Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 11

Operational noise and vibration

11 Operational noise and vibration

This chapter considers the potential noise and vibration impacts associated with the operation of the project and identifies management measures to address these impacts. Potential noise and vibration impacts associated with the construction of the project are included in Chapter 10 (Construction noise and vibration).

A detailed noise and vibration assessment has been carried out for the project and is included in Appendix G (Technical working paper: Noise and vibration).

Common acoustic terms used throughout this chapter are explained in Chapter 10 (Construction noise and vibration).

The Secretary's environmental assessment requirements as they relate to operational noise and vibration and where in the environmental impact statement these have been addressed, are detailed in Table 11-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to operational noise and vibration are included in Section 11.8.

Table 11-1 Secretary's environmental assessment requirements – operational noise and vibration

Secretary's requirement	Where addressed in EIS
Noise and Vibration – Amenity	
1. The Proponent must assess construction and operational noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must take into consideration and address the redistribution of traffic (including on local feeder roads) and operational plant and equipment, and must include consideration of impacts to sensitive receivers and include consideration of sleep disturbance and, as relevant, the characteristics of noise and vibration (for example, low frequency noise).	**Section 11.5** and **Section 11.6** documents the impacts from the redistribution of traffic (including on local feeder roads), operational plant and equipment and the new and improved open space and recreation facilities at Balgowlah. **Chapter 10** (Construction noise and vibration) outlines the relevant NSW noise and vibration guidelines informing the construction noise and vibration assessment.
Noise and Vibration – Structural	
1. The Proponent must assess construction and operation noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to the structural integrity and heritage significance of items (including Aboriginal places and items of environmental heritage).	**Section 11.2**, **Section 11.7** and **Appendix G** (Technical working paper: Noise and vibration) presents details on the assessment of operational noise and vibration impacts in respect to relevant NSW noise and vibration guidelines as well as the consideration of impacts on the structural integrity of buildings and heritage significance items. **Chapter 10** (Construction noise and vibration) details similar information in respect to construction impacts.

11.1 Legislative and policy framework

Operational road traffic noise relating to State significant infrastructure projects is primarily regulated by the Department of Planning, Industry and Environment through project approval requirements under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979*.

In addition, the Protection of the Environment Operations (Noise Control) Regulation 2017 includes controls on noise from motor vehicles, while the Heavy Vehicle (Vehicle Standards) National Regulation (NSW) includes controls on noise from heavy vehicles.

NSW Road Noise Policy (DECCW, 2011) is the NSW Environment Protection Authority guideline which defines criteria to be used in assessing the impact of road traffic noise and to protect amenity and wellbeing. The policy is intended for use during the environmental assessment of road proposals to develop feasible and reasonable noise mitigation measures.

NSW Road Noise Policy (DECCW, 2011) is supported by *Noise Criteria Guideline* (Roads and Maritime Services, 2015f) and *Noise Mitigation Guideline* (Roads and Maritime Services, 2015g), which present a practical approach in applying *NSW Road Noise Policy* (DECCW, 2011) and address specific situations relevant to Transport for NSW road projects.

Noise Policy for Industry (NSW EPA, 2017a) provides intrusiveness and amenity criteria for fixed facilities that operate continuously and is relevant to the assessment project components including substations, wastewater treatment plants and ventilation facilities.

Noise Guide for Local Government (NSW EPA, 2013b) provides guidance on whether noise from the new and improved open space and recreation facilities at Balgowlah would be considered intrusive in the absence specific noise criteria for open areas and recreation facilities.

11.2 Assessment methodology

The operational noise assessment for the project considered the potential impacts associated with changes in traffic noise and noise from the operation of fixed facilities. The assessment included the following key steps:

- Identification of potentially affected noise catchment areas (NCAs) and noise sensitive receivers, development of a study area for the assessment, and background noise monitoring to determine existing noise levels. These are documented in Chapter 10 (Construction noise and vibration)
- Confirmation of noise and vibration objectives with reference to *NSW Road Noise Policy* (DECCW, 2011) and *Noise Criteria Guideline* (Roads and Maritime Services, 2015f)
- Selection and definition of the road traffic noise scenarios to be modelled and compared. Operational road traffic noise scenarios are presented in Table 11-2, which include scenarios with the project (‘Do Something’ and ‘Do something cumulative’) and without the project (‘Do minimum’)
- Calculation of road traffic noise changes for each scenario and for both the year of opening of the project and ten years after opening
- Prediction of operational noise from fixed facilities using the sound power levels expected from typical plant and equipment, for comparison against *Noise Policy for Industry* (NSW EPA, 2017a) intrusiveness and amenity criteria
- Prediction of operational noise associated with the new and improved open space and recreation facilities at Balgowlah using indicative sound power levels of recreational activities, for comparison against *Noise Guide for Local Government* (NSW EPA, 2013b) intrusiveness criterion
- Identification of environmental management measures to avoid, minimise and mitigate noise and vibration impacts during operation.

Operational road traffic noise scenarios have been modelled at the anticipated year of opening of the project (2027) and ten years later (2037). These scenarios have been informed by road traffic volumes from the Sydney Motorway Projects Model. A summary of scenarios is provided in Table 11-2 with full details of projects described in Chapter 9 (Operational Traffic and Transport).

Table 11-2 Summary of operational road traffic noise modelling scenarios for year of opening of the project (2027) and ten years later (2037)

Modelled Scenario	Included projects					
	Beaches Link and Gore Hill Freeway Connection	Western Harbour Tunnel[1]	Warringah Freeway Upgrade[1]	WestConnex	Sydney Gateway	M6 Motorway[2]
'Do minimum'	×	×	×	✓	×	×
'Do something'	✓	×	✓	✓	×	×
'Do something cumulative'	✓	✓	✓	✓	✓	✓

Note 1: Part of the Western Harbour Tunnel and Warringah Freeway Upgrade project

Note 2: For assessment at the year of opening Stage 1 of the M6 Motorway was included in the 'Do something cumulative' scenario. For 2037, the full M6 Motorway was included.

11.3 Assessment objectives and criteria

The operational noise and vibration assessment objectives and criteria applied to the project are summarised in the following sections and consider recommendations provided in the guidelines, policies and standards discussed in Section 11.1.

11.3.1 Road traffic noise

Residential receivers

Potential road traffic noise impacts on residential receivers are assessed using assessment criteria based on the category of the road that would generate the noise. In some instances, a residence may be exposed to traffic noise from a combination of new and redeveloped roads or different categories of roads.

In addition to road traffic noise which exceeds the assessment criteria, large increases in the level of noise can change the acoustic environment of a location, particularly for quieter areas. To address large increases in noise levels, a relative increase criterion was used.

Where criteria for a particular road category or relative increase criteria are likely exceeded due to the project, the eligibility of reasonable and feasible mitigation measures is evaluated in accordance with *Noise Mitigation Guideline* (Roads and Maritime Services, 2015g).

A summary of the applicable road traffic noise criteria for residential receivers in accordance with *Noise Criteria Guideline* (Roads and Maritime Services, 2015f) is presented in Table 11-3.

Table 11-3 Road traffic noise criteria for residential receivers (external)

Road category	Type of project/land use	Assessment criteria dB(A)[1]	
		Daytime (7am 10pm)	Night time (10pm 7am)
Freeway/ arterial/ sub–arterial roads	Existing residences affected by noise from new freeway/arterial/sub-arterial road corridors.	55 $L_{Aeq(15\ hour)}$[2]	50 $L_{Aeq(9\ hour)}$
	Existing residences affected by noise from redevelopment of existing freeway/arterial/sub-arterial roads. Existing residences affected by additional traffic on existing freeways/arterial/sub-arterial roads generated by land use developments.	60 $L_{Aeq(15\ hour)}$	55 $L_{Aeq(9\ hour)}$
	Existing residences affected by both new roads and the redevelopment of existing freeway/arterial/sub-arterial roads in a transition zone[3].	55–60 $L_{Aeq(15\ hour)}$	50–55 $L_{Aeq(9\ hour)}$
	Existing residences affected by increases in traffic noise of 12 dB(A) or more from new freeway/arterial/sub-arterial roads.	42–55 $L_{Aeq(15\ hour)}$	42–50 $L_{Aeq(9\ hour)}$
	Existing residences affected by increases in traffic noise of 12 dB(A) or more from redevelopment of existing freeway/arterial/sub-arterial roads.	42–60 $L_{Aeq(15\ hour)}$	42–55 $L_{Aeq(9\ hour)}$
Local roads	Existing residences affected by noise from new local road corridors.	55 $L_{Aeq(1\ hour)}$	50 $L_{Aeq(1\ hour)}$
	Existing residences affected by noise from redevelopment of existing local roads.		
	Existing residences affected by additional traffic on existing local roads generated by land use developments.		

Note 1: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.4 in Chapter 10 (Construction noise and vibration) for a comparison of dB(A) for various activities

Note 2: $L_{Aeq(X\ hour)}$ is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a number of hours

Note 3: The applicable noise criteria for a particular receiver would be dependent on its location relative to where the new road joins the redeveloped road (transition zone). See Section 7.1 and Table 1 of the Noise Criteria Guideline (Roads and Maritime Services, 2015f) for further information.

Non-residential receivers

Consistent with *NSW Road Noise Policy* (DECCW, 2011), *Noise Criteria Guideline* (Roads and Maritime Services, 2015f) also sets criteria for the assessment of road traffic noise on the internal or external areas of non-residential land uses, such as schools, hospitals, places of worship and recreation areas. The applicable criteria for non-residential receivers are shown in Table 11-4.

Outdoor open space can be characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion. Indoor spaces that are deemed 'noise sensitive' generally serve the purpose of education, health care, religious practice or sleeping.

For sensitive land uses such as schools, hospitals, places of worship and childcare centres, criteria have been set for internal areas so the associated activities will not be unduly disturbed by external noise. It is generally accepted that with open windows, the noise level within a building will be at least 10 dB(A) less than the external noise level. This attenuation can increase to more than 30 dB(A) depending on the building type, location of the room within the building, window type and whether the use of the space requires the window to be fully opened, slightly opened or closed. For assessment purposes, a noise reduction of 10 dB(A) is added to the criterion for an internal area to identify an external screening criterion. The non-residential receivers identified to exceed the external screening criterion in this assessment will require further investigation during further design development to confirm the extent of noise impact and eligibility for consideration of noise mitigation.

Table 11-4 Criteria for non–residential sensitive land uses

Existing sensitive land use	Assessment criteria, dB(A)[1]	
	Day (7am 10pm)	Night (10pm 7am)
School classrooms	40 $L_{Aeq(1\ hour)}$[2] (internal)	–
Hospital wards	35 $L_{Aeq(1\ hour)}$ (internal)	35 $L_{Aeq(1\ hour)}$ (internal)
Places of worship	40 $L_{Aeq(1\ hour)}$ (internal)	40 $L_{Aeq(1\ hour)}$ (internal)
Open space (active use)	60 $L_{Aeq(15\ hour)}$ (external) when in use	–
Open space (passive use)	55 $L_{Aeq(15\ hour)}$ (external) when in use	–
Childcare facilities	Sleeping rooms 35 $L_{Aeq(1\ hour)}$ (internal) Indoor play areas 40 $L_{Aeq(1\ hour)}$ (internal) Outdoor play areas 55 $L_{Aeq(1\ hour)}$ (external)	–
Aged care facilities	Residential land use noise assessment criteria apply	Residential land use noise assessment criteria apply

Note 1: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.4 in Chapter 10 (Construction noise and vibration) for a comparison of dB(A) for various activities
Note 2: $L_{Aeq(X\ hour)}$ is the A-weighted “equivalent noise level”. It is the summation of noise events and integrated over a number of hours

Road traffic noise impacts along existing roads

Noise Criteria Guideline (Roads and Maritime Services, 2015f) provides guidance for assessing traffic noise from existing roads not subject to any redevelopment. This is where there is a predicted increase in traffic noise levels of more than 2 dB(A) on the surrounding road network due to the redistribution of traffic flow facilitated by the project. The criteria are provided in Table 11-5.

Table 11-5 Criteria for existing roads not subject to redevelopment

Existing road category	Target noise level dB(A)[1]	
	Day (7am 10pm)	Night (10pm 7am)
Freeway/ arterial/ sub-arterial road	$L_{Aeq(15\ hour)}$[2] 60 (external)	$L_{Aeq(9\ hour)}$ 55 (external)
Local road	$L_{Aeq(1\ hour)}$ 55 (external)	$L_{Aeq(1\ hour)}$ 50 (external)

Note 1: dB(A) stands for A-–weighted decibel, a unit used to measure noise. Refer to Section 10.4 in Chapter 10 (Construction noise and vibration) for a comparison of dB(A) for various activities
Note 2: $L_{Aeq(X\ hour)}$ is the A-weighted “equivalent noise level”. It is the summation of noise events and integrated over a number of hours.

Maximum road traffic noise levels

Maximum noise levels are generally due to heavy vehicles passing by. The measured maximum noise level and the number of maximum noise level events are used as indicators of the potential for sleep disturbance.

11.3.2 Sleep disturbance

Guidance for considering sleep disturbance due to maximum noise levels is provided in Practice Note (iii) of *Environmental Noise Management Manual* (RTA, 2001). The relevant considerations are:

- Maximum noise levels
- The extent to which the maximum noise levels for individual vehicle pass-bys exceed the L_{Aeq} noise level for each hour of the night
- The number of maximum noise events.

At locations where road traffic is continuous rather than intermittent, the $L_{Aeq(9\ hour)}$ criteria for operational noise assessment accounts for sleep disturbance impacts. However, where the emergence of L_{Amax} over the ambient L_{Aeq} is equal to or greater than 15 dB(A), the $L_{Aeq(9\ hour)}$ criteria may not sufficiently account for sleep disturbance impacts.

The sleep disturbance assessment does not influence the extent of mitigation required but is used to rank and prioritise design options and noise mitigation strategies.

11.3.3 Operational road traffic mitigation

Modelling of operational road traffic noise based on the ‘Do minimum’ (without the project) and the ‘Do something cumulative’ (with the project and other projects) scenarios were used to identify road traffic noise levels at receivers in the vicinity of the project.

The following *Noise Mitigation Guideline* (Roads and Maritime Services, 2015g) eligibility triggers were applied where a sensitive receiver may qualify for consideration of noise mitigation beyond the adoption of road design and traffic management measures:

- The predicted ‘build’ (with the project) noise level exceeds *Noise Criteria Guideline* (Roads and Maritime Services, 2015f) controlling criteria and the predicted noise level increase due to the project
(ie the noise predictions for the ‘build’ (with the project) minus the ‘no build’ (without the project)) is greater than 2 dB(A), or
- The predicted ‘build’ (with the project) noise level is 5 dB(A) or more above the criteria (at or exceeds the cumulative limit) and the receiver is significantly influenced by traffic noise from the road project, regardless of the incremental impact of the project, or
- The noise level contribution from the project is acute even if noise levels are dominated by another road. The acute noise level for day time (7am to 10pm) is an $L_{Aeq(15\ hour)}$ of 65 dB(A) or higher, and for night time (10pm to 7am) is an $L_{Aeq(9\ hour)}$ of 60 dB(A) or higher. Buildings predicted to be subject to acute noise levels qualify for consideration of noise mitigation even if noise levels are dominated by another road.

When the eligibility triggers are exceeded, additional mitigation is considered. The mitigation options considered (in order of preference) include:

- Source controls (such as quieter noise pavements)
- Path controls (such as noise barriers)
- At-property controls (such as architectural treatments).

A noise barrier analysis was also completed to identify reasonable and feasible locations where barriers would potentially be provided. The analysis followed the process outlined in *Noise*

Mitigation Guideline (Roads and Maritime Services, 2015g) and guidance in *Noise Wall Design Guideline* (Roads and Maritime Services, 2016ba).

11.3.4 Operational noise from fixed facilities

Fixed facilities and ancillary infrastructure associated with the operation of the project would include motorway facilities and ventilation outlets, a motorway control centre, tunnel support facilities, and groundwater and tunnel drainage management and treatment systems, including a wastewater treatment plants. Certain equipment associated with the fixed facilities, such as in-tunnel jet fans, axial fans at ventilation outlets, substations and pumps, have the potential to emit noise that could impacts sensitive receivers the vicinity.

Noise levels from fixed facilities are assessed in accordance with *Noise Policy for Industry* (NSW EPA, 2017a), which includes both intrusiveness and amenity criteria. The intrusiveness criterion aims to minimise noise increases from a single new development by applying a criterion of 5 dB(A) above background levels. The amenity criteria aims to limit continuing increases in ambient noise by applying recommended levels for certain receiver types. The most stringent of the two applies.

11.3.5 Open space and recreation facilities noise

Noise impacts from the use of the new and improved open space and recreational facilities at Balgowlah was assessed in accordance with *Noise Guide for Local Government* (NSW EPA, 2013b). This guideline applies a criterion of 5 dB(A) above background levels to determine whether noise levels from open space and recreational facilities would be considered intrusive. It is noted that the open space and recreation facilities are anticipated to operate during the day and evening periods (up to 10pm). Therefore, potential noise impacts have been assessed for the quieter evening period.

11.4 Existing noise environment

The existing noise environment, including ambient noise levels, is described in Chapter 10 (Construction noise and vibration). These ambient noise levels would also be applicable to the operational noise assessment discussed below.

11.5 Assessment of operational impacts

11.5.1 Overview

This section provides an assessment of operational road traffic noise impacts for surface roads associated with the project as well impacts from project operational facilities. This section assesses potential operational noise levels and impacts without any mitigation in place. It also outlines indicative mitigation measures to address the predicted noise levels and impacts. This assessment is for environmental impact assessment and planning approval purposes and would be reviewed and adjusted during further design development to confirm the suite of mitigation measures that would be adopted for the project.

11.5.2 Road traffic noise before mitigation

The operational road traffic noise model scenarios listed in Table 11-2 were first considered before the inclusion of additional or augmented noise barriers, but do consider the following:

- Existing noise barriers
- Quieter pavements for some surface roads (eg open grade asphalt where functionality appropriate) providing up to 2 dB(A) noise reduction benefits (compared to dense graded asphalt).

This analysis is presented below.

'Do something' scenario

Table 11-6 shows predicted changes in noise levels for receivers under a 'Do minimum' (without the project) and 'Do something' (with the project) noise model scenarios for sensitive receiver buildings at the following locations:

- Warringah Freeway and surrounds
- Gore Hill Freeway and Artarmon – includes connections to and from the Gore Hill Freeway
- Balgowlah and surrounds – includes connections to and from Burnt Bridge Creek Deviation and surface road works at Balgowlah
- Seaforth to Frenchs Forest – includes connections to and from the Wakehurst Parkway and the realignment and upgrade of the Wakehurst Parkway.

Table 11-6 Predicted changes in noise levels before mitigation (2037 'Do minimum' scenario compared to 'Do something' scenario)[1]

Location	Number of receiver buildings experiencing changes in noise levels from operational traffic					
	Noise level reduction		Increase 0 dB(A)[2] 2 dB(A)		Increase > 2 dB(A)	
	Day	Night	Day	Night	Day	Night
Warringah Freeway and surrounds	5326	5582	1423	1169	15	13
Gore Hill Freeway and Artarmon	149	719	993	425	5	3
Balgowlah and surrounds	822	896	1493	1303	37	153
Seaforth to Frenchs Forest	17	33	901	783	317	419

Note 1: The 'with the project' scenario includes the Beaches Link and Gore Hill Freeway Connection, WestConnex, and the Warringah Freeway Upgrade component of the Western Harbour Tunnel and Warringah Freeway Upgrade project

Note 2: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.4 in Chapter 10 (Construction noise and vibration) for a comparison of dB(A) for various activities.

Overall:

- The project is predicted to reduce traffic noise for about 59 per cent of receiver buildings within noise catchment areas surrounding the project surface road works
- Thirty-seven per cent of receiver buildings are predicted to experience traffic noise level increases of less than 2 dB(A), which represents a minor impact that is likely to be barely perceptible
- Four per cent of receiver buildings are predicted to experience increases greater than 2 dB(A) due to the project.

The project is predicted to decrease the number of receiver buildings exceeding the relevant noise criteria when compared to the 'Do minimum' scenario during the day and night periods at noise catchment areas surrounding the Warringah Freeway and Gore Hill Freeway and Artarmon. This is due to traffic being moved from the existing surface roads into the proposed tunnels.

The project is predicted to result in road traffic noise levels that exceed the criteria and increase by 2 dB(A) or more compared to the 'Do minimum' scenario during the day and night periods in certain locations in the noise catchment areas surrounding Balgowlah, Seaforth, North Balgowlah, Killarney Heights, Allambie Heights and Frenchs Forest. This is due to predicted increases in traffic volumes and redistributed traffic on local roads associated with vehicles entering and exiting the tunnel portals at Killarney Heights and Balgowlah. In the absence of additional traffic calming measures, the following local roads are predicted to be impacted:

- Traffic volumes during the night period along Wanganella Street at Balgowlah are forecast to increase noise levels by more than 2 dB(A) and result in exceedances of the road traffic noise criteria
- Traffic volumes during the night period along Judith Street at Seaforth and Woodbine Street at North Balgowlah are forecast to increase noise levels by more than 2 dB(A), which could potentially result in exceedances of the road traffic noise criteria.

Traffic calming measures would be designed and implemented in consultation with Northern Beaches Council to ensure impacts due to potential increased traffic are minimised (refer to environmental management measure ONV3 in Table 11-12).

With the exception of Wakehurst Parkway at Frenchs Forest and local roads indicated above, the majority of properties that are eligible for consideration of noise mitigation beyond the adoption of road design and traffic management measures (refer to Section 11.3.3) are due to predicted exceedances of the cumulative limit and acute noise levels, rather than increases due to the project. This indicates that existing road traffic noise levels, rather than changes due to the project, are the main driver for additional noise mitigation.

'Do something cumulative' scenario

Table 11-7 shows predicted changes in noise levels for receivers under a 'Do minimum' (without the project) and 'Do something cumulative' (with the project and other projects) noise model scenarios for sensitive receiver buildings surrounding the Warringah Freeway, the Gore Hill Freeway and Artarmon, Balgowlah and surrounds and Seaforth to Frenchs Forest. The properties that would be eligible for consideration of noise mitigation beyond the adoption of road design and traffic management measures in this scenario, based on the criteria specified in Section 11.3.3, are indicated in Figure 11-1 to Figure 11-3. For further detail refer to Annexure N of Appendix G (Technical working paper: Noise and vibration). Noise barriers around the Warringah Freeway would be deliver as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.

Table 11-7 Predicted changes in noise levels before mitigation (2037 'Do minimum' scenario compared to 'Do something')[1]

Location	Number of receiver buildings experiencing changes in noise levels from operational traffic					
	Noise level reduction		Increase 0 dB(A)[2] 2 dB(A)		Increase > 2 dB(A)	
	Day	Night	Day	Night	Day	Night
Warringah Freeway and surrounds	5140	5923	1588	808	36	33
Gore Hill Freeway and Artarmon	79	1002	1056	142	12	3
Balgowlah and surrounds	813	901	1500	1301	39	150
Seaforth to Frenchs Forest	36	22	868	790	331	423

Note 1: 'The project and other projects' scenario includes the following projects: Beaches Link and Gore Hill Freeway Connection, Western Harbour Tunnel and Warringah Freeway Upgrade, WestConnex, Sydney Gateway, and the M6 Motorway

Note 2: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.4 in Chapter 10 (Construction noise and vibration) for a comparison of dB(A) for various activities.

Overall:

- The project, in combination with other projects, is predicted to reduce traffic noise for about 61 per cent of receiver buildings within noise catchment areas surrounding the project surface road works
- Thirty-five per cent of receiver buildings are predicted to experience traffic noise level increases of less than 2 dB(A) which represents a minor impact that is likely to be barely perceptible

- Four per cent of receiver buildings are predicted to experience increases greater than 2 dB(A).

Changes in traffic from the project and other major road projects are predicted to decrease the number of receiver buildings exceeding the *Noise Criteria Guideline* (Roads and Maritime Services, 2015f) noise criteria when compared to the ‘Do minimum’ scenario during the day and night periods at noise catchment areas surrounding the Warringah Freeway and Gore Hill Freeway. This is due to traffic being moved from the existing surface roads into the proposed tunnels.

The project is predicted to result in road traffic noise levels that exceed the criteria and increase by 2 dB(A) or more (compared to the ‘Do minimum’ scenario) during the day and night periods in the same locations in Balgowlah and Seaforth to Frenchs Forest as for the ‘Do something’ scenario. Traffic calming measures would be designed and implemented in consultation with Northern Beaches Council to ensure impacts due to potential increased traffic are minimised (refer to environmental management measure ONV3 in Table 11-12).

As for the ‘Do something’ scenario, with the exception of Wakehurst Parkway at Frenchs Forest and certain local roads in Seaforth, North Balgowlah and Balgowlah indicated above, the majority of properties that are eligible for consideration of noise mitigation beyond the adoption of road design and traffic management measures (refer to Section 11.3.3) are due to predicted exceedances of the cumulative limit and acute noise levels, rather than increases due to the project. This indicates that existing road traffic noise levels, rather than changes due to the project, are the main driver for additional noise mitigation.

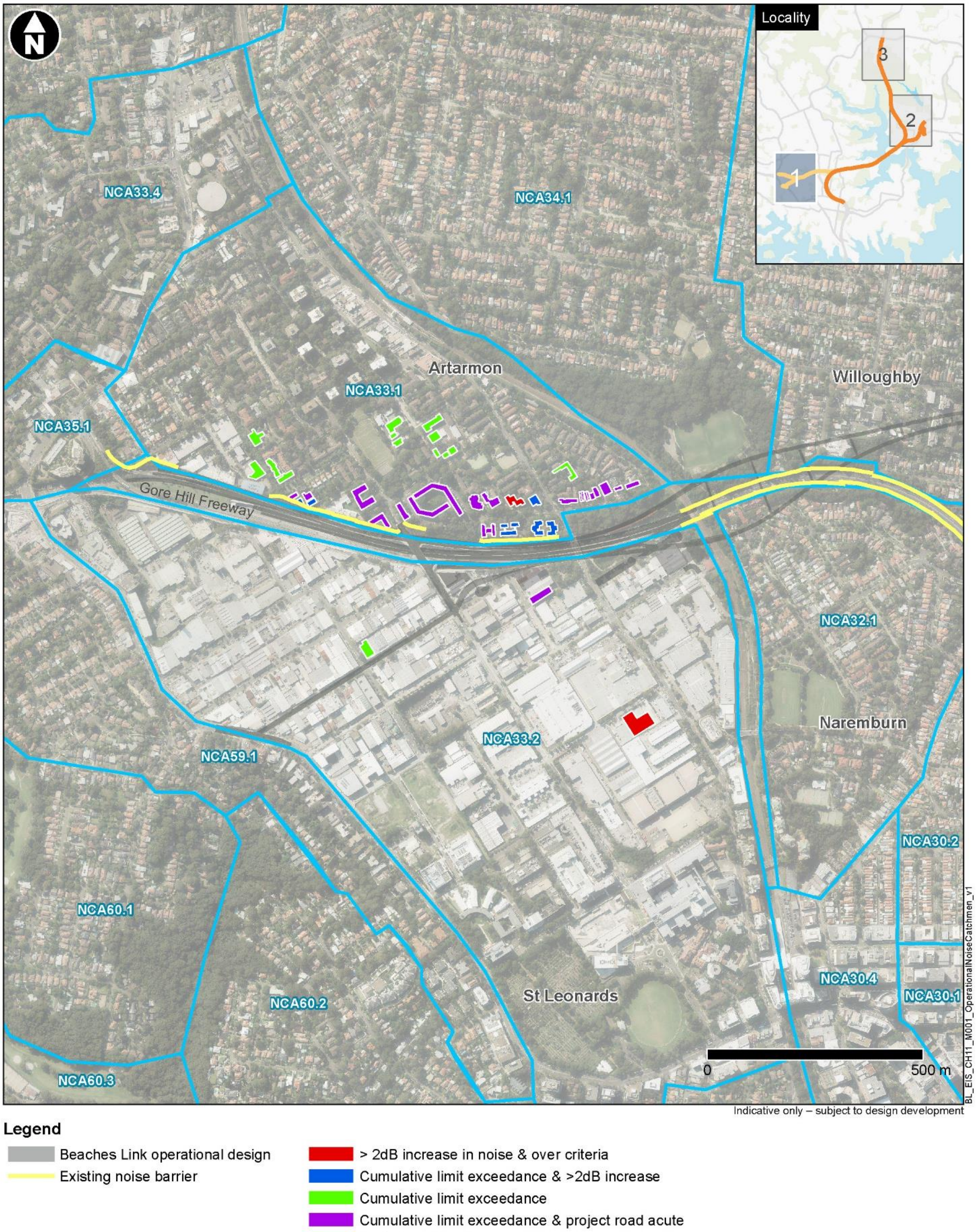
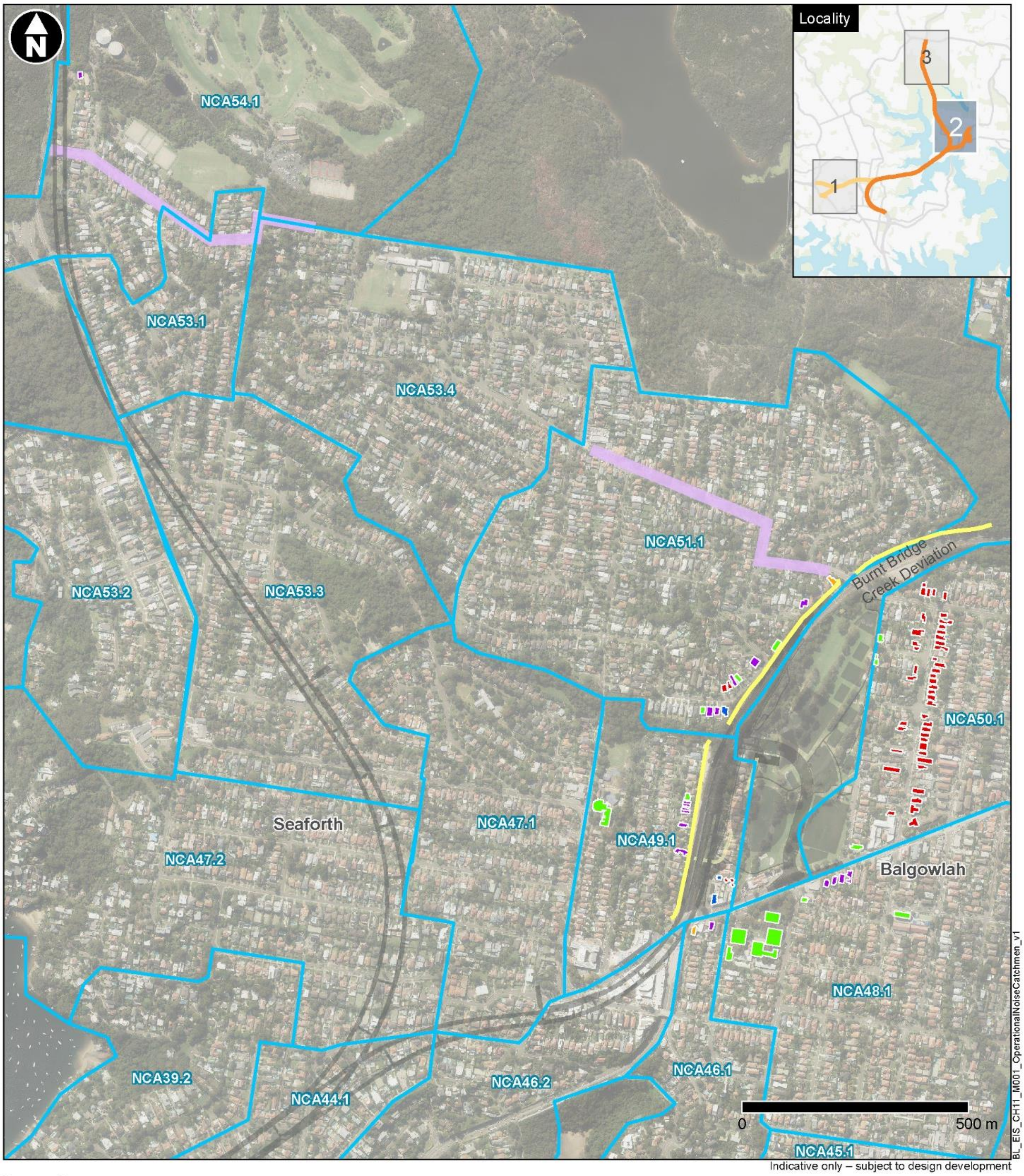


Figure 11-1 Receiver buildings eligible for consideration of additional noise mitigation (map 1)



Legend

- Beaches Link operational design
- Existing noise barrier
- > 2dB increase in noise & over criteria
- Cumulative limit exceedance & >2dB increase
- Cumulative limit exceedance
- Cumulative limit exceedance & project road acute
- Project road acute
- Potential >2 dB increase

Figure 11-2 Receiver buildings eligible for consideration of additional noise mitigation (map 2)

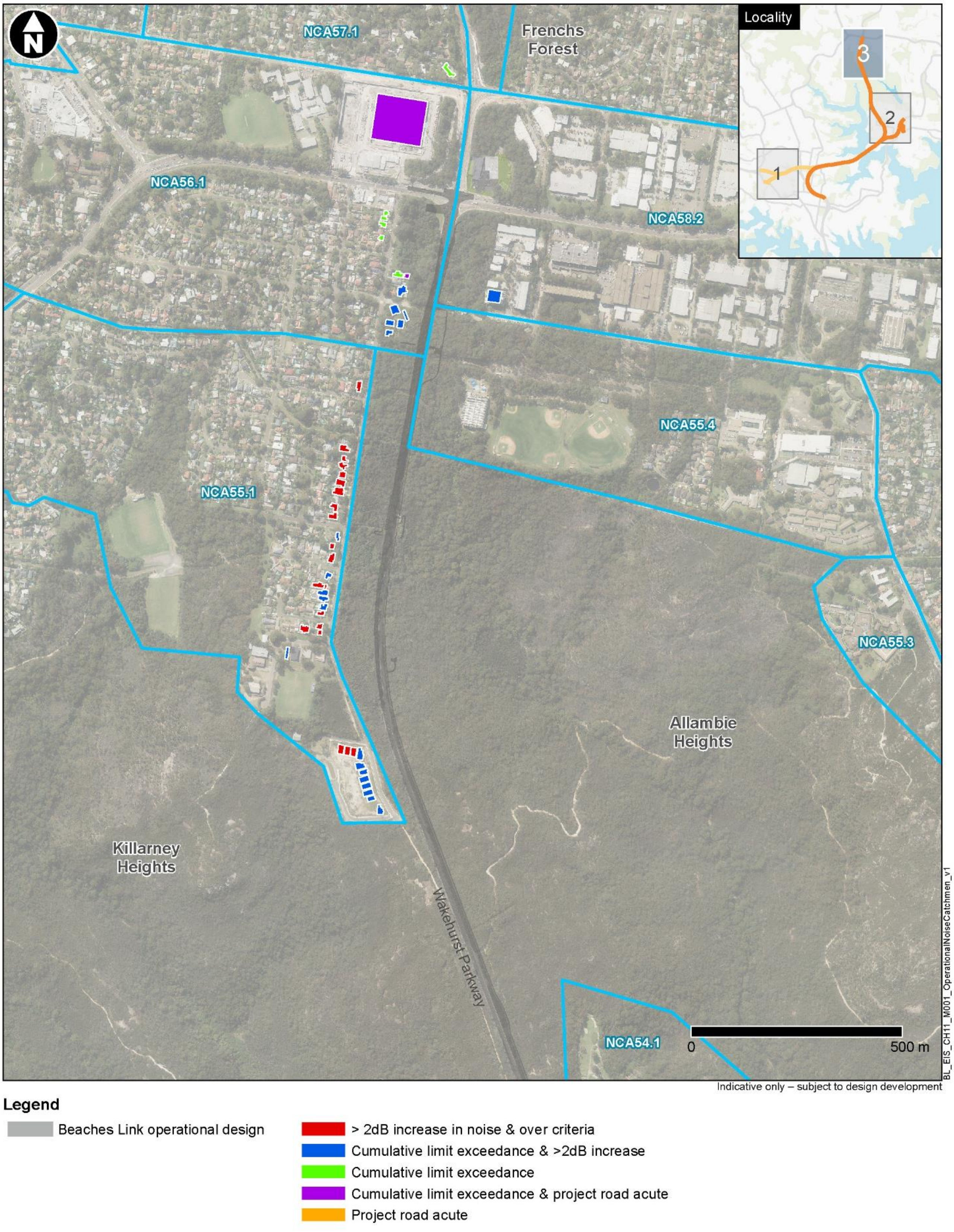


Figure 11-3 Receiver buildings eligible for consideration of additional noise mitigation (map 3)

11.5.3 Mitigation of road traffic noise

Quieter pavements

Noise Mitigation Guideline (Roads and Maritime Services, 2015g) sets out that quieter pavement is the preferred form of noise mitigation for road traffic noise as it reduces source noise levels and provides protection to both external and internal sensitive areas and also has the least visual impact. Quieter pavements may be considered where there are groups of four or more closely spaced receivers (ie facades are separated by less than 20 metres) that exceed the *Noise Criteria Guideline* (Roads and Maritime Services, 2015f). Quieter pavement, however, is not always appropriate for engineering reasons (durability) based on likely traffic conditions and does not always provide reasonable attenuation based on likely traffic speed. Quieter pavement is not, therefore, appropriate in all locations and situations.

For the purpose of operational noise assessment, quieter pavements, such as open grade asphalt or similar, has been assumed for sections of Gore Hill Freeway and Burnt Bridge Creek deviation affected by the project. A 2 dB(A) noise reduction (compared to dense graded asphalt) has been assumed for the quieter pavements. The resultant road traffic noise levels have been used to consider additional mitigation required.

The use of quieter pavements to reduce operational road traffic noise would continue to be investigated during further design development. Pavements would ultimately be selected by balancing performance, design life, durability, serviceability and noise emissions.

Noise barriers

Noise barriers are considered reasonable and feasible where four or more receivers are predicted to experience noise levels that exceed the noise criteria and are closely grouped (ie facades are separated by less than 20 metres), where the barriers do not make access to properties difficult, and where they are visually acceptable.

The process provided in *Noise Mitigation Guideline* (Roads and Maritime Services, 2015g) was used to identify the design barrier height for each existing barrier and new barrier proposed in the areas affected by the project. The feasibility of each barrier at the identified design height was then evaluated by considering engineering constraints, constructability constraints, land and property impacts, potential over shadowing, visual amenity and other environmental considerations in accordance with the process provided in *Noise Mitigation Guideline* (Roads and Maritime Services, 2015g). For a number of the proposed new and existing barriers, the identified design height is not feasible and reasonable based on these considerations. For the proposed new barriers, an alternative feasible and reasonable barrier height is proposed. The alternative barrier heights were assessed to confirm that they provide appropriate noise attenuation benefits. The existing barriers were also assessed. As they provide appropriate attenuation, the existing barriers would be retained at the existing heights. The alternative barrier heights and existing barriers were then assessed to identify which property would be eligible for consideration for at-property treatment.

The noise barrier analysis is presented in Table 7-7 and Annexure N in Appendix G (Technical working paper: Noise and vibration). A summary of indicative noise barriers proposed as part of the project is provided in Table 11-8. Chapter 5 (Project description) provides the locations of the proposed new and existing retained noise barriers relevant to the Beaches Link and Gore Hill Freeway Connection project. New noise barriers have not been proposed as a result of the connection to and from the Burnt Bridge Creek Deviation due to reasonable and feasible considerations (see Table 7-7 of Appendix G (Technical working paper: Noise and vibration) for further discussion).

The proposed new and upgraded noise barriers along Warringah Freeway described in Appendix G (Technical working paper: Noise and vibration) would be delivered as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project and are not included here.

The details of new barriers, any changes to existing barriers and the eligibility and suitability of receiver buildings for at-property treatment would be confirmed during detailed design (refer to environmental management measure ONV1 in Table 11-12 below).

Table 11-8 Summary of indicative new noise barriers

Approximate location	Barrier considered	Approx. length (metres)	Barrier height (metres)
Gore Hill Freeway			
Northern side, between Hampden Road, Artarmon and the T1 North Shore and Western and T9 Northern rail lines	New	263	5
Wakehurst Parkway			
Western side, adjacent to Bayview Close, Frenchs Forest	New	339	5
Western side, south from Yarraman Avenue Walkway bus stop, Frenchs Forest	New	253	4

Receiver buildings potentially eligible for consideration of additional noise mitigation

Further assessment has been conducted to compare the 'Do minimum' and the 'Do something cumulative' scenarios, including proposed quieter pavements (eg open grade asphalt where functionality appropriate) and proposed new and existing retained noise barriers.

Table 11-9 identifies the number of receivers to be considered for at-property treatment after the potential benefits of quieter pavements and new and existing retained noise barriers have been included. At-property treatments may include but are not limited to mechanical ventilation, glazing, window and door seals, sealing of vents and sealing of underfloor areas.

Noise mitigation options (quieter pavements, noise barriers, at-property treatment or a combination) will be confirmed as part of the further design development taking into consideration community preferences (refer to environmental management measure ONV1 in Table 11-12).

Due to the widening of the Burnt Bridge Creek Deviation and the Wakehurst Parkway and the predicted increase in traffic volumes due to the project and other major road projects, the overall number of receiver buildings at which road traffic noise levels are predicted to exceed the noise criteria during the day and night periods is predicted to increase compared to the 'Do Minimum' scenario. Receivers along some local roads in Balgowlah, North Balgowlah and Seaforth are predicted to experience traffic noise levels increasing by more than 2 dB(A) due to operational road traffic volume increases (refer to Section 11.5.2). This has resulted in a large number of receivers being considered for at-property treatment. Transport for NSW will investigate the implementation of traffic calming on the affected local roads with the aim of limiting road traffic noise increases to no more than 2 dB(A) in consultation with Northern Beaches Council to reduce road traffic noise impact at these receivers (refer to environmental management measure ONV3 in Table 11-12).

Annexure R of Appendix G (Technical working paper: Noise and vibration) shows the locations of receiver buildings identified in Table 11-9. It is noted that Annexire R includes properties along Warringah Freeway and in adjacent areas. Mitigation for road traffic noise, including at-property treatment, for Warringah Freeway and surrounds would be carried out as part of the Western Harbour Tunnel and Warringah Freeway Upgrade, and are not considered further here.

The properties that are eligible for consideration for at-property treatments, with all other proposed mitigations in place, would be confirmed during further design development in accordance with the process in *Noise Mitigation Guideline* (Roads and Maritime Services, 2015g).

Table 11-9 Number of receivers considered for at–property treatment[1]

NCA[2]	Location	Number of receiver floors[3]	Number of receiver buildings
Gore Hill Freeway and Artarmon			
33.1	Artarmon	79	42
33.2	Artarmon	13	3
	Total	**92**	**45**
Balgowlah and surrounds			
46.1	Balgowlah	4	2
48.1	Balgowlah	23	10
49.1	Seaforth	16	13
50.1	Balgowlah	63	47
51.1	North Balgowlah	72	62
	Total	**178**	**134**
Seaforth to Frenchs Forest			
53.1	Seaforth	15	11
53.4	North Balgowlah	1	1
54.1	Seaforth	36	30
55.1	Forestville	14	11
56.1	Frenchs Forest	14	12
57.1	Frenchs Forest	15	2
58.2	Frenchs Forest	6	1
	Total	**101**	**68**
Project Total		**371**	**247**

Note 1: Number of receivers considered for at-property treatment would be subject to further design development and confirmation of all proposed mitigations measures, and would be based on the resultant predicted road traffic noise levels
Note 2: Refer to Figure 10-1 in Chapter 10 (Construction noise and vibration) for location of noise catchment areas
Note 3: Receiver floors represent the individual receiver floor levels of a multi-level building. For example, a ten-storey residential apartment block would have ten receiver floors and one receiver building.

11.5.4 Maximum road traffic noise level

Where road traffic noise dominates the noise environment, maximum noise levels (mainly generated by heavy vehicles) have the potential to cause disturbance to sleep.

Changes in the maximum noise levels and the number of events generating these levels would depend on changes in traffic volumes and changes on road alignment or width. The project is predicted to increase maximum noise level events at sensitive receivers within the following noise catchment areas:

- NCA 23.1 located in Neutral Bay– sensitive receivers to the east of the Warringah Freeway are predicted to experience an increase in maximum noise levels and the number of events compared to the existing situation due to the widening of the Warringah Freeway resulting in the southbound carriageway moving closer to receivers in this NCA
- NCAs 49.1 and 50.1 located in Seaforth and Balgowlah – sensitive receivers to the west and east of the new access road which forms part of the connections to and from Burnt Bridge

Creek Deviation are predicted to experience an increase in maximum noise levels and the number of events compared to the existing levels due to traffic along the new access road between Sydney Road and the Burnt Bridge Creek Deviation. The new access road would include traffic lights at Sydney Road and the Burnt Bridge Creek Deviation, which would contribute to the increase in maximum noise levels and the number of events. Furthermore, new bus stops along the new access road would also introduce maximum noise levels and events to these receivers

- NCA 48.1 located in Balgowlah – sensitive receivers to the south of the new access road intersection with Sydney Road are predicted to experience an increase in maximum noise levels and the number of events compared to the existing situation. This is due to the new traffic lights on Sydney Road impacting receivers in this NCA
- NCA 55.1 located in Frenchs Forest– sensitive receivers to the west of the new access road intersection with the Burnt Bridge Creek Deviation are predicted to experience an increase in maximum noise levels and the number of events compared to the existing situation. This is due to the new traffic lights on the Burnt Bridge Creek Deviation impacting receivers in this NCA
- NCAs 54.1 and 55.1 located in Seaforth, Allambie Heights, Killarney Heights and Frenchs Forest – sensitive receivers to the east and west of Wakehurst Parkway are predicted to experience an increase in maximum noise levels and the number of events compared to the existing situation. This is due to the realignment and upgrade of Wakehurst Parkway resulting in both the northbound and southbound carriageways moving closer to receivers and the introduction of new traffic light intersections or new bus stops in these NCAs, which in turn are likely to increases maximum noise levels and the number of events at the affected receivers.

Maximum noise levels are not expected to significantly change as a result of the project within other noise catchment areas where no major road realignments or widening would be carried out.

Changes in maximum noise levels are a consideration when prioritising and ranking mitigation strategies and will be considered during further design development. Mitigation measures to be considered are described in Section 11.8.

11.5.5 Operational facilities

Table 11-10 compares predicted fixed facility noise levels with *Noise Policy for Industry* (NSW EPA, 2017a) intrusiveness and amenity criteria. No criteria exceedances are predicted. Noise predictions and assessment of operational fixed facilities will be updated when actual types, makes and models of the plant and equipment are confirmed.

Table 11-10 Predicted noise levels ($L_{Aeq(15 minute)}$)[1] from fixed facilities, dB(A)

Fixed facility location	NCA[2]	Project noise criteria[3]		Predicted noise level
		Intrusiveness	Amenity	
Warringah Freeway	NCA 23.1	49	43	39
	NCA 23.2	42	43	39
	NCA 24.1	42	43	37
	NCA 25.1	48	43	36
	NCA 26.1	46	43	38
	NCA 26.2	42	43	40
	NCA 29.1	52	43	35

Fixed facility location	NCA[2]	Project noise criteria[3]		Predicted noise level
		Intrusiveness	Amenity	
Gore Hill Freeway	NCA 32.1	45	43	<35
	NCA 33.1	51	43	38
	NCA 33.2[4]	N/A	68	45
Burnt Bridge Creek Deviation	NCA 49.1	36	43	<35
	NCA 50.1	40	43	<35
	NCA 51.1	41	43	38
Wakehurst Parkway	NCA 54.1	35	43	<35

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

Note 2: Refer to Figure 10-1 in Chapter 10 (Construction noise and vibration) for location of noise catchment areas

Note 3: Project noise levels based on night-time period. Most stringent criteria used for assessment is shown in bold font

Note 4: Noise catchment area 33.2 in Artarmon comprises industrial premises only.

11.6 Assessment of open space and recreation facilities at Balgowlah

Noise impacts from the proposed new and improved open space and recreation facilities at Balgowlah have been determined through noise modelling of typical activities associated with the facilities. The indicative layout of these facilities at Balgowlah provided in Chapter 5 (Project description) was subject to assessment, and noise predictions are based on all the playing fields, courts, playgrounds and carpark areas operating concurrently (conservative).

The indicative layout of these facilities at Balgowlah would comply with the noise criterion at sensitive receivers in NCA 48.1 located in Balgowlah south of Sydney Road. However, some sensitive receivers in NCA 50.1 located in Balgowlah north of Sydney Road and east of the Burnt Bridge Creek Deviation may potentially experience noise exceedances during periods where all activities at the facilities are occurring concurrently.

A dedicated consultation process, jointly led by Transport for NSW and Northern Beaches Council will, is proposed to give the community an opportunity to provide input into the final layout of the new and improved open space and recreation facilities at Balgowlah. This consultation would be separate to the consultation for the Beaches Link environmental impact statement. The final layout would be designed to meet intrusive noise criteria derived in accordance with the *Noise Guide for Local Government* (NSW EPA, 2013b) where reasonable and feasible. The final layout would be subject to further noise assessment to confirm the need for and details of any noise additional attenuation required.

Refer to Annexure U of Appendix G (Technical working paper: Noise and vibration) for the location of receiver buildings identified in Table 11-11.

Table 11-11 Predicted noise levels ($L_{Aeq(15\ minute)}$)[1] from the new and improved open space and recreation facilities, dB(A) and potential exceedances based on indicative layout

NCA	Location	Noise criteria	Predicted noise level	Number of exceedances
48.1	Balgowlah	55	52	-
50.1	Balgowlah	50	56	6

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

11.7 Assessment of operational impacts – vibration

The potential for operational ground-borne noise and tactile vibration impacts on nearby sensitive receivers from traffic on project surface roads and tunnels has been reviewed.

Vehicles operating on a roadway are unlikely to cause a perceptible level of vibration unless there are significant road irregularities (eg potholes), particularly if the affected receiver is more than 20 metres from the roadway.

As the new and upgraded roads on the surface and in the tunnels associated with the project would be designed and constructed to avoid road irregularities, operational ground-borne noise and tactile vibration impacts from operation traffic are not expected.

Vibration impacts from traffic travelling on the proposed surface roads, through tunnels and portals are considered negligible and are unlikely to result in ground-borne noise or tactile vibration impacts to sensitive receivers directly adjacent to surface roads, tunnels and portals.

Similarly, vibration from operational fixed facilities is not anticipated to exceed objectives given the distance between these facilities and the nearest sensitive receiver.

11.8 Environmental management measures

Environmental management measures for potential noise and vibration impacts during operation are outlined in Table 11-12. Additional measures to address cumulative impacts are included in Chapter 27 (Cumulative impacts).

Table 11-12 Environmental management measures – operational noise and vibration

Ref	Phase	Impact	Environmental management measure	Location
ONV1	Operation	Operational road traffic noise	The operational noise performance of the project will be reviewed during further design development and functionally appropriate operational noise mitigation (quieter pavements eg open grade asphalt, noise barriers, at-property treatments or a combination of treatments) will be confirmed in accordance with *NSW Road Noise Policy* (DECCW, 2011), *Noise Criteria Guideline* (Roads and Maritime Services, 2015f) and *Noise Mitigation Guideline* (Roads and Maritime Services, 2015g).	BL/GHF
ONV2	Operation	Operational road traffic noise	Within 12 months of the commencement of the operation of the project, actual operational noise performance will be compared to predicted operational noise performance (as reviewed during further design development) to analyse the effectiveness of the operational road traffic noise mitigation measures. Additional reasonable and feasible mitigation will be considered where any additional receivers are identified as qualifying for consideration of noise mitigation in accordance with the *Noise Mitigation Guideline* (Roads and Maritime Services, 2015g).	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
ONV3	Design and construction	Operational road traffic noise	For local roads in Balgowlah, North Balgowlah and Seaforth where predicted increases in traffic are likely to result in exceedances of the relevant road traffic noise criteria, traffic calming measures with the aim of limiting potential road traffic noise increases to no more than 2 dB(A) will be investigated in consultation with Northern Beaches Council and implemented. As a minimum, traffic calming measures will be investigated for Wanganella Street at Balgowlah, Woodbine Street at Balgowlah and Judith Street at Seaforth. The need for at-property treatments will be confirmed during further design development and will consider the potential impact of the proposed traffic calming measures on traffic volumes and speeds.	BL
ONV4	Operation	Operational facilities noise	Operational fixed facilities will be designed to meet project specific noise criteria derived in accordance with the *Noise Policy for Industry* (NSW EPA, 2017a).	BL/GHF
ONV5	Operation	Sporting and recreation noise impacts	Open space and recreation facilities at Balgowlah will be designed to meet intrusive noise criteria derived in accordance with the *Noise Guide for Local Government* (NSW EPA, 2013b) where reasonable and feasible. The final layout will be subject to further noise assessment to confirm the need for and details of any additional noise attenuation required.	BL

BL = Beaches Link, GHF = Gore Hill Freeway Connection

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 12

Air quality

12 Air quality

This chapter outlines the potential air quality impacts associated with the project and identifies measures which address these impacts. A detailed air quality impact assessment has been carried out for the project and is included in Appendix H (Technical working paper: Air quality).

An assessment of potential human health impacts associated with air quality is provided in Chapter 13 (Human health).

The Secretary's environmental assessment requirements as they relate to air quality, and where in the environmental impact statement these have been addressed, are detailed in Table 12-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to air quality are included in Section 12.7.

Table 12-1 Secretary's environmental assessment requirements – air quality

Secretary's requirements	Where addressed in EIS
Air quality	
1. The Proponent must undertake an air quality impact assessment (AQIA) for construction and operation of the project in accordance with the current guidelines.	**Appendix H** (Technical working paper: Air quality) documents the air quality impact assessment undertaken for the project in accordance with current guidelines. **Chapter 12** provides the air quality impacts related to the project. **Section 12.5** and **Section 12.6** outline the potential air quality impacts of the construction and operation of the project respectively.
2. The Proponent must ensure the AQIA also includes the following: a. Demonstrated ability to comply with the relevant regulatory framework, specifically the *Protection of the Environment Operations Act 1997* and the Protection of the Environment Operations (Clean Air) Regulation 2010;	**Section 12.1** outlines information in respect to the *Protection of the Environment Operations Act 1997* and the Protection of the Environment Operations (Clean Air) Regulation 2010. **Section 12.6** outlines the compliance of the project with relevant criteria and regulatory requirements.
b. The identification of all potential sources of air pollution including details of the location, configuration and design of all potential emission sources including ventilation systems and tunnel portals;	The methodology for identifying all potential sources of air pollution during construction and operation are outlined in **Section 12.2**. Details of potential sources of air pollution are provided in **Section 12.4**, **Section 12.5** and **Section 12.6**. The configuration and design of ventilation systems and tunnel portals are described and shown in **Chapter 5** (Project description).
c. A review of vehicle emission trends and an assessment that uses or sources	Best available information on vehicle emission trends are presented in **Section 12.4**.

Secretary's requirements	Where addressed in EIS
best available information on vehicle emission factors;	
d. An assessment of impacts (including human health impacts) from potential emissions from PM_{10}, $PM_{2.5}$, CO, NO_2, and other nitrogen oxides and volatile organic compounds (eg BTEX) including consideration of short and long term exposure periods;	An assessment of impacts of air pollutants during short and long term exposure periods are outlined in **Section 12.6**. Impacts to human health due to the operation of the project is provided in **Section 13.5** of **Chapter 13** (Human health).
e. Consider the impacts from the dispersal of these air pollutants on the ambient air quality along the proposal route, proposed ventilation outlets and portals, surface roads, ramps and interchanges and the alternative surface road network;	An assessment of impacts from the dispersal of air pollutants on ambient air quality along the project alignment is outlined in **Section 12.6**.
f. A qualitative assessment of the redistribution of ambient air quality impacts compared with existing conditions, due to the predicted changes in traffic volumes;	A qualitative assessment of the redistribution of ambient air quality impacts in comparison to existing conditions is presented in **Section 12.6.3**.
g. Assessment of worst case scenarios for in-tunnel and ambient air quality, including a range of potential ventilation scenarios and range of traffic scenarios, including worst case design maximum traffic flow scenarios (variable speed) and the worst case breakdown scenario, and discussion of the likely occurrence of each;	**Section 12.6** outlines the assessment of in-tunnel air quality in addition to the assessment of issues related to ambient air quality.
h. Details of the proposed tunnel design and mitigation measures to address in-tunnel air quality and the air quality in the vicinity of portals and any mechanical ventilation systems (ie ventilation outlets and air inlets) including details of proposed air quality monitoring (including frequency and criteria);	Details of the proposed tunnel design and monitoring are presented in **Chapter 5** (Project description), while mitigation and management measures in relation to in-tunnel air quality and air quality in the vicinity of portals and mechanical ventilation systems are outlined in **Section 12.7.2**.
i. A demonstration of how the project and ventilation design ensures that concentrations of air emissions meet NSW, national and international best practice for in-tunnel and ambient air quality, and taking into consideration the approved criteria for the M4 East project, New M5 project and the In-Tunnel Air Quality (Nitrogen Dioxide) Policy;	Information relating to the design standard of the proposed ventilation system for the project is provided in **Chapter 5** (Project description). Criteria applied in this assessment are discussed in **Section 12.1** and **Section 12.3**. The project and ventilation system have been designed to meet in-tunnel criteria and ambient air quality goals and criteria as outlined in **Section 12.3**.
j. Details of any emergency ventilation systems, such as air intake/exhaust outlets, including protocols for the operation of these systems in	Details of any emergency ventilation systems, such as air intake/ventilation outlets, including protocols for the operation of these systems in emergency situations, potential emission of air

Secretary's requirements	Where addressed in EIS
emergency situations, potential emission of air pollutants and their dispersal, and safety procedures;	pollutants and their dispersal, and safety procedures are presented in **Chapter 5** (Project description).
k. Details of in-tunnel air quality control measures considered, including air filtration, and justification of the proposed measures or for the exclusion of other measures;	Details of in-tunnel air quality control measures considered, including air filtration, and justification of the proposed measures or for the exclusion of other measures are outlined in **Section 12.7.2** and expanded upon in **Chapter 5** (Project description). **Chapter 4** (Project development and alternatives), **Section 4.5** provides the ventilation system design alternatives.
l. A description and assessment of the impacts of potential emission sources relating to construction, including details of the proposed mitigation measures to prevent the generation and emission of dust (particulate matter and TSP) and air pollutants (including odours) during the construction of the proposal, particularly in relation to ancillary facilities (such as concrete batching plants), dredge and tunnel spoil handling and storage, the use of mobile plant, stockpiles and the processing and movement of spoil; and	A description and assessment of impacts relating to potential emission sources relating to construction are outlined in **Section 12.5**, while mitigation measures to prevent the generation and emission of dust and other air pollutants (including odours) are presented in **Section 12.7.1** of this chapter.
m. A cumulative assessment of the in-tunnel, local and regional air quality impacts from the operation of the project and due to the operation of and potential continuous travel through motorway tunnels and surface roads.	The cumulative assessment of the in-tunnel, local and regional air quality impacts, as well as consideration of continuous travel through motorway tunnels, is outlined in **Section 12.6**.

12.1 Legislative and policy framework

The *Protection of the Environment Operations Act 1997* (NSW) allows the NSW Environment Protection Authority to regulate air emissions in NSW. Further, it specifies that road tunnel emissions are regulated by the NSW Environment Protection Authority. The Secretary's environmental assessment requirements for the project refer to the *Protection of the Environment Operations Act 1997* and the Protection of the Environment Operations (Clean Air) Regulation 2010*.* Although the Protection of the Environment Operations (Clean Air) Regulation 2010 specifies concentration limits for air emissions, these limits are designed primarily for industrial activities and the limit values are much higher than those imposed for motorway tunnels in Sydney.

The monitoring and management of dust emissions during construction and the ventilation outlet emissions during operation would be regulated under an Environment Protection Licence prescribed under the *Protection of the Environment Operations Act 1997*.

In February 2018, the NSW Government announced stronger measures on emissions from motorway tunnels and then established a new process for the assessment, determination, and compliance of significant road tunnels (and associated ventilation systems). The process, which applies to this project, is summarised below:

- Prior to public exhibition of the environmental impact statement:

- The Office of the Chief Scientist and Engineer (OCSE) provides a scientific review of a project's air emissions from ventilation outlets for the Minister of Planning and Public Spaces' consideration
- The NSW Chief Health Officer releases a statement on the potential health impacts of emissions from the tunnel ventilation outlets informed by the review by the OCSE

- The NSW Environment Protection Authority provides technical advice to the Department of Planning, Industry and Environment on operational air quality impacts during the assessment of the environmental impact statement
- The Department of Planning, Industry and Environment seeks advice from an independent air quality expert during the assessment of the environmental impact statement, if required
- If the project is approved, the Department of Planning, Industry and Environment regulates the construction and operation of the project in accordance with the project approval
- The NSW Environment Protection Authority licenses emissions from the ventilation outlets under the *Protection of the Environment Operations Act 1997*.

As part of the preparation of the air quality impact assessment for the project, Appendix H (Technical working paper: Air quality) was issued to the Office of the Chief Scientist and Engineer on 26 October 2020, and the Advisory Committee on Tunnel Air Quality (ACTAQ) coordinated a scientific review of the project's air emissions from ventilation outlets.

For the operating years of the project, nitrogen dioxide (NO_2) would be the pollutant that determines the required airflow and drives the design of the tunnel ventilation system. In February 2016, the ACTAQ issued a policy entitled *'In-tunnel air quality (nitrogen dioxide) policy'* (ACTAQ, 2016). The policy consolidates the approach taken for similar projects (NorthConnex, New M4 and M8 Motorway), and requires tunnels to be 'designed and operated so that the tunnel average NO_2 concentration is less than 0.5 parts per million (ppm) as a rolling 15 minute average'. In 2018, ACTAQ released *Technical Paper TP07: Criteria for In-tunnel and Ambient Air Quality* (ACTAQ, 2018a), which concluded that the NO_2 criterion is the most stringent in Australia and compares favourably to the international in-tunnel NO_2 design guidelines which range from between 0.4 ppm to 1 ppm. The ventilation system would be designed to achieve this criterion.

With regards to regional air quality, the NSW Environment Protection Authority has developed a *Tiered Procedure for Estimating Ground Level Ozone Impacts from Stationary Sources* (ENVIRON, 2011). This procedure was applied to the air quality impact assessment of the project to give an indication of the likely significance of the project's effect on ozone concentrations in the broader Sydney region.

The in-tunnel and ambient air quality assessment was carried out against criteria, or levels of pollutants, that have been adopted by the NSW Government. Schedule 4 of the Protection of the Environment Operations (Clean Air) Regulation 2010 specifies standards of concentrations for general activities and plant. The project was assessed against the air quality criteria listed in the *Modelling and Assessment of Air Pollutants in NSW* (NSW EPA, 2016) (NSW EPA Approved Methods) as the statutory method used for assessing air pollution from stationary sources.

Odour emissions would be assessed and managed in accordance with the *Technical framework for the assessment and management of odour from stationary sources in NSW* (DEC, 2006a). This framework introduces a system that protects the environment and the community from the impacts of odour emissions, while promoting fair and equitable outcomes for the operators of activities that emit odour.

12.2 Assessment methodology

12.2.1 Overview

The assessment methodology for air quality impacts has included the following key tasks:

- Assessment of potential dust impacts and odour impacts on sensitive receivers during construction of the project
- Assessment to ensure the tunnel ventilation system can achieve acceptable in-tunnel air quality outcomes for carbon monoxide, nitrogen dioxide and visibility during operation of the project
- Modelling of changes in the concentrations of key pollutants at community, residential, workplace and recreational receiver locations for expected traffic and operation of the project under a number of worst case operational scenarios
- Assessment of regional air quality impacts associated with the operation of the project
- Prediction of changes in the levels of three representative odorous pollutants (toluene, xylenes, and acetaldehyde) at receivers with the operation of the project.

The methodology for the assessment of both construction and operational air quality impacts, as well as the modelling inputs and assumptions used to carry out this assessment is provided in full at Appendix H (Technical working paper: Air quality).

12.2.2 Construction air quality assessment methodology

Air quality impacts as a result of construction of the project include those associated with exhaust emissions from tunnelling operations, and from the generation of dust and odour.

Exhaust emissions during construction would occur due to the use of some plant and equipment. These impacts are considered to be minor and unlikely to have a noticeable impact on the surrounding environment including sensitive receivers. Any impacts associated with exhaust emissions would be managed through the environmental management measures described in Section 12.7.

Some construction activities could also result in the generation of dust and odours. The assessment methodology for the air quality impacts associated with the generation of dust and odour are described below.

Dust assessment

For the purpose of the construction dust assessment, construction activities have been categorised into four types to reflect their potential impacts:

- Demolition is any activity that involves the removal of existing structures
- Earthworks covers the processes of topsoil stripping, ground levelling, excavation (including blasting) and landscaping and primarily involves excavating, loading, hauling, tipping and compaction of material including stockpiling where required
- Construction is any activity that involves the provision of new structures, or modification or refurbishment of existing structures, including buildings, ventilation outlets and roads
- Track-out involves the transport of dust and dirt from the construction/demolition site onto the public road network using construction vehicles. These materials may then be deposited and re-suspended by vehicles using the road network.

It is difficult to quantify dust emissions from construction activities since it is not possible to predict the weather conditions that would prevail during specific construction activities. The effects of construction on airborne particulate matter would generally be temporary and of relatively short duration, and mitigation should be straightforward since dust suppression measures are routinely employed as ‘good practice’ at most construction sites.

A semi-quantitative, risk-based approach was used for the assessment in accordance with the United Kingdom Institute of Air Quality Management’s *Guidance on the assessment of dust from demolition and construction* (Institute of Air Quality Management (IAQM), 2014). The IAQM guidance has been adapted for use in NSW, taking into account factors such as the assessment criteria for ambient PM_{10} (being particulate matter less than or equal to 10 micrometres in diameter) concentrations. The potential construction air quality impacts were assessed based on the proposed works, plant and equipment, and the potential emission sources and levels. The assessment considered the risk of dust deposition and elevated concentrations of dust (as PM_{10}) in the air from construction activities, and potential impacts on amenity, human health and the environment.

The IAQM guidance (IAQM, 2014) specifies that a dust assessment is required where:

- Human receivers are within 350 metres of the assessment zone boundary. A human receiver refers to any location where a person or property may experience the adverse effects of airborne dust or dust settlement, or exposure to dust emissions over a time period that is relevant to air quality standards and goals
- Ecological receivers are within 50 metres of the boundary of the assessment zone. An ecological receiver refers to any sensitive habitat or fauna affected by dust settlement.

Key steps in the assessment included:

- An initial screening to identify whether there is a risk of construction dust impacts based on the proximity of human and ecological receivers to construction activities
- A risk assessment to determine which construction activities have the potential to generate a dust impact based on the scale and nature of the activities, and the sensitivity of nearby human and ecological receivers
- Identification of appropriate dust mitigation and management measures depending on the level of assessment risk of impact.

Further details of the construction dust assessment methodology are provided in Appendix H (Technical working paper: Air quality) of this environmental impact statement. The assessment of construction dust using the IAQM guidance (IAQM, 2014) is outlined in Figure 12-1. The construction dust assessment carried out for the project is summarised in Section 12.5.1.

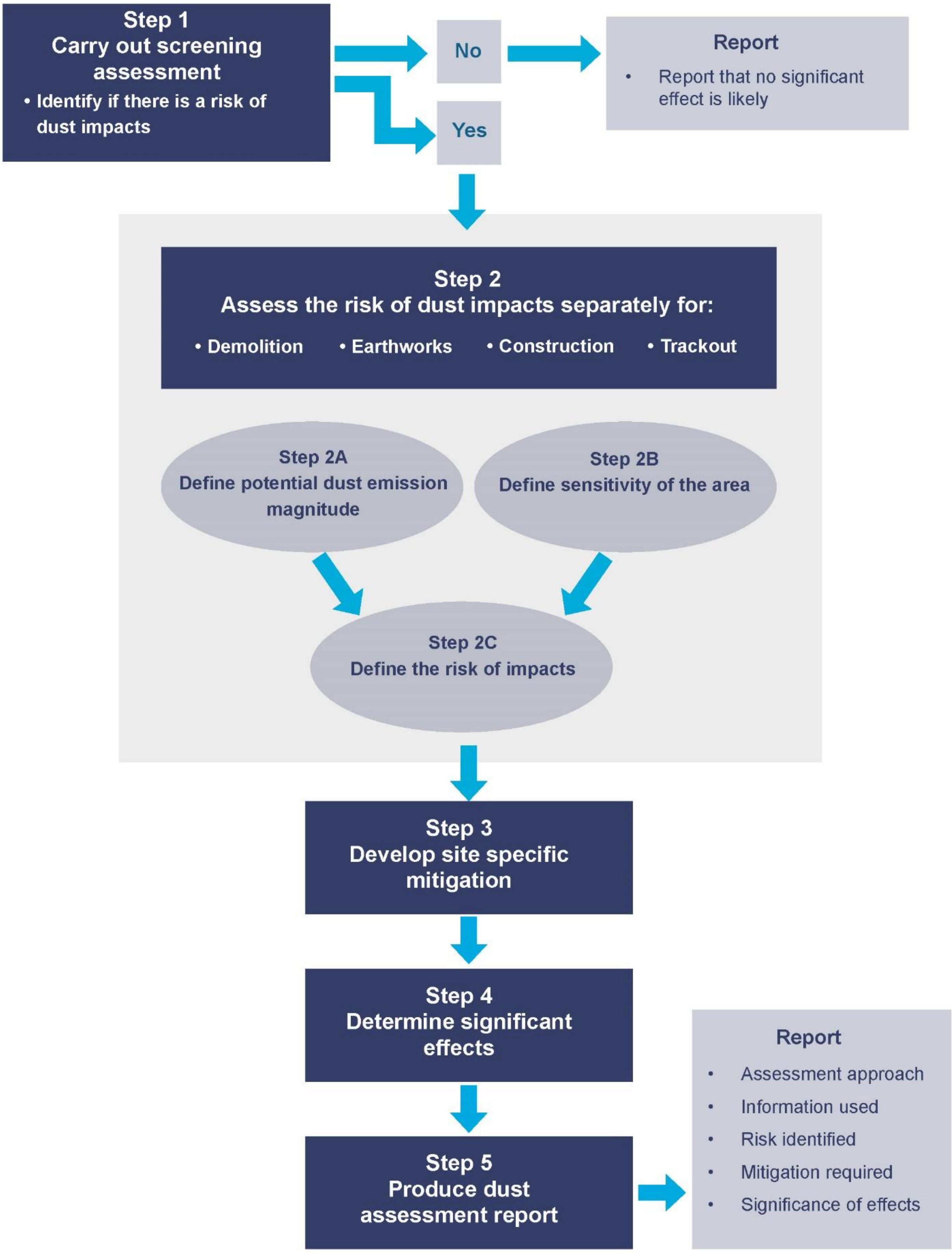


Figure 12-1 Construction dust assessment procedure (IAQM, 2014)

Odour assessment

During construction, there is the potential for odour impacts due to emissions from dredged or excavated material being exposed to air, temporarily stored and transported for treatment or disposal to landfill. As a location for temporary storage would be determined during detailed design, a qualitative assessment of odour impacts has been carried out and is discussed in Section 12.5.

12.2.3 Operational air quality assessment methodology

Air quality impacts from the operation of the project are associated with emissions from vehicles using the project. The impact of vehicle emissions was considered in terms of effects on in-tunnel air quality, local air quality, regional air quality and odour.

In-tunnel air quality

The tunnel ventilation system would be operated to achieve acceptable in-tunnel air quality outcomes for carbon monoxide (CO), NO_2 and visibility (as a measure of in-tunnel particulate matter concentrations) (refer to Section 12.3.2 for additional information relating to air quality criteria).

In-tunnel air quality modelling was carried out using IDA Tunnel software. The modelling considered traffic volumes, tunnel air flow and vehicle emission levels. The modelling incorporated the Beaches Link, Western Harbour Tunnel and WestConnex projects and considered the following scenarios:

- Expected traffic – 24-hour operation of the project ventilation system under day-to-day conditions of expected traffic demand in 2027 (planned opening date) and 2037
- Worst case traffic – the most onerous traffic conditions for the ventilation system (refer below)
- Travel route scenarios – a worst case trip scenario for in-tunnel exposure to NO_2.

Operational worst case scenarios

Operational worst case scenarios consider emissions from traffic within the tunnels and represent the theoretical maximum pollutant concentrations for all potential traffic operations in the tunnel, including unconstrained traffic conditions from an emissions perspective, as well as vehicle breakdown situations. The operational worst case scenarios are conservative and result in pollutant emission concentrations that are much higher than those that could occur under any foreseeable operational conditions in the tunnel.

The operational worst case assessments of in-tunnel air quality considered worst case (variable speed) traffic operations and worst case (breakdown or major incident) operations.

The worst case (variable speed) traffic operation scenario represents the upper limit of daily operations on the ventilation system of the mainline and ramp tunnels, regardless of the year of operation and is based on the traffic flow splits of the predicted traffic peak periods with the tunnels reaching a theoretical maximum lane capacity traffic flow rate. This scenario also includes the highest predicted number of buses using the tunnels. The worst case (variable speed) traffic operation scenario was considered under four different average speeds for lane capacity; 20, 40, 60 and 80 kilometres per hour.

The worst case (breakdown or major incident) operation scenario assesses the most conservative case from a traffic perspective, where congestion that occurs as a result of a breakdown affects the longest length within the mainline and ramp tunnels. This worst case operational scenario assumes a breakdown would result in a complete blockage on the specific ramp causing traffic that would ordinarily use the mainline tunnel to take other routes.

In-tunnel air quality for extended journeys

The assessment for in-tunnel air quality for extended journeys considers the estimated average concentration of NO_2 for the longest potential journey that could be taken by motorists in the connected motorway network. This was identified as a journey that used the project, the Western Harbour Tunnel, WestConnex and the M6 Motorway (Stage 1) tunnel network.

Provided that each project satisfies the air quality criteria (which requires NO_2 concentrations to be below an average of 0.5 ppm over the trip length through each tunnel), the average through the entire network would remain at, or below, 0.5 ppm under all traffic conditions. For this assessment, the estimated journey assessment completed as part of the *WestConnex M4-M5 Link environmental impact statement* (Roads and Maritime Services, 2017a) has been combined with the in-tunnel modelling completed for the 'Do something cumulative 2037' scenario.

Ambient air quality

The potential impacts of the project on ambient air quality during operation were assessed in relation to CO, NO_2, PM_{10} and $PM_{2.5}$ (particulate matter less than or equal to 2.5 micrometre diameter) and air toxics (benzene, polycyclic aromatic hydrocarbons (PAHs), formaldehyde, 1,3-butadiene and ethylbenzene), in accordance with the NSW EPA Approved Methods or the *National Environment Protection (Ambient Air Quality) Measure* (National Environment Protection Council (NEPC), 2003b) as relevant. The pollutants and criteria considered are provided in Section 12.3.3.

The following terms have been used to describe the concentration of pollutants at a specific location or receiver:

- Background concentration describes all contributing sources of a pollutant concentration other than road traffic. It includes contributions from natural sources, industry and domestic activity
- Surface road concentration describes the contribution of pollutants from the surface road network. It includes not only the contribution of the nearest road at the receiver, but also the net contribution of the rest of the modelled road network at the receiver
- Tunnel portal concentration is the contribution from the portals of existing tunnels for which portal emissions are permitted (Sydney Harbour Tunnel and Eastern Distributor tunnel)
- Ventilation outlet concentration describes the contribution of pollutants from tunnel ventilation outlets
- Total concentration is the sum of the sources defined above: background, surface road and ventilation outlet concentrations. It may relate to conditions with or without the project under assessment
- The change in concentration due to the project is the difference between the total concentration with the project and the total concentration without the project (increase or decrease), depending on factors such as the redistribution of traffic on the network as a result of the project.

The modelling scenarios, modelling process, receivers considered and approach to the analysis of results are discussed below.

Modelling scenarios

Seven expected traffic scenarios were included in the operational air quality assessment and considered future changes in the composition and performance of the vehicle fleet, as well as predicted traffic speeds, traffic volumes and the distribution of traffic on the road network. Each expected traffic scenario is set out in Chapter 9 (Operational traffic and transport) and has been modelled from an air quality perspective in order to assess the potential air quality impacts of the traffic scenario. The expected traffic scenarios that were modelled are summarised in Table 12-2.

Table 12-2 Operational air quality assessment modelling – expected traffic scenarios

Scenario	Existing network	Western Harbour Tunnel and Warringah Freeway Upgrade	Beaches Link and Gore Hill Freeway Connection	WestConnex	Other projects		
					Sydney Gateway	M6 Motorway (Stage 1)	M6 Motorway (full project)
Scenario in the base year (2016)							
Base year (existing conditions)	✓	-	-	-	-	-	-
Scenarios at project opening (2027)							
'Do minimum 2027' (without the project)	✓	-	-	✓	-	-	-
'Do something 2027' (with the project)	✓	Warringah Freeway Upgrade only	✓	✓	-	-	-
'Do something cumulative 2027' (with the project and other projects)	✓	✓	✓	✓	✓	✓	-
Scenarios ten years after the project opening (2037)							
'Do minimum 2037' (without the project)	✓	-	-	✓	-	-	-
'Do something 2037' (with the project)	✓	Warringah Freeway Upgrade only	✓	✓	-	-	-
'Do something cumulative 2037' (with the project and other projects)	✓	✓	✓	✓	✓	-	✓

Modelling process

The modelling process involved an emissions model, a meteorological model (Graz Mesoscale Model – GRAMM) and a dispersion model (Graz Langrangian Model – GRAL). The relationship between these models is illustrated in Figure 12-2.

For each expected traffic scenario, a spatial emissions inventory (emissions model) was developed for road traffic sources within the domain of the dispersion model. The following components were treated separately to take into account potential changes in traffic emissions across the road network:

- Emissions from existing and proposed tunnel ventilation outlets for tunnels where portal emissions are, or would not be, conducted
- Emissions from the portals of a small number of existing tunnels, where these are currently conducted
- Emissions from the traffic on the surface road network, including any new surface roads associated with the project.

The GRAMM meteorological model predicted wind fields (three-dimensional spatial pattern of winds). Predicted wind fields then became an input into the dispersion model following alignment with meteorological observations.

The GRAL dispersion model predicted ground-level pollutant concentrations by simulating the movement of individual 'particles' of a pollutant emitted from an emission source in a three-dimensional wind field.

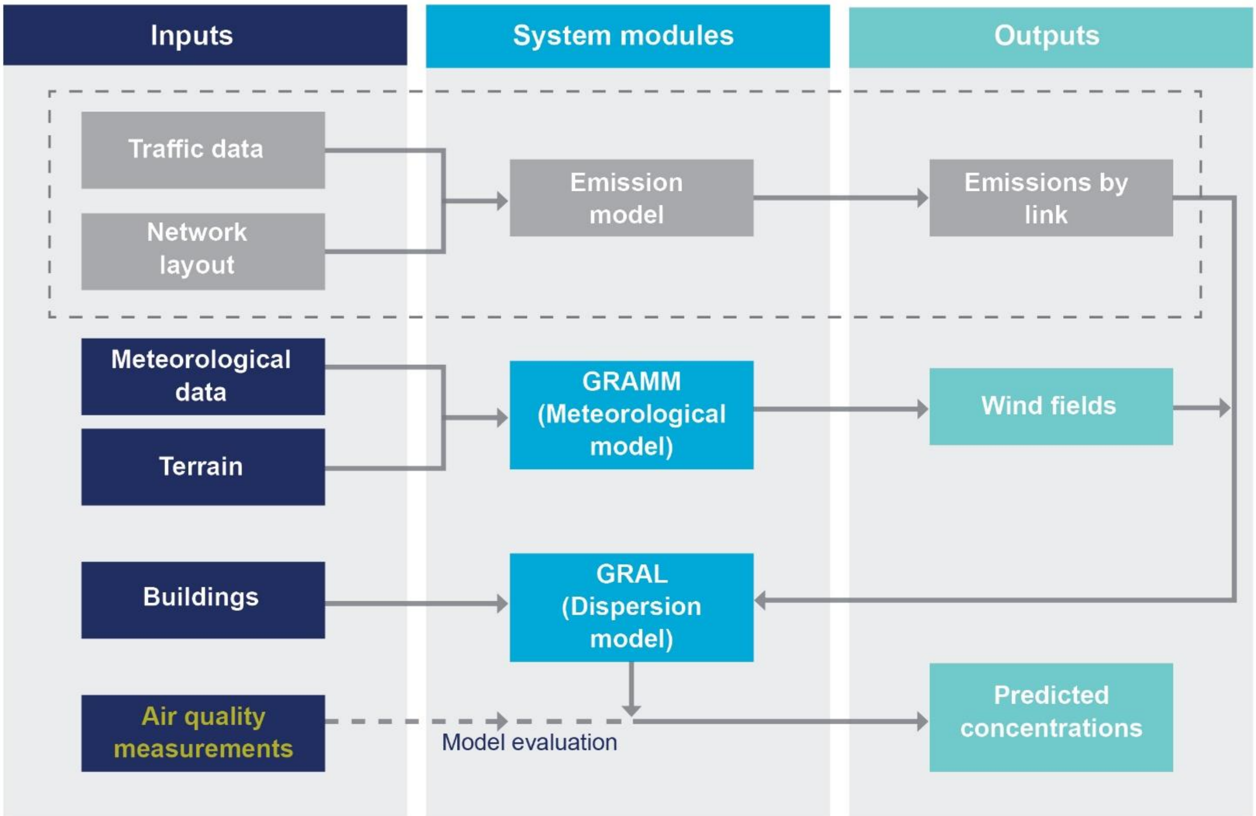


Figure 12-2 Overview of operational air quality modelling process

Receivers

Receivers are defined as anywhere someone works or resides, or may work or reside, including residential areas, hospitals, hotels, shopping centres, playgrounds and recreational centres. Due to its location in a highly built-up area, the dispersion modelling domain for the project contains many receivers.

Two types of receivers were considered in the air quality assessment:

- ‘Community receivers’. These were taken to be representative of particularly sensitive locations such as schools, child care centres and hospitals within a zone up to 1.5 kilometres either side of the Western Harbour Tunnel and Beaches Link program of works corridor, and generally near significantly affected roadways. In total, 42 community receivers were included in the assessment (refer to Figure 12-3)
- ‘Residential, workplace and recreational receivers’. These were all discrete receiver locations along the Western Harbour Tunnel and Beaches Link program of works corridor, and mainly covered residential and commercial land uses. A maximum of 35,484 residential, workplace and recreational receiver locations were considered in the assessment of project air quality impacts.

The identified community and residential, workplace and recreational receiver locations were representative and not exhaustive. They have been selected using professional judgement to demonstrate potential impacts at a more detailed level. While some sensitive locations might not have been selected as representative community receivers, they have still been assessed as residential, workplace and recreational receivers in the model. For example, while the Northern Beaches Secondary College – Balgowlah Boys Campus has not been included as a community receiver, the potential air quality impacts at that location have been predicted and are considered in the discussion of results for residential, workplace and recreational receivers below in Section 12.5 and Section 12.6.

The main emphasis in the assessment was on ground-level concentrations (as specified in the NSW EPA Approved Methods). However, at several locations there are existing multi-storey residential and commercial buildings, or the land zoning permits the construction of such buildings, and the potential impacts of the project at these elevated points are likely to be different to the impacts at ground level. Elevated receivers were therefore evaluated separately.

Based on a review of available building height information, four elevated receiver heights were selected to cover both existing buildings and future developments: 10 metres, 20 metres, 30 metres and 45 metres.

The modelling extent extended beyond the project to allow for the traffic interactions between the Western Harbour Tunnel and Warringah Freeway Upgrade and the WestConnex M4-M5 Link projects, as well as changes along affected surface roads. A large model extent also increased the number of meteorological and air quality monitoring stations that could be included for model evaluation purposes.

Regional air quality

The potential impacts of the project on air quality more widely across Greater Sydney were assessed through consideration of the changes in emissions across the road network. The regional air quality impacts of a project can also be considered in terms of its capacity to influence ozone production. As noted in Section 12.1, The NSW Environment Protection Authority has developed a *Tiered Procedure for Estimating Ground Level Ozone Impacts from Stationary Sources* (ENVIRON, 2011). Although this procedure does not relate specifically to road projects, it was applied here to give an indication of the likely significance of the project’s effect on ozone concentrations in the Greater Sydney region.

Odour

The generation of odours from motor vehicle emissions tend to be very localised and short-lived, and there are unlikely to be any significant, predictable or detectable changes in odour due to the project. Odour was assessed based on the maximum change in 1-hour total hydrocarbon concentrations as a result of the project, which was converted into an equivalent change for three of the odorous pollutants identified in the NSW EPA Approved Methods (toluene, xylenes and acetaldehyde). These pollutants were taken to be representative of other odorous pollutants from motor vehicles.

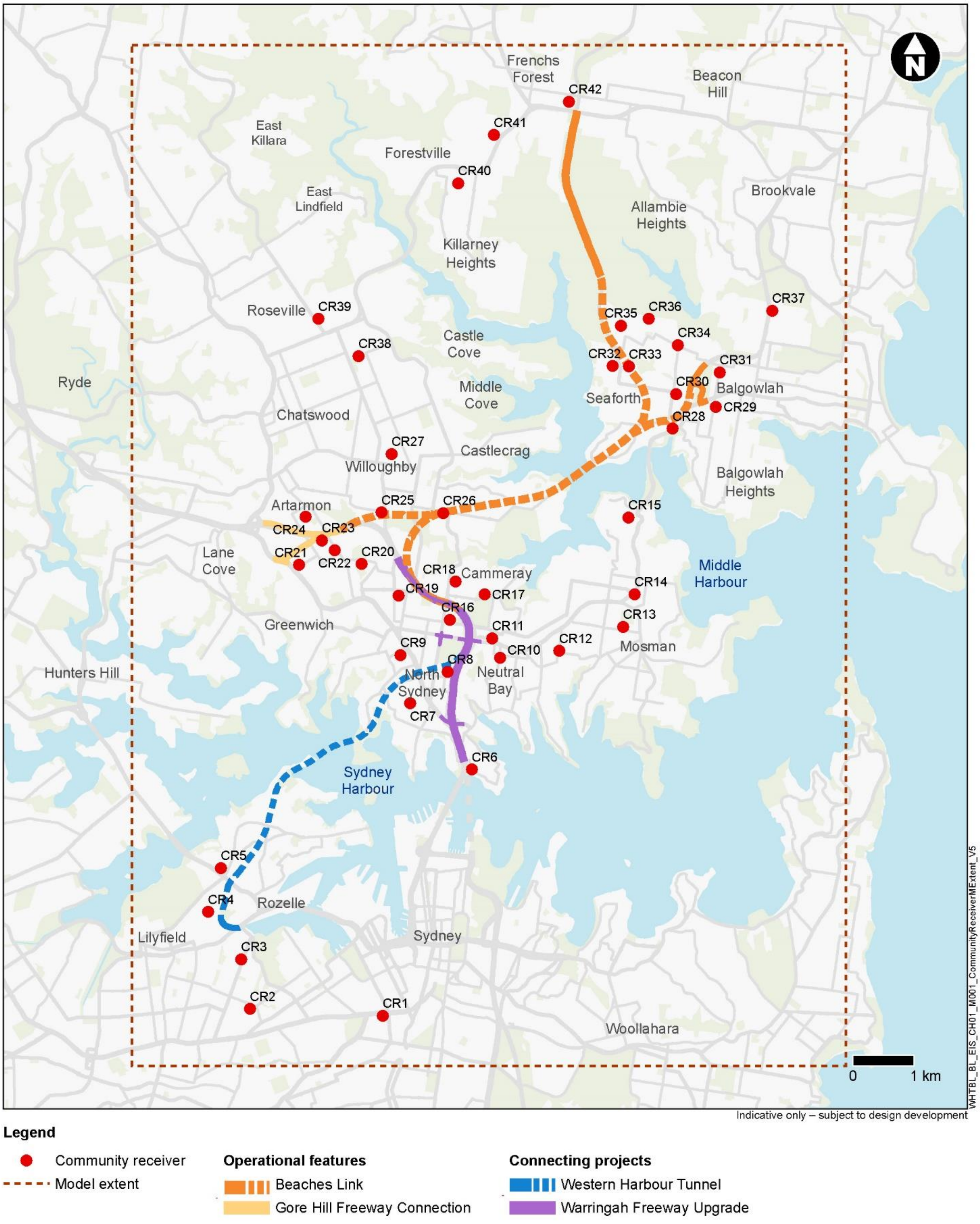


Figure 12-3 Location of community receivers and model extent

12.3 Criteria and standards

12.3.1 Overview

There are two types of criteria and standards that are relevant to the assessment of air quality impacts from construction and operation of the project:

- In-tunnel air quality criteria, which apply to the air quality inside the mainline tunnels
- Ambient air quality criteria and standards, which apply to outdoor air quality.

Air quality criteria and standards applied to the assessment of the project are outlined in the following sections, with further details provided in Appendix H (Technical working paper: Air quality).

12.3.2 In-tunnel air quality criteria

The project has been designed to achieve in-tunnel air quality that is protective of human health and amenity and provides a safe travel environment. Further details of the project's ventilation system design are provided in Chapter 5 (Project description).

The project's ventilation system would be operated to achieve the in-tunnel air quality criteria summarised in Table 12-3. The in-tunnel air quality limits for the project reflect those identified by the ACTAQ (ACTAQ, 2016; ACTAQ, 2018a) and are consistent with the limits provided in planning approvals for recent motorway tunnel projects in NSW.

Table 12-3 In-tunnel operational limits for CO, NO_2 and visibility

Parameter	Averaging period	Criteria
CO	3-minute (rolling), single point exposure limit	200 ppm
	15-minute (rolling), average along tunnel length	87 ppm
	30-minute (rolling), average along tunnel length	50 ppm
NO_2	15-minute (rolling), average along tunnel length	0.5 ppm
Visibility	15-minute (rolling), at any point in the tunnel	0.005 m^{-1}

12.3.3 Ambient air quality criteria

Air quality criteria and standards applied to the assessment of the project are outlined in the following sections, with further details provided in Appendix H (Technical working paper: Air quality), including Annexure B of that report.

Air pollutant criteria

The ambient air quality criteria applied to the assessment of the project are set in the NSW EPA Approved Methods and summarised in Table 12-4. Some of these criteria are among the lowest in the world (see Annexure B of Appendix H (Technical working paper: Air quality)). For example, the annual average $PM_{2.5}$ criterion used, on which a key health metric is based, is lower than any other $PM_{2.5}$ standard in the world, including the World Health Organisation guideline.

Table 12-4 Ambient air quality criteria applied to the assessment of the project

Pollutant	Criteria	Averaging period
CO	30 mg/m^3	1 hour
	10 mg/m^3	8 hours (rolling)

Pollutant	Criteria	Averaging period
NO_2	246 µg/m^3	1 hour
	62 µg/m^3	1 year
PM_{10}	50 µg/m^3	24 hours
	25 µg/m^3	1 year
$PM_{2.5}$	25 µg/m^3	24 hours
	20 µg/m^3 (goal by 2025)	24 hours
	8 µg/m^3	1 year
	7 µg/m^3 (goal by 2025)	1 year
Benzene[1]	0.029 mg/m^3	1 hour
Polycyclic aromatic hydrocarbons (PAHs) (as benzo(a)pyrene)[1]	0.0004 mg/m^3	1 hour
Formaldehyde[1]	0.02 mg/m^3	1 hour
1,3-butadiene[1]	0.04 mg/m^3	1 hour
Ethylbenzene[1]	8 mg/m^3	1 hour

Note 1: These compounds were taken to be representative of the much wider range of air toxics associated with motor vehicles

Odour criteria

The NSW EPA Approved Methods provides assessment criteria for complex mixtures of odorous compounds, as summarised in Table 12-5. These criteria are 99th percentile values, meaning that they must not be exceeded more than one per cent of the time.

Table 12-5 Assessment criteria for odour

Population of affected community	Criterion for complex mixtures of odour (OU)
≤~2	7
~10	6
~30	5
~125	4
~500	3
Urban (>2000) and/or schools and hospitals	2

For the assessment of operational odour impacts, the change in the maximum 1-hour total hydrocarbon concentration as a result of the project was calculated at each of the residential, workplace and recreational receiver locations. The hydrocarbon pollutants were taken to be representative of other odorous pollutants from motor vehicles. The odorous pollutants assessed along with their relevant criteria include:

- Toluene (360 µg/m^3)
- Xylene (190 µg/m^3)
- Acetaldehyde (42 µg/m^3).

12.4 Existing environment

Air quality in a region is influenced by a number of factors including the terrain, meteorology (weather patterns), historical trends in road traffic emissions and the current (ambient) and historical air quality environment.

12.4.1 Meteorology

Analysis of meteorological data found that the Randwick station (operated by the Department of Planning, Industry and Environment (Environment, Energy and Science)) was the most representative of the project corridor. At Randwick, the wind speed and wind direction patterns over the five-year period between 2011 and 2016 were reasonably consistent. Average wind speeds ranged from 2.4 to 2.6 meters per second.

12.4.2 Vehicle emissions

The most comprehensive source of information on current and future air pollutant emissions in the Sydney area is the emissions inventory that is compiled periodically by the NSW Environment Protection Authority.

For 2016, the emissions inventory identifies that road transport, including cars, light duty vehicles, heavy duty vehicles such as buses and trucks and other transport such as motorbikes, was the second largest sectoral contributor to emissions of CO (34 per cent) and the largest contributor to NO_X (47 per cent) in Sydney. The sector was also responsible for substantial proportions of emissions of volatile organic compounds (13 per cent), PM_{10} (nine per cent) and $PM_{2.5}$ (10 per cent). Road transport contributed only two per cent of total sulfur dioxide (SO_2) emissions in Sydney, reflecting the reduced sulfur in road transport fuels in recent years.

Petrol passenger vehicles (mainly cars) accounted for a large proportion of the vehicle kilometres travelled in Sydney and exhaust emissions from these vehicles were responsible for 65 per cent of CO from road transport in Sydney in 2016, 37 per cent of NO_X, and 71 per cent of SO_2. Non-exhaust processes, such as brake wear, tyre wear, road surface wear and resuspension of road dust during on-road vehicle usage, were the largest source of road transport PM_{10} (71 per cent) and $PM_{2.5}$ (57 per cent), whereas exhaust emissions from petrol passenger vehicles were only a minor source of road transport PM_{10} (three per cent) and $PM_{2.5}$ (four per cent).

The road transport contribution to CO, volatile organic compounds and NO_X emissions is projected to decrease substantially between 2011 and 2036 due to improvements in emission-control technology. For PM_{10}, $PM_{2.5}$ and SO_2 the road transport contributions are also expected to decrease, but their smaller contributions to these pollutants mean that these decreases would have only a minor impact on total emissions.

12.4.3 Ambient air quality

Air quality in Sydney is monitored across a network of monitoring stations operated by the Department of Planning, Industry and Environment (Environment, Energy and Science), and at project-specific monitoring stations operated by Transport for NSW. A summary of ambient air quality in Sydney is provided in Table 12-6, based on data from these monitoring stations from 2004 to 2019.

Table 12-6 Ambient air quality in Sydney (2004 to 2019)

Air pollutant	Ambient air quality
CO (maximum 1-hour)	All monitoring data shows ambient concentrations well below the air quality criteria of 30 mg/m^3 (1-hour) and 10 mg/m^3 (8-hour). With the exception of 2019, there is a general downward trend in maximum concentrations over time.
CO (rolling 8-hour)	

Air pollutant	Ambient air quality
NO_2 (maximum 1-hour)	Although variable from year to year, maximum 1-hour NO_2 concentrations are relatively stable in the longer term. Data from all monitoring stations typically range from 80 µg/m^3 to 140 µg/m^3, and continue to be well below the criterion of 246 µg/m^3.
NO_2 (annual mean)	Concentrations at all monitoring stations are well below the air quality criterion of 62 µg/m^3. There is a general downward trend in annual mean concentrations over time.
PM_{10} (maximum 24-hour)	Maximum 24-hour mean PM_{10} concentrations show a slight downward until 2015, but there is a large variation from year to year. In 2016 the concentrations recorded at the Transport for NSW monitoring stations were about 40 µg/m^3, below the air quality criterion of 50 µg/m^3. Since 2018, maximum 24-hour PM_{10} concentrations at Department of Planning, Industry and Environment (Environment, Energy and Science) stations exhibited an upward trend due to extended drought conditions and widespread bushfires.
PM_{10} (annual mean)	Concentrations at the Department of Planning, Industry and Environment (Environment, Energy and Science) stations show a downward trend between 2004 and 2016, by as much as 21 to 23 per cent in the case of the Chullora and Earlwood stations. In recent years the annual mean PM_{10} concentration at the Department of Planning, Industry and Environment (Environment, Energy and Science) stations has increased, from around 20 µg/m^3 in 2018 to close to or above the air quality criterion of 25 µg/m^3 in 2019. This is largely due to drought conditions worsening and then severe bushfire activity in 2018 and 2019. The monitoring station at Lindfield shows substantially lower concentrations, about 15 to 16 µg/m^3. Monitoring data from stations operated by Transport for NSW away from busy roads is generally about 15 µg/m^3, which is well below the air quality criterion of 25 µg/m^3.
$PM_{2.5}$ (maximum 24-hour)	There has been no trend in the maximum 24-hour $PM_{2.5}$ concentration. The maximum 24-hour concentrations are often close to or above the air quality criterion of 25 µg/m^3, and were generally above the long-term goal of 20 µg/m^3. Exceedances are largely due to hazard reduction burns and bushfires.
$PM_{2.5}$ (annual mean)	$PM_{2.5}$ has only been measured over several years at three of the Department of Planning, Industry and Environment (Environment, Energy and Science) stations reviewed (ie Chullora, Earlwood and Liverpool). Concentrations show a similar pattern, with a steady 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. The increases in measured concentrations meant that background $PM_{2.5}$ concentrations between 2013 and 2016 were already very close to or above the air quality criterion of eight µg/m^3, and above the long-term goal of seven µg/m^3. In 2018 and 2019, the annual mean $PM_{2.5}$ concentrations exceeded the air quality criterion at all three monitoring stations.

12.5 Assessment of potential construction impacts

Potential sources of air quality impacts during construction of the project would include:

- Dust generated at construction sites and temporary construction support sites
- Emissions from vehicles, plant and equipment used on construction sites and temporary construction support sites
- Emissions during blasting
- Odour generated during handling and management of harbour sediments and material excavated from the former landfill site at the Flat Rock Drive construction support site (BL2).

Environmental management measures that are proposed to address these impacts are outlined in Section 12.7.

12.5.1 Dust

Overall, dust generated as a result of construction works, with best practice management measures in place, is unlikely to represent a serious ongoing problem. Any effects would be temporary and relatively short-lived and would likely only arise during dry weather where the wind is blowing towards a receiver at a time when dust is being generated and environmental management measures are not fully effective.

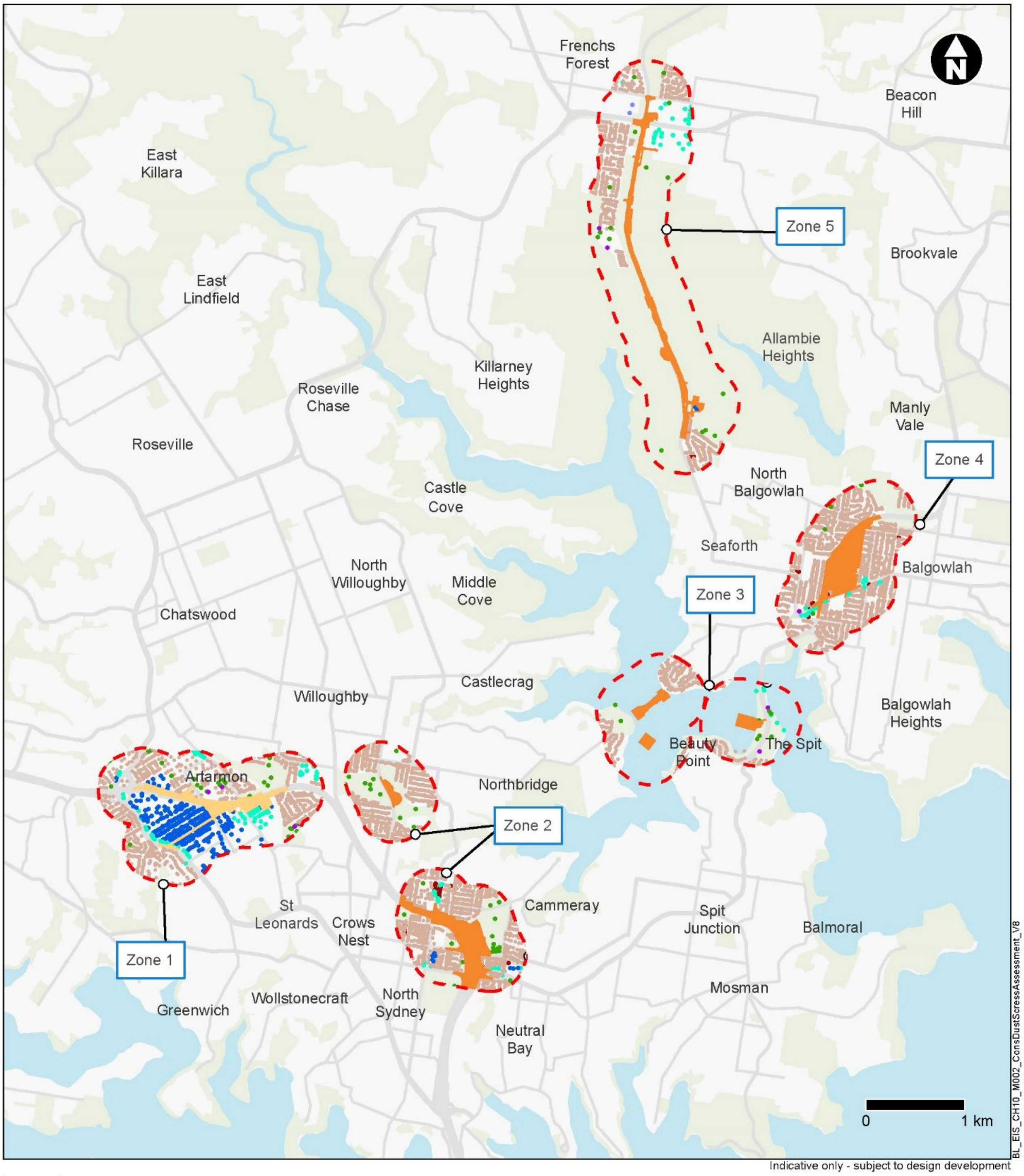
Screening assessment

The construction dust assessment considered potential dust impacts across five assessment zones. The assessment zones, and their associated temporary construction support sites and surface construction areas are summarised in Table 12-7. As shown in Figure 12-4, there are a large number of human receivers located within 350 metres, as well as ecological receivers located within 50 metres, of the assessment zones. This has triggered the need for further assessment of potential dust impacts.

Table 12-7 Assessment zones

Assessment zone	Construction support sites within assessment zone	Surface construction areas within assessment zone
Zone 1	Punch Street (BL3), Dickson Avenue (BL4), Barton Road (BL5), Gore Hill Freeway median (BL6)	Beaches Link and Gore Hill Freeway works. This includes tunnel decline structures and construction of tunnel portals and ramps, construction of operational ancillary infrastructure and adjustments to other infrastructure (eg active transport infrastructure).
Zone 2	Cammeray Golf Course (BL1), Flat Rock Drive (BL2)	Beaches Link tunnel decline structures and tunnel portals at Cammeray Golf Course (BL1) and Flat Rock Drive (BL2), and connections to Warringah Freeway, including fitout of the ventilation outlet and motorway facility. Note: The majority of this construction assessment zone would have already undergone significant disturbance during the construction of the Western Harbour Tunnel and Warringah Freeway Upgrade. The construction activities assessed in this zone therefore assumes that much of the works have already been completed as part of that project.

Assessment zone	Construction support sites within assessment zone	Surface construction areas within assessment zone
Zone 3	Middle Harbour south cofferdam (BL7), Middle Harbour north cofferdam (BL8), Spit West Reserve (BL9)	Harbour crossing including cofferdam excavation, dredging and handling of dredged material.
Zone 4	Balgowlah Golf Course (BL10), Kitchener Street (BL11)	Connections and integration of Beaches Link to the surrounding road network at Balgowlah. This includes construction of portals and the new access road, modifications to existing surface roads and construction of the Burnt Bridge Creek Deviation ventilation outlet and motorway facility.
Zone 5	Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13), Wakehurst Parkway north (BL14)	Connections and integration of Beaches Link with Wakehurst Parkway at Seaforth, Killarney Heights and Frenchs Forest. This includes surface road works associated with the realignment and upgrade of Wakehurst Parkway and minor changes to intersections, as well as the construction of the Wakehurst Parkway motorway facility and ventilation outlet.



Legend

- Beaches Link construction footprint
- Gore Hill Freeway construction footprint
- Assessment zone

Reciever type

- Residential
- Commercial
- Community
- Hospital
- Recreation
- Industrial
- Mixed use

Figure 12-4 Construction dust screening assessment – receivers near the construction footprint

Risk assessment

The risk of potential dust impacts, without mitigation, is determined by combining the following to provide an overall summary of potential risk:

- The scale and nature of the works, which determined the magnitude of potential dust emissions (refer to Table 12-8)
- The sensitivity of the surrounding area to dust settlement effects, human health impacts and ecological impacts (refer to Table 12-9).

Potential for dust emissions from surface construction works

The potential magnitude of dust emissions for the construction works that would be carried out for demolition, earthworks, construction, and track-out (as defined in Section 12.2.2) is shown in Table 12-8, and is based on the scale and nature of the works.

Table 12-8 Potential magnitude of dust emissions of construction works in each assessment zone

Type of activity	Site category by assessment zone				
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Demolition	Large	Small	N/A	Medium	Small
Earthworks	Large	Medium	Small	Large	Large
Construction	Large	Medium	Small	Large	Large
Track-out	Large	Medium	Medium	Large	Large

Sensitivity of receivers during construction

The sensitivity of an area to dust settlement effects, human health impacts and ecological impacts during construction takes into account factors such as the number of receivers in the area, the proximity of receivers from construction activities and the local annual mean background PM_{10} concentration. The sensitivity of receivers to dust settlement effects, human health impacts and ecological impacts (without mitigation) within the five surface construction zones assessed is provided in Table 12-9. The results in Table 12-9 show that:

- For construction dust settlement effects:
  - Zone 1, zone 2, zone 4 and zone 5 were considered to have a high sensitivity to dust settlement effects due to the high number of receivers, located near the surface construction works
  - Zone 3 was considered to have a medium sensitivity to dust settlement effects as there were fewer receivers located near construction works. No demolition or track-out dust settlement effects would occur within zone 3.
- For human health impacts,
  - The sensitivity of receivers in zone 1, zone 2, zone 4 and zone 5 would be considered high, due to the high number of receivers located near surface construction works
  - Zone 3 would have a low sensitivity to human health impacts during all construction works. Demolition would not occur in this zone.
- For ecological impacts, sensitive ecological receivers within all the zones are located within 20 metres of the construction disturbance footprint. As a result, the sensitivity of these ecological receivers to construction dust would be considered high at all locations.

Risk of dust impacts

The summary of potential risk relating to construction dust, without mitigation, is provided in Table 12-9.

Without mitigation, sites and works that were determined to have a high and medium risk of dust impacts include:

- Punch Street (BL3), Dickson Avenue (BL4), Barton Road (BL5) and Gore Hill Freeway median (BL6) construction support sites: High risk of dust settlement, human health and ecological impacts as a result of demolition, earthworks, construction and track-out activities
- Cammeray Golf Course (BL1) and Flat Rock Drive (BL2) construction support sites: Medium risk of dust settlement, human health and ecological impacts as a result of demolition, earthworks, construction and track-out activities
- Middle Harbour south cofferdam (BL7), Middle Harbour north cofferdam (BL8) and Spit West Reserve (BL9) construction support sites: Medium risk of ecological impacts and a low risk of dust settlement and human health impacts as a result of track-out activities. Low risk of dust settlement and ecological impacts as a result of earthworks and construction activities
- Balgowlah Golf Course (BL10) and Kitchener Street (BL11) construction support sites: Medium risk of dust settlement, human health and ecological impacts as a result of demolition activities. High risk of dust settlement, human health and ecological impacts as a result of earthworks, construction and track-out activities
- Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites: Medium risk of dust settlement, human health and ecological impacts as a result of demolition activities. High risk of dust settlement, human health and ecological impacts as a result of earthworks, construction and track-out activities.

The effects of airborne dust during construction works would likely be temporary and of relatively short duration. For all construction works, the aim would be to prevent dust related impacts on receivers, through the implementation of best management practices routinely used on construction sites. The proposed environmental management measures are outlined in Section 12.7 and would include measures such as:

- Suppressing dust with water
- Covering stockpiles of loose materials
- Cleaning up loose materials from hard surfaces
- Stabilising unsealed areas
- Selection of equipment and materials handling techniques that minimise the potential for dust generation
- Ceasing dust generating activities during unfavourable weather conditions or changing how they are managed to minimise dust emission
- Site inspections and activity supervision to monitor the effectiveness of implemented measures and identify any additional measures to be implemented.

However, even with rigorous air quality management in place and the effective best practice management measures described above, there is the risk that nearby residences, commercial premises and schools near construction works might experience occasional dust impacts. This does not imply that impacts are likely, or that if they did occur, that they would be frequent or persistent. Overall dust generated as a result of construction works is unlikely to represent a serious ongoing problem.

Table 12-9 Summary of potential risk relating to construction dust (without mitigation)

Zone	Activity	Step 2A: Potential for dust emissions	Step 2B: Sensitivity of area			Step 2C: Risk of dust impacts		
			Dust settlement	Human health	Ecological	Dust settlement	Human health	Ecological
Zone 1 (BL3, BL4, BL5 and BL6)	Demolition	Large	High	High	High	High	High	High
	Earthworks	Large	High	High	High	High	High	High
	Construction	Large	High	High	High	High	High	High
	Track-out	Large	High	High	High	High	High	High
Zone 2 (BL1, BL2)	Demolition	Small	High	High	High	Medium	Medium	Medium
	Earthworks	Medium	High	High	High	Medium	Medium	Medium
	Construction	Medium	High	High	High	Medium	Medium	Medium
	Track-out	Medium	High	High	High	Medium	Medium	Medium
Zone 3 (BL7, BL8 and BL9)	Demolition	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Earthworks	Small	Medium	Low	High	Low	Negligible	Low
	Construction	Small	Medium	Low	High	Low	Negligible	Low
	Track-out	Medium	Low	Low	High	Low	Low	Medium
Zone 4 (BL10 and BL11)	Demolition	Medium	High	High	High	Medium	Medium	Medium
	Earthworks	Large	High	High	High	High	High	High
	Construction	Large	High	High	High	High	High	High
	Track-out	Large	High	High	High	High	High	High
Zone 5 (BL12, BL13 and BL14)	Demolition	Small	High	High	High	Medium	Medium	Medium
	Earthworks	Large	High	High	High	High	High	High
	Construction	Large	High	High	High	High	High	High
	Track-out	Large	High	High	High	High	High	High

Dust emissions containing contaminants

There is the potential for dust emissions to contain contaminants mobilised through the disturbance of contaminated soils, and other hazardous materials (such as asbestos fibres or organic matter) during demolition of buildings and other structures. These issues would be considered on a site-by-site basis and would be effectively managed through standard air quality mitigation and management measures as outlined in Table 12-11.

Areas identified as potentially containing contaminated soils and other hazardous substances, which may be disturbed during construction, include:

- Warringah Freeway, North Sydney to Cammeray
- Punch Street, Artarmon
- Freeway Hotel, Artarmon
- Flat Rock Reserve, Northbridge
- Spit West Reserve, Mosman
- Balgowlah Golf Course, Balgowlah
- Dudley Street, Balgowlah
- Judith Street and Kirkwood Street, Seaforth
- Sydney Water Bantry Bay Reservoir site, Killarney Heights
- Burnt Bridge Creek Deviation, Balgowlah
- Wakehurst Parkway, Seaforth to Frenchs Forest.

These areas are described in more detail in Chapter 16 (Geology, soils and groundwater). These areas would be investigated further in accordance with requirements of guidance endorsed under Section 105 of the *Contaminated Land Management Act 2008* to confirm the contamination present, and the implementation of Remedial Action Plans prepared in accordance with *Managing Land Contamination: Planning Guidelines SEPP 55 – Remediation of Land* (Department of Urban Affairs and Planning and Environment Protection Authority, 1998). Remedial Action Plans consider all potential risk pathways for exposure to contaminants and specify the controls required to reduce those risks to acceptable levels. This includes potential emissions of contaminated dust. Refer to Chapter 16 (Geology, soils and groundwater) for more details.

12.5.2 Emissions from vehicles, plant and equipment

The use of on-site diesel-powered vehicles, generators and construction equipment, and the handling and/or on-site storage of fuel and other chemicals, would result localised increased concentrations of airborne particle matter, CO, NO_X, sulfur dioxide and volatile organic compounds. Minor emissions from these sources would be localised and would be managed with standard environmental management measures.

12.5.3 Emissions during blasting

As discussed in Chapter 6 (Construction work), it is anticipated that controlled blasting might be used to excavate bedrock along sections of Wakehurst Parkway, as an alternative to ripping or hammering of rock, to minimise the duration of this activity and potential noise and amenity impacts. In addition, controlled blasting may also be carried out during construction of the driven tunnels.

Controlled underground blasting would not result in direct emissions to the external air. The potential for impacts to sensitive receivers due to dust from surface-based blasting would depend on the location where the blasting is proposed, the blasting approach, and whether there are any sensitive receivers in the vicinity that could be impacted. Emissions to air from any blasting required at Wakehurst Parkway would be managed to ensure safe working conditions for workers and minimise potential impacts to sensitive receivers in the vicinity.

12.5.4 Odour

This section assesses impacts associated with potential odours due to dredging activities, stockpiling and transport of dredged material at Middle Harbour, as well as excavation activities within a former landfill site at the Flat Rock Drive construction support site (BL2).

Environmental management measures such as odour supressing additives, use of sealed trucks and the development of an odour management strategy (where required) would be implemented to minimise the potential for odour during construction.

Excavated material from Middle Harbour

As part of the tunnelling activities for the project, a significant amount of material would be excavated from beneath the water. This would be done using mechanical dredging, bringing potentially odorous material to the surface. While on the barges in the vicinity of the dredging activity or while in transit to the sea disposal location or onshore disposal area, dredged material would be covered with water which would significantly reduce any odour emissions. Any odour impacts from this material would be negligible to low, given it would remain wet and located at some distance from any sensitive receiver.

For dredged material that is determined to be unsuitable for sea disposal, the material would be transported by barge to land, made spadable and then transported by truck to an appropriately licensed waste management facility for disposal. The unloading location for the dredged material would be determined during detailed design, and necessary environmental planning approvals obtained to operate the facility to accept and, if required, treat the material. Odour measurements carried out on dredged material from Middle Harbour showed extremely low concentrations. Modelling for the same material for the Western Harbour Tunnel air quality assessment showed if handled in manageable quantities, it is unlikely that emissions from dredged material would result in detectable levels of odour at any sensitive receivers.

Excavation at Flat Rock Drive construction support site (BL2)

The Flat Rock Drive construction support site (BL2) is a tunnel support site and would have an access decline to the tunnels underground.

The area to the west of Flat Rock Drive and east of Willoughby Road at Willoughby was used extensively as a municipal landfill prior to redevelopment as recreation facilities. Following the construction of Flat Rock Drive in 1968, and prior to 1971, areas to the east of the road were filled with material comprising of putrescible waste. Since that time the majority of fill has been non-putrescible, predominantly consisting of building debris and so the material most likely to be encountered during excavation in this area would the more recent non-putrescible waste. A geotechnical investigation carried out within the construction footprint at this location identified clayey material with some building debris but did not encounter any putrescible waste.

There is some potential that landfill gases might be present in the soils underneath the Flat Rock Drive construction support site (BL2) from any putrescible waste present, or that might have migrated from the landfilled areas to the west.

To manage the potential risks associated with the historic use of the area, the Flat Rock Drive construction support site (BL2) has been designed to minimise excavations. The main excavations that would be required are associated with piling for structures and excavation of the tunnel access decline. The location of the decline has been chosen to minimise the amount of excavation required to reach bedrock. As such, there is limited potential to encounter putrescible landfilled waste (if present) that could generate odour. Additionally, the potential for the release of significant volumes of landfill gases (if present) is also limited.

As there is a low potential for significant amounts of putrescible waste materials and landfill gases to be present beneath the proposed Flat Rock Drive construction support site (BL2) site, the potential for significant odour issues during excavation is very low. However, prior to excavations at the temporary construction support site, further investigations would be carried out to confirm the potential to encounter odorous materials and gases and need for any site-specific management measures (refer to environmental management measures SG14 in Chapter 16 (Geology, soils and groundwater) and AQ4 in Section 12.7.1).

12.6 Assessment of potential operational impacts

Key areas of consideration with regards to air quality impacts during the operation of the project would include:

- In-tunnel air quality, including protection of amenity and motorist health when using the project tunnels and during longer trips through other parts of the motorway network
- Ambient air quality for receivers at ground level, as a result of changes in the distribution of surface traffic and operation of the project's ventilation facilities
- Ambient air quality for elevated receivers in existing and potential future high rise buildings, as a result of operation of the project's ventilation facilities
- Odour caused by odorous compounds in vehicle emissions.

12.6.1 In-tunnel air quality

The project's ventilation systems have been designed to achieve the in-tunnel air quality criteria summarised in Section 12.3.2 under all traffic conditions, and to effectively manage smoke in the event of a fire in the project tunnels. The tunnel ventilation system would include:

- Jet fans installed in the ceiling of the tunnels
- Axial fans within the motorway facilities to extract air from the tunnel via ventilation tunnels
- Axial fans within the motorway facilities to supply air to the tunnel via ventilation tunnels
- Ventilation outlets to effectively disperse tunnel air into the atmosphere
- Air quality monitoring systems in the tunnels and ventilation outlets to monitor and control the ventilation system.

The design and operation of the tunnel ventilation system is shown in Figure 5-1 of Chapter 5 (Project description) and described in Section 5.2.7 of that chapter and Appendix H (Technical working paper: Air quality).

The design of the tunnel ventilation system would ensure there would be no emissions from the tunnel portals. This would involve using jet fans close to the exit portals to draw air back into the tunnel, to be emitted via the ventilation outlets.

Simulations have been carried out to demonstrate that in-tunnel air quality criteria would not be exceeded. The simulations consider in-tunnel air quality based on:

- Expected traffic volumes using the project tunnels
- Maximum traffic volumes based on the design capacity of the tunnels at different average traffic speeds
- Congestion due to a breakdown or incident in the project tunnels.

In-tunnel air quality under expected traffic conditions

The change in the peak in-tunnel NO_2 (rolling 15-minute average) emissions throughout the project tunnel and the adjoining tunnels confirm that the tunnel ventilation system would maintain in-tunnel air quality well within operational limits. The predicted in-tunnel NO_2 levels modelled for all 'Do something' and 'Do something cumulative' scenarios in 2027 and 2037 are provided in Section 7 of

Annexure K of Appendix H (Technical working paper: Air quality). The in-tunnel operational air quality limits for CO and visibility would also be achieved under all expected traffic scenarios.

In-tunnel air quality under worst case variable speed operation

In-tunnel air quality was assessed with the mainline tunnels operating at theoretical maximum lane capacity over the full length of the tunnels (which is not expected to actually occur). Four variable speed scenarios were assessed along all northbound and southbound routes: 20 kilometres per hour, 40 kilometres per hour, 60 kilometres per hour and 80 kilometres per hour. Vehicles travelling at 20 kilometres per hour are predicted to result in the highest pollutant levels in the tunnel, due to less air moving through the tunnel. This is considered the worst case variable speed operation scenario.

The predicted in-tunnel NO_2 (rolling 15-minute average) emissions for the worst case northbound route through the tunnel confirms that the tunnel ventilation system would achieve the NO_2 emissions criteria during all variable speed operation scenarios. The in-tunnel operational air quality limits for CO and visibility would also be achieved during all variable speed operation scenarios (refer to Annexure K of Appendix H (Technical working paper: Air quality)).

In-tunnel air quality under worst case breakdown or major incident

The tunnel ventilation system would be designed to cater for various traffic scenarios, including a case where there is a breakdown or major incident at a point along the tunnel. The worst case scenario from a traffic perspective would be where the resulting congestion due to a breakdown affects the longest length within the tunnel operating at capacity. The assessment considered breakdowns in a range of plausible locations.

The highest trip average NO_2 concentration for the breakdown scenarios considered was 0.29 ppm. This was predicted during a breakdown or major incident along the route for traffic originating in Killarney Heights and Balgowlah and exiting at the Warringah Freeway exit ramp (prior to the Western Harbour Tunnel). The predicted in-tunnel trip average NO_2 concentration for the worst case vehicle breakdown or major incident scenario in the tunnel confirms that the tunnel ventilation system would achieve the NO_2 emissions criteria during all breakdown scenarios. The in-tunnel operational air quality limits for NO_2, CO and visibility would also be achieved during all breakdown or major incident scenarios (refer to Annexure K of Appendix H (Technical working paper: Air quality)).

In-tunnel air quality for extended journeys

The extended journey assessment considered the longest potential journey that could be taken by motorists in the connected motorway network in 2037. This was identified as a journey that used the project, the proposed Western Harbour Tunnel, WestConnex and the M6 Motorway (Stage 1) tunnel network. It is expected that the in-tunnel trip average NO_2 concentrations would remain below the 0.5 ppm criterion under all traffic conditions, provided that NO_2 emissions criteria are achieved in every tunnel (which is expected). Further detail can be found in Section 5.2.7 of Annexure K of Appendix H (Technical working paper: Air quality).

12.6.2 Ambient air quality (receivers at ground level)

The predicted ambient air quality for the expected traffic scenarios are presented, by pollutant in this section. All results, including tabulated concentrations and contour plots are provided in Appendix H (Technical working paper: Air quality).

For the pollutants assessed, the following has been determined for over 35,000 residential, workplace and recreational receiver locations and 42 community receivers:

- The total ground-level concentrations for comparison against the NSW impact assessment criteria and international air quality standards

- The change in the total ground-level concentrations. This was calculated as the difference in concentration between the ‘Do something’ and ‘Do minimum’ scenarios, ie the difference in ground-level concentrations as a result of the project
- The contributions of the background, surface road and ventilation outlet sources to the total ground-level concentrations.

Due to the number of residential, workplace and recreational receiver locations, ranked plots for pollutant concentrations at each receiver location have been included. In each figure the background concentration, maximum contributions from each source (ventilation outlets and surface roads) and the maximum total concentration have been included for all the ‘Do something’ and ‘Do something cumulative’ scenarios.

For community receivers, a figure showing the pollutant concentrations (background plus the project scenario contribution) at each receiver relative to the air quality criterion has been provided. A second figure showing the change in pollutant concentration as a result of the different project scenario contributions at each receiver has also been provided.

Nitrogen dioxide (maximum 1-hour mean)

Residential, workplace and recreational receiver locations

There are some predicted exceedances of the NSW 1-hour NO_2 criterion (246 µg/m^3), both with and without the project at residential, workplace and recreational receiver locations. In the ‘Do minimum 2027’ scenario, the maximum concentration of NO_2 exceeds the NSW criterion at 201 receivers (0.6 per cent of all receivers). With the introduction of the project in the ‘Do something 2027’ scenario, the number of receivers experiencing exceedances of the maximum concentration of NO_2 decreases to 153 receivers. In the ‘Do something cumulative 2027’ scenario, the number of receivers experiencing exceedances of the maximum 1-hour mean concentration of NO_2 further decreases to 88 receivers (0.2 per cent of all receivers).

In the ‘Do minimum 2037’ scenario, there are predicted to be exceedances at 234 receivers (0.7 per cent of all receivers), and this remained the same for the ‘Do something 2037’ scenario. In the ‘Do something cumulative 2037’ scenario, the number decreases to 75 receivers (0.2 per cent of all receivers).

Most exceedances in all scenarios were located along Warringah Freeway (and the Warringah Freeway Upgrade) in future years. There were also a small number of exceedances close to Victoria Road in Rozelle and along Manly Road at The Spit. These exceedances reduced even further in the cumulative scenarios when the Western Harbour Tunnel is introduced.

Figure 12-5 shows the predicted contributions of the project to the maximum 1-hour mean NO_2 concentration at all of the residential, workplace and recreational receiver locations.

The maximum contribution of ventilation outlets to NO_2 at any receiver was 60 µg/m^3 in the ‘Do something cumulative 2037’ scenario. Since this contribution would not coincide with maximum contributions from surface roads, this would not lead to an exceedance of the 1-hour NO_2 criterion.

Community receivers

Figure 12-6 shows the maximum 1-hour NO_2 concentrations at all the community receivers in the project and cumulative scenarios. At all these receiver locations in all scenarios assessed, the maximum concentration is predicted to be below the impact assessment criterion of 246 µg/m^3, and in most cases below 200 µg/m^3.

Figure 12-7 shows the predicted change in maximum 1-hour mean NO_2 concentration as a result of the project and cumulatively with other projects (the difference between the ‘Do something’ scenarios and the ‘Do minimum’ scenarios) in 2027 and 2037. There was a mixture of small (relative to the NSW criterion) increases and decreases across the scenarios assessed and some notable increases in the maximum concentration at a small number of receivers, but as noted above, these did not result in any exceedances of the criterion.

In the hour in which the maximum 1-hour NO_2 concentration occurred, the background concentration was the most important source of NO_2, with generally a small contribution from surface roads. The main exceptions were CR06 (St Aloysius College, Milsons Point) and CR11 (Neutral Bay Public School, Neutral Bay), which had a large contribution from surface roads in the ‘Do something’ scenario and the ‘Do something cumulative’ scenario respectively. The tunnel ventilation outlet contribution to the maximum 1-hour mean NO_2 concentration was either zero or negligible.

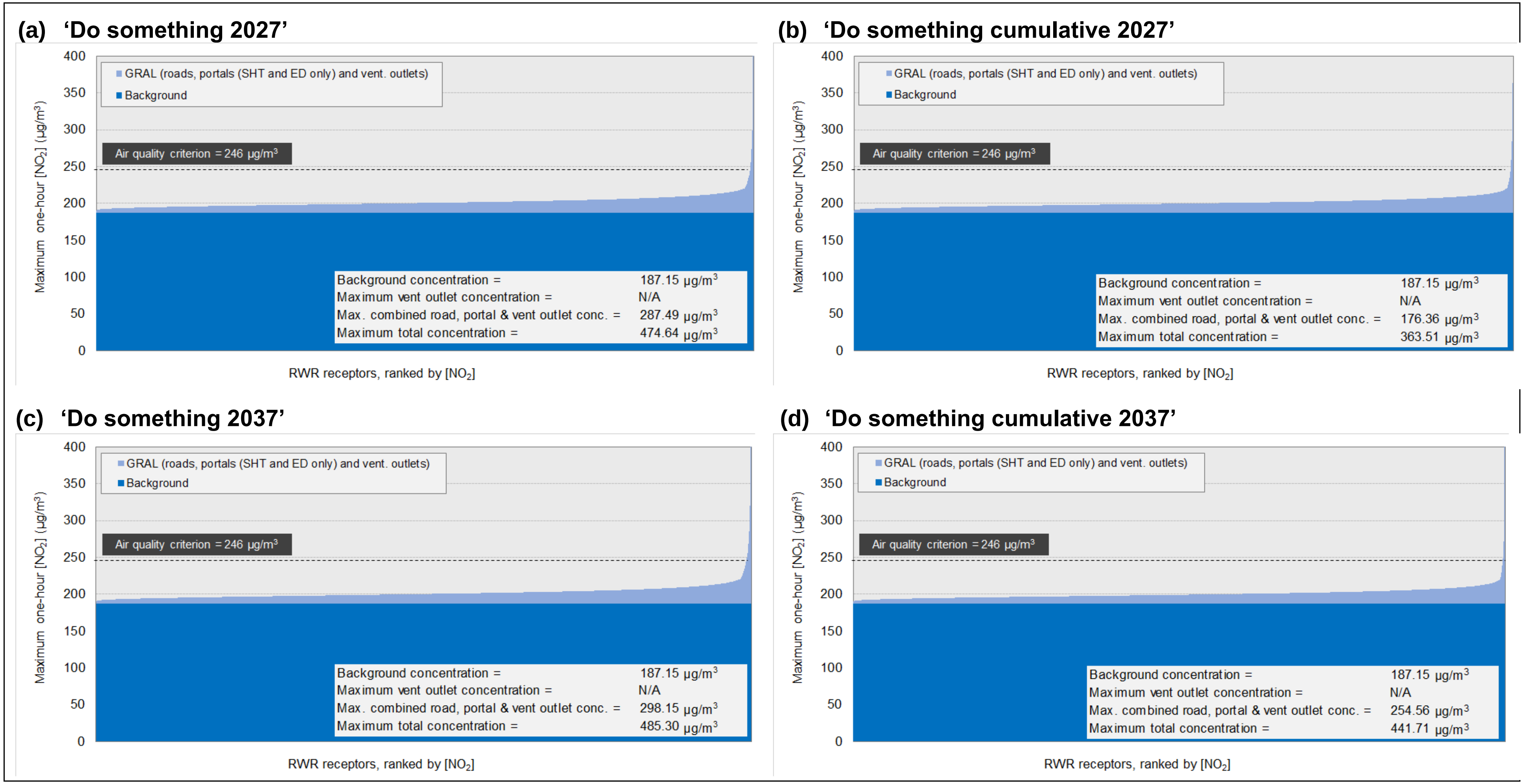


Figure 12-5 Contributions to maximum 1-hour mean NO_2 concentration at residential, workplace and recreational receivers

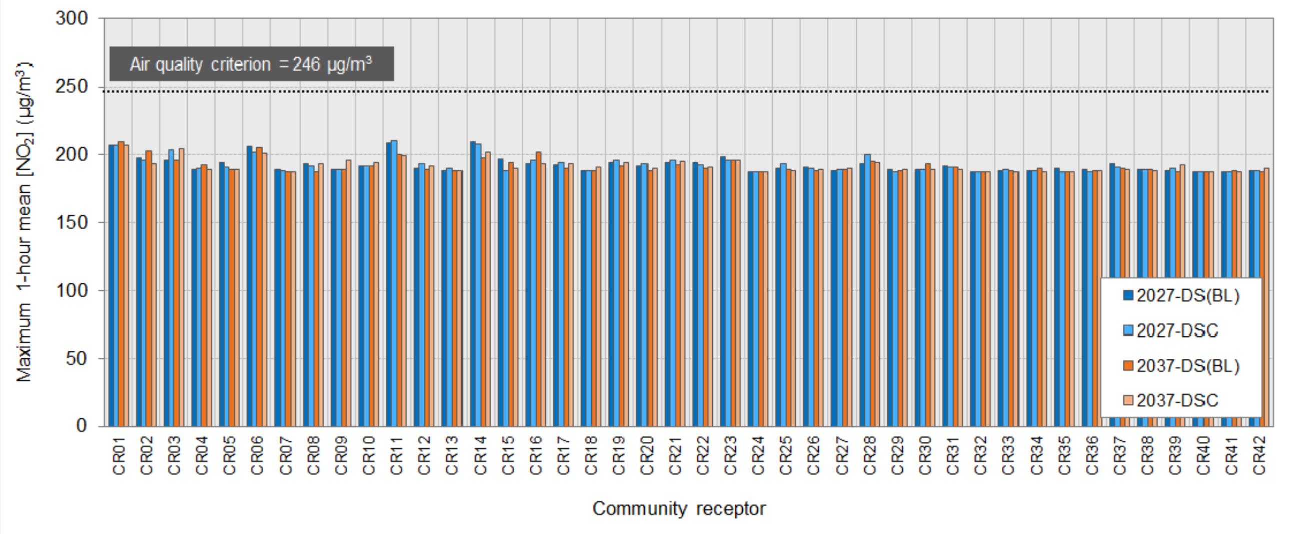


Figure 12-6 Maximum 1-hour mean NO_2 concentration at community receivers

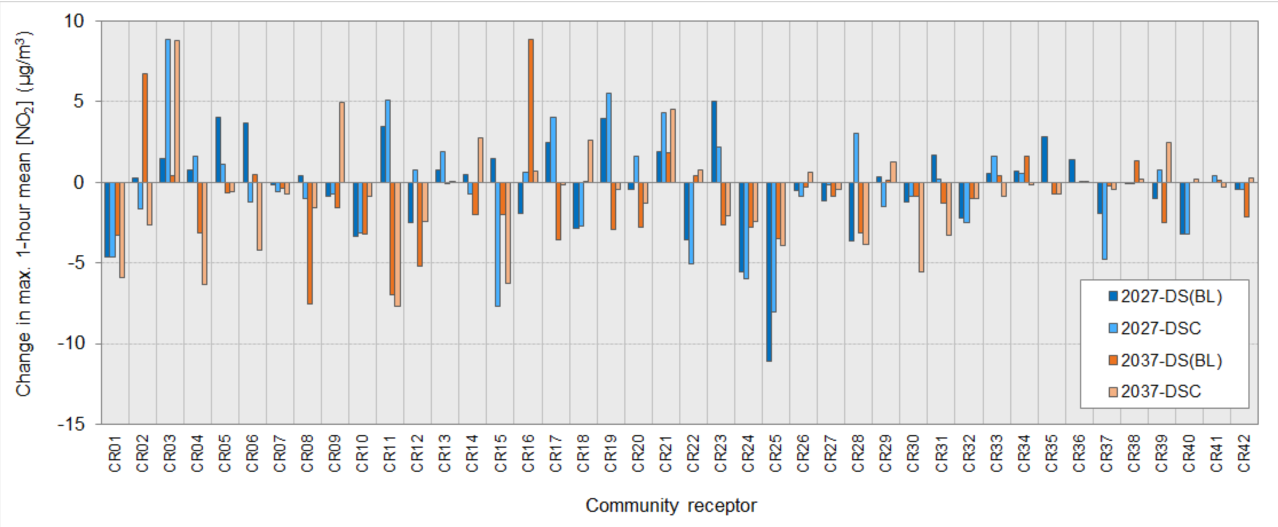


Figure 12-7 Change in maximum 1-hour mean NO_2 concentration at community receivers

Nitrogen dioxide (annual mean)

Residential, workplace and recreational receiver locations

Figure 12-8 shows the predicted contribution of the ‘Do something’ and ‘Do something cumulative’ scenarios to annual mean NO_2 concentration at residential, workplace and recreational receiver locations. The predicted annual mean NO_2 concentrations at most (more than 97 per cent) of the receiver locations are between about 13 µg/m^3 and 25 µg/m^3. The annual mean NO_2 criterion of 62 µg/m^3 would not be exceeded at any receiver locations under all scenarios assessed.

The maximum predicted NO_2 contribution at ground level from the ventilation outlets would be 0.7 µg/m^3, and the maximum predicted surface road contribution would be 24.3 µg/m^3, under all scenarios assessed. Given that annual mean NO_2 concentrations at most receiver locations would be well below the criterion, the contribution of the ventilation outlets at ground level is considered negligible.

Community receivers

Figure 12-9 shows the predicted annual mean NO_2 concentrations for the project and cumulative scenarios at community receivers. At all these locations the concentration is predicted to be below 40 µg/m^3, and well below the annual mean NO_2 criterion of 62 µg/m^3 for all scenarios assessed.

Figure 12-10 shows the predicted change in annual mean NO_2 concentration at all of the community receivers. There is a small predicted increase (<2 µg/m^3) in the NO_2 concentration at some community receivers. The largest increase with the project under the scenarios assessed would be about 1.3 µg/m^3 in the 2037 ‘Do something’ scenario, equating to less than three per cent of the criterion. There would also be some notable decreases in the annual mean NO_2 concentration at some receivers (in North Sydney, Mosman and Seaforth) in both the ‘Do something’ and ‘Do something cumulative’ scenarios in 2027 and 2037.

For the scenarios assessed, the background component at the community receivers is likely to be responsible for, on average, about 80 to 90 per cent of the predicted total annual mean NO_2, with most of the remainder being due to surface roads. At most receivers, surface roads would contribute between 10 and 30 per cent of the total annual mean NO_2 concentration. The contributions of tunnel ventilation outlets were less than three per cent in all scenarios.

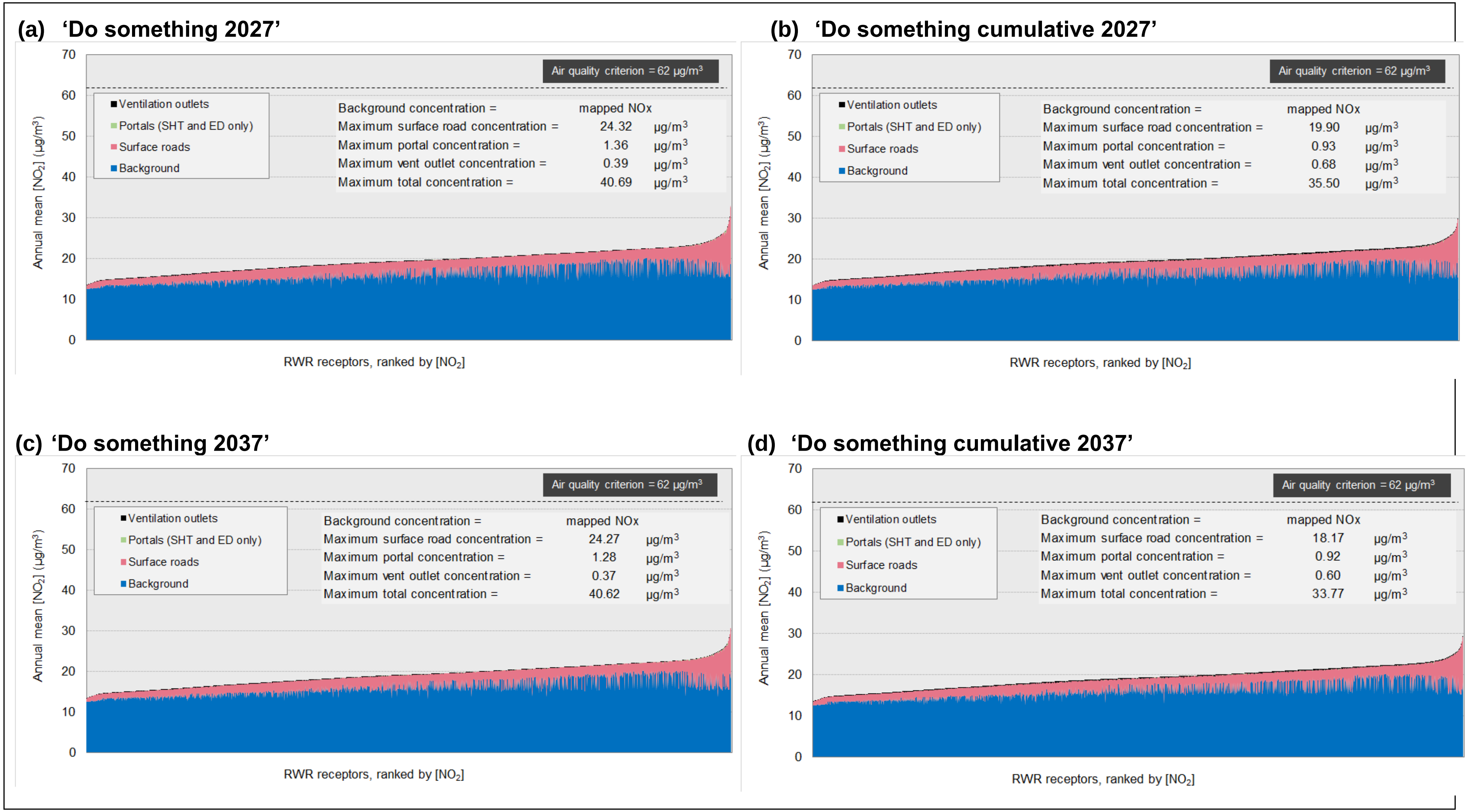


Figure 12-8 Contributions to annual mean NO_2 concentration at residential, workplace and recreational receivers

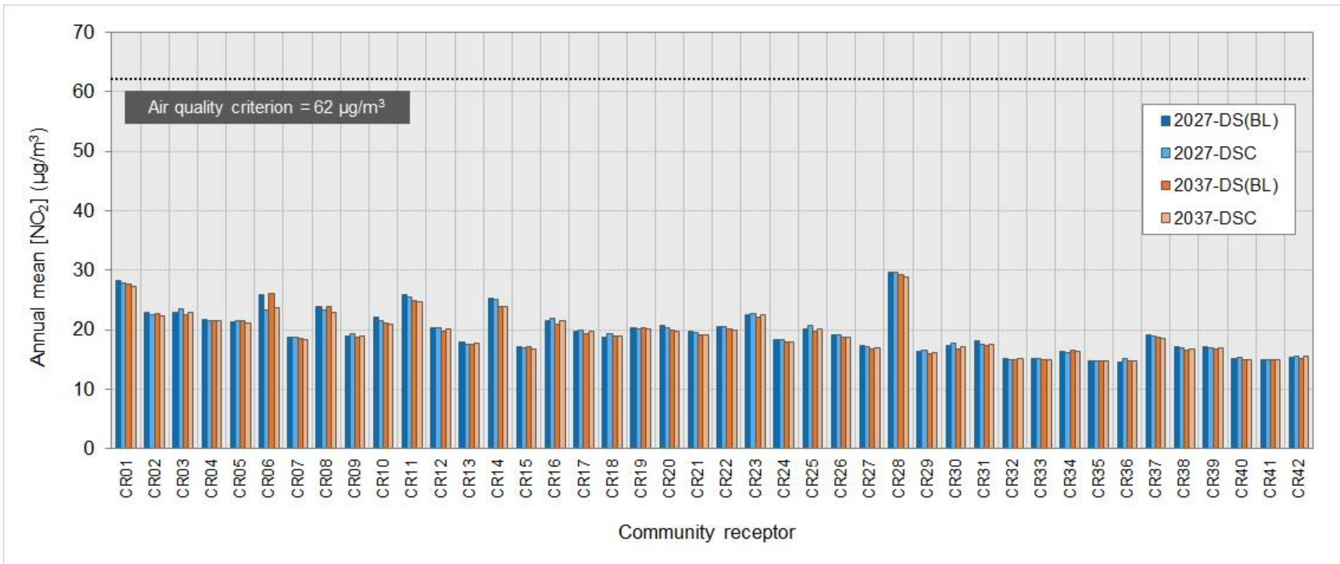


Figure 12-9 Annual mean NO_2 concentration at community receivers

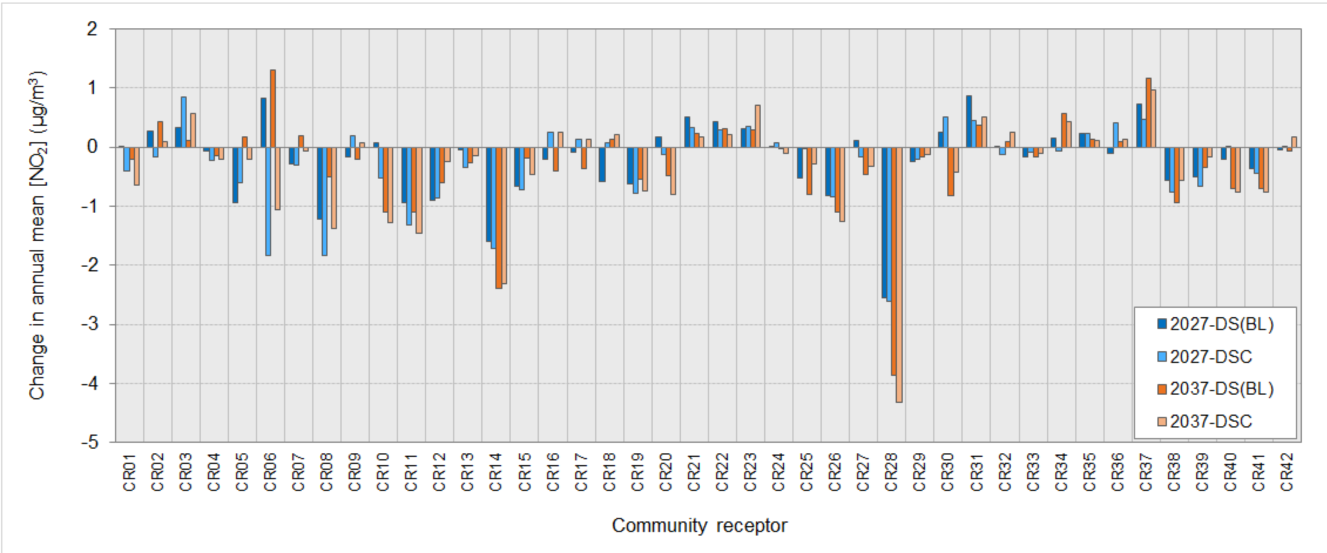


Figure 12-10 Change in annual mean NO_2 concentration at community receivers

PM_{10} (maximum 24-hour mean)

Residential, workplace and recreational receiver locations

Figure 12-11 shows predicted contributions of the project to maximum 24-hour mean PM_{10} concentrations at all the residential, workplace and recreational receiver locations. The results are highly dependent on the assumption for the background concentration (48.04 µg/m^3), which is driven by extreme events such as dust storms, bushfires and hazard reduction burns that occurred in 2016. Accordingly many of the receivers in the 'Do something' and 'Do something cumulative' scenarios (around 63 per cent) are predicted to be above the criterion of 50 µg/m^3. For the 'Do something' and 'Do something cumulative' scenarios, the maximum predicted contribution at ground level from the project's tunnel ventilation outlets at any receiver location would be between 0.7 µg/m^3 and 1.8 µg/m^3.

The largest predicted increase in concentration at any receiver as a result of the project was 6.1 µg/m^3, and the largest predicted decrease was 9.8 µg/m^3. The number of receivers for which a concentration above the criterion is predicted to reduce as a result of the project are as follows:

- From 23,065 in the 'Do minimum 2027' scenario to 21,795 in the 'Do something 2027' scenario and to 21,083 in the 'Do something cumulative 2027' scenario
- From 24,341 in the 'Do minimum 2037' scenario to, 23,236 in the 'Do something 2037' scenario and 22,507 in the 'Do something cumulative 2037' scenario.

Community receivers

Figure 12-12 shows the predicted maximum 24-hour mean PM_{10} concentrations at all of the community receivers in the project and cumulative scenarios. The predicted maximum 24-hour mean PM_{10} concentration is predicted to exceed the criterion of 50 µg/m^3 under all modelled scenarios, due to elevated background concentrations which occur during extreme events such as dust storms, bushfires and hazard reduction burns.

The background concentration is the largest contributor to predicted peak 24-hour PM_{10} concentrations under all modelled scenarios. For the majority of community receivers, the maximum total 24-hour concentration occurred on one day of the year, which coincided with the highest 24-hour background concentration in the PM_{10} profile (126.2 µg/m^3), recorded during a hazard reduction burn. The predicted surface road contribution to the maximum 24-hour PM_{10} concentration at each community receiver is relatively small (less than 4.2 µg/m^3). In the 'Do something' scenarios (ie with the operation of the project), the ventilation outlet contributions at all community receivers were less than 0.3 µg/m^3.

Figure 12-13 shows the predicted change in maximum 24-hour mean PM_{10} concentration as a result of the project and cumulatively with other projects (the difference between the 'Do something' scenarios and the 'Do minimum' scenarios) in 2027 and 2037. The changes were variable and there was no systematic changes by year or by scenario. At several receivers, there would be a predicted increase in concentration, but this would be less than about one µg/m^3.

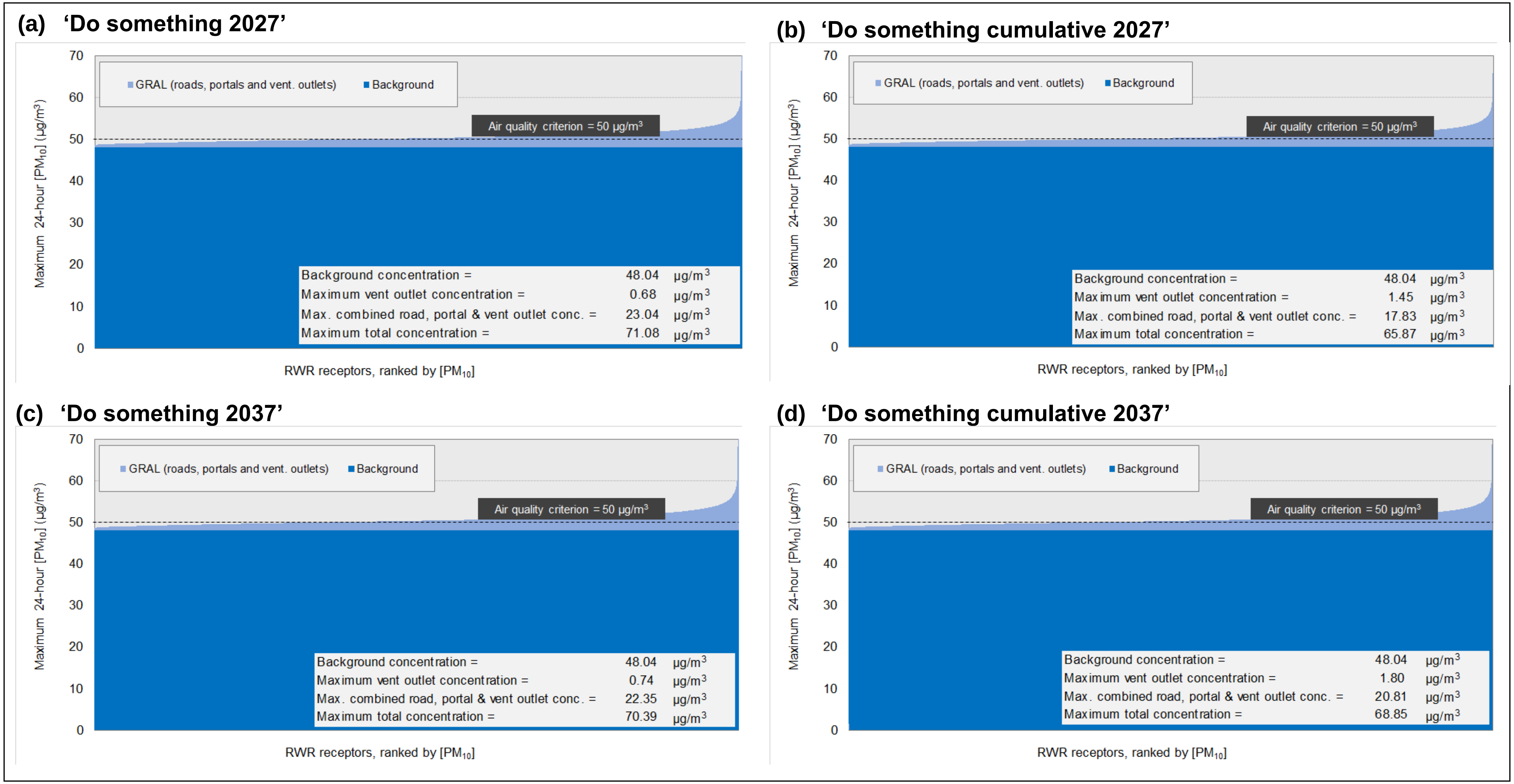


Figure 12-11 Contributions to maximum 24-hour mean PM_{10} concentration at residential, workplace and recreational receivers

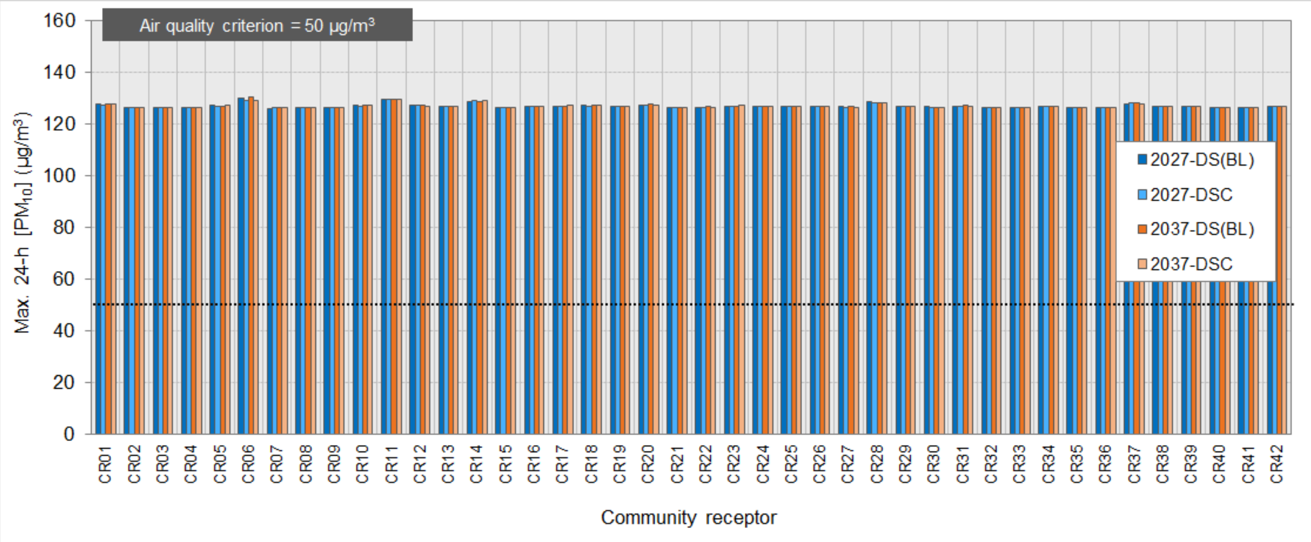


Figure 12-12 Maximum 24-hour mean PM_{10} concentration at community receivers

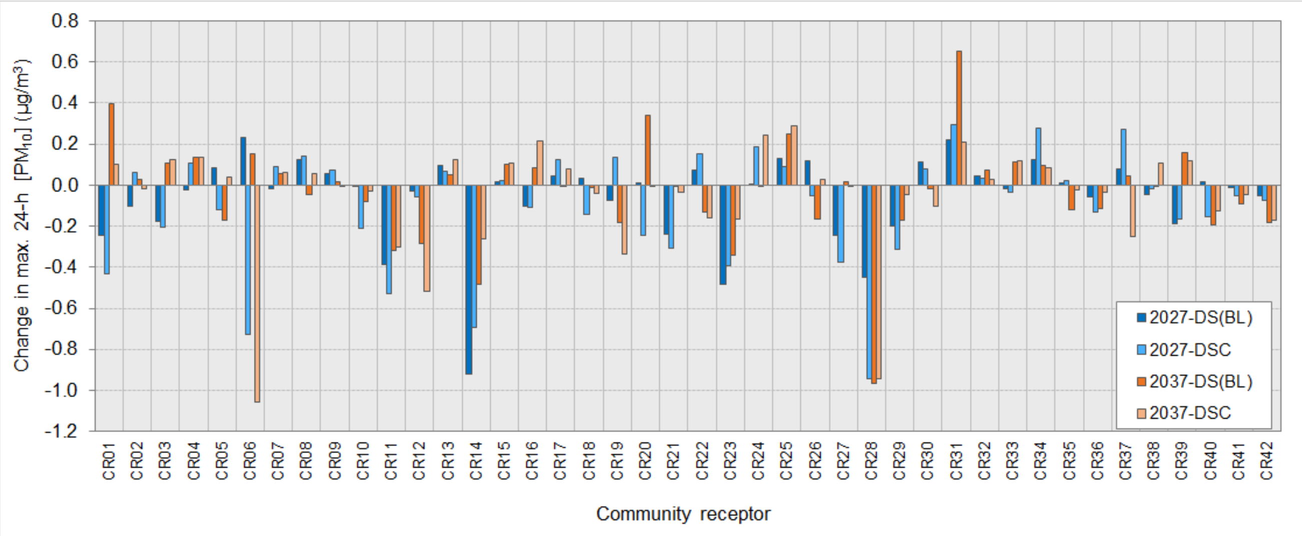


Figure 12-13 Change in maximum 24-hour mean PM_{10} concentration at community receivers

PM_{10} (annual mean)

Residential, workplace and recreational receiver locations

Figure 12-14 shows the 'Do something' and 'Do something cumulative' scenarios predicted contributions to the annual mean PM_{10} concentration at all the residential, workplace and recreational receiver locations. It demonstrates that the concentration at most receivers is predicted to be below 20 µg/m^3, and only one receiver is predicted to have a concentration above the criterion of 25 µg/m^3 under all scenarios assessed. The receiver is a commercial property (the control centre for Sydney Harbour Tunnel), located in the middle of the Bradfield Highway. This receiver had exceedances in the 'Do minimum' and 'Do something' scenarios.

An increase in annual mean PM_{10} concentration is predicted at less than half of receivers (between around 39 per cent and 45 per cent of receivers), with the increase considered to be negligible at the majority of receivers. The largest predicted surface road contribution was about 10.7 µg/m^3, with an average about 0.8 to 0.9 µg/m^3. The largest predicted contribution at ground level from the project's ventilation outlets would be 0.3 µg/m^3 in the 'Do something cumulative 2037' scenario.

Community receivers

Figure 12-15 shows the predicted annual mean PM_{10} concentrations at all the community receivers in the project and cumulative scenarios. PM_{10} concentrations are predicted to be below the criterion of 25 µg/m^3 at all receivers in all scenarios.

Figure 12-16 shows the predicted changes in annual mean PM_{10} concentration as a result of the project and cumulatively with other projects (the difference between the 'Do something' and 'Do something cumulative' scenarios and the 'Do minimum' scenarios) in 2027 and 2037. The largest predicted increase would be about 0.5 µg/m^3 (two per cent of the criterion) at receiver CR03 (St Basil's, Annandale), and the largest decrease would be 1.5 µg/m^3 at receiver CR28 (Peek A Boo Cottage, Seaforth).

Annual mean PM_{10} concentrations in the 'Do something' and 'Do something cumulative' scenarios for 2027 and 2037 would be dominated by existing PM_{10} concentrations (background). The predicted contribution from surface roads at most receivers would be small (up to three µg/m^3) and the contribution from the project's ventilation outlets would be negligible (less than about 0.2 µg/m^3).

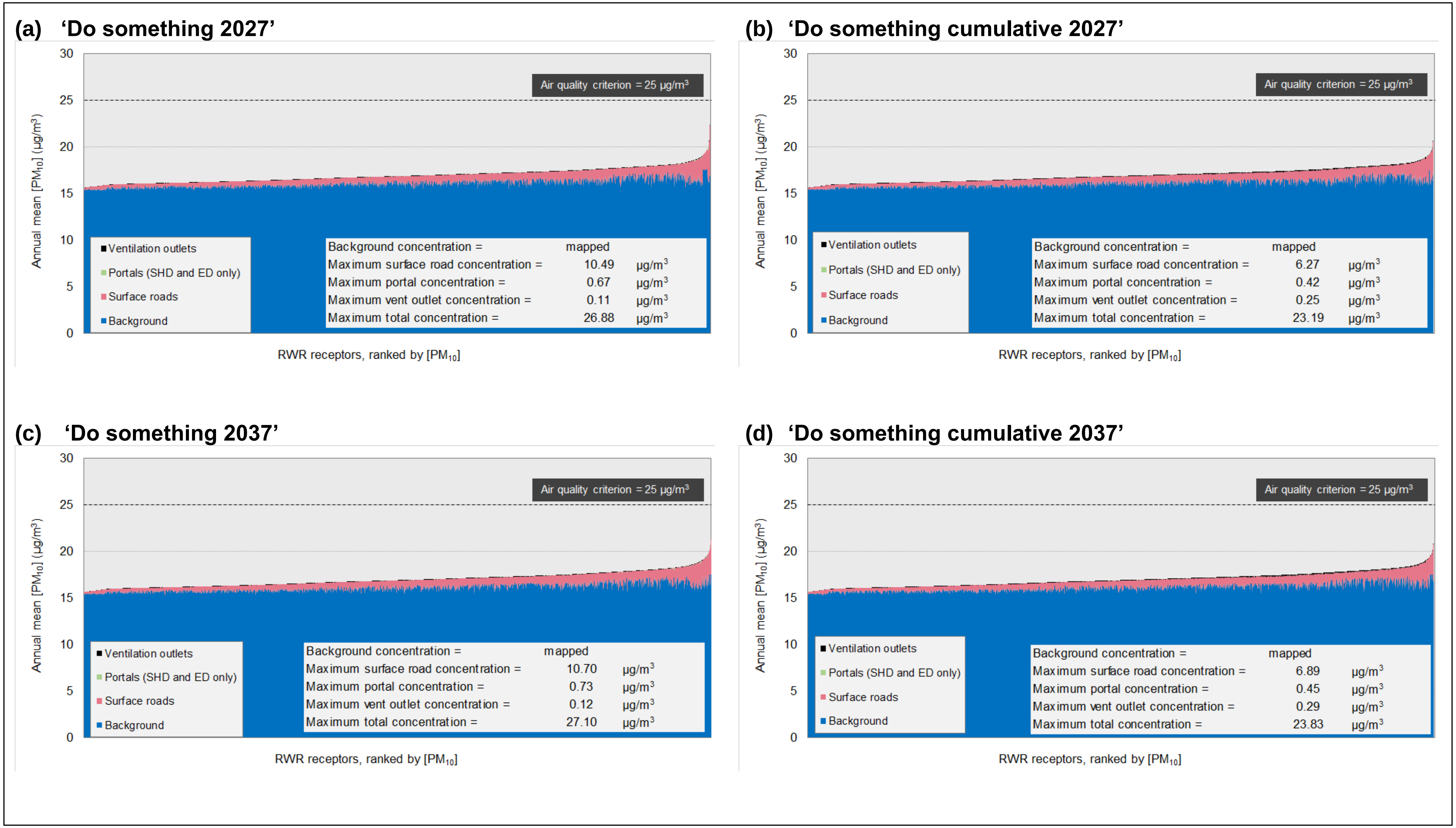


Figure 12-14 Contributions to annual mean PM_{10} concentration at residential, workplace and recreational receivers

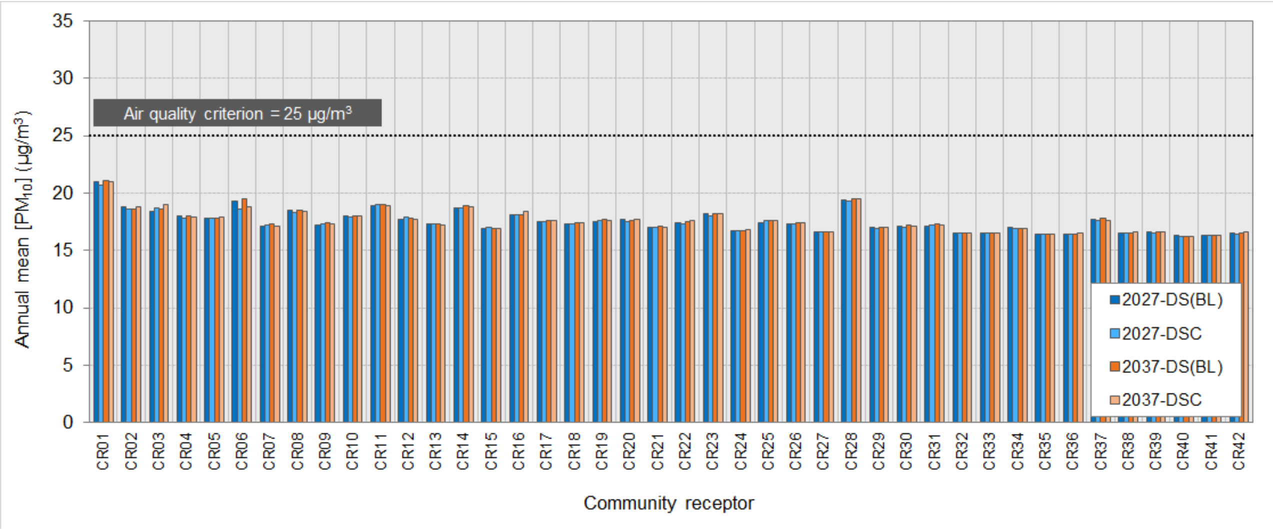


Figure 12-15 Annual mean PM_{10} concentration at community receivers

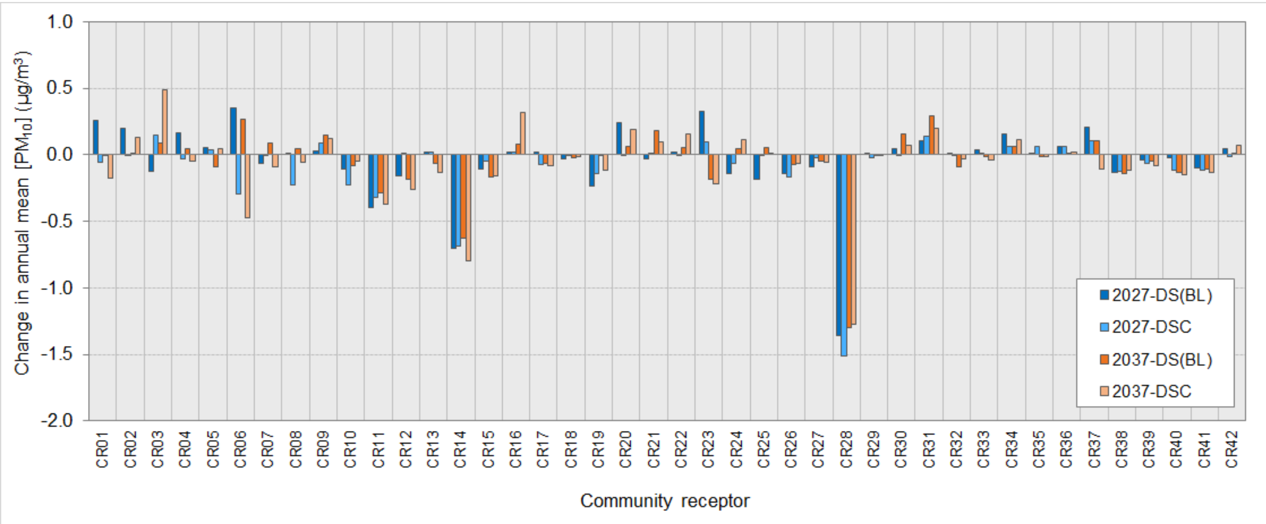


Figure 12-16 Change in annual mean PM_{10} concentration at community receivers

$PM_{2.5}$ (maximum 24-hour mean)

Residential, workplace and recreational receiver locations

Figure 12-17 shows predicted contributions of the project to the maximum 24-hour mean $PM_{2.5}$ concentration at all of the residential, workplace and recreational receiver locations. The main contributor to the predicted maximum 24-hour mean $PM_{2.5}$ concentration was elevated background concentrations that occur during extreme events such as dust storms, bushfires and hazard reduction burns. Consequently, the predicted maximum 24-hour mean $PM_{2.5}$ concentration at a large proportion of receivers was above the criterion of 25 µg/m^3, although this decreased slightly with the project. The proportion of exceedances decreased from 8.6 per cent in the 'Do minimum 2027' scenario to 7.1 per cent in the 'Do something 2027' scenario and 5.9 per cent in the 'Do something cumulative 2027' scenario. The proportion of exceedances are slightly higher in the 2037 scenarios, likely due to predicted increases in traffic. The predicted maximum contribution of the project's ventilation outlets would be 1.1 µg/m^3 in the 'Do something cumulative 2037' scenario at Rozelle.

At most receivers, the changes in the maximum 24-hour mean $PM_{2.5}$ concentration would be very small. The largest predicted increase in concentration at any receiver as a result of the project is predicted to be 4.2 µg/m^3, near Mowbray Road West in Lane Cove North and the largest predicted decrease is 6.3 µg/m^3, at North Sydney near Little Alfred Street. Where increases are predicted, they are greater than one µg/m^3 at less than one per cent of receivers.

Community receivers

Figure 12-18 shows the maximum 24-hour mean $PM_{2.5}$ concentrations at all the community receivers in the 'Do something' and 'Do something cumulative' scenarios. At all receiver locations, the predicted maximum concentrations were above the criterion of 25 µg/m^3, as exceedances were already predicted without the project. At all community receivers, the maximum total 24-hour concentration coincided with the highest 24-hour background concentration in the $PM_{2.5}$ profile at 49.4 µg/m^3, which is due to the extreme events described above. The combined non-background contributions to the predicted maximum 24-hour mean $PM_{2.5}$ concentration at community receivers would be relatively small. On the days when the maximum total concentration occurred, the project's ventilation outlet contributions would be small in all cases (less than 0.2 µg/m^3).

Figure 12-19 shows the predicted changes in maximum 24-hour mean $PM_{2.5}$ concentration as a result of the project and cumulatively with other projects (the difference between the 'Do something' scenarios and the 'Do minimum' scenarios) in 2027 and 2037. All of the increases in concentration were less than one µg/m^3. The largest predicted increase in maximum 24-hour mean $PM_{2.5}$ concentrations is 0.54 µg/m^3 at a receiver CR25 in Willoughby (Sue's Childcare Castlevale, Willoughby East) in the 'Do something cumulative 2037' scenario, which is less than two per cent of the criterion for $PM_{2.5}$.

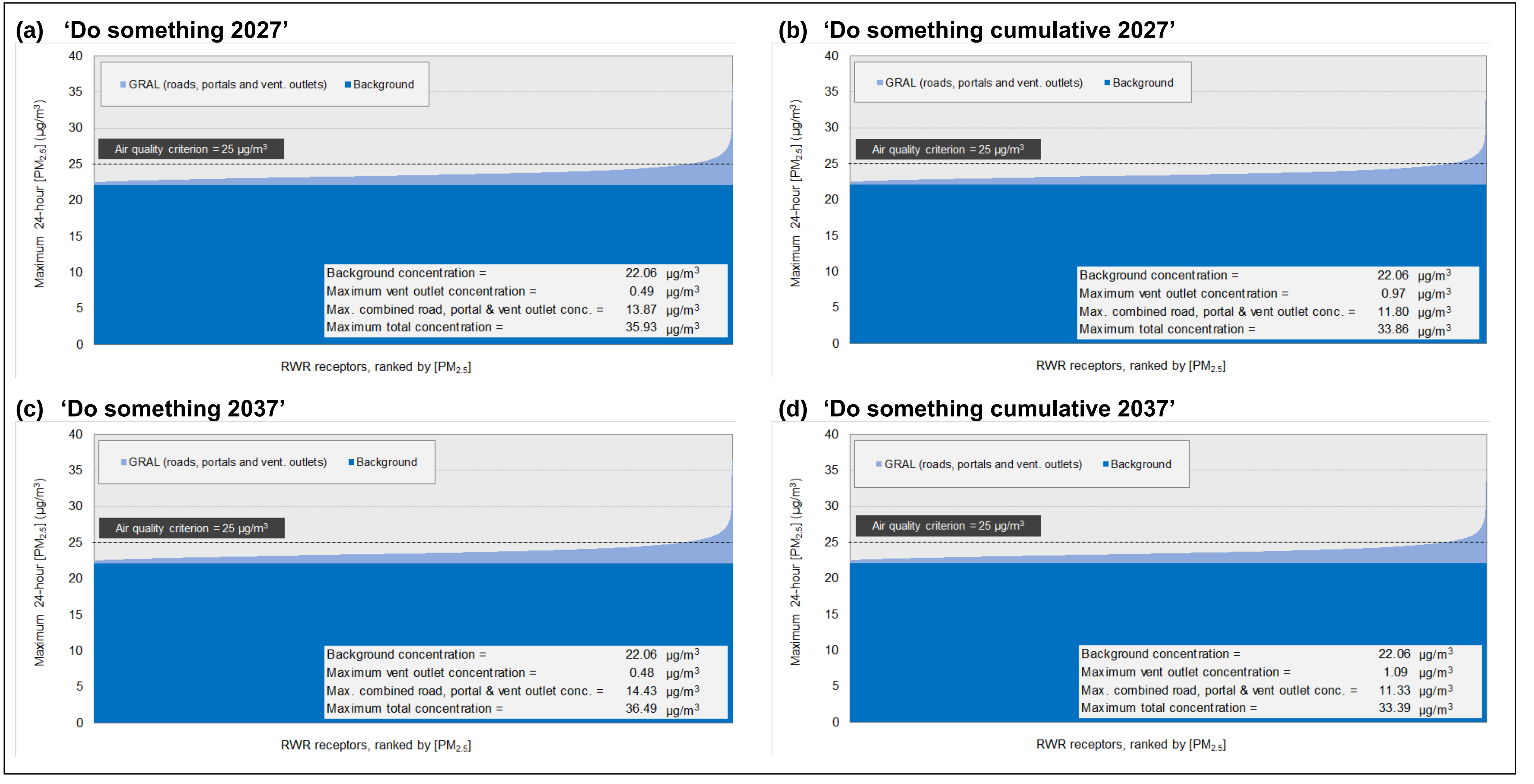


Figure 12-17 Contributions to maximum 24-hour $PM_{2.5}$ mean concentration at residential, workplace and recreational receivers

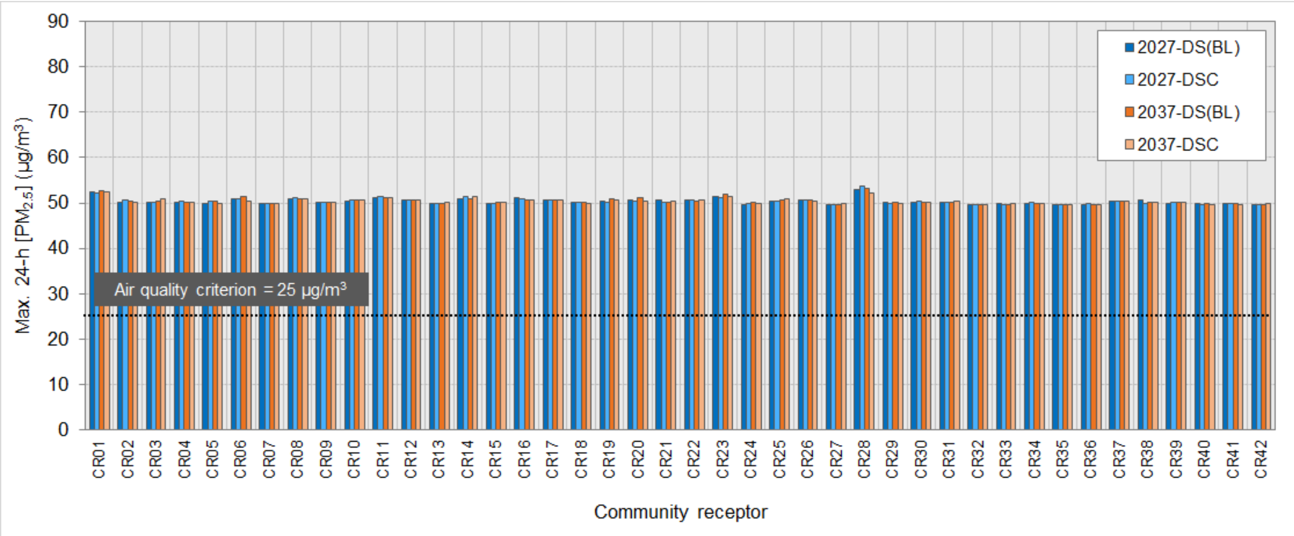


Figure 12-18 Maximum 24-hour $PM_{2.5}$ mean concentration at community receivers

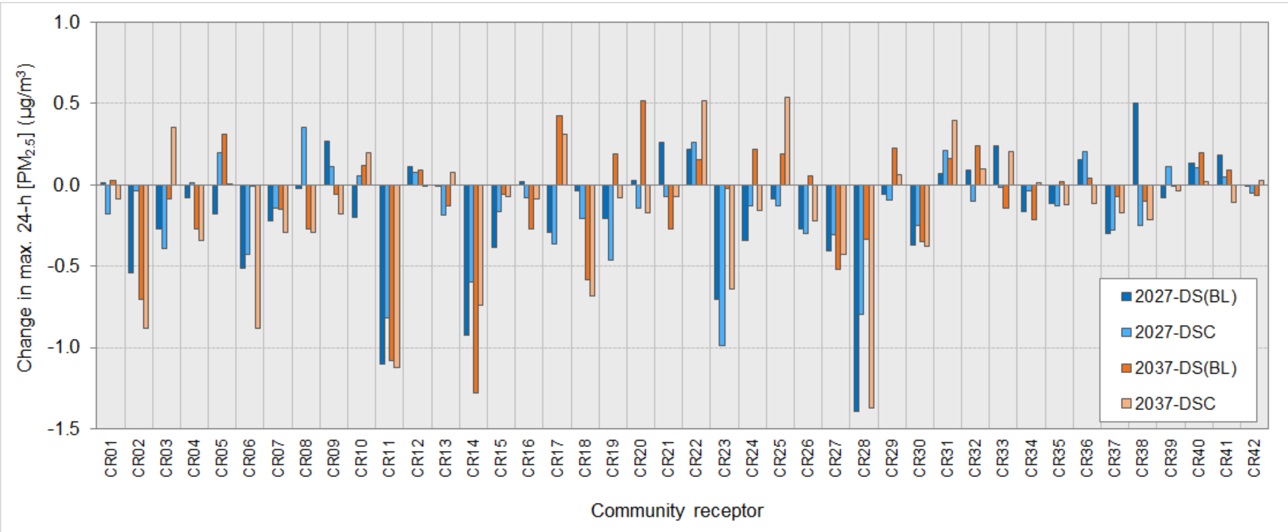


Figure 12-19 Change in maximum 24-hour $PM_{2.5}$ mean concentration at community receivers

$PM_{2.5}$ (annual mean)

Residential, workplace and recreational receiver locations

Figure 12-20 shows predicted contributions of the project to the annual mean $PM_{2.5}$ concentration at all the residential, workplace and recreational receiver locations. Elevated background levels of $PM_{2.5}$ currently exist at these receiver locations that often exceed the criterion of eight µg/m^3, as well as the 2025 goal of seven µg/m^3. Therefore, the background $PM_{2.5}$ concentration was the main contributor to predicted annual mean $PM_{2.5}$ concentrations in the 'Do something' and 'Do something cumulative' scenarios. Nevertheless, the annual mean $PM_{2.5}$ concentration was unchanged or slightly lower at the majority of residential, workplace and recreational receiver locations in the 'Do something' and 'Do something cumulative' scenarios.

The highest predicted annual mean $PM_{2.5}$ concentration at any receiver location would be 14.5 µg/m^3. In the 'Do something' and 'Do something cumulative' scenarios, the largest surface road contribution at any receiver is predicted to be 6.7 µg/m^3. The largest predicted contribution from the project's ventilation outlets in these scenarios would be 0.18 µg/m^3, at Rozelle.

The largest predicted increase in concentration at any receiver location as a result of the project would be 1.6 µg/m^3, in Kirribilli at the northern end of the Sydney Harbour Bridge. The largest predicted decrease would be 2.3 µg/m^3, at North Sydney near Little Alfred Street. The increases were mainly along the Warringah Freeway Upgrade, north east of the Burnt Bridge Creek Deviation, along Wakehurst Parkway and particularly near the Sydney Harbour Bridge and Cammeray. The predicted increases in concentration along Wakehurst Parkway are limited to within the road corridor and do not extend out to the nearby residential, workplace and recreational receivers. There were also increases at Gore Hill Freeway, Manly Road and Rozelle.

Community receivers

Figure 12-21 shows the annual mean $PM_{2.5}$ concentrations at all the community receivers. As with the residential, workplace and recreational receivers, the annual mean $PM_{2.5}$ concentrations in the 'Do something' and 'Do something cumulative' scenarios for 2027 and 2037 would be dominated by background $PM_{2.5}$ concentrations. Given that the predicted background concentration at some community receivers (up to 7.9 µg/m^3) is already close to the air quality criterion (eight µg/m^3) under the 'Do minimum' scenario, some exceedances of the 2025 goal (seven µg/m^3) are predicted with the project under the scenarios assessed for 2027 and 2037. These exceedances also occur in the 'Do minimum' scenarios.

The contribution from surface roads is predicted to be between 0.1 µg/m^3 and 2.1 µg/m^3 whereas the largest predicted contribution from the project's ventilation outlets at any receiver would be 0.1 µg/m^3.

Figure 12-22 shows the predicted change in the annual mean $PM_{2.5}$ as a result of the project and cumulatively with other projects (the difference between the 'Do something' scenarios and the 'Do minimum' scenarios) in 2027 and 2037. Overall, the changes would generally be less than 0.3 µg/m^3. The largest predicted increase in annual mean $PM_{2.5}$ concentration at any community receiver as a result of the project would be 0.3 µg/m^3 at receiver CR03 (St Basil's, Annandale) in the 'Do something cumulative 2037' scenario. This increase is less than four per cent of the air quality criterion. The largest reduction in the annual mean $PM_{2.5}$ concentration (up to 1.1 µg/m^3) is predicted at receiver CR28 (Peek A Boo Cottage, Seaforth) with the project.

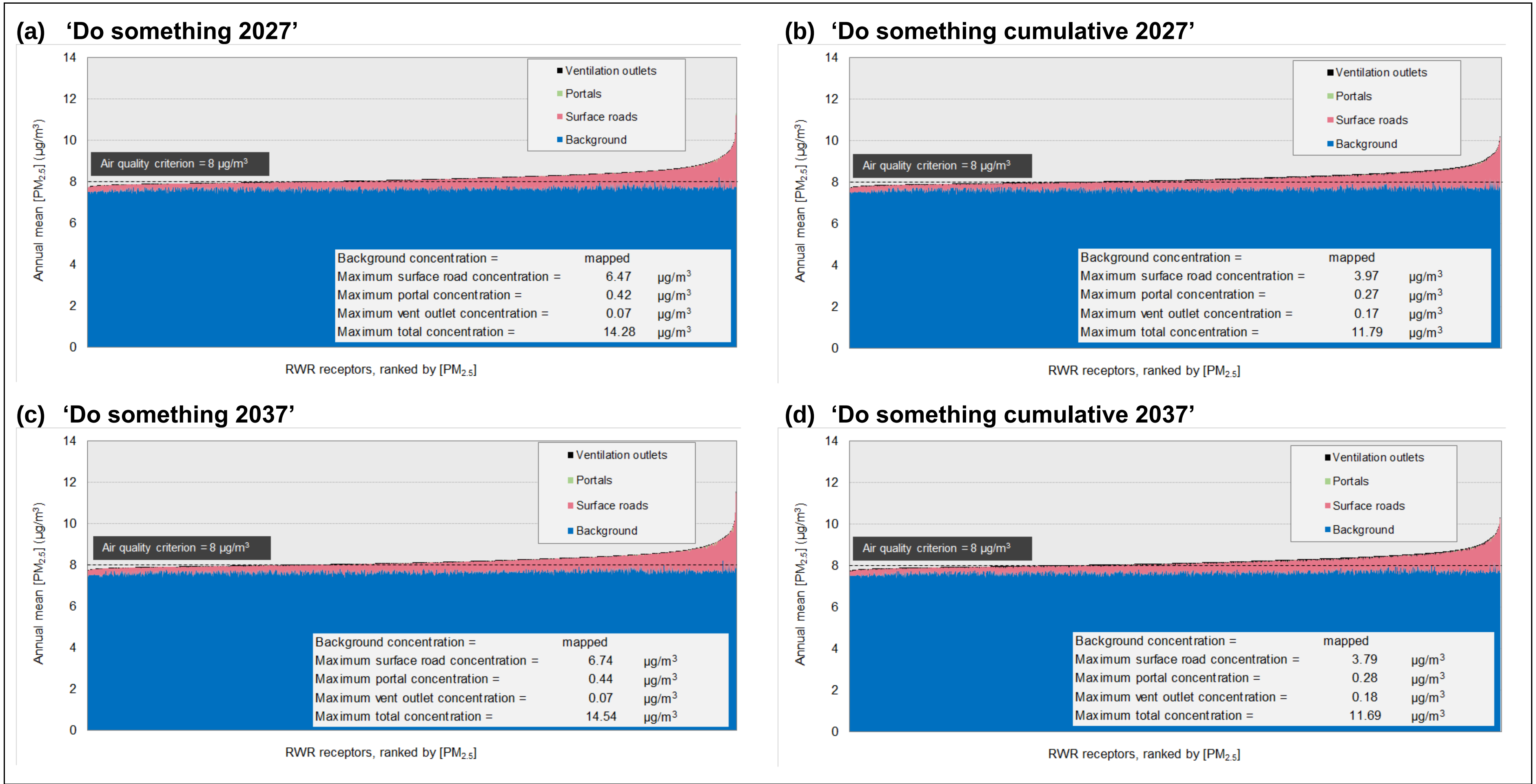


Figure 12-20 Contributions to annual mean $PM_{2.5}$ concentration at residential, workplace and recreational receivers

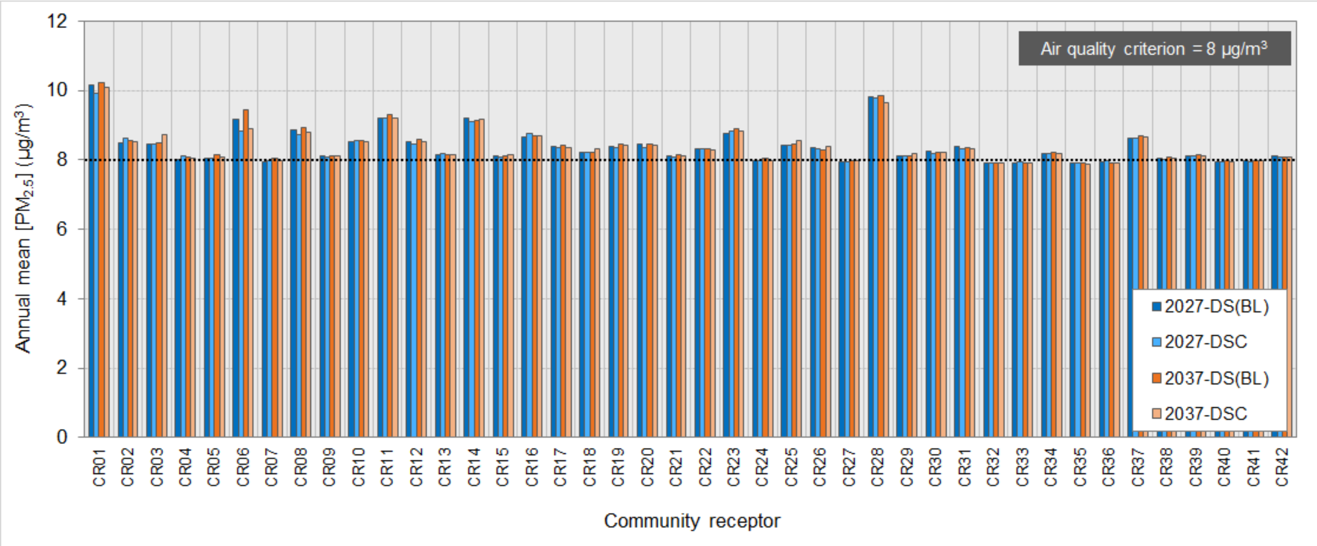


Figure 12-21 Annual mean $PM_{2.5}$ concentration at community receivers

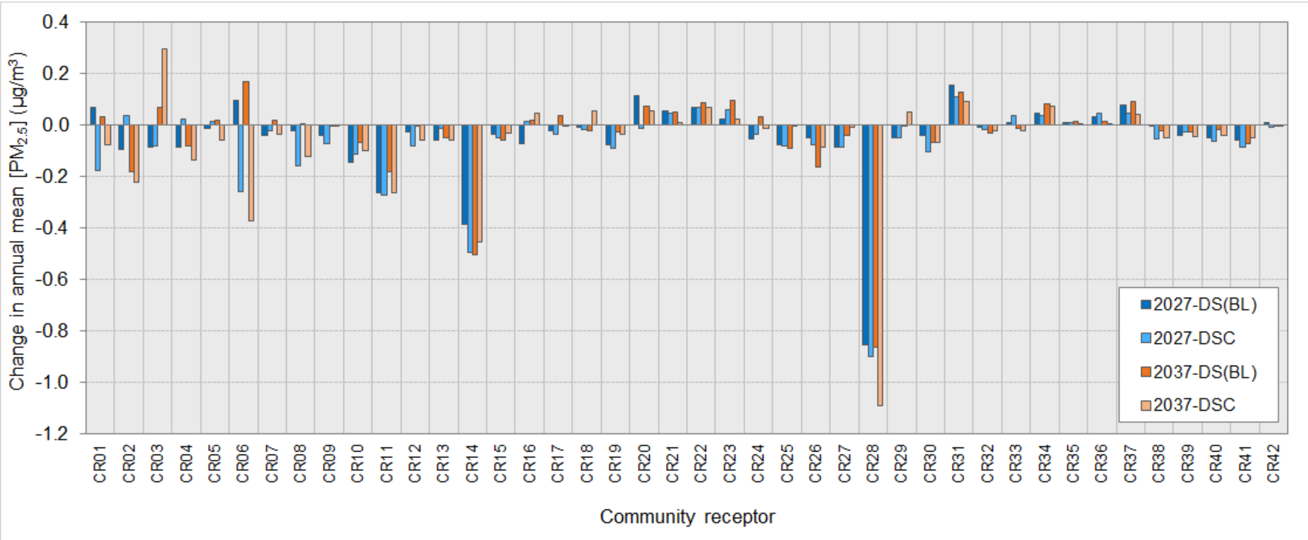


Figure 12-22 Change in annual mean $PM_{2.5}$ concentration at community receivers

Carbon monoxide (CO)

Residential, workplace and recreational receiver locations

The maximum 1-hour and rolling 8-hour mean CO concentrations are predicted to be below the 1-hour and rolling 8-hour CO criteria at all the receiver locations for all the scenarios. The highest total 1-hour CO concentration in any of the 'Do something' or 'Do something cumulative' scenarios is predicted to be 5.5 mg/m^3, in Rozelle. The largest predicted contribution from ventilation outlets at any receiver is predicted to be less than 0.1 mg/m^3, also in Rozelle. Rolling 8-hour mean CO concentrations at all of the residential, workplace and recreational receiver locations are predicted to be similar to those obtained for maximum 1-hour concentrations.

Community receivers

The CO concentration at all of the community receiver locations, is predicted to be well below the impact assessment criterion for both the maximum 1-hour and maximum rolling 8-hour mean CO concentrations.

The largest contribution of surface roads to the maximum total concentration in any of the 'Do something' and 'Do something cumulative' scenarios is predicted to be small for both the maximum 1-hour and maximum rolling 8-hour mean CO concentrations (1.2 mg/m^3 at receiver CR01 (University of Notre Dame, Broadway)). The contribution of the project's ventilation outlets to the maximum CO concentration is zero or negligible (ie less than 0.01 mg/m^3) for all receivers.

Air toxics

Five compounds, benzene, polycyclic aromatic hydrocarbons, formaldehyde, 1,3-butadiene and ethylbenzene, were considered in the assessment. These compounds were taken to be representative of the much wider range of air toxics associated with motor vehicles and have commonly been assessed for road projects.

The predicted changes in the maximum 1-hour concentrations for these compounds showed that there would be minor increases in concentrations as a result of the project, however, all air toxic concentrations would be well below their respective assessment criterions. The increases (and decreases) for the most affected residential, workplace and recreational receiver locations would be higher for those that are in close proximity to the surface roads, but in all 'Do something' and 'Do something cumulative' scenarios for all five compounds considered in the assessment, the total predicted concentrations would be well below their respective criteria. For example, the largest increase in benzene concentrations at any residential, workplace and recreational receiver location for a 'Do something cumulative' scenario is predicted to be 3.7 µg/m^3, but the total concentration of 8.7 µg/m^3 still remains well below the criterion of 29 µg/m^3 (0.029 mg/m^3).

12.6.3 Redistribution of air quality impacts

Spatial changes in air quality

The spatial changes in pollutant concentrations are assessed with respect to annual mean $PM_{2.5}$ concentration, given its importance in terms of human health risks. However, the spatial changes would be qualitatively similar for all pollutants.

The annual mean $PM_{2.5}$ concentration as a result of the project ('Do something 2027' scenario relative to the 'Do minimum 2027' scenario) is predicted to decrease along Military Road, Spit Road, Manly Road and Warringah Road. These reductions would be associated with the reductions in traffic and would result in improved amenity along these built-up road corridors. The human health benefits associated with the decrease in $PM_{2.5}$ concentration as a result of the project is discussed in Chapter 13 (Human health).

There would be increases in the $PM_{2.5}$ concentration along Sydney Harbour Bridge and Wakehurst Parkway. In the case of Wakehurst Parkway there would be a large increase in traffic (about 140 per cent) as a result of the project. However, the section of Wakehurst Parkway that is affected crosses bushland, and there are no sensitive receivers close to the road. Predicted increases in pollutant concentrations along Wakehurst Parkway are also limited to the road corridor and do not extend out to nearby receivers. There would be broadly similar changes in the ‘Do something 2037’ scenario.

For the cumulative scenarios, there would be some additional changes as a result of the Western Harbour Tunnel and Warringah Freeway Upgrade project, including reductions in the $PM_{2.5}$ concentration along the Western Distributor, Sydney Harbour Bridge and Warringah Freeway.

Overall, there would be no marked redistribution of air quality impacts, and there would generally be a shift towards lower concentrations. Most notably, there would be no significant increase in concentration at receiver locations which already had high concentrations in the ‘Do minimum’ scenarios.

12.6.4 Ambient air quality (elevated receivers)

Modelling of all pollutants at elevated receivers, for the ‘Do something cumulative 2037’ scenario was carried out at heights of 10 metres, 20 metres, 30 metres and 45 metres above ground level. The changes in the annual mean and maximum 24-hour mean PM_{10} and $PM_{2.5}$ concentrations were considered in addition annual average and maximum 1-hour average NO_2 concentrations and air toxics (only the incremental (ventilation outlet) contribution).The aim of this assessment is to provide an evaluation of impacts at elevated receivers within 300 metres of the project’s ventilation outlets.

It should be noted that existing buildings at receiver locations are not as tall as the heights discussed above (eg at a receiver location, an existing building may be up to 10 metres in height but was assessed at all four selected heights).

As summary of the outcomes of the elevated receivers assessment for existing buildings is provided below with the full methodology and results provided in Section 8.4.9 of Appendix H (Technical working paper: Air quality):

- For the annual average PM_{10} and $PM_{2.5}$ concentrations, there are no predicted exceedances of the respective criteria at any modelled height
- For the maximum 24-hour average PM_{10} concentrations, there are no predicted exceedances of the criterion of 50 $\mu g/m^3$ at any height for the buildings present
- For the maximum 24-hour average $PM_{2.5}$ concentrations, there are no predicted exceedances of the criterion of 25 $\mu g/m^3$ at any height for the buildings present
- For the annual average and maximum 1-hour average NO_2 concentrations, there are no predicted exceedances of the criterion at any modelled height
- For the maximum 1-hour average benzene, PAHs, formaldehyde, 1,3-butadiene and ethylbenzene concentrations, there are no predicted exceedances of the criteria at any modelled height.

Considering the above, it can be concluded that no adverse impacts are predicted at any existing buildings.

The modelling predicted no exceedances at any modelled height for concentrations for annual average PM_{10} and $PM_{2.5}$, annual average and maximum 1-hour average NO_2 and air toxics. The assessment predicted some exceedances at heights above 30 metres within 300 metres of the project’s ventilation outlets for $PM_{2.5}$ and PM_{10} maximum 24-hour average concentrations, which might impact any future buildings at these heights. This would not necessarily preclude such development and further consideration at rezoning or development application stage would be required.

In addition, 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 a ventilation outlet.

Transport for NSW would assist councils and the Department of Planning, Industry and Environment (as appropriate) in determining relevant land use considerations applicable to future development in the immediate vicinity of the project's ventilation outlets for inclusion in Local Environmental Plans or Development Control Plans, where required, to manage interactions between the project and future development. This may include procedures for identifying the requirement for consultation with Transport for NSW for proposed rezoning or development applications.

12.6.5 Regional air quality

The absolute changes in the total emissions resulting from the project can be viewed as a proxy for the project's regional air quality impacts which, based on the results, are likely to be negligible. For example:

- Changes in NO_X emissions for the assessed road network for the 'Do something' scenarios in a given assessment year ranged from an increase of around one tonne per year to a decrease of around four tonnes per year, depending on the scenario. In the 'Do something cumulative' scenarios, changes in NO_X emissions ranged from an increase of around 29 tonnes to 125 tonnes per year. These values equated to small proportions of human activity related NO_X emissions in the Greater Sydney airshed in 2016 (about 53,700 tonnes)
- The projected reduction in the NO_X emission rate between 2016 and 2037 (about 2000 tonnes per year) exceed the relatively small increases in the NO_X emission rate due to the project in a given year.

The regional air quality impacts of a project can also relate to its capacity to influence ozone production. The project's impact on ozone concentrations in the Greater Sydney region was assessed in accordance with the NSW Environment Protection Authority's *Tiered Procedure for Estimating Ground Level Ozone Impacts from Stationary Sources* (ENVIRON, 2011). The assessment indicated that the largest increase in NO_X emissions due to the project (125 tonnes per year in the 'Do something cumulative 2037' scenario) would be above the 90 tonnes per year threshold for conducting a further detailed assessment. Further assessment using the NSW Environment Protection Authority Level 1 screening tool indicated that the maximum 1-hour and 4- hour incremental ozone concentrations due to the project in the 'Do something cumulative 2037' scenario would not exceed the screening impact level of 0.5 parts per billion, and therefore no further consideration is required.

Overall, the regional impacts of the project would be negligible, and undetectable in ambient air quality measurements at background locations.

12.6.6 Odour

For each of the residential, workplace and recreational receivers, the change in the maximum one hour total hydrocarbon concentration as a result of the project was calculated. The largest change in the maximum one hour total hydrocarbon concentration across all receivers was then determined, and this was converted into an equivalent change for three of the odorous pollutants identified in the NSW EPA Approved Methods (toluene, xylenes, and acetaldehyde). Some hydrocarbons emitted from the burning of fuel by motor vehicles create odour. These pollutants were taken to be representative of other odorous pollutants from motor vehicles.

The changes in the levels of three odorous pollutants as a result of the project, and the corresponding odour assessment criteria from the NSW EPA Approved Methods, are shown in Table 12-10.

Table 12-10 Changes in odorous pollutant concentrations

Scenario	Largest predicted increase in maximum 1 hour hydrocarbon concentration		
	Toluene ($\mu g/m^3$)	Xylenes ($\mu g/m^3$)	Acetaldehyde ($\mu g/m^3$)
'Do something 2027'	6.7	5.6	1.5
'Do something cumulative 2027'	5.9	4.8	1.3
'Do something 2037'	3.9	3.2	1.3
'Do something cumulative 2037'	3.5	2.9	1.2
Odour criterion ($\mu g/m^3$)	360	190	42

12.7 Environmental management measures

12.7.1 Management of construction impacts

Environmental management measures relating to air quality impacts are outlined in Table 12-11.

Table 12-11 Environmental management measures – air quality

Ref	Phase	Impact	Environmental management measure	Location
AQ1	Pre-construction and construction	General	Standard construction air quality mitigation and management measures will be detailed in construction management documentation and implemented during construction, such as: a) Reasonable and feasible dust suppression and/or management measures, including the use of water tanks and/ or carts, sprinklers, site exit controls (eg wheel washing systems and rumble grids), stabilisation of exposed areas or stockpiles, and surface treatments b) Selection of construction equipment and/or materials handling techniques that minimise the potential for dust generation c) Management measures to minimise dust generation during the transfer, handling and on site storage of spoil and construction materials (such as sand, aggregates or fine materials) (eg the covering of vehicle loads) d) Adjustment or management of dust generating activities during unfavourable weather conditions, where reasonable and feasible e) Minimisation of exposed areas during construction f) Measures for managing odour generation likely to result in odour impacts at sensitive receivers in the vicinity during the	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			disturbance, handling and storage of potentially odorous materials, including any contingency measures g) Internal project communication protocols to ensure dust-generating activities in the same area are coordinated and mitigated to manage cumulative dust impacts of the project h) Site inspections will be carried out to monitor the effectiveness of implemented measures and identify any additional measures to be implemented.	
AQ2	Pre-construction and construction	Odour	Further site investigations will be carried out during the detailed design and construction planning phase to determine the potential to encounter odorous gases or materials during the proposed excavations at the Flat Rock Drive construction support site (BL2). If the investigations indicate that there is potential for odorous materials to be uncovered or odorous gases to be released, the potential for off-site impacts (informed by meteorological studies and modelling as required) will be investigated. If unacceptable off-site impacts are predicted, appropriate mitigation and management measures will be identified to minimise potential impacts, with consideration of the investigation results, proposed site activities and meteorological conditions, and the identified measures will be implemented during relevant site activities. Odour monitoring will be carried out during relevant site activities and mitigation and management measures adjusted as required to minimise potential off-site impacts.	BL
AQ3	Construction	General	Dust and air quality complaints will be managed in accordance with the overarching complaints handling process for the project. Appropriate corrective actions; if required, will be taken to reduce emissions in a timely manner.	BL/GHF
AQ4	Construction	Odour	Any areas of exposed material at the Flat Rock Drive construction support site that have the potential to generate odour will be kept to a minimum during site establishment works and while the area is uncovered. If odorous areas are to remain uncovered at the end of the work shift, temporary cover or other suitable measures to minimise odour emissions will be implemented.	BL

Ref	Phase	Impact	Environmental management measure	Location
AQ5	Construction	Odour	If the dredged materials require some form of land-based processing prior to disposal, an assessment of potential odour impacts will be carried out for the proposed processing site in accordance with the *Technical framework for the assessment and management of odour from stationary sources in NSW* (DEC, 2006). This will include modelling to assess whether the use of the site and the proposed processing and treatment activities for the dredged material can comply with a criterion of 2 odour units at all sensitive receivers in the vicinity.	BL
AQ6	Construction	Odour	Where the assessment carried out in environmental management measure AQ5 indicates that compliance is not likely, an odour management strategy will be developed. The strategy will describe appropriate mitigation and management measures to ensure that the 2 odour units criterion is met, odour survey requirements and contingency actions that will be implemented if significant odour issues are observed in the vicinity of sensitive receivers. The strategy will be developed prior to accepting dredged material at the site and implemented for the duration of the processing of dredged material at the site.	BL

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

12.7.2 Management of operational impacts

The Secretary's environmental assessment requirements for the project require details of, and justification for, the air quality management measures that were considered for the project. This section reviews the environmental management measures that are available for improving tunnel-related air quality, and then describes their potential application in the context of the project. The measures are categorised as follows:

- Tunnel design
- Ventilation design and control
- Air treatment systems
- Emission controls and other measures.

Tunnel design

Tunnel infrastructure is designed in such a way that the generation of pollutant emissions by traffic using the tunnel is minimised. Tunnel design provisions for this project include:

- Minimal gradients as far as reasonably practicable
- Large tunnel cross-sectional area to reduce the pollutant concentration for a given emission into the tunnel volume, and to permit greater volumetric air throughput
- Increased height to reduce the risk of incidents involving high vehicles blocking the tunnel and disrupting traffic. This would reduce the risk of higher pollutant concentrations associated with flow breakdown.

Ventilation design and control

The project ventilation system has been designed and would be operated so that it would achieve some of the most stringent standards in the world for in-tunnel air quality, and would be effective at maintaining local air quality. The design of the ventilation system would ensure zero portal emissions.

The ventilation system would be automatically controlled using real-time air velocity and air quality sensor data to ensure that in-tunnel conditions are managed effectively in accordance with the agreed criteria. Furthermore, specific ventilation modes would be developed to manage breakdown, congested and emergency situations.

There are several reasons why a tunnel needs to be ventilated. The main reasons are:

- Control of the internal environment: It must be safe and comfortable to drive through the tunnel. Vehicle emissions must be sufficiently diluted so as not to be hazardous during normal operation, or when traffic is moving slowly or stationary
- Protection of the external environment: Ventilation, and the dispersion of pollutants, is the most widely used method for minimising the impacts of tunnels on ambient air quality. Collecting emissions and venting them via elevated ventilation outlets is a very efficient way of dispersing pollutants. Studies show that the process of removing surface traffic from heavily trafficked roads and releasing the same amount of pollution from an elevated location results in substantially lower concentrations at sensitive receivers (Permanent International Association of Road Congress (PIARC), 2008)
- Emergency situations: When a fire occurs in a tunnel, the ventilation system is able to control the heat and smoke in the tunnel so as to permit safe evacuation of occupants, and to provide the emergency services with a safe route to deal with the fire and to rescue any trapped or injured persons.

The ventilation system design options that were considered for the project are discussed in Chapter 4 (Project development and alternatives) and the system adopted for the project is described in Chapter 5 (Project description).

Air treatment systems

In November 2018, the ACTAQ, chaired by the NSW Chief Scientist and Engineer, published a review of lessons learnt from other major road tunnel projects in NSW (ACTAQ, 2018c). The review found that emissions from well designed ventilation outlets have little, if any, impact on surrounding communities and, as such, there is little health benefit in installing filtration and air treatment systems.

There are several air treatment options for mitigating the effects of tunnel operation on both in-tunnel and ambient air quality. Where in-tunnel treatment technologies have been applied to road tunnels, these technologies have focused on the management and treatment of particulates.

ACTAQ's review of options for treating road tunnel emissions (ACTAQ, 2018b) demonstrated that the appropriate design of ventilation outlets would achieve the same (or better) outcomes as installing air filtration systems – that is, the contribution of tunnel ventilation outlets to pollutant concentrations would be negligible for all receivers. In Australia, tunnel projects therefore generally implement the primary approach of dilution of air pollution (through ventilation systems) (PIARC, 2008; Centre d'Etudes des Tunnels (CETU), 2016).

Emission controls and other measures

In addition to the operation and management of the tunnel ventilation system, there are various operational measures available to manage in-tunnel emissions and air quality. These include the following:

- Traffic management: Traffic management will be employed by tunnel operators to control exposure to vehicle-derived air pollution. Measures can include (PIARC, 2008):

- Allowing only certain types of vehicle
- Regulating time of use
- Tolling (including differential tolling by vehicle type, emission standard, time of day, occupancy)
- Reducing traffic throughout
- Lowering the allowed traffic speed

- Incident detection: Early detection of incidents and queues is essential to enable tunnel operators and the highway authority to put effective traffic management in place. Monitoring via CCTV cameras is normally a vital part of the procedure for minimising congestion within tunnels and allowing timely operator response to changes in traffic flow
- Public information and advice: Traffic lights, barriers, variable message signs, radio broadcasts, public address systems (used in emergencies) and other measures can help to provide driver information and hence influence driver behaviour in tunnels
- Cleaning the tunnel regularly assists in reducing concentrations of small particles (PIARC, 2008), as is common practice in Sydney tunnels.

Further design development of the in-tunnel air quality monitoring system will be carried out during future project development phases and will include the following:

- Air quality monitoring of key pollutants will be carried out throughout the tunnel. The locations of monitoring equipment will generally be at the beginning and end of each ventilation section. This will include, for example, monitors at each entry ramp, exit ramp, merge point and ventilation exhaust and supply point. The location of monitors will be governed by the need to meet in-tunnel air quality criteria for all possible journeys through the tunnel system, especially for NO_2. This will require sufficient, appropriately placed monitors to calculate a journey average
- Velocity monitors will be placed in each tunnel ventilation section and at portal entry and exit points. The velocity monitors in combination with the air quality monitors will be used to modulate the ventilation within the tunnel to manage air quality and to ensure net air inflow at all tunnel portals.

During operation, air quality monitoring data will be made publicly available on the new motorway website.

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 13

Human health

13 Human health

This chapter outlines the potential human health impacts associated with the project and identifies measures to address these impacts. 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 (Secretary's environmental assessment requirements checklist).

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The proposed environmental management measures relevant to human health impacts are discussed in Section 13.6.

Table 13-1 Secretary's environmental assessment requirements – human 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 and benefits maximised in project design. Adverse and beneficial impacts associated with the project are discussed in **Section 13.4** and **Section 13.5**.
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	**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
social infrastructure and active transport impacts) during the construction and operation of the proposal;	
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** (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**.
Air Quality	
2. The Proponent must ensure the AQIA also includes the following: d. an assessment of impacts (including human health impacts) from potential emissions of PM_{10}, $PM_{2.5}$, CO, NO_2 and other nitrogen oxides and volatile organic compounds (eg BTEX) including consideration of short and long term exposure periods;	Health related air quality impacts are discussed in **Section 13.5.1** and **Section 13.5.2**.

Secretary's requirement	Where addressed in EIS
Water – Quality	
1. The Proponent must: c. identify and estimate the quality and quantity of all pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment;	Potential pollutants of concern are identified in **Chapter 17** (Hydrodynamics and water quality) and **Appendix O** (Technical working paper: Surface water quality and hydrology). An assessment of the potential for construction to introduce pollutants into receiving waterways and discharge quantities and locations are provided in **Chapter 17** (Hydrodynamics and water quality). Practical management measures to be adopted for the project are provided in **Chapter 17** (Hydrodynamics and water quality). Management measures to ensure the protection of human health are outlined in **Section 13.6.**
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;	Potential pollutants of concern are identified in **Chapter 17** (Hydrodynamics and water quality) and **Appendix O** (Technical working paper: Surface water quality and hydrology). An assessment of the potential for construction to introduce pollutants into receiving waterways and discharge quantities and locations are provided in **Chapter 17** (Hydrodynamics and water quality). Practical management measures to be adopted for the project are provided in **Chapter 17** (Hydrodynamics and water quality). Management measures to ensure the protection of human health are outlined in **Section 13.6.**
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.	**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). **Section 16.4**, **Chapter 16** (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 and is described below.

13.1.1 Principal guidance

Principle guidance used for the assessment of human health impacts included 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 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), 2013a
- *Air Quality in and Around Traffic Tunnels*, National Health and Medical Research Council (NHMRC, 2008a)
- State Environmental Planning Policy No. 33 – Hazardous and Offensive Development
- Assessing the environmental burden of disease at national and local levels, Ostro, 2004 (World Health Organisation).

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 which is Annexure K to Appendix H)
- 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
- Tolerable or acceptable health related risks – between one chance in a million and one chance in ten thousand
- Unacceptable health related risks – more than one chance in ten thousand.

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 the following noise guidelines, the noise assessment criteria adopted relate to levels of noise that can be tolerated or permitted above background before some adverse effect (annoyance, discomfort, sleep disturbance or complaints) occurs:

- *Interim Construction Noise Guideline* (Department of Environment and Climate Change (DECC), 2009a),
- *NSW Road Noise Policy* (Department of Environment, Climate Change and Water (DECCW), 2011)
- *NSW Noise Policy for Industry* (NSW Environment Protection Agency (EPA), 2017a)
- *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a)
- *Noise Criteria Guideline* (Roads and Maritime Services, 2015f).

As annoyance would usually occur before physiological and other health-based impacts, annoyance-based criteria are considered to be conservative from a human health impact perspective. Some of the other criteria are based on specific 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 open 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 the following characteristics:

- 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 Northern Sydney Health District only

- Lower rates of hospitalisations, except for cardiovascular disease hospitalisations in the South Eastern Sydney District, which are similar to the rates for NSW
- High or very high rates of psychological distress reported in 2015 in the Sydney Local Health District (13.9 per cent) where rates are slightly higher than the state average. In Northern Sydney (10 per cent) and South Eastern Sydney local health districts (9.3 per cent) rates are slightly 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 proposed temporary construction support sites, surface connections (ie where the tunnels would interface 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 the adjoining WestConnex 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. Community receiver locations include 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

Potential 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 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 temporary construction support sites and disturbance areas, use of water carts, maintenance and controls on vehicles and machinery, waste management and modifying of site activities during atmospheric conditions conducive to dust generation and emission. 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 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. However, odours from dredged material from Middle Harbour are unlikely to be detectable at any sensitive receptor.

For tunnelling works proposed at Flat Rock Reserve, there is a risk of encountering odorous waste material and landfill gases from historical waste landfilling activities in the locality. Detailed investigations have not been carried out to confirm the presence and extent of potentially odorous materials and landfill gases within the project site at this location. The investigation that was carried out, however, did not identify putrescible waste and landfill gases in the vicinity of the locations that would be excavated as part the project. This indicates that the risk of encountering odorous materials and landfill gases is low. Further investigations are proposed prior to commencement of excavations to confirm the potential for odour issues based on the detailed construction methodology and identify appropriate mitigation and management measures (if required) to reduce the potential for odour impacts at sensitive receivers in the vicinity. Further landfill gas investigations should be carried out within these areas to assess the potential presence or absence of gas which could potentially impact upon construction and/or operation of the project if not managed appropriately.

Overall, potential 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 during construction 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. Worst case predicted construction noise levels would occur at any one receiver only infrequently, if at all. Typical construction noise levels would be significantly lower than worst case predictions.

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 tunnel in Middle Harbour.

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 measures to manage and mitigate potential health impacts associated with noise and vibration during construction include:

- Location and activity specific assessments to confirm ground-borne noise potential impacts
- Proactive engagement with the community including water users for underwater noise
- Noise and vibration monitoring including during piling activities
- Respite periods.

The following sections describe potential impacts related to noise and vibration criteria, possible human health impacts and proposed environmental management measures.

Construction noise impacts from the movement of construction vehicles

Potential increases in noise for sensitive receivers due to construction traffic have been assessed separately from the assessment of noise from other construction activities. Temporary 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. Use of the temporary construction support sites is unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Ground-borne construction noise

Ground-borne noise occurs when vibration is transmitted through the ground and into building structures, where it then produces an audible noise. The project would involve tunnelling using vibration intensive equipment such as roadheaders and rock hammers that have the potential to generate ground-borne noise. Many of the more significant activities with the potential to generate ground-borne noise would take place at depth (with a large proportion of the mainline and ramp tunnels at depths of 10 metres to greater than 50 metres).

Modelling carried out for potential ground-borne noise impacts 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. Ground-borne noise would typically increase as the roadheader nears a receiver and decrease as the roadheader moves way. It is noted that receivers might also experience ground-borne noise on multiple occasions, associated with excavation of different (adjacent) tunnel tubes and other subsurface elements such as ventilation shafts, cross-passages and niches for motorway operational equipment.

Ground-borne noise from excavation by the roadheaders may be noticeable in some areas during the evening and during the night for one to two weeks at each affected receiver as the roadheader passes below them. Ground-borne noise from roadheader activity is predicted to exceed the night time noise criteria at about 107 residential receiver buildings. Worst case impacts are likely to occur in locations where the tunnel would be relatively shallow, such as in the immediate vicinity of tunnel on ramps and off ramps or tunnel access declines at Cammeray, Northbridge, Balgowlah, Seaforth and Killarney Heights.

Following the excavation by roadheaders, rock hammers would then be required for sub-surface activities that include tunnel floor (bench) excavation, utility and stormwater trench excavation and excavation of niches for tunnel operational equipment. When rock hammers are in use within the tunnel, there is potential for intermittent audible ground-borne noise within buildings at the surface. The potential ground-borne levels would be influenced by the separation distance between the building and work location, the underlying geology and the structure of building. Where rock hammering has the potential to exceed the relevant criteria for ground-borne noise, it would be scheduled during standard construction hours where feasible and reasonable, reducing the potential for associated amenity impacts during the more sensitive evening and night time period. If rock hammering is required outside standard daytime construction hours, ground-borne noise levels could exceed the night time criteria for up to 638 residential receiver buildings and could exceed the evening criteria for 419 residential receiver buildings, depending on the location of works. It is noted that there are locations in Cammeray, Naremburn, Northbridge Artarmon and Seaforth where it is predicted that rock hammers could be used outside standard construction hours without exceeding the evening and night time ground-borne noise criteria.

Measures to manage and mitigate potential impacts associated with ground-borne noise include location and activity specific assessments to confirm potential impacts, scheduling, and community notification and engagement to confirm that actual ground-borne noise levels and impacts are not worse than predicted.

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 environmental management measures. In some instances, maximum noise levels are also predicted to exceed the sleep disturbance screening level and awakening reaction levels at several receivers.

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

Exceedances of the noise management levels and the number of impacted residential receiver buildings would vary over the duration of construction. For example, the predicted worst case airborne 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 levels might routinely be lower than predicted, reducing the potential for annoyance and health impacts. Further, the mitigation and management measures 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.

Where the recommended noise management levels cannot be achieved, reasonable and feasible mitigation measures would be implemented to reduce potential impacts. 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. Refer to Chapter 10 (Construction noise and vibration) for environmental 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 observing suitable separation distances between the equipment and receiver locations for highly vibration-intensive activities.

Vibration monitoring would be carried out to confirm that the adopted controls are effective and respite periods would be offered to affected residents where human comfort levels are to be exceeded for an extended period during any one day.

Underwater noise impacts

Piling and dredging in Middle Harbour would generate underwater noise. Noise can propagate for long distances underwater.

Piling would be required in Middle Harbour to install immersed tube tunnel unit supporting piles and for the construction of cofferdams adjacent to each shore line. Piling would predominately consist of vibratory piling (in harbour sediments), however impact piling would be required to ensure that piles are adequately bedded into the underlying bedrock. Piling has the potential to generate significant underwater noise levels. Impact piling has the potential to generate significantly higher underwater noise levels than vibratory piling and other proposed underwater construction activities.

Dredging also generates underwater noise levels. The potential for dredging to generate significant noise levels is less than for piling.

Underwater sound pressure levels would likely exceed the precautionary guideline of 145 dB re 1µPa in the vicinity of the proposed piling and dredging locations Middle Harbour (Jasco, 2019). The locations in the vicinity of the piling activities that could experience underwater noise levels in excess of this guideline value would vary depending on the type of equipment and operation being carried out and the bathymetry in the vicinity of the activity location. The precautionary guideline value could exceeded at distances of around two kilometres for impact pile driving. The piling program would be refined during detailed construction planning with the consideration of reasonable and feasible alternatives to reduce potential underwater noise levels. It is, however, unlikely there is a feasible alternative construction methodology that does not involve some impact piling.

For divers, a sudden increase in sound pressure levels could startle, or cause discomfort, dizziness and vertigo. Excessive underwater noise can lead to life-threatening situations.

CNV14 (refer to Section 10.7) commits that impact piling in any given week will be carried out over durations of no more than either two hours each work day or six hours on a single work day, to provide respite to noise affected receivers in the vicinity. This would also limit the frequency of potential underwater noise impacts.

The areas affected by elevated underwater noise levels due to project activities would be managed during construction to minimise the risk of potential amenity and health impacts divers and swimmers. This would include monitoring during the early stages of impact piling activities at each location to measure underwater noise levels and compare against acoustic thresholds to confirm the affected areas and appropriate management measures, and a proactive communication strategy to inform water users and other potential stakeholders of the potential impacts and risks. Management measures would be informed by the final construction methodologies and mitigation measures, and management areas. Environmental management measure HH1 would be reviewed and, if required, amended over the course of 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
- Open space
- Visual amenity
- Construction fatigue
- Economic aspects.

Measures to manage and mitigate potential health related impacts during construction include:

- Use of communication and traffic control management measures to limit delays and disruptions to road users and for the safety of motorists, cyclists and pedestrians
- Use of silt curtains and a backhoe dredge with a closed bucket attachment to minimise the risk of sediment and contaminants within the sediments being mobilised into the water during dredging
- Management of property acquisition impacts 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.

- Design of the project to optimise opportunities for the repurposing of remaining project land at Balgowlah to provide new open space and recreation facilities for the community. The residual land would progressively become available through the construction period for use by the community
- Consideration of construction fatigue as when developing the detailed project design and construction methodology to mitigate these impacts where possible.

The following sections describe the potential impacts, possible human health impacts and proposed environmental management measures.

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, removal of some on-street parking and reductions in speed limits, changes to property accesses
- Temporary 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
- Temporary disruptions to public transport services, and changes to road conditions and the temporary relocation of some bus stops near construction works for safety, resulting in possible delays and disruptions for bus users and changes in bus access for some people
- Temporary 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
- Temporary relocation of moorings in the vicinity of works in Middle Harbour, with relocated moorings to be placed as close as possible to their original locations during construction and restored where possible to the original position on completion of construction
- Temporary adjustments to bus priority infrastructure on Burnt Bridge Creek Deviation in Balgowlah would also be required, resulting in a minor increase in bus travel times
- Temporary changes and diversions to pedestrian and cyclist networks have the potential to affect commuter departure times, travel durations, movement patterns and accessibility.

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 would 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, in consultation with the relevant road authorities.

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 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 the health of the local community is not impacted.

Sediment sampling was carried out within the proposed locations of Middle Harbour crossing and temporary construction support sites (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 there would be negligible impacts to human health associated with recreational exposures in areas surrounding the proposed works.

Property acquisition

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

The project has been designed to minimise the need for property acquisitions. Wherever possible, temporary 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 open space

Open space (also referred to as 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. Epidemiological studies have been carried out that show a positive relationship between open space and health and wellbeing (de Vries et al. 2003, Health Scotland et al. 2008, Kendal et al. 2016, Maas et al. 2006, Mitchell & Popham 2007). The health benefits of open space in urban areas include the following:

- Protection of people from environmental exposures associated with air pollution 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 several existing sporting/recreation facilities and parks in the project area that would be impacted by the project including sporting fields, parks and reserves and playgrounds. Impacts on these open spaces include:

- Temporary and permanent loss of a portion of land, including recreation land at Artarmon Park and Cammeray Golf Course, noting that works have been designed to ensure that the golf course can continue to function as a nine hole golf course, subject to some reconfiguration during the construction phase that would temporarily affect golf activities
- Permanently acquiring or temporarily leasing parts of the Balgowlah Golf Course, with construction resulting in the permanent closure of the golf course. However, the project would return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved public open space and recreation facilities

- Temporary use of parks and open space areas for temporary construction support sites (for example parts of Artarmon Park adjacent to Gore Hill Freeway, Flat Rock Reserve and the Spit West Reserve) resulting in the temporary loss of access to and use of land within the construction footprint
- Reduced amenity due to construction activities and temporary 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 loss of open space associated with construction of the project would be short term, except for permanent land loss at Balgowlah Golf Course. Other golf courses are accessible in the area and hence, while some additional travel may be required, recreational golf activities are not expected to be substantially affected overall. Alternative open space is located in the area and can be easily accessed by the community, and so the potential effects on community health associated with the temporary use of parks and open space areas during construction would be minimal. The reduced amenity may affect the desirability of active recreational use of some areas. Other recreation areas are available and accessible in the community, hence the potential impact on community health is considered to be minimal. The project has been designed to optimise opportunities for the repurposing of remaining project land at Balgowlah. Residual land, primarily to the east and north of the new access road, would progressively become available through the construction period, which would facilitate re-purposing it to the new and improved open space and recreation facilities. This would allow it to be handed over progressively for use by the community. The new open space and recreation facilities to the west of the proposed access road, between the access road and Burnt Bridge Creek Deviation, would be constructed and handed over to Northern Beaches Council after completion of the project.

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 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 temporary 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 change 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. 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.

Construction fatigue

Construction fatigue relates to receivers that experience construction impacts from a variety of projects over an extended period 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 in this report includes the following projects that may immediately precede or overlap with the construction phase of the project:

- Western Harbour Tunnel and Warringah Freeway Upgrade (North Sydney, Cammeray and Artarmon)
- Sydney Metro City & Southwest (Chatswood to Sydenham).

As outlined in Chapter 27 (Cumulative impacts), the potential cumulative impacts during construction of the project based on likely interactions with other projects may occur around North Sydney and Cammeray, Artarmon, and Naremburn and Willoughby. Cumulative impacts could be generated by interactions between the project and the Western Harbour Tunnel and Warringah Freeway Upgrade at North Sydney, Cammeray and Artarmon and the Sydney Metro City & Southwest (Chatswood to Sydenham) at Artarmon. 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. There is also potential for residential receivers around Naremburn and Willoughby to experience construction fatigue as a result of the project and its proximity to Western Harbour Tunnel and Warringah Freeway Upgrade construction sites. Construction fatigue at this location is likely to be limited to temporary increases in construction noise and are expected to be minor.

The project design and construction methodology has been developed with consideration of these impacts and attempts to mitigate many of these 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 feasible and reasonable. 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 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 both positive and negative 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 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.

Some of the key findings of the assessments, as discussed below, indicate:

- There would be no significant changes in the incidence of health impacts associated with exposure to NO_2 in the community as a result of the project

- Concentrations of total particulate matter ($PM_{2.5}$ and PM_{10}) within the local community would essentially remain unchanged in most cases with the operation of the project. The potential incident of health impacts associated with exposure to particulate matter is anticipated to remain unchanged as a result of the project
- No health impacts due to exposures to CO are anticipated in the local area surrounding the project as a result of the project
- No significant health impacts are anticipated within the tunnel due to exposures to vehicle emissions under any plausible traffic and tunnel operational scenarios
- For most receivers assessed, the project would result in either reduced or relatively minor changes in traffic noise levels. In areas where there is a reduction in traffic noise there would be associated health benefits in these communities
- Where traffic noise levels are predicted to increase, additional mitigation measures would be implemented to reduce potential amenity and associated health impacts
- Public safety is anticipated to improve as a result of improvements to road safety with reduced traffic volumes along key road transport corridors
- New or upgraded pedestrian and cyclist infrastructure is anticipated to encourage increased active transport, with associated improvements in community health and wellbeing
- Most changes in visual impacts are not expected to have a significant impact on the health of the community.

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 tunnel ventilation system and tunnel operational parameters for the project have been designed to ensure the in-tunnel air quality concentration limits are not exceeded under any plausible tunnel operation scenarios, including major breakdowns, and to control the concentration of pollutants discharged to the external environment.

The assessment of impacts on air quality associated with the operation of the project considered a range of expected traffic 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).

This assessment included a calculation of the emissions from vehicles using the tunnel and surface roads in the vicinity 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 the emissions from the ventilation outlets are at the maximum levels permitted by regulatory criteria at all hours of the day. While not a realistic scenario, it is used to demonstrate that contributions from the ventilation outlets to air quality at ground level under even the most extreme of conditions would still be negligible. 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.

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 nitrogen dioxide (NO_2). In Sydney, it was estimated that on-road vehicles account for about 55 per cent of emissions of nitrogen oxides, industrial facilities account for 13 per cent, other mobile sources account for about 27 per cent with the remainder from domestic/commercial sources (NSW EPA, 2019).

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 Environment Protection Authority and National Environment Protection Council (NEPC) (NEPC, 2003b) that 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 NO_2 in air, averaged over a year, 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 community threshold established for acute 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 National Environment Protection Council 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 micrograms per cubic metre for all scenarios. Therefore, no adverse health impacts would be expected as a result of chronic exposures to NO_2 from the project.

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 one in ten thousand 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 NO_2 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 approximately one case, this change would not be measurable within the community
- 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. Overall, there are no individual suburbs within the Local Government Areas (LGAs) where there is a change in incidence that is of significance or would be measurable.

Overall, there would be no significant changes in the incidence of 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 National Environment Protection Council and NSW Environment Protection Authority 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 tunnel 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 considers 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 was 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 the air within the urban environment, the maximum total concentrations of $PM_{2.5}$ are above the guidelines for both the 24-hour average and the annual average (including the 2025 goal set 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, would be essentially unchanged or slightly lower in most cases within the study area 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 the 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 the 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 less than or equal to one in ten thousand, 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 considered) relevant to the health impacts evaluated for the project in 2027 ('Do something') are mostly negative, meaning an overall decrease in incidence as a result of the project. The number of cases, however is small, with a decrease of approximately one case. This change would not be measurable within the community
- Within these local government areas there are several 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 per cent of the receiver buildings assessed have a height of less than 10 metres, with less than 0.5 per cent 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 in areas where elevated receptors are currently present.

Further assessment (see Annexure H of Appendix I (Technical working paper: Health impact assessment)) was carried out relating to exposure to NO_2 and volatile organic compounds within in 300 metres of the ventilation outlets for the project, at the Warringah Freeway, the Gore Hill Freeway, the Burnt Bridge Creek Deviation and Wakehurst Parkway. Based on the assessment carried out, the following was identified:

- The assessment of potential health risks for elevated receptors is dominated by the assessment of individual risks relevant to changes in NO_2 and $PM_{2.5}$
- No unacceptable risks have been identified considering existing and expected traffic emissions
- For the regulatory worst case emissions, unacceptable risks have been identified for elevated receptors in the 300 metres adjacent to ventilation outlets at the Warringah Freeway, the Gore Hill Freeway and the Wakehurst Parkway for elevated receptors that may be present at 45 metres height.

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 within 300 metres of the ventilation outlet.

Carbon monoxide

Motor vehicles are the dominant source of carbon monoxide (CO) in the air (NSW Department of Environment, Climate Change and Water (DECCW, 2010a)). Adverse health effects of exposure to CO 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 CO 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, 2019).

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 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 the predicted concentrations (for at least one individual compound) are above the health based guidelines, or 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 the total Hazard Index predicted for acute exposures to VOCs 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 risk 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 four in one hundred thousand and are considered to be tolerable. The approach adopted is expected to overestimate concentrations of PAHs in air. Hence the calculations presented are a conservative upper limit estimate. Based on this, there would be no chronic health risk issues predicted in the local community as a result of the project.

13.5.2 Health related in-tunnel air quality impacts during operation

Air quality in-tunnel impacts in the operational period are presented in Chapter 12 (Air Quality). 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 Annexure K to Appendix H (Technical working paper: 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.

Nitrogen dioxide

A study of nitrogen dioxide (NO_2) concentrations inside vehicles travelling in Sydney and using existing road tunnels was commissioned by Roads and Maritime Services (now Transport for NSW) in 2016 (Pacific Environment Limited (PEL), 2016) to better understand the relationship between NO_2 outside the vehicle, and inside the vehicle. Within existing tunnels investigated in the study, trip average concentrations of NO_2 were generally less than 0.15 parts per million (ppm) (PEL, 2016). During periods of high traffic volumes and a high proportion of heavy vehicles, the trip average concentrations inside the M5 East tunnels have been recorded in excess of the 0.5 ppm criterion, with levels up to 0.7 ppm. The average concentrations inside the vehicles when ventilation was on recirculation, however, were less than 0.2 ppm. The most recent tunnels in Sydney are designed to ensure that trip average concentrations of NO_2 do not exceed the 0.5 ppm criterion.

The project's ventilation systems have been designed to achieve the in-tunnel air quality criteria for NO_2 of 0.5 ppm (tunnel average as a 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 cumulative' scenario in 2037 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, which is less than the in-tunnel limit of 0.5 ppm. Lower average concentrations may occur within vehicles with windows up and ventilation on recirculation. 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 NO_2 within vehicles using the tunnels, as the trip average concentrations would be below 0.5 ppm.

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

The in-tunnel NO_2 criterion 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 (Health impact assessment)).

For individuals involved in occupations that may require more regular use of the road network, such as point to point transport 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 vehicle 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 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 CO have been adopted based on the conditions of approval for other Sydney road projects. The assessment indicates there would be no health issues of concern related to in-tunnel exposures to CO. Furthermore, closing vehicle windows and switching the ventilation to recirculation can reduce exposures by about 70 to 75 per cent for CO.

Carbon dioxide

A study was carried out on behalf of Transport for NSW (enRiskS, 2017) to determine carbon dioxide (CO_2) 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 CO_2 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 CO_2 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 vehicle 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 CO_2 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 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 most receivers assessed, the project would result in either reduced or relatively minor changes in traffic noise levels. In areas where there is a reduction in traffic noise, as a result of the project due to a decrease in traffic volumes on parts of the surface road network, there would be associated health benefits in these communities. However, the assessment also predicts that without mitigation, incremental noise increases greater than 2 dB(A) would be experienced at several properties adjacent to the project during operation, which may result in health impacts if not appropriately mitigated. Additionally, many properties have been identified where cumulative noise levels exceed the relevant guidelines, with and without the project.

Mitigation measures considered to address potential road traffic noise levels during operation would principally involve the use of quieter pavements, noise barriers and at-property treatments. The use of the use of quieter pavements and noise barriers are favoured, as they provide a benefit to external and internal spaces. Even with appropriate mitigation measures in place, however, 616 buildings under the 'Do something cumulative' scenario are still predicted to be eligible for consideration for at-property treatment. It is noted, however, that most receivers predicted to experience exceedances of the operational road traffic noise criteria already experience exceedances (ie the reason for additional mitigation is existing noise levels, rather than predicted increases due to the project). In this regard, installation of at-property treatments would also be addressing existing road traffic noise and amenity issues and the project would have a positive impact on community amenity and health. Further details are presented in Chapter 11 (Operational noise and vibration).

Where there are predicted increases in road traffic noise and the specific individuals impacted do not take up the recommended at-property treatments, there is the potential for adverse health effects including increased levels of noise annoyance and sleep disturbance. While of at-property treatments can reduce impacts within a dwelling, they do not generally reduce noise levels in external areas. The number of properties subject to increases in noise levels which may be of concern to health as a result of the project, however, is very small. If at-property treatments area appropriate and are installed at the properties, the impact on road traffic noise levels within dwelling will be adequately reduced and no significant health impacts are expected.

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
- Open space
- Visual amenity
- Economic aspects and
- 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 Middle Harbour. The project would improve travel times on the Military Road/Spit Road corridor, Warringah Road and Eastern Valley Way. It would enable better access to jobs and businesses, with direct access to the new Northern Beaches Hospital at Frenchs Forest, and better access to businesses on the Northern Beaches from Greater Sydney. The project would also enhance the resilience of the road network due to reduced demand on other surface roads, including Frenchs Forest Road and the Ourimbah Road, and would enable a major reduction of heavy vehicle traffic on the Warringah Road, Spit Road and Military Road corridor. The substantial additional travel that would be facilitated by the project would also increase localised traffic demands at either ends of the project where it would be integrated with the existing transportation network. At some locations there would be some residual delay at these interface precincts. This includes some increases in localised delays for traffic through French Forest, particularly on Warringah Road and Wakehurst Parkway as a result of changes to traffic patterns caused by the project. In such cases localised delays at these precincts would be offset by the strategic travel time benefits provided by the project at the broader network level.

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 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 (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 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.

Open space

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

Cammeray Golf Course

The project would occupy parts of the golf course acquired as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project to accommodate a temporary construction support site and Beaches Link motorway facilities (including an access road) (see Section 13.4.3). This would require the reconfiguration of the golf course to allow its ongoing use, noting that golf activities would likely be temporarily affected during the reconfiguration. The site would initially be established as a temporary construction support site for the Western Harbour Tunnel and Warringah Freeway Upgrade project. Potential impacts to the golf course were assessed as part of the environmental impact statement for Western Harbour Tunnel and Warringah Freeway Upgrade (Transport for NSW, 2020b).

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.

Artarmon Park

The project would require the permanent acquisition of a portion of land at Artarmon Park to accommodate road infrastructure associated with the Gore Hill Freeway Connection. This is not expected to impact on the ongoing use or functioning of the park and facilities within the park.

Balgowlah Golf Course

Acquisition and temporary leasing of Balgowlah Golf Course during construction (see Section 13.4.3) would result in the permanent closure of the golf course (and club). This would require members and visitors to access golf courses elsewhere, impacting on social networks associated with the club. It is likely some members would use the closure of the club as a reason to stop playing golf. This is most likely to be long-term members or older golfers, potentially impacting individuals' general levels of physical activity, and overall wellbeing associated with the possible loss of social networks and personal relationships.

However, engagement with Northern Beaches Council has identified potential for the residual land to be returned as new and improved open space and recreation facilities. Use of the residual land for such facilities would align with the Northern Beaches Sportsground Strategy (Northern Beaches Council, 2017a) and address the current under supply of sporting grounds available for public use in the local area.

A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council would take place to give the community an opportunity to provide input on the final layout of the new and improved open space and recreation facilities at Balgowlah. This consultation would be separate to the consultation for the environmental impact statement. This process would start after the environmental impact statement public exhibition period and well in advance of construction starting. As part of this consultation process, a community reference group would be established, with representative stakeholder groups and the community, to support Transport for NSW and Northern Beaches Council with the development of this important public space. The project would return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved public open space and recreation facilities.

Spit West Reserve

Land within Spit West Reserve affected by the project during construction would be rehabilitated and reinstated and no operational impacts would be expected.

Flat Rock Reserve

Land affected by the project at Flat Rock Reserve during construction would be rehabilitated and reinstated. The final land use of the temporary construction support site after project completion would be subject to further consultation with Willoughby City Council and the community. No operational impacts would be expected.

Visual amenity

The operational project would include changes to local visual amenity due to the presence of new and amended infrastructure (including motorway facilities, ventilation outlets, water treatment plants, substations, bridges, retaining walls, flood walls, noise walls 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 would be beneficial for employee and customer access, servicing and delivery and demand for services across most business centres. Some business centres would also benefit from improvements in passing trade, character and amenity and business visibility. However, any impact is considered to be moderate to low, given the sensitivity of the centre and the magnitude of change by the project. Further changes are also expected in this area as associated with the development of the Northern Beaches Hospital Precinct Structure Plan.

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 State Gross Product (GSP) in 2011, this represented 13.8 per cent of NSW GSP at the time.

The project would encourage heavy and commercial vehicle movements into the tunnel, due to 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 potential benefits for freight and commercial vehicle movements. 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. Ongoing or improved economic vitality is of significant health benefit to the community. Employment opportunities would grow in the region through the potential increase in business customers and improved regional connectivity as a result of the project.

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 would be a proportion of the population that avoid the use of tollways due to affordability. In July 2018, the NSW Government implemented a toll relief initiative to ease the cost of living for frequent NSW toll road users through the provision of free vehicle registration. This was expanded in July 2019 to also provide half-priced vehicle registration for eligible road users.

13.6 Environmental management measures

Key environmental management measures specific to human health impacts are provided in Table 13-2. In addition, environmental management measures relating to human health impacts are also provided in other chapters within this environmental impact statement, particularly:

- Transport and travel management measures – Chapter 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)
- Contamination management measures – Chapter 16 (Geology, soils and groundwater)
- 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).

Table 13-2 Environmental management measures – human health

Ref	Phase	Impact	Environmental management measure	Location
HH1	Construction	Underwater noise impacts	Monitoring during the early stages of impact piling activities at each location will be carried out to measure underwater noise levels and compare against acoustic thresholds to confirm the extent of areas that need to be managed with respect to underwater noise, and to confirm appropriate management measures (as required). Appropriate management measures will be implemented during impact piling. The monitoring results, management areas and proposed management measures will be peer-reviewed to ensure they adequately address potential health impacts. Monitoring will be carried out following implementation of management measures (as required) to confirm they are appropriate and to	BL (Middle Harbour)

Ref	Phase	Impact	Environmental management measure	Location
			identify any additional management measures required.	
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 Middle Harbour. The communication tools and management measures that would be contemplated within the management zone include: a) Coordination of piling programs with the planned activities of key recreational stakeholders to minimise interaction with planned or peak activity periods of these stakeholders, where feasible and reasonable b) Communication of the piling program and management area so 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 e) Surveillance within the areas in which precautionary guideline level is exceeded to proactively monitor users in the prior to and during relevant activities that could pose a risk to recreational users.	BL (Middle Harbour)

Note: BL = Beaches Link