potential hazards associated with encountering acid sulfate soils, asbestos and contaminated soils during construction activities
- Potential accidental spills or leaking of fuels, chemicals or other hazardous substances during construction activities, including during refuelling of construction vehicles and machinery
- Potential hazards associated with mobile construction plant
- Potential hazards relating to flooding
- Potential rupture of, or interference with, utilities
- Potential hazards relating to bushfires.

The following risks have been assessed for the construction of the project:

- Human health risks
- Social impacts (including from acquisitions) (discussed in **Chapter 15** (Social and economic)
- Pedestrian safety risks (discussed in **Chapter 8** (Traffic and transport))
- Subsidence (ground settlement) risks (discussed in **Chapter 14** (Property and land use) and **Chapter 17** (Geology and groundwater))
- Bushfire risks
- Risks associated with the storage and handling of dangerous goods
- Potential risk of encountering acid sulfate soils, asbestos and contaminated soils during construction activities (discussed in **Chapter 16** (Surface water) and **Chapter 17** (Soils and contamination))
- Potential risks associated with the impact of project construction and operational activities on air quality (refer to **Chapter 9** (Air quality))
- Potential risks associated with climate change impacts, including changes in the frequency of air temperature extremes, changes in mean and extreme rainfall, and changes in the frequency and intensity of storm events (discussed in **Chapter 25** (Climate change risk and adaption)).

10.3.1 Air quality impacts on community health

Appendix E (Air quality technical report) evaluated impacts on air that may occur during construction. The assessment considered impacts that may occur during tunnelling activities and surface works and involved a semi quantitative assessment approach. The assessment was split into two different construction 'zones' (refer to **Figure 10-4**).

The assessment identified the range of activities during construction, potential emissions from these activities and the location of these activities in relation to sensitive receptors. **Figure 10-4** shows the location of the sensitive receptors considered in the air quality impact assessment during construction works. The figure also shows the location of the zones considered in each of the construction sites.

Figure 10-4 Location of sensitive human receptors in proximity to construction works

For all demolition, earthworks, construction and track-out activities, where no mitigation measures are implemented, the risk of impacts on human health were evaluated and considered in terms of the location of sensitive receptors. Risk ratings that varied from low to high were adopted in the review presented in **Appendix E** (Air quality technical report). In relation to health impacts, the following levels of risk were identified for the two zones:

- Zone 1: Low risk for construction, medium risk for earthworks and track-out with no applicable risk for demolition
- Zone 2: High risk for all activities.

On this basis, appropriate mitigation measures would be required to minimise impacts on the local community during construction. Experience from similar construction projects shows that significant impacts to community receptors can be avoided through the use of effective mitigation.

Hence, where mitigation measures are appropriately implemented, **Appendix E** (Air quality technical report) concluded that the residual risk level would normally be 'not significant'.

However, even with a rigorous Dust Management Plan in place, it is not possible to guarantee that the dust mitigation measures will be effective all the time. There is the risk that nearby residences, commercial buildings, hotel, cafés and schools in the immediate vicinity of the construction zone, might experience some occasional dust soiling impacts. This does not imply that impacts are likely, or that if they did occur, that they would be frequent or persistent.

Overall construction dust is unlikely to represent a serious ongoing problem. Any effects would be temporary and relatively short-lived, and would only arise during dry weather with the wind blowing towards a receptor, at a time when dust is being generated and mitigation measures are not being fully effective. The likely scale of this would not normally be considered sufficient to change the conclusion that with mitigation the effects will be 'not significant'.

Appendix E (Air quality technical report) did not identify the construction of the powerline as a significant source of dust that required impact assessment.

A Construction Air Quality Management Plan will be produced to cover all construction stages of the project. These measures include site management, monitoring, preparing and maintaining the construction sites, maintenance and controls on vehicles and machinery and construction. **Chapter 9** (Air quality) provides the dust management measures proposed for the project.

Issues related to health impacts from construction fatigue, where the community may be located close to construction facilities for extended periods of time, as a result of the number of construction projects being undertaken for WestConnex, are further addressed in **section 10.3.6**

Odour impacts

The potential source of odour for the project is the release of hydrogen sulphide gas when excavation activities for the construction of the cut and cover structures disturb a historical landfill site, which may contain contaminated acid sulfate soils. These soils have the potential to be exposed to air. This has the potential to release odorous hydrogen sulphide gas (H_2S) into the atmosphere impacting nearby receptors.

Chapter 9 (Air quality) outlines the NSW EPA criteria for community exposure to H_2S odour and the results of the assessment undertaken for odour impacts during construction activities.

The results indicate that the predicted 99th percentile H_2S concentration at the nearest receptors are well below the criterion and likely to be below the level of detection. Therefore this assessment did not find that there would be significant odour impacts. However on-site odour measurements would be carried out during excavation works to determine odour emission rates (refer to environmental management measure AQ3 in **Chapter 9** (Air quality)). Results from the monitoring would be used to inform future excavation and treatment activities on site. Odorous material would be treated immediately on-site, and removed from site where necessary. Areas of odorous materials would be excavated in a staged process to allow for treatment and handling. Exposed areas of odorous material would be kept to a minimum to reduce the total emissions from the site.

10.3.2 Noise and vibration impacts on community health

Air-borne construction noise

A detailed assessment of noise and vibration impacts associated with the project is presented in **Appendix G** (Noise and vibration technical report). **Appendix G** (Noise and vibration technical report) has been reviewed to determine if the predicted impacts have the potential to affect the health of the surrounding community, and if impacts are predicted, if they can be effectively mitigated.

The assessment of noise during construction and operations involved consideration of impacts at 17 noise catchment areas (NCAs) presented in **Appendix G** (Noise and vibration technical report). An NCA is defined by what is considered a similar noise environment. Thus receptors belonging to the same NCA are assigned the same background noise level and noise management level.

Potential noise impacts of the project have been assessed against Australian or NSW criteria, including the ICNG and the Road Noise Policy.

The criteria of these guidelines have been established on the basis of noise annoyance or specific health effects such as sleep disturbance, which are considered to be the effects that precede physiological effects. As a result, these guidelines are designed to be protective and indicative of adverse health effects and have been used to assess construction and operational noise impact associated with the project.

Where the guidelines cannot be met then there is the potential for the above adverse health effects to occur for the receptors in the vicinity of the project, such as sleep disturbance and annoyance.

A number of receptors have been identified as highly affected from standard and out of hours construction noise, especially around C2, C3, the cut-and-cover works at West Botany Street, the President Avenue surface works and the C6 construction ancillary facility for the Princes Highway and President Avenue intersection upgrade. Construction noise is also predicted to cause sleep disturbances for several receptors during out of hours works. Construction road traffic noise was estimated to be generally compliant with the relevant guidelines except for some roads around C2 (especially Wickham Street) during night time periods where increased traffic noise was predicted to be up to 7.3 dB(A) above the existing level of road traffic noise. Night-time haulage would be avoided during night time off-peak traffic periods to minimise noise impacts where feasible. Sensitive receptors are likely to be highly affected by construction of the permanent power supply when the works are directly opposite the receptor location. As the works move further away from receptors, noise levels would reduce significantly. High noise impacts at any one receptor are unlikely to last for more than a few days for each sensitive receptor.

The detailed design for the mitigation measures will be outlined in the Construction Noise and Vibration Management Plan (CNVMP) as discussed in **Appendix G** (Noise and vibration technical report). The mitigation measures would including temporary noise walls or hoarding, respite periods, plant and equipment selection, an out of hours protocol and traffic management. The aim of the measures would be to reduce noise and vibration to levels that comply with the management goals established in this assessment.

Receptors identified as requiring at-property operational noise mitigation would be identified and offered treatment prior to commencement of construction works that would affect them.

The assessment has also addressed the impact of simultaneous construction noise resulting from the construction of a number of different infrastructure projects in the vicinity of the project. An identification of developments planned in the area along with current developments was undertaken. It was estimated that the cumulative construction noise impact may increase by as much as 3 dB(A). A discussion on the impacts of consecutive construction works was also undertaken and is further discussed in **section 10.3.6**.

Ground-borne construction noise

Ground-borne noise occurs when works are being undertaken under the ground surface or in some other fashion that results in the vibrations from noise moving through the ground rather than the air. When vibrations reach a building they enter the foundations, it can be transmitted into the walls and ceiling. The vibration of the walls and ceiling could result in the generation of low-frequency noise (or ‘rumble) which could be audible if the vibration levels are high enough.

Vibration would be generated during tunnelling works for the project from the operation of road headers. Blasting is not proposed as a core tunnelling activity but may be required. Tunnelling activities are expected to occur 24 hours per day. Associated surface activities would generally be carried out in acoustic sheds.

Tunnelling would typically progress around a maximum of seven metres per day. It is likely that ground-borne noise would be discernible for up to five days at each affected receptor with exceedances occurring for up to two days. Only one receptor is predicted to exceed the ground-borne noise criteria. This exceedance would be up to 1 dB(A) during the night-time period, which is considered to have negligible health impacts.

Vibration impacts

A range of construction equipment has the potential to result in vibration impacts. These potential impacts can be managed by ensuring suitable separation distances between the equipment and receptor locations.

The noise and vibration assessment did not identify any receptors that would exceed the vibration criteria for human comfort, and concluded that the structural damage criteria would not be exceeded by the tunnelling activities.

10.3.3 Dangerous goods and substances

Storage and handling

The storage, handling and use of dangerous goods and hazardous substances would be undertaken in accordance with:

- *Work Health and Safety Act 2011* (NSW) (WHS Act)
- Storage and Handling of Dangerous Goods Code of Practice (WorkCover NSW 2005)
- Environment Protection Manual for Authorised Officers: Bunding and Spill Management, technical bulletin (NSW Environment Protection Authority (NSW EPA) 1997)
- *Dangerous Goods (Road and Rail Transport) Act 2008* (NSW)
- *Dangerous Goods (Road and Rail Transport) Regulation 2014* (NSW)
- Other relevant Australian Standards.

The types and estimated quantities of dangerous goods and hazardous substances that would be stored within the construction ancillary facilities, and used for construction activities, are outlined in **Table 10-6**. Minor quantities of other hazardous materials may also be used at the construction ancillary facilities from time to time.

SEPP 33 is not strictly applicable to the project given it is State significant infrastructure. Nevertheless, the principles which are applied in relation to SEPP 33 have been followed to consider potential hazards associated with the use and transport of dangerous goods for the project, as outlined below.

The thresholds specified in *Hazardous and Offensive Development Application Guidelines: Applying SEPP 33*[6] (SEPP 33 Guidelines) have been applied to the inventories of dangerous goods to be transported to and stored at each construction ancillary facility. These screening thresholds represent the level at which dangerous goods may present a credible offsite hazard that requires a further, more detailed assessment of risks. Application of the screening thresholds specified in the SEPP 33 Guidelines is included in **Table 10-6**.

[6] Hazardous and Offensive Development Application Guidelines: Applying SEPP 3 NSW Department of Planning 2011

Table 10-6 Indicative dangerous goods (DG) and hazardous substances used on site during the construction period (quantities are indicative only)

Material and Australian DG Code class	C1	C2	C3	C4	C5	C6	Assessment against inventory thresholds in the SEPP 33 Guidelines
Acetylene (litres) DG class 2.1	Y	Y	Y	Y	Y	Y	Individual cylinders containing acetylene would not trigger the threshold in the SEPP 33 Guidelines (100 kilograms). Maximum stored inventories (1,040 litres) would also be located more than 50 metres away from the nearest construction ancillary facility boundary and would also not trigger the threshold in the SEPP 33 Guidelines if considered in aggregate.
Ammonium nitrate emulsion DG class 5.1	Y	Y	N	N	N	N	Ammonium nitrate would not trigger the threshold in the SEPP 33 Guidelines (five tonnes) if considered as individual containers or in aggregate.
Concrete bonding agent base (litres) DG class N/A	Y	Y	Y	N	N	Y	Concrete bonding agent bases are not dangerous goods and therefore do not trigger the thresholds in the SEPP 33 Guidelines.
Concrete bonding agent hardener (litres) DG class 8	Y	Y	Y	N	N	Y	Concrete bonding agent hardener would not trigger the threshold in the SEPP 33 Guidelines (25 tonnes) if considered as individual containers or in aggregate.
Concrete surface retarder (litres) DG class 3 PGIII	Y	Y	Y	N	N	Y	Concrete surface retarder would not trigger the threshold in the SEPP 33 Guidelines (five tonnes) if considered as individual containers or in aggregate.
Construction grout (kilograms) DG class N/A	Y	Y	Y	Y	Y	Y	Construction grout is not a dangerous good and therefore does not trigger the threshold in the SEPP 33 Guidelines.
Curing compound (litres) DG class N/A	Y	Y	Y	Y	Y	Y	Curing compounds are not dangerous goods and therefore do not trigger the thresholds in the SEPP 33 Guidelines.
Diesel DG class C1 PGIII	Y	Y	Y	Y	Y	Y	Diesel would not be stored with Class 3 materials and would therefore not be subject to the thresholds in the SEPP 33 Guidelines.
Epoxy paste part A (litres) DG class 3 PGIII	Y	Y	Y	N	N	Y	Epoxies would not trigger the threshold in the SEPP 33 Guidelines (five tonnes) if considered as individual containers or in aggregate.
Epoxy paste part B (litres) DG class 3 PGIII	Y	Y	Y	N	N	Y	Epoxies would not trigger the threshold in the SEPP 33 Guidelines (five tonnes) if considered as individual containers or in aggregate.
Form oil (litres) DG class C2	Y	Y	Y	Y	Y	Y	Form oil would not be stored with Class 3 materials and would therefore not be subject to the thresholds in the SEPP 33 Guidelines.
Grease (kilograms) DG class C2	Y	Y	Y	Y	Y	Y	Grease would not be stored with Class 3 materials and would therefore not be subject to the thresholds in the SEPP 33 Guidelines.
Hydraulic oil (litres) DG class C2	Y	Y	Y	N	N	Y	Hydraulic oil would not be stored with Class 3 materials and would therefore not be subject to the thresholds in the SEPP 33 Guidelines.

Material and Australian DG Code class	C1	C2	C3	C4	C5	C6	Assessment against inventory thresholds in the SEPP 33 Guidelines
Injectable mortar (kilograms) DG class N/A	Y	Y	Y	N	N	Y	Injectable mortar is not a dangerous good and therefore does not trigger the thresholds in the SEPP 33 Guidelines.
Joint sealant (kilograms) DG class N/A	Y	Y	Y	Y	Y	Y	Joint sealant is not a dangerous good and therefore does not trigger the thresholds in the SEPP 33 Guidelines.
Line marking aerosol (kilograms) DG class 2.1	Y	Y	Y	Y	Y	Y	Individual cylinders containing line marking aerosol would not trigger the threshold in the SEPP 33 Guidelines (100 kilograms).
Liquid nails (kilograms) DG class 3 PGII	Y	Y	Y	Y	Y	Y	Liquid nails would not trigger the threshold in the SEPP 33 Guidelines (five tonnes) if considered as individual containers or in aggregate.
Oxygen (litres) DG class 2.2	Y	Y	Y	N	N	Y	Industrial grade oxygen is a Class 2.2 dangerous good and is therefore not subject to the thresholds in the SEPP 33 Guidelines. Oxygen has a subsidiary risk of Class 5.1. Oxygen would not trigger the threshold in the SEPP 33 Guidelines (five tonnes) if considered as individual containers or in aggregate.
Polyurethane foam (kilograms) DG class 2.1	Y	Y	Y	Y	Y	Y	Individual cylinders containing polyurethane foam would not trigger the threshold in the SEPP 33 Guidelines (100 kilograms) if considered as individual containers or in aggregate.
Sodium hydroxide (litres) DG class 8 PGII	Y	Y	Y	N	N	Y	Sodium hydroxide would not trigger the threshold in the SEPP 33 Guidelines (25 tonnes) if considered as individual containers or in aggregate.
Sulfuric acid (litres) DG class 8 PGII	Y	Y	Y	N	N	Y	Sulfuric acid would not trigger the threshold in the SEPP 33 Guidelines (25 tonnes) if considered as individual containers or in aggregate.
Unleaded Petrol (litres) DG class 3 PGII	Y	Y	Y	Y	Y	Y	Epoxies would not trigger the threshold in the SEPP 33 Guidelines (five tonnes) if considered as individual containers or in aggregate.

Table 10-6 demonstrates that the dangerous goods and hazardous substances proposed to be stored and used for construction activities would not exceed the inventory thresholds in the SEPP 33 Guidelines. This indicates that the proposed storage of dangerous goods and hazardous substances at construction ancillary facilities would not pose a material off-site hazard, in the unlikely event of an incident at the proposed construction ancillary facility locations.

At each construction ancillary facility:

- Liquid dangerous goods and hazardous chemicals would be stored within a bunded storage container or spill tray
- Gases would be secured and stored in a storage cage in a well ventilated area
- Storage areas would be located away from natural or built drainage lines, to minimise the likelihood of pollutants entering adjacent watercourses in the event of a spill or leak escaping the bunded area
- Self-bunded fuel storage areas would be located within or adjacent to acoustic sheds.

A register and inventory of the dangerous goods and hazardous substances to be stored at each construction ancillary facility would be kept as part of the Incident Response Plan for the project. Material Safety Data Sheets would also be kept on site for each relevant material.

Implementation of environmental management measures for the storage and handling of dangerous goods and hazardous substances, as detailed in **Table 10-34**, would reduce the risk to the environment, construction personnel and the public. Safety hazards associated with the use of hazardous materials during construction, including within enclosed tunnel environments, are discussed in **section 10.3.4**.

Transport of dangerous goods and substances

Transportation of dangerous goods would not exceed the thresholds in the SEPP 33 Guidelines and would be undertaken in accordance with suppliers' instructions as well as the WHS Act, the Storage and Handling of Dangerous Goods Code of Practice[7], *Dangerous Goods (Road and Rail Transport) Act 2008* (NSW), *Dangerous Goods (Road and Rail Transport) Regulation 2014* (NSW) and relevant Australian Standards.

Table 10-7 outlines the dangerous goods and hazardous substances that would be transported to construction ancillary facilities. Potential hazards and risks associated with the transportation of dangerous goods and hazardous substances have been considered by comparing the type, quantity and frequency of delivery of dangerous goods and hazardous substances with the thresholds presented in the SEPP 33 Guidelines.

[7] WorkCover NSW (2005) Storage and Handling of Dangerous Goods

Table 10-7 Dangerous goods and hazardous substances transported to construction sites

Material and Australian Dangerous Goods Code class	Transport quantity and frequency of delivery to each facility (indicative only)	Construction ancillary facility destination	Transportation thresholds in the SEPP 33 Guidelines	Assessment against transportation thresholds in the SEPP 33 Guidelines
Acetylene DG class 2.1	20 litres per month	All construction ancillary facilities	Minimum transport load or transport frequency of two tonnes more than 30 times per week	Industrial grade acetylene would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Ammonium nitrate emulsion DG class 5.1	2,000 litres once during the project	Arncliffe construction ancillary facility (C1) and Rockdale construction ancillary facility (C2)	Minimum transport load or transport frequency of two tonnes more than 30 times per week	Ammonium nitrate emulsion would trigger the minimum transport load threshold of two tonnes. However, it would not trigger the threshold for transport frequency and thus is unlikely to be significant.
Concrete bonding agent base DG class N/A	15 litres per month	All construction ancillary facilities	N/A	Concrete bonding agent base is not subject to the transportation thresholds in the SEPP 33 Guidelines.
Concrete bonding agent hardener DG class 8	15 litres per month	All construction ancillary facilities	Minimum transport load or transport frequency of two tonnes more than 30 times per week	Concrete bonding agent hardener would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Concrete surface retarder DG class 3 PGIII	180 litres per month	All construction ancillary facilities	Minimum transport load or transport frequency of 10 tonnes more than 60 times per week	Concrete surface retarder would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Construction grout DG class N/A	50 kilograms per month	All construction ancillary facilities	N/A	Construction grout is not subject to the transportation thresholds in the SEPP 33 Guidelines.
Curing compound DG class N/A	200 litres per month	All construction ancillary facilities	N/A	Curing compounds are not subject to the transportation thresholds in the SEPP 33 Guidelines.

Material and Australian Dangerous Goods Code class	Transport quantity and frequency of delivery to each facility (indicative only)	Construction ancillary facility destination	Transportation thresholds in the SEPP 33 Guidelines	Assessment against transportation thresholds in the SEPP 33 Guidelines
Diesel DG class C1 PGIII	1,500 litres per day	All construction ancillary facilities	N/A	Diesel would not be transported with Class 3 dangerous goods. Therefore, it would not be subject to the transportation thresholds in the SEPP 33 Guidelines.
Epoxy paste part A DG class 3 PGIII	15 litres per month	C1, C2, President Avenue construction ancillary facility (C3) and Prince Highway construction ancillary facility (C6)	Minimum transport load or transport frequency of 10 tonnes more than 60 times per week	Epoxies would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Epoxy paste part B DG class 3 PGIII	15 litres per month	C1, C2, C3 and C6	Minimum transport load or transport frequency of 10 tonnes more than 60 times per week	Epoxies would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Form oil (litres) DG class C2	180 litres per month	C1, C2 and C3	N/A	Form oil is not a dangerous good and would not be transported with Class 3 dangerous goods. Therefore, it would not be subject to the transportation thresholds in the SEPP 33 Guidelines.
Grease DG class C2	10 kilograms per month	C1, C2, C3 and C6	N/A	Grease is not a dangerous good and would not be transported with Class 3 dangerous goods. Therefore, it would not be subject to the transportation thresholds in the SEPP 33 Guidelines.
Hydraulic oil DG class C2	200 litres per month	All construction ancillary facilities	N/A	Hydraulic oil is not a dangerous good and would not be transported with Class 3 dangerous goods. Therefore, it would not be subject to the transportation thresholds in the SEPP 33 Guidelines.
Injectable mortar DG class N/A	8 kilograms per month	All construction ancillary facilities	N/A	Injectable mortar is not subject to the transportation thresholds in the SEPP 33 Guidelines.

Material and Australian Dangerous Goods Code class	Transport quantity and frequency of delivery to each facility (indicative only)	Construction ancillary facility destination	Transportation thresholds in the SEPP 33 Guidelines	Assessment against transportation thresholds in the SEPP 33 Guidelines
Joint sealant DG class N/A	10 kilograms per month	All construction ancillary facilities	N/A	Joint sealant is not subject to the transportation thresholds in the SEPP 33 Guidelines.
Line marking aerosol DG class 2.1	20 kilograms per month	All construction ancillary facilities	Minimum transport load or transport frequency of two tonnes more than 30 times per week	Line marking aerosol would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Liquid nails DG class 3 PGII	10 kilograms per month	All construction ancillary facilities	Minimum transport load or transport frequency of three tonnes more than 45 times per week	Liquid nails would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Oxygen DG class 2.2	150 litres per month	C1, C2, C3 and C6	N/A	Industrial grade oxygen is not subject to the transportation thresholds in the SEPP 33 Guidelines.
Oxygen subsidiary risk DG class 5.1	180 litres per month	C1, C2, C3 and C6	Minimum transport load or transport frequency of two tonnes more than 30 times per week	Oxygen has a subsidiary risk class of 5.1. Oxygen would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Polyurethane foam DG class 2.1	7 kilograms per month	All construction ancillary facilities	Minimum transport load or transport frequency of two tonnes more than 30 times per week	Polyurethane foam would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Sodium hydroxide DG class 8 PGII	2,000 litres per month	C1, C2, C3 and C6	25 tonnes as individual containers or in aggregate	Sodium hydroxide would not trigger the transportation threshold in the SEPP 33 Guidelines.
Sulfuric acid DG class 8 PGII	2,000 litres per month	C1, C2, C3 and C6	25 tonnes as individual containers or in aggregate	Sulfuric acid would not trigger the transportation threshold in the SEPP 33 Guidelines.

Material and Australian Dangerous Goods Code class	Transport quantity and frequency of delivery to each facility (indicative only)	Construction ancillary facility destination	Transportation thresholds in the SEPP 33 Guidelines	Assessment against transportation thresholds in the SEPP 33 Guidelines
Unleaded Petrol DG class 3 PGII	180 litres per month	All construction ancillary facilities	Minimum transport load or transport frequency of three tonnes more than 45 times per week	Unleaded petrol would not trigger the transportation thresholds in the SEPP 33 Guidelines.

Note:

1 For some construction ancillary facilities, the quantity of diesel and unleaded petrol delivered to site would be greater than the quantity stored within the facility at any time, because the delivery volume takes into the account fuel which is brought to the facility by mini-tanker and used to directly refuel plant. As this fuel is 'in use' in the plant it is not classified as 'stored'

10.3.4 Public safety risks to the community

A range of potential hazards have been identified that have the potential to affect public safety during construction. These are outlined in the following sections.

On the basis of the conclusions drawn in this section, there are no issues related to construction of the project that have the potential to result in significant safety risks to the community.

Tunnel collapse

The project tunnels would generally be excavated in good quality Hawkesbury sandstone, with poorer geological conditions present in the vicinity of the President Avenue intersection. A number of major design and construction method reviews have been undertaken to better understand historical tunnel collapses. Consequently, the risks of a similar incident occurring during a Sydney tunnelling project are extremely low. The reasons for this include:

- Vastly improved geotechnical assessment and modelling
- Improved predictive two dimensional and three dimensional modelling of geology, excavation spans, temporary and permanent loads
- Fit for purpose design to develop the appropriate type of 'support' to match the ground conditions on a day to day basis as the excavation progresses
- Continuous independent review of the temporary and permanent works design and construction methods by experts
- Continual construction verification that tunnel support is installed and performing as per design
- Robust change management processes for conditions that are out of the ordinary or unexpected, including probe drilling and ground treatment through suspected poor ground zones
- Continuous assessment of likely excavation and groundwater conditions
- Detailed survey monitoring of surface roads, buildings and structures in the tunnel vicinity.

Construction of the tunnels would be undertaken in sections. A 'permit to tunnel' system would be implemented, which would require authorisation from the tunnel construction manager (or authorised delegate) and geotechnical engineer before tunnelling is allowed to continue to the next section. The 'permit to tunnel' authorisation considers the anticipated and observed ground support performance, and geotechnical and groundwater conditions. This would minimise the risk of tunnel collapse.

Tunnel fires or explosions

Combustible materials within a tunnel have the potential to cause tunnel fires and explosions. Diesel equipment fire precautions, hot work procedures and electrical equipment procedures would be followed and adequate training would be provided to minimise risks associated with fire and explosion. Construction ancillary facilities would be maintained in a tidy and orderly condition, with the aim of minimising potential fuel loads and isolating fuel sources from ignition sources.

Rock falls at cuttings

Rock falls can occur during excavation of a tunnel portal, if the portal breakthrough areas are not secured before excavation. Rock falls have the potential to injure construction workers and cause damage to construction equipment. The intersection dive structures have the potential to create rock fall hazards as steep slope sites have the potential to pose slip, fall and unsecured equipment hazards.

Standard construction and mitigation measures would be applied to manage rock fall risk, including the use of appropriate personal protective equipment, frequent tunnel inspections, scaling, progressive installation of properly secured ground support, safety fencing and overhead protection.

Exposure to airborne pollutants

During construction and demolition activities, airborne pollutants have the potential to be generated, including dust and toxic gas. If this were to occur, it may result in oxygen deficient or toxic environments and other potential health risks for construction workers and local community members. The operation of diesel and petrol-fuelled equipment and the use of hazardous materials also have the potential to produce a range of air contaminants, including diesel particulate matter from diesel combustion. Dust generation in the tunnels would be minimised by wetting down the cutting face and by using temporary fans and dry dust scrubbers. Standard ventilation, dust extraction and monitoring procedures would be carried out when appropriate.

Acid sulfate soils

Acid sulfate soils are naturally occurring soils that contain iron sulfides. When acid sulfate soils are exposed to the air, they oxidise and create sulfuric acid. This increase in acidity can result in the mobilisation of aluminium, iron and manganese from the soils. Other impacts include the de-oxygenation of water. Potential acid sulfate soils are waterlogged soils rich in pyrite that have not been oxidised. Disturbance of potential acid sulfate soils during construction causing exposure to oxygen would lead to the development of actual acid sulfate soil layers.

For construction workers, physical contact with ground and water containing toxic concentrations of acid and metal contaminants is a health risks. Standard construction and mitigation measures would be applied to mitigate the potential risks associated with the disturbance of acid sulfate soils, including the use of appropriate personal protective equipment.

Further information regarding acid sulfate soils is provided in **Chapter 16** (Soils and contamination).

Contamination

Appendix J (Contamination technical report) has considered the location of the construction activities in relation to known areas of contamination in soil, as well as issues associated with the impact of construction on the environment, where the community may be exposed.

Acid sulfate soils, asbestos and other contamination is known to be present within the construction boundary. Exposure to asbestos, landfill gas associated with historic landfill areas adjacent to President Avenue intersection, and other contaminants during construction may result in health risks for construction workers, as well as people and waterways in neighbouring communities.

Appendix J (Contamination technical report) also outlines the measures required to be adopted during construction to manage soil and surface water contamination. These would be detailed in the Construction Environmental Management Plan (CEMP). The proposed surface water management measures for the project (refer to **Chapter 18** (Surface water and flooding)) aim to minimise short term impacts on the receiving waterways during construction. With the implementation of the management measures, and in the context of the overall catchment, any potential short term impacts are unlikely to have a material impact on ambient water quality within the receiving waterways and therefore the health of the surrounding community.

Standard mitigation measures would be applied to manage potential risks to the construction workers from exposure contaminated material including the use of appropriate personal protective equipment.

Removal of asbestos containing material would be undertaken in accordance with the relevant procedures and guidelines, and by suitably qualified experts in accordance with the Work Health and Safety Plan and would include notification requirements to communities and relevant stakeholders. Refer to **Chapter 17** (Soils and contamination) and **Chapter 21** (Waste management) for further information on asbestos management.

Groundwater quality

During tunnelling works, groundwater would be extracted and would be collected, and groundwater along the tunnel alignment has the potential to be contaminated.

Should contaminated groundwater be encountered, it would be treated and discharged in accordance with the appropriate discharge criteria (refer to **Chapter 18** (Surface water and flooding). Meeting these guidelines would ensure that discharged water would not affect the health of the community using these waterways for recreation.

There is also the potential to contaminate groundwater through incidents within the construction ancillary facilities associated with the storage of hazardous materials or refuelling operations. Groundwater could become contaminated via fuel and chemical spills, petrol, diesel, hydraulic fluids and lubricants, particularly if a leak or incident occurs over the alluvium, a palaeochannel or fractured sandstone. Stockpiling of construction materials may also introduce contaminants that could potentially leach into and contaminate local groundwater. The risks to groundwater as a result of such incidents would be managed through standard construction management procedures in accordance with site specific environmental management plans developed for the project as outlined in **Chapter 16** (Soils and contamination).

Spills and leaks from construction vehicles and machinery

There is potential for fuel spills to occur during refuelling of construction vehicles and machinery, and for oil spills or the emission of other hazardous substances as a result of mechanical or other failures of construction plant. For construction workers, physical contact with fuels, oils and other hazardous materials is associated with health risks.

All materials will be stored in accordance with appropriate legislation and guidelines, including the thresholds prescribed under SEPP 33 (refer to **section 10.3.3**) that includes the use of bunding and ventilation of areas where gases are stored, maintaining a register and inventory. All materials would also be transported in accordance with the appropriate legislation and guidelines, including the thresholds prescribed under SEPP 33 (refer to **section 10.3.3**).

Spills and leaks and accidental handling of materials by workers would be managed by the implementation of standard construction environmental measures, including measures for fuel and chemical handling, spill containment and the use of appropriate personal protective equipment. These measures would form part of the Construction Environmental Management Plan (CEMP) for the project. Therefore, the risk to public safety is considered to be low.

Mobile plant

The operation of powered mobile plant during construction would be associated with a number of safety hazards including:

- The plant overturning
- Objects falling on the operator of the plant
- The operator being ejected from the plant
- The plant colliding or coming into contact with any person or object (e.g. workers, other vehicles or plant, energised powerlines).

In order to manage these hazards, mobile plant on construction sites would be operated in accordance with *Moving Plant on Construction Sites: Code of Practice*[8].

Flooding

Flooding during construction of the project could potentially impact areas within and near the construction sites. Flood related impacts during construction could include:

- Inundation of excavated tunnels
- Damage to facilities, infrastructure, equipment, stockpiles and downstream sensitive areas caused by inundation from floodwaters
- Release of contamination due to flooding of bunded areas
- Increased risk of flooding of adjacent areas due to temporary loss of floodplain storage (due to displacement of water) or impacts on the conveyance of floodwaters.

The project proposes permanent tunnel portals at the President Avenue intersection. These would be created using cut-and-cover techniques. Tunnelling would also occur through temporary shafts at the Arncliffe construction ancillary facility (C1) and a decline access at the Rockdale construction ancillary facility (C2).

[8] SafeWork NSW (2004) Moving Plant on Construction Sites: Code of Practice

Ingress of floodwater into the shafts or portals during construction would pose significant risk to personal safety for those working in the tunnel. Where these facilities occur within the floodplain or other areas that are flood prone, protection measures such as bunding or floodwater barriers would be provided to ensure floodwaters do not enter shafts or portals. Other flooding impacts during construction, such as flooding of stockpiles and erosion of cleared areas, are expected to be minor.

These impacts would be mitigated by planning sites to recognise the identified flood conditions and minimise the potential for off-site flood impacts. Mitigation measures that would be employed are outlined in **Chapter 18** (Surface water and flooding).

Road and pedestrian safety risks

Impacts to pedestrian safety are discussed in **Chapter 8** (Traffic and transport). An increase in the number of heavy vehicles during the construction period has the potential to impact walking and cycling amenity and safety. However, construction road traffic volumes are expected to be low compared with existing traffic volumes, and are not expected to substantially impact on road safety.

Pedestrian footways and cycling paths may need to be closed or diverted during construction. Alternate safe pedestrian and cycle access is to be provided where it is practical and safe to do so during construction. This will be addressed in the Construction Traffic Management and Access Plan (CTAMP).

At this stage, the expected changes (including detours) across the active transport network during construction are not expected to have a significant impact on cyclist and pedestrian safety.

Subsidence risks

It is generally accepted that the risk of damage to surface features is negligible when subjected to total settlements of less than 10 mm (refer to **Chapter 17** (Groundwater and geology)). For the majority of the tunnel length, the ground settlement is predicted to be less than 10mm due to the depth of the tunnel. Increased levels of settlement (up to around 30mm) may be observed at the southern end of the project, where the tunnel is shallower.

Monitoring of settlement throughout the construction program would be included as part of the CEMP and may include the installation of settlement markers or inclinometers. Pre-construction condition surveys of property and infrastructure that could be impacted by settlement would be undertaken before the commencement of construction activities. In the event that project settlement criteria (which would be determined in the conditions of approval for the project, if approved) are exceeded during construction for property and infrastructure, measures would be taken to ‘make good’ or to manage the impact (refer to **Chapter 17** (Groundwater and geology) for further information regarding settlement criteria). Environmental management measures to control groundwater inflows (which influence groundwater drawdown and therefore ground movement) during construction are outlined in **Chapter 17** (Groundwater and geology). Utilities

The potential rupture or severing of underground utilities due to construction activities could pose a hazard in the form of loss of service to local communities, electrocution, release of sewage from a sewer main or fire if a gas main is impacted. The risks associated with these hazards would be minimised by undertaking the following activities during the works:

- Utility checks (such as ‘dial before you dig’)
- Consulting with the relevant utility service providers
- Service and utility identification works (where possible by non-destructive means, e.g. vacuum truck)
- Relocating and/or protecting utilities in and around the project before construction begins, if required.

Consultation with utility service providers has commenced and would be ongoing during the detailed design and throughout construction, to mitigate the risk of unplanned or unexpected disturbance of utilities.

Bushfire risks

The project would not be located in or near bushfire-prone land. The construction boundary and surrounding area is highly urbanised and does not contain large areas of vegetation that are associated with bushfire risk. As such, bushfire risks associated with the project are considered to be minor.

Temporary construction ancillary facilities and construction infrastructure would be generally less sensitive to bushfire risks than operational facilities, given the temporary nature of the construction ancillary facilities and the absence of critical infrastructure within the facilities. Notwithstanding the low likelihood of bushfire events within the vicinity of the project, measures to mitigate and manage bushfire risks would be developed and included as part of site specific hazard and risk management measures within the CEMP.

Temporary construction ancillary facilities would be maintained in a tidy and orderly condition to minimise potential fuel loads in the event that the facilities are affected by fire. Storage and management of dangerous goods and hazardous materials would occur in a safe, secure location consistent with the requirements of applicable Australian Standards.

Construction activities involving flammable materials and ignition sources (for example, welding) would be proactively managed to ensure that fire risks are effectively minimised. High risk construction activities, such as welding and metal work, would be subject to a risk assessment on total fire ban days, and restricted or ceased as appropriate.

Aviation risks

The *Airports Act 1996* (Commonwealth) (Airports Act) and the *Airports (Protection of Airspace) Regulations 1996* (Commonwealth) (Airspace Regulations) were established for the protection of airspace at and around regulated airports in Australia including Sydney Airport. The Airspace Regulations define the ‘prescribed airspace’ for Sydney Airport as the airspace above any part of either an obstacle limitation surface (OLS) or procedures for air navigation systems operations (PANS-OPS) surface for the airport. Part 139.370 of the Civil Aviation Safety Regulations 1998 (Commonwealth) provides for determination that a plume is a hazardous object if the vertical velocity exceeds 4.3 metres per second.

The OLS is an invisible surface that defines the height limits to which objects, including turbulence from plumes, may project into the airspace around an airport so that aircraft operations may be conducted safely. PANS-OPS protection surfaces are imaginary surfaces in space that establish the airspace that is to remain free of any potential disturbance (including physical objects and other disturbances such as emissions from ventilation outlets) so that aircraft navigation and operations may be conducted safely. Where structures may (under certain circumstances) be permitted to penetrate the OLS, they would not ordinarily be permitted to penetrate any PANS-OPS surface.

Requirements under section 183 of the *Airports Act 1996* are outlined in **Chapter 2** (Assessment process). Construction activities would be carried out to ensure that equipment such as cranes and materials do not intrude into the OLS or PANS-OPS.

CASA and DIRDC have been consulted during the development of the project design and would be consulted further prior to commencement of construction to ensure that the construction activities proposed at Arncliffe, Rockdale and President Avenue are undertaken in line with the Airspace Regulations and the Airports Act, in a manner that satisfies the requirements of CASA.

CASA, under the *Civil Aviation Regulations 1998* (Commonwealth), also regulates ground lighting where it has the potential to impact airport operations (such as causing confusion or distraction from glare to pilots in the air). The Sydney Airport Master Plan 2033 outlines the requirements for external lighting. Lighting during construction would adhere to established guidelines including *Lighting in the vicinity of aerodromes: Advice to lighting designer*[9] and *National Airports Safeguarding Framework Guideline E: Managing the Risk of Distractions to Pilots from Lighting in the Vicinity of Airports*[10] in relation to the location and permitted intensities of ground lights within a six kilometre radius of Sydney Airport.

10.3.5 Social impacts on community health

Changes in the urban environment associated with the project have the potential to result in a range of impacts on health and wellbeing of the community. **Chapter 15** (Social and economic) of the environmental impact statement provides details of the social impacts associated with the project. Aspects that are specifically relevant to potential impacts on the health and wellbeing of the community, either positive or negative, have been highlighted for the human health assessment.

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[9] CASA (1999) Lighting in the vicinity of aerodromes: Advice to lighting designer

[10] DIRD (2012) National Airports Safeguarding Framework Guideline E: Managing the Risk of Distractions to Pilots from Lighting in the Vicinity of Airports

Traffic and transport

Road network

Changes to local roads are proposed during the construction phase of works. While it is expected that access to all properties on the local roads would be maintained during the construction works, some permanent and temporary closures or reduced capacity of some local roads may affect the movement of local traffic through the area. In relation to traffic changes in the project area during construction, most of the issues that are relevant to community health relate to public safety, which is addressed in **section 10.3.4**.

In addition to safety risks to the public, construction works are expected to result in some increases in travel times for motorists, bus travel, pedestrians and cyclists. 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.

A CTAMP would be prepared for the project, detailing temporary road closures and including traffic control procedures, signage requirements, construction traffic management requirements of the relevant Roads and Maritime manuals and procedures and Australian Standards.

Construction of the permanent power supply line would require local traffic changes including partial local road closures. However works would move progressively along the route and therefore receptors would only be impacted for a short period of time. A Traffic Control Plan (TCP) and Road Occupancy Licence (ROL) would be submitted for approval by the relevant authorities prior to works in several construction areas along the route.

Public transport

Access to public transport is important, particularly for people who cannot or are unable to drive (such as the elderly and those with disabilities). Lack of good access to public transport for these individuals can result in increased feelings of isolation, helplessness and dependence.

During construction of the project, public transport in the project corridor and surrounding areas will be temporarily affected. The construction of the project would not directly affect heavy rail or light rail services however passenger access to stations may be affected by temporary traffic changes and congestion arising from the presence of construction works. Most impacts related to the project relate to bus travel, where construction activities would result in the relocation of some bus stops and increased travel times.

Shared Cycle and Pedestrian Pathways

Walking and cycling have many health benefits including maintaining a healthy weight and improved mental status[11]. There is currently a network of cycle paths in the vicinity of the project, comprising a mixture of separated cycleways and on road paths in areas of medium to high difficulty for on road cyclists.

During construction, temporary alterations and diversions to pedestrian and cyclist networks have the potential to affect commuter departure times, travel durations, movement patterns and accessibility. Construction and operation of the project would result in changes to pedestrian and cycle access, including temporary and permanent closures or diversions of some pathways and pedestrian bridges, especially along Presidents Avenue and Rockdale wetlands. While the opportunity to walk or cycle in the project area would be addressed in a Construction Traffic and Access Management Plan (CTAMP), the alterations and changes to amenity may detract from the experience of an environment and potentially deter people from enjoying an active lifestyle or feeling connected with their community. Hence it is important that the diversions and detours are safe, and perceived by the community to be a safe alternative.

Impacts on health and emergency services

The existing 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. Comprehensive communication of changes to roads or paths to emergency services will be an integral part of the CTAMP.

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[11] Hansson et al. 2011; Lindström 2008; Wen & Rissel 2008; WHO 2000b).

Access and connectivity

Roads and freeways can divide residential communities hindering social contact. The presence of busy roads inhibits residents from socialising and children from playing, or accessing nearby recreational areas. Social connectedness and relationships are important aspects of feeling safe and secure. Streets with heavy traffic have been associated with fewer neighbourhood social support networks and have been linked to adverse health outcomes[12]. Any temporary and permanent changes to the access to social infrastructure, community resources or to other desirable locations (such as employment, study, friends and family) and safety to movement may affect community networks and in turn trigger community severance.

Community severance effects often occur during major transportation projects (during construction and operation) due to detours in the local road network, changes to active and public transport routes, and connector roads receiving an increase or decrease in traffic movements. The changes to the road networks may contribute to feelings of community severance and disconnection. The project is not introducing new major roadways that would change existing conditions.

Construction of the project would involve the temporary disruption of pedestrian and cycleway routes especially around Rockdale Bicentennial Park. This reduced connectivity may deter people from participating in community activities or active transport, potentially reducing the connection to an environment and feeling of community cohesion.

Property acquisition

The project requires 15 property acquisitions as well as other temporary and permanent impacts on land use.

The acquisition and relocation of households and businesses due to property acquisition can disrupt social networks and affect health and wellbeing due to raised levels of stress and anxiety. This includes increased levels of stress and anxiety during the process of negotiating reasonable compensation. The purchase of and moving into a house can be one of the most significant events in a person’s life. Both a house and a workplace are central to daily routine with the location of these premises influencing how a person may travel to/from work or study, the social infrastructure and businesses they visit and the people they interact with.

Impacts associated with property acquisition would be managed through a property acquisition support service (refer to **Chapter 3** (Consultation)). All acquisition required for the project would be undertaken in accordance with the relevant standards and guidelines (refer to **Chapter 14** (Property and land use)).

Green space

Green space within urban areas includes green corridors (paths, rivers and canals), grassland, parks and gardens, outdoor sporting facilities, playing fields and children play areas. Studies have shown a positive relationship between green space and health and wellbeing[13], including improved mental health (particularly lower stress levels), reduced morbidity and improved opportunities for physical activity and social interactions. Green spaces that include large trees and shrubs can also protect people from environmental exposures such as air pollution, noise and extreme temperatures (such as the urban heat island effect) due to the cooling effect of vegetation.

During construction, the project would require:

- Acquisition of approximately 1.1 hectares plus the temporary lease of 3.9 hectares of Rockdale Bicentennial Park
- Acquisition of approximately 0.5 hectares plus temporary lease of 0.5 hectares of Scarborough Park North
- Acquisition of approximately 0.7 hectares plus temporary lease of 6.1 hectares of Kogarah Golf Course. The golf course is currently operating with 15 holes instead of 18 holes as it is partially occupied by the Arncliffe construction site for the New M5 Motorway project. The project would result in the golf course continuing to operate with 15 holes during construction.

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[12] WHO 2000b, *Transport, environment and health,* WHO Regional Publications, European Series, No. 89.
[13] de Vries et al. 2003; Health Scotland 2008; Kendal et al. 2016; Maas et al. 2006; Mitchell & Popham 2007.

Works would temporarily restrict access to much of Rockdale Bicentennial Park and the recreational facilities located within the park including the Rockdale Skate Park and disability playground. These impacts to green space during construction of the project may reduce opportunities for physical activity and exercise, social interactions and result in increased levels of stress for members of the community. A reduction in green spaces with trees and shrubs (for example, parts of Rockdale Bicentennial Park) may also reduce the protection offered by these green spaces from air pollution, noise and extreme temperatures.

The Rockdale Bicentennial East soccer fields would be temporarily relocated and the Brighton Memorial Playing Fields may be reconfigured at their current location to allow the community to continue to benefit from their use during the construction period. Roads and Maritime has commenced discussions with Bayside Council regarding the reinstated layout of Rockdale Bicentennial Park following construction and compensatory facilities during construction. The final layout would be determined in consultation with Bayside Council.

Visual impacts

Visual amenity is an important part of an area's identity and offers a wide variety of benefits to the community in terms of quality of life, wellbeing and economic activity. For some individuals, changes in visual amenity can increase levels of stress and anxiety. These impacts, however, are typically of short duration as most people adapt to changes in the visual landscape, particularly within an already urbanised area. As a result, most changes in visual impacts are not expected to have a significant impact on the health of the community.

During construction, visual amenity throughout the project area has the potential to be affected by factors such as the removal of vegetation, the installation of construction hoardings and/or the visual appearance of construction sites. In some areas, the acoustic sheds and hoardings required to manage noise impacts during construction are large and may cause overshadowing. Further factors may include the alteration of view corridors to heritage, open space, water bodies or the city skyline.

Economic impacts

The construction expenditure of the project would be of significant benefit to the economy. This expenditure would inject economic stimulus benefits into the local, regional and state economies. Ongoing or improved economic vitality brings significant health benefit to the community. Employment opportunities would grow in the region through the potential increase in business customers and through the increase in demand for construction workers. The increase in demand for labour may increase wages in the region, particularly for construction workers, who would be in high demand.

It is noted that some local businesses will be adversely impacted by both construction and operational activities, along with other businesses marked for acquisition. This can cause stress for the impacted individuals and lead to health impacts if not appropriately managed. To minimise these impacts the project would include development of a Business Management Plan. This plan should include ways to minimise stress to impacted individuals.

Stress and anxiety

A number of changes within the community (as discussed above and in **section 10.3.6**) have the potential to affect an individual's level of stress and anxiety.

An acute stressful event results in changes to the nervous, cardiovascular, endocrine and immune systems. , more commonly known as the "fight or flight" response . Unless there is an accident or other significant event, such acute stress events are not expected to be associated with construction or operation of the project.

For shorter-term events, stress causes the immune system to release hormones that trigger the production of white blood cells. This response is important for fighting injuries and acute illness. However, this activity within the body is not beneficial if it occurs for a long period of time. It will make some individuals more susceptible to infections.

Chronic and persistent negative stress, or distress, can lead to many adverse health problems including physical illness and mental, emotional and social problems. Response to stress will vary between individuals[14].

[14] Schneiderman et al. 2005 'STRESS AND HEALTH: Psychological, Behavioral, and Biological Determinants', *Annual review of clinical psychology,* vol. 1, pp. 607-628.

Other physiological effects associated with chronic stress include:[15]

- Digestive disorders, with hormones released in response to stress causing a number of people to experience stomach ache or diarrhoea, with appetite also affected in some individuals
- Chronic activation of stress hormones can raise an individual's heart rate, cause chest pain and increase blood pressure and blood lipid (fat) levels. Sustained high levels of fatty substances can lead to atherosclerosis and other cardiovascular diseases[16].
- Cortisol releases at higher levels of stress and plays a role in the accumulation of abdominal fat, which has been linked to a range of other health conditions.
- Stress can cause muscles to contract or tighten, cause tension aches and pains[17].

More generally, it must be noted that urbanisation, or increased urbanisation, regardless of specific projects has been found to affect levels of stress and mental health. These impacts are greater where there is urbanisation without improvements in infrastructure to improve equitable access to employment and social areas/communities[18].

The role of either acute or long-term environmental stress on the health of any community, in general and for specific project(s), including the project, cannot be quantified. There are a wide range of complex factors that influence health and wellbeing, specifically mental health. It is not possible to determine any specific outcomes that may occur as a result of a specific project, or number of projects. However, it is noted that within any urban environment there will be a wide range of stressors present from infrastructure projects as well as other urban developments that may or may not contribute to the health effects outlined above.

It is noted that the project aims to improve infrastructure, connections and access within the urban environment. Hence on a broader scale, the longer-term projects, while requiring long-term management to minimise construction impacts, may assist in reducing stress and associated physiological and mental health impacts within the urban environment.

10.3.6 Construction fatigue

Construction fatigue relates to receptors that experience construction impacts from a variety of projects over an extended period of time with few or no breaks between construction periods. Construction fatigue typically results from continued traffic and access disruptions, noise and vibration, air quality, visual amenity and social impacts from projects that have overlapping construction phases or are back to back. Construction impacts are no longer considered to be transient and/or short-term.

The assessment of construction fatigue in this report includes the construction impacts of the New M5 Motorway project that may overlap with the timing of the construction of the project. It is noted that construction fatigue is particularly relevant for the community surrounding C1, a facility anticipated to be used for both the New M5 Motorway and the project. Other potential construction fatigue risk areas identified include in the vicinity of C2, C3 and the C6 Princes Highway/President Avenue intersection upgrade, where construction requires extended construction timeframes or coordination with other works such as utility relocations or reconfigurations.

The area is also subject to ongoing urban development, with many of the LGAs in the study area projected to have significant population growth (refer to section 4.4) driven by increased development density in the Arncliffe, Banksia, Rockdale and Kogarah areas, as well as the proposed Cooks Cove development.

Dust management measures identified for the project to minimise dust impacts and health risks during construction would be need to be applied through the duration of the works, consistent with standard construction management practices. Such measures would need to be applied across all construction projects, for major infrastructure and other construction activities (including building works) to minimise impacts in the long-term and would be subject to the requirements of approvals for those projects.

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[15] Brosschot et al. 2006; McEwen, Bruce S. 2008; McEwen, B.S. & Stellar 1993; Mills et al. 2008; Moreno-Villanueva & Bürkle 2015.
[16] Pimple et al. 2015; Seldenrijk et al. 2015.
[17] Ortego et al. 2016; 'Is there an relationship between psychological stress or anxiety and chronic nonspecific neck-arm pain in adults? A systematic review and meta-analysis', *Journal of Psychosomatic Research,* vol. 90, 2106/11/01/, pp.70-81.
[18] Srivastava, K. 2009, 'Urbanization and mental health', *Industrial Psychiatry Journal,* vol. 18, no. 2, Jul-Dec, pp. 75-76.

Appendix G (Noise and vibration technical report) has included an assessment of noise impacts that may occur where there are construction activities from a number of road or other infrastructure projects that occur consecutively (one after another) and result in exposure to construction noise impacts for a longer period of time. It identified construction noise of up to 8 years could potentially affect some receptors surrounding the area of the Arncliffe ventilation facility, currently being built as part of the New M5 Motorway project. A number of receptors have been identified as highly affected from standard and out of hours construction noise due to the project, which may result in construction fatigue for some receptors currently experiencing noise impacts due to the construction of the New M5 Motorway project at Arncliffe. However, the scale of construction for this project would be less than for the New M5 Motorway project. The current New M5 Motorway project is expected to operate 60 heavy vehicle movements an hour, whilst the project is expecting 26 heavy vehicle movements an hour.

A strategy would be prepared and implemented to address potential construction fatigue impacts. Discussions with the affected community would occur and where practicable noise attenuation and respite would be provided. Receptors identified as requiring at-property or operational noise mitigation will be identified and offered treatment prior to commencement of construction works that affects them.

10.4 Potential impacts – operation

10.4.1 In-tunnel air quality impacts on community health

Traditionally, the approach to managing air quality within tunnels was based on carbon monoxide levels. However, modern petrol fuelled cars now have low levels of carbon monoxide emissions, and with an increasing proportion of diesel fuelled cars, nitrogen dioxide concentrations are now commonly used for tunnel ventilation design.

The operational in-tunnel limits for carbon monoxide and nitrogen dioxide in several Sydney road tunnels are shown in **Table 10-8**. With the current pollution limits, and for the assessment years of the project, NO_2 would be the pollutant that determines the required air flows and drives the design of ventilation for in-tunnel pollution.

Table 10-8 Operational limits in Sydney road tunnels

Tunnel	CO concentration (ppm, rolling average)			NO_2 concentration (ppm)
	3 min	15 min	30 min	15 min
Cross City Tunnel	200	87	50	N/A
Lane Cove Tunnel	–	87	50	N/A
M5 East Tunnel	200	87	50	N/A
NorthConnex	200[(a)]	87[(b)]	50[(b)]	0.5[(b)]
WestConnex M4 East				
WestConnex New M5				
M4 M5 Link				

Notes:
(a) In-tunnel single point exposure limit
(b) In-tunnel average limit along tunnel length
Sources: NHMRC (2008), Longley (2014c), PIARC (visibility), NSW Government (2015, 2016a, 2016b)

In February 2016, the NSW Government Advisory Committee on Tunnel Air Quality (ACTAQ) issued a document entitled 'In-tunnel air quality (nitrogen dioxide) policy'[19]. That document further consolidated the approach taken earlier for the NorthConnex, M4 East and New M5 projects. The policy wording requires tunnels to be *'designed and operated so that the tunnel average nitrogen dioxide (NO_2) concentration is less than 0.5 ppm as a rolling 15 minute average'*.

For the project's tunnel the 'tunnel average' has been interpreted as a 'route average', being the 'length-weighted average pollutant concentration over a portal-to-portal route through the system'. Tunnel average NO_2 has been assessed north and southbound from the New M5 to President Ave.

The tunnel ventilation system would be designed and operated so that the in-tunnel air quality limits, consistent with those in the conditions of approval for NorthConnex and other approved WestConnex projects, are not exceeded.

A number of factors have been considered in this assessment. Firstly, concentrations in the tunnel are expected to vary depending on the 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. Second, the concentration of pollutants within the vehicle itself would be lower, particularly when all windows are closed when inside the tunnel, as most vehicles have filters on the air intake. When the air conditioning/ventilation in the car is set to recirculation the contribution of air from within the tunnel to the air within the vehicle would be limited. Measurements conducted by NSW Health in relation to the M5 East Tunnel[20] identified that closing car windows and switching the ventilation to recirculation can reduce exposures by about 70–75 per cent for carbon monoxide and nitrogen dioxide, 80 per cent for fine particulates and 50 per cent for volatile organic compounds. Further testing of the reduction in nitrogen dioxide levels inside vehicles using road tunnels was commissioned by Roads and Maritime in 2016[21].

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[19] ACTAQ 2016, *In-Tunnel Air Quality (Nitrogen Dioxide) Policy,* NSW Advisory Committee on Tunnel Air Quality.
[20] NSW Health 2003, *M5 East Tunnels Air Quality Monitoring Project,* South Eastern Sydney Public Health Unit & NSW Department of Health.
[21] PEL 2016, *Road tunnels: reductions in nitrogen dioxide concentrations in-cabin using vehicle ventilation systems,* Prepared by Pacific Environment Limited for NSW Road and Maritime Services.

The study involved a range of vehicles representative of the existing vehicle fleet, travelling through existing tunnels in Sydney and simulating travel times between 45 minutes and 60 minutes over a distance of 30 kilometres.

The study found that recirculation reduced exposures by around 70 per cent. Finally, there may be individuals who use the network of tunnels in the Sydney area on a frequent basis throughout the day. These individuals may include taxi drivers, courier drivers and some truck drivers. More frequent and cumulative exposures in these tunnels are considered below.

Carbon monoxide (CO)

Table 10-9 presents the maximum in-tunnel concentration of carbon monoxide predicted for the project. The table presented is for the year 2036 cumulative scenario, that is with all tunnels in consideration.

Table 10-9 Maximum estimated in-tunnel air quality for CO based on expected traffic in 2036

Time Period	CO (ppm) (one hour average)		30 minute CO criteria (ppm)
	Southbound	Northbound	
7am – 9am	4.3	1.2	48.7*
9am – 3pm	5.1	0.8	48.7
3pm – 6pm	7.8	0.7	48.7
6pm – 7am	2.9	0.5	48.7

* The modelling has been undertaken without consideration of CO background concentrations of 1.3 ppm. Therefore 1.3 ppm is subtracted from the 30 minute criteria of 50 ppm

In relation to the carbon monoxide concentrations predicted within the tunnel, the following is noted:

- The maximum one hour average concentration of carbon monoxide in the tunnels is predicted to be less than 10 ppm in both directions for all times of the day. These concentrations are lower than the health based guideline of 25 ppm (one-hour average) established by the WHO[22] and 34 ppm established by the USEPA[23]. The concentrations are lower than PIARC in-tunnel limits[24].
- The NHMRC (2008) has published measured concentrations of carbon monoxide from a range of tunnels in Sydney and around the world. The measured concentrations come from a number of different studies where the averaging time for the collection of the data varies significantly. This makes it difficult to directly compare the range of reported concentrations with the concentrations predicted in this assessment (i.e. not comparing data reported over similar averaging/exposure periods). While noting this difficulty in comparing the data, a range of average concentrations of carbon monoxide have been reported from six to 38 ppm. The predicted hourly average concentration in the project tunnel is within the range reported in other tunnels.

On the basis of the above, there are no health issues of concern related to in-tunnel exposures to carbon monoxide. This relates to exposures that may occur in the F6 Extension Stage 1.

Nitrogen dioxide (NO_2)

Table 10-10 presents the maximum route average concentration of nitrogen dioxide predicted for the project, while travelling in both directions. The table presented is for the year 2036 cumulative scenario, that is with all tunnels in consideration. The previous in-tunnel assessment undertaken for the WestConnex M4-M5 Link EIS, that considered all possible tunnel travel routes (including the then proposed F6 extension) remains valid for the journeys through the WestConnex tunnels (refer to Annexure L to **Appendix F** (Air quality technical report). This assessment showed that the in-tunnel nitrogen dioxide concentrations for all trips fell below the 0.5 ppm criteria.

[22] WHO 2010, *WHO Guidelines for Indoor Air Quality, Selected Pollutants,* WHO Regional Office for Europe.
[23] NHMRC 2008, *Air Quality in and Around Traffic Tunnels, Systematic Literature Review,* National Health and medical Research Council.
[24] Longley, 2014, *TP11: Criteria for in-Tunnel and Ambient Air Quality,* NSW Advisory Committee on Tunnel Air Quality.

Table 10-10 Maximum estimated in-tunnel air quality for NO_2 based on expected traffic in 2036

Time Period	NO_2 route average (ppm)				Criteria (ppm)
	St Peters to President Ave	M4-M5 to President Ave	President Ave to St Peters	President Ave to M4-M5	
7am – 9am	0.14	0.18	0.12	0.11	0.47*
9am – 3pm	0.15	0.20	0.07	0.07	0.47
3pm – 6pm	0.19	0.23	0.05	0.05	0.47
6pm – 7am	0.07	0.10	0.03	0.03	0.47

* The modelling has been undertaken without consideration of NO_2 background concentrations of 0.3 ppm. Therefore 0.03 ppm is subtracted from the 0.5 ppm criteria

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

- The maximum concentrations in the project's tunnel vary throughout the day, with the maximum concentration predicted at any time of the day less than 0.5 ppm
- The NHMRC (2008) has published measured concentrations of nitrogen dioxide from a range of tunnels in Sydney and around the world. The measured concentrations come from a number of different studies where the averaging time for the collection of the data varies significantly. This makes it difficult to directly compare the range of reported concentrations with the concentrations predicted in this assessment (i.e. not comparing data reported over similar averaging/exposure periods). While noting this difficulty in comparing the data, the NHMRC (2008) have reported a range of average concentrations of nitrogen dioxide in tunnels that range from 0.05 to 0.3 ppm with levels up to 0.4 ppm reported during peak periods. These levels are based on data with averaging times that vary from 30 seconds during travel through a tunnel, six minute averages, to long term data with (unspecified averaging times). At the downstream end of a tunnel (where exposure is very short, i.e. minutes) levels up to 0.8 ppm have been reported.

The concentrations discussed above relate to nitrogen dioxide levels inside the tunnels, not inside the vehicles.

Within existing tunnels utilised in the Roads and Maritime study[25] of in-vehicle nitrogen dioxide levels, concentrations of nitrogen dioxide were generally less than 0.15 ppm, however during periods of high traffic volume and a high proportion of heavy vehicles, the concentrations inside existing tunnels exceeded 0.5 ppm, with levels up to 0.7 ppm. Inside these tunnels with high external concentrations of nitrogen dioxide, the average concentrations inside the vehicles when ventilation was on recirculation was less than 0.2 ppm.

The study found that the use of ventilation on recirculation can significantly reduce concentrations of nitrogen dioxide inside vehicles. The ratio of indoor to outdoor concentrations ranged from 0.06 to 0.32. This is consistent with the findings from a NSW Health study on vehicles using the M5 East tunnel, where an indoor to outdoor ratio of 0.25 to 0.3ppm was determined for nitrogen dioxide where ventilation is set to recirculate. When ventilation was not set to recirculate the concentration of nitrogen dioxide was higher inside the vehicles, and in some cases accumulated inside the vehicle after travelling through short tunnels.

A summary of the health effects of short-term exposure to NO_2 is provided in **Appendix F** (Human health technical report)

The average concentration of nitrogen dioxide has been calculated for the north and south bound trips through the project. However, users of the tunnel network are likely to travel further in the connecting tunnel networks. A previous in-tunnel assessment undertaken for the WestConnex M4-M5 Link EIS considered all possible tunnel travel routes between the western portal of the M4 East, through the M4-M5 Link to the western portal of the New M5, in both directions.

[25] PEL 2016, *Road tunnels: reductions in nitrogen dioxide concentrations in-cabin using vehicle ventilation systems,* Prepared by Pacific Environment Limited for NSW Road and Maritime Services

In the current in-tunnel assessment (refer to **Appendix E** (Air quality technical report)) it is confirmed that the ventilation system of New M5 and F6 Extension, as outlined in this report, meets or exceeds the functional performance requirements of the M4-M5 Link EIS. As such, the integrated analysis of the overarching tunnel network completed as part of the M4-M5 Link EIS remains valid.

Further information for bus travellers is presented in **Appendix F** (Human health technical report).

Table 10-11 and **Table 10-12** present a summary of the maximum (by time of the day) predicted average concentrations of nitrogen dioxide for the routes of travel with the highest NO_2 concentrations, using the project and different parts of the tunnel system (assuming all motorway tunnel projects are completed in 2033), for expected traffic within the tunnel. Average nitrogen dioxide levels in some of the travel routes have also been calculated for the extreme congestion scenario of traffic at 20 kilometres per hour. The tables also present the predicted worst case in-cabin concentration of nitrogen dioxide, where windows are up and ventilation is on recirculation.

Table 10-11 Average nitrogen dioxide levels for different trips using completed tunnel network 2033: to the project

Path No.	Travel			Tunnels used for travel along path				Average NO_2 concentration (ppm) Maximum from travel over all hours of the day				
								Expected traffic		Hour of day for maximum: expected traffic	Extreme congestion	
	Enter at	Exit at	Distance	M4 East	M4-M5 Link	New M5	F6 Extension Stage 1*	In-tunnel	In-vehicle (recirculation)		In-tunnel	In-vehicle (recirculation)
1F	M4 East	F6 Extension	19.5 km	X	X	X	X	0.25	0.076	7am		
1M	Concord Rd	F6 Extension	18.4 km	X	X	X	X	0.26	0.079	7am	0.39	0.12
1R	Wattle St	F6 Extension	13 km		X	X	X	0.25	0.074	4pm	0.38	0.11
1U	Western Harbour Tunnel	F6 Extension	13 km		X	X	X	0.23	0.068	4pm	0.34	0.10
1W	St Peters	F6 Extension	6.9 km			X	X	0.22	0.066	4pm		
1AA	Iron Cove	F6 Extension	13.4 km		X	X	X	0.22	0.066	4pm	0.33	0.10
1AD	City West Link	F6 Extension	12.1 km		X	X	X	0.24	0.073	4pm	0.36	0.11
NO2 guideline: 15 minute average = 0.5 ppm												

Table 10-12 Average nitrogen dioxide levels for different trips using completed tunnel network 2033: from the project

Path No.	Travel			Tunnels used for travel along path				Average NO_2 concentration (ppm) Maximum from travel over all hours of the day				
								Expected traffic		Hour of day for maximum	Extreme congestion	
	Enter at	Exit at	Distance	M4 East	M4-M5 Link	New M5	F6 Extension*	In-tunnel	In-vehicle (recirculation)		In-tunnel	In-vehicle (recirculation)
2F	F6 Extension Stage 1	St Peters	7.1 km			X	X	0.05	0.02	7am		
2G	F6 Extension	Western Harbour Tunnel	12.8 km		X	X	X	0.13	0.04	7am		
2H	F6 Extension	Wattle St	14.3 km		X	X	X	0.14	0.04	7am		
2J	F6 Extension	Concord Rd	18.5 km	X	X	X	X	0.19	0.06	7am		
2K	F6 Extension	M4 East	19.7 km	X	X	X	X	0.24	0.07	7am	0.41	0.12
2AA	F6 Extension	Iron Cove	13.6 km		X	X		0.13	0.04	7am	0.39	0.12
2AB	F6 Extension	City West Link	12.3 km		X	X		0.12	0.04	7am	0.35	0.11
NO_2 guideline: 15 minute average = 0.5 ppm												

In relation to the trips emanating and exiting from the project these trips including the extreme congestion scenario, these trips have been found to be below the 0.5ppm guideline and therefore it is unlikely that significant health effects would occur.

The NO_2 guideline may not be protective of all health effects for all individuals. There is the potential for severe asthmatic individuals, especially if they use motorbikes, to experience some change in respiratory response after using the tunnels, particularly when congested.

Repeated use of tunnels also requires consideration. The available data on health effects associated with short-duration exposures indicates the effects are transient, i.e. only relate to the peak exposure that has occurred. Repeated exposures that may occur as a result of morning peak and afternoon peak travel, have not been considered to be additive. Provided the average nitrogen dioxide concentrations that occur during the travel times in the vehicle are below the health based guidelines, which is expected to be the case for the expected traffic conditions, then no significant adverse health effects are expected.

For individuals involved in occupations that may require more regular use of the road network, such as taxi and courier drivers, there is the potential for these individuals to make more frequent and varied trips over different travel segments in any one day. For these drivers, it is important that they keep their window up and ventilation on recirculation to minimise exposures throughout the day.

Particulate matter

There are no health based guidelines available for the assessment of short-duration exposures to particulate matter (PM) within a tunnel. In-tunnel criteria relate to visibility (and safety in using the tunnel). It is expected that the concentration of PM within the tunnel would be higher than ambient air concentrations, and the concentration of PM would increase with increasing distance travelled through the tunnel.

Potential concentrations of PM inside the tunnel are derived from exhaust as well as non-exhaust sources. Non-exhaust sources include tyre and break wear and dust from surface road wear and the resuspension of road dust. The modelling of PM and visibility within the tunnel did consider both sources. **Table 10-13** presents a summary of the peak concentrations of PM estimated inside the tunnels in 2023, for the expected traffic conditions.

Table 10-13 Predicted peak concentrations of particulate matter in-tunnel: 2023

Scenario/Tunnel segment	Peak PM concentration (mg/m^3)	
	Exhaust	Non-exhaust sources
	Cumulative	Cumulative
To F6 Extension Stage 1		
New M5 including F6 Extension Stage 1	0.08	0.64
From F6 Extension Stage 1		
New M5 including F6 Extension Stage 1	0.03	0.2

The characteristics of PM derived from exhaust and non-exhaust sources are different. The available evidence suggests that non-exhaust particles are generally larger than exhaust particles. It is likely that non-exhaust particles are greater than 10 micrometres in diameter, however this is not well characterised. Where the particles are larger than 10 micrometres in diameter they are of less importance in terms of potential health effects, as these relate to the finer particles that are less than 10 micrometres in diameter, with stronger health effects relevant to exposure to particles less than 2.5 micrometres in diameter. The tunnel design and air quality assessment is based on both exhaust and non-exhaust PM emission factors that relate to PM_{10} and $PM_{2.5}$ from relevant emissions studies. PM_{10} concentrations in the tunnels are dominated by non-exhaust sources. Regular cleaning of the tunnel walls and roadways would reduce these levels.

The exposure-response relationships for particulate matter that have been established on the basis of adverse health effects from short term exposures relate to changes in the health effects associated with variability in 24 hour average concentrations of $PM_{2.5}$ in urban air. They do not relate to much shorter variations in $PM_{2.5}$ exposure that may occur within a 24 hour period, where there may be exposures over a few minutes to higher levels of $PM_{2.5}$. No guidelines are currently available for assessing potential health effects that may occur as a result of exposures to particulates that may occur for minutes (or even an hour).

Specific health effects from the short duration variations in particulate exposures throughout any specific day have not been determined. It is therefore important to consider if exposures to $PM_{2.5}$ in the project tunnels 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 density of the traffic, the age of the vehicle, the choice of ventilation mode used within the vehicle and the type of fuel used[26]. Levels of $PM_{2.5}$ reported in vehicles in Europe[27] 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[28]
- Keeping windows closed and switching ventilation to recirculate has been shown to reduce exposures to particulates inside the vehicle by up to 80 per cent[29]. While noting no guidelines are available for very short duration exposures, this would further reduce exposure to motorists
- For individuals who regularly use tunnels for commuting or as part of their employment, there is the potential for repeated exposures to higher levels of nitrogen dioxide and particulates during the day. While these exposures are not likely to be additive, in terms of potential health effects, it is important that these road users utilise ventilation on recirculation whenever they are using the tunnels
- Where advice is provided to place ventilation on recirculation when using any tunnel, it is not expected to result in carbon dioxide levels inside the vehicle that may adversely affect driver safety. However, where Roads and Maritime provides specific advice to drivers entering road tunnels to put ventilation on recirculation, it is recommended that further advice is provided that recirculation should be switched off at some point after using the tunnel network and not left on for an extended period of time.

10.4.2 Ambient air quality impacts on community health

Assessment of volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs)

Appendix E (Air quality technical report) has considered emissions of volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) to air from the project. Both VOCs and PAHs refer to a group of compounds with a mix of different proportions and toxicities. It is the individual compounds within the group that are of importance for evaluating adverse health effects. The composition of individual compounds in the VOCs and PAHs evaluated would vary depending on the source of the emissions. Hence it is important that the key individual compounds present in emissions considered for this project are speciated (i.e. identified and quantified as a percentage of the total VOCs or total PAHs) to ensure that potential impacts associated with exposure to these compounds can be adequately assessed.

VOCs in air in Sydney (OEH 2012) are primarily derived from domestic/commercial sources (54 per cent) with on-road vehicles contributing approximately 24 per cent, industrial emissions eight per cent with the remainder from off-road mobile sources and other commercial sources.

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[26] Knibbs, de Dear & Morawska 2010, 'Effect of cabin ventilation rate on ultrafine particle exposure inside automobiles', *Environmental science & Technology,* vol. 44, no. 9, May 1. Pp. 3546-3551.
[27] ETC 2013, *Assessment of population exposure to air pollution during commuting in European cities, ETC/ACM Technical Paper 2013/2,* European Topic Centre on Air Pollution and Climate Change Mitigation.
[28] NSW Health, 2004, *Comparison of personal exposures to air pollutants by commuting mode in Sydney, BTEX & NO_2,* NSW Department of Health, Sydney.
[29] NSW Health, 2003, *M5 East Tunnels Air Quality Monitoring Project,* South Eastern Sydney Public Health Unit & NSW Department of Health.

VOCs and PAHs from the project are associated with emissions from vehicles assumed to be using the tunnel (and approaches) and surface roads. The makeup of the VOCs and PAHs emissions would depend on the mix of vehicles considered as these pollutants would be emitted in different proportions from petrol and diesel powered vehicles. In addition, the age and the fuel used by the vehicle fleet would affect these emissions. The vehicle fleet mix considered in this project is summarised in **Table 10-16**.

Table 10-14 Volatile organic compounds speciation profile for vehicle emissions

Pollutant/metric	% of VOC			
	Petrol light duty		Diesel light duty	Diesel heavy duty
	Petrol	Petrol		
Benzene	4.95	4.54	1.07	1.07
PAHs (as b(a)p) (a)	0.03	0.03	0.08	0.08
Formaldehyde	1.46	1.82	9.85	9.85
1,3-butadiene	1.27	1.20	0.40	0.40

Based on a combination of PAH fraction of THC from NSW EPA (2012b) and the b(a)p fraction of PAH of 4.6 per cent from Environment Australia (2003)

Volatile organic compounds

VOCs have been modelled in **Appendix E** (Air quality technical report) based on emissions from all vehicles considered. The proportion of each of the individual VOCs that may be present in the air is then estimated based on the assumed composition of the vehicle fleet during the different years and the type of fuel used.

Most of the VOC emissions comprise a range of hydrocarbons that are of low toxicity (such as methane, ethylene, ethane, butenes, butanes, pentenes, pentanes and heptanes)[30]. From a toxicity perspective the key VOCs that have been considered for the vehicle emissions are BTX, 1,3-butadiene, acetaldehyde and formaldehyde (consistent with those identified and targeted in studies conducted in Australia on vehicle emissions (Australian Department of Environment and Heritage[31][32].

The proportion of each of the key VOCs considered are derived from the 2008 Calendar Year Air Emissions Inventory for the Greater Metropolitan Region in NSW[33], for the vehicle fleet assessed in **Appendix E** (Air quality technical report) (as summarised above). In relation to passenger vehicles it has been assumed that 60 per cent[34] of fuel used is E10. It is conservatively assumed that the composition of VOCs in vehicle emissions remains the same over time, and does not improve with enhanced vehicle emissions technology.

Table 10-15 presents a summary of the weighted mass fraction for these VOCs considered for the project in 2026 and 2036.

Table 10-15 Weighted volatile organic compounds speciation profile for vehicle emissions

VOC	Weighted % of total VOC estimate	
	2026	2036
Benzene	3.9	3.4
Toluene	7.1	5.9
Xylenes	5.9	4.9
1,3-butadiene	1.1	0.9
Formaldehyde	3.4	4.6
Acetaldehyde	1.6	2.0

30 NSW EPA 2012, *Air Emissions Inventory for the Greater Metropolitan Regional in New South Wales, 2008 Calendar Year, On-Road Mobile Emissions: Results,* NSW Environment Protection Authority Sydney,
31 DEH 2003, *Technical Report No. 1: Toxic Emissions from Diesel Vehicles in Australia,* Environment Australia.
32 NSW EPA 2012, *Air Emissions Inventory for the Greater Metropolitan Regional in New South Wales, 2008 Calendar Year, On-Road Mobile Emissions: Results,* NSW Environment Protection Authority Sydney,
33 NSW EPA 2012, *Air Emissions Inventory for the Greater Metropolitan Regional in New South Wales, 2008 Calendar Year, On-Road Mobile Emissions: Results,* NSW Environment Protection Authority Sydney,
34 The value of 60 per cent of ethanol in total fuel volume sales comes from the requirement that a minimum of 6% ethanol in the total volume of petrol sold in NSW as outlined in the Biofuels Act 2007 (NSW). This equates to selling 60% E10 fuel.

Polycyclic aromatic hydrocarbons

PAHs have been considered in **Appendix E** (Air quality technical report) as key pollutants that may be derived from diesel powered heavy goods vehicles. The total PAH concentration that may be derived from the project has been determined on the basis of a proportion of the total VOCs. While not all of the PAHs would be volatile the approach adopted provides an estimate of potential levels of total PAHs that may be in air, as a result of the change in emissions derived from the project.

For the year 2026 and 2036 total PAHs have been estimated to comprise 0.79 and 0.95 per cent respectively of the total VOCs.

In relation to the toxicity of PAHs, this differs significantly for the different individual PAHs that may be present. The detailed review of the potential health impacts associated with exposures to PAHs in air from the project requires an assessment of the key individual PAHs (see **Appendix F** (Human health technical report).

The toxicity of individual PAHs varies significantly, with some considered to be carcinogenic while others are not carcinogenic. For the carcinogenic PAHs, these are commonly assessed as a group with the total carcinogenic PAH concentration calculated using weighting factors that relate the toxicity of individual carcinogenic PAHs to the most well studied PAH, benzo(a)pyrene. For the carcinogenic PAHs the weighting factors presented by the Canadian Council of Ministers of the Environment[35] have been adopted. Other PAHs that are not carcinogenic have been considered separately.

On the basis of this approach the speciation of individual PAHs (as per cent of total PAHs) has been calculated based on the data from DEH (2003). The data presented relates to emissions that occur in congested or stop/start traffic. This data has been used to be representative of the worst case situation of heavy congested traffic in the project area and is considered to be conservative for expected traffic conditions in the motorway tunnels.

Table 10-16 presents a summary of the PAH speciation profile considered in this assessment for the above traffic conditions.

Table 10-16 Polycyclic aromatic hydrocarbon speciation profile for diesel vehicle emissions

Individual PAH	Per cent of total PAH emissions (PAHs)
	Used to evaluate emissions in 2026 and 2036
Non-carcinogenic PAHs	
Naphthalene	70
Acenaphthylene	4.9
Acenaphthene	2.0
Fluorene	5.0
Phenanthrene	3.4
Anthracene	0.49
Fluoranthene	0.45
Pyrene	0.71
Carcinogenic PAHs	
Benzo(a)pyrene TEQ	4.6

Assessment of health impacts

The change in VOC and PAH concentrations associated with the project is a decrease for most receptors, however in some areas there is an increase in concentrations. These changes relate to the redistribution of emissions from vehicles, primarily associated with surface roads. The following evaluation has been undertaken to assess the potential health impacts associated with the maximum increases predicted.

[35] CCME 2010, *Canadian Soil Quality Guidelines, Carcinogenic and Other Polycyclic Aromatic Hydrocarbons* (*PAHs*) (*Environmental and Human Health Effects*), *Scientific Criteria Document (revised)*, Canadian Council of Ministers of the Environment, Quebec.

The assessment of potential health impacts associated with exposure to changes in VOCs and PAHs concentrations (calculated for individual VOCs and PAHs based on the speciation outlined above) in air within the community has been assessed on the basis of the following:

For VOCs and PAHs that are considered to be genotoxic carcinogens (consistent with guidance provided by enHealth[36] an incremental lifetime carcinogenic risk has been calculated. For the VOCs and PAHs evaluated in this assessment a carcinogenic risk calculation has been adopted for the assessment of maximum potential (incremental) increase in benzene, 1,3-butadiene and carcinogenic PAHs (as a benzo(a)pyrene toxicity equivalent or TEQ). The assessment undertaken has adopted the calculation methodology outlined in Annexure B, adopting the inhalation unit risk values presented in **Table 10-18**.

For other VOCs and PAHs, where the health effects are associated with a threshold (i.e. a level below which there are no effects), the maximum predicted concentration from all sources (i.e. background plus the project) of individual VOCs and PAHs associated with the project have been compared against published peer-reviewed health based guidelines that are relevant to acute and chronic exposures (where relevant). The health based guidelines adopted (identified on the basis of guidance from enHealth 2012) are relevant to exposures that may occur to all members of the general public (including sensitive individuals) with no adverse health effects. The guidelines available relate to the duration of exposure and the nature of the health effects considered where:

Acute guidelines are based on exposures that may occur for a short period of time (typically between an hour or up to 14 days). These guidelines are available to assess peak exposures (based on the modelled one hour average concentration) that may be associated with volatile organic compounds in the air, and are presented in **Table 10-17**.

Chronic guidelines are based on exposures that may occur all day, every day for a lifetime. These guidelines are available to assess long term exposures (based on the modelled annual average concentration) that may be associated with volatile organic compounds and PAHs in the air, and are presented in **Table 10-18**.

Table 10-17 Adopted acute inhalation guidelines based on protection of public health

Compound assessed	Acute health based guideline (µg/m3)	Basis
Volatile organic compounds		
Benzene	580	Acute 1 hour health based guideline, based on depressed peripheral lymphocytes from Texas Commission on Environmental Quality (TCEQ) evaluation[37].
Toluene	15000	Acute 1 hour health based guideline, based on eye and nose irritation, increased occurrence of headache and intoxication in human male volunteers from TCEQ evaluation[38].
Xylenes	7400	Acute 1 hour health based guideline, based on mild respiratory effects and subjective symptoms of neurotoxicity in human volunteers from TCEQ evaluation[39].
1,3-Butadiene	660	Acute 1 hour health based guideline, based on developmental effects derived by the California Office of Environmental Health Hazard Assessment[40]. The guideline developed is lower than developed by TCEQ[41] based on the same critical study.

[36] enHealth 2012b, *Environmental Health Risk Assessment, Guidelines for assessing human health risks from environmental hazards,* Commonwealth of Australia, Canberra.
[37] TCEQ 2013b, *Development Support Document, Xylenes,* Texas Commission on Environmental Quality
[38] TCEQ 2013c, *Development Support Document, Toluene,* Texas Commission on Environmental Quality
[39] TCEQ 2013e, *1,3-Butadiene*, *Development Support Document,* Commission on Environmental Quality
[40] OEHHA 2013, *Individual Acute, 8-hour, and Chronic Reference Exposure Level Summaries,* California Office of Environmental Health Hazard Assessment.
[41] TCEQ 2007, *1,3-Butadiene*, TEXAS COMMISSION ON ENVIRONMENTAL QUALITY.

Compound assessed	Acute health based guideline (µg/m3)	Basis
Formaldehyde	50	Acute 1 hour health based guideline, based on eye and nose irritation in human volunteers from TCEQ evaluation[42]). This guideline is noted to be lower than the acute guideline available from the WHO[43][44] of 100 µg/m3 for formaldehyde.
Acetaldehyde	470	Acute 1 hour health based guideline, based on effects on sensory irritation, bronchoconstriction, eye redness and swelling derived by the California OEHHA[45].

[42] TCEQ 2014, *Formaldehyde, 24-hours Ambient Air Monitoring Comparison Value, Development Support Document,* Texas Commission on Environmental Quality.

[43] WHO, 2000a, *WHO air quality guidelines for Europe, 2nd edition, 2000 (CD ROM version),* World Health Organisation.

[44] WHO 2010, *WHO Guidelines for Indoor Air Quality, Selected Pollutants,* WHO Regional Office for Europe.

[45] OEHHA 2013, *Individual Acute, 8-hour, and Chronic Reference Exposure Level Summaries,* California Office of Environmental Health Hazard Assessment.

Table 10-18 Adopted chronic guidelines and carcinogenic unit risk values based on protection of public health

Compound assessed	Chronic health based guideline (µg/m3)	Basis
Threshold guidelines for volatile organic compounds		
Benzene	30	The most significant chronic health effect associated with exposure to benzene is the increased risk of cancer, specifically leukaemia, which is assessed separately (below). The assessment of other health effects (other than cancer) has been undertaken using a chronic guideline derived by the USEPA[46] based on haematological effects in an occupational inhalation study (converted to public health value using safety factors). This is the most current evaluation of effects associated with chronic inhalation exposure to toluene and is consistent with the value used to derive the NEPM[47] health based guidelines.
Toluene	5000	Chronic guideline derived by the USEPA[48] based on neurological effects in an occupational study (converted to public health value using safety factors). This is the most current evaluation of effects associated with chronic inhalation exposure to toluene and is consistent with the value used to derive the NEPM[49] health based guidelines.
Xylenes	220	Chronic guideline derived by the Agency for Toxic Substances and Disease Register (ATSDR)[50] based on mild subjective respiratory and neurological symptoms in an occupational study (converted to public health value using safety factors).
Formaldehyde	3.3	Formaldehyde is classified by IARC as carcinogenic to humans. The guideline developed by TCEQ[51] is derived on the basis of irritation of the eyes and airway discomfort in humans, with review of carcinogenic and other non-carcinogenic effects found to be adequately protected by this guideline. The guideline is more conservative than derived by the WHO[52].
Acetaldehyde	9	Chronic guideline derived by the USEPA[53] based on nasal effects (in a rat study) (converted to a public health value using safety factors). Value is more conservative that more recent evaluations from WHO and Californian OEHHA.
Threshold guidelines for polycyclic aromatic hydrocarbons		
Naphthalene	3	Chronic guideline from USEPA[54] based on nasal effects (in a mice study) (converted to a public health value using safety factors) and is consistent with the value used to derive the NEPC[55] health based guidelines.
Acenaphthylene	200#	These are the non-carcinogenic PAHs. Guideline available from the USEPA[56]. Chronic guidelines are based on criteria derived from oral studies (for critical effects on the liver, kidney and haematology) which are then converted to an inhalation value (relevant for the protection of public health, including the use of safety factors) for use in this assessment. The value presented in the above table
Acenaphthene	200	

[46] USEPA 2002b, *Health Assessment Document For Diesel Engine Exhaust*, United States Environmental Protection Agency.
[47] NEPC 1999 amended 2013b, *Schedule B1, Guideline on Investigation Levels For Soil and Groundwater, National Environment Protection (Assessment of Site Contamination) Measure*, National Environment Protection Council.
[48] USEPA 2005a, *Toxicological Review of Toluene (CAS No. 108-88-3), In Support of Summary Information on the Integrated Risk Information System (IRIS)*, U.S. Environmental Protection Agency, Washington.
[49] NEPC 1999 amended 2013b, *Schedule B1, Guideline on Investigation Levels For Soil and Groundwater, National Environment Protection (Assessment of Site Contamination) Measure*, National Environment Protection Council.
[50] ATSDR 2007, *Toxicological Profile for Xylene*, US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry.
[51] TCEQ 2013a, *Development Support Document, Formaldehyde*, Texas Commission on Environmental Quality.
[52] WHO 2010, *WHO Guidelines for Indoor Air Quality, Selected Pollutants*, WHO Regional Office for Europe.
[53] USEPA database.
[54] USEPA 1998, *Toxicological Review of Naphthalene (CAS No. 91-20-3), In Support of Summary Information on the Integrated Risk Information System (IRIS)*, U.S. Environmental Protection Agency, Washington.
[55] NEPC 1999 amended 2013b, *Schedule B1, Guideline on Investigation Levels For Soil and Groundwater, National Environment Protection (Assessment of Site Contamination) Measure*, National Environment Protection Council.
[56] USEPA.

Compound assessed	Chronic health based guideline (µg/m3)	Basis
Fluorene	140	has been converted from an acceptable dose in mg/kg/day to an acceptable air concentration assuming a body weight of 70 kg and inhalation of 20 m3/day (as per[57]. # No guideline available for individual PAHs, hence a surrogate compound has been used for the purpose of assessment. The surrogate compound is a PAH of similar structure and toxicity. In relation to the surrogates adopted in this evaluation, acenaphthene has been adopted as a surrogate for acenaphthylene, fluoranthene has been adopted as a surrogate for phenanthrene.
Phenanthrene	140#	
Anthracene	1000	
Fluoranthene	140	
Pyrene	100	
Carcinogenic inhalation unit risk values adopted for carcinogenic risk calculation		
Benzene	6x10-6 (µg/m3)-1	Benzene is classified as a known human carcinogen by the International Agency for Research on Cancer (IARC). Inhalation unit risk value is from the WHO[58] [59] and is based on excess risk of leukaemia from epidemiological studies.
1,3-Butadiene	5x10-7 (µg/m3)-1	1,3-Butadiene is classified as a known human carcinogen by the International Agency for Research on Cancer (IARC). Inhalation unit risk values are available from a number of agencies, including the WHO, USEPA and TCEQ. The most current evaluation has been undertaken by TCEQ[60]. This has considered the same studies as WHO and USEPA, but included more recent studies and more relevant dose-response modelling.
Benzo(a)pyrene TEQ	0.087 (µg/m3)-1	BaP is classified by IARC as a known human carcinogen, which relates to BaP as well as all the other carcinogenic PAHs assessed as a BaP toxicity equivalent (TEQ) value. Inhalation unit risk value is from the WHO[61] and is based on protection from lung cancer for an occupational study associated with coke oven emissions, which are very different from those from diesel emissions, and is expected to be conservative. It is noted that carcinogenic risks associated with lung cancer from diesel particulate matter (which is dominated by the presence of carcinogenic PAHs) is also assessed as outlined in section 5.9.5 and Annexure B).

Table 10-19 and **Table 10-20** present a summary of the maximum predicted one hour or annual average concentrations of VOCs and PAHs assessed on the basis of a threshold with comparison against acute and chronic health based guidelines. The table also presents a Hazard Index (HI) which is the ratio of the maximum predicted concentration to the guideline. Each individual HI is added up to obtain a total HI for all the 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[62]:

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

[57] USEPA 2009a, *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, (Part F, Supplemental Guidance for Inhalation Risk Assessment)*, United States Environmental Protection Agency, Washington, D.C.
[58] WHO 2000a, *WHO air quality guidelines for Europe, 2nd edition, 2000 (CD ROM version)*, World Health Organisation.
[59] WHO 2010, *WHO Guidelines for Indoor Air Quality, Selected Pollutants*, WHO Regional Office for Europe.
[60] TCEQ 2013d, *Development Support Document, Benzene*, Texas Commission on Environmental Quality.

[61] WHO 2010, *WHO Guidelines for Indoor Air Quality, Selected Pollutants*, WHO Regional Office for Europe.
[62] enHealth 2012b, *Environmental Health Risk Assessment, Guidelines for assessing human health risks from environmental hazards*, Commonwealth of Australia, Canberra.

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 or 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 assessment of acute exposures, presented in **Table 10-19** and **Table 10-20**, has compared the maximum predicted total (background plus existing roads and project) one-hour average concentration against the relevant acute guidelines. This is the maximum one-hour average concentration reported anywhere in the project area, regardless of land use.

The assessment of chronic exposures, presented in **Table 10-21** and **Table 10-22**, has compared the maximum predicted total annual average concentration relevant to residential land use against the relevant chronic guidelines. For exposures in other areas, **Table 10-21** and **Table 10-22** also present the maximum calculated HI relevant to exposures in commercial/industrial areas, where the maximum change in VOC concentrations is predicted. The calculated HI takes into account that these exposures occur for eight hours per day over 240 days per year.

Table 10-23 and **Table 10-24** presents a summary of the calculated incremental lifetime carcinogenic risk associated with exposure to the maximum predicted change in concentrations of benzene, 1,3-butadiene and carcinogenic PAHs (as benzo(a)pyrene TEQ) in residential areas. The calculation presented assumes residents are exposed to these pollutants all day, every day for a lifetime. The calculated carcinogenic risk for these compounds has been summed, in accordance with enHealth guidance where the following has been considered[63]. The table also presents the calculated total carcinogenic risk relevant to exposures in commercial/industrial areas, where the maximum change in VOCs and PAHs is predicted to occur. This calculation assumes workers are exposed eight hours per day, 240 days per year for 30 years. The calculated risks are considered in conjunction with what are considered negligible, tolerable/acceptable and unacceptable risks as outlined in Annexure C.

The values presented in the tables have been rounded to two significant figures for individual 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 concentration in air for the relevant assessment scenarios for 2026 and 2036 as modelled in **Appendix E** (Air quality technical report) . The concentrations models are the total concentration, namely background plus emissions from surface roads plus emissions from ventilation outlets. Concentrations in all other areas of the surrounding community are lower than the maximum as evaluated in this assessment. In many locations, the change due to the project is a lowering of VOC and PAH concentrations in air (i.e. a benefit).

Table 10-19 Assessment of acute exposures to VOCs – maximum impacts in community associated with project: 2026

Key VOC	Maximum predicted 1 hour average concentration associated with project (background plus project) and calculated HI			
	2026: Without project		2026: With project	
	Maximum concentration (µg/m3)	HI	Maximum concentration (µg/m3)	HI
Benzene	9.7	0.017	7.7	0.013
Toluene	17.8	0.0012	14.0	0.00093
Xylenes	14.6	0.0020	11.5	0.0016
1,3-Butadiene	2.6	0.0039	2.0	0.0031
Formaldehyde	8.0	0.16	6.3	0.13
Acetaldehyde	3.8	0.0082	3.0	0.0064
Total HI		0.19	0.15	

[63] enHealth 2012b, *Environmental Health Risk Assessment, Guidelines for assessing human health risks from environmental hazards*, Commonwealth of Australia, Canberra.

Table 10-20 Assessment of acute exposures to VOCs – maximum impacts in community associated with project: 2036

Key VOC	Maximum predicted 1 hour average concentration associated with project (background plus project) and calculated HI					
	2036: Without project		2036: With project		2036: Cumulative	
	Maximum concentration (µg/m3)	HI	Maximum concentration (µg/m3)	HI	Maximum concentration (µg/m3)	HI
Benzene	5.4	0.0093	5.2	0.0089	5.2	0.0090
Toluene	9.4	0.00062	9.0	0.00060	9.1	0.00061
Xylenes	7.7	0.0010	7.4	0.0010	7.5	0.0010
1,3-Butadiene	1.5	0.0022	1.4	0.0021	1.4	0.0022
Formaldehyde	7.0	0.14	6.7	0.13	6.8	0.14
Acetaldehyde	3.1	0.0066	3.0	0.0063	3.0	0.0064
Total HI		0.16	0.18		0.16	

Table 10-21 Assessment of chronic exposures to VOCs and PAHs – maximum impacts in community associated with project: 2026

Key VOCs and PAHs	Maximum predicted annual average concentration associated with project (background plus project) and calculated HI Residential exposures			
	2026: Without project		2026: With project	
	Max concentration (µg/m3)	HI	Max concentration (µg/m3)	HI
Benzene	0.51	0.017	0.52	0.017
Toluene	0.93	0.0002	0.96	0.0002
Xylenes	0.76	0.003	0.79	0.004
Formaldehyde	0.42	0.13	0.43	0.13
Acetaldehyde	0.20	0.022	0.21	0.023
Naphthalene	0.069	0.023	0.071	0.024
Acenaphthylene	0.0048	2.4 x10-5	0.0050	2.5 x10-5
Acenaphthene	0.0020	9.9 x10-6	0.0020	1.0 x10-5
Fluorene	0.0049	3.5 x10-5	0.0051	3.6 x10-5
Phenanthrene	0.0034	2.4 x10-5	0.0035	2.5 x10-5
Anthracene	0.00048	4.8 x10-7	0.00050	5.0 x10-7
Fluoranthene	0.00044	3.2 x10-6	0.00046	3.3 x10-6
Pyrene	0.00070	7.0 x10-6	0.00072	7.2 x10-6
Total HI – Residential		0.18		0.18
Max HI – Commercial/Industrial		0.039		0.040

Table 10-22 Assessment of chronic exposures to VOCs and PAHs – maximum impacts in community associated with project: 2036

Key VOCs and PAHs	Maximum predicted annual average concentration associated with project (background plus project) and calculated HI Residential exposures					
	2036: Do minimal		2036: With project		2036: Cumulative	
	Max concentration (µg/m3)	HI	Max concentration (µg/m3)	HI	Max concentration (µg/m3)	HI
Benzene	0.34	0.011	0.34	0.011	0.34	0.011
Toluene	0.60	0.0001	0.59	0.0001	0.59	0.0001
Xylenes	0.49	0.002	0.48	0.002	0.49	0.002
Formaldehyde	0.44	0.13	0.44	0.13	0.44	0.13
Acetaldehyde	0.20	0.022	0.19	0.022	0.19	0.022
Naphthalene	0.065	0.022	0.064	0.021	0.064	0.021
Acenaphthylene	0.0045	2.3 x10-5	0.0045	2.2 x10-5	0.0045	2.2 x10-5
Acenaphthene	0.0018	9.2 x10-6	0.0018	9.1 x10-6	0.0018	9.2 x10-6
Fluorene	0.0046	3.3 x10-5	0.0046	3.3 x10-5	0.0046	3.3 x10-5
Phenanthrene	0.0031	2.2 x10-5	0.0031	2.2 x10-5	0.0031	2.2 x10-5
Anthracene	0.00045	4.5 x10-7	0.00045	4.5 x10-7	0.00045	4.5 x10-7
Fluoranthene	0.00042	3.0 x10-6	0.00041	2.9 x10-6	0.00041	2.9 x10-6
Pyrene	0.00066	6.6 x10-6	0.00065	6.5 x10-6	0.00065	6.5 x10-6
Total HI – Residential		0.18		0.18		0.18
Max HI – Commercial/Industrial		0.039		0.039		0.039

Table 10-23 Assessment of incremental lifetime carcinogenic risk – maximum impacts in community associated with project: 2026

Key VOC	Maximum predicted change in annual average concentration associated with project and cancer risk Residential			
	2026: With project		2026: Cumulative	
	Maximum concentration (µg/m3)	ILCR	Maximum concentration (µg/m3)	ILCR
Benzene	0.061	2 x 10-7		
1,3-Butadiene	0.0162	3 x 10-9		
Benzo(a)pyrene TEQ	5.4E-04	2 x 10-5		1 x 10-5
Total carcinogenic risk – Residential		2 x 10-5	1 x 10-5	
Maximum carcinogenic risk – Commercial/Industrial		4 x 10-6	3 x 10-6	

Note: ILCR = incremental lifetime carcinogenic risk (refer to Annexure B for calculation methodology and Table 5-5 for inhalation unit risk values)

Table 10-24 Assessment of incremental lifetime carcinogenic risk – maximum impacts in community associated with project: 2036

Key VOC	Maximum predicted change in annual average concentration associated with project and cancer risk Residential			
	2036: With project		2036: Cumulative	
	Maximum concentration ($\mu g/m^3$)	ILCR	Maximum concentration ($\mu g/m^3$)	ILCR
Benzene	0.044	1×10^{-7}	0.052	1×10^{-7}
1,3-Butadiene	0.012	2×10^{-9}	0.014	3×10^{-9}
Benzo(a)pyrene TEQ	5.5×10^{-4}	2×10^{-5}	6.5×10^{-4}	2×10^{-5}
Total carcinogenic risk – Residential		2×10^{-5}	2×10^{-5}	
Maximum carcinogenic risk – Commercial/Industrial		4×10^{-6}	5×10^{-6}	

Note: ILCR = incremental lifetime carcinogenic risk (refer to Annexure B for calculation methodology and **Table 5-5** for inhalation unit risk values)

For the assessment of acute exposures to VOCs (**Table 10-19** and **Table 10-20**) the calculated HI associated with exposure to the maximum concentrations predicted is less than one for 2026, 2036 and the cumulative scenario. On this basis, there are no acute risk issues in the local community associated with the project.

For the assessment of chronic exposures to VOCs and PAHs (**Table 10-21 and Table 10-22**), the calculated HI associated with exposure to the maximum concentrations predicted is less than or equal to one for the 2026, 2036 Do something and the cumulative scenarios. The calculated lifetime cancer risks associated with the maximum change in benzene, 1,3-butadiene and carcinogenic PAHs (as benzo(a)pyrene TEQ) are less than or equal to 2×10^{-5} and are considered to be tolerable **Table 10-21 and Table 10-22**). It is noted that the calculations undertaken for PAHs is based on a conservative estimate of the fraction of emissions from vehicles that comprises PAHs (as a percentage of total VOCs). The approach adopted is expected to overestimate concentrations of PAHs in air. Hence the calculations presented are considered to be a conservative upper limit estimate.

On this basis, there are no chronic risk issues in the local community associated with the project.

Assessment of carbon monoxide

Motor vehicles are the dominant source of carbon monoxide in air (DECCW 2009). Adverse health effects of exposure to carbon monoxide are linked with carboxyhaemoglobin (COHb) in blood. In addition, association between exposure to carbon monoxide and cardiovascular hospital admissions and mortality, especially in the elderly for cardiac failure, myocardial infarction and ischemic heart disease, and some birth outcomes (such as low birth weights) have been identified[64].

Guidelines are available in Australia from NEPC[65] and NSW EPA that are based on the protection of adverse health effects associated with carbon monoxide. Review of these guidelines by NEPC (2010) identified additional supporting studies[66] for the evaluation of potential adverse health effects and indicated that these should be considered in the current review of the National Ambient Air Quality NEPM (no interim or finalisation date available). The air guidelines currently available from NEPC are consistent with health based guidelines currently available from the WHO (2005) and the USEPA (2011)[67], specifically listed to be protective of exposures by sensitive populations including asthmatics, children and the elderly). On this basis, the current NEPC guidelines are considered appropriate for the assessment of potential health impacts associated with the project.

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[64] NEPC 2010, *Review of the National Environment Protection (Ambient Air Quality) Measure, Discussion Paper, Air Quality Standards*, National Environmental Protection Council.
[65] NEPC 2003, *National Environment Protection (Ambient Air Quality) Measure*, National Environment Protection Council.
66 Many of the more current studies are epidemiology studies that relate to a mix of urban air pollutants (including particulate matter) where it is more complex to determine the effects that can be attributed to carbon monoxide exposure only.
67 Most recent review of the Primary National Ambient Air Quality Standards for Carbon Monoxide published by the USEPA in the Federal Register Volume 76, No. 169, 2011, available from: http://www.gpo.gov/fdsys/pkg/FR-2011-08-31/html/2011-21359.htm.

The NEPC ambient air quality guideline for the assessment of exposures to carbon monoxide has considered lowest observed adverse effect level (LOAEL) and no observed adverse effect level (NOAEL) associated with a range of health effects in healthy adults, people with ischemic heart disease and foetal effects. In relation to these data, a guideline level of carbon monoxide of nine parts per million (ppm) by volume (or ten 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 USEPA) guideline is protective of adverse health effects in all individuals, including sensitive individuals.

The NSW EPA has also established a guideline for 15-minute average (100 milligrams per cubic metre) and one-hour average (30 milligrams per cubic metre) concentrations of carbon monoxide in ambient air. These guidelines are based on criteria established by the WHO[68] using the same data used by the NEPC to establish the guideline (above) with extrapolation to different periods of exposure on the basis of known physiological variables that affect carbon monoxide uptake.

Table 10-25 presents a summary of the maximum predicted cumulative one-hour average and eight-hour average concentrations of carbon monoxide for the assessment years 2026 and 2036, without the project, with the project and for the cumulative scenario.

Table 10-25 Review of potential acute and chronic health impacts – carbon monoxide (CO)

Scenario	Maximum 1 hour average concentration of CO (mg/m³)			Maximum 8 hour average concentration of CO (mg/m³)		
	Without project	With project	Cumulative	Without project	With project	Cumulative
2026						
Maximum	5.3	5.3		3.7	3.7	
2036						
Maximum	5.0	4.7	4.8	3.5	3.3	3.3
Relevant health based guideline	30			10		

All the concentrations of carbon monoxide presented in the above table are below the relevant health based guidelines. On the basis of the assessment undertaken there are no adverse health effects expected in relation to exposures (acute and chronic) to carbon monoxide in the local area surrounding the project footprint.

Assessment of nitrogen dioxide

Approach

Nitrogen oxides (NOx) refers to nitrogen oxide and nitrogen dioxide, which are highly reactive gases containing nitrogen and oxygen. Nitrogen oxide gases form when fuel is burnt. Motor vehicles, along with industrial, commercial and residential (e.g. gas heating or cooking) combustion sources, are primary producers of nitrogen oxides.

In terms of health effects, nitrogen dioxide is the only oxide of nitrogen that may be of concern[69]. Nitrogen dioxide can cause inflammation of the respiratory system and increase susceptibility to respiratory infection. Exposure to elevated levels of nitrogen dioxide has also been associated with increased mortality, particularly related to respiratory disease, and with increased hospital admissions for asthma and heart disease patients[70]. Asthmatics, the elderly and people with existing cardiovascular and respiratory disease are particularly susceptible to the effects of nitrogen dioxide[71]

[68] WHO 2000c, *Guidelines for Air Quality*, World Health Organisation, Geneva
[69] WHO 2000b, *Transport, environment and health*, WHO Regional Publications, European Series, No. 89.
[70] WHO 2013b, *Health Effects of Particulate Matter, Policy implications for countries in eastern Europe, Caucasus and central Asia*, WHO Regional Office for Europe.
[71] Morgan, G, Broom, R & Jalaludin, B 2013, *Summary for Policy Makers of the Health Risk Assessment on Air Pollution in Australia*, Prepared for National Environment Protection Council by the University Centre for Rural Health, North Coast, Education Research Workforce, A collaboration between The University of Sydney, Southern Cross University, The University of Western Sydney, The University of Wollongong, Canberra.

[72]. The health effects associated with exposure to nitrogen dioxide depend on the duration of exposure as well as the concentration.

Guidelines are available from the NSW EPA and NEPC[73] which indicate acceptable concentrations of nitrogen dioxide. These guidelines are based on protection from adverse health effects following both short term (acute) and longer term (chronic) exposure for all members of the population including sensitive populations like asthmatics, children and the elderly. Recently these guidelines have been reviewed by NEPC[74] [75] [76]. The review identified additional supporting studies for the evaluation of potential adverse health effects. The reviews undertaken to date have not recommended any change to the existing health based guidelines.

When reviewing the available literature on the health effects associated with exposure to nitrogen dioxide it is important to consider the following:

- Whether the evidence suggests that associations between exposure to nitrogen dioxide concentrations and effects on health are causal. The most current review undertaken by the USEPA[77] specifically evaluated evidence of causation. The review identified that a causal relationship existed for respiratory effects (for short term exposure with long term exposures also likely to be causal). All other associations related to exposure to nitrogen dioxide (specifically cardiovascular effects, mortality and cancer) were considered to be suggestive
- Whether the reported associations are distinct from, and additional to, those reported and assessed for exposure to particulate matter. Co-exposures to nitrogen dioxide and particulate matter complicates review and assessment of many of the epidemiology studies as both these air pollutants occur together in urban areas. There is sufficient evidence (epidemiological and mechanistic) to suggest that some of the health effect associations identified relate to exposure to nitrogen dioxide after adjustment/correction for co-exposures with particulate matter[78].
- Whether the assessment of potential health effects associated with exposure to different levels of nitrogen dioxide can be undertaken on the basis of existing guidelines, or whether specific risk calculations are required to be undertaken. The current guidelines in Australia for the assessment of nitrogen dioxide in air relate to cumulative (total) exposures, and adopt criteria that are considered to be protective of short and long term exposures. Hence, it is relevant that these guidelines be considered in this assessment.
- In addition, it is noted that in areas of high traffic congestion (as is the case with the project area evaluated in this assessment) background levels of nitrogen dioxide may already be elevated such that use of the existing guideline is limited for the purpose of assessing health impacts from a particular project or activity. For these situations, it is relevant to also evaluate the impact on community health of the change in nitrogen dioxide concentration in the local community using appropriate risk calculations. For the conduct of risk assessments in relation to exposure to nitrogen dioxide, the WHO[79] identified that the strongest evidence of health effects related to respiratory hospitalisations and to a lesser extent mortality (associated with short term exposures) and recommend that these health endpoints should be considered in any core assessment of health impacts associated with exposure.

On the basis of the above, potential health effects associated with exposure to nitrogen dioxide were assessed for this project using both comparison with guidelines (assessing total exposures) and an assessment of incremental impacts on health (associated with changes in air quality from the project).

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[72] NEPC 2010, *Review of the National Environment Protection (Ambient Air Quality) Measure*, Discussion Paper, Air Quality Standards, National Environmental Protection Council.
[73] NEPC 2003, *National Environment Protection (Ambient Air Quality) Measure*, National Environment Protection Council
[74] Golder 2013, Exposure Assessment and Risk Characterisation to Inform Recommendations for Updating Ambient Air Quality Standards for PM2.5, PMN10, O3, NO2, SO2, Golder Associates for National Environment Protection Council Service Corporation.
[75] NEPC 2010, *Review of the National Environment Protection (Ambient Air Quality) Measure*, Discussion Paper, Air Quality Standards, National Environmental Protection Council.
[76] NEPC 2014, *Draft Variation to the National Environment, protection (Ambient Air Quality) Measure*, Impact Statement, National Environment Protection Council.
[77] USEPA 2015, *Integrated Science Assessment for Oxides of Nitrogen–Health Criteria, Second External Review Draft*, National Center for Environmental Assessment-RTP Division, Office of Research and Development, U.S. Environmental Protection Agency.
[78] COMEAP 2015, *Statement on the Evidence for the Effects of Notrogen Dioxide on Health*, Committee on the Medical Effects of Air Pollutants.
[79] WHO 2013b, *Health Effects of Particulate Matter, Policy implications for countries in eastern Europe, Caucasus and central Asia*, WHO Regional Office for Europe.

Assessment of total exposures

Assessment of acute exposures

The NEPC ambient air quality guideline for the assessment of acute (short term) exposures to nitrogen dioxide relates to the maximum predicted total (cumulative) one-hour average concentration in air. The guideline of 246 micrograms per cubic metre (or 120 parts per billion by volume) is based on a LOAEL of 409–613 micrograms per cubic metre derived from statistical reviews of epidemiological data suggesting an increased incidence of lower respiratory tract symptoms in children and aggravation of asthma. An uncertainty factor of two to protect susceptible people (i.e. asthmatic children) was applied to the LOAEL (NEPC 1998). On this basis, the NEPC (and Environment Protection Authority) acute guideline is protective of adverse health effects in all individuals, including sensitive individuals.

Table 10-26 presents a summary of the maximum predicted cumulative one-hour average concentration of nitrogen dioxide the modelled scenarios.

Table 10-26 Review of potential acute health impacts – nitrogen dioxide (NO_2)

Location and scenario	Maximum 1 hour average concentration of NO_2 (µg/m^3)		
	Without the project	With the project	Cumulative
2027			
Maximum	348.5	307.9	
2037			
Maximum	375.1	334.9	321.5
Acute health based guideline	246	246	246

The maximum cumulative concentrations of nitrogen dioxide presented in the above table exceed the acute NEPC guideline of 246 micrograms per cubic metre for all the scenarios, with and without the project. The elevated levels listed above are not considered to be representative of exposure concentrations that would occur within the study area. This is due to the combined effect of the approach adopted for converting NOx to nitrogen dioxide (that overestimates short-term one-hour average concentrations), and the use of a contemporaneous assessment of background and project impacts. The contemporaneous approach assumes that the highest background concentrations may occur during the same hour as the maximum incremental change from the project. This results in a very high estimate of total nitrogen dioxide concentrations that is not likely to ever occur (refer to **Appendix E** (Air quality technical report) for more detailed discussion). As a result, the magnitude of the maximum total concentrations reported for nitrogen dioxide over a one-hour average cannot be used to evaluate the potential for adverse health effects in the community.

As assessment of total concentrations to nitrogen dioxide cannot be used to determine the potential for adverse health impacts in the community, and because there is no clear threshold established for community exposures to nitrogen dioxide, the assessment of incremental exposures is of most relevance.

Assessment of chronic exposures

The NEPC ambient air quality guideline for the assessment of chronic (long term) exposures to nitrogen dioxide relates to the maximum predicted total (cumulative) annual average concentration in air. The guideline of 62 micrograms per cubic metre (or 30 ppbv [parts per billion by volume]) is based on a lowest observed adverse effect level (LOAEL) of the order of 40–80 parts per billion by volume (around 75–150 micrograms per cubic metre) during early and middle childhood years which 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 parts per billion by volume (38–75 micrograms per cubic metre)[80]. On this basis, the NEPC (and OEH) chronic guideline is protective of adverse health effects in all individuals, including sensitive individuals.

Table 10-27 presents a summary of the maximum predicted cumulative annual average concentration of nitrogen dioxide for the modelled scenarios.

Table 10-27 Review of potential chronic health impacts – Nitrogen dioxide (NO_2)

Location and scenario	Maximum annual average concentration of NO_2 (µg/m^3)		
	Without the project	**With the project**	**Cumulative**
2026			
Maximum	42.5	40.7	N/A
2036			
Maximum	44.8	42.7	42.2
Chronic health based guideline	62		

All the concentrations of nitrogen dioxide presented in the above table are below the chronic NEPC guideline of 62 micrograms per cubic metre. In addition, the concentrations of nitrogen dioxide are lower with the project (in both assessment years) and for the cumulative scenario. Hence there are no adverse health effects expected in relation to chronic exposures to nitrogen dioxide in the local area surrounding the project.

Assessment of incremental exposures

The evidence base supports quantification of effects of short term exposure to nitrogen dioxide, using the averaging time as in the relevant studies. The strongest evidence is for respiratory effects, in particular exacerbation of asthma, with some support also for all-cause mortality. These health endpoints have been evaluated in relation to changes in nitrogen dioxide concentrations in air associated with the project within the local community in 2026 and 2036.

The approach adopted for the assessment of incremental exposures is consistent with that adopted for particulates as outlined in **section 5.9.5**. This involves the calculation of a change in individual risk, as well as the change in incidence, or the number of cases, that occur in the community as a result of the project.

Table 10-28 presents a summary of the health endpoints considered in this assessment, the β coefficient relevant to the calculation of a relative risk (refer to Annexure A 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[81] and are considered to be robust.

[80] NEPC 1998, *National Environment Protection (Ambient Air Quality) Measure - Revised Impact Statement*, National Environment Protection Council.

[81] Golder 2013, *Exposure Assessment and Risk Characterisation to Inform Recommendations for Updating Ambient Air Quality Standards for PM2.5, PMN10, O3, NO2, SO2*, Golder Associates for National Environment Protection Council Service Corporation.

Table 10-28 Adopted exposure-responses relationships for assessment of changes in nitrogen dioxide concentrations

Health endpoint	Exposure period	Age group	Adopted β coefficient (also as per cent) for 1 µg/m^3 increase in NO_2	Reference
Mortality, all causes (non-trauma)	Short term	30+	0.00188 (0.19%)	Relationship derived for from modelling undertaken for 5 cities in Australia and 1 day lag
Mortality, respiratory	Short term	All ages*	0.00426 (0.43%)	Relationship derived for from modelling undertaken for 5 cities in Australia and 1 day lag[82]
Asthma emergency department (ED) 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[83] [84]

Note: * Relationships established for all ages, including young children and the elderly

It is noted that while the maximum concentrations of nitrogen dioxide are lower in the local community with the operation of the project, the concentrations at individual receptors vary. While the concentrations at most receptors decrease with the operation of the project, there are some receptors where there is an increase, associated with the redistribution of emissions from vehicles using surface roads.

Table 10-29 presents the change in individual risk associated with changes in nitrogen dioxide at the maximum impacted receptors relevant to the various land use in the community, as well as the community receptors, for the operational years 2026 and 2036, including the cumulative scenario (refer to Annexure A to **Appendix F** (Human health technical report) for methodology for the calculation of individual risks). The assessment assumes an individual is exposed at each maximum impacted location over all hours of the day, regardless of the land use. This has been undertaken to address any future changes in land use that may occur. Risks for all other receptors (including other sensitive receptors) are lower than the maximums presented.

All risks are presented to one significant figure, reflecting the level of uncertainty associated with the calculations presented.

Figure 10-5 presents a summary of the calculated change in individual risk associated with changes in nitrogen dioxide concentrations at each community receptor location evaluated.

Annexure C to **Appendix F** (Human health technical report) presents a discussion on levels of the levels of risk that are considered to be negligible, tolerable/acceptable and unacceptable. A summary of these risk levels is included in **Table 5-16**.

Calculations relevant to the characterisation of risks associated with changes in nitrogen dioxide concentrations in the community are presented in Annexure D of **Appendix F** (Human health technical report). **Table 10-30** presents a summary of the calculated change in incidence of the relevant health effects for the population living in the LGAs within the study area, associated with changes in nitrogen dioxide concentrations for 2026 and 2036. All calculations relevant to the LGAs, including calculation for each individual suburb considered in the LGAs, are presented in Annexure E of **Appendix F** (Human health technical report).

[82] EPHC 2010, *Expansion of the multi-city mortality and morbidity study, Final Report*, Environment Protection and Heritage Council.
[83] Golder 2013, *Exposure Assessment and Risk Characterisation to Inform Recommendations for Updating Ambient Air Quality Standards for PM2.5, PMN10, O3, NO2, SO2*, Golder Associates for National Environment Protection Council Service Corporation.
[84] Jalaludin, B, Khalaj, B, Sheppeard, V & Morgan, G 2008, 'Air pollution and ED visits for asthma in Australian children: a case-crossover analysis', *Int Arch Occup Environ Health*, vol. 81, no. 8, Aug, pp. 967-974.

Table 10-29 Maximum calculated risks associated with short term exposure to changes in nitrogen dioxide concentrations with operation of the project

Scenario and receptor	Maximum change in individual risk from short term exposure to nitrogen dioxide for the following health endpoints		
	Mortality: All causes (ages 30+)	Mortality: Respiratory (all ages)	Asthma ED Admissions (1–14 years)
2026 – with project			
Maximum residential	2×10^{-5}	3×10^{-6}	2×10^{-5}
Maximum workplace	1×10^{-5}	2×10^{-6}	2×10^{-5}
Maximum childcare and schools	7×10^{-6}	1×10^{-6}	1×10^{-5}
Maximum aged care	4×10^{-6}	7×10^{-7}	5×10^{-6}
Maximum hospitals/medical	2×10^{-6}	4×10^{-7}	3×10^{-6}
Maximum open space	4×10^{-6}	7×10^{-7}	5×10^{-6}
Maximum from sensitive receptors	2×10^{-5}	3×10^{-6}	2×10^{-5}
2036 – with project			
Maximum residential	1×10^{-5}	2×10^{-6}	2×10^{-5}
Maximum workplace	1×10^{-5}	2×10^{-6}	2×10^{-5}
Maximum childcare and schools	6×10^{-6}	1×10^{-6}	9×10^{-6}
Maximum aged care	3×10^{-6}	5×10^{-7}	4×10^{-6}
Maximum hospitals/medical	4×10^{-6}	7×10^{-7}	6×10^{-6}
Maximum open space	5×10^{-6}	1×10^{-6}	8×10^{-6}
Maximum from sensitive receptors	1×10^{-5}	2×10^{-6}	2×10^{-5}
2036 – cumulative			
Maximum residential	9×10^{-6}	2×10^{-6}	1×10^{-5}
Maximum workplace	2×10^{-5}	3×10^{-6}	2×10^{-5}
Maximum childcare	7×10^{-6}	1×10^{-6}	1×10^{-5}
Maximum aged care	2×10^{-6}	4×10^{-7}	3×10^{-6}
Maximum hospitals/medical	9×10^{-7}	2×10^{-7}	1×10^{-6}
Maximum open space	6×10^{-6}	1×10^{-6}	9×10^{-6}
Maximum from sensitive receptors	2×10^{-5}	3×10^{-6}	2×10^{-5}
Negligible risks	$<1 \times 10^{-6}$		
Tolerable/acceptable risks	$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$		
Unacceptable risks	$>1 \times 10^{-4}$		

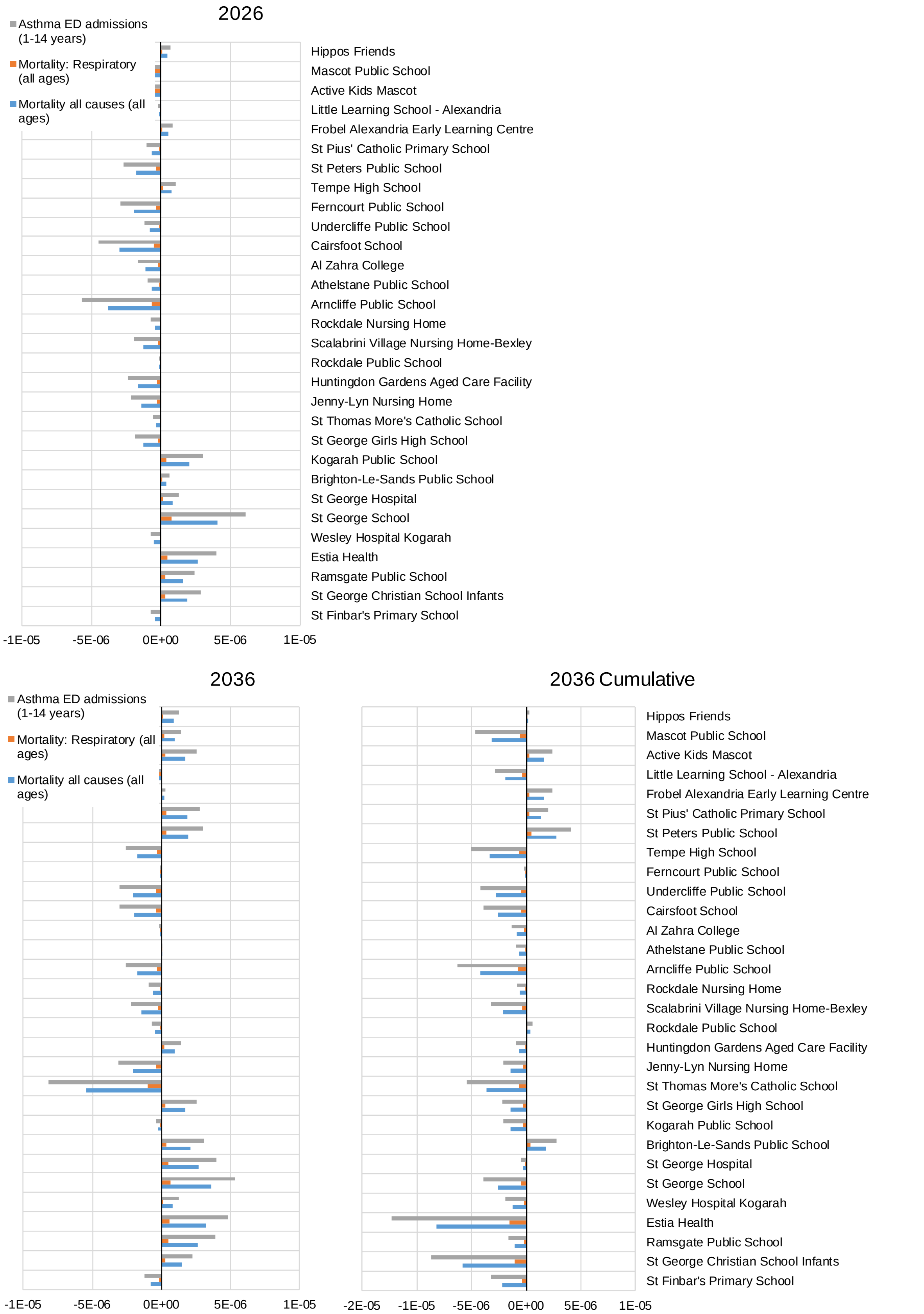

Figure 10-5 Change in calculated risk for key health endpoints associated with changes in nitrogen dioxide concentrations at community receptors (2026 and 2036)

Table 10-30 Calculated changes in incidence of health effects in population associated with changes in NO_2 concentrations

LGA	Change in population incidence number of cases					
	2026			2036		
	Mortality – All Causes	Mortality – Respiratory	Morbidity – Asthma ED Admissions	Mortality – All Causes	Mortality – Respiratory	Morbidity – Asthma ED Admissions
	All ages	All ages	1-14 years	All ages	All ages	1–14 years
With project						
Strathfield - Burwood - Ashfield LGA	-0.00026	-0.000050	-0.000078	-0.00011	-0.000022	-0.000034
Sydney Inner City LGA	-0.000057	-0.000010	-0.0000049	-0.00078	-0.00014	-0.000067
Marrickville - Sydenham - Petersham LGA	-0.00093	-0.00016	-0.00018	-0.0013	-0.00023	-0.00026
Canterbury LGA	-0.0000089	-0.0000016	-0.0000026	-0.00018	-0.000034	-0.000053
Botany LGA	-0.0024	-0.00041	-0.00053	-0.0041	-0.00071	-0.00091
Kogarah - Rockdale LGA	0.0011	0.00018	0.00021	0.00030	0.000051	0.000060
Hurstville LGA	0.000024	0.0000041	0.0000049	0.000031	0.0000053	0.0000063
Total for all LGAs	-0.0026	-0.00045	-0.00058	-0.0062	-0.0011	-0.0013
Cumulative						
Strathfield - Burwood - Ashfield LGA				-0.000061	-0.000012	-0.000018
Sydney Inner City LGA				-0.00063	-0.00011	-0.000054
Marrickville - Sydenham - Petersham LGA				-0.00018	-0.000031	-0.000035
Canterbury LGA				-0.000043	-0.0000080	-0.000013
Botany LGA				-0.0033	-0.00057	-0.00073
Kogarah - Rockdale LGA				-0.0056	-0.00094	-0.0011
Hurstville LGA				-0.0000052	-0.00000088	-0.0000011
Total for all LGAs				-0.0098	-0.0017	-0.0020

Negative value indicates that there is a decrease in incidence associated with the project

Assessment of particulate matter

Particulate matter is a widespread air pollutant with a mixture of physical and chemical characteristics that vary by location (and source). Unlike many other pollutants, particulate matter includes a broad class of diverse materials and substances, with varying morphological, chemical, physical and thermodynamic properties, with sizes that vary from less than 0.005 micrometres (or microns) to greater than 100 microns. Particles can be derived from natural sources such as crustal dust (soil), 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).

The health effects of particulate matter is provided in **Appendix F** (Human health technical report).

Review of the calculated changes in risk indicates the following in relation to impacts associated with the expected operation of the project in 2026 and 2036, including the cumulative scenario:

- A number of the calculated individual risks as shown in **Figure 10-5** for the community receptors are negative, meaning that the operation of the project would result in lower levels of risk, when compared with the situation where the project is not operating
- The maximum risks calculated for exposures in residential areas are less than $1x10^{-4}$ and considered to be tolerable/acceptable
- The maximum risks calculated for exposures in commercial/industrial areas are less than $1x10^{-4}$ and considered to be tolerable/acceptable
- All maximum risks calculated for continuous exposures in childcare centres, schools, aged care homes and open space areas are below $1x10^{-4}$ and considered to be tolerable/ acceptable
- In relation to impacts on the health of the population in the local community, the calculated change in incidence of the health indicators evaluated shows that the increased incidence of the evaluated health effects occurring in the population in the study area ranges from 0.001 to 0.11 cases per year, which would not be measurable and is considered to be negligible.

Review of the calculated impacts in terms of the change in incidence of the relevant health effects for $PM_{2.5}$ in the community, indicates the following:

- The total change in the number of cases relevant to the health effects evaluated, for both 2026 and 2036 is negative, meaning a decrease in incidence as a result of the project. The number of cases however is very small, less than one for all health effects considered. As a result, these changes would not be measurable within the community
- Most individual LGAs show a total decrease in health incidence. There are two LGAs (Kogarah - Rockdale and Hurstville) where there is an increase. These increases and decreases are also very small, less than one for all health effects considered. As a result, these changes would not be measurable in the community
- The incidence calculations presented in **Table 10-30** are the totals for each LGA. Within these LGAs are a number of smaller suburbs. The calculated change in incidence relevant to each of these suburbs has also been evaluated, as presented in Annexure G of **Appendix F** (Human health technical report). Review of the incidence calculated for the individual suburbs indicates that these predominantly relate to small decreases in health incidence with some suburbs showing an increase. The largest increase in health incidence for any individual suburb is less than 0.1 cases. Hence there are no individual suburbs within the LGAs where there is a change incidence that is of significance or would be measurable.

Elevated receptors

Appendix E (Air quality technical report) has conducted a screening assessment of potential issues related to exposures that may occur at elevated receptors, close to ventilation outlets, to identify areas that may need to have more detailed analysis and where future development controls may be required for high-rise buildings. This has been undertaken on the basis of evaluating predicted concentrations of $PM_{2.5}$ at 10 metres, 20 metres and 30 metres above the ground level, representative of potential exposures that may occur in multi-storey buildings. The assessment undertaken has evaluated impacts at 10 metres, 20 metres and 30 metres across the whole study area, regardless of whether a multi-storey building is present or not. 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, 20 metres and 30 metres height has focused on the cumulative scenario in the year 2036 where impacts from the F6 Extension, Western Harbour Tunnel and Warringah Freeway Upgrade, Beaches Link and Gore Hill Connection, Sydney Gateway and WestConnex projects are included. The maximum change in $PM_{2.5}$ relevant to this scenario has been evaluated. As the approach adopted in **Appendix E** (Air quality technical report) is a screening level assessment no other pollutants have been evaluated.

Table 10-31 presents the calculated risks associated with the maximum predicted change (based on unconstrained and worst case traffic conditions) in $PM_{2.5}$ concentrations at a height of 10 metres, 20 metres and 30 metres above ground level throughout the study area. It should be noted that it was not necessarily the case that there are existing buildings at these heights at the RWR receptor locations, however this analysis has been included to evaluate potential future development.

Table 10-31 Calculated individual risk associated with changes in $PM_{2.5}$ concentrations – cumulative scenario in 2036 for elevated receptors

Health endpoint	Maximum calculated		
	10 m height	**20 m height**	**30 m height**
Annual average concentration			
$PM_{2.5}$ ($\mu g/m^3$)	1.4	0.23	0.30
Primary health indicators: $PM_{2.5}$			
Mortality all causes (long term effects, ages 30+)	8×10^{-5}	1×10^{-5}	2×10^{-5}
Cardiovascular hospitalisations (short term effects, ages 65+)	1×10^{-4}	2×10^{-5}	2×10^{-5}
Respiratory hospitalisations (short term effects, ages 65+)	2×10^{-5}	4×10^{-6}	5×10^{-6}
Secondary health indicators: $PM_{2.5}$			
Mortality all causes (short term effects, all ages)	6×10^{-6}	1×10^{-6}	1×10^{-6}
Mortality, cardiopulmonary (long term effects, ages 30+)	7×10^{-5}	1×10^{-5}	2×10^{-5}
Mortality, cardiovascular (short term effects, all ages)	2×10^{-6}	3×10^{-7}	4×10^{-7}
Mortality, respiratory (short term effects, all ages)	1×10^{-6}	2×10^{-7}	2×10^{-7}
Asthma emergency department hospitalisations (1–14 years)	3×10^{-5}	4×10^{-6}	5×10^{-6}
Negligible risks	$<1 \times 10^{-6}$		
Tolerable/acceptable risks	$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$		
Unacceptable risks	$>1 \times 10^{-4}$		

The calculations presented in **Table 10-31** indicate the following:

- The maximum change in PM2.5 decreases by around 5 fold with increasing height from 10 to 30 metres.
- All calculated risks at elevated receptors, at 10 metres, 20 metres and 30 metres height are considered to be in the range of tolerable/acceptable risk.

Assessment of regulatory worst-case scenario

Table 10-32 presents the calculated change in individual risk associated with residential exposure to worst-case emissions of $PM_{2.5}$. The table includes the assumptions adopted for the assessment.

Table 10-32 Maximum calculated risks associated with short-term residential exposure changes in $PM_{2.5}$ concentrations: regulatory worst case 2036 cumulative scenario

Scenario	Maximum change in individual risk for the following short term health endpoints					
	Cardiovascular hospitalisations (65 years+)	Respiratory hospitalisations (65 years +)	Mortality all causes (all ages)	Mortality cardiovascular (all ages)	Mortality respiratory (all ages)	Asthma ED admissions (1–14 years)
The project						
Maximum annual risk – expected operations	3×10^{-5}	6×10^{-6}	1×10^{-6}	5×10^{-7}	3×10^{-7}	7×10^{-6}
Increase in risk for 1 day of worst-case emissions (24 hours which is highly conservative)	4×10^{-7}	8×10^{-8}	2×10^{-8}	7×10^{-9}	5×10^{-9}	9×10^{-8}
Increase in risk assuming worst-case event occurs 1 day each week (52 days per year)*	2×10^{-5}	4×10^{-6}	1×10^{-6}	3×10^{-7}	2×10^{-7}	5×10^{-6}
Maximum annual risk – expected conditions plus worst-case event**	5×10^{-5}	1×10^{-5}	2×10^{-6}	8×10^{-7}	5×10^{-7}	1×10^{-5}
Negligible risks	$< 1 \times 10^{-6}$					
Tolerable/acceptable risks	$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$					
Unacceptable risks	$> 1 \times 10^{-4}$					

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

** Assumes the maximum annual average impact and maximum short-term change occur that the same location (receptor) 1 day per week

Review of the maximum calculated changes in risk associated with short-term changes in $PM_{2.5}$ (**Table 10-32**) 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 receptor location every time), the maximum individual risk increases
- The total maximum individual risk increases to but does not exceed 1×10^{-4} and hence there are no unacceptable risks identified in the community surrounding the project
- The calculated maximum individual risks are in the range 1×10^{-6} to 1×10^{-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.

Sensitivity analysis

A sensitivity analysis was undertaken to determine the impact from emissions where the emission limit for the ventilation outlets were reached for at least 1 hour every day. **Figure 10-6** shows the different contributions to $PM_{2.5}$ concentrations for the expected traffic conditions (for background plus traffic), the sensitivity test (1 hour per day $PM_{2.5}$ concentrations reach the emission limit) and regulatory worse case (24 hours per day of $PM_{2.5}$ concentrations reaching the emission limit) for the 2036 do something cumulative scenario. This figure essentially shows that all assumptions for ventilation outlets result in relatively small contributions compared with the total.

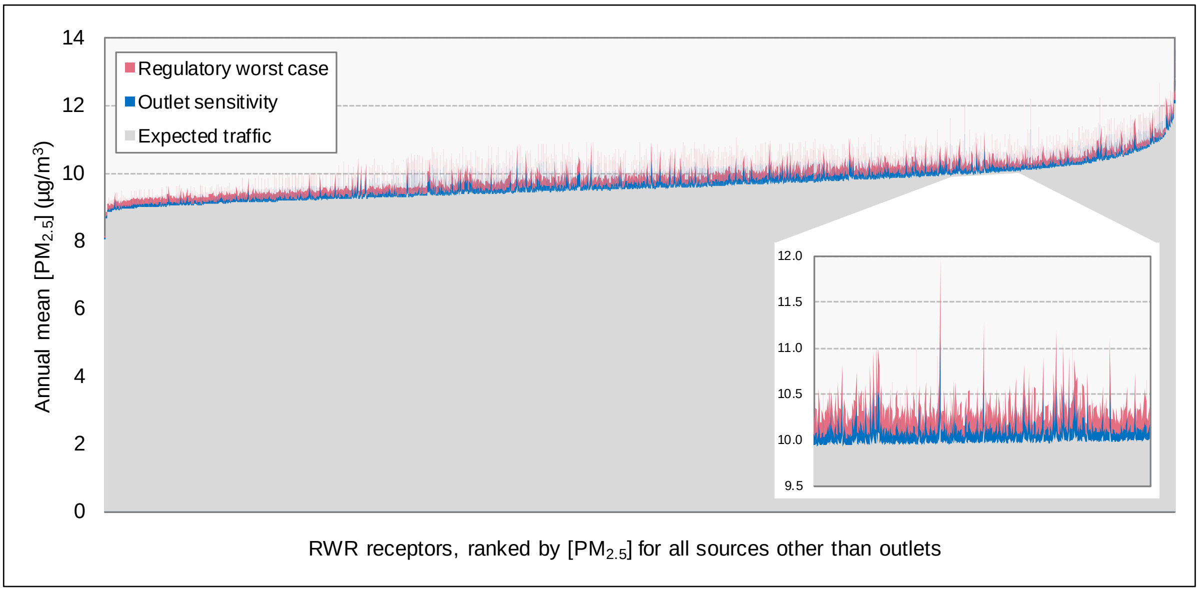

Figure 10-6 Results of sensitivity tests for ventilation outlets – total annual mean PM2.5 concentration at RWR receptors (2036-DSC scenario)

In relation to potential impacts on health, risk calculations have been undertaken for the change in $PM_{2.5}$ (for the primary health endpoints) and NO_2. These risk calculations have been undertaken for the 2036 cumulative scenario, consistent with the scenario evaluated in **Appendix E** (Air quality technical report).

Table 10-33 presents the maximum calculated risk, from all receptors, associated with the change in $PM_{2.5}$ and NO_2, for the expected traffic conditions and the sensitivity test.

Table 10-33 Calculated individual risk associated with maximum changes in $PM_{2.5}$ and NO_2 concentrations: sensitivity test – 2036 cumulative scenario

Health endpoint	Maximum calculated	
	Expected traffic	Sensitivity test
Primary health indicators: $PM_{2.5}$		
Mortality all causes (long term effects, ages 30+)	2×10^{-5}	6×10^{-5}
Cardiovascular hospitalisations (short term effects, ages 65+)	3×10^{-5}	7×10^{-5}
Respiratory hospitalisations (short term effects, ages 65+)	6×10^{-6}	2×10^{-5}
Health indicators: NO_2		
Mortality all causes (short term effects, all ages)	1×10^{-5}	2×10^{-5}
Mortality, respiratory (short term effects, all ages)	3×10^{-6}	4×10^{-6}
Asthma emergency department hospitalisations (1–14 years)	2×10^{-5}	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	$>1 \times 10^{-4}$	

Review of the maximum calculated changes in risk associated with changes in $PM_{2.5}$ and NO_2 concentrations relevant to the sensitivity test scenario evaluated indicates the following:

- For NO_2, the sensitivity test shows a very small increase in the maximum calculated risks. The calculated risks however remain low and are considered tolerable/acceptable.
- For $PM_{2.5}$, the sensitivity test shows a small increase in the maximum calculated risks. The calculated risks however remain low and are considered tolerable/acceptable.

On the basis of the above, emissions from the ventilation outlets, where the sensitivity test scenario is considered, has the potential result in a small increase in NO_2 and $PM_{2.5}$ risks, however the maximum individual risks associated with $PM_{2.5}$ and NO_2 are considered to be tolerable/acceptable.

Odour impacts

The changes in the levels of three odorous pollutants as a result of the project, and the corresponding odour assessment criteria from the Approved Methods for the Modelling and Assessment of Air Pollutants in NSW[85] are presented in **Chapter 9** (Air quality). It was concluded that that maximum 1-hour concentration of each pollutant was an order of magnitude below the corresponding odour assessment criterion in the Approved Methods.

10.4.3 Noise and vibration impacts on community health

The worst case assessment predicts that noise criteria will be exceeded at a number of properties adjacent to the project without mitigation measures, with 107 properties considered appropriate for mitigation measures due to operational noise. These properties are listed in **Appendix G** (Noise and vibration technical report) and shown in **Figure 10-7**. The worst-case levels estimated are sufficiently high for some receptors that health impacts are likely to occur. The main health effects in relation to road traffic noise are annoyance, sleep disturbance, cardiovascular disease, stroke and memory/concentration (cognitive) effects. In addition, impacts on the use and enjoyment of outdoor areas due to increased road noise may result in increased levels of stress at individual properties.

The criteria for consideration of noise mitigation from operational noise was either if the noise criteria was exceeded by 2.0 dB(A) or if the cumulative noise exceeded the noise criteria by 5 dB(A) and the receptor is impacted by the project.

The use of at or near source noise treatments would be preferred for the 107 receptors considered appropriate for mitigation measures during operation. Receptors identified as requiring at-property construction or operational noise mitigation will be identified and offered treatment prior to commencement of construction works that affects them. In-property treatments are not preferred as they have the potential to result in the loss or reduced use of outdoor areas for receptors, which has been shown to reduce wellbeing and increase levels of stress.

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

[85] NSW EPA (2016). Approved Methods for the Modelling and Assessment of Air Pollutants in NSW. NSW Environment Protection Authority, Sydney. http://www.epa.nsw.gov.au/resources/epa/approved-methods-for-modelling-and-assessment-of-air-pollutants-in-NSW-160666.pdf

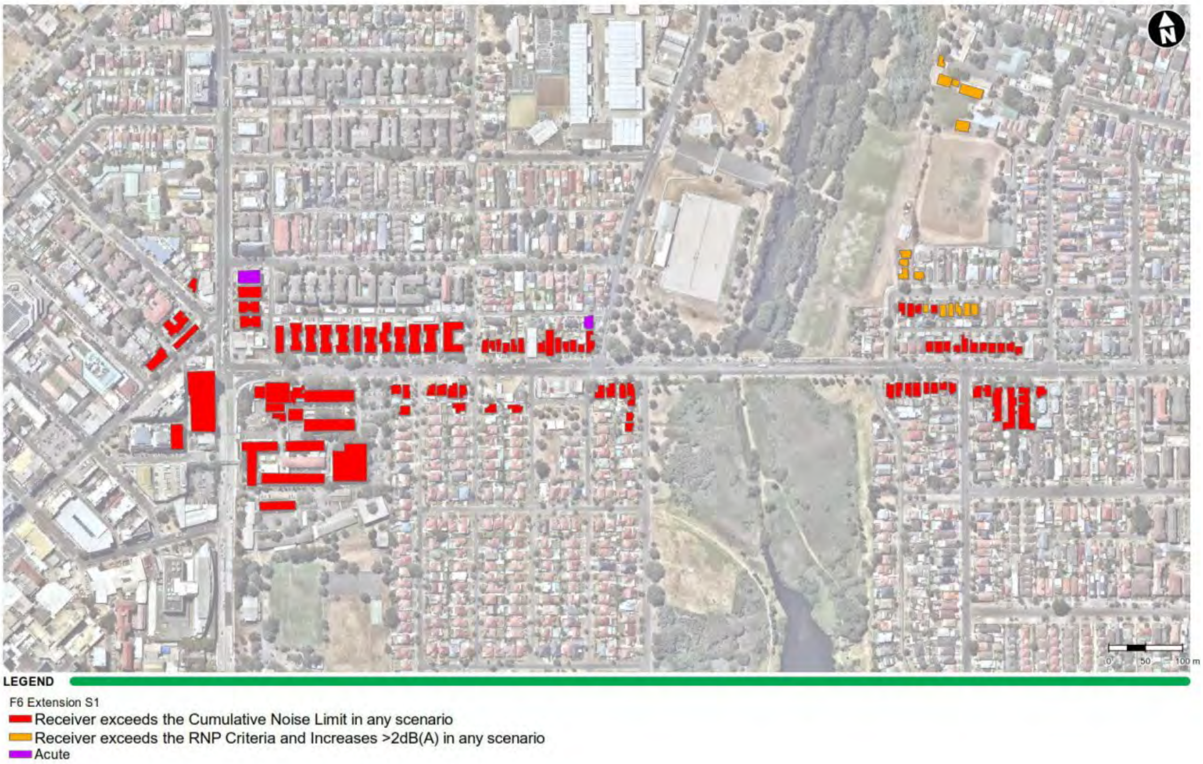

Figure 10-7 Receptors eligible for the consideration of noise mitigation

10.4.4 Dangerous goods and substances

Storage and handling

Dangerous goods and hazardous substances stored, used and transported for the project during operation would be limited and may include coagulants, polymers, acid and bases. Additional small quantities of other hazardous materials may occasionally be required on site to support maintenance activities.

The regulations and safe practices described for the construction phase of the project would also apply to the operational stage (refer to **section 10.3.3**).

Transport

Dangerous goods and hazardous substances are not allowed to be transported within prohibited areas, in accordance with Road Rules 2014 – Regulation 300-2: NSW rule: carriage of dangerous goods in prohibited areas (Regulation 300-2). Prohibited areas are listed under Regulation 300-2 and include Sydney's major tunnels.

The project tunnels would be listed as a prohibited area under Regulation 300-2 prior to the commencement of the operation of the project. Signage would be provided near tunnel entry portals advising of applicable restrictions to ensure compliance with Regulation 300-2.

10.4.5 Public safety risks to the community

A range of potential hazards have been identified that have the potential to affect public safety during the operation of the project, principally in relation to traffic accidents. These are outlined in the following sections.

On the basis of the discussion below there are no issues related to operation of the project that have the potential to result in significant safety risks to the community.

Storage, handling and transport of dangerous goods

All materials will be stored and transported in accordance with the relevant legislation and codes (refer to **section 10.4.4**. Risks to public safety are therefore considered to be low.

Traffic incidents in the tunnels

Any road project carries an inherent risk of vehicle collision associated with its operation. The potential for incidents and crashes to occur is a function of:

- The design of the project
- The type and volumes of traffic using the project
- Driving conditions, including light conditions
- Human factors, including compliance with road rules, attention to driving conditions, driver behaviour and fatigue
- Vehicle failure and breakdown.

The project has been designed to provide for efficient, free-flowing traffic in the tunnels with physical capacity to accommodate predicted traffic volumes. The design has incorporated all feasible and reasonable design measures in relation to geometry, pavement, breakdown bays, lighting and signage. The design is consistent with current Australian Standards, road design guidelines and industry best practice, inherently minimising the likelihood of incidents and crashes.

Tunnel features designed to minimise the disruption caused by incidents and crashes include:

- Height detection system prior to the tunnel entry portals
- Tunnel barrier gates to prevent access in the event of tunnel closure
- Closed-circuit television (CCTV) throughout the tunnel and approaches
- Adjustable speed signs
- Appropriately spaced breakdown bays and emergency telephones.

The project has also been designed to meet appropriate fire and life safety requirements in the event of an incident or accident in the tunnel, as described in **Chapter 6** (Project description). Consultation has been undertaken and would be ongoing with Fire and Rescue NSW and other emergency services to ensure the fire and life safety requirements are achieved.

Each project tunnel would be one-directional, reducing the risk of crashes through head-on collisions and simplifying smoke management and egress requirements. The transport of dangerous goods and hazardous substances would be prohibited through the mainline tunnels and entry and exit ramps, reducing the risk of very large fires or the release of toxic materials in the tunnel.

Other fire and life safety aspects that would be incorporated into the project include:

- Public address systems to manage evacuation processes
- Multiple pedestrian cross-passages between the mainline tunnels and longitudinal egress passages along the entry and exit ramps, to allow pedestrians to exit the tunnel and ramps in the event of a major incident (refer to **Chapter 6** (Project description)). Cross-passages would cater for egress for people with disabilities; therefore, stairs or ramps with steep grades would be limited, or alternative safe holding zones would be provided where necessary
- Automatic fire and smoke detection within the tunnels
- Longitudinal ventilation to 'push' smoke in the direction of traffic flow away from the fire source towards a ventilation facility or tunnel portal
- A water deluge system that would be activated manually or automatically at the fire source
- Structures, linings and services that would be fire hardened to protect them from fire damage before the activation of the deluge system, or if the deluge system fails.

The likelihood of a fire during operation of the project cannot be entirely removed. Uncontrollable human factors inherently lead to a residual risk of incidents and crashes, although the likelihood of such events would be low.

In the event of an incident, approaching traffic would be prevented from entering the mainline tunnels. Vehicle occupants at the location of the fire and upstream of the fire source would be instructed to stop their vehicles, and exit in the opposite direction through the section of carriageway that would be protected by the smoke management system, or through an exit door to a cross-passage leading to the other ('non-incident') mainline tunnel.

Occupants downstream of the fire source would be encouraged to continue driving out of the tunnel. If this is not possible and they are forced to evacuate on foot, egress would be provided via an exit door to a cross-passage leading to the non-incident mainline tunnel. Emergency services would be able to reach the fire source via the non-incident tunnel (by vehicle or foot), or from the upstream direction in the affected tunnel (by foot).

Traffic incidents on surface roads

Traffic incidents on surface roads (including cyclist and pedestrian safety) are considered to pose a moderate risk to public safety, however the design of the project has been developed to inherently minimise the likelihood of incidents and crashes. Surface roads and infrastructure have been designed to provide an efficient and safe road network.

The project will involve a reduction in traffic on some roads. A detailed discussion of the impact of the project on traffic volumes is provided in **Chapter 8** (Traffic and transport).

The traffic reductions would result in the following traffic related benefits:

- Improved traffic flow and intersection performance
- Reduced crash rates
- Improved road safety for pedestrians, cyclists and motorists
- Improved travel times for bus services and motorists.

These traffic-related benefits are expected to result in an improved road safety environment. Section 8.2.5 of **Appendix D** (Traffic and transport technical report) provides further detail about the forecast changes in crash frequency and cost on road sections in the President Avenue intersection and surrounds. Impacts and improvements to air quality and noise are discussed in **Chapter 9** (Air quality), and **Chapter 11** (Noise and vibration).

Pedestrian safety during operation would improve with the provision of the shared cycle and pedestrian pathways. A safe connection over President Avenue would be provided by the shared cycle and pedestrian bridge.

Contamination

The potential for contamination risks to the community during operation is primarily related to contaminated tunnel groundwater ingress, and spills and leaks of dangerous goods or hazardous substances. An assessment of contamination risk within the study area is provided in **Appendix J** (Contamination technical report). Areas within the vicinity of the project that may contain contaminated soil and/or groundwater due to past or present land use practices have been investigated.

During operation, tunnel drainage infrastructure will be designed to accommodate a combination of water ingress events including groundwater ingress, stormwater ingress at portals, tunnel wash-down water, fire suppressant deluge or fire main rupture and spillage of flammable and other hazardous materials.

Groundwater along the tunnel alignment may be impacted by contamination. If contaminated groundwater occurs, it would enter the tunnels and would be treated at the Arncliffe Motorway Operations Complex (MOC1) to meet the appropriate discharge criteria (refer to **Chapter 18** (Surface water and flooding)) prior to discharge to the Cooks River.

Any contaminant spill of oils, lubricants, hydraulic fluids and chemicals from vehicle or plant or a vehicle crash within the project footprint has the potential to pollute downstream waterways, if conveyed to waterways via the stormwater network. The severity of the potential impact depends on the magnitude and/or location of the spill in relation to sensitive receptors, emergency response procedures and/or management controls implemented on site, and the nature of the receiving environment.

For the project, there would be spill containment facilities at the following locations:

- President Avenue water quality basin
- Mainline tunnel sump
- Ancillary facilities site at West Botany Street
- Water treatment plant site at Arncliffe

The proposed spill containment facilities would be designed to manage the potential risks to an acceptable level. Impacts to Scarborough Ponds and Cooks River are therefore likely to be minimal. Impacts and management measures for contaminated runoff and spills are discussed further in **Chapter 16** (Soils and contamination).

Electric and magnetic fields

The Draft Radiation Standard – Exposure Limits for Magnetic Fields[86] is based on a large body of scientific research since 1989. It proposes a series of exposure standards to replace the Interim Guidelines on Limits of Exposure to 50/60 Hz Electric and Magnetic Fields[87].

Although the Draft Radiation Standard has never been finalised and published, the exposure limits presented are typically applied when considering electric and magnetic fields from new development. The project would include the provision of three aboveground substations, one located at Arncliffe Motorway Operations Complex, and two located at Rockdale Motorway Operations Complex. As identified in **Chapter 14** (Property and land use), the project would also require the provision of new high voltage (132kV) utility infrastructure and the relocation, treatment and/or protection of existing high voltage utility infrastructure, within the vicinity of the project.

The detailed design of project substations and high voltage utility infrastructure would ensure that the exposure limits for the general public in the Draft Radiation Standard – Exposure Limits for Magnetic Fields[88] would not be exceeded at the boundary of the substation sites or for high voltage utility infrastructure. Electric and magnetic fields are therefore not expected to pose a significant risk to public safety.

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[86] Australian Radiation Protection and Nuclear Safety Agency (2006) Draft Radiation Standard – Exposure Limits for Magnetic Fields

[87] National Health and Medical Research Council (1989) Interim Guidelines on Limits of Exposure to 50/60 Hz Electric and Magnetic Fields

[88] Australian Radiation Protection and Nuclear Safety Agency December (2006) Draft Radiation Standard – Exposure Limits for Magnetic Fields

Bushfire risks

The project is in a highly urbanised area that is not in or near a bushfire prone area. Operational infrastructure is largely invulnerable to bushfires as it is not combustible (road surface materials, retaining walls, road barriers) and a significant proportion of the infrastructure is in tunnels. Indirect bushfire risks to the project, including risks related to damage to communications networks or power supply are discussed in **Chapter 25** (Climate change risk and adaption).

Aviation risks

The operational design of the project has considered airspace protection and associated risks and hazards. As discussed in **Chapter 2** (Assessment process) and **section 10.3.4**, under the Airports Act, a ‘controlled activity’ in relation to a prescribed airspace must not be carried out or caused to be carried out, without the approval of the Secretary of DIRDC or otherwise exempt under the Airspace Regulations.

Australia’s Civil Aviation Safety Authority (CASA) has determined that exhaust plumes with vertical velocities exceeding 4.3 metres per second may cause damage to aircraft airframes, or upset an aircraft flying at low levels. Light aircraft, including helicopters, are more likely to be affected by a plume than heavier aircraft cruising at the same altitude.

The exhaust plumes from the ventilation facilities have the potential to penetrate either or both the OLS or PANS-OPS levels. The project has been designed to satisfy requirements set by the DIRDC in relation to erected structures (such as ventilation outlets), equipment manoeuvring and lighting. To determine whether plume rise resulting from the operation of these ventilation facilities would be a controlled activity as defined in section 183 of the Airports Act, a plume rise assessment would be carried out in accordance with the CASA *Advisory Circular Plume Rise Assessments AC 139-5(1) November 2012* prior to the approval and operation of the project.

Aviation hazard lighting may be required on ventilation outlets at Arncliffe and Rockdale. Surface road lighting would include an ‘aeroscreen’ type lens to minimise upward light spill. Aviation hazard lighting and surface road lighting would be in accordance with the requirements of CASA and Sydney Airport.

Subsidence risks

Surface settlement due to drawdown of groundwater is expected to be negligible along the tunnel alignment other than at the palaeochannels in the vicinity of Spring Street, Bay Street and President Avenue. Preliminary estimates of the ground settlements at these locations are provided in **Chapter 17** (Groundwater and geology). As with construction, settlement monitoring would be undertaken during operation at buildings and infrastructure where exceedances of the settlement criteria are predicted. Settlement monitoring may include the installation of settlement markers or inclinometers. In the event that settlement criteria are exceeded for property and infrastructure during operation, measures would be taken to ‘make good’ the impact. These measures would be included as part of the OEMP. Any stress or anxiety experienced by property owners would be expected to be temporary.

10.4.6 Social impacts on community health

Changes in the urban environment associated with the project have the potential to result in a range of impacts on health and wellbeing of the community. **Chapter 15** (Social and economic) of the environmental impact statement provides details of the social impacts associated with the project. Aspects that are specifically relevant to potential impacts on the health and wellbeing of the community, either positive or negative, have been highlighted for the human health assessment.

Traffic and transport

Once the project is complete, it is expected to result in reductions in vehicle delays in a number of areas. There are some areas, however, where traffic volumes would increase, mainly around the President Ave corridor.

Traffic congestion and long commuting times can contribute to increased levels of stress and fatigue, more aggressive behaviour and increased traffic and accident risks on residential and local roads as drivers try to avoid congested areas[89]. Increased travel times reduce the available time to spend on heathy behaviours such as exercise, or engage in social interactions with family and friends. Long commute times are also associated with sleep disturbance, low self-rated health and absence from work[90]. Reducing travel times and road congestion has the potential to reduce these health impacts.

Public transport

From a public transport network perspective, the project, once complete, is expected to slightly increase bus travel times in 2026 AM peak periods around President Ave intersection, with minimal time changes over other periods. Minimal changes in bus travel times are predicted around the St. Peters interchange.

Shared cycle and pedestrian pathways

Once completed, the project would deliver new pedestrian and cyclist infrastructure project in the form of shared cycle and pedestrian pathways. The shared cycle and pedestrian pathways would be developed from Bestic Street, Brighton-le-Sands south to Civic Avenue, Kogarah through the reinstated Rockdale Bicentennial Park. A dedicated shared bridge would be built over President Avenue as part of the shared cycle and pedestrian pathways.

Improvements in the active transport network, including improvements in transport connections, will have a positive benefit on community health. Where active transport opportunities are improved and offer safe alternatives to driving and public transport, they can encourage more active recreation and commuting activities.

Access and connectivity

Community severance effects often occur during both construction and operation of major transportation projects due to detours in the local road network, changes to active and public transport routes, and connector roads receiving an increase or decrease in traffic movements. Changes to the road networks may contribute to feelings of community severance and disconnection. The project is not introducing new major surface roadways that would change existing conditions in relation to severance.

Green space

An urban design strategy has been developed for the reinstatement of Rockdale Bicentennial Park (refer to **Appendix C** (Place making and urban design)) in accordance with the urban design objectives and principles for the project.

Upon project completion, the sporting facilities would be reinstated to maintain the same number of fields and level of amenity. Detailed plans for Rockdale Bicentennial Park would be developed in consultation with Bayside Council and Sydney Water.

During operation, the majority of Rockdale Bicentennial Park would be reinstated, including landscaping and reinstated facilities works. A concept design for urban design and landscaping works at Bicentennial Park has been prepared (refer to **Appendix C** (Place making and urban design)). The landscape plan for Rockdale Bicentennial Park would be further developed during detailed design, in consultation with Bayside Council.

Visual impacts

The operation of the project would include changes to local visual amenity due to the presence of new and amended infrastructure (including ventilation facilities, water treatment plants, substations, bridges and drainage channels), landscaping and urban design features. These impacts have the potential to increase stress and anxiety for some community members. However in order to mitigate such potential impacts, residual land would be subject to the Urban Design and Landscaping Plan (UDLP) for the project. The plan will detail built and landscape features to be implemented prior to operation of the project.

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[89] Hansson, E, Mattisson, K, Björk, J, Östergren, P-O & Jakobsson, K 2011, *'Relationship between commuting and health outcomes in a cross-sectional population survey in southern Sweden'*, BMC Public Health, vol. 11, no. 1, p. 834.
[90] Hansson, E, Mattisson, K, Björk, J, Östergren, P-O & Jakobsson, K 2011, *'Relationship between commuting and health outcomes in a cross-sectional population survey in southern Sweden'*, BMC Public Health, vol. 11, no. 1, p. 834.

Social equity

The health effects associated with impacts related to transport projects are not equally distributed across the community.

To further evaluate potential equity issues associated with the project, the location of impacts identified in relation to air quality, noise and traffic were reviewed individually and in combination, in conjunction with available information on the location of sensitive community groups.

It is noted that in many urban areas housing prices are lower along main roadways. The median house prices in the 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. However, there is an alignment of noise and air impacts along President Avenue and Princes Highway that coincide with increased traffic volumes.

Canterbury Bankstown is the only local government area in the study area identified as disadvantaged, based on the 2016 Census Data - Socio-Economic Index for Australia (SEIFA). However, it is noted that the major air and noise impacts are not located in this local government area. Therefore, the major impacts from the project are not impacting a low socioeconomic local government area.

In relation to broader equity aspects the project, along with approved WestConnex projects (M4-M5 Link, M4 East and New M5), is aimed at improving access to the area from outer lying areas in the south and west. The SEIFA for populations in the outer south and west are lower, indicating they are more disadvantaged, than populations in the study area. Improving access and travel times for these more disadvantaged populations provides the potential for health benefits such as those that are derived from reduced levels of stress and anxiety.

Economic impacts

It is noted that some local businesses would be adversely impacted by both construction and operational activities, along with other businesses marked for acquisition. This can cause stress for the impacted individuals and lead to health impacts if not appropriately managed. To minimise these impacts the project will include development of a Business Management Plan. This plan will include ways to minimise stress to impacted individuals.

Road tolling

The implementation of road tolls can have direct impacts on the management of congestion, which has an impact on economic productivity, and social elements such as stress, time with family and friends, cost and environmental amenity such as reduced traffic emissions.

One impact is the potential to increase congestion volumes on surrounding roads as a result of toll avoidance. The use of a toll road can also increase the cost of living and can exacerbate social inequality. Specifically, the impact of roads tolls on households can be assessed as a function of household income, urban spatial structure, and available mobility choices. Depending on the travel routes of individuals, and the individual economic situation, there may be a proportion of the population that avoid the use of tollways due to affordability.

An evaluation of road tolling undertaken in **Chapter 15** (Social and economic) found an overall positive impact from the toll road. However, this is undertaken on a regional scale and individual benefits would vary. Road tolling may increase the cost of living for individuals, and lower income households may travel long distances to avoid road tolls. These impacts have the potential to result in increased stress and anxiety for these households.

10.5 Management of impacts

The implementation of environmental management measures for the project would avoid, to the greatest extent possible, risk to public safety and achieve the desired performance outcomes in relation to the hazards identified in **Table 10-1**. Environmental management measures relating to hazards and risk are outlined in **Table 10-34**. Additional management measures relevant to human health are provided in the following chapters:

- Air quality management measures, including the management of air quality and odour during construction and operation – **Chapter 9** (Air quality)
- Noise and vibration management measures – **Chapter 11** (Noise and vibration)
- Social and economic management measures, including the management of construction fatigue – **Chapter 15** (Social and economic)
- Surface water and flooding management measures, including the management of contaminated material and migration off-site – **Chapter 16** (Surface water and flooding)
- Groundwater and geology management measures, including the management of groundwater quality and contamination during construction and operation – **Chapter 17** (Geology and groundwater)

In addition to these measures, a CEMP would be developed for the project and would be supplemented by site and activity specific Safe Work Method Statements.

Table 10-34 Environmental management measures

Impact	Reference	Environmental management measure	Timing
Construction			
Hazardous substances and dangerous goods spill	HS1	A Pollution Incident Response Management Plan (PIRMP) will be prepared for the project. The PIRMP will be prepared in accordance with legislative requirements and include measures to manage hazardous substances and dangerous goods including storage, handling and spill response.	Construction
Improper handling and transport of hazardous substances and dangerous goods	HS2	A Work Health and Safety Plan will be implemented during construction of the project, supplemented by site and activity specific Safe Work Method Statements.	Construction
	HS3	Transport of dangerous goods and hazardous substances will be conducted in accordance with relevant legislation and codes.	Construction Operation
	HS4	An Incident Response Protocol will be developed as part of the Emergency Response Plan for the project and implemented in the event of an accident or incident. The protocol is to detail operational management measures associated with the storage, handling and transport of hazardous substances and dangerous goods, including spill response.	Prior to operation
	HS5	The transport of dangerous goods and hazardous substances will be prohibited through the mainline tunnels and entry and exit ramps during operation.	Operation
Impact of lighting on airport operations	HS6	The project will be constructed and operated in accordance with the design requirements of CASA and the Sydney Airport Master Plan 2033, with respect to lighting.	Construction
	HS7	Should the exhaust plumes or structures at any of the F6 Extension Stage 1 ventilation outlets be assessed as a 'controlled activity' under the Airports Act and the Airspace Regulations, then the project will be operated in accordance with conditions of approval from the Secretary of DIRDC.	Operation
Impact of electric and magnetic fields	HS8	The project substations will be designed to ensure that the exposure limits for the general public detailed in by the Draft Radiation Standard (Australian Radiation Protection and Nuclear Safety Agency 2006) will not be exceeded at the boundary of the substation sites.	Detailed design

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10.6 Environmental risk analysis

An environmental risk analysis was undertaken for health safety and hazards and is provided in **Table 10-35** below.

A level of assessment was undertaken commensurate with the potential degree of impact the project may have on that issue. This included an assessment of whether the identified impacts could be avoided or minimised (for example, through design amendments). Where impacts could not be avoided, environmental management measures have been recommended to manage impacts to acceptable levels.

The residual risk is the risk of the environmental impact after the proposed mitigation measures have been implemented. The methodology used for the environmental risk analysis is outlined in **Appendix O** (Methodologies).

Table 10-35 Environmental risk analysis – Health safety and hazards

Impact	Construction/ operation	Management and mitigation reference	Likelihood	Consequence	Residual risk
Spills and leaks from the storage and transport of dangerous goods and hazardous substances	Construction and operation	HR1, HR2, HR3, HR4, HR5, HR6 OpHR6, OpHR7, OpHR8, OpHR9	Unlikely	Moderate	Low
Potential impacts from fire and safety incidents	Operation	OpHR1, OpHR2, OpHR3, OpHR4, OpHR5	Unlikely	Major	Medium
Exposure to electric and magnetic fields	Operation	OpHR10	Unlikely	Minor	Low
Impacts on aviation safety	Operation	OpHR11, OpHR12	Unlikely	Moderate	Low