Chapter 13

Human health

January 2020

13 Human health

This chapter outlines the potential human health impacts associated with the project. A human health impact assessment has been carried out for the project and is included in Appendix I (Technical working paper: Health impact assessment).

The Secretary's environmental assessment requirements as they relate to human health impacts, and where in the environmental impact statement these have been addressed, are detailed in Table 13-1.

The proposed environmental management measures relevant to human health impacts are discussed in Section 13.6.

Table 13-1 Secretary's environmental assessment requirements checklist – Health

Secretary's requirement	Where addressed in EIS
Health and Safety	
1. The Proponent must assess the potential health risks from the construction and operation of the project.	**Section 13.4** and **Section 13.5** describe the potential human health risks from the construction and operation of the project.
2. The assessment must: a. describe the current known health status of the potentially affected population;	**Section 13.3** describes the potentially affected community and their current health status.
b. describe how the design of the proposal minimises adverse health impacts and maximises health benefits;	Section 2.3 of **Appendix I** (Technical working paper: Health impact assessment) outlines how health issues have been considered in project design.
c. assess human health risks from the operation and use of the tunnel under a range of conditions, including worst case operating conditions and the potential length of motorway tunnels in Sydney;	**Section 13.5** assesses the human health risks associated with the operation and use of the project.
d. human health risks and costs associated with the construction and operation of the proposal, including those associated with air 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 13.4** and **Section 13.5** outline the construction and operational impacts including those related to air quality, noise and vibration, construction fatigue, social impacts and cumulative impacts associated with the project. **Appendix I** (Technical working paper: Health impact assessment) includes consideration of opportunity costs for particulates, noting there are no methods to quantify health costs other than particulates.

Secretary's requirement	Where addressed in EIS
e. include both incremental changes in exposure from existing background pollutant levels and the cumulative impacts of project specific and existing pollutant levels at the location of the most exposed receivers and other sensitive receptors (including public open space areas child care centres, schools, hospitals and aged care facilities);	Health related air quality impacts during operation, including cumulative impacts, are discussed in **Section 13.5**.
f. assess the likely risks of the project to public safety, paying particular attention to pedestrian safety, subsidence risks, bushfire risks and the handling and use of dangerous goods;	**Section 13.4** and **Section 13.5** considers pedestrian/public safety during construction and operation. Subsidence is considered in **Chapter 16.4.2** (Geology, soils and groundwater). **Chapter 23** (Hazards and risks) includes an assessment of bushfire risks and the handling and use of dangerous goods.
g. assess the opportunities for health improvement;	Beneficial impacts associated with the project are discussed in **Section 13.4** and **Section 13.5**.
h. assess the distribution of the health risks and benefits; and	The distribution of the health related risks and benefits are presented in **Section 13.4** and **Section 13.5**. Consideration of the distribution of noise and air quality impacts are presented in **Chapter 10** (Construction noise and vibration), **Chapter 11** (Operational noise and vibration) and **Chapter 12** (Air Quality).
i. include a cumulative human health risk assessment inclusive of in-tunnel, local and regional impacts due to the operation of and potential continuous travel through motorway tunnels and surface roads.	Health related air quality impacts are discussed in **Section 13.5.1** and **Section 13.5.2**.
Water – Quality	
1. The Proponent must: h. demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented;	Practical management measures to be adopted for the project are provided in **Chapter 17** (Hydrodynamics and water quality). Health related risks are considered in **Section 13.4**. Management measures to ensure the protection of human health are outlined in **Section 13.6**.

Secretary's requirement	Where addressed in EIS
Soils	
3. The Proponent must assess whether the land and harbour sediment is likely to be contaminated and identify if remediation is required, having regard to the ecological and human health risks posed by the contamination in the context of past, existing and future land uses. Where assessment and/or remediation is required, the Proponent must document how the assessment and/or remediation would be undertaken in accordance with current guidelines.	**Section 13.4** discusses human health risks and impacts due to potential contaminated soil/groundwater exposure. Further details are presented in **Appendix I** (Technical working paper: Health impact assessment). **Chapter 16.4** (Geology, soils and groundwater) considers areas of potential and known land and harbour sediment contamination, having regard to risks to human and environmental receivers. Further details are presented in **Appendix M** (Technical working paper: Contamination).

13.1 Legislative and policy framework

The human health impact assessment was carried out in accordance with national and international guidance that is endorsed or accepted by Australian health and environmental authorities.

13.1.1 Principal guidance

Principle guidance used for the assessment of human health impacts include the following:

- *Health Impact Assessment: A Practical Guide*, Harris et al., 2007
- *Health Impact Assessment Guidelines*, Environmental Health Committee, enHealth, 2001
- *Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards: 2012*, enHealth, 2012
- *Schedule B8 Guideline on Community Engagement and Risk Communication, National Environment Protection (Assessment of Site Contamination Contamination) Measure*, National Environment Protection Council (NEPC), 2013.

13.1.2 Supporting guidance

Supporting guidance for the health implications of air quality impacts has included the following:

- *National Environmental Protection (Air Toxics) Measure, Impact Statement for the National Environment Protection (Air Toxics) Measure*, National Environment Protection Council (NEPC), 2003a
- *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), 2009
- *Building Better Health, Health considerations for urban development and renewal in the Sydney Local Health District*, NSW Health 2016
- *Healthy Urban Development Checklist, A guide for health services when commenting on development policies, plans and proposals*, NSW Health, 2009

- *Methodology for Valuing the Health Impacts of Changes in Particle Emissions*, NSW Environment Protection Authority (EPA) 2013
- *Air Quality in and Around Traffic Tunnels*, National Health and Medical Research Council (NHMRC) 2008
- State Environmental Planning Policy No. 33 – Hazardous and Offensive Development
- *Assessing the environmental burden of disease at national and local levels*, Ostro, 2004.

13.2 Assessment methodology

The methodology for the human health impact assessment is aimed at assessing impacts and risks to human health from the construction and operation of the project. The human health assessment has focused on health-related impacts associated with key air quality, noise and vibration and social aspects.

13.2.1 Air quality

The assessment methodology for health impacts related to air quality involved:

- Review of Appendix F (Technical working paper: Traffic and transport) and Appendix H (Technical working paper: Air quality (including the in-tunnel ventilation report))
- Identification of sensitive receivers within potentially impacted communities surrounding the project, and assessment of the current health metrics for those communities
- Assessment of potential human health impacts from key pollutants during construction and operation of the project.

When evaluating human health risks with respect to air quality, the quantification of risk involves the calculation of an increased probability of some adverse health effect, disease or mortality occurring, over and above the baseline incidence of that health effect, disease or mortality in the community. A one in a million chance of developing a certain health effect due to exposure to a substance is considered negligible. The risk scale used for the assessment of incremental air quality exposure is as follows:

- Negligible health related risks – less than one chance in a million ($<1 \times 10^{-6}$)
- Tolerable or acceptable health related risks – between 1×10^{-6} and one chance in ten thousand (1×10^{-4})
- Unacceptable health related risks – more than 1×10^{-4}.

Further details of the assessment guidelines adopted is provided in the relevant sections below.

13.2.2 Noise and vibration

The assessment methodology for health impacts related to noise and vibration involved:

- Review of technical assessments including Appendix F (Technical working paper: Traffic and transport) and Appendix G (Technical working paper: Noise and vibration)
- Identification of sensitive receivers within potentially impacted communities surrounding the project, and assessment of the current health metrics for those communities
- Assessment of potential human health impacts associated with the generation of noise during construction and operation of the project.

For a number of the noise guidelines, the criteria has been established on the basis of noise annoyance, which is considered to be the more sensitive impact and an impact that precedes the physiological impacts. As a result, these guidelines are designed to be protective of all adverse health impacts. Other guidelines are based on specific sensitive health impacts such as sleep disturbance for the assessment of night-time noise.

13.2.3 Social

The assessment methodology for health impacts related to social aspects involved:

- Review of all available information relevant to the assessment including:
  - Appendix U (Technical working paper: Socio-economic assessment)
  - Data from the Australian Bureau of Statistics
  - Information relevant to local government areas and health districts (in particular Sydney Local Health District and Northern Sydney Local Health District)
- Identification of sensitive receivers within potentially impacted communities surrounding the project, and assessment of the current health metrics for those communities
- Assessment of potential human health impacts associated with public safety; traffic changes; property acquisitions; impacts on green space; changes in community access and connectivity; visual amenity; construction fatigue; economic access; and stress and anxiety issues during construction and operation of the project, including short-term and long-term impacts.

13.3 Existing environment

This section outlines the existing environment as it relates to human health including:

- Potentially impacted receivers within the communities surrounding the project
- The current health status of these communities.

The existing environment for air quality, noise and vibration and social aspects are detailed in the following chapters:

- Chapter 12 (Air quality)
- Chapter 10 (Construction noise and vibration)
- Chapter 11 (Operational noise and vibration)
- Chapter 21 (Socio-economics).

13.3.1 Health status of the community

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.

Information in relation to health-related behaviours (that are linked to poorer health status and chronic disease including cardiovascular and respiratory diseases, cancer, and other conditions that account for much of the burden of morbidity and mortality in later life) is available for the larger populations within the local area health services in Sydney and NSW. This includes excessive alcohol consumption, smoking, inadequate consumption of fruit and vegetables, being overweight or obese, and inadequate physical activity.

The study population is largely located within the Northern Sydney, Sydney and South Eastern Sydney Area Health Services. Review of this data generally indicates that, when compared to

NSW as a whole, the population in the Northern, Sydney and South Eastern Sydney Area Health Service areas (that include the study area) have:

- Lower rates of physical inactivity and of being overweight and obese
- Lower rates of smoking (Northern Sydney Local Health District)
- Lower rates of mortality, except for lung cancer, which was lower in the Sydney Health District only
- Lower rate of hospitalisations, with the exception of cardiovascular disease hospitalisations in the South Eastern Sydney District, which is similar to the rate for NSW.
- High or very high rates of psychological distress reported in 2015 in the Sydney Local Health District (13.9 per cent) is a little higher than the state average, and in Northern Sydney (10 per cent) and South Eastern Sydney local health districts (9.3 per cent) is a little lower than the state average (11.8 per cent), however none were substantially different
- High or very high rates of psychological distress in Northern Sydney Local Health District has varied between eight and 15 per cent, while in the Sydney Local Health District it has varied between 10 and 15 per cent between 2003 and 2015. In the South Eastern Sydney Local Health District, the rate has declined from around 14 per cent in 2003 to less than 10 per cent in 2015.

Section 3.5 of Appendix I (Technical working paper: Health impact assessment) provides further detail on health-related behaviours and health indicators for the study area.

13.3.2 Potentially impacted communities

The potentially impacted communities considered in the assessment include those who live or work within the vicinity of the construction support sites, surface connections (ie where the tunnel interfaces with the surface road network), motorway facilities, ventilation facilities and the road network associated with the combined Western Harbour Tunnel and Beaches Link program of works as well as the adjoining M4-M5 Link. The human health impact assessment study area is an amalgamation of the air quality, noise and vibration, and social and economic study areas.

The human health impact assessment considers community receivers identified in the suburbs close to the project. Community receivers 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 comprise hospitals, child care facilities, schools and aged care homes/facilities. Details of the sensitive or community receivers included in the assessment are provided in Chapter 12 (Air quality) and Appendix H (Technical working paper: Air quality).

13.4 Assessment of potential construction impacts

Impacts on human health during construction have been assessed below in relation to:

- Air quality
- Noise and vibration
- Social impacts.

The following sections provide a high-level overview of the key considerations in these areas, with further detail provided in referenced environmental impact assessment chapters and appendices.

13.4.1 Health related air quality impacts during construction

Air quality impacts and details of the distribution of impacts in the construction period are presented in Chapter 12 (Air Quality).

The assessment of construction air quality was carried out using a qualitative assessment approach for dust, emissions and odour impacts.

The construction air quality assessment found that for almost all construction activities, substantial impacts on receivers would be avoided through project design and the implementation of effective, industry standard mitigation and management measures. However, dust management measures may not be fully effective all of the time. In situations where the construction air quality management measures are not fully effective, impacts on the community would generally be temporary and short-term and are not considered to be significant.

Measures to manage dust impacts include site management, preparing and maintaining construction support sites and disturbance areas, use of water carts, maintenance and controls on vehicles and machinery, and waste management. The effectiveness of dust control measures would be monitored and adjusted as required to ensure impacts on the health of the community are minimised.

Air quality impacts during construction also include exhaust emissions from the use of plant and equipment. These impacts would be minor and would be unlikely to have a noticeable impact on the surrounding environment and would be managed through standard management measures.

As part of the marine construction activities for the project, a large amount of material would be dredged from the harbour bed bringing potentially odorous material to the surface, which has the potential to generate odour once exposed to air.

Dredged material on barges would be covered with water which would reduce any odour emissions. Any odour impacts from the dredged material would be low, given it would remain wet and located at some distance from any sensitive receivers during dredging, transportation and treatment. At the White Bay construction support site (WHT3), odour from dredged material would be undetectable for all sensitive receivers near the site.

Overall, air quality impacts during construction are unlikely to result in any health-related impacts.

13.4.2 Health related noise and vibration impacts during construction

Potential noise and vibration impacts in the construction period are presented in Chapter 10 (Construction noise and vibration). Noise impacts in relation to human health have been considered in relation to sleep disturbance; annoyance; hearing impairment; interference with speech and other daily activities; children's cognitive function; and cardiovascular health.

Noise that may be generated during construction has been modelled based on the type of equipment to be used, the proximity of community receivers, the hours of work, the duration of the activities carried out and the local terrain.

This assessment has considered ground-borne noise from tunnelling and rock-hammering, construction vibration generated from tunnelling, surface works, piling and heavy equipment, and underwater noise impacts associated with the construction of the immersed tube tunnel.

This modelling has identified areas where, if unmitigated, potential noise levels may exceed:

- Day, Evening or Night noise management levels
- Sleep disturbance criteria, including the criteria for awakening.

Results from this modelling, and associated assessments including distribution of potential impacts, are provided in Appendix G (Technical working paper: Noise and vibration) and discussed

in Chapter 10 (Construction noise and vibration). The following sections describe potential impacts related to noise and vibration criteria and possible human health impacts.

Construction noise impacts from the movement of construction vehicles

Potential increases in noise for sensitive receptors due to construction traffic has been assessed separately from the assessment of noise from other construction activities. Construction support sites have been configured such that heavy vehicles involved in construction are expected to travel via existing major roadways with minimal use of local roads. Potential exceedances in noise criteria have been identified at Berrys Bay and Cammeray Golf Course.

Ground-borne construction noise

Ground-borne noise occurs when works are being carried out underground or in a way that results in the vibrations from noise moving through the ground rather than the air. The project involves tunnelling, so many of the more significant noise activities would take place at depth (with a large proportion of the mainline tunnels at depths of 10 metres to greater than 50 metres). Ground-borne noise would consist of roadheader and rock hammer tunnelling. Modelling carried out contemplated the worst-case scenario when the tunnelling is occurring immediately beneath a sensitive receiver. The roadheader excavation would typically progress at around 20 to 30 metres per week subject to local geology and confirmation of the tunnel excavation methods. Roadheader advance rates would reduce to two to five metres a day around the tunnel portals, which may slightly increase the duration of exposure for receivers in these areas.

The excavation by the roadheaders may be noticeable in some areas during the evening and during the night for up to about three weeks at each affected receiver as the roadheader passes below them. Ground-borne noise from roadheader activity is expected to exceed the night time noise criteria at about 23 residential properties.

For rock hammering in tunnels, a large number of residential receiver buildings have been identified as exceeding the night time noise management level or evening noise management level (1507 receiver buildings and 731 receiver buildings respectively). Two hundred and seventy one residential receiver buildings have been identified as exceeding the day time noise criteria. Thirty five non-residential receiver buildings may also be affected by ground-borne noise.

Mitigation and management measures include the validation of predicted impacts from the noise and vibration modelling (which is based on a conservative worst-case assessment) and notifying the community of noise impacts anticipated at specific times.

Use of rock hammers during out of hours construction periods would be considered only if verification monitoring during construction determines ground-borne construction noise levels comply with noise management levels.

Airborne construction noise

Chapter 10 (Construction noise and vibration) identifies residential receiver buildings that are predicted to experience noise levels above the noise management levels, in the absence of additional mitigation measures. In some instances, maximum noise levels are also predicted to exceed the sleep disturbance screening level and awakening reaction levels at a number of receivers.

Where criteria cannot be met, then there is the potential for adverse health effects to occur for the receivers in the vicinity of construction sites, such as sleep disturbance and annoyance, or where noise increases of greater than 5dB(A) occur in the long-term (over a year or more).

Exceedances of the noise management level and the number of impacted residential receiver buildings would vary over the duration of construction. For example, the predicted air-borne noise levels are only likely to occur when works are at the closest point to each receiver building. However, for many work areas, construction activities are mobile and so construction noise impacts may be lower than predicted. Further mitigation and management measures as identified

in Chapter 10 (Construction noise and vibration) would be implemented to minimise potential health-related impacts on the surrounding community. This includes noise management approaches for works that would occur outside of standard construction hours.

Following the implementation of all reasonable and feasible mitigation measures, additional measures would be implemented to manage residual noise impacts and to minimise potential health impacts where the recommended noise management levels cannot be achieved. Monitoring would also be carried out periodically throughout all stages of construction to ensure that noise and vibration impacts are being appropriately managed, and the effectiveness of implemented mitigation and management measures.

Construction vibration

Some items of equipment to be used during construction have the potential to cause unacceptable levels of vibration. Managing the potential for such vibration to cause discomfort or structural damage at sensitive receiver locations is based on selecting site-specific suitable plant and methods as well as providing suitable separation distances between the equipment and receiver locations.

The proposed management of vibration impacts involves monitoring of the predicted impacts, advising the community of impacts and offering respite periods to affected residents where human comfort levels are to be exceeded for an extended period of time during any one day.

Underwater noise impacts

Piling in Sydney Harbour would be carried out for the construction of cofferdams at Sydney Harbour south (WHT5) and Sydney Harbour north (WHT6). Piling would predominately consist of vibratory piling (in harbour sediments) and impact piling (through rock). Impact piling would generate higher potential impact compared to vibratory piling.

Sound pressure levels during the installation of piles and dredging would exceed the precautionary guideline of 145 dB re 1µPa (Jasco, 2019). The various headlands and islands that are located near the construction noise source, such as Birchgrove, Ballast Point, Balls Head, Blues Point and Goat Island, are expected to reduce or block acoustic energy that would otherwise propagate through Sydney Harbour (Jasco, 2019). The exceedance of the precautionary guideline would depend on the proximity to construction activities, lessening as distance from construction activities increases. The distances of this exceedance would be better understood in the initial phases of works through monitoring. The piling program would then be refined with the consideration of reasonable and feasible program alternatives and appropriate environmental management measures to minimise underwater noise impacts.

Piling would occur during standard construction hours with respite periods required for impact piling (Appendix G (Technical working paper: Noise and Vibration)). A marine exclusion area would also be provided in the immediate vicinity of construction activities to manage navigation conflicts.

For divers, a sudden increase in sound pressure levels could potentially startle, or cause discomfort, dizziness and vertigo. Some startled divers subjected to excessive sound pressure level can potentially place themselves in a life-threatening situation.

A hierarchy of risk management measures would be implemented for divers and recreational swimmers within the area where exceedances of the precautionary guideline of 145 dB re 1µPa are predicted to potentially occur. This would be supported by a proactive communication strategy. Management measures would be informed by the final construction methodologies and mitigation measures, and an initial trial of piling to validate thresholds and management areas.

Management measures for underwater noise impacts would be implemented according to the type of works occurring and the extent to which exceedances of the precautionary guideline are predicted (the management zone). Management measures would be reviewed and, if required, amended over the piling program to reflect monitoring outcomes.

13.4.3 Health related social impacts during construction

Social impacts in the construction period are presented in Chapter 21 (Socio-economics).

Health related social impacts are discussed below in terms of:

- Changes in traffic, public transport, access and connectivity
- Public safety and contamination
- Property acquisition
- Green space
- Visual amenity
- Construction fatigue
- Economic aspects.

Changes in traffic, public transport, access and connectivity

Changes in traffic, access and connectivity during construction are presented in Chapter 8 (Construction traffic and transport). During construction, potential short-term impacts may include:

- Temporary changes to road conditions, which could include partial and full road closures, diversions and access changes, shared user path closures, removal of on-street parking and reductions in speed limits, changes to property accesses
- Increased construction traffic on roads leading to longer travel times and potentially impacting on community perceptions of safety for motorists, cyclists and pedestrians if not appropriately managed
- Potential disruptions to public transport services including from the temporary closure of Birchgrove Wharf, and changes to road conditions and the temporary relocation of some bus stops near to construction works for safety, resulting in possible delays and disruptions for bus users and changes in bus access for some people
- Changes to pedestrian and cycle access near to construction works, resulting in possible disruptions which may result in delays and disruptions to commuters
- Temporary changes to property access near construction works, with suitable access arrangements to be implemented
- Relocation of swing moorings in the vicinity of Berrys Bay construction support site (WHT7), with relocated moorings to be placed as close as possible to the original location during construction and restored where possible to the original position on completion of construction.

Changes to traffic, access and connectivity during construction have the potential to result in short-term increased levels of stress and anxiety in the local community. Traffic impacts will be managed through standard communication and traffic control management measures, which would limit delays and disruptions to road users as well as ensuring the safety of motorists, cyclists and pedestrians.

Public safety and contamination

A range of potential hazards were considered that have the potential to affect public safety during construction of the project. There would be no issues related to construction that have the potential to result in significant safety risks to the community.

Known and potentially contaminated sites and potential contamination impacts are discussed in Chapter 16 (Geology, soils and groundwater). Contamination risk issues to the community would

be associated with the construction phase of the project, when exposure to contaminated soil, sediment or groundwater would most likely occur during the excavation and construction works. If contamination is identified in construction, measures including the development of appropriate Remediation Action Plans would be put in place so that the health of the local community is not impacted.

Sediment sampling was carried out within the Sydney Harbour crossing and at construction support sites at White Bay and Berrys Bay (Douglas Partners and Golder Associates, 2017; Appendix M (Technical working Paper: Contamination)). Where sediments require excavation and removal to facilitate construction, the use of silt curtains and a backhoe dredge with a closed bucket attachment would minimise the risk of sediment, and contaminants within the sediments, being mobilised into the water during dredging. This control in conjunction with the behaviour of sediment bound contaminants means it is unlikely that water quality would be significantly impacted by contaminants mobilised from dredging and marine construction activities (Appendix Q (Technical working paper: Marine water quality)).

Provided the proposed management measures are adopted, it is expected that there would be negligible impacts to human health in the event that recreational exposures occur in areas surrounding the proposed works.

Property acquisitions

Property acquisition impacts are presented in Chapter 20 (Land use and property).

The project has been designed and developed to minimise the need for property acquisition. Wherever possible, construction support sites have been located to minimise the overall property acquisition requirements, as well as impacts on heritage items and ecologically sensitive areas.

The acquisition and relocation of households and businesses due to property acquisition could disrupt social networks and affect health and wellbeing due to raised levels of stress and anxiety. Both a house and a workplace are central to daily routines and the location of these premises influences 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 and in accordance with the *Land Acquisition (Just Terms Compensation) Act 1991* (NSW) and the land acquisition reforms announced by the NSW Government in 2016.

Loss of 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's play areas. Epidemiological studies have been carried out that show a positive relationship between green space and health and wellbeing (de Vries et al. 2003; Health Scotland 2008; Kendal et al. 2016; Maas et al. 2006; Mitchell & Popham 2007). The health benefits of green space in urban areas include the following:

- Protection of people from environmental exposures associated with air pollution, noise and extreme temperature (by regulating microclimates and reducing the urban heat island effect)
- Reduced morbidity
- Improved opportunities for physical activity and exercise
- Improved mental health and feelings of wellbeing, particularly lower stress levels
- Improved opportunities for social interactions.

There are a number of existing sporting/recreational facilities and parks in the project area, that include sporting fields, parks and reserves and playgrounds. Impacts on these green spaces include:

- Temporary and permanent loss of a portion of land, including recreation land at Cammeray Golf Course – noting that Western Harbour Tunnel and Beaches Link program of works has been designed to enable Cammeray Golf Course to remain operational during construction and operation
- Temporary use of public open space areas for construction sites (for example, Yurulbin Park and St Leonards Park), resulting in the temporary loss of access to and use of land within the construction footprint
- Reduced amenity due to construction activities and construction support sites and changes in noise, dust and visual environment, detracting from the use and enjoyment for users of social infrastructure near the project.

The reduced amenity may affect the desirability of active recreational use of some areas. Alternate green spaces are available in the project area and are accessible by the community, and so the potential effects on community health associated from the temporary use of parks and open space areas during construction is considered to be minimal.

Visual amenity

Landscape and visual impacts are presented in Chapter 22 (Urban design and visual amenity).

Visual amenity can be described as the pleasantness of the view or outlook of an identified receiver or a group of receivers (eg residences, recreational users). 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.

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

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.

Construction fatigue

Construction fatigue relates to receivers 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 relates to 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.

The assessment of construction fatigue includes the following projects that may overlap with the construction phase of the project:

- M4-M5 Link
- White Bay and Glebe Island projects

- Sydney Metro City & Southwest (Chatswood to Sydenham), including the White Bay truck marshalling yard
- The New Sydney Fish Markets
- Sydney Metro West
- Projects within North Sydney (eg commercial developments)
- Beaches Link and Gore Hill Freeway Connection.

As outlined in Chapter 27 (Cumulative impacts), the areas of greatest potential for cumulative impacts are in Rozelle and White Bay in the south, and in North Sydney and Cammeray in the north. These impacts are most likely to be generated by interactions between the project, the M4-M5 Link, projects in White Bay and Glebe Island, Beaches Link and Gore Hill Freeway Connection, Sydney Metro City & Southwest (Chatswood to Sydenham) and Sydney Metro West.

Based on the environmental impact assessment for the project and for the projects listed above, potential impacts considered most likely to result in construction fatigue include construction traffic and parking, construction noise and vibration, visual and amenity impacts, and impacts to community perceptions of public health and safety.

The project design and construction methodology has been developed with consideration of these impacts, and attempts to mitigate many of these impacts where possible. The community consultation framework presented in Chapter 7 (Stakeholder and community engagement) and Appendix E (Community consultation framework) has also been developed with consideration of complaint fatigue and includes procedures to proactively manage this issue where possible. Potential cumulative construction impacts would be managed in accordance with the measures outlined in Chapter 27 (Cumulative impacts).

Economic aspects

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 is of significant health benefit to the community. Employment opportunities would grow in the construction period through the potential increase in business customers and through the increase in demand for construction workers.

It is noted that both positive and negative temporary effects may occur for some businesses during construction activities. While construction activities may bring greater demand from construction workers, lack of access to businesses through reduced parking and physical barriers could impact on local economies. Specific consultation would be carried out with businesses potentially impacted during construction. Consultation would aim to identify specific potential construction impacts for individual businesses. Based on consultation with businesses that are potentially impacted, feasible and reasonable measures would be identified and implemented to minimise business impacts.

13.5 Assessment of potential operational impacts

Impacts on human health during operation have been assessed below in relation to:

- Air quality impacts outside the tunnels
- Air quality impacts inside the tunnels
- Noise and vibration impacts
- Social impacts.

13.5.1 Health related ambient air quality impacts during operation

Air quality impacts and details of the distribution of impacts outside of the tunnel during operation are presented in Chapter 12 (Air Quality).

The assessment of impacts on air quality associated with the operation of the project considered a range of scenarios that includes the operation of the project in 2027 and 2037 ('Do something'); both with and without the project and including other projects ('Do something cumulative'). For further details of the scenarios considered, refer to Chapter 12 (Air quality).

The assessment included a calculation of the emissions from vehicles using the tunnel under expected traffic conditions (ie operating normally with traffic volumes fluctuating over the day to reflect peak and out of peak periods).

In addition, a regulatory worst-case scenario has been evaluated. The regulatory worst case assumes that the tunnel is full of vehicles, such that the emissions from the ventilation outlets are at the maximum level, at all hours of the day. This is not a realistic scenario however it is used to demonstrate compliance with regulatory assessment requirements. Further detail is available in Section 5.10 of Appendix I (Technical working paper: Health impact assessment).

Health-related air quality impacts outside of the tunnel have been assessed for nitrogen dioxide, particulate matter, carbon monoxide and air toxics. Health-related air quality impacts associated with particulate matter on elevated receivers have also been assessed.

The tunnel ventilation system and tunnel operational parameters for the project have been designed so that the in-tunnel air quality concentration limits are not exceeded, and to control the concentration of pollutants discharged to the external environment. The predicted ambient air quality for the expected traffic scenarios are presented, by pollutant, in Chapter 12 (Air quality).

Nitrogen dioxide

Motor vehicles, along with industrial, commercial and residential (for example gas heating or cooking) combustion sources, are primary producers of nitrogen oxides, including NO_2. In Sydney, it was estimated that on-road vehicles account for about 62 per cent of emissions of nitrogen oxides, industrial facilities account for 12 per cent, other mobile sources account for about 22 per cent with the remainder from domestic/commercial sources (NSW EPA, 2012a).

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

Guidelines are available from the NSW EPA and NEPC (NEPC, 2003b) which indicate acceptable concentrations of NO_2. The assessment of acute exposures relates to the maximum predicted total one-hour average concentration in air and considers the 'Do minimum', 'Do something' and 'Do something cumulative' scenarios. An acute exposure guideline of 246 micrograms per cubic metre of NO_2 in air over a one-hour average period has been adopted for the project. The assessment of chronic exposures relates to the maximum predicted annual average concentration in air, and considers the 'Do minimum', 'Do something' and 'Do something cumulative' scenarios. A chronic exposure guideline of 62 micrograms per cubic metre of nitrogen dioxide in air over a one-hour average period has been adopted for the project. An uncertainty factor of two was applied to both the acute and chronic exposure guidelines to account for susceptible people (ie asthmatic children). On this basis, the acute and chronic exposure guidelines are protective of adverse health effects in all individuals, including sensitive individuals like asthmatics, children and the elderly.

Potential health effects associated with NO_2 consider both comparison with guidelines for cumulative exposure (acute and chronic) and an assessment of incremental impacts on health (associated with changes in air quality from the project).

Assessment of acute exposures

As there is no clear threshold established for community exposures to NO_2, the assessment of incremental exposures is of most relevance to potential human health impacts and is discussed further below.

Assessment of chronic exposures

The NEPC ambient air quality guideline for the assessment of chronic (long-term) exposures to NO_2 relates to the maximum predicted total (cumulative) annual average concentration in air (NEPC, 2003b).

The assessment completed for the project indicates that all concentrations of NO_2 would be below the chronic guideline by more than 15 µg/m^3 for all scenarios. Therefore, no adverse health impacts would be expected as a result of chronic exposures to NO_2 from the project.

The operation of the project would provide some human health benefit by lowering the concentrations of NO_2 in the local community because of the removal of traffic demand from some surface roads.

Assessment of incremental exposures

The assessment indicates that the individual risks (ie of mortality (respiratory and all causes) and asthma admissions) calculated for changes in NO_2 levels associated with the project would be less than $1x10^{-4}$ (1 in 10,000) for residential areas, commercial/industrial areas, childcare centres, schools, aged care homes and open space areas and all community receivers and would therefore be considered tolerable and acceptable.

Review of the calculated impacts in terms of the change in incidence of the relevant health impacts associated with exposure to nitrogen dioxide in the whole community associated with the 'Do something' and 'Do something cumulative' scenarios, indicates the following:

- The total change in the number of cases relevant to the health impacts evaluated, for both 2027 and 2037 ('Do something' and 'Do something cumulative') is negative, meaning a decrease in incidence as a result of the project (due to the redistribution of traffic on surface roads). The change however is small, with a decrease of around one case
- 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 one case/person.

Overall, there would be no significant changes in the incidence of the relevant health impacts associated with exposure to NO_2 in the community as a result of the project.

Particulate matter

Particulate matter is a widespread air pollutant with a mixture of physical and chemical characteristics that vary by location, source and substance. Particulates can be derived from natural sources such as soil dust, pollen and moulds, and other sources that include combustion and industrial processes.

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

The particle sizes addressed in the human health risk assessment relate to the particulates most commonly measured in the urban air environment studies, including:

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

The current NEPC and NSW Environment Protection Authority (EPA) air quality goals and guidelines/standards for particulate matter are presented in Chapter 12 (Air quality).

The assessment of potential health impacts associated with particulate matter generated by vehicles using the tunnels considered both total exposure impacts and incremental exposure impacts associated with changes in $PM_{2.5}$ and PM_{10} concentrations as a result of the project.

The assessment of total exposures involves the assessment of total concentrations of particulate matter in the air from all sources including the project, and takes into account background air quality data for the project.

To assess potential risks to human health that may be associated with localised changes (or redistribution) in exposures to $PM_{2.5}$ and PM_{10} that relate to the project, an assessment of incremental impacts has been carried out.

Consideration of opportunity costs associated with particulate matter impacts is provided in Section 5.12 of Appendix I (Health impact assessment).

Assessment of total exposures

Due in large part to the existing levels of $PM_{2.5}$ in air within the existing urban environment, the maximum total concentrations of $PM_{2.5}$ are above the guidelines for both a 24-hour average and the annual average (including the 2025 goal by NEPC (2016)) with or without the operation of the project. These elevated background levels would be present in the community regardless of the construction and operation of the project. Concentrations of total $PM_{2.5}$, however, are essentially unchanged to slightly lower in most cases within the local community with the operation of the project only ('Do something') and in conjunction with other road tunnel projects by 2037 ('Do something cumulative').

Similarly, the maximum total concentrations of PM_{10} would exceed the 24-hour average guidelines. The maximum total concentrations of PM_{10} would also exceed the annual average guideline in most cases with or without the operation of the project, but would be below the guideline in the cumulative scenario ('Do something cumulative'). The elevated levels of total PM_{10} is due to the existing levels of PM_{10} in air within the existing urban environment. These elevated background levels would be present in the community regardless of the operation of the project. Concentrations of total PM_{10}, however, are essentially unchanged in most cases within the local community with operation of the project in 2027 and 2037.

Assessment of incremental exposures

The calculated changes in risk (associated with individual mortality; cardiovascular illness, respiratory or asthma hospitalisations; and lung cancer) associated with the expected operation of the project in 2027 and 2037 ('Do something'), including the cumulative scenarios ('Do something cumulative') indicates the maximum risks associated with the changes to $PM_{2.5}$ and PM_{10} concentrations would be below $1x10^{-4}$ (1 in 10,000) for exposures in residential, commercial and industrial areas, childcare centres, schools, aged care homes and open space areas. This is considered to be tolerable or acceptable.

A review of the calculated impacts in terms of the change in incidence of the relevant health impacts for $PM_{2.5}$ in the community (being the change in the number of cases per year of mortality, hospital or emergency department admissions), indicates the following:

- The total change in the number of cases (totals for each local government area (LGA) considered) relevant to the health effects evaluated for the project in 2027 ('Do something') are mostly negative, meaning an overall decrease in incidence as a result of the project
- The total change in the number of cases (totals for each Local Government Area (LGA) considered) relevant to some of the health impacts evaluated for the 'Do something cumulative 2027' scenarios is positive, indicating an increase. These increases are small (less than one case per year for all health impacts considered). There are also small negative changes associated with some health impacts considered. These changes (positive and negative) would not be measurable within the community and the impacts are considered to be negligible

- The total change in the number of cases (totals for each Local Government Area (LGA) considered) relevant to all the health impacts evaluated for the 'Do something 2037' and 'Do something cumulative 2037' scenarios are negative, meaning a decrease in incidence as a result of the project (due to the redistribution of traffic demand on surface roads)
- Many of the individual LGAs show a total decrease in health incidence. There are a few LGAs where there is an increase. These increases and decreases are also very small, less than one case per year for all health impacts considered. As a result, these changes would not be measurable in the community and the impacts are considered to be negligible
- Within these LGAs there are a number of smaller suburbs. 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 would be less than one case per year. Therefore, there would be no individual suburbs within the LGAs assessed for which the increased health incidence would be of significance or measurable.

Assessment of elevated receivers

The air quality impact assessment (Appendix H (Technical working paper: Air quality)) carried out a screening assessment of potential issues related to exposures that may occur at elevated receivers to model concentrations of $PM_{2.5}$ at 10 metres, 20 metres, 30 metres and 45 metres above ground level in the 'Do something cumulative 2037' scenario. These heights were chosen as a representative of potential exposures that may occur in multi-storey buildings. The assessment has evaluated the impacts at these heights across the study area, regardless of whether a multi-storey building is present or not, as well as receivers that do currently exist at these heights. For existing receivers, more than 90 percent of the receiver buildings assessed have a height of less than 10 metres, with less than 0.5 percent having a height of 40 metres or more.

The calculated health risks associated with changes in annual $PM_{2.5}$ concentrations for elevated receivers at 10, 20 and 30 metre heights would range from negligible to acceptable and are not expected to result in any measurable health-related impacts.

For elevated receptors at 45 metres height, the maximum increase in $PM_{2.5}$ and individual risks are higher, with the maximum individual risk exceeding 1×10^{-4}, which is considered unacceptable. However, the maximum increases in $PM_{2.5}$ and individual risks are at locations close to the ventilation outlets, where there are no buildings of that height present. The maximum predicted increase in $PM_{2.5}$ at an existing building that is about 45 metres in height is 0.05 µg/m^3, where the maximum individual risk is 4×10^{-6}, which is considered tolerable/acceptable.

The implications of this assessment on surrounding land use is discussed in considered in Chapter 20 (Land use and property). Land use considerations would be required to manage any interaction between the project and future development for buildings with habitable structures above 20 metres and within 300 metres of the ventilation outlet.

Carbon monoxide

Motor vehicles are the dominant source of Carbon Monoxide (CO) in air (NSW Department of Environment, Climate Change and Water (DECCW, 2010a). Adverse health effects of exposure to carbon monoxide are linked with carboxyhaemoglobin (COHb) in blood. In addition, association between exposure to CO and cardiovascular hospital admissions and mortality, especially in the elderly for cardiac failure, myocardial infarction and ischemic heart disease; and some birth outcomes (such as low birth weights), have been identified (NEPC, 2010).

The assessment completed for this project indicates that all concentrations would be below the relevant health-based guidelines presented in the *National Environment Protection (Ambient Air Quality) Measure* (NEPC, 2003b), which is consistent with international guidelines currently prescribed by the WHO (2005) and USEPA (2011). Therefore, no acute or chronic health impacts are expected as a result of the project for all scenarios in relation to exposures to carbon monoxide in the local area surrounding the project.

Volatile organic compounds and polycyclic aromatic hydrocarbons

Air toxics assessed for the project include volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) and are associated with emissions from vehicles using the mainline tunnels and adjacent surface road network. From a toxicity perspective, the key VOCs from vehicle emissions that have been considered are benzene, toluene, ethylbenzene, and xylenes (BTEX), 1,3-butadiene, acetaldehyde and formaldehyde (consistent with those identified and targeted in studies conducted in Australia on vehicle emissions (NSW EPA, 2012a).

The assessment of acute and chronic exposures of air toxics involves calculating a hazard index for each pollutant, which is the ratio of the maximum predicted concentration of the pollutant to their respective guidelines. Each individual hazard index is added up to obtain a total hazard index for all the air toxics considered. The total hazard index is a sum of the potential hazards associated with all the air toxics together assuming the health effects are additive, and is evaluated as follows (enHealth 2012):

- A total Hazard Index less than or equal to one means that all the maximum predicted concentrations are below the health based guidelines and there are no additive health impacts of concern
- A total Hazard Index 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 air toxics 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.

Assessment of acute exposure

The assessment indicates that the total Hazard Index predicted for acute exposures to VOCs and chronic exposures to VOCs and PAHs would be less than one for the 'Do something' and 'Do something cumulative' scenarios for 2027 and 2037. Based on this, there would be no acute or chronic health issues predicted in the local community as a result of the project.

Assessment of chronic exposure and incremental lifetime carcinogenic risk

For the assessment of chronic exposures to VOCs and PAHs, the total Hazard Index associated with exposure to the predicted maximum concentrations would be less than one for the Do something' and 'Do something cumulative' scenarios for 2027 and 2037. 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 $2x10^{-5}$ and are considered to be tolerable. 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.

13.5.2 Health related air quality (in-tunnel) impacts during operation

Air quality in-tunnel impacts in the operational period are presented in Chapter 12 (Air Quality).

Health related in-tunnel air quality impacts in operation have been assessed for nitrogen dioxide, particulate matter, carbon monoxide and carbon dioxide. This includes cumulative exposures for users of the project and connected tunnel network, or frequent users of the tunnel network.

The tunnel ventilation system would be designed and operated so that the operational in-tunnel air quality limits would not be exceeded. The ventilation report is provided as an annexure to Appendix H (Technical working paper: Air quality).

Nitrogen dioxide

A study of NO_2 concentrations inside vehicles travelling in Sydney and using existing road tunnels was commissioned by Roads and Maritime (now Transport for NSW) in 2016 (PEL, 2016) to better

understand the relationship between NO_2 outside the vehicle, and inside the vehicle. Within existing tunnels investigated in the study, concentrations of NO_2 were generally less than 0.15 ppm, however during periods of high traffic volumes 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 NO_2 dioxide, the average concentrations inside the vehicles, when ventilation was on recirculation was less than 0.2 ppm.

The project's ventilation systems have been designed to achieve the in-tunnel air quality criteria for NO_2 of 0.5 ppm (rolling 15-minute average) for all traffic scenarios, including the worst case variable speed and breakdown scenarios. Recent reviews of health effects of exposure to NO_2 supports the NO_2 criteria for up to 60 minutes of exposure (NSW Health, 2018).

The average concentration in the tunnels considered in the 'Do something' and 'Do something cumulative' would vary throughout the day, with the average concentration through the entire tunnel (trip average) would be expected to be (at most) around 0.25 ppm. Lower average concentrations may occur with windows up and ventilation on recirculation. All concentrations in all parts of the project are under the in-tunnel limit for NO_2. A summary of the health effects of short-term exposures to NO_2 is provided in Section 6.3 of Appendix I (Technical working paper: Health impact assessment). As discussed in Appendix I, no significant health impacts are expected as a result of the project from exposures to nitrogen dioxide within vehicles using the tunnels, as the exposure would be below 0.5 ppm. The same can be said for passengers in buses travelling through the tunnels.

Individuals using motorbikes would not have the opportunity to reduce exposure inside the tunnel through the use of ventilation controls. However, the time spent inside tunnels under congested conditions would be less than for other users given their ability to lane filter during heavy traffic.

The NO_2 criteria may not be protective of all health effects for all individuals. For severe asthmatic individuals travelling by motorcycle or within vehicles where advice to keep windows up and ventilation on recirculation is not adopted, there is the potential for these individuals to experience some minor change in respiratory response after using the tunnels following prolonged exposure (refer to Section 6.3 of the Appendix I (Technical working paper: Health impact assessment)).

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 windows up and ventilation on recirculation to minimise exposures throughout the day.

Particulate matter

Potential concentrations of particulate matter inside the tunnel are derived from exhaust as well as non-exhaust sources. Non-exhaust sources include tyre and brake wear and dust from surface road wear and the resuspension of road dust. The modelling of particulate matter and visibility issues within the tunnel has considered both sources.

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

Exposures that may occur within the tunnels would be consistent with expected variability of exposure to particulate matter throughout any day where a range of activities are carried out in an urban setting. Keeping windows closed and switching ventilation to recirculation has been shown to reduce exposures inside the vehicle by up to 80 per cent (NSW Health, 2003). While noting no guidelines are available for very short duration exposures, this would further reduce exposure to motorists.

In congested conditions inside the tunnels, it is not considered likely that significant adverse health impacts would occur.

Carbon monoxide

The operational in-tunnel limits for carbon monoxide have been adopted based on the conditions of approval for other Sydney road projects. The assessment indicates that there would be no health issues of concern related to in-tunnel exposures to carbon monoxide for motorists using the project, or for motorists with longer journeys that include the project. Furthermore, closing car windows and switching the ventilation to recirculation can reduce exposures by about 70–75 per cent for carbon monoxide.

Carbon dioxide

A study was carried out on behalf of Transport for NSW (enRisks, 2017) to determine carbon dioxide levels for passengers in vehicles travelling through tunnels (ie to represent the likely conditions for the project). This study found that for passengers in vehicles travelling through tunnels for a period of up to an hour, levels of carbon dioxide would not be expected to adversely affect driver safety. However, for periods of exposure up to two hours where ventilation is left on recirculation, levels of carbon dioxide inside a vehicle where there are one or more passengers may affect an already fatigued driver.

The assessment indicates that where Transport for NSW provides specific advice to drivers entering road tunnels to put ventilation on recirculation, further advice may need to be 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. However, this situation would be considered rare as travel time in the tunnels is unlikely to be for such extended periods.

Overall, no significant health impacts related to exposure to carbon dioxide would be expected in the operation of the project.

13.5.3 Health related noise and vibration impacts during operation

Noise and vibration impacts in the operational period are presented in Chapter 11 (Operational noise and vibration). Sound is a natural phenomenon that only becomes noise when it has some undesirable effect on people or animals. Noise and vibration can potentially have both short-term and long-term adverse effects on people. These health effects can include:

- Sleep disturbance (sleep fragmentation that can affect psychomotor performance, memory consolidation, creativity, risk-taking behaviour and risk of accidents)
- Annoyance
- Hearing impairment
- Interference with speech and other daily activities
- Children's school performance (through effects on memory and concentration)
- Cardiovascular health.

Other potential effects which may occur, but for which the evidence is weaker, include:

- Effects on mental health (usually in the form of exacerbation of existing issues for vulnerable populations rather than direct effects)
- Tinnitus (which manifests as a ringing in the ears when no physical noise is present, can also result in sleep disturbance, anxiety, depression, communication and listening problems, frustration, irritability, inability to work, reduced efficiency and a restricted participation in social life)
- Cognitive impairment in children (including deficits in long term memory and reading comprehension)
- Some evidence of indirect effects such as impacts on the immune system.

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

The assessment of potential health impacts relating to noise has focused on whether the guidelines/criteria that have been established can be met. The NSW noise policies and guidelines against which this project is assessed are designed to protect the most sensitive receivers from annoyance and sleep disturbance. Where the guidelines cannot be met there is the potential to interfere with communication, disturb sleep and cause annoyance. Further, communities subjected to long-term exposure of acute noise levels may experience impairment of cardiovascular health and reduced cognitive performance in children.

The noise modelling for the project has been carried out to address impacts associated with the operation of the project in 2027 and 2037 ('Do something'), including a cumulative scenario ('Do something cumulative'). The modelling has evaluated noise impacts at the façade of all buildings, including on all floors of multi-storey buildings. An assessment was carried out to determine how well the model estimated noise impacts based on a current scenario. The modelled and measured results were found to be within acceptable tolerances, which are ±2 dB(A).

For the majority of receivers assessed, the project would result in either reduced or relatively minor changes in traffic noise levels. This includes a reduction in traffic noise at a significant number of receiver buildings at Warringah Freeway due to the project (around 75 per cent) as a result of the redistribution of traffic. In areas where there is a reduction in traffic noise, there would be associated health benefits in these communities. However, the assessment also predicts that without mitigation, around one percent of receiver buildings adjacent to the project would experience incremental noise increases greater than 2 dB(A), which may result in health impacts if not appropriately mitigated. Additionally, a number of properties have also been identified where additional mitigation is required due to existing high road traffic noise levels in exceedance of the cumulative noise limit criterion or because traffic noise levels are acute (refer to Chapter 11 (Operational noise and vibration). These elevated noise levels would be present without the project and the implementation of additional noise mitigation would result in lower levels of noise experienced at these receiver buildings.

Mitigation measures considered during operation would principally involve the use of low noise pavement and noise barriers. However, a number of receiver buildings have been identified for being eligible for at-property treatment surrounding the Rozelle Interchange and to the Warringah Freeway Upgrade (refer to Chapter 11 (Operational noise and vibration)) under the 'Do something cumulative' scenario. Where noise mitigation measures are proposed, no significant health impacts are expected. For most properties the implementation of mitigation measures (including at-property treatment) would reduce overall noise impacts from existing noise which triggered the need for mitigation, as well as project related noise. The outcome is expected to be an overall improvement in noise levels within the community (compared with the existing situation) and some potential for improvements in community health.

13.5.4 Health related social impacts during operation

Social impacts in the operation period are presented in Chapter 21 (Socio-economics).

Health related social impacts are discussed below in terms of:

- Changes in traffic, public transport, access and connectivity
- Public safety
- Green space
- Visual amenity
- Economic aspects
- Road tolling.

Changes in traffic, public transport, access and connectivity

Changes in traffic, access and connectivity during operation are presented in Chapter 9 (Operational traffic and transport).

The project would improve regional access and connectivity for road based public transport, freight and servicing, private vehicles and other road users by providing an alternate crossing of Sydney Harbour. The project would improve travel times on key corridors (such as the Western Distributor, Sydney Harbour Bridge, Sydney Harbour Tunnel and the Victoria Road corridor), improving traffic flow and journey times for buses, freight and other vehicles accessing key commercial and employment centres including the Sydney CBD and North Sydney.

Localised traffic and transport impacts, including localised delays and increased traffic demands on some roads and intersections, may result from the operation of the project at either end of the project where it would integrate with the existing transport network (refer to Chapter 9, Section 9.4 (Operational traffic and transport)). These localised delays would generally be offset by large travel time benefits provided by the project at the broader network level (for example, the project would improve travel times by up to 75 per cent for travel between North Sydney and Rozelle). The impacts of increased traffic demand and delays in the North Sydney area would be further minimised through the North Sydney Integrated Transport Program, which is being developed by Transport for NSW.

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 (Hansson et al. 2011). Increased travel times reduce the available time to spend on healthy 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 (Hansson et al. 2011). Reducing travel times and road congestion is expected to reduce these health impacts. From a public transport network perspective, the project, once complete, is expected to improve access to public transport and improve journey times for buses for local and regional communities.

Public safety

A range of potential hazards were considered that have the potential to affect public safety during the operation of the project, principally in relation to traffic accidents. It was identified that there are no issues related to operation that have the potential to result in significant safety risks to the community.

Improvements to road safety with reduced traffic volumes along key road transport corridors, and new or upgraded pedestrian and cyclist infrastructure would improve pedestrian and cyclist safety. Therefore, there would be a beneficial health impact in terms of public safety.

Green space

The health benefits of green space are described in Section 13.4.3. Impacts on green space during operation are summarised below.

Yurulbin Park

After construction, the project is not expected to impact on the ongoing use or functioning of the park and facilities within the park.

Cammeray Golf Course

The project would occupy parts of the golf course as required as part of the Warringah Freeway Upgrade and to accommodate the motorway facilities (including an access road). This would require the reconfiguration of the golf course to allow its ongoing use.

The establishment of the operational facilities would change the visual setting of this location when viewed from within the golf course and adjoining sporting facilities and surrounding locations, including the Warringah Freeway and Ernest Street.

Landscaping and other architectural treatments would be provided to reduce the visual impacts of these facilities when viewed from some locations.

St Leonards Park

Should the project require the permanent strip acquisition of a small area of St Leonards Park to accommodate upgrades to the Falcon Street/Miller Street intersection as part of the Warringah Freeway Upgrade, the ongoing use or functioning of the park and facilities within the park is not expected to be impacted. Further review of the impacts in this area is currently being carried out and permanent impacts to St Leonards Park would be minimised or, where possible eliminated.

ANZAC Avenue Reserve

The project would require the permanent strip acquisition of a small area of ANZAC Avenue Reserve to accommodate the widening of the Warringah Freeway. This is not expected to impact on the ongoing use or functioning of the park and facilities within the park.

ANZAC Park

After construction, the project is not expected to impact on the ongoing use or functioning of the park and facilities within the park.

Merlin Street Reserve

The project would require the permanent strip acquisition of a small area of Merlin Street Reserve to accommodate the widening of the Warringah Freeway. This is not expected to impact on the ongoing use or functioning of the park and facilities within the park.

Rose Avenue Reserve

The project would permanently affect a strip of Rose Avenue Reserve to accommodate the widening of the Warringah Freeway. This is not expected to impact on the ongoing use of the reserve.

Jeaffreson Jackson Reserve

After construction, the project is not expected to impact on the ongoing use or functioning of the park.

Visual amenity

The operational project would include changes to local visual amenity due to the presence of new and modified/upgraded infrastructure (including motorway facilities, ventilation outlets, wastewater treatment plants, substations, bridges and drainage channels), landscaping and urban design features.

Changes in visual amenity have the potential to increase levels of stress and anxiety, however, most people adapt to changes in the visual landscape, particularly within an already urbanised area. Where long term visual impacts would be negative, mitigation measures including landscape screening would be utilised where feasible to reduce these impacts. Design development has been influenced by urban design principles that have been established for the project including integrating the project elements and infrastructure into the surrounding environment. A detailed review and finalisation of architectural treatment of the project operational infrastructure would be carried out during further design development.

As a result, most changes in visual impacts are not expected to have a significant impact on the health of the community.

Economic aspects

Economic impacts are presented in Chapter 21 (Socio-economics). The operational impacts on business are predicted to be positive with improved connectivity and accessibility to business centres. Some localised impacts to access may be experienced due to alternative route arrangements, potentially resulting in delays or inefficiencies. However, these effects are considered minor in comparison to the broader benefits across the region.

Freight and commercial vehicle movements are an important component of the economy. Numerous industries are dependent upon efficient transport to service operational requirements. Transport for NSW estimated that freight and logistics contributed $66 billion to NSW Gross State Product (GSP) (Transport for NSW, 2018a).

The project would encourage heavy and commercial vehicle movements into the tunnel, due to the increased efficiencies and reducing freight costs through increased travel speeds and reliability and reduced travel distances.

The transport modelling carried out for the project highlighted that the project would result in substantial travel time savings for freight vehicles, improving their productivity and increasing the efficiency of the freight network particularly for trips that currently use Sydney Harbour Bridge. Improvements in the efficiency and reliability of these transport networks would likely result in increased productivity, reduced costs and broader economic benefits for these workforces.

Road tolling

While no decision on tolls has yet been made, works for Western Harbour Tunnel and Warringah Freeway Upgrade includes provision for tolling gantries for northbound traffic should the government elect to introduce a northbound toll. 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 would be a proportion of the population that avoid the use of tollways due to affordability. In July 2019, the NSW Government implemented a toll relief initiative to ease the cost of living for frequent NSW toll road users through the provision of half-priced or free vehicle registration.

13.6 Environmental management measures

Key environmental management measures relating to human health impacts are mentioned in other chapters within this environmental impact statement, particularly

- Transport and travel management measures – Chapters 8 (Construction traffic and transport) and Chapter 9 (Operational traffic and transport)
- Air quality management measures – Chapter 12 (Air quality)
- Noise and vibration management measures – Chapter 10 (Construction noise and vibration) and Chapter 11 (Operational noise and vibration)
- Property acquisition and relocation services – Chapter 20 (Land use and property)
- Social impact management measures – Chapter 21 (Socio-economics)
- Visual amenity measures – Chapter 22 (Urban design and visual amenity)
- Cumulative impact measures – Chapter 27 (Cumulative impacts).

Additional environmental management measures specific to human health impacts are provided in Table 13-2.

Table 13-2 Environmental management measures for human health impacts

Ref	Phase	Impact	Environmental management measure	Location
HH1	Construction	Underwater noise impacts	Monitoring during piling activities will be carried out to validate the predicted underwater acoustic thresholds and management areas, and to further adapt management measures (as required). This will include a monitoring program with an initial trial of piling with corresponding communication measures to validate the predicted underwater acoustic thresholds and management areas. The monitoring results and management areas will be peer-reviewed prior to implementation to ensure they are appropriately protective of health.	WHT (Sydney Harbour)
HH2	Construction	Underwater noise impacts	Communication and management measures will be implemented during construction to manage potential underwater noise impacts to water-based recreational users during dredging and piling activities in Sydney Harbour. The communication tools and management measures that would be contemplated within the management zone include: a) Coordination of piling programs to minimise interaction with significant planned events on the harbour, where feasible and reasonable b) Communication of the piling program and management area so that recreational users know when the piling, dredging and other noise generating activities will be taking place, what they can expect, and the zones to minimise the possibility of being startled from a sudden increase in sound pressure underwater c) Direct communication with key local recreational stakeholders during the piling and dredging program to provide up-to-date scheduling d) Use of advertisements, signage, letter box drops and project updates to communicate the implementation of a management area during the works. This could include floating markers or signage on approach to the construction work	(WHT) Sydney Harbour

Ref	Phase	Impact	Environmental management measure	Location
			e) Surveillance within the areas in which the precautionary guideline level is exceeded to proactively monitor users prior to and during relevant activities that could pose a risk to recreational users.	

Note: WHT = Western Harbour Tunnel

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