10 Air quality

This chapter describes the methodology used to assess the impacts of the New M5 project (the project) on regional, local and in-tunnel air quality, and summarises the results of that assessment. The Technical working paper: Air Quality (**Appendix H)** provides greater detail of the air quality monitoring and modelling methodologies and air quality impact assessment results.

The Secretary of the NSW Department of Planning and Environment (DP&E) has issued environmental assessment requirements for the project. **Table 10-1** sets out the Secretary's Environmental Assessment Requirements (SEARs) as they relate to air quality, and identifies where they have been addressed in this environmental impact statement (EIS).

Table 10-1 SEARs – air quality

SEAR	Section where requirement is addressed
An assessment of construction and operational activities that have the potential to impact on in-tunnel, local and regional air quality. The air quality impact assessment must provide an assessment of the risk associated with potential discharges of fugitive and point source emissions on sensitive receivers, and include:	An assessment of potential air quality impacts from construction, closure of the Alexandria Landfill and operation is provided in **Section 10.6**, **Section 10.7** and **Section 10.8**.
• The identification of all sources of air pollution and assess potential emissions of PM_{10}, $PM_{2.5}$, CO, NO_2 and other nitrogen oxides and volatile organic compounds (e.g. BTEX) and 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 and ramps, the alternative surface road network, and in-tunnel air quality.	The identification of emission sources relevant to the project are detailed in **Section 10.5.4**. An assessment of PM_{10}, $PM_{2.5}$, CO, NO_2 and other nitrogen oxides and volatile worst case organic compounds is provided in **Section 10.6**, **Section 10.7** and **Section 10.8**.
• Assessment of worst case scenarios for in-tunnel and ambient air quality, including assessment of a range of traffic scenarios, including worst case design maximum traffic flow scenario (variable speed) and worst case breakdown scenario, and discussion of the likely occurrence of each.	An assessment of in-tunnel and ambient air quality is provided in **Section 10.8**.
• 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 (i.e. ventilation outlets and air inlets) including details of proposed air quality monitoring (including criteria).	The tunnel design and management measures to address in-tunnel air quality, including mechanical ventilation and air quality is described in **Section 10.10**. **Table 10-32**
• Demonstrate 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 NorthConnex project.	The tunnel ventilation system is described in **Section 10.10.2**.

SEAR	Section where requirement is addressed
• Consideration of any advice from the Advisory Committee on Tunnel Air Quality on the project.	Advice provided by the Advisory Committee for the NorthConnex project was taken into account when developing the assessment methodology, which is summarised in **Section 10.2**, **Section 10.3** and **Section 10.4**.
• Details of any emergency ventilation systems, such as air intake/exhaust outlets, including protocols for the operation of these systems in emergency situations, potential emission of air pollutants and their dispersal, and safety procedures.	Emergency ventilation systems are described in **Section 10.10**.
• Details of in-tunnel air quality control measures considered, including air filtration. Justification must be provided to support the proposed measures.	Environmental management measures relating to in-tunnel air quality are described in **Section 10.10**.
Details of the proposed mitigation measures to prevent the generation and emission of dust (particulate matter and total suspended particulate (TSP)) and air pollutants (including odours) during the construction of the proposal, particularly in relation to ancillary facilities (such as concrete batching plants), the use of mobile plant, stockpiles and the processing and movement of spoil.	Environmental management measures to be implemented during construction are described in **Section 10.10**.
Cumulative assessment of the local and regional air quality due to the operation of the M4-M5 Link and surface road operations.	A cumulative air quality assessment is provided in **Section 10.9**.
The air quality assessment, including the setting of air quality criteria, must be done in consultation with NSW Health and the Environment Protection Authority and with the consideration of any applicable advice provided by the Advisory Committee on Tunnel Air Quality.	The air quality assessment approach is described in **Section 10.1.1**.
Modelling (including dispersion modelling) must be conducted in accordance with the Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (DEC, 2005b) or a suitably justified and verified alternative method based on current scientific understanding of atmospheric dispersion. Particular attention must be given to the verification of the method of predicting local air quality or meteorological conditions based on non-local or modelled data.	A summary of the air quality approach is provided in **Section 10.1**. Additional detail regarding air quality modelling is provided in the Technical working paper: Air Quality (**Appendix H**)

10.1 Assessment approach

10.1.1 Overview

The air quality assessment considers the potential impacts of the project on regional and local air quality. Consideration is also given to the potential cumulative impacts of the project with the other component projects of the WestConnex program of works. The assessment also includes detailed analysis of the predicted quality of air inside the main alignment tunnels during operation of the project.

Recent air quality assessments for surface roads and road tunnels in Australia and New Zealand were reviewed to identify appropriate methodologies, tools and findings to inform the project assessment. These previous assessments are summarised in Appendix D of the Technical working paper: Air quality in **Appendix H** of this EIS. The summary includes details of the pollutants considered, the sources of emissions, the dispersion models used, and the approaches used to assess impacts on air quality during construction and operation of the project.

The following Government agencies and bodies were consulted during the development and preparation of the assessment methodology and the air quality assessment for the project:

- NSW Environmental Protection Authority (NSW EPA)
- NSW Health
- Roads and Maritime Services (Roads and Maritime)
- The Advisory Committee on Tunnel Air Quality.

Comments provided by the Government agencies and bodies, and how these have been considered during the assessment, are provided in the Technical working paper: Air quality in **Appendix H**.

10.1.2 Terminology

The concentration of a pollutant at a given location comprises contributions from various sources. The following terms have been used in this chapter to describe the concentration of a pollutant at a specific location (receiver) over a specific averaging period:

- **Background concentration** describes all contributing sources of a pollutant concentration other than road traffic. It includes, for example, 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 modelled road network at the receiver
- **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, and may be either an increase or a decrease, depending on factors including the redistribution of traffic on the road network as a result of the project.

10.1.3 Air quality criteria

Two types of criteria were applied to the air quality assessment to determine the potential air quality issues associated with the project. These are ambient air quality criteria and in-tunnel criteria.

Compliance with ambient air quality standards is a major consideration during road project design and operation. An ambient air quality standard defines a metric relating to the concentration of an air pollutant in the ambient air. Standards are usually designed to protect human health, including sensitive populations such as children, the elderly, and individuals suffering from respiratory disease, but may relate to other adverse effects such as damage to buildings and vegetation. The form of an air quality standard is typically a concentration limit for a given averaging period (eg annual mean, 24-hour mean), which may be stated as a 'not-to-be-exceeded' value or with some exceedances permitted. Several different averaging periods may be used for the same pollutant to address long-term and short-term exposure. Each metric is often combined with a goal, such as a requirement for the limit to be achieved by a certain date.

Air pollutants are often divided into 'criteria' pollutants and 'air toxics'. Criteria pollutants tend to be ubiquitous (ie present, appearing or found everywhere) and emitted in relatively large quantities, with their effects on health studied in some detail. Air toxics are gaseous or particulate organic pollutants that are present in the air in low concentrations, but are defined on the basis that they are, for example, highly toxic, carcinogenic or highly persistent in the environment so as to be a hazard to humans, plants or animal life.

10.1.4 Criteria pollutants

Ambient Air quality NEPM

In 1998 Australia adopted a *National Environment Protection (Ambient Air Quality) Measure* (AAQ NEPM) with the goal of ensuring compliance with air quality standards within 10 years of commencement in order to attain 'ambient air quality that allows for the adequate protection of human health and wellbeing'.

The AAQ NEPM established national standards for six criteria pollutants:

- Carbon monoxide (CO)
- Nitrogen dioxide (NO_2)
- Sulfur dioxide (SO_2)
- Lead (Pb)
- Photochemical oxidants as ozone (O_3)
- Particulate matter with an aerodynamic diameter of less than 10 µm (PM_{10}).

The AAQ NEPM was extended in 2003 to include advisory reporting standards for particulate matter with an aerodynamic diameter of less than 2.5 µm ($PM_{2.5}$), and these are shown in **Table 10-2**.

Table 10-2 Advisory reporting standards for $PM_{2.5}$ in AAQ NEPM

Pollutant or metric	Criterion		Averaging method	Source
	Concentration	Averaging period		
Particulate matter <2.5 µm ($PM_{2.5}$)	25 µg/m^3	24 hour	Calendar day	AAQ NEPM 2003
	8 µg/m^3	1 year	Calendar year	AAQ NEPM 2003

It should be noted that the AAQ NEPM is a national monitoring and reporting protocol. The AAQ NEPM standards are applicable to urban background monitoring sites which are broadly representative of population exposure. The use of any AAQ NEPM air quality criteria in relation to the assessment of projects and developments is outside the scope of the NEPM itself, and is decided by the Australian States and Territories. The criteria for air quality assessments for projects / developments in NSW are contained in the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (DEC, 2005b) (NSW Approved Methods) (see below). However, should the Approved Methods be revised it is possible that they will take into account the new AAQ NEPM standards, but they may not necessarily take exactly the same form. Nevertheless, the project would be designed so that any increases in $PM_{2.5}$ concentrations due to emissions from the ventilation outlets are minimal.

NSW Approved Methods

The Australian States and Territories manage emissions and air quality in relation to certain types of source (eg landfills, quarries, crematoria, and coal mines). The Australian States and Territories have legislation or guidance which includes design goals, licence conditions or other instruments for protecting local communities from ground-level impacts of pollutants in residential areas outside site boundaries. Where this is the case, the AAQ NEPM standards are often used for air quality assessments.

The NSW Approved Methods sets out the statutory methods to be used for assessing air pollution from stationary sources in NSW. The NSW Approved Methods are designed mainly for the assessment of industrial point sources, and do not contain specific information on the assessment of, for example, transport schemes and land use changes. Air quality must be assessed in relation to standards and averaging periods for specific pollutants that are taken from several sources, notably the AAQ NEPM.

The metrics, criteria and goals set out for criteria pollutants in the NSW Approved Methods are listed in **Table 10-3**. The $PM_{2.5}$ advisory standards (refer to **Table 10-2**) are designed for the evaluation of overall population exposure rather than the impacts of a specific facility, and there is no requirement to evaluate $PM_{2.5}$ in the NSW Approved Methods. However, they are often considered to be applicable in this respect.

Table 10-3 Impact assessment criteria for ‘criteria pollutants’ in NSW Approved Methods (DEC, 2005b)

Pollutant or metric	Criterion		Calculation	Source
	Concentration	Averaging period		
CO	87 ppm[(a)] or 100 mg/m³	15 minutes		WHO (2000)
	25 ppm or 30 mg/m³	1 hour	One hour clock mean	WHO (2000)
	9 ppm or 10 mg/m³	8 hours	Rolling mean of 1-hour clock means	AAQ NEPM 1998
NO_2	120 ppb[(b)] or 246 µg/m³	1 hour	One hour clock mean	AAQ NEPM 1998
	30 ppb or 62 µg/m³	1 year	Calendar year mean	AAQ NEPM 1998
PM_{10}	50 µg/m³	24 hours[(c)]	Calendar day mean	AAQ NEPM 1998
	30 µg/m³	1 year	Calendar year mean	NSW EPA (1998)[(d)]
SO_2	250 ppb or 712 µg/m³	10 minutes		NHMRC (1996)
	200 ppb or 570 µg/m³	1 hour	One hour clock mean	AAQ NEPM 1998
	80 ppb or 228 µg/m³	1 day	Calendar day mean	AAQ NEPM 1998
	20 ppb or 60 µg/m³	1 year	Calendar year mean	AAQ NEPM 1998

Pollutant or metric	Criterion Concentration	Averaging period	Calculation	Source
Pb	0.5 µg/m^3	1 year	Calendar year mean	AAQ NEPM 1998
Total suspended particulate matter (TSP)	90 µg/m^3	1 year	Calendar year mean	NHMRC (1996)
Photochemical oxidants (as ozone (O_3))	100 ppb or 214 µg/m^3	1 hour	One hour clock mean	AAQ NEPM 1998
	80 ppb or 171 µg/m^3	4 hours	Rolling mean of 1-hour clock means	AAQ NEPM 1998
Hydrogen fluoride (HF)[e]	0.50/0.25 µg/m^3	90 days		ANZECC (1990)
	0.84/0.40 µg/m^3	30 days		ANZECC (1990)
	1.70/0.40 µg/m^3	7 days		ANZECC (1990)
	2.90/1.50 µg/m^3	24 hours		ANZECC (1990)

(a) ppm = parts per million
(b) ppb = parts per billion
(c) Up to 5 exceedances per year are allowed in the AAQ NEPM, but not in the Approved Methods
(d) The AAQ NEPM does not specify an annual mean standard for PM_{10}
(e) The first value is for general land use, which includes all areas other than specialised land use. The second value is for specialised land use, which includes all areas with vegetation that is sensitive to fluoride, such as grape vines and stone fruits.

10.1.5 Air toxics

Air toxics NEPM

In recognition of the potential health problems arising from the exposure to air toxics, the *National Environment Protection (Air Toxics) Measure* (Air Toxics NEPM) identifies 'investigation levels' for five priority pollutants: benzene, formaldehyde, toluene, xylenes and benzo(a)pyrene (as a marker for polycyclic aromatic hydrocarbons (PAH)). **Table 10-4** outlines these investigation levels for air toxics. These are not compliance standards but are for use in assessing the significance of the monitored levels of air toxics with respect to protection of human health.

Table 10-4 Investigation levels for air toxics in accordance with the Air Toxics NEPM

Substance	Concentration	Averaging period
Benzene	0.003 ppm	1 year[a]
Toluene	1.0 ppm	24 hours
	0.1 ppm	1 year[a]
Xylenes	0.25 ppm	24 hours
	0.20 ppm	1 year[a]
PAH (as b(a)p)[b]	0.3 ng/m^3 [c]	1 year[a]
Formaldehyde	0.04 ppm	24 hours

(a) Arithmetic mean of concentrations of 24-hour monitoring results
(b) b(a)p – benzo(a)pyrene, the most widely studied PAH and used as an indicator compound
(c) ng/m3 – nanograms per cubic metre

NSW Approved Methods

The NSW Approved Methods specify air quality impact assessment criteria and odour assessment criteria for many other substances (mostly hydrocarbons), including air toxics, which are too numerous to reproduce in this chapter. The SEARs for the project require an evaluation of BTEX compounds: benzene, toluene, ethylbenzene, and xylenes. The impact assessment criteria in the NSW Approved Methods for priority air toxics and BTEX compounds are given in **Table 10-5**.

Table 10-5 Impact assessment criteria for air toxics

Source	Substance	Concentration	Averaging period
NSW Approved Methods (impact assessment criteria)	Benzene	0.009 ppm or 0.029 mg/m^3	1 hour
	Toluene[(a)]	0.09 ppm or 0.36 mg/m^3	1 hour
	Ethylbenzene	1.8 ppm or 8 mg/m^3	1 hour
	Xylenes[(a)]	0.04 ppm or 0.19 mg/m^3	1 hour
	PAH (as benzo(a)pyrene)	0.0004 mg/m^3	1 hour
	1,3-butadiene	0.018 ppm or 0.04 mg/m^3	1 hour
	Acetaldehyde[(a)]	0.023 ppm or 0.042 mg/m^3	1 hour
	Formaldehyde	0.018 ppm or 0.02 mg/m^3	1 hour

(a) Odour criterion

In-tunnel air quality

Carbon monoxide

CO has historically been an indicator of the level of motor vehicle emissions in tunnels and has therefore been used as the basis for in-tunnel air quality criteria. Advances in vehicle technology have been effective in reducing the levels of CO emissions so that other emissions are now more relevant indicators of in-tunnel air quality. Chief among these is NO_2.

Nitrogen dioxide

NO_2 is a respiratory irritant with identified health effects at levels that may be encountered in road tunnels. NO_2 was identified as the key pollutant of concern for in-tunnel air quality during the assessment of the NorthConnex project, with new criteria applied to the NorthConnex tunnel in its approval conditions (NSW Department of Planning and Environment, 2015). The new criterion for NO_2 is a tunnel average of 0.5 ppm, measured as a rolling average throughout the tunnel, with a limit at any point in the tunnel of 1.0 ppm. This criterion is equivalent to the most stringent international workplace health and safety criteria and compares favourably to international design guidelines for in-tunnel NO_2 levels, which range between 0.4 ppm and 1.0 ppm. Detailed design of the project tunnel would ensure that the project's ventilation system is appropriately designed to achieve these criteria under all operating conditions, in addition to the CO and visibility (particulate) limits noted in **Table 10-6** and **Table 10-7**. These are the same operational criteria applied to the recently approved NorthConnex tunnel.

Table 10-6 In-tunnel operational criteria for CO and NO_2

Parameter	Averaging period	Concentration limit (ppm)
In-tunnel average limit along tunnel length		
CO	Rolling 15-minute	87
	Rolling 30-minute	50
NO_2	Rolling 15-minute	0.5
In-tunnel single point exposure limit		
CO	Rolling 3-minute	200

Visibility and particulate matter

Visibility is an important consideration in the design of a road tunnel ventilation system. The visibility is required to be greater than the minimum vehicle stopping distance at the design speed (Permanent International Association of Road Congresses (PIARC), 2012). Visibility is reduced by the scattering and absorption of light by particles suspended in the air. The measurement of visibility in a tunnel (using an opacity meter) is based on the concept that a light beam 'decays' (reduces in intensity) as it passes through air containing particles or other pollutants. The level of decay can thus be used to determine the opacity of the air. For tunnel ventilation, visibility is expressed by the extinction coefficient K.

The amount of light scattering, or absorption, in road tunnels is principally dependent on the composition, diameter and density of the particles in the air. Particles that affect visibility are generally in a size range of 0.4 to 1.0 micrometres. **Table 10-7** provides the in-tunnel operational criteria for visibility.

Table 10-7 In-tunnel operational criteria for visibility

Parameter	Averaging period	Average extinction coefficient limit (m^{-1})[a]
In-tunnel average limit along tunnel length		
Visibility	Rolling 15-minute	0.005

(a) m^{-1} = reciprocal metre: Standard unit of measurement for extinction coefficient

The operational extinction coefficient limit of 0.005 m^{-1} may result in tunnel emissions being visible under congested conditions, but not at sufficient levels to produce hazy conditions (PIARC, 2012).

Pollutants and metrics not assessed in detail

The following pollutants and metrics were not considered to be relevant to the ambient air quality assessment of the project (nor to road transport projects in general):

- SO_2 - Although emitted from road vehicles, SO_2 emissions are directly proportional to the sulfur content of the fuel, and given that petrol and diesel in NSW now contain less than 50 ppm and 10 ppm of sulfur respectively, the emissions of SO_2 are very low. SO_2 is therefore not a major concern in terms of transport related air quality
- Pb - The removal of Pb from petrol means that it is no longer considered to be an air quality problem other than in relation to specific industrial activities, such as smelting
- TSP - For road transport, TSP can be broadly assumed to be equivalent to PM_{10}, and therefore within the controlling standard. While this is certainly the case for exhaust particles, it is possible that some non-exhaust particles are greater than 10 μm in diameter
- O_3 - Because of its secondary and regional nature, ozone cannot practicably be considered in a local air quality assessment. In addition, the changes in emissions associated with the project were well below the thresholds that trigger an ozone assessment (see **Section 10.8.2**)
- HF - The standards for HF relate to sensitive vegetation rather than human health, and HF is not a pollutant that is relevant to road vehicle operation.

There are currently no standards for assessment of 'ultrafine' particles. These are particles with a diameter of less than 0.1 μm. While there is some evidence that particles in this size range are associated with adverse health effects, it is not currently practical to incorporate them into an environmental impact assessment. There are several reasons for this including:

- The rapid transformation of such particles in the atmosphere
- The need to treat 'ultrafine' particles in terms of number rather than mass
- The lack of robust emission factors
- The lack of robust concentration response functions
- The lack of ambient background measurements
- The absence of air quality standards.

In relation to concentration response functions, the World Health Organisation (WHO) Regional Office for Europe (2013) has stated the following:

> '… *the richest set of studies provides quantitative information for $PM_{2.5}$. For ultrafine particle numbers, no general risk functions have been published yet, and there are far fewer studies available. Therefore, at this time, a health impact assessment for ultrafine particles is not recommended*.'

For the purpose of the project, assessment the effects of 'ultrafine' particles on health are adequately included in the assessment of the health effects of $PM_{2.5}$ (refer **Section 10.8.6**).

10.1.6 Modelling scenarios

Overview

Two types of scenario were considered for ambient air quality modelling:

- Expected traffic scenarios - These scenarios take into account future changes over time in the composition and performance of the vehicle fleet, as well as predicted traffic volumes and the distribution of traffic on the road
- Regulatory worst case scenarios - The objective of these scenarios is to demonstrate that compliance with the concentration limits for the tunnel ventilation outlets will deliver acceptable ambient air quality.

In each case the following were determined:

- The total pollutant concentration from all contributions (background, surface roads and ventilation outlets)
- The change in the total pollutant concentration
- The pollutant contribution from ventilation outlets alone.

The results have been presented as:

- Pollutant concentrations at discrete receivers (in charts and tables)
- Pollutant concentrations across the modelling domain (as contour plots).

The scenarios evaluated for in-tunnel air quality reflected the potential modes of operation of the tunnel ventilation system. These scenarios are detailed in the following section and include:

- Expected traffic - these scenarios reflected the optimum or best operating conditions, where traffic volumes were high and traffic was flowing freely
- Capacity (maximum) traffic flow scenarios - these were included to reflect conditions that can generate high in-tunnel pollution levels. Several different speeds were considered, including congestion
- Vehicle breakdown scenario - this included incidents such as vehicle breakdowns or accidents and heavy congestion. It was assessed on the basis that it would represent a worst case in terms of pollution generation, especially over the shorter term, and all in-tunnel and ambient air quality limits must be met.

Expected traffic scenarios

The expected traffic scenarios included in the operational ambient air quality assessment are summarised in **Table 10-8**. The scenarios took into account changes over time in the composition and performance of the vehicle fleet, as well as predicted traffic volumes and the distribution of traffic on the road network. The results from the modelling of these scenarios were also used in the health risk assessment for the project (described in **Chapter 11** (Human health)).

Future year land use projections and infrastructure were included in the traffic modelling to understand the level of traffic demand and associated travel patterns, including induced demand. The air quality scenarios modelled used the expected traffic conditions in the corresponding years in terms of volume, composition and speed, as represented in the WestConnex Road Traffic Model (WRTM).

Table 10-8 Expected traffic scenarios for the operational assessment

Scenario code	Scenario description	WestConnex projects included
2014-BY	2014 − Base year (existing conditions)	No WestConnex projects
2021-DM	2021 – 'Do minimum' (ie without project)	King Georges Road Interchange Upgrade and M4 Widening
2021-DS	2021 – 'Do something' (ie with project)	King Georges Road Interchange Upgrade, M4 Widening and New M5
2031-DM	2031 – 'Do minimum' (ie without project)	King Georges Road Interchange Upgrade and M4 Widening
2031-DS	2031 – 'Do something' (ie with project)	King Georges Road Interchange Upgrade, M4 Widening and New M5
2031-DSC	2031 – 'Do something cumulative' (ie with the project and future M4-M5 Link)	King Georges Road Interchange Upgrade, M4 Widening, New M5 and other WestConnex stages including M4 East, future M4−M5 Link, and Sydney Gateway. The future Southern extension was also included.

2014 Base Year

For the purpose of the air quality assessment, a 2014 base year was used. This was used to establish existing conditions. The inclusion of a base year enables the dispersion modelling methodology to be verified against real-world air pollution monitoring data. The base year also provided a current baseline that helped to define underlying trends in projected emissions and air quality, and provided a sense of scale and context for the project impacts.

2021 'Do minimum' (ie without the project)

The year 2021 was adopted as the primary year for forecasting impacts of the project. The primary 'do minimum' case (ie without the project) assumes that the King Georges Road Interchange Upgrade and M4 Widening projects are complete, but that the remainder of the WestConnex program of works and future Southern extension is not built. It is called 'do minimum' rather than 'do nothing' as it assumes that infrastructure schemes currently incomplete but scheduled for opening prior to the assessment year are operational.

2021 'Do something' (ie with the project)

As per the primary 'do minimum' scenario, this represents conditions with the project complete and open to traffic, but without the operation of any other subsequent WestConnex projects or the Southern extension.

2031 'Do minimum' (ie without the project)

A future network including the King Georges Road Interchange Upgrade and M4 Widening and some upgrades to the broader transport network over time to improve capacity and cater for traffic growth, but does not include the other components of the WestConnex program of works or the future Southern extension.

2031 'Do something' (ie with the project)

As per the 2031 'do minimum' scenario with the New M5 project complete and open to traffic, but without other WestConnex program of works or the future Southern extension.

2031 'Do something (cumulative)'

An additional 'do something' scenario with the M4 East, New M5 and future M4-M5 Link projects in place. This excluded contributions from the M4 East ventilation outlets (including the shared outlet with the future M4-M5 Link) given geographical distance. In other words, it was assumed that there would be no 'overlap' in the areas affected by the emissions from the M4 East and New M5 ventilation outlets (approximately six to eight kilometres away) as contribution from the project outlets would be negligible at these distances.

Regulatory worst case scenarios

The objective of these scenarios was to demonstrate that compliance with the proposed emission limits for the tunnel ventilation outlets would provide acceptable ambient air quality. The proposed emission limits were assumed to be the same as those specified in the conditions of approval for the NorthConnex project.

The regulatory worst case scenarios assessed for the project were:

- RWC-A. This scenario applied to the operation of the project only. The scenario considered air quality in 2021 and 2031, and assumed no change in the New M5 ventilation outlets or their operation
- RWC-B. This scenario applied to the operation of the project and the future M4-M5 Link, taking into account additional ventilation outlets required for the future M4-M5 Link (in addition to the ventilation outlets forming part of the New M5 project).

These scenarios assessed constant ventilation outlet concentrations (at proposed maximum allowable limits) over a 24-hour period to provide a representation of the theoretical maximum changes in air quality across all potential operational modes, including unconstrained and worst case traffic conditions (from an emissions perspective) as well as vehicle breakdown situations.

The proposed concentration limits for the ventilation outlets are summarised in **Table 10-9** and are consistent with the limits specified in the approval for the NorthConnex project. These limits were converted to mass emission rates (in kilograms per hour (kg/h)) based on tunnel ventilation rates. A 'medium' level air flow of 400 cubic metres per second (m^3/s) was assumed for each ventilation outlet, with fans in operation, effective outlet diameters and normal exit velocities.

Table 10-9 Concentration limits for ventilation outlets

Pollutant	Limit concentration (mg/m^3)
PM_{10}	1.1[(a)]
$PM_{2.5}$	1.1
NO_X	20.0
NO_2	2.0
CO	40.0
Volatile organic hydrocarbons/total hydrocarbons (VOC/THC)	1.0

(a) Stated as 'solid particles' in the NorthConnex conditions of approval.

The ventilation outlet assumptions for the regulatory worst case scenarios are detailed in **Appendix H** (Table 9.22) and the air quality impact assessment results are presented in **Section 10.8.2**.

The assessment of regulatory worst case scenarios was undertaken to assist regulatory authorities in assessing and determining potential ventilation outlet concentration limits that could be applied through conditions of approval. Assuming that concentration limits are applied to the ventilation outlets, the results of the analysis would demonstrate the air quality performance of the project if it operates continuously at the limits. In reality, ventilation outlet concentrations would vary over a daily cycle due to changing traffic volumes and tunnel fan operation. The regulatory worst case assessment scenarios would therefore overestimate anticipated actual ambient air quality impacts.

10.1.7 Accuracy and conservatism

There is generally a desire for an appropriate level of conservatism in air quality assessments. The reasons for this include:

- Allowing for uncertainty: An assessment on the scale undertaken for this project is a complex, multi-step process that involves a range of assumptions, inputs, models and post-processing procedures. There is an inherent uncertainty in each of the methods used to estimate emissions and concentrations, and there are clearly limits to how accurately any impacts in future years can be predicted. Conservatism is built into predictions to ensure that a margin of safety is applied (ie to minimise the risk that any potential impacts are underestimated)
- Providing flexibility: It is undesirable to define the potential environmental impacts of a project too narrowly in the early stages of the development process. A conservative approach provides flexibility, allowing for ongoing design refinements within an approved environmental envelope. Conversely, excessive conservatism in an assessment risks overstating potential air quality impacts and associated human health risks. This, in turn, may lead to some undesirable outcomes that need to be mitigated and managed. An overly conservative approach may create, or contribute to, concerns within the local community and among other stakeholders about the impacts of the project. It may lead to additional or more stringent conditions of approval than necessary, including requirements for the mitigation, monitoring and management of air quality. Overstatement of vehicle contributions to local air quality may also lead to overstating the benefit where vehicle emissions are reduced by the project (AECOM, 2014b).

Air quality assessments therefore need to strike a balance between these potentially conflicting requirements.

The operational air quality assessment for the project has been conducted, as far as possible, with the intention of providing accurate and realistic estimates of pollutant emissions and concentrations. The general approach has been to use inputs, models and procedures that are as accurate as possible, except where the context dictates that a degree of conservatism is sensible. An example of this is the estimation of the maximum one-hour NO_2 concentration during a given year. Any method that provides a 'typical' or 'average' one-hour NO_2 concentration will tend to result in an underestimate of the likely maximum concentration, and therefore a more conservative approach is required.

However, the scale of the conservatism can be difficult to define, and this can sometimes result in assumptions being overly conservative. Skill and experience is required to estimate impacts that err on the side of caution but are not unreasonably exaggerated or otherwise skewed. By demonstrating that a deliberate overestimate of impacts is acceptable, it can be confidently predicted that the actual impacts that are likely to be experienced in reality would also lie within acceptable limits (AECOM, 2014c).

10.1.8 Model selection and validation

Both the emissions and dispersion models were validated for use in the air quality assessment of this project. The Graz Lagrangian (GRAL) dispersion model (version 14.11) was selected for this study and was validated by comparing model predictions and actual air quality monitoring data collected in the 2014 base year.

GRAL was chosen as the most suitable dispersion model because it is:

- Suitable for regulatory applications and can utilise a full year of meteorological data
- Able to predict low wind speed conditions (less than one metre per second) better than most other models
- Specifically designed for the simultaneous modelling of road transport networks, including line sources (surface roads), point sources (tunnel ventilation outlets) and other sources
- Able to take into account vehicle wake effects
- Able to characterise pollution dispersion in complex local terrain and topography, including the presence of buildings in urban areas

- Validated in a wide range of studies featuring complex and flat terrain and with varying meteorological conditions (high/low wind speeds, stable/unstable atmospheric conditions etc.).

While the GRAL system has not been used extensively in Australia, it was used in the assessment of the Waterview Connection tunnels near Auckland, New Zealand and more recently for the assessment of the WestConnex M4 East project. The model set up for this project has been tailored to suit the needs of both the study at hand and the regulatory requirements in NSW in relation to air quality. The GRAL model is described in more detail in **Appendix H**.

For the purpose of model validation, GRAL was configured to provide concentration predictions for each main pollutant (CO, NO_X, NO_2 and PM_{10}) at each of nine air quality monitoring sites (seven background and two roadside) in the WestConnex GRAL domain and for the full 2014 base year. The WestConnex and New M5 model domains are described in **Section 10.4.2**. $PM_{2.5}$ was not included as no independent testing of the model performance for $PM_{2.5}$ was possible.

The GRAL predictions used in the model validation were for the combined surface road network and the M5 East tunnel ventilation outlet. For each monitoring site the GRAL predictions were extracted for an hourly time series of concentrations for 2014. These were combined with an estimated background contribution for each monitoring site.

The performance of the GRAL model was also validated at each of the project-specific air quality monitoring stations, by comparing model predictions with data from the monitoring stations. Given that only partial monitoring data for 2014 were available at each site, the comparisons between the model and the monitoring data were made for the monitoring period covered at each site.

The vehicle emission models used in the in-tunnel and ambient air quality assessments were validated by comparison with the NSW EPA measured emissions from the Lane Cove Tunnel (see Appendix E of the Technical working paper: Air quality in **Appendix H**).

Further details on the method and results of the model evaluation are provided in Appendix K of the Technical working paper: Air quality provided in **Appendix H**.

10.1.9 Sensitivity tests

Sensitivity tests were conducted to investigate the effects of varying the key assumptions in the ambient air quality assessment. These included:

- The influence of ventilation outlet temperature
- The influence of ventilation outlet height
- The inclusion of buildings near tunnel ventilation outlets.

These tests were based on a sub-area of the New M5 GRAL domain of approximately three kilometres by three kilometres around the project's western ventilation outlet. Only the ventilation outlet contribution, and annual mean $PM_{2.5}$ and maximum 24-hour $PM_{2.5}$, were included in the sensitivity tests. A sub-set of nine sensitive receivers was evaluated. The predicted concentrations were indicative as the aim of the sensitivity tests was to assess the proportional sensitivity of the model to specific input parameters.

10.1.10 Alexandria Landfill

The site of the Alexandria Landfill at St Peters is currently licensed by the NSW EPA as a solid waste landfill, waste storage and recycling facility. The area would form a major component of the St Peters interchange, which would include surface roads, tunnel portals, overpasses and associated infrastructure. The remainder of the site is planned to be redeveloped as public open space, comprising a mixture of parkland and pathways.

The redevelopment of the site means that it would need to be closed and managed in accordance with the *Protection of the Environment and Operations Act 1997*. Assessments were therefore undertaken to estimate the potential impacts of operations during the closure of the landfill on dust (particulate matter) and odour.

Dust assessment

Activities associated with dust generation include:

- Excavators loading material to trucks
- Hauling cut and fill material on unsealed roads
- Dumping material from trucks
- Dozers pushing and shaping material
- Grading roads
- Wind erosion from exposed surfaces.

The criteria that were applied to the assessment were those stated for airborne particulate matter and deposited dust in the NSW Approved Methods. The criteria for airborne particulate matter are summarised in **Table 10-10**.

Table 10-10 Assessment criteria for particulate matter (DEC, 2005b)

Pollutant	Criterion	Averaging period
TSP	90 μgm^3	Annual
PM_{10}	50 $\mu g/m^3$	24-Hour
	30 $\mu g/m^3$	Annual
$PM_{2.5}$	25 $\mu g/m^3$	24 - Hour
	8 $\mu g/m^3$	Annual

Table 10-11 shows the maximum acceptable increase in dust deposition over the existing dust levels, as well as the maximum total deposition. The criteria for dust deposition are set to protect against nuisance impacts (DEC, 2005b).

Table 10-11 EPA criteria for dust fallout (insoluble solids)

Pollutant	Averaging period	Maximum increase in deposited dust level	Maximum total deposited dust level
Deposited dust	Annual	2 g/m^2/month	4 g/m^2/month

Odour assessment

The main activity associated with odour generation is the excavation of non-putrescible waste during earthworks at the former Alexandria Landfill site. The site has operated as a landfill for non-putrescible solid waste and so any excavation of that waste and its subsequent exposure to the atmosphere may result in odour emission.

In order to conservatively assess the potential impacts, it has been assumed that the Sequencing Batch Reactor (SBR) tanks that hold the collection of leachate from the landfill site and the sludge dewatering area may be exposed to the atmosphere.

Two modelling scenarios were completed. The first scenario considered the predicted impacts of the exposed excavated waste areas and a fully enclosed leachate treatment system. The second scenario considered the exposed excavated waste areas combined with open SBR tanks and dewatered sludge bin.

The Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in NSW (DEC, 2005b) include ground-level concentration criteria for complex mixtures of odorous air pollutants, taking into account the population density in the affected area. **Table 10-12** lists the odour criteria which cannot be exceeded more than one per cent of the time for different population densities.

The most stringent impact assessment criterion of two odour units (OU) (at the 99th percentile; EPA, 2005) has been applied for this assessment.

Table 10-12 Odour performance criteria for the assessment of odour

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

It is common practice to use dispersion models to determine compliance with odour goals. This introduces a complication because Gaussian dispersion models directly predict concentrations over an averaging period of three-minutes or greater. The human nose, however, responds to odours over periods of the order of a second or so. During a three-minute period, odour levels can fluctuate significantly above and below the mean depending on the nature of the source.

As a result, the NSW EPA commissioned a study to more rigorously determine the ratio between the one-second peak concentrations and the three-minute, longer period average concentrations (referred to as the peak-to-mean ratio) that might be predicted by a Gaussian dispersion model. The study carried out by Katestone Scientific Pty Ltd (1995, 1998) recommended peak-to-mean ratios for a range of variables, such as source type, receptor distance, stability class and stack height (for point sources).

It is important to note that those peak-to-mean factors determined are based on the Pasquill-Gifford stability classes. Since AERMOD replaces the Pasquill-Gifford stability based dispersion with a turbulence-based approach that uses the Monin-Obukhov length scale to account for the effects of atmospheric turbulence based dispersion, a conservative approach has been taken for area sources and a value of 2.5 has been applied when multiplying the peak mean factor.

The Approved Methods take account of this peaking factor and the goals shown in **Table 10-12** are based on nose-response time.

10.2 Construction air quality assessment methodology

Construction activities can be categorised into four types to reflect their potential impacts. The potential for dust emissions has been assessed for each likely activity in each category:

- **Demolition** is any activity that involves the removal of existing structures
- **Earthworks** covers the processes of soil stripping, ground levelling, excavation and landscaping. Earthworks primarily involves excavating material, haulage, tipping and stockpiling
- **Construction** is any activity that involves the provision of new structures, or modification or refurbishment of existing structures. 'Structures' include buildings, ventilation outlets and roads
- **Track-out** involves the transport of dust and dirt from the construction/demolition site onto the public road network on construction vehicles. These materials may then be deposited and re-suspended by vehicles using the network.

It is difficult to quantify dust emissions from construction activities since it is not possible to predict the weather conditions that will prevail during specific construction activities. In any case, 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. It is therefore common practice to provide a qualitative assessment of potential construction dust impacts. This approach follows the guidance published by the UK Institute of Air Quality Management (IAQM, 2014), the aim of which is to identify risks and recommend appropriate mitigation measures.

Construction activities would occur at several sites within the project area, as described in **Chapter 6** (Construction work). Many of these activities would be transitory (ie not permanent). The majority of the construction footprint would be underground; however, surface works would be required to support tunnelling activities and to construct surface infrastructure including the western surface works, St Peters interchange, local road upgrades, tunnel portals, ventilation facilities, ancillary operations buildings and facilities.

The guidance published by the IAQM (2014) was used for the assessment of air quality during construction (see **Appendix H**). The IAQM guidance has been adapted for use in NSW, taking into account factors such as the assessment criteria for ambient PM_{10} 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 IAQM procedure for assessing construction dust impacts is shown in **Figure 10-1**.

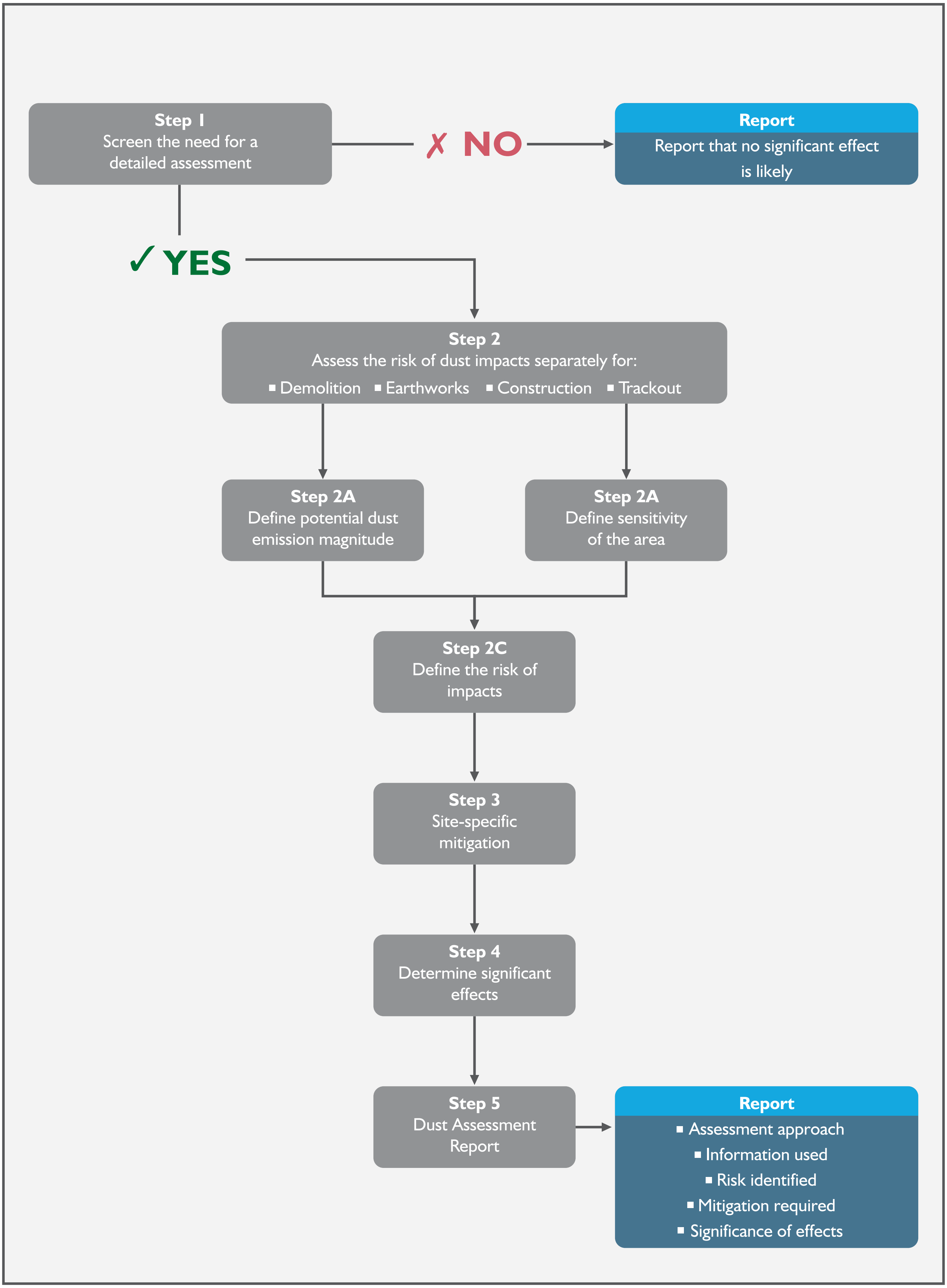

Figure 10-1 Steps in an assessment of construction dust (IAQM, 2014)

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The main air pollution and amenity issues from construction activities are:

- Dust deposition (soiling of surfaces) and visible dust plumes
- Elevated PM_{10} concentrations due to dust-generating activities
- Exhaust emissions from diesel-powered construction equipment.

The assessment methodology considers three types of dust impacts:

- Annoyance due to dust deposition (soiling of surfaces)
- The risk of health effects from increased exposure to PM_{10}
- Harm to ecological receivers.

The risk of dust impacts from a demolition / construction ancillary facility causing loss of amenity and / or health or ecological impacts is related to the following (IAQM, 2014):

- The nature of the activities being undertaken
- The duration of the activities
- The size of the site
- The meteorological conditions (wind speed, direction and rainfall) - adverse impacts are more likely to occur downwind of the site and during drier periods
- The proximity of receivers to the activities
- The sensitivity of the receivers to dust
- The adequacy of the mitigation measures applied to reduce or eliminate dust.

10.3 Alexandria Landfill air quality assessment methodology

10.3.1 Dust assessment

Relevant activities

Activities associated with dust generation during the closure and remediation of Alexandria Landfill include:

- Excavation and exhuming wastes to develop the required final landform
- Excavators loading material to trucks
- Hauling cut and fill material on unsealed roads
- Dumping material from trucks
- Dozers pushing and shaping material
- Grading roads
- Wind erosion from exposed areas.

Model used

Off-site dust concentration and deposition levels due to the landfill closure activities were predicted using the AERMOD dispersion model. The AERMOD system includes AERMET, used for the preparation of meteorological input files and AERMAP, used for the preparation of terrain data.

Appropriate values for three surface characteristics are required for AERMET. These are:

- Surface roughness, which is the height at which the mean horizontal wind speed approaches zero, based on a logarithmic profile
- Albedo, which is an indicator of reflectivity of the surface
- Bowen ratio, which is an indicator of surface moisture.

Values of surface roughness, albedo and Bowen ratio were determined based on a review of aerial photography for a radius of three kilometres centred on the project site. Default values for land use were chosen to represent the surrounding area.

Background concentrations

The air quality goals relate to the total dust burden in the air and not just the dust from the landfill closure activities. In other words, consideration of background dust levels has been made when using these goals to assess potential impacts.

Background concentrations of PM_{10} and $PM_{2.5}$ are discussed in Appendix F of the Technical working paper: Air quality in **Appendix H**. Conservative estimates were made of the concentrations in the vicinity of the landfill. These were:

- Annual average PM_{10} – 21 µg/m^3
- Annual average $PM_{2.5}$ – 8 µg/m^3
- Annual average TSP – 52 µg/m^3 (assuming a PM_{10}:TSP ratio of about 0.4)
- Annual average deposition – 2 g/m^2/month

Emission estimation

Estimates of emissions for each source were developed taking into account the activities that would take place (noted above). For each source and for each hour, an emission rate which depended on the level of activity and the wind speed was determined. Dust generating activities were represented by a series of volume sources situated across the site. The locations of these volume sources as represented in the model are shown in Figure 8-4 of the Technical working paper: Air quality in **Appendix H**.

The proposed activities were analysed and estimates of dust emissions for the key dust generating operations were made. Emission factors developed by the US EPA were applied to estimate the amount of dust produced by each activity.

10.3.2 Odour assessment

Odour concentrations were predicted using the dispersion model AERMOD, the configuration of which was described in **Section 10.3.1**.

Emission estimation

In order to represent a disturbed area of excavated non-putrescible waste, a specific odour emission rate of 0.424 odour units per cubic metre of air per second per square metre of exposed surface (OU.m^3/s/m^2) was used. This value was taken from measurements made at the tipping face of a landfill which receives both putrescible and non-putrescible solid waste, and would be considered conservative for this assessment.

The value of 0.424 OU.m^3/s/m^2 was multiplied by a peak to mean ratio of 2.5 to account for nose-response time. The resultant emission rate was then multiplied by the estimated area of exposed material, which was assumed to be emitting odour at that constant rate for the entire one year modelling period. These are conservative estimates as it is likely that any odorous material would be covered at the end of each day.

For modelling purposes it was assumed that there would be six areas being excavated at any one time across the site and that these areas would be emitting at the full rate for every hour of the year.

In addition to the excavated areas, open SBR tanks and a dewatered sludge bin were also assessed. The specific odour emission rate for these point sources are summarised in **Table 10-13.**

The specific odour emission rate from the leachate contained in the SBR tanks was estimated to be approximately 0.06 $OU.m^3/s/m^2$ (direct measurement made from a leachate pond). This was then multiplied by the exposed area (two tanks with a diameter of 9.75 m) and again by the peak to mean ratio of 2.5. The emission from the dewatered sludge bin is approximately 0.17 $OU.m^3/s/m^2$ (representative of dewatered sewage sludge), multiplied by the exposed area of approximately 50 m^2 and the 2.5 peak to mean ratio.

Table 10-13 Point source specific odour emission rate

Source	Specific odour emission rate ($OU.m^3/s/m^2$)
Excavated waste	0.424
SBR tanks	0.06
Dewatered sludge bin	0.17

10.4 Operational air quality assessment methodology

Details of the various components of the operational air quality assessment methodology are provided in **Appendix H** and a summary of the in-tunnel and external air quality assessment is provided below.

10.4.1 In-tunnel assessment methodology

In-tunnel traffic, airflow, pollution levels and temperature for the project and for the future M4-M5 Link were modelled using IDA Tunnel software. The data used in the tunnel ventilation simulation, and the results of the simulation, are provided in full within Appendix L of the Technical working paper: Air quality in **Appendix H**.

Scenarios

The scenarios evaluated for in-tunnel air quality reflected the potential modes of operation of the tunnel ventilation system. These scenarios were:

- **Expected traffic**: The expected traffic scenarios included in the in-tunnel air quality assessment are summarised in **Table 10-14.** The objective of these scenarios was to demonstrate that the expected operation of the project would result in acceptable in-tunnel air quality capacity (maximum) traffic flow scenarios. These were included to reflect conditions that can generate high in-tunnel vehicle emission concentrations. Several different speeds were considered, including congested traffic conditions
- **Vehicle breakdown scenario**: This included incidents such as vehicle breakdowns or accidents and heavy congestion. It was assessed on the basis that it would represent a worst case in terms of vehicle emissions generation, particularly over the shorter term until the breakdown or accident had been cleared.

Table 10-14 Expected traffic scenarios for the in-tunnel air quality assessment

Scenario code	Scenario description
2021-DS	2021 – 'Do something (ie with project)
2031-DS	2031 – 'Do something (ie with project)
2031-DSC	2031 – 'Do something cumulative' (ie with the project and future M4-M5 Link)

The three pollutants assessed for in-tunnel air quality were NO_2, CO and $PM_{2.5}$ (exhaust only, as visibility). For the operating years of the project, NO_2 would be the pollutant that determines the required airflow and drives the design of ventilation for in-tunnel pollution.

10.4.2 External air quality assessment methodology

The operational ambient air quality assessment was based on the GRAMM / GRAL modelling system. This system consists of two main modules: a prognostic wind field model (the Graz Mesoscale Model, or GRAMM) and a dispersion model (GRAL). The elements of the system are shown in **Figure 10-2** and summarised below. Full details of the methodology are presented in the Technical working paper: Air quality in **Appendix H**.

The GRAL dispersion model is a three-dimensional model used to predict pollutant concentrations. It is suitable for regulatory applications and can use a full year of meteorological data. It predicts pollutant concentrations under low wind speed conditions (less than one metre per second) more accurately than Gaussian models (eg CALINE). It is specifically designed for the simultaneous modelling of surface roads, point sources (tunnel ventilation outlets) and tunnel portals, and takes into account vehicle wake effects.

GRAL characterises pollution dispersion in complex local terrain and topography, including the presence of buildings in urban areas. It has been validated in a wide range of studies featuring complex and flat terrain, and with different meteorological conditions such as high and low wind velocities, and stable or unstable atmospheric conditions (refer to Appendix J of the Technical working paper: Air quality in **Appendix H**) and is not inherently conservative (see discussion of conservatism in **Section 10.1.7**).

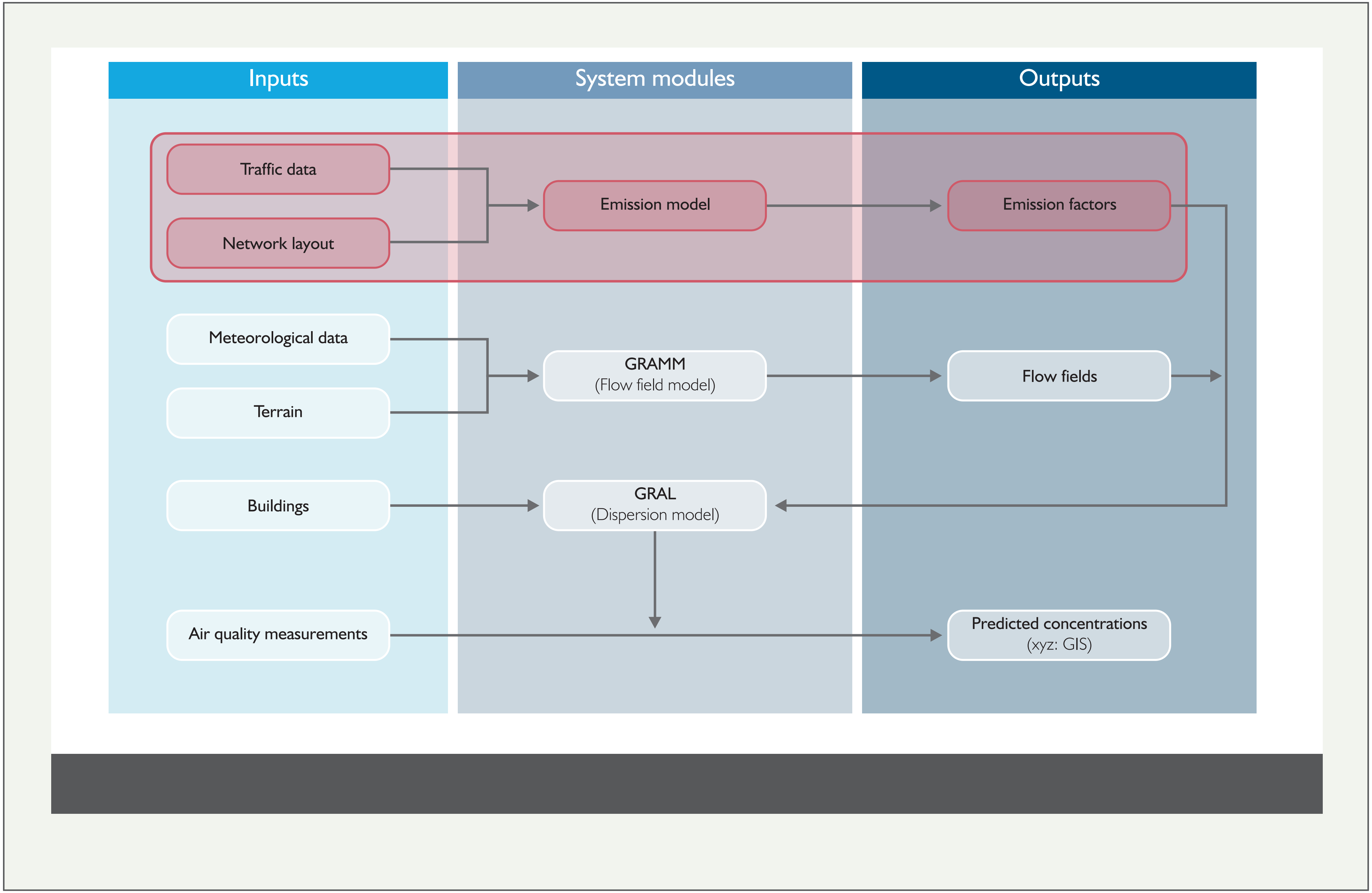

Figure 10-2 Overview of the GRAMM/GRAL modelling system

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Definition of modelling domains

The modelling domains for the project are shown in **Figure 10-3**. The following terms are used in this report to describe the different geographical areas of the assessment:

- The GRAMM domain (also referred to as the 'study area') is shown by the red boundary in **Figure 10-3**. This was used for the modelling of meteorology, and was the largest area included in the assessment. The GRAMM domain covers a substantial part of Sydney, extending 25 kilometres in the east−west (x) alignment and 20 kilometres in the north−south (y) alignment.
- The WestConnex GRAL domain for dispersion modelling is shown by the green boundary in **Figure 10-3**. This extended 15 kilometres in the east−west (x) alignment and 14 kilometres in the north−south (y) alignment. Every dispersion model run was undertaken for the WestConnex GRAL domain, which includes all project components of the WestConnex program of works (a section of the M4 Widening, M4 East, King Georges Road Interchange Upgrade, New M5 and future M4−M5 Link). The large size of the WestConnex GRAL domain was defined for a number of reasons:
  - It facilitated a 'whole of project' modelling approach, whereby the specific information for each WestConnex project could be extracted and presented in more detail for the separate EISs (in this case, for the New M5 project). This improved both the efficiency and consistency of the air quality assessments for the various WestConnex projects
  - It provided the cumulative impacts of all relevant projects, such as the combined ventilation outlet for the New M5 and future M4−M5 Link, but excluded contributions from the M4 East ventilation outlets (including the shared outlet with the future M4-M5 Link) given geographical distance
  - It maximised the flexibility of the assessment process, and is capable of accommodating any future changes in the requirements of any project
  - It refined the model outcomes by maximising the number of meteorological and air quality monitoring stations that could be included for model evaluation purposes.
- The New M5 GRAL domain is shown by the orange boundary in **Figure 10-3**. This extended 12 kilometres in the east−west (x) alignment and eight kilometres in the north−south (y) alignment. No separate modelling was undertaken for this domain; rather, the model results for this area were extracted from the model results for the WestConnex GRAL domain.

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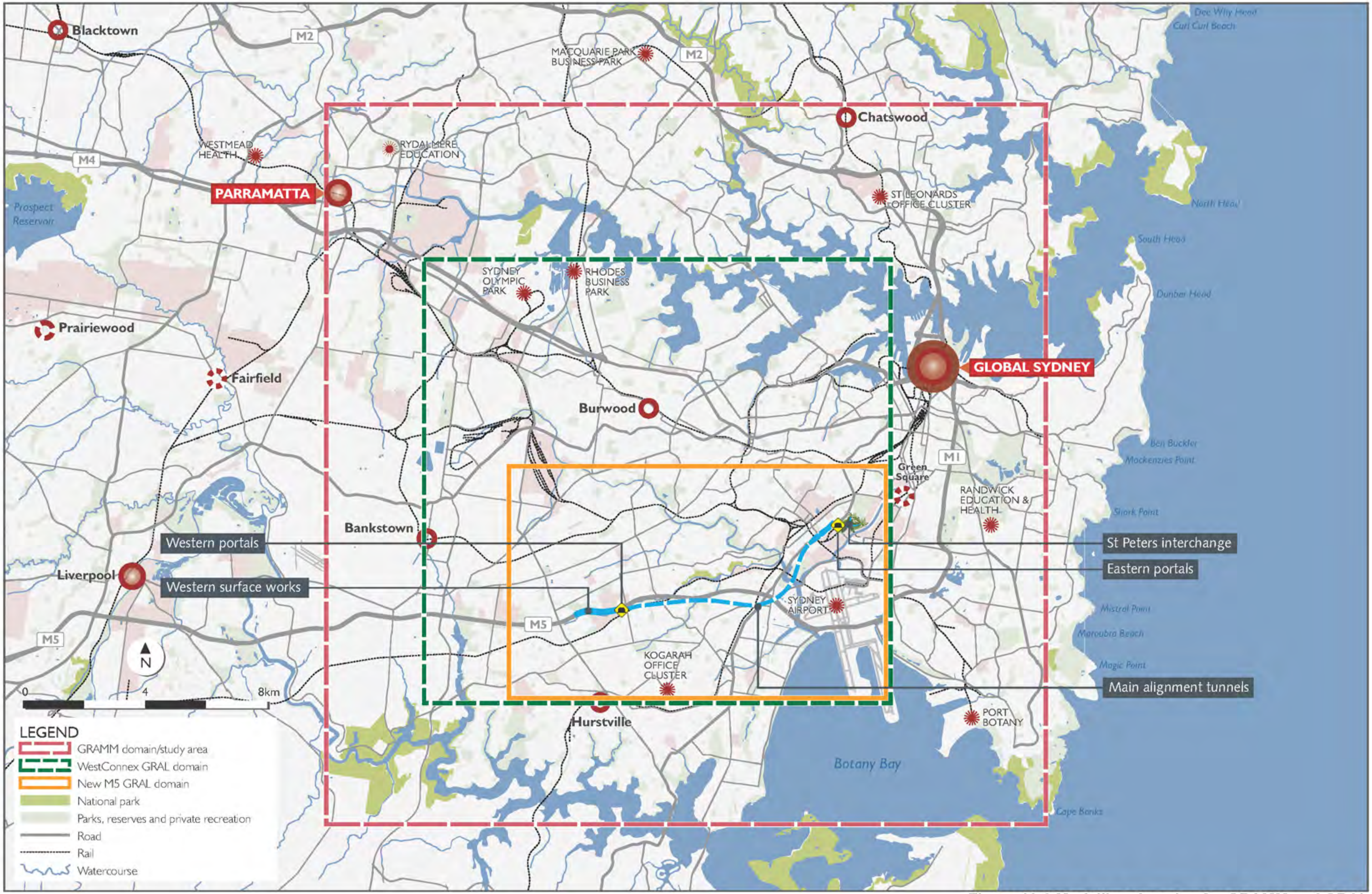

Figure 10-3 Modelling domains for GRAMM and GRAL

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Determination of components of assessment

The various pollutant concentrations were determined as follows:

- Background concentrations were based on measurements from air quality monitoring stations at urban background locations in the study area, but well away from roads (as defined in Australian Standard AS/NZS 3580.1.1:2007 - *Methods for sampling and analysis of ambient air – Guide to siting air monitoring equipment*). The approaches used to determine long-term and short-term background concentrations are explained in Appendix F of the Technical working paper: Air quality in **Appendix H**. Background concentrations were assumed to remain unchanged in future years
- Surface road concentrations and ventilation outlet concentrations were estimated (separately) using the GRAL dispersion model
- For all pollutants except NO_2, the project increment was equal to the difference between the road concentration (surface roads and ventilation outlets) with and without the project. A different method was required for NO_2 to account for the change in atmospheric chemistry in the roadside environment (see Appendix G of the Technical working paper: Air quality in **Appendix H**).

Receivers

Appendix H presents contour maps showing concentrations, and changes in concentration, across the entire New M5 GRAL domain. The concentrations are based on a Cartesian grid of points with an equal spacing of 10 metres in the east to west (x) and north to south (y) directions. This results in 960,000 grid locations across the New M5 GRAL domain.

Appendix H also presents distributions of changes in concentration at over 46,000 discrete receiver locations along the project corridor where people are likely to be present for some period of the day.

Two types of discrete receiver locations were defined for use in the assessment:

- 'Community receivers' - these were taken to be representative of particularly sensitive locations within a zone (600 metres either side) along the project corridor, including, but not limited to schools, child care centres and hospitals. For these receivers a detailed approach was used to calculate the total concentration of each pollutant. This involved the combination of the contemporaneous road / outlet time series of concentrations from GRAL and the background time series of concentrations, stated as a one-hour mean for each hour of the year in each case. The number of such receivers that could be treated in this way was dictated by the limit on the number of time series that could be extracted from GRAL. In total, 35 community receivers were included in the assessment
- 'Residential, workplace and recreational (RWR) receivers' - These were all discrete receiver locations along the project corridor, and mainly covered residential and commercial land uses. The 35 community receivers were also included. For these receivers a simpler statistical approach was used to combine a concentration statistic for the modelled roads and outlets (eg maximum 24-hour mean PM_{10}, annual mean NO_X) with an appropriate background statistic. Around 46,219 RWR receivers were included in the assessment.

Not all particularly sensitive receivers along the project corridor were included as community receivers. However, all receivers were included in the assessment as RWR receivers.

The RWR receivers are discrete points in space, classified according to the land use identified at that location. The RWR receivers do not identify the number of residential (or other) properties at the location. The residential land use at an RWR receiver location may range from a single-storey dwelling to a multi-storey and multi-dwelling building.

The RWR receivers are therefore not designed for the assessment of changes in total population exposure. The human health risk assessment (**Appendix I**) combines the air quality information with the highest available resolution population data from the Australian Bureau of Statistics to calculate key health indicators that reflect population-weighted change in concentrations across the study area. This included, for example, aged care facilities and some additional schools.

Community receivers are listed in **Table 10-15**. RWR receiver types are listed in **Table 10-16**. The locations of both types of receiver are shown in **Figure 10-4**.

Table 10-15 Full list of community receivers

Receiver code	Receiver name	Receiver location	
		x	y
SR01	Active Kids Beverly Hills	321759.34	6242522.13
SR02	Active Kids Narwee	321834.82	6242572.24
SR03	Beverly Hills North Public School	322057.56	6242739.38
SR04	Beverly Hills Girls High School	322434.56	6241894.31
SR05	Barfa Bear Child Care Centre	322502.71	6242962.37
SR06	Regina Coeli Catholic Primary School	322534.93	6242106.78
SR07	Footsteps Early Learning Centre	322598.30	6242038.13
SR08	Footsteps Early Learning Centre Out of Hours School Care	322634.72	6242067.94
SR09	McCallums Hill Public School	322983.85	6243411.42
SR10	Hurstville City Council Family Day Care Scheme	323188.07	6242153.07
SR11	Kingsgrove North High School	324163.24	6243526.44
SR12	Kingsgrove Early Childhood Health Centre	324237.76	6242567.09
SR13	Kingsgrove World Of Learning	324302.13	6243159.06
SR14	Kingsgrove Day Hospital	324605.26	6242446.62
SR15	Kings Medical Clinic	324617.41	6242385.68
SR16	Kids Oasis Childcare Centre	324938.30	6242947.28
SR17	Clemton Park Public School	325159.24	6244031.99
SR18	The Salvation Army Booth College	326159.87	6242931.27
SR19	Alloa Nursing Home	327926.14	6242694.31
SR20	Athelstane Public School	327937.74	6243217.07
SR21	Kinderoos Childcare Centre	327972.63	6243279.07
SR22	Ladybugs Day Care	328350.84	6243727.16
SR23	Macedonian Community Child Care Centre	328728.78	6243409.25
SR24	Arncliffe Public School	328787.20	6242894.84
SR25	Tempe High School	329994.39	6245223.50
SR26	Tillman Park Child Care Centre	330313.10	6245488.42
SR27	St Pius' Catholic Primary School	331168.07	6246637.69
SR28	Camdenville Public School	331336.13	6246750.02
SR29	Camdenville Public School Preschool	331417.05	6246696.75
SR30	St Peters Public School	331427.41	6246008.99
SR31	Sydney Park Childcare Centre	332359.96	6246661.46
SR32	Sydney Park Childcare Centre	332434.93	6246719.45
SR33	Lady Gowrie Child Centre	332545.11	6247280.29
SR34	Active Kids Mascot	332608.90	6245071.23
SR35	Building Blocks Early Childhood Learning	332838.53	6245806.12

Table 10-16 Summary of RWR receiver types

Receiver type	Number	% of total
Child care / pre-school	25	0.05%
School	129	0.28%
Further education	9	0.02%
Aged care	14	0.03%
Residential	41,579	89.96%
Commercial	2,210	4.78%
Industrial	1,468	3.18%
Hotel	29	0.06%
Park / sport / recreation	136	0.29%
Public services	11	0.02%
Community	13	0.03%
Medical	101	0.22%
Religion	80	0.17%
Construction site	22	0.05%
Other	393	0.85%
Total	**46,219**	**100.0%**

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Figure 10-4 Modelled discrete receiver locations

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Treatment of elevated receivers

The main emphasis in the external air quality assessment was on ground-level concentrations (as specified in the NSW Approved Methods). However, at a number of locations in the GRAL New M5 domain there are multi-storey residential and commercial buildings. The potential impacts of the project at elevated points at these locations may be different to the impacts at ground level and therefore these were evaluated separately. In addition, it was considered important to understand how future building developments (eg apartment blocks) in the domain might be affected from an air quality perspective.

Information on building height was not available for all RWR receivers in the New M5 domain. The heights of those buildings for which this information was available are shown in **Figure 10-5** and the distribution of building heights is shown in **Figure 10-6**.

The distribution in **Figure 10-6** also includes locations (around 300 in number) that were not buildings and had a height of less than one metre.

Most of the buildings had a height of less than 10 metres and only a small proportion of buildings had a height of more than 15 metres. However, there were some buildings in the vicinity of the Arncliffe ventilation outlet that were taller than 30 metres. Based on this assessment, two elevated receiver heights were selected to cover both existing buildings and future developments: 10 metres and 30 metres. For both heights, a full modelling run across the GRAL WestConnex domain was conducted across the New M5 domain.

This part of the assessment did not cover all pollutants and averaging periods. The focus was on annual average $PM_{2.5}$ concentrations in the 2031-DSC scenario. The GRAL model was used to predict $PM_{2.5}$ concentrations associated with surface roads and tunnel ventilation outlets.

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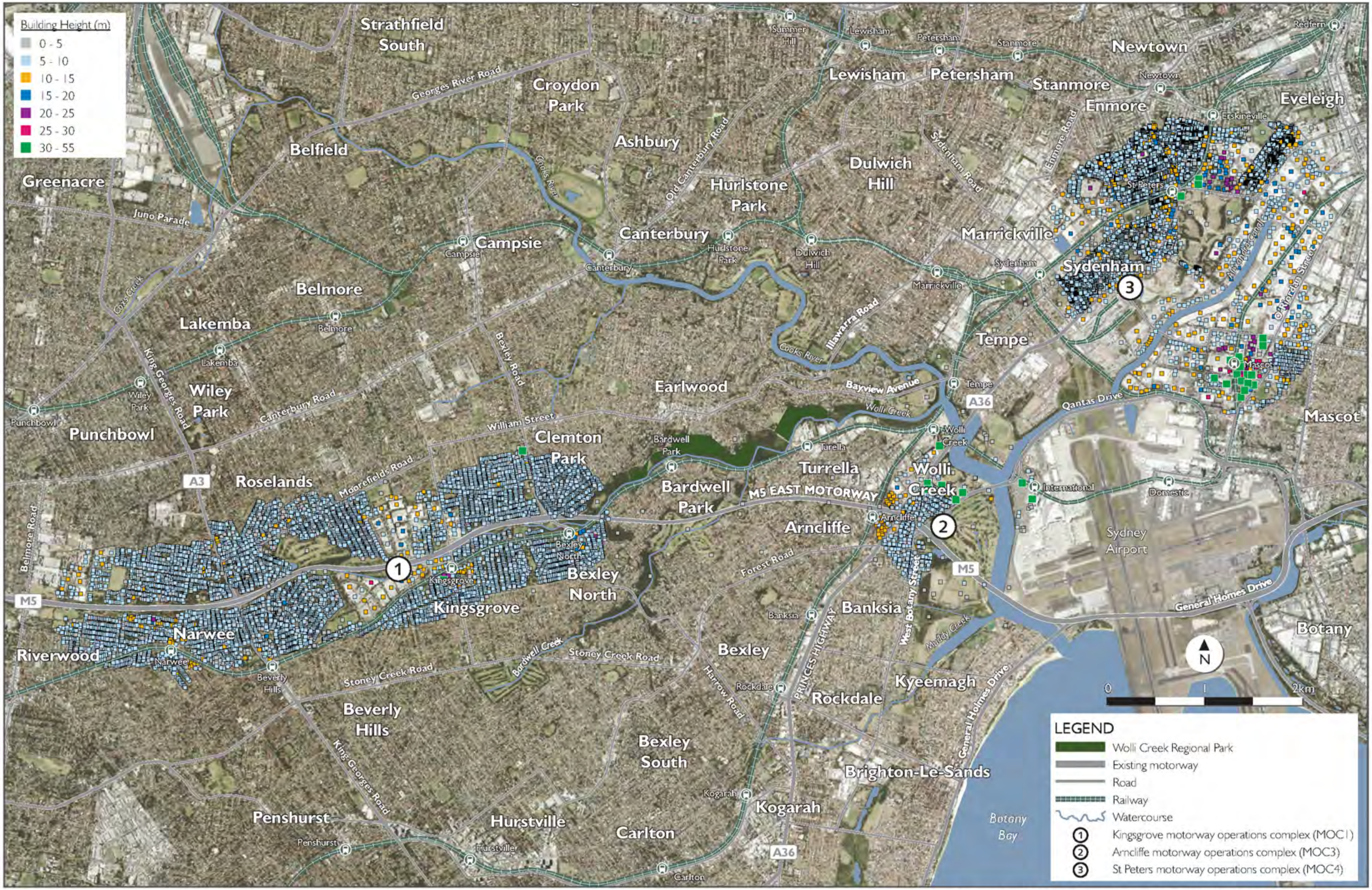

Figure 10-5 Building heights at RWR receiver locations

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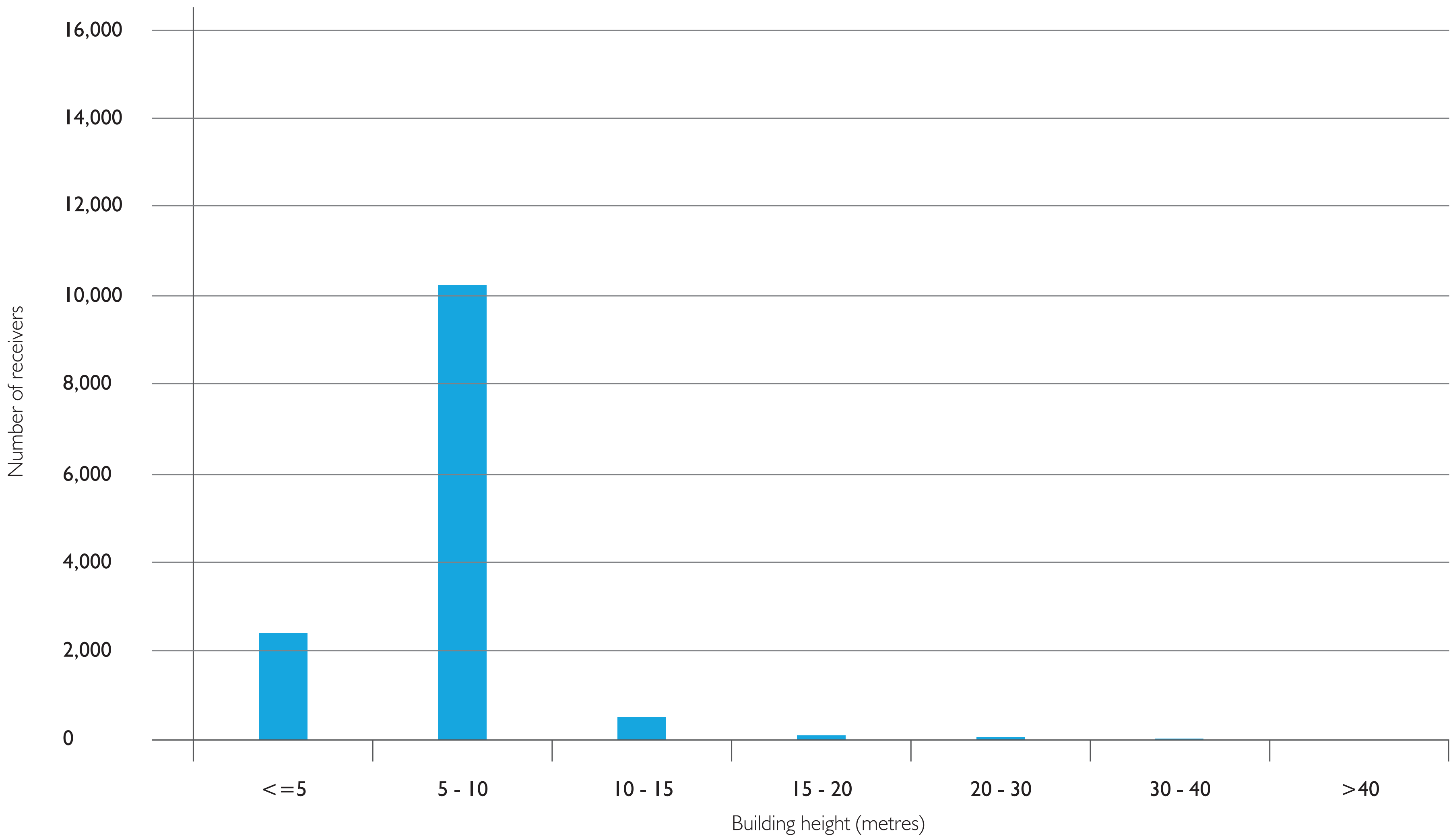

Figure 10-6 Frequency distribution of building heights at RWR receiver locations

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The following cases were assessed with regards to elevated receivers:

- 2031-DM at a height of 10 metres (surface roads only)
- 2031-DM at a height of 30 metres (surface roads only)
- 2031-DSC at a height of 10 metres (surface roads and ventilation outlets)
- 2031-DSC at a height of 30 metres (surface roads and ventilation outlets)
- Change in annual $PM_{2.5}$ (2031-DSC minus 2031-DM) at a height of 10 metres
- Change in annual $PM_{2.5}$ (2031-DSC minus 2031-DM) at a height of 30 metres

Background concentrations were not taken into account as these could not be quantified at elevated locations. For the same reason, only the changes in the $PM_{2.5}$ concentration are presented in the report.

10.5 Existing environment

This section describes the existing environment and conditions in the study area, including:

- A description of the terrain and land use in the study area
- The meteorology (weather patterns) in the study area
- Consideration of historical trends in road traffic emissions
- The historical and current air quality environment in the study area
- The meteorological inputs for the operational air quality assessment
- The background concentrations for the operational air quality assessment.

10.5.1 Terrain and land use

The topography of the land in an area plays an important role in the dispersion of air pollutants. It steers winds, generates turbulence and large scale eddies (a current of air moving in a different direction that the main current), and generates drainage flows at night (when air cools and flows downslope) and upslope flows during the day (as a result of surface heating).

Terrain data for Sydney was obtained from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) website. The terrain within the study area is predominantly flat, but increases in elevation to the north of the Five Dock Bay area towards the Hills District and to the south towards the Sutherland Shire and adjoining parkland.

The terrain along the project corridor rises from an elevation of around 41 metres Australian Height Datum (AHD) at the western end to an elevation of around seven metres AHD at Kogarah and 10 metres AHD at St Peters, at the eastern end.

Land use within the New M5 GRAL domain consists primarily of urban areas, with pockets of recreational reserves and waterbodies including Wolli Creek and the Alexandra Canal.

The uniformity of the terrain, and the lack of major obstacles to wind flow, supports good dispersion and air flow throughout the study area.

10.5.2 Climate

Table 10-17 and **Table 10-18** present the 20-year temperature and rainfall data for the two closest Bureau of Meteorology (BoM) sites, located at Sydney Olympic Park (Archery Centre) (site number 066195) and the Canterbury Racecourse (site number 066194). Monthly averages of maximum and minimum temperatures are presented, as well as rainfall data consisting of mean monthly rainfall and the average number of rain days per month.

Table 10-17 Climate averages for Sydney Olympic Park

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean daily maximum temperature (ºC)												
28.4	28.1	26.6	23.9	20.8	18.3	17.6	19.5	22.5	24.3	25.3	27.4	23.6
Mean daily minimum temperature (ºC)												
19.3	19.4	17.8	14.3	11.2	8.9	7.8	8.7	11.6	13.7	15.8	17.9	13.9
Mean monthly rainfall (mm)												
84.4	109.8	66.0	89.2	88.2	75.8	63.5	56.7	52.7	64.9	76.2	58.0	884.0
Mean rain days per month (number)												
7.6	7.7	7.6	6.9	7.7	6.9	6.3	4.4	5.5	7.1	7.8	6.8	82.3

Source: BoM (2015b) Climate averages for Station: 066195; Commenced: 1995 – last record 2015; Latitude: 33.85°S; Longitude: 151.06 °E

Table 10-18 Climate averages for Canterbury Racecourse

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean daily maximum temperature (ºC)												
27.6	27.2	25.9	23.3	20.5	18.1	17.5	19.0	22.1	23.4	24.6	26.3	23.0
Mean daily minimum temperature (ºC)												
18.3	18.3	16.4	12.7	9.3	7.1	5.8	6.5	9.5	12.0	14.8	16.8	12.3
Mean monthly rainfall (mm)												
76.0	103.6	73.3	113.4	84.9	98.8	57.8	63.3	45.7	62.4	81.4	64.7	927.8
Mean rain days per month (number)												
7.6	7.8	7.5	7.8	7.1	8.9	6.7	5.1	4.7	6.2	8.3	6.8	84.5

Source: BoM (2015c) Climate averages for Station: 066194; Commenced: 1995 – last record 2015; Latitude: 33.91°S; Longitude: 151.11 °E

The annual average maximum and minimum temperatures recorded at the Sydney Olympic Park station are 23.6 degrees and 13.9 degrees respectively and 23.2 degrees and 12.3 degrees at Canterbury Racecourse respectively. On average, January is the hottest month, with average maximum temperatures of 28.4 degrees and 27.6 degrees at Olympic Park and Canterbury, respectively. July is the coldest month at both stations, with average minimum temperatures of 7.8 degrees and 5.8 degrees, at Olympic Park and Canterbury respectively.

Rainfall data collected at the Sydney Olympic Park station shows that February is the wettest month, with an average rainfall of about 110 millimetres over an average of eight rain days. The average annual rainfall is 884 millimetres over an average of about 82 rain days per year. Rainfall data from the Canterbury site shows the wettest month on average occurring in April, with about 113 millimetres falling over eight rain days. The average annual rainfall is slightly higher, at about 928 millimetres over an average of about 85 rain days per year.

10.5.3 Meteorology

Several meteorological stations in the study area were considered, and their locations are shown in **Figure 10-7**. Data relevant to the dispersion modelling such as wind speed, wind direction, temperature and cloud cover was obtained for the following locations:

- NSW Office of Environment and Heritage (OEH) meteorological stations:
  - Chullora
  - Earlwood
  - Rozelle
- BoM meteorological stations:
  - Canterbury Racecourse Automatic Weather Station (AWS) (site number 066194)
  - Fort Denison (site number 066022)
  - Sydney Airport Allied Meteorological Office (AMO) (site number 066037)
  - Sydney Olympic Park AWS (site number 066195)
  - Sydney Olympic Park AWS (Archery Centre) (site number 066212).

An analysis of the data required as input for GRAMM was carried out to examine the availability and validity of the data from these meteorological stations. Data recovery, wind speed, wind direction, temperature and relative humidity information for years 2009 to 2014 was analysed, where available, for each of the abovementioned sites. A minimum of five years of data was used for the analysis in line with the requirements of determining site-representative data outlined in the Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (DEC, 2005b). It is noted that the OEH Randwick site is also located within the model domain. However, as it would be less than 500 metres away from the western edge of the domain, it was not considered for inclusion in the model due to potential model boundary effects, which could skew the wind fields at this location.

Appendix H (Meteorological model evaluation) of the Technical working paper: Air quality in **Appendix H** provides a summary of the annual data recovery, average wind speed and percentage of calms (wind speeds less than 0.5 metres per second) for each of the selected meteorological stations from 2009 to 2014. The table shows a generally high percentage of data recovery at each site over the last six years which is consistent with the data requirements in the Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (DEC, 2005b). There was a high level of consistency in the annual average wind speed and annual percentage of calms across the years within each meteorological station database. Wind speed conditions, including episodes of calm conditions, have remained relatively consistent over the period.

Annual and seasonal wind roses for all six years and for all sites were used to analyse the general wind patterns across the modelling domain. These are presented in **Appendix H**. The wind roses showed very similar wind patterns for all six years at each individual site. The dominant wind patterns are predominantly from the northwest and southeast directions. The seasonal patterns are also very similar between each site.

Based on the analysis of the available meteorological data within the GRAMM modelling domain presented in **Appendix H**, data from the BoM Canterbury Racecourse AWS meteorological station were chosen as the input to GRAMM for modelling. The site was considered to be representative of the meteorology in the domain.

Analysis of the Canterbury Racecourse data showed that the wind speed and direction patterns for the past six years (2009 to 2014) were consistent from year to year, and as detailed in Appendix H (Meteorological Data and Evaluation) of the Technical working paper: Air quality in **Appendix H** of this EIS. Other sites also showed consistencies, but the Canterbury Racecourse AWS site was the most centrally located with respect to WestConnex. The analysis of six years of data also showed that 2014, the most recent year available, was representative of longer term weather conditions. The selection of the 2014 meteorological data was consistent with the use of 2014 measured ambient air quality data to define background concentrations for the assessment.

Figure 10-8 to **Figure 10-11** show the annual and diurnal plots of wind speed and temperature from the Canterbury Racecourse site for 2014. The annual plots show a typical distribution of wind speed and temperature over the course of a year. The diurnal plots also show typical patterns, with higher wind speeds and temperatures during the day, decreasing at night and in the early morning.

Having determined that 2014 was a representative year, the data were then used to run the meteorological model (GRAMM) to determine three-dimensional wind fields across the modelling domain. Wind speed and direction values were extracted at each of the meteorological stations shown in **Figure 10-7** and some statistical analysis was carried out to compare these extracted (predicted) data with the observations at each of those sites. This process is discussed further in **Appendix H**.

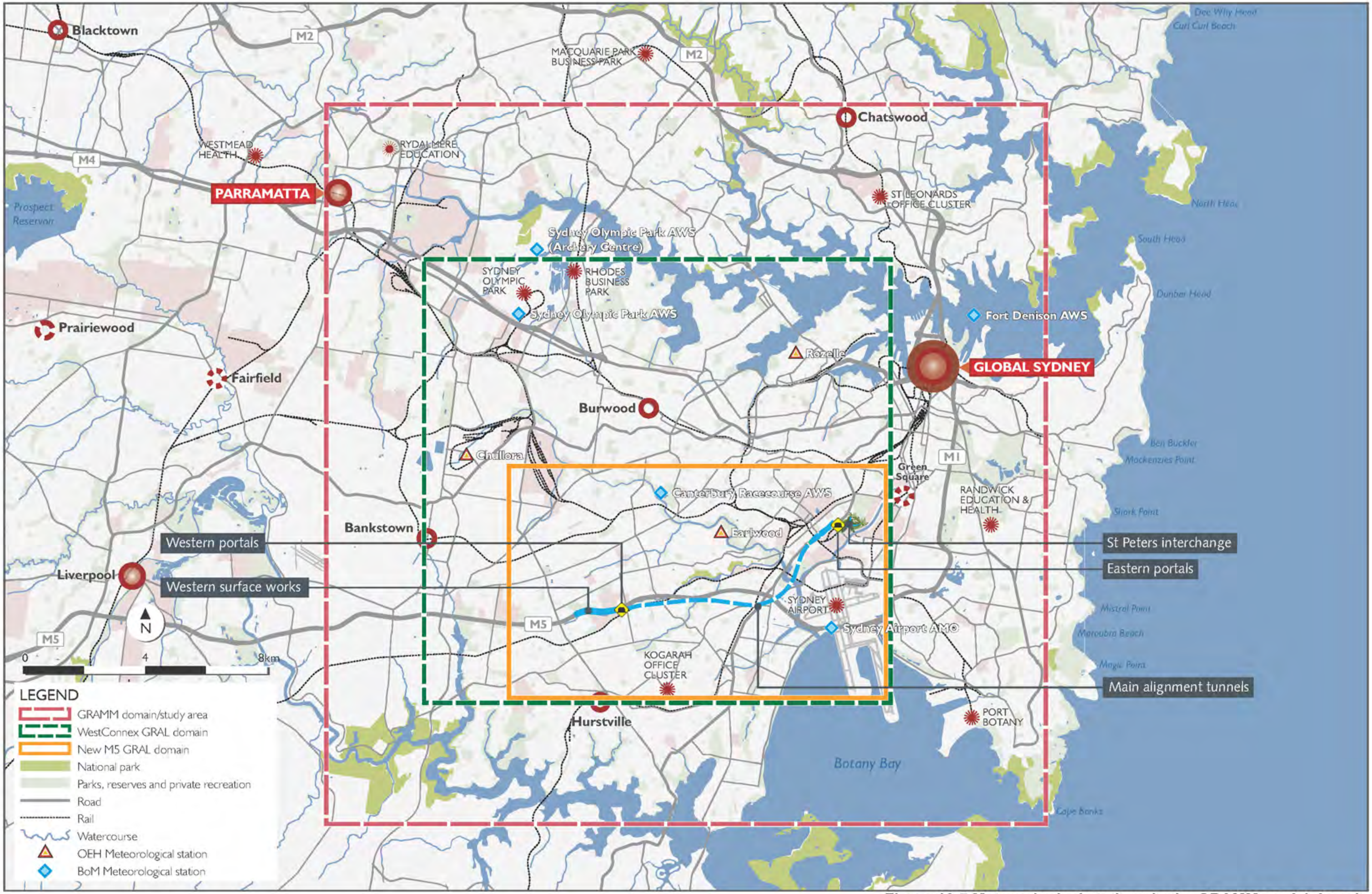

Figure 10-7 Meteorological stations in the GRAMM model domain

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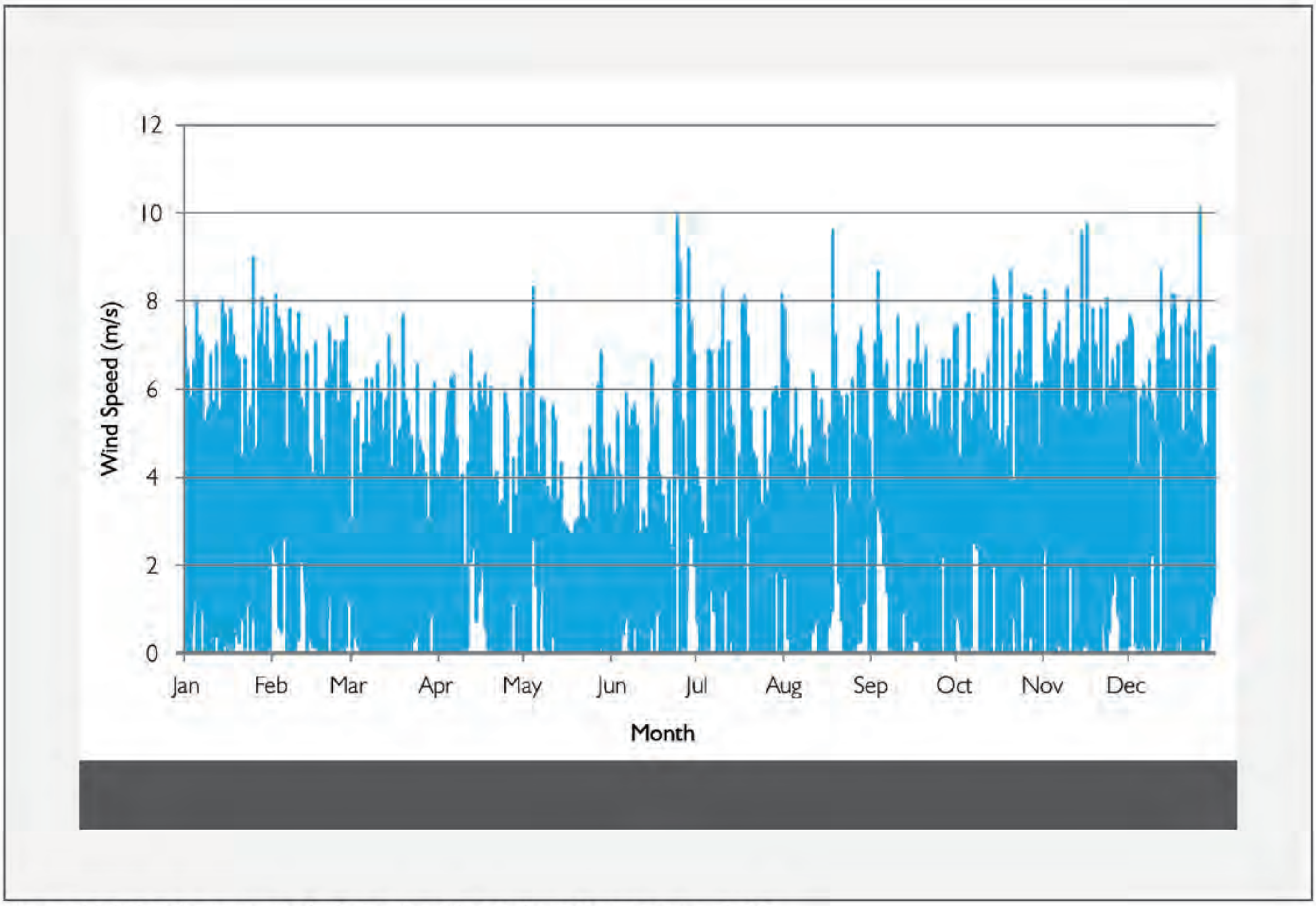

Figure 10-8 Hourly average wind speeds at Canterbury Racecourse - 2014

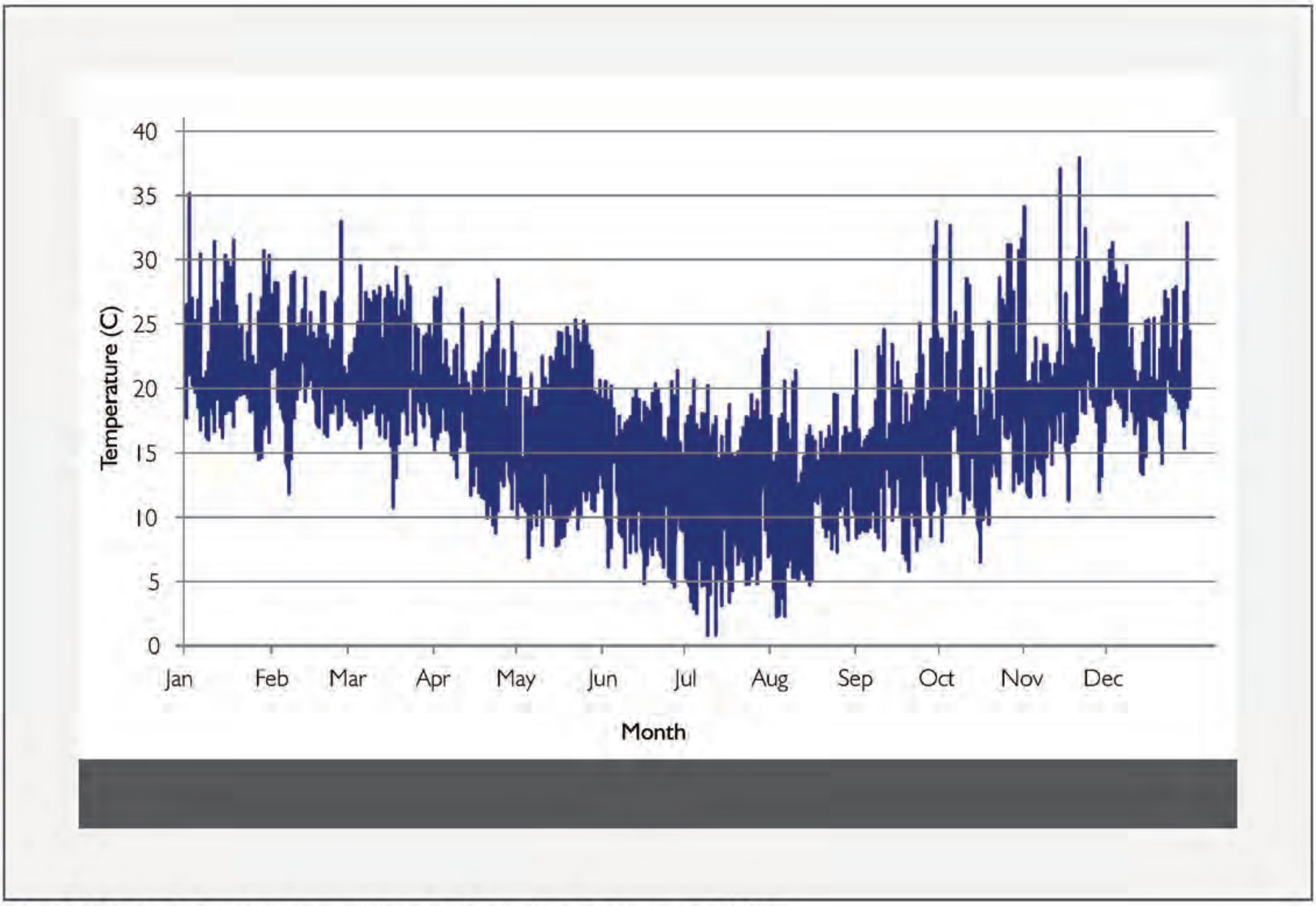

Figure 10-9 Hourly average temperatures at Canterbury Racecourse - 2014

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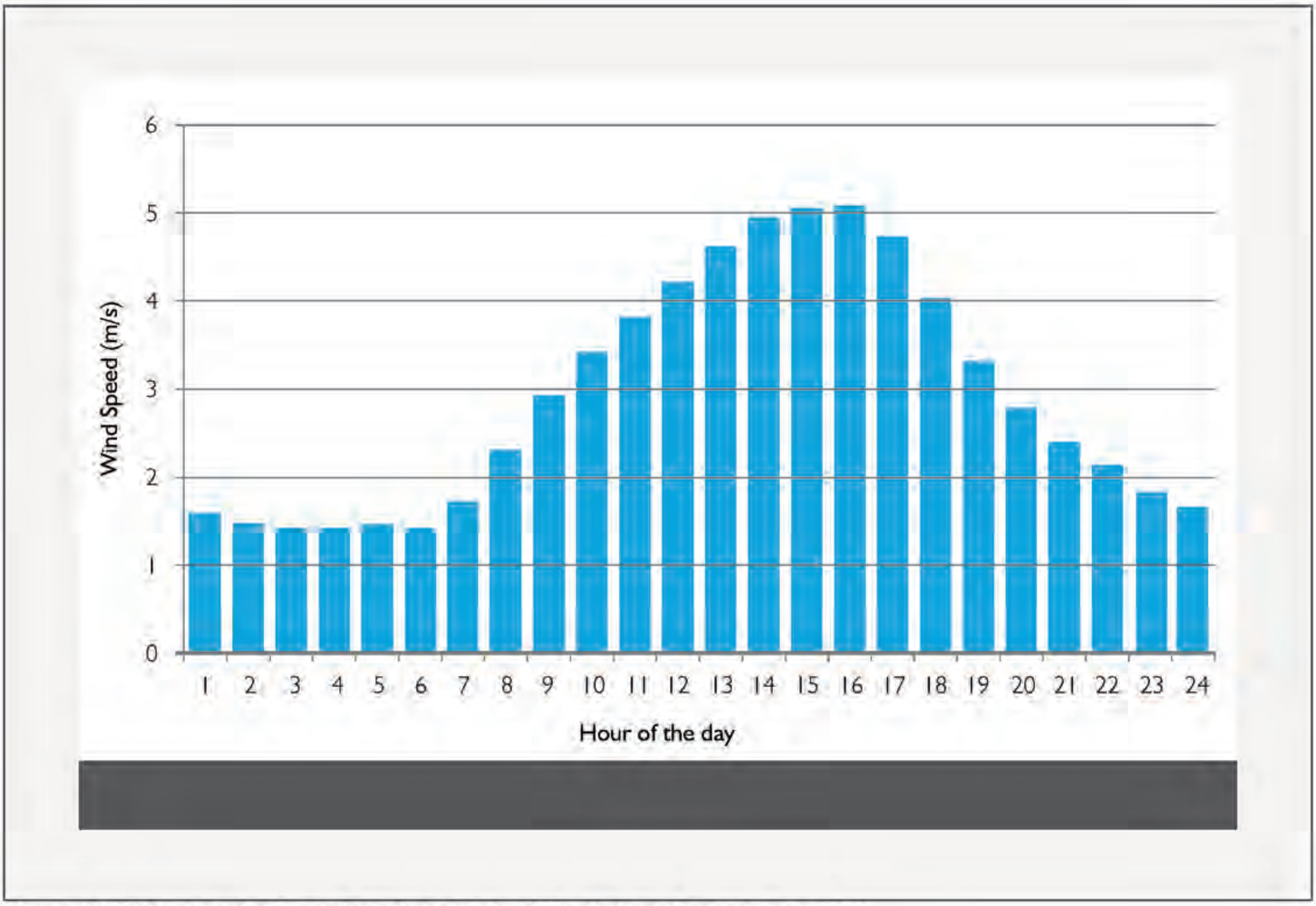

Figure 10-10 Average wind speeds by hour of day at Canterbury Racecourse - 2014

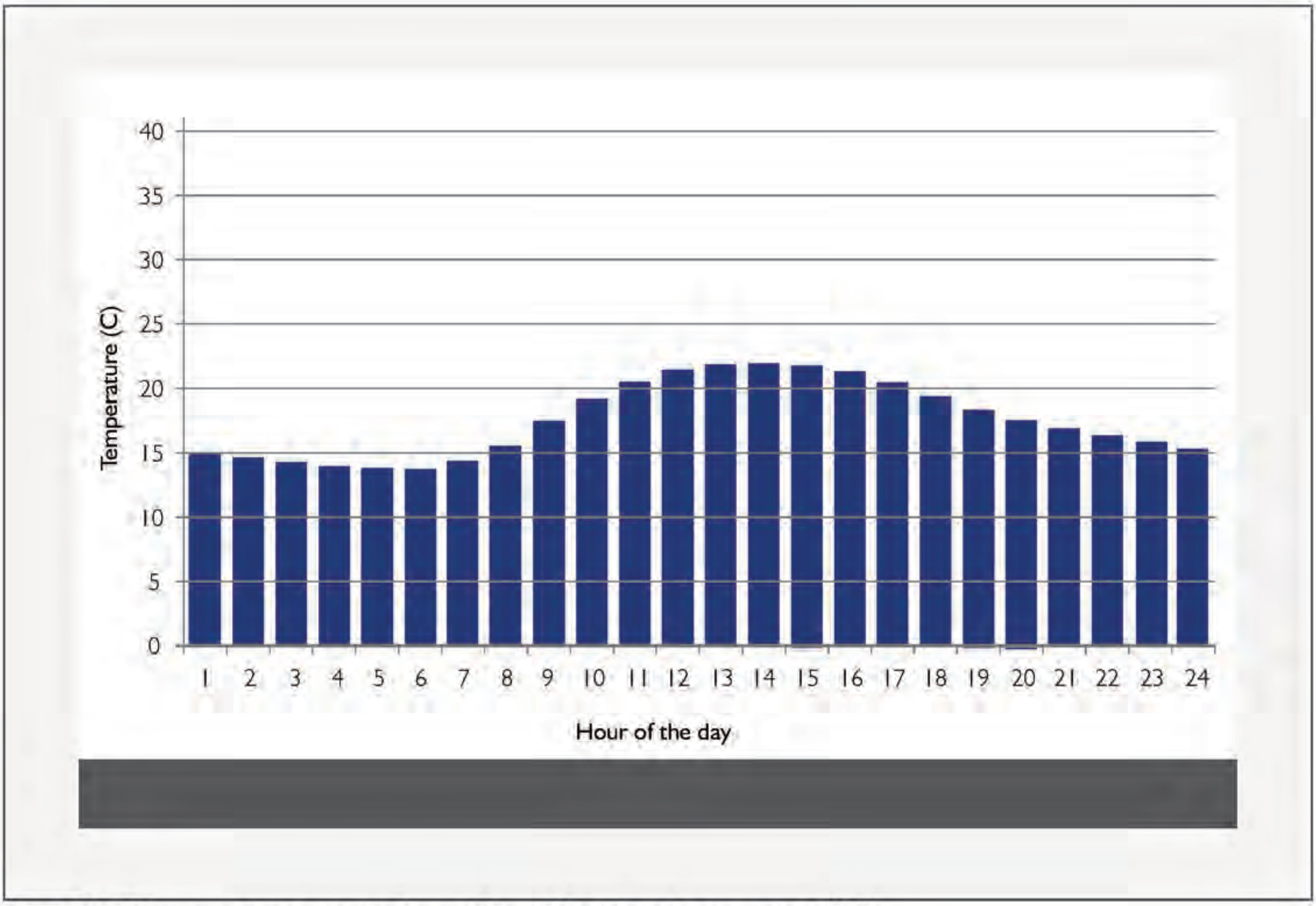

Figure 10-11 Average temperatures by hour of day at Canterbury Racecourse - 2014

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10.5.4 Emissions

Calculations have established that exhaust emissions of some pollutants from road transport have decreased over time as vehicle emissions legislation has tightened, and are predicted to continue to decrease in the future (Bureau of Infrastructure, Transport and Regional Economics (BITRE), 2010). However, over the longer term, it is anticipated that emission levels will start to rise again as increases in annual vehicle activity (associated with the projected population growth in Sydney) begin to offset the reductions achieved by the current emission standards and vehicle technologies (Department of Infrastructure and Transport (DIT), 2012).

The most detailed and comprehensive source of information on current and future emissions in the Sydney area is the emissions inventory compiled by the NSW EPA. An emissions inventory defines the amount (in tonnes per year) of each pollutant that is emitted from each source in a given area. The base year of the latest published NSW EPA inventory is 2008 (EPA, 2012a), and projections are available for 2011, 2016, 2021, 2026, 2031 and 2036. The importance of road transport as a source of pollution in Sydney can be illustrated by reference to sectoral emissions. The data for anthropogenic (caused by humans) and biogenic (caused by plants and animals) emissions in Sydney, and also for road transport in Sydney, was extracted from the latest NSW EPA inventory. Emissions were considered for the most recent historical year (2011) and for the future years.

Sectoral emissions

Figure 10-12 shows that in 2011, road transport in Sydney was the largest sectoral contributor to emissions of CO (44 per cent) and NO_X (57 per cent). Road transport was also responsible for a significant proportion of emissions of volatile organic compounds (VOCs) (17 per cent), PM_{10} (10 per cent) and $PM_{2.5}$ (12 per cent). The main contributors to VOCs were domestic and commercial activity and biogenic sources such as volatile oils from vegetation. The most important sources of PM_{10} and $PM_{2.5}$ emissions were the domestic and commercial sector, and industry. The contribution to particulate matter from the domestic sector in Sydney was largely due to wood burning for heating in winter. Emissions from natural sources, such as bushfires, dust storms and marine aerosol, also contributed significantly to particulate matter concentrations. Road transport contributed only two per cent of total SO_2 emissions in Sydney, reflecting the reduction in sulfur in road transport fuels in recent years. SO_2 emissions in Sydney were dominated by the off-road mobile sector and industry.

The projections of sectoral emissions shown in **Figure 10-14** demonstrate that the contribution of road transport CO, VOCs and NO_X emissions are forecast to decrease substantially between 2011 and 2036 as a result of improvements in emission control technology. For PM_{10}, $PM_{2.5}$ and $SO_{2,}$ the contribution from the road transport sector will also decrease, but their smaller contributions mean that these reductions will have only a minor impact on total emissions.

Road transport sector emissions

The breakdown of emissions in 2011 from the road transport sector by process and vehicle type is presented in **Figure 10-13**. Petrol passenger vehicles (mainly cars) accounted for a large proportion of the vehicle kilometres travelled (VKT) in Sydney. Diesel passenger vehicles have represented only a very small proportion of the total passenger vehicle fleet. However, the improved performance of light-duty diesel vehicles over the last 10 years, together with superior fuel economy, has boosted sales and the market share is increasing (EPA, 2012b). Exhaust emissions from these vehicles were responsible for 62 per cent of CO from road transport in Sydney in 2011, 45 per cent of NO_x and 76 per cent of SO_2. They were a minor source of PM_{10} (around four per cent) and $PM_{2.5}$ (around nine per cent). Non-exhaust processes were the largest source of road transport PM_{10} (around 60 per cent) and $PM_{2.5}$ (around 46 per cent). This is a larger proportion than in most European countries, as there are relatively few diesel cars in Australia. Heavy-duty diesel vehicles are disproportionate contributors of NO_x and particulate matter emissions due to their inherent combustion characteristics, high operating mass (and hence high fuel usage) and level of emission control technology (NSW EPA, 2012b).

The projections of road transport sector emissions are broken down by process and vehicle group in **Figure 10-15**. Substantial reductions in emissions of CO, VOCs, and NO_X are projected between 2011 and 2036. There will be smaller changes in emissions of PM_{10} and $PM_{2.5}$. SO_2 emissions are proportional to fuel sulfur content, and this is assumed to remain constant in the inventory.

The inventory also records emissions of specific organic compounds, based on speciation profiles of petrol and diesel fuels.

Projected emissions for sectoral and road transport emissions in Sydney from 2011 to 2036 are shown in **Figure 10-14** and **Figure 10-15**.

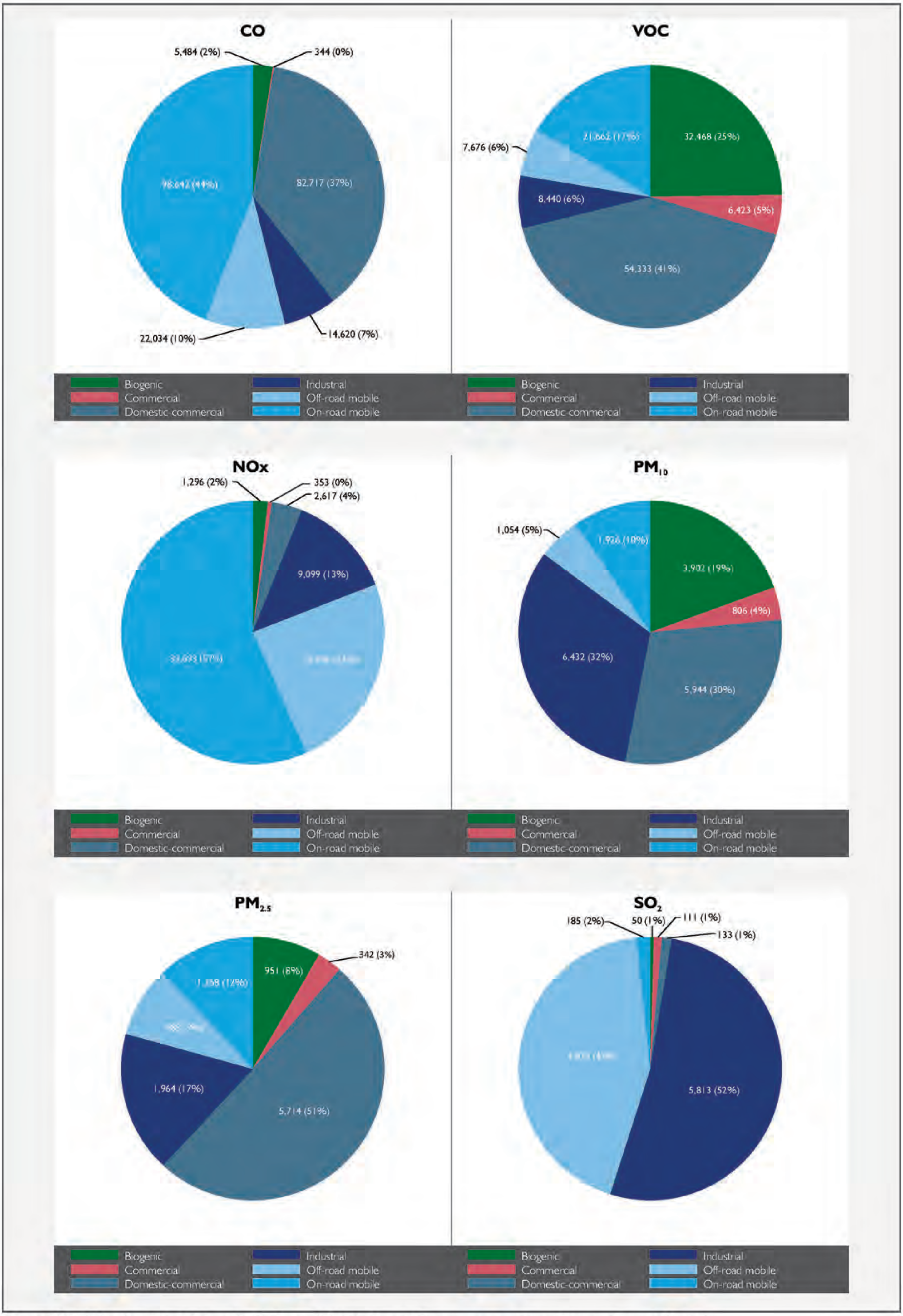

Figure 10-12 Sectoral emissions in Sydney, 2011 (values in tonnes per year and percentage of total)

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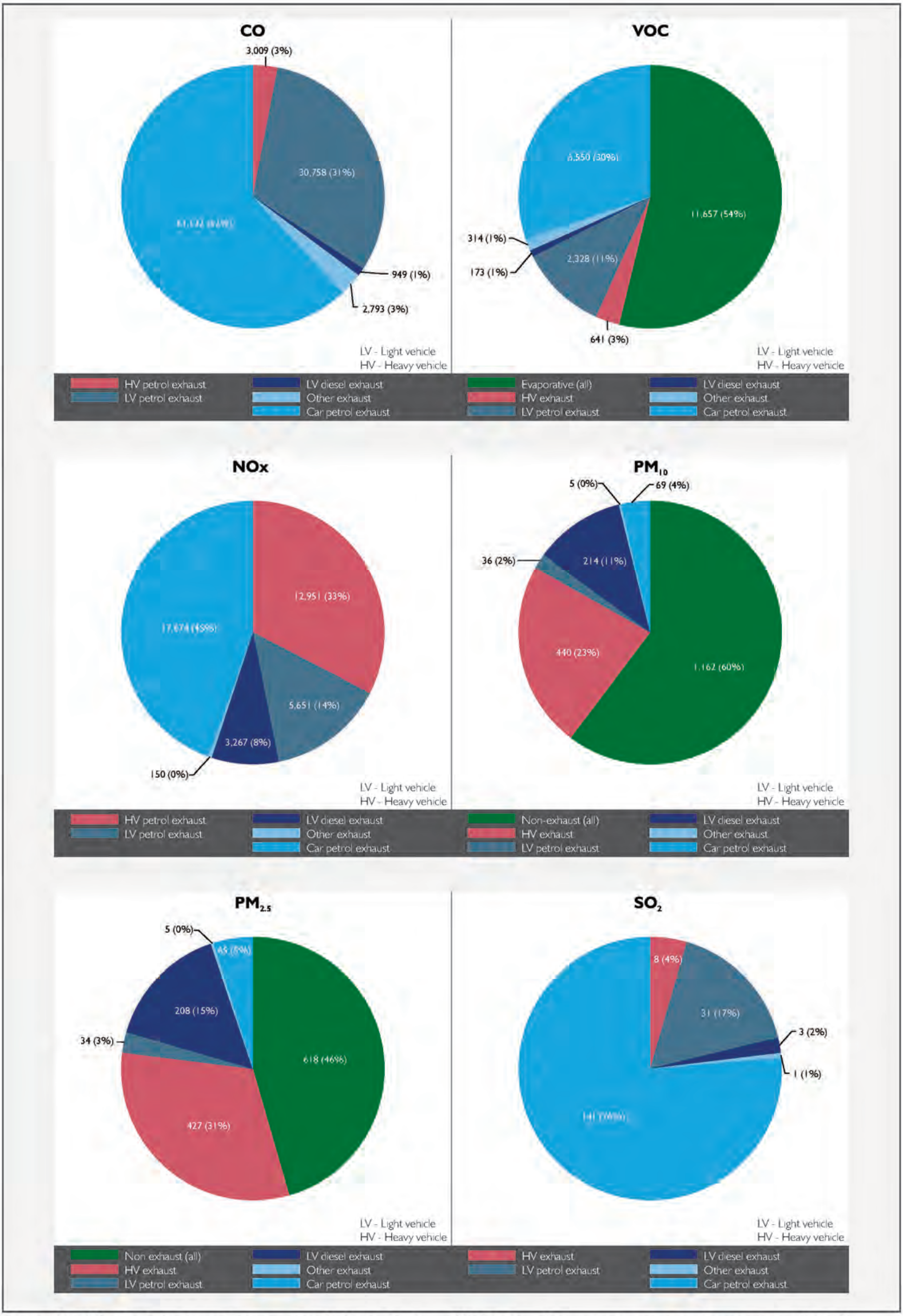

Figure 10-13 Breakdown of road transport emissions - Sydney, 2011 (values in tonnes per year and percentage of total)

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Figure 10-14 Future projections of sectoral emissions - Sydney, 2011 - 2036

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Figure 10-15 Future projections of road transport emissions - Sydney, 2011 - 2036

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10.5.5 General characteristics of Sydney air quality

Air quality in the Sydney region has improved over the last few decades. The improvements have been attributed to initiatives to reduce emissions from industry, motor vehicles, businesses and residences.

Historically, elevated levels of CO were generally only encountered near busy roads, but concentrations have fallen as a result of improvements in motor vehicle technology. Since the introduction of unleaded petrol and catalytic converters in 1985, peak CO concentrations in central Sydney have significantly decreased, and the last exceedance of the air quality standard for CO in NSW was recorded in 1998 (NSW Department of Environment, Climate Change and Water (DECCW), 2009 and 2010).

While levels of NO_2, SO_2 and CO continue to be below national standards, levels of ozone and particulate matter (PM_{10} and $PM_{2.5}$) sometimes exceed the standards.

Ozone and particulate matter concentrations are affected by:

- The annual variability in the weather
- Natural events such as bushfires and dust storms, as well as hazard-reduction burns
- The location and intensity of local emission sources, such as wood heaters, transport and industry (OEH, 2015a).

10.5.6 Data from existing monitoring sites in the study area

A detailed analysis of historical trends (2004−2014) and the current state of Sydney's air quality is provided in Appendix F of the Technical working paper: Air quality in **Appendix H**. The analysis was based on data from multiple long-term monitoring stations operated by OEH and Roads and Maritime, as well as from monitoring stations established more recently and specifically for the project. The data from the monitoring sites were also used to identify appropriate background concentrations of pollutants for the project assessment.

The data for specific air quality metrics during the period 2004−2014 can be summarised as follows:

- Maximum one-hour and rolling eight-hour mean CO concentrations
  - All maximum CO values were well below the air quality criteria of 30 mg/m^3 (one-hour) and 10 mg/m^3 (eight-hour)
  - There was a general downward trend in concentrations, but it was not statistically significant at any site
- Annual mean NO_2 concentrations
  - Concentrations of NO_2 at all sites were well below the NSW air quality criterion of 62 µg/m^3. Values at the OEH monitoring sites exhibited a systematic, and generally significant, downward trend. However, in recent years the concentrations at some sites appear to have stabilised. At the Roads and Maritime monitoring sites there was no significant downward trend
  - The average NO_2 concentrations at the roadside monitoring sites were 34-37 µg/m^3, and therefore around 10-15 µg/m^3 higher than those at monitoring sites away from roads. Even so, the NO_2 concentrations at roadside monitoring sites were also well below the assessment criterion
- Maximum one-hour NO_2 concentrations
  - Although variable, maximum NO_2 concentrations have remained largely stable over time and the values at all monitoring sites continue to be below the NSW air quality criterion of 246 µg/m^3
  - The maximum one-hour mean NO_2 concentrations at the Roads and Maritime roadside monitoring sites in 2014 were 115 µg/m^3 and 122 µg/m^3 respectively. These values are similar to the higher maximum values recorded at monitoring sites away from roads

- Annual mean PM_{10} concentrations
  - Concentrations at the OEH monitoring sites showed a downward trend between 2004 and 2014, but this was only statistically significant at two sites. In recent years the annual mean concentration at the OEH sites has been between 17 µg/m^3 and 20 µg/m^3, except at Lindfield where the concentration is substantially lower (around 14 µg/m^3). The concentration at the Roads and Maritime background monitoring sites appears to have stabilised at around 15 µg/m^3. These values can be compared with an air quality criterion of 30 µg/m^3
- Maximum 24-hour PM_{10} concentrations
  - Maximum 24-hour PM_{10} concentrations exhibited a slight downward trend, but there was significant variability in data from year to year. In 2014 the concentrations at the various monitoring sites were around 40 µg/m^3, but the large between-site variation in recent years suggests that this clustering would be unlikely to continue into the future
- Annual mean $PM_{2.5}$ concentrations
  - $PM_{2.5}$ is only measured at three OEH monitoring sites in the study area. Concentrations at the two OEH sites closest to the project – Chullora and Earlwood − showed a broadly similar pattern, with a systematic reduction between 2004 and 2012 being followed by a substantial increase between 2012 and 2014. The main reason for the increase was a change in the measurement method, which indicated that background $PM_{2.5}$ concentrations in the study area during 2014 were already very close to, or above, the advisory reporting standard in the AAQ NEPM of 8 µg/m^3
- Maximum 24-hour $PM_{2.5}$ concentrations
  - There has been no systematic trend in the maximum 24-hour $PM_{2.5}$ concentration based on data from OEH and Roads and Maritime monitoring stations. As with the annual mean $PM_{2.5}$ concentration, the maximum one-hour concentrations are very close to, or above, the advisory reporting standard in the AAQ NEPM of 25 µg/m^3.

10.5.7 Project-specific monitoring

There are seven air quality monitoring stations in the New M5 GRAL domain to support the development and assessment of the project. The monitoring stations were designed to supplement the existing OEH and Roads and Maritime stations, to establish the representativeness of the data from these sites, and to provide long-term air quality data in the vicinity of the project. The locations of the monitoring stations were determined with consideration given to a number of criteria. Three stations are located at urban background sites and four stations are located to characterise population exposure near busy roads.

All monitoring stations are listed in **Table 10-19**. Further details are provided in Appendix F of the Technical working paper: Air quality in **Appendix H**.

Table 10-19 Air quality monitoring stations

Authority	Project	Location	Site type	Period covered
OEH	N/A	Southern Sydney TAFE, Worth Street, Chullora	Urban background	2004-2014
		Beaman Park, Earlwood	Urban background	2004-2014
		Bradfield Road, Lindfield	Urban background	2004-2014
		Rose Street, Liverpool	Urban background	2004-2014
		William Lawson Park, Prospect	Urban background	2004-2014
		Randwick Barracks, Randwick	Urban background	2004-2014
		Rozelle Hospital, Rozelle	Urban background	2004-2014
Roads and	M5 East	Gipps Street, Bardwell Valley	Urban	2008-2013

Authority	Project	Location	Site type	Period covered
Maritime	tunnel		background[(a)]	
		Thompson Street, Turrella	Urban background[(a)]	2008-2013
		Jackson Place, Undercliffe	Urban background[(a)]	2008-2013
		Wavell Parade, Earlwood	Urban background[(a)]	2008-2013
		Flat Rock Rd, Kingsgrove (M5 East Freeway)	Peak (roadside)[(b)]	2008-2013
		M5 East tunnel portal	Peak (roadside)[(b)]	2008-2013
	NorthConnex	Headen Sports Park	Urban background	Dec 2013 to Jan 2015
		Rainbow Farm Reserve	Urban background	Dec 2013 to Jan 2015
		James Park	Urban background	Dec 2013 to Jan 2015
		Observatory Park	Peak (roadside)	Dec 2013 to Jan 2015
		Brickpit Park	Peak (roadside)	Dec 2013 to Jan 2015
	Lane Cove Tunnel	Longueville Road/ Epping Road	Peak (roadside)	Oct 2008 to Nov 2009
Sydney Motorway Corporation	WestConnex M4 East	Wattle Street, Haberfield	Peak (roadside)	Aug 2014 to Apr 2015
		Edward Street, Concord	Peak (near-road)[(c)]	Sep 2014 to Apr 2015
		Bill Boyce Reserve, Homebush	Peak (near-road)[(c)]	Sep 2014 to Apr 2015
		Concord Oval, Concord	Peak (roadside)	Nov 2014 to Apr 2015
		St Lukes Park, Concord	Urban background	Nov 2014 to Apr 2015
	WestConnex New M5	St Peters Public School, Church St, St Peters	Urban Background	Aug 2015
		Princes Highway, St Peters	Peak (roadside)	Jul 2015 to Aug 2015
		West Botany St, Arncliffe	Peak (roadside)	Jul 2015 to Aug 2015
		Bestic St, Rockdale	Urban Background	Jul 2015 to Aug 2015
		Bexley Rd, Kingsgrove	Peak (roadside)	Jul 2015 to Aug 2015
		Beverley Hills Park, Beverley Hills	Urban Background	Jul 2015 to Aug 2015
		Canal Rd, St Peters	Peak (roadside / industrial)	Jul 2015 to Aug 2015

(a) These sites were established to characterise air quality in the vicinity of the M5 East tunnel ventilation outlets, but are effectively at urban background locations.
(b) These sites were established to characterise air quality in the vicinity of the M5 East tunnel portals.
(c) Due to practical constraints at this location, the monitoring site is some distance from the closest major road (M4 motorway). Nevertheless, the monitoring station should adequately characterise exposure to air pollution at nearby properties.

10.6 Assessment of air quality impacts during construction

An assessment of construction impacts on air quality was undertaken in accordance with the procedure described in **Section 10.1**. A risk based assessment is provided in the Technical working paper: Air quality in **Appendix H**. The following sections discuss the potential impacts on air quality during construction as identified through this assessment.

10.6.1 Significance of risks

For all construction activity, the aim is to prevent significant effects on receivers through the use of effective mitigation. Experience shows that this is normally possible. Hence the residual impacts will normally be 'not significant' (IAQM, 2014).

However, even with a rigorous Construction Air Quality Management Plan in place, it is not possible to guarantee that the dust mitigation measures will be effective all the time. There is the risk that nearby residences, commercial buildings, hotel, cafés and schools in the immediate vicinity of the construction zone might experience some occasional dust impacts. This does not imply that impacts are likely, or that if they did occur, that they would be frequent or persistent. Overall construction dust is unlikely to represent a serious ongoing problem. Any effects would be temporary and relatively short-lived, and would only arise during dry weather with the wind blowing towards a receiver at a time when dust is being generated and mitigation measures are not being fully effective. The likely scale of this would not normally be considered sufficient to change the conclusion that with mitigation the effects would be 'not significant'.

There are unlikely to be any construction projects of this magnitude occurring concurrently with this project in the immediate vicinity. As such, cumulative impacts due to dust from construction are unlikely.

10.7 Assessment of air quality impacts during Alexandria Landfill closure

10.7.1 Dust assessment

This section presents the results for the particulate matter concentrations and dust deposition rates predicted due to proposed activities as part of the landfill closure. The model predictions already incorporate dust mitigation measures including watering of unsealed haul routes, keeping travel routes moist for dozers and graders onsite and watering of exposed areas that are likely to be prone to wind erosion such as unseeded temporary stockpiles.

For the annual averages, model predictions were added to the background estimates listed in **Section 10.3.1** and the total cumulative concentrations are presented in Figure 8-5 to Figure 8-10 in the Technical working paper: Air quality in **Appendix H**.

The predicted concentrations due to the closure and remediation works are low and even when added to existing concentrations will remain below their relevant air quality criteria. The exceptions to this are annual average $PM_{2.5}$ and 24-hour average PM_{10} at a single receiver to the south of the landfill boundary (Figure 8-6 in the Technical working paper: Air quality in **Appendix H)**.

In the case of annual average $PM_{2.5}$, existing levels are already estimated to be at the criterion of 8 $\mu g/m^3$. The estimated contribution from the closure works at the nearest receivers is less than 0.5 $\mu g/m^3$ and is based on activities occurring across the entire site continuously, 24-hours per day every day of the year. This is considered an overestimation and would not happen in practice.

The other potential exceedance relates to cumulative 24-hour PM_{10} in the industrial area on the southern boundary. Again, this is unlikely to be an exceedance in reality. The maximum predicted 24-hour PM_{10} concentration due to operations at the landfill closure site is approximately 10-20 $\mu g/m^3$ in that area. To exceed the criterion, this modelled maximum would need to occur on the same day as the conservative background of 40 $\mu g/m^3$. This is considered conservative as the maximum prediction is based on all activities occurring at the maximum rate on all days of the year.

In terms of predicted off-site dust concentrations due to activities at the landfill closure site, it is unlikely that any further dust mitigation measures would be required, other than those already set out in the Landfill Closure Management Plan.

10.7.2 Odour assessment

This section provides the modelled results for the predicted odour concentrations as a result of activities as part of the proposed landfill closure works. The results presented in **Figure 10-16** show that the predicted 99th percentile odour concentrations at most of the nearest receivers are below 1 OU, the theoretical level of detection. For all but one of the off-site receivers, the NSW EPA odour criterion of 2 OU (99th percentile) would not be exceeded.

There is the chance of some industrial receivers at the southern boundary of the landfill site experiencing odour levels of up to 7 OU and therefore some occupants may experience occasional; odour annoyance. However, the modelling has assumed that large areas of the whole site would be exposed continuously which is unlikely to be the case. Daily cover would be applied to exposed areas as part of the odour management plan which would significantly reduce impacts to receivers near site.

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Figure 10-16 Predicted 99th percentile odour concentration due to landfill closure works – waste excavation and leachate management

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10.8 Assessment of air quality impacts during operation

10.8.1 In-tunnel air quality

Air quality is monitored continuously in all of Sydney's major road tunnels, with monitors installed along the length of each tunnel. These typically measure CO and visibility, and are specially designed for use in road tunnels where access for routine essential maintenance is restricted by the need to minimise traffic disruption. While these instruments typically only have a coarse resolution, more precise instrumentation has been installed in the ventilation outlets of some tunnels, with measurements including PM_{10}, $PM_{2.5}$, NO_X and NO_2. Some of the data from these instruments are available on the web sites of the tunnel operators of the Lane Cove and Cross City Tunnels. Measurements from those tunnels were used to inform the air quality assessment for this project.

In-tunnel traffic, airflow, vehicle emissions concentrations and tunnel air temperature for the project and for the future M4–M5 Link were modelled using the IDA Tunnel software. The data used in the tunnel ventilation simulation, and the results of the simulation, are provided in full in Appendix L of the Technical working paper: Air quality in **Appendix H**.

The three pollutants assessed for in-tunnel air quality were NO_2, CO and $PM_{2.5}$ (exhaust only, as visibility). For the operating years of the project, NO_2 will be the pollutant that determines the required airflow and drives the design of ventilation for in-tunnel pollution. The NSW Department of Planning and Environment issued a report that included discussion on this topic for the NorthConnex project in January 2015. From the Secretary's Environmental Assessment Report for the NorthConnex project:

> *"The Department considers that nitrogen dioxide (NO_2) is now the key pollutant of concern for in-tunnel air quality. While carbon monoxide has historically been the basis for in-tunnel criteria in NSW and internationally, improvements in modern vehicle technology mean that NorthConnex will comply with existing health based carbon monoxide standards. By contrast, vehicle emissions of NO_2 have fallen less quickly, and uptake of diesel vehicles (which produce more NO_2 than petrol based vehicles) has risen……..Accordingly, it is recommended that the Proponent's design criteria for NO_2 of 0.5 ppm (averaged over 15 minutes) be applied as an average across the tunnel under all operating conditions."*

Because most urban road tunnels, including WestConnex, have portals higher than the general tunnel, pollutant generation is higher when climbing toward the exit, biasing the exposure towards the end of the tunnel trip. This means that the average level is somewhat less than half the peak level near the exit. With an average NO_2 limit of 0.5 ppm, a peak limit of 1.0 ppm is used, acknowledging that it will generally be slightly conservative.

The results for the 2021-DS, 2031-DS and 2031-DSC scenarios are presented in **Figure 10-17**. These plots, which show the diurnal change in the peak in-tunnel value, confirm that the tunnel ventilation system would be designed to maintain in-tunnel air quality well within operational limits.

The maximum in-tunnel concentrations across all time periods for the expected traffic scenarios, the capacity traffic scenarios and the worst case regulatory assessment are presented in **Table 10-20**. The maximum concentrations for all traffic scenarios, including worst-case conditions, were within the concentrations associated with the regulatory worst case.

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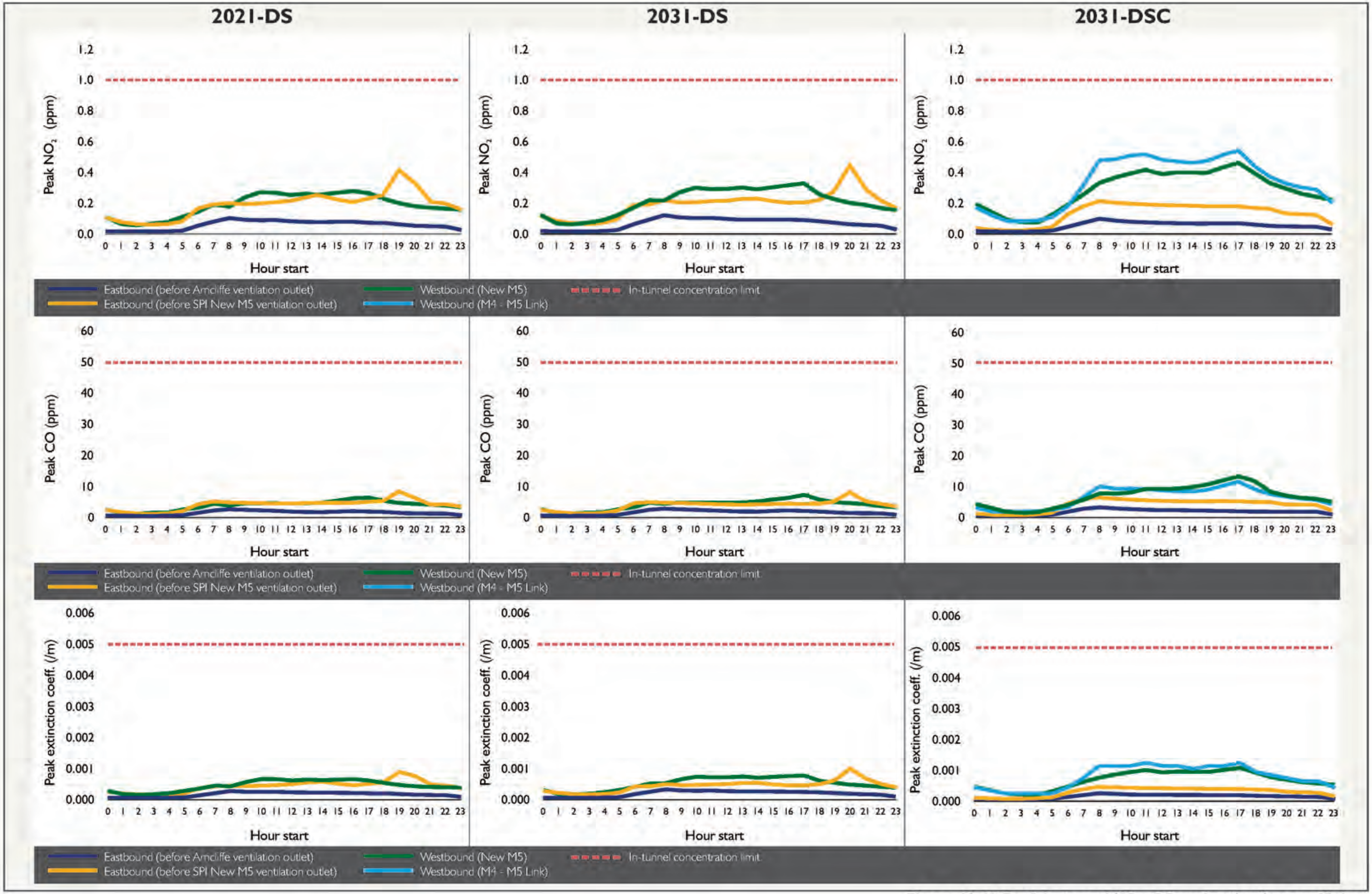

Figure 10-17 Peak in-tunnel NO_2, CO and extinction coefficient

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Table 10-20 Maximum in-tunnel concentrations for all scenarios

Scenario		Maximum in-tunnel concentration					
		NO_2 (ppm)[b]		CO (ppm)[c]		$PM_{2.5}$ (mg/m^3)	
		East-bound	West-bound	East-bound	West-bound	East-bound	West-bound
Expected traffic	2021-DS	0.41	0.27	7.99	5.99	0.42	0.38
	2031-DS	0.46	0.32	8.33	6.87	0.5	0.47
	2031-DSC	0.38	0.53	7.15	12.97	0.53	0.8
Capacity traffic	2021-DS	n/a	n/a	n/a	n/a	n/a	n/a
	2031-DS	n/a	n/a	n/a	n/a	n/a	n/a
	2031-DSC	0.52	0.66	9.73	14.84	0.75	0.96
Regulatory worst case[a]		**1.07**	**1.07**	**35.0**	**35.0**	**1.1**	**1.1**

(a) CO and NO_2 volume concentrations estimated for a temperature of 25°C.

(b) 1 ppm NO_2 is equivalent to 2.03 mg/m^3

(c) 1 ppm CO is equivalent to 1.23 mg/m^3

10.8.2 Assessment of ambient air quality impacts

Surface roads

Comparing total vehicle emissions with and without the project has been used to assess the air quality impacts of the project at a regional level. Total emissions were calculated for all surface roads included in the WRTM for the WestConnex GRAL domain.

The emissions in the WestConnex GRAL domain, in tonnes per year, are shown in **Table 10-21** and the changes in emissions are shown in **Table 10-22**. For the pollutants NO_X and PM_{10}, the net effects of the project on total emissions in 2021 and 2031 were small. In the cumulative case for 2031 there would be an increase in emissions of NO_X and PM_{10} of around 1.6 and two per cent respectively. The effects of the project on emissions were similar to the projected reductions in emissions with time. For example, between 2014 and 2031, NO_X emissions without the project were projected to decrease by 55 per cent, which is similar to the decrease for the 2014 and 2031 NO_X emissions with the project.

Table 10-21 Total emissions in the WestConnex GRAL domain

Scenario code	Scenario description	Total VKT[a] per day (million vehicle-km)	Total emissions (tonnes/year)				
			CO	NO_x	PM_{10}	$PM_{2.5}$	THC
2014-BY	2014 - Base Year (existing conditions)	14.5	15,240	6,581	322	234	1,542
2021-DM	2021 - Do Minimum (no New M5)	15.7	9,025	4,068	278	182	934
2021-DS	2021 - Do Something (with New M5)	15.8	9,196	4,056	275	180	940
2031-DM	2031 - Do Minimum (no New M5)	17.6	6,102	2,963	288	179	598
2031-DS	2031 - Do Something (with New M5)	17.7	6,253	2,925	285	176	599
2031-DSC	2031 - Do Something Cumulative (with New M5 and future M4-M5 Link)	19.1	6,582	3,010	294	182	585

(a) VKT = vehicle kilometres travelled

Table 10-22 Changes in total emissions in the WestConnex model domain

Scenario comparison	Change in total emissions (per cent)				
	CO	NO_x	PM_{10}	$PM_{2.5}$	THC
Do Minimum (without project) scenarios					
2021-DM vs 2014-BY	-40.8	-38.2	-13.7	-22.4	-39.4
2031-DM vs 2014-BY	-60.0	-55.0	-10.4	-23.6	-61.2
Do Something (with project) scenarios					
2021-DS vs 2021-DM	+1.9	-0.3	-0.9	-0.8	+0.7
2031-DS vs 2031-DM	+2.5	-1.3	-1.0	-1.2	+0.3
2031-DSC vs 2031-DM	+7.9	+1.6	+2.0	+1.9	-2.2

Regional air quality can also be measured in terms of a change in the capacity for ozone production. The NSW EPA has recently developed a Tiered Procedure for Estimating Ground Level Ozone Impacts from Stationary Sources (ENVIRON, 2011). While this does not relate specifically to road projects, it gives an emission threshold for NO_X and VOCs of 90 tonnes / year for new sources, above which projects should proceed to a detailed modelling assessment for ozone. The changes in emissions associated with this project were well below this threshold.

For example, in 2021 there was a projected decrease in NO_X emissions for the assessed road network of around 12 tonnes per year. This value also equates to a tiny proportion of anthropogenic NO_X emissions in the Sydney airshed in 2016 (around 53,700 tonnes). It was therefore concluded that as well as being below the emission threshold for NO_X and VOCs of 90 tonnes/year for new sources, the regional impacts of the project would be negligible, and undetectable in ambient air quality measurements at background locations.

No emission modelling was required for the regulatory worst case scenarios, as the emissions from the ventilation outlets were simply determined by the outlet concentration limits.

New M5 tunnel ventilation outlets

The tunnel would be designed and operated to avoid emissions from the tunnel portals as far as practicable. Elevated ventilation outlets would be designed and constructed as described in **Chapter 5** (Project description) and **Chapter 6** (Construction works). Tunnel ventilation outlets are effective in dispersing emissions from tunnels using the momentum and buoyancy of the plume. A combination of the design height of the outlet and the amount of fresh air mixed with the contaminated air from a tunnel can be used to ensure appropriate dilution and compliance with local air quality standards.

The locations and heights of the New M5 (and future M4-M5 Link) ventilation outlets included in the assessment are given in **Table 10-23**.

Table 10-23 Ventilation outlet locations and heights

Tunnel project	Ventilation facility	Traffic direction	Ventilation outlet	Outlet location (MGA) X	Outlet location (MGA) Y	Ground elevation (metres) Z	Outlet height (metres AHD)
New M5	**A** (Kingsgrove)	WB	KIN-01	323916.00	6242795.00	23	30
	B (Arncliffe)	EB	ARN-01	329446.00	6243283.10	4.0	35
			ARN-02	329453.90	6243289.20	3.5	35
			ARN-03	329450.30	6243276.70	3.7	35
			ARN-04	329458.20	6243283.10	3.2	35
	C (St Peters, New M5)	EB	SPI-01	331340.00	6245650.00	5.3	20
			SPI-02	331346.00	6245655.00	5.2	20
			SPI-03	331334.00	6245656.00	5.1	20
			SPI-04	331340.30	6245661.90	5.4	20
New M5 and future M4-M5 Link	**A** (Kingsgrove)	WB	KIN-01	323916.00	6242795.00	23.0	30
	B (Arncliffe)	EB	ARN-01	329446.00	6243283.10	4.0	35
			ARN-02	329453.90	6243289.20	3.5	35
			ARN-03	329450.30	6243276.70	3.7	35
			ARN-04	329458.20	6243283.10	3.2	35
			ARN-05	329454.20	6243300.00	3.4	35
			ARN-06	329450.30	6243305.10	3.7	35
			ARN-07	329458.00	6243311.30	3.1	35
			ARN-08	329461.80	6243306.00	2.8	35
	C (St Peters, New M5)	EB	SPI-01	331340.00	6245650.00	5.3	20
			SPI-02	331346.00	6245655.00	5.2	20
			SPI-03	331334.00	6245656.00	5.1	20
			SPI-04	331340.30	6245661.90	5.4	20
	D (Southern Extension)	WB	SC-01	329025.00	6240855.00	5.0	20
			SC-02	329031.00	6240860.00	5.0	20
			SC-03	329037.00	6240865.00	5.0	20
			SC-04	329026.00	6240865.00	5.0	20
	E (St Peters, future M4-M5 Link)	WB	SPI-05	331894.00	6245838.00	11.0	20
			SPI-06	331900.00	6245843.00	11.0	20
			SPI-07	331889.00	6245843.00	11.0	20
			SPI-08	331895.00	6245848.00	11.0	20

Emissions from the traffic in the New M5 tunnel were calculated using the emission factors provided in the Permanent International Association of Road Congress (PIARC) *Road Tunnels: Vehicle Emissions and Air Demand for Ventilation* (PIARC, 2012).

Appendix 3, Section 3.1 of the PIARC guidance includes aggregated emission rates for Australian vehicles. These Australia-specific emission rates have recently been used for tunnel ventilation calculations in NSW and they were also used for this project. The three pollutants assessed for tunnel ventilation purposes were NO_2, CO and $PM_{2.5}$.

Some modifications were required to the emission rates of these pollutants for the purpose of dispersion modelling. These modifications involved the following:

- Converting the NO_2 emission rates to the NO_X emission rates required for dispersion modelling
- Estimating emissions of pollutants and metrics not included in the in-tunnel assessment (PM_{10} and THC).

The diurnal profiles of outlet emission rates for each scenario and ventilation outlet are given in Appendix I of the Technical working paper: Air quality in **Appendix H**. The diurnal profiles for the emission rates of CO, NO_X, PM_{10}, $PM_{2.5}$ and THC in the 2021-DS, 2031-DS and 2031-DSC scenarios are shown in **Figure 10-18** and **Figure 10-19**.

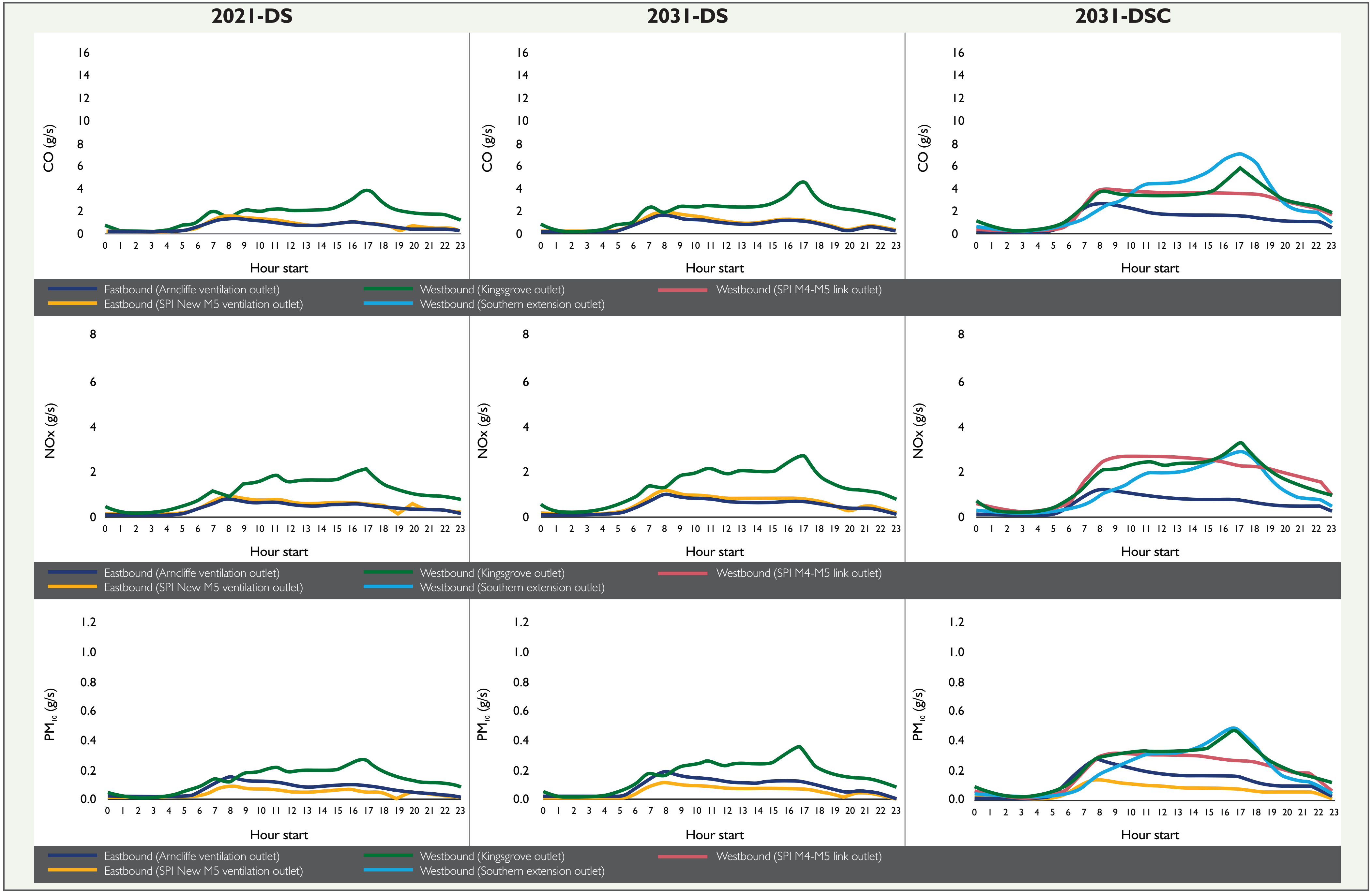

Figure 10-18 Emission rates for project ventilation outlets (CO, NOx and PM_{10})

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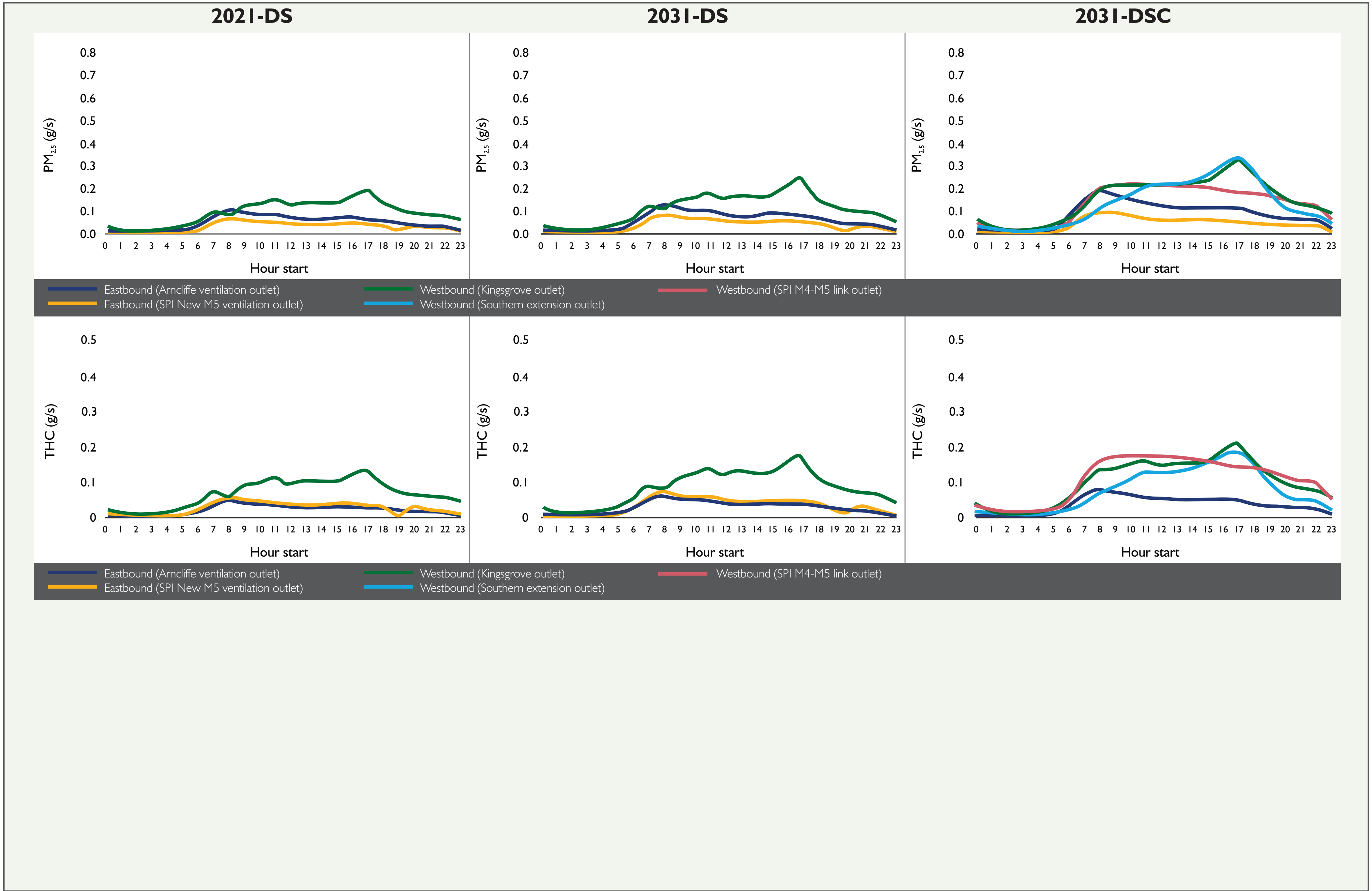

Figure 10-19 Emission rates for project ventilation outlets ($PM_{2.5}$ and THC)

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A summary of the results for the regulatory worst case scenario and expected traffic scenario for the 46,219 RWR receivers is presented in **Table 10-24**.

Table 10-24 Results of regulatory worst case assessment (RWR receivers)

Pollutant and period	Units	Maximum ventilation outlet contribution at any receiver				
		Regulatory worst case scenario		Expected traffic scenario		
		RWC-A	RWC-B	2021-DS	2031-DS	2031-DSC
CO (one hour)	(mg/m^3)	0.29	0.33	N/A[(a)]	N/A[(a)]	N/A[(a)]
NO_X (annual)	($\mu g/m^3$)	10.61	13.44	2.48	2.98	2.63
NO_X (1 hour)	($\mu g/m^3$)	146.43	173.34	92.51	120.17	43.45
NO_2 (annual)	($\mu g/m^3$)	1.70[(b)]	2.14[(b)]	0.57	0.75	0.61
NO_2 (1 hour)	($\mu g/m^3$)	23.43[(b)]	27.73[(b)]	14.80[(b)]	19.23[(b)]	6.95[(b)]
PM_{10} (annual)	($\mu g/m^3$)	0.58	0.74	0.11	0.11	0.31
PM_{10} (24 hour)	($\mu g/m^3$)	3.67	4.29	0.54	0.53	1.84
$PM_{2.5}$ (annual)[(c)]	($\mu g/m^3$)	0.58	0.74	0.08	0.07	0.22
$PM_{2.5}$ (24 hour)[(c)]	($\mu g/m^3$)	3.67	4.29	0.39	0.39	1.25
THC (one hour)	($\mu g/m^3$)	30.25	31.64	N/A[(a)]	N/A[(a)]	N/A[(a)]

(a) Not determined
(b) Estimated as 16% of NO_X.
(c) The same emission rates were used for PM_{10} and $PM_{2.5}$.

Emissions from the project ventilation outlets, even in the regulatory worst case scenarios, would be extremely unlikely to result in adverse impacts on local air quality. Roads and Maritime would conduct ambient air quality monitoring to demonstrate that emissions from the ventilation outlets will have no detectable impact on local air quality.

Existing M5 East tunnel ventilation outlet

The ventilation outlet for the M5 East Motorway tunnel was also included as it was within the New M5 GRAL domain. The location and height of the M5 East ventilation outlet is provided in **Table 10-25.**

Table 10-25 M5 East ventilation outlet location and height

Tunnel ventilation outlet	Outlet location (MGA)		Outlet height (m)
	x	y	
M5 East	328204.2	6244290.1	35

Emissions of NO_X, CO, PM_{10} and $PM_{2.5}$ from the M5 East tunnel were calculated using hourly in-stack concentration and air flow measurements for 2014 supplied by Roads and Maritime. Emission scaling factors for the future years (2021 and 2031) were developed using the NSW EPA emission model and typical tunnel traffic. The emission rates are summarised in **Table 10-26**. As with the project ventilation outlets, two separate source groups were defined to reflect different air flow regimes, and hourly 'modulation factors' (ratios relative to the average) were used in GRAL to replicate the variation in emissions within each time period. Seasonal variation in emissions was represented using monthly modulation factors.

Table 10-26 Emission rates: existing M5 East outlet

Year	Period (hour start)	Emission rate (kilograms per hour)			
		NO_X	CO	PM_{10}	$PM_{2.5}$
2014	Hours 00-05 and 22-23	6.31	32.89	0.14	0.07
	Hours 06-21	20.39	74.21	0.84	0.63
2021	Hours 00-05 and 22-23	3.52	22.13	0.10	0.04
	Hours 06-21	11.65	40.48	0.67	0.45
2031	Hours 00-05 and 22-23	2.41	18.08	0.10	0.04
	Hours 06-21	7.95	27.01	0.63	0.40

10.8.3 Carbon monoxide (maximum rolling eight-hour mean)

Results for community receivers

Figure 10-20 shows the maximum rolling eight-hour mean CO concentrations at community receivers with the project in 2021 and 2031. The maximum background value was combined with the maximum model prediction at each receiver. The background was therefore taken to be the same at all locations. As with the one-hour mean (refer to Section 9.5.1 of the Technical working paper: Air quality in **Appendix H**), at all the receivers the concentration was well below the NSW impact assessment criterion, which in this case is 10 $\mu g/m^3$.

The main contributor at these receivers in the 2021-‘Do something’ scenario was the background concentration (**Figure 10-21**). The surface road contribution ranged from eight per cent to 25 per cent, whereas the tunnel ventilation outlet contribution was less than one per cent.

Figure 10-22 shows that the change in the maximum rolling eight-hour CO concentration at all the community receivers was less than 0.4 mg/m^3. The largest increase was around 0.1 mg/m^3.

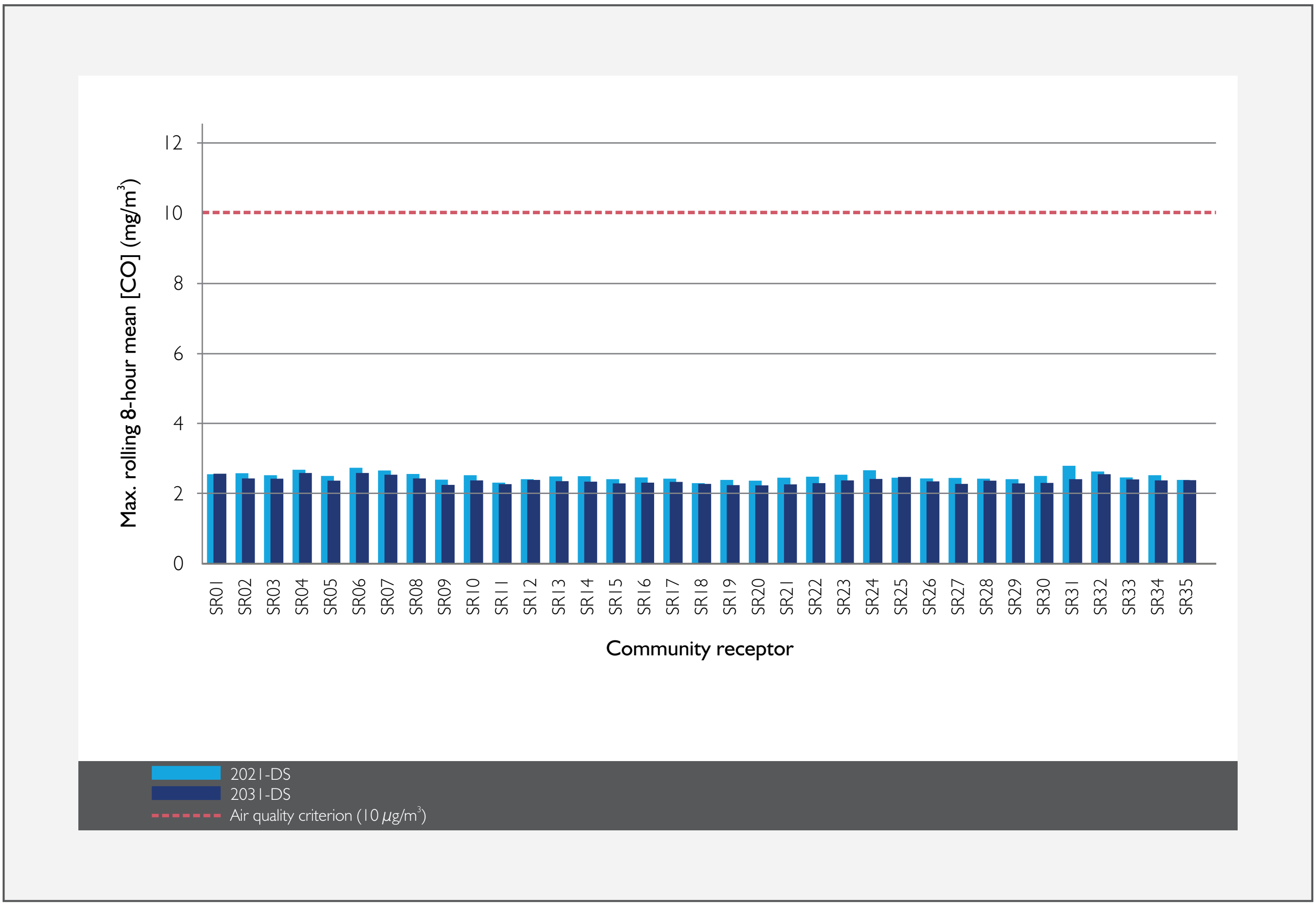

Figure 10-20 Maximum rolling 8-hour mean CO at community receivers (2021-DS and 2031-DS)

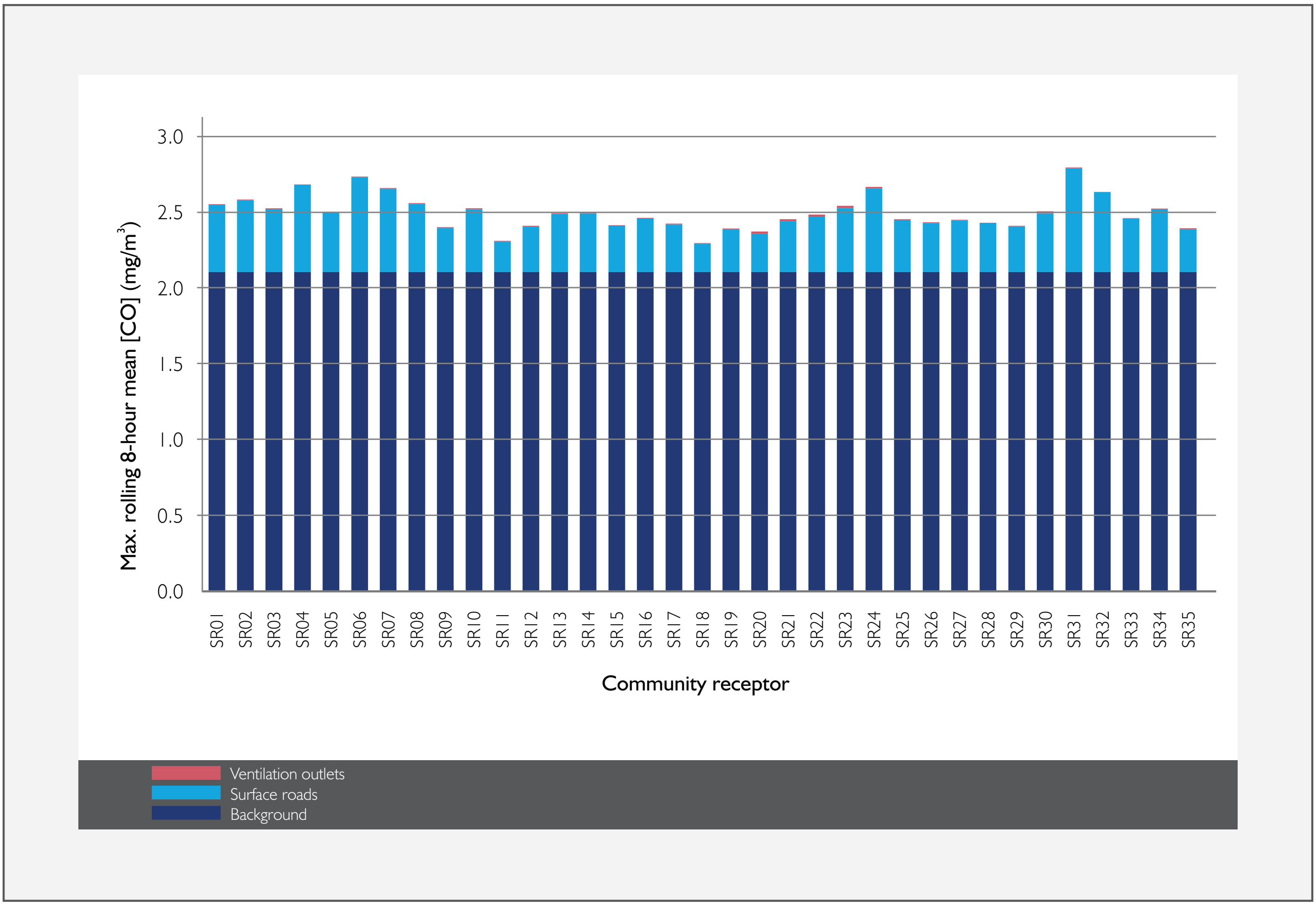

Figure 10-21 Source contributions to maximum rolling 8-hour mean CO at community receivers (2021-DS)

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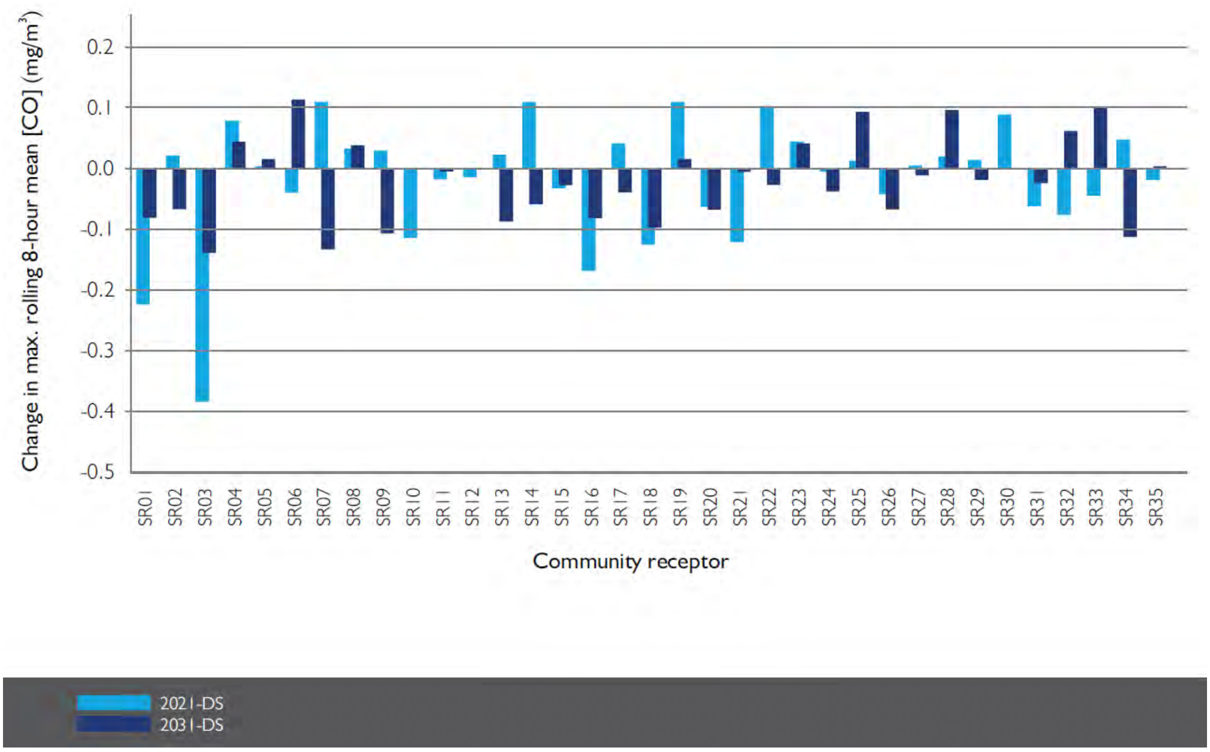

Figure 10-22 **Change in maximum rolling 8-hour mean CO at community receivers (2021-DS and 2031-DS)**

Results for residential, workplace and recreational (RWR) receivers

Rolling eight-hour mean CO concentrations were not extracted from GRAL as these would be broadly similar to those obtained for maximum one-hour concentrations.

10.8.4 Nitrogen dioxide (annual mean)

Results for community receivers

Figure 10-23 shows the annual mean NO_2 concentrations at the 35 community receivers with the project in 2021 and 2031. At all these receiver locations the concentration was below 35 µg/m^3 and therefore well below the NSW impact assessment criterion of 62 µg/m^3.

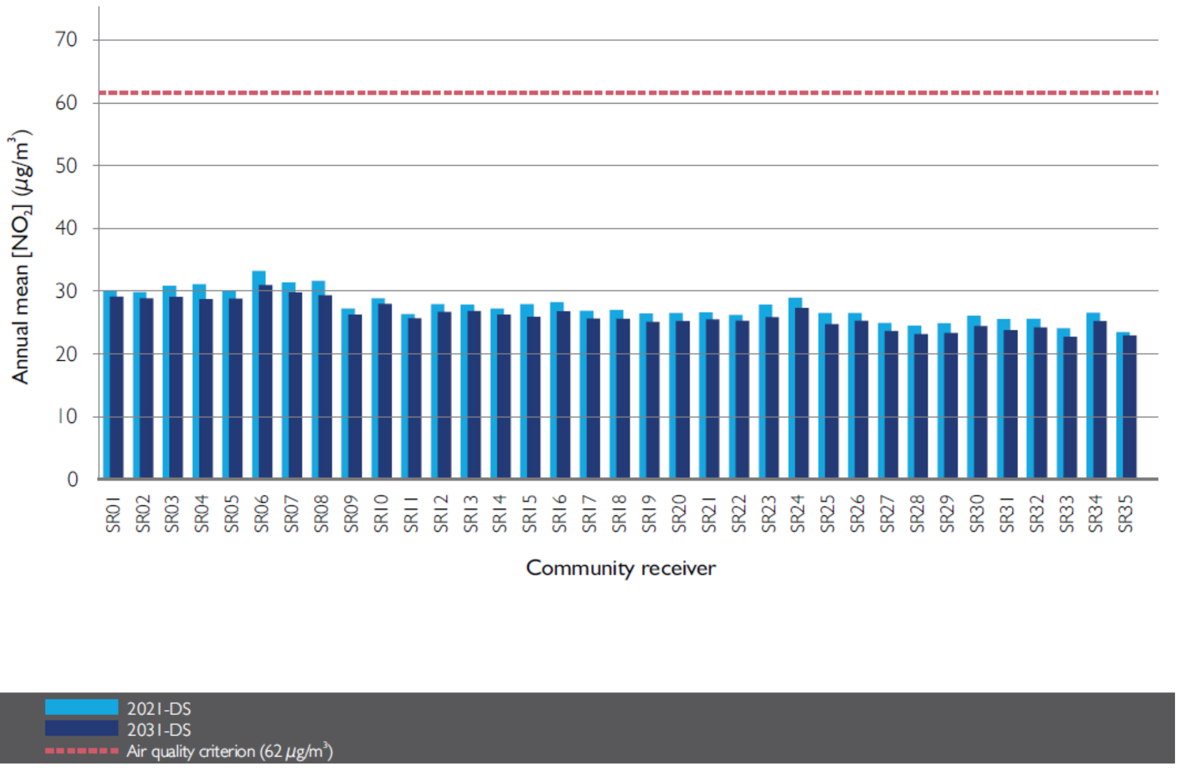

Figure 10-23 **Annual mean NO_2 at community receivers (2021-DS and 2031-DS)**

Figure 10-24 presents the source contributions to total annual mean NO_2 concentrations in the 2021-DS scenario.

The source contributions were estimated using a 'cumulative' approach as described in Section 9.5.3 of the Technical working paper: Air quality in **Appendix H**. The results indicate that the background air quality at these receivers is likely to responsible for, on average, around 80 per cent of the predicted annual mean NO_2, with most of the remainder being due to surface roads. Surface roads were responsible for between 12 per cent and 30 per cent of the total NO_2 in 2021, depending on the receiver. The contribution of tunnel ventilation outlets was less than 1.3 per cent.

Figure 10-25 shows the changes in concentration in the do something (ie with the project) scenarios relative to the do minimum scenarios (without the project) for community receivers. There was a small increase in NO_2 concentration at some receivers (generally <1 µg/m^3), although at some locations there were larger reductions. The largest reduction for these community receivers was around 2.7 µg/m^3 in 2021 and was predicted to occur at receiver SR13 (Kingsgrove World of Learning).

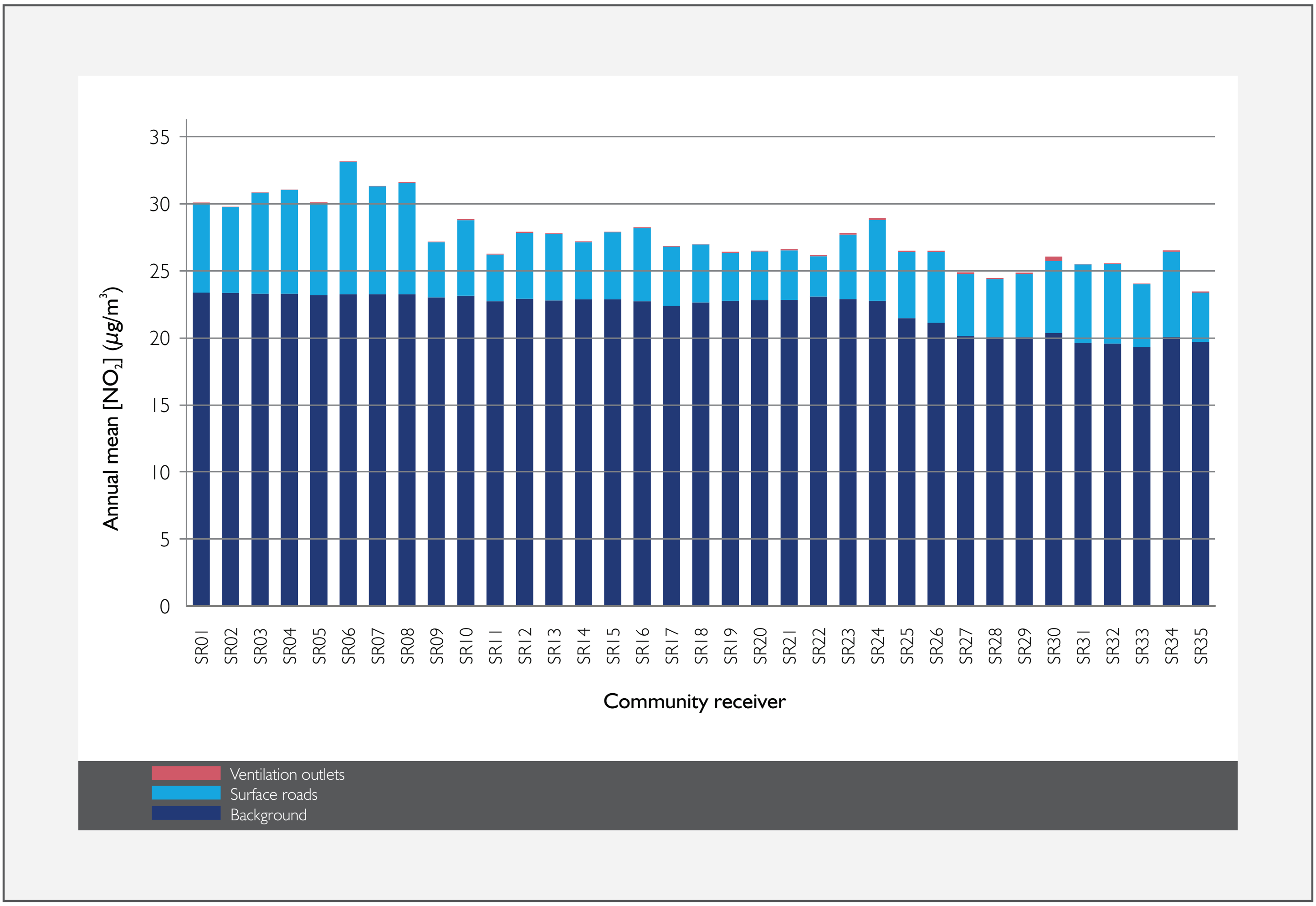

Figure 10-24 Source contributions to annual mean NO_2 at community receiver (2021-DS)

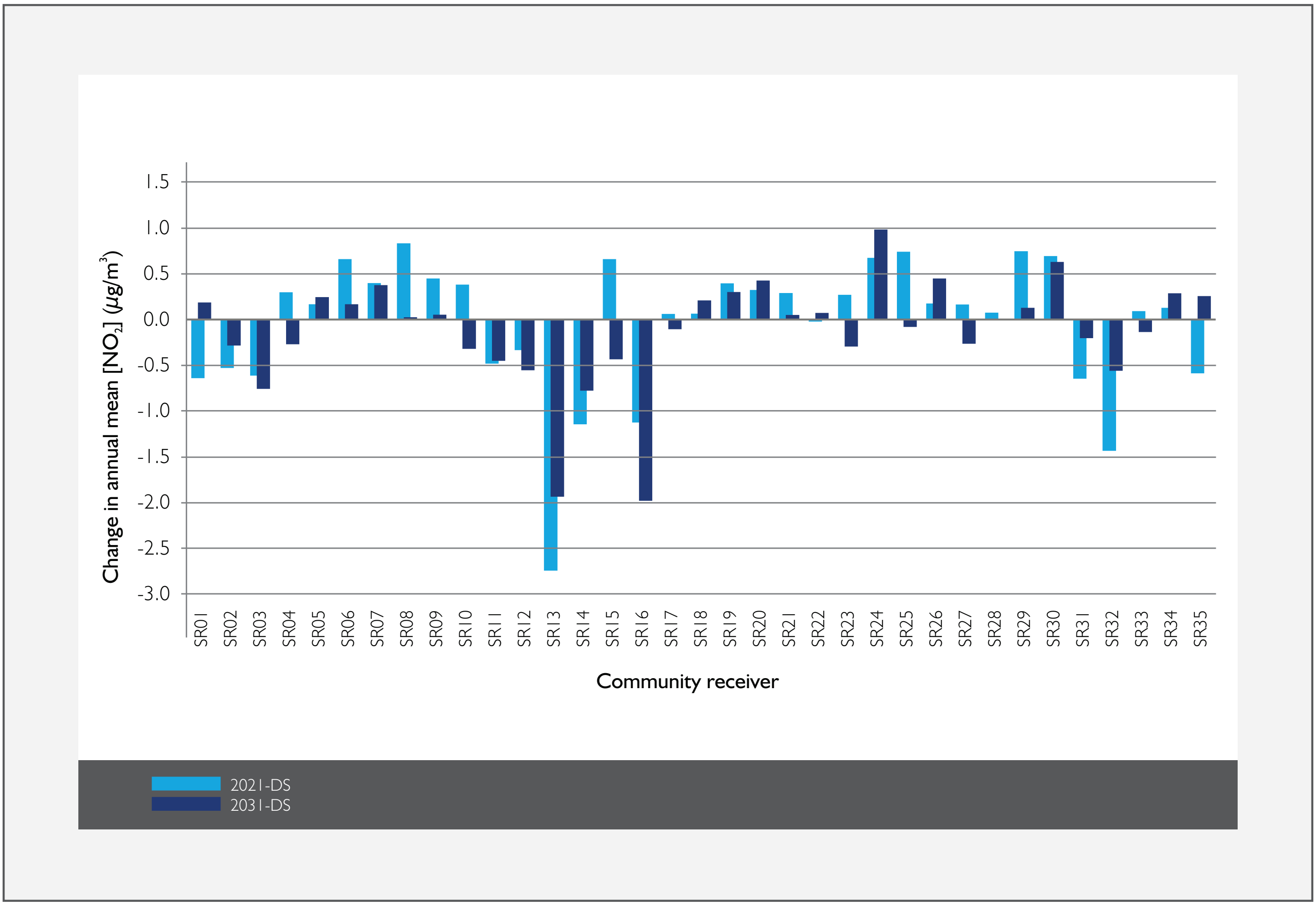

Figure 10-25 Change in annual mean NO_2 at community receiver (2021-DS and 2031-DS)

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Results for residential, workplace and recreational (RWR) receivers

The modelled annual mean NO_2 criterion for NSW was not exceeded at any of the 46,219 RWR receivers in any scenario. In 2021 and 2031, the highest concentrations under the 'do something' scenario were predicted to be 43.0 μg/m^3 and 39.8 μg/m^3 respectively. The maximum annual mean NO_2 concentration in the cumulative case (2031-DSC) was 36.8 μg/m^3.

The annual mean NO_2 concentrations at the RWR receivers in the 2021-do something scenario are shown, with a ranking by total concentration, in **Figure 10-26**. Concentrations at the majority (more than 95 per cent) of receivers were between around 23 μg/m^3 and 32 μg/m^3. As noted above, all concentrations were well below the assessment criterion of 62 μg/m^3. The maximum contribution of tunnel ventilation outlets at any location in the 2021-do something scenario was 0.6 μg/m^3, whereas the surface road contribution ranged between 2.2 μg/m^3 and 19.8 μg/m^3. The corresponding values for the 2031-do something scenarios were 0.7 μg/m^3 for the maximum contribution of tunnel ventilation outlets and a range of 1.4 μg/m^3 and 16.6 μg/m^3 for the surface road contribution.

The changes in the annual mean NO_2 concentration at the RWR receivers in the 2021-DS scenario (relative to the 2021-DM scenario) are shown, ranked by change in concentration, in **Figure 10-27**. There was predicted to be an increase in the annual mean NO_2 concentration at 62 per cent of receivers, and a decrease at 38 per cent, in 2021 as a result of the project. Whilst the largest increase was 5.5 μg/m^3, less than one per cent of receivers would experience an increase greater than 2 μg/m^3.

The annual mean NO_2 concentrations, and the changes in the annual mean, in the 2031-DS scenario are given in Appendix K of the Technical working paper: Air quality in **Appendix H**. These closely resemble the results for 2021, with the largest increase in concentration in 2031 being 4.0 μg/m^3.

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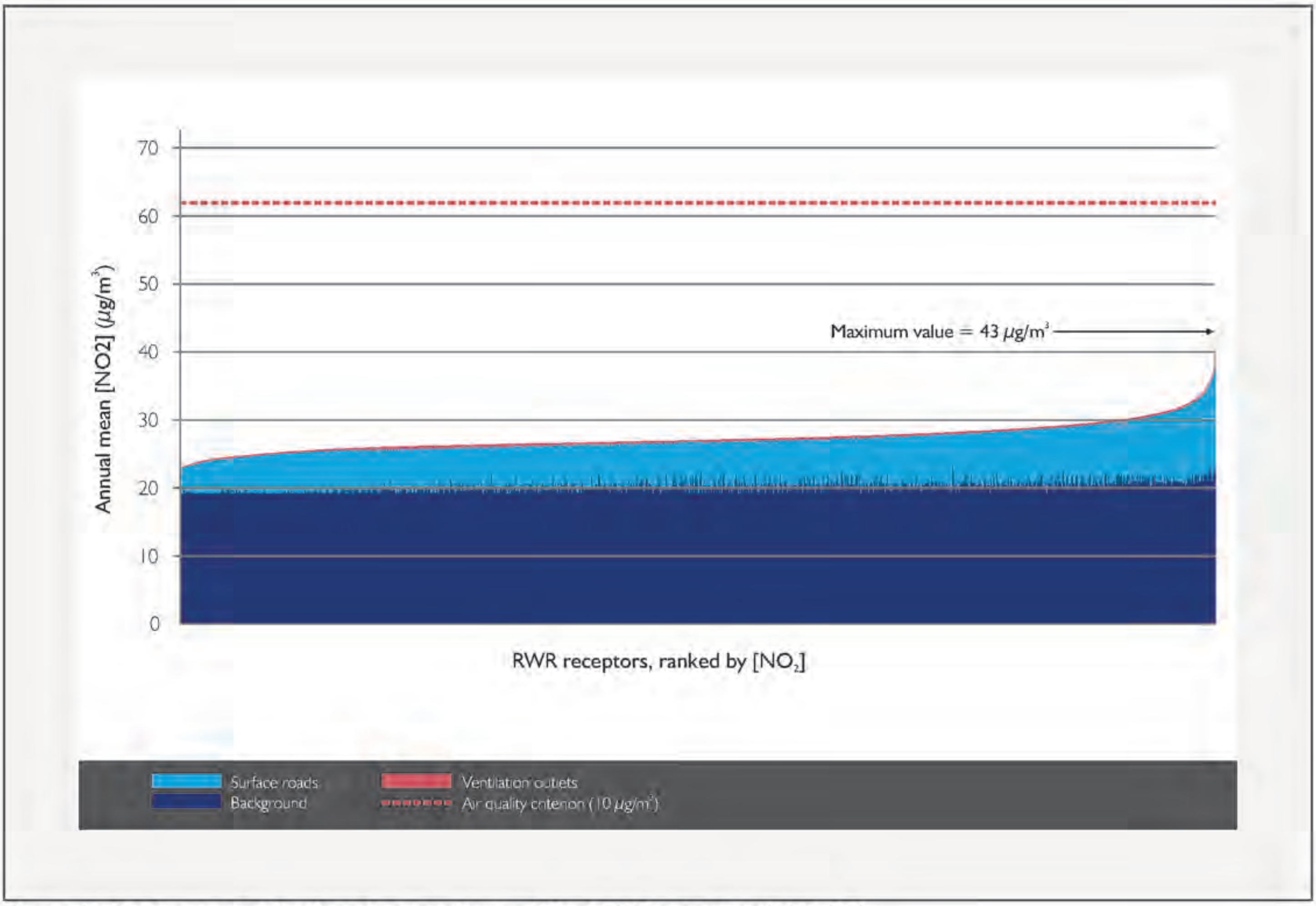

Figure 10-26 Source contributions to annual mean NO_2 at RWR receptors (2021-DS)

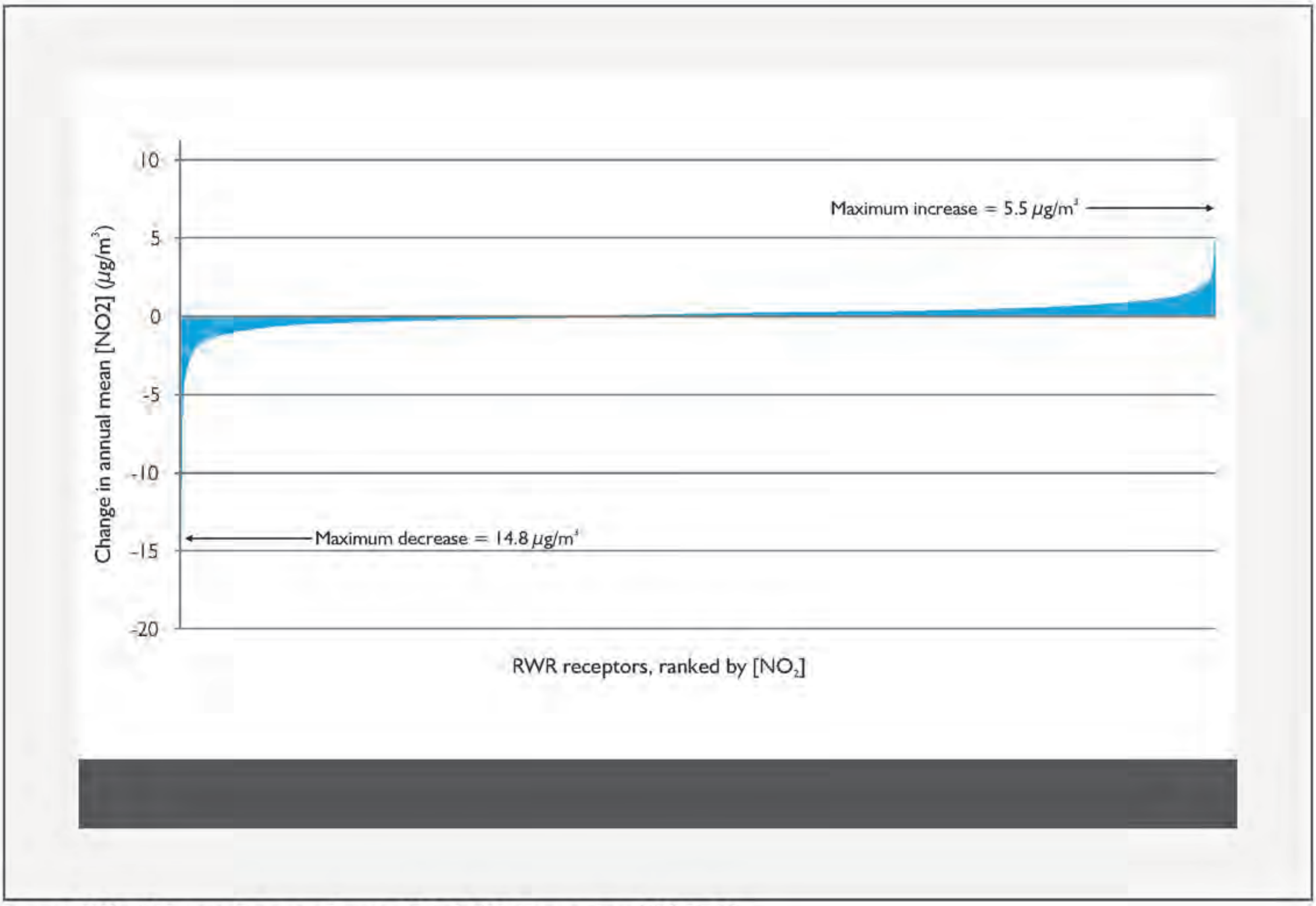

Figure 10-27 Changes in annual mean NO_2 at RWR receptors (2021-DS)

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Contour plots

Contour plots showing the spatial distribution of annual mean NO_2 concentrations across the New M5 GRAL domain in 2021 are provided for the do minimum case (ie. without the project) in **Figure 10-28**, and for the do something case (ie. with the project) in **Figure 10-29**.

These plots are based on 960,000 data points, spaced at 10 metre intervals across the GRAL domain. Many of the points therefore fall along the axes of roads and are not necessarily representative of population exposure. The maps also show main surface roads and the locations of the project's ventilation facilities.

The contour plots illustrate the strong links between the spatial distribution of air pollution and the traffic on the surface road network. The highest concentrations are found along the most heavily trafficked roads in the New M5 GRAL domain, being the M5 East Motorway, General Holmes Drive and King Georges Road. The M5 East Motorway tunnel is also apparent where there is a 'gap' in concentrations along the east-west axis of the M5 East Motorway. It is also noticeable that the tunnel ventilation outlets have little impact on annual mean NO_2 concentrations, including around the M5 East ventilation outlet.

The contour plot for the change in concentration of NO_2 with the project in 2021 (**Figure 10-30**) shows a fairly complex pattern. The green shading represents a decrease in concentration with the project, and the purple shading an increase in concentration. Changes of less than 2 $\mu g/m^3$ are not shown.

In 2021 under the do something scenario, there are predicted to be substantial reductions in concentration of NO_2 along the M5 East Motorway, both to the east and west of the M5 East Motorway tunnel, as well as along General Holmes Drive and other roads around the airport. In 2021 the New M5 is predicted to have a two-way average weekday traffic of around 29,500 vehicles per day. By comparison, average weekday traffic volumes on the M5 East Motorway under the do something scenario in 2021 are predicted to decrease from about 116,000 and 101,500 vehicles per day to about 69,000 and 81,000 vehicles per day with the project at the western and eastern end of the M5 East respectively. This equates to a 40 per cent and 20 per cent reduction in daily volumes respectively. Reductions in concentrations are also predicted along the section of King Georges Road to the north of the M5 East Motorway, around the northern perimeter of Sydney Park, and on a number of other roads.

Increases in concentration of NO_2 in the 2021 'do something' scenario are predicted for King Georges Road to the south of the M5 East Motorway, Stoney Creek Road, Bexley Road to the south of the M5 East Motorway, Harrow Road, Bay Street, Forest Road, and around the southern perimeter of Sydney Park, amongst other roads. Daily two-way volumes on Stoney Creek Road are predicted to increase by around 35 per cent with the project. This increase reflects the relocation of traffic from the M5 East due to tolling. This relocation would mainly occur in off-peak periods, as the peak hour spare capacity on Stoney Creek Road is limited.

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Figure 10-28 Contour plot showing annual mean NO_2 without the project (2021-DM)

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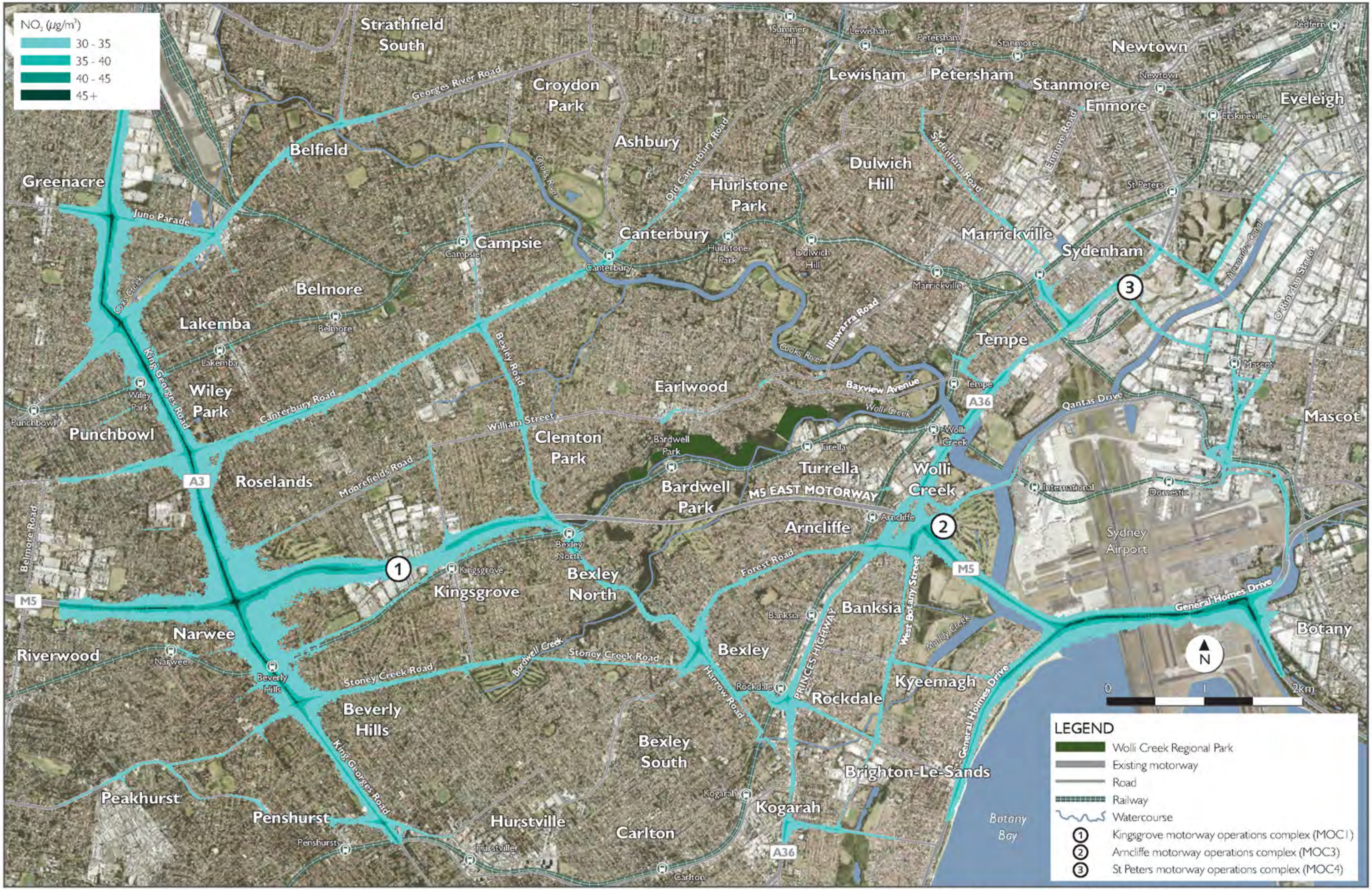

Figure 10-29 Contour plot showing annual mean NO_2 with the project (2021-DS)

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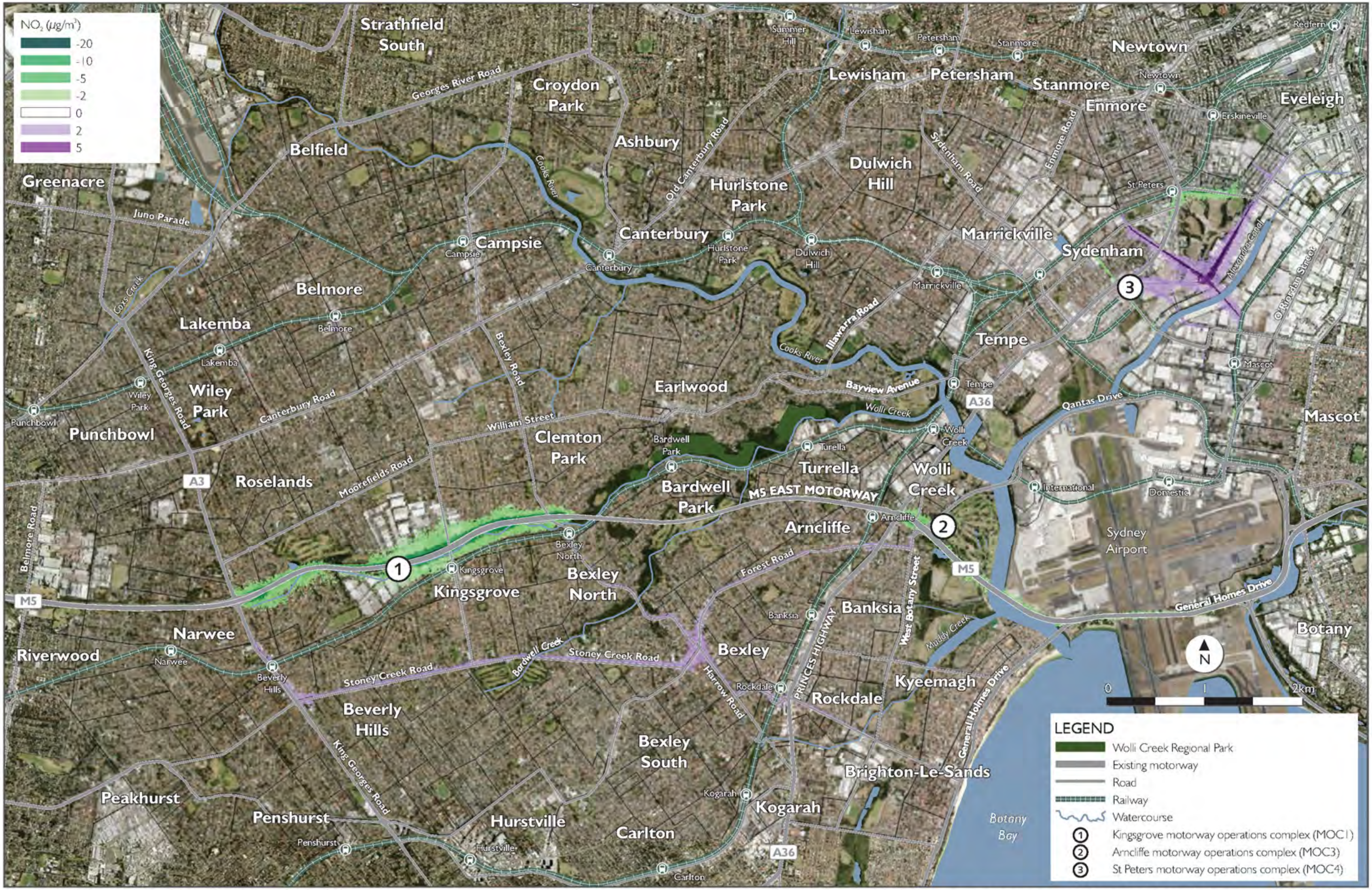

Figure 10-30 Contour plot showing change in annual mean NO_2 with the project (2021-DS)

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Contour plots for ventilation outlets only

Contour plots for annual mean NO_X (not NO_2) were also produced for the New M5 ventilation outlets only. These are shown in **Figure 10-31** (Kingsgrove outlet), **Figure 10-32** (Arncliffe outlet) and **Figure 10-33** (St Peters interchange New M5 outlet). The contributions from the surface road network and the background are not included in these plots.

The range of annual NO_X concentrations at each ventilation outlet under the 'do something' scenario in 2021, 2031 and 2031 under the cumulative case is provided in **Table 10-27**. It should be noted that the values across the grid do not necessarily coincide with receiver location, and the ranges of values at actual receivers would be lower.

The NO_X increments from each ventilation outlet were very low and their effects were quite localised. The values in the 2021 'do something' scenario ranged from 0.20 µg/m^3 to 2.2 µg/m^3 (0.20 µg/m^3 to 2.5 µg/m^3 in the 2031 'do something' scenario). The outlet contributions to NO_2 would be even lower and negligible compared with the annual mean criterion of 62 µg/m^3.

Table 10-27 Contribution of project ventilation outlets to annual mean NO_X concentration

Ventilation outlet	Outlet contribution to annual mean NO_x (µg/m^3)		
	2021-DS	2031-DS	2031-DSC
Kingsgrove	0.2 - 0.5	0.2 - 0.6	0.2 - 0.6
Arncliffe	0.4 – 1.0	0.4 – 1.0	0.4 - 0.6
St Peters interchange	0.5 – 2.2	0.5 – 2.5	0.5 – 2.5

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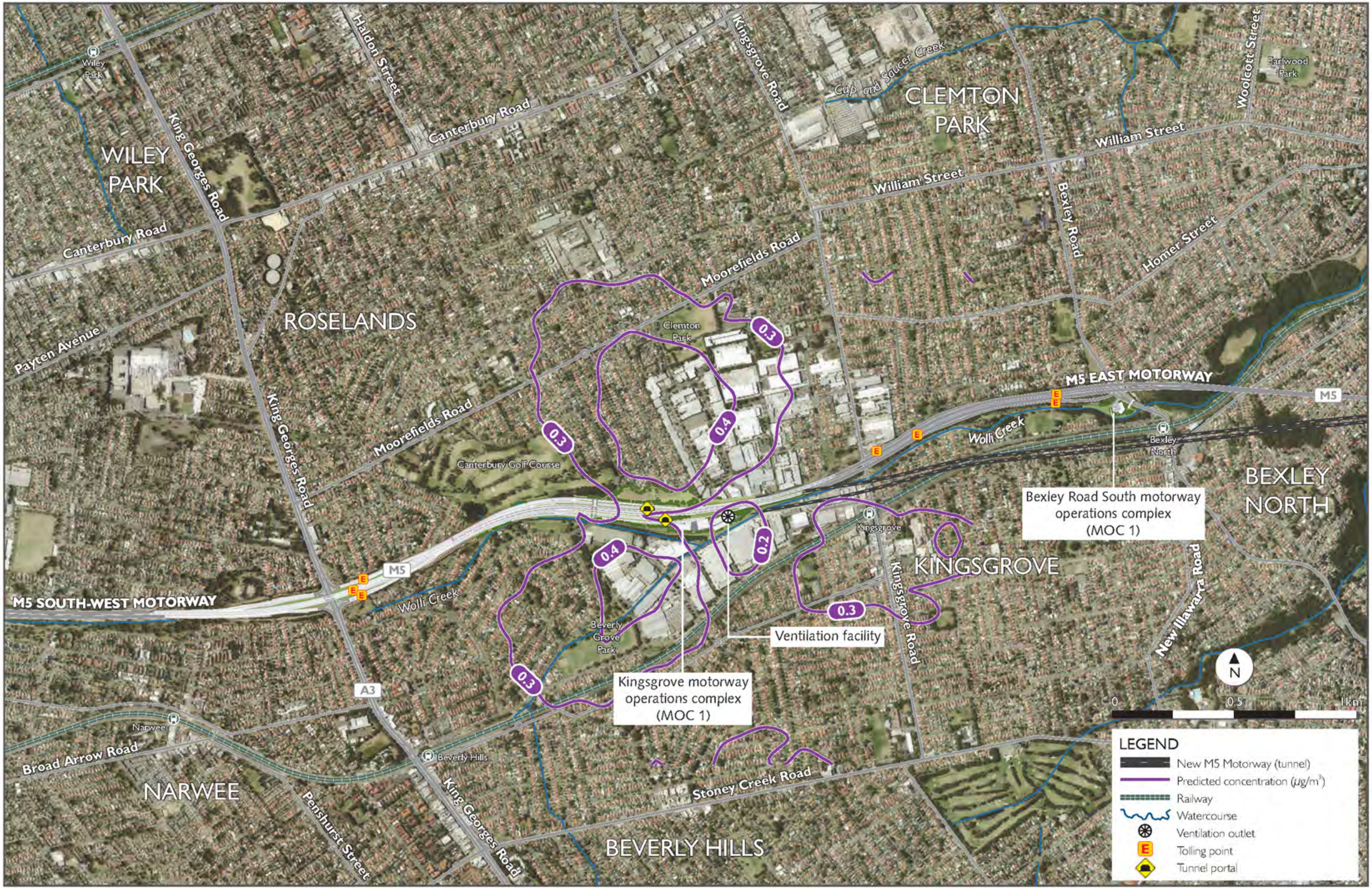

Figure 10-31 Contour plot showing annual mean NOx for ventilation outlets only (Kingsgrove outlet, 2021-DS)

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Figure 10-32 Contour plot showing annual mean NOx for ventilation outlets only (Arncliffe outlet 2021-DS)

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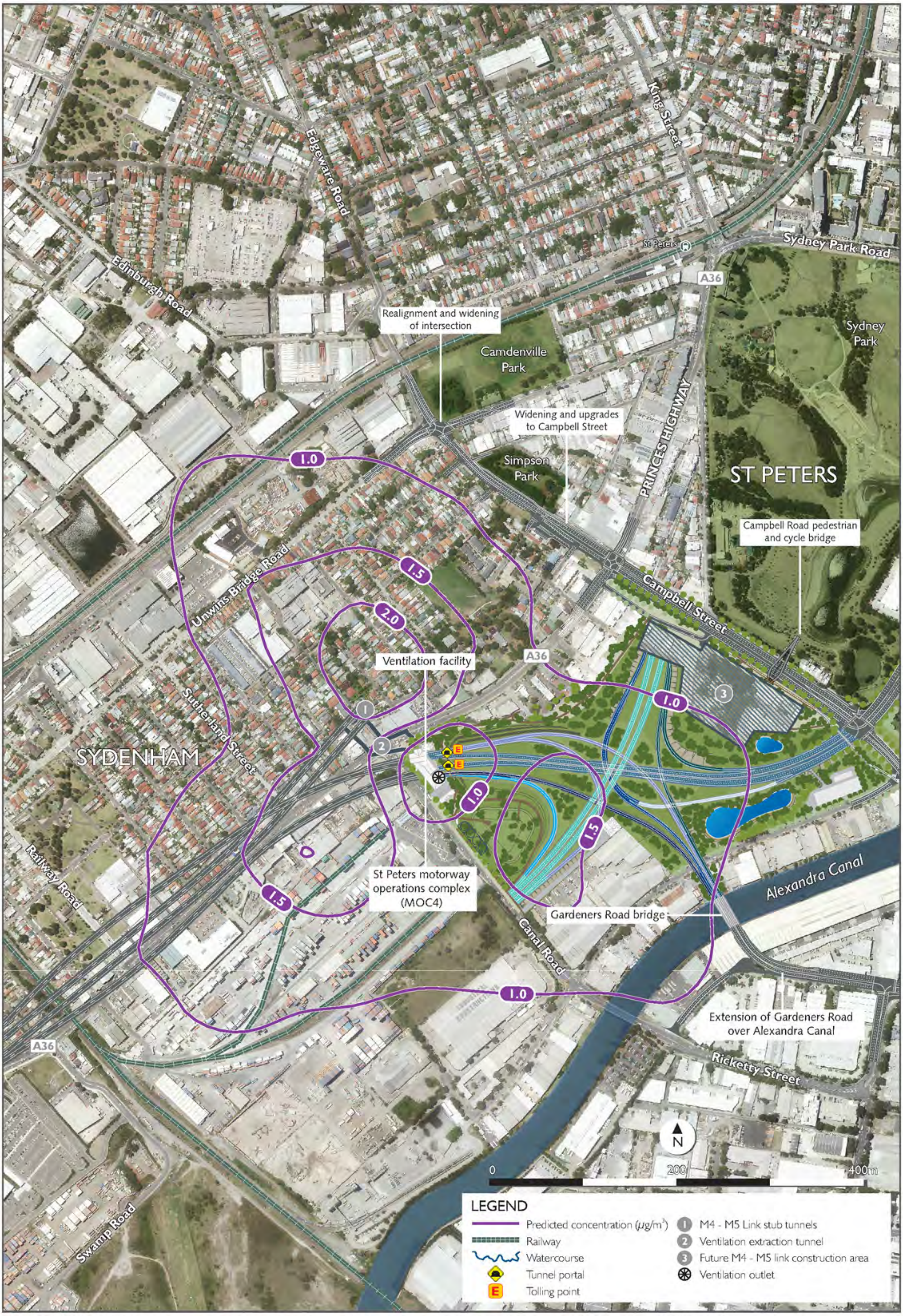

Figure 10-33 Contour plot showing annual mean NOx for ventilation outlets only (SPI outlet, 2021-DS)

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10.8.5 PM_{10} (annual mean)

Results for community receivers

The annual mean PM10 concentrations at the 35 community receivers under the ‘do something’ scenario in 2021 and 2031 are shown in **Figure 10-34**. At all community receivers the concentration was below or equal to 20 µg/m3, and therefore well below the NSW impact assessment criterion of 30 µg/m3. PM10 concentrations at these receivers, which are near busy roads, were mostly lower than the proposed target for NSW of 20 µg/m3.

Concentrations in the 2021 ‘do something’ scenario were again dominated by the background (**Figure 10-35**) with a small contribution from roads (0.9 µg/m3 - 3.1 µg/m3) and a negligible contribution from ventilation outlets.

Figure 10-36 shows the changes in concentration in the ‘do something’ scenarios relative to the ‘do minimum’ scenarios for community receivers. The largest increase was around 0.6 µg/m3 and the largest decrease around 0.8 µg/m3.

Results for residential, workplace and recreational (RWR) receivers

The ranked annual mean PM_{10} concentrations at the RWR receivers in the 2021 ‘do something’ scenario are shown in **Figure 10-37**. The concentration at the majority of receivers was below 20 µg/m3 and concentrations at all receivers were well below the NSW assessment criterion of 30 µg/m3.

The highest predicted concentration at any receiver in this scenario was 24.6 µg/m3, but as with other pollutants and metrics the highest values were only predicted for a small proportion of receivers. The surface road contribution was between 1.4 µg/m3 and 7.4 µg/m3. The largest contribution from tunnel ventilation outlets was 0.11 µg/m3 in the 2021 and 2031 ‘do something’ scenarios.

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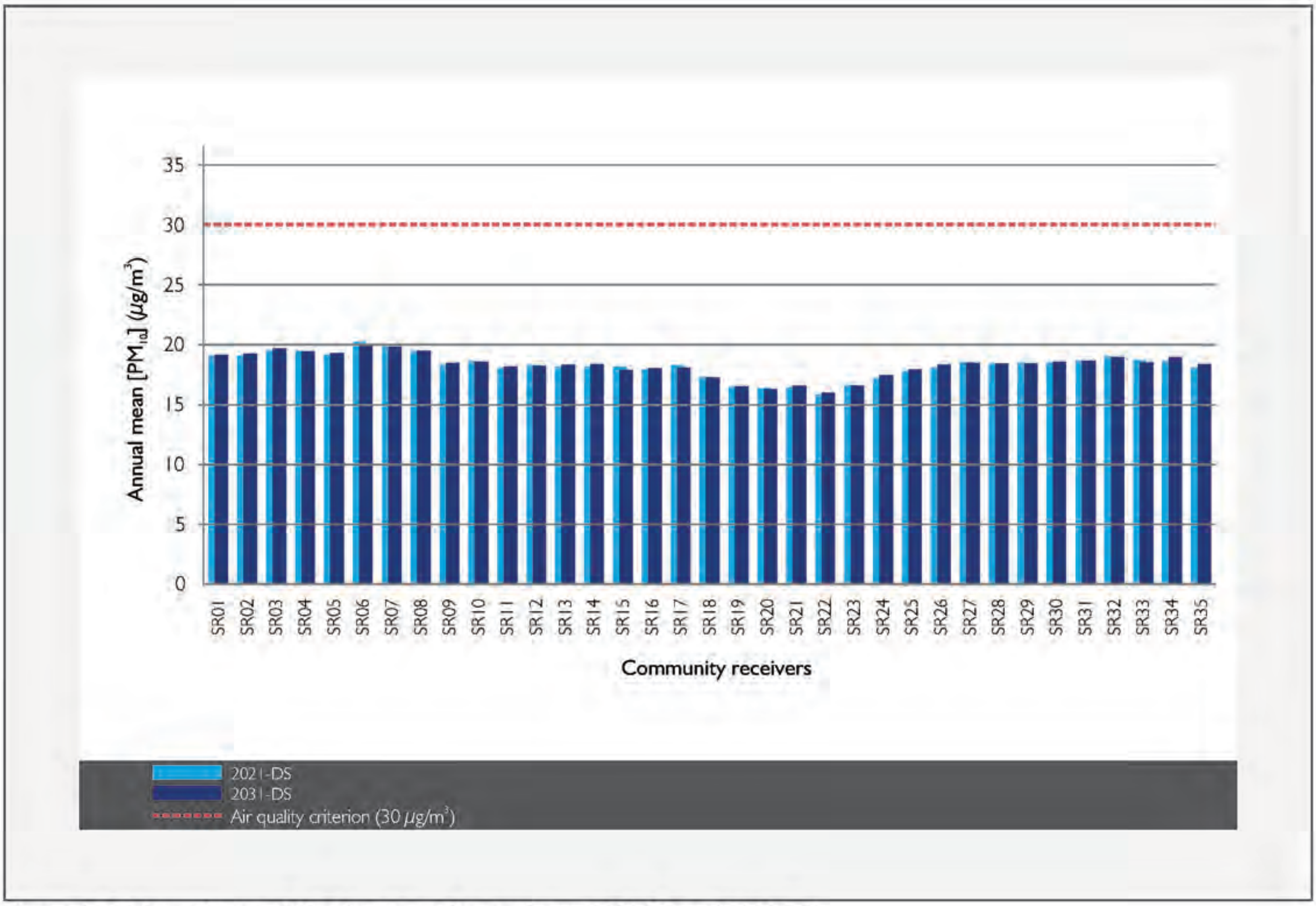

Figure 10-34 Annual mean PM_{10} at community receivers (2021-DS and 2031-DS)

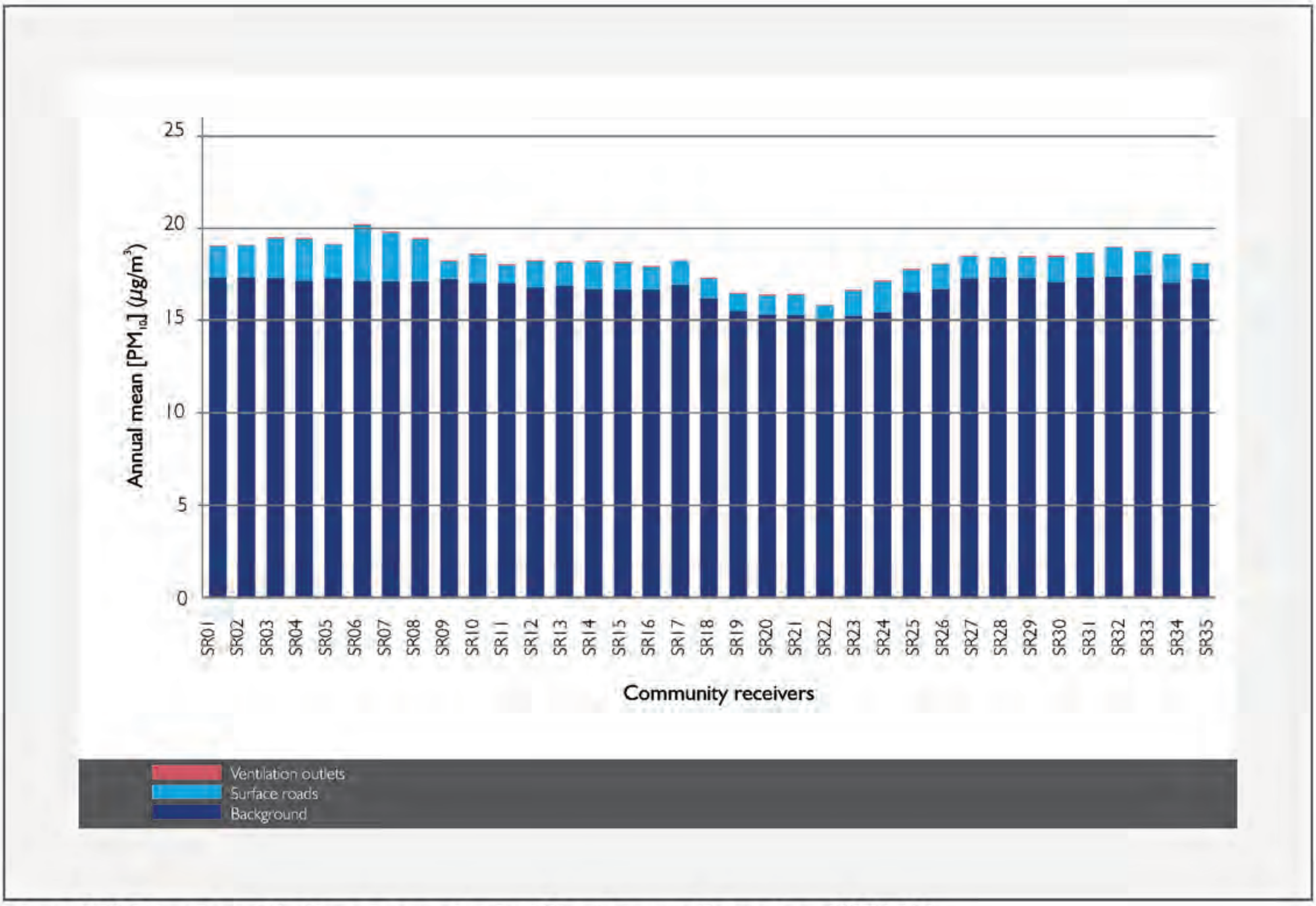

Figure 10-35 Source contributions to annual mean PM_{10} at community receivers (2021-DS)

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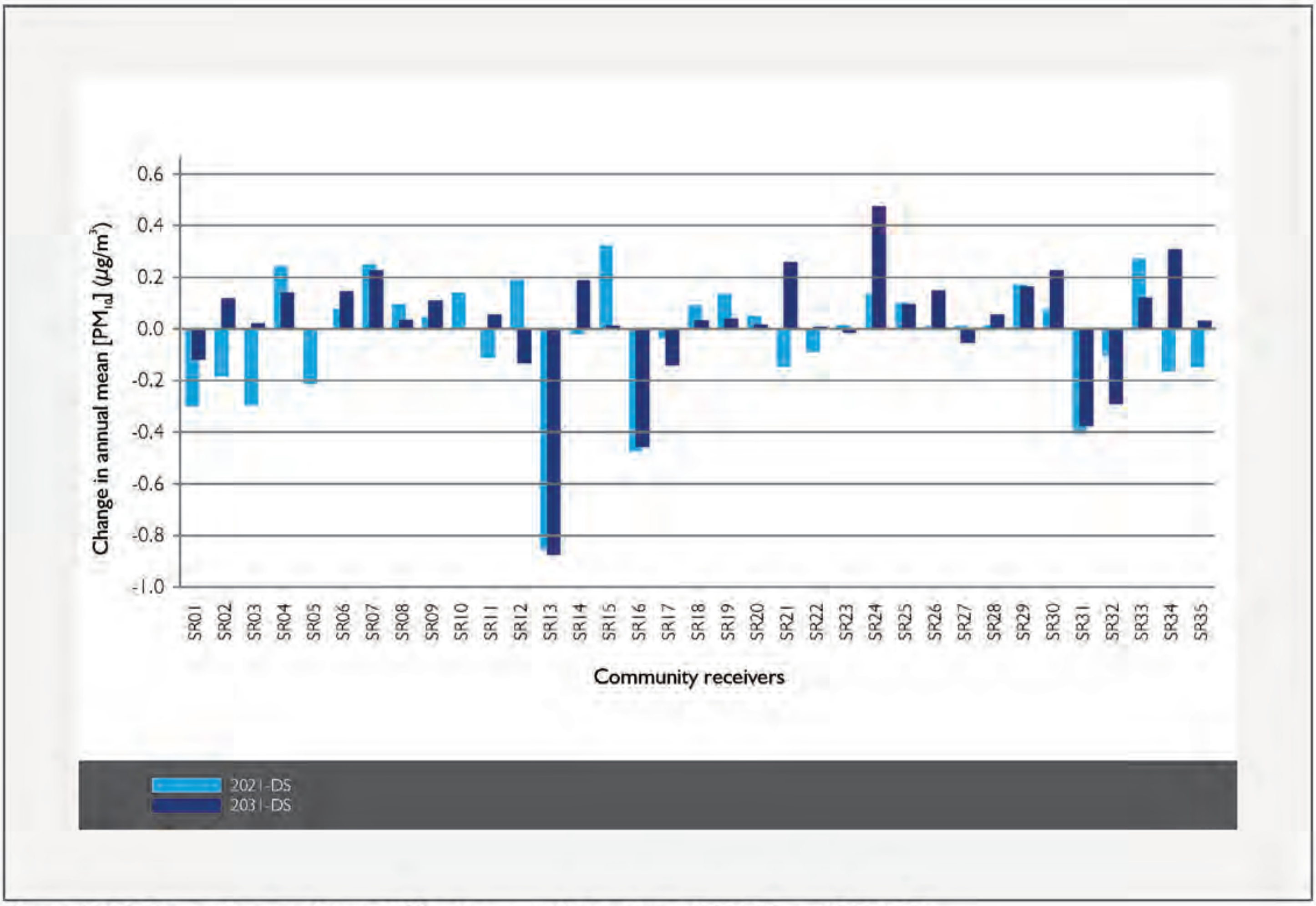

Figure 10-36 Change in annual mean PM_{10} at community receivers (2021-DS and 2031-DS)

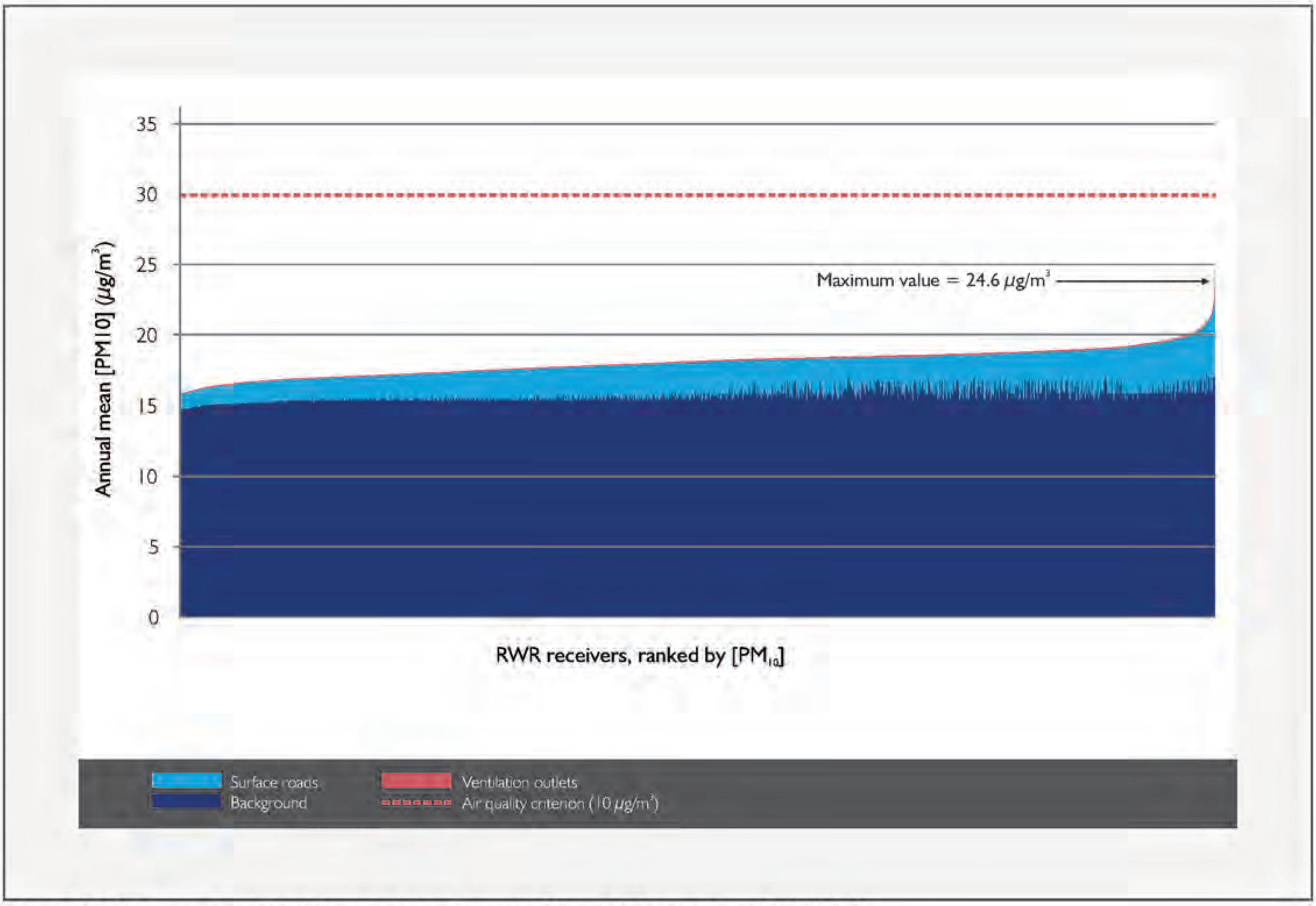

Figure 10-37 Source contributions to annual mean PM_{10} at RWR receivers (20-21DS)

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The changes in the annual mean PM10 concentration at the RWR receivers in the 2021 'do something' scenario (relative to the 2021'do minimum' scenario) are shown, ranked by change in concentration, in **Figure 10-38**. There was an increase in concentration at 64 per cent of the RWR receivers. At the majority of receivers the change was relatively small and only 0.1 per cent of receivers would experience an increase greater than 1 μg/m3.

The corresponding plots for the 2031 'do something' scenario are given in Appendix K of the Technical working paper: Air quality in Appendix H.

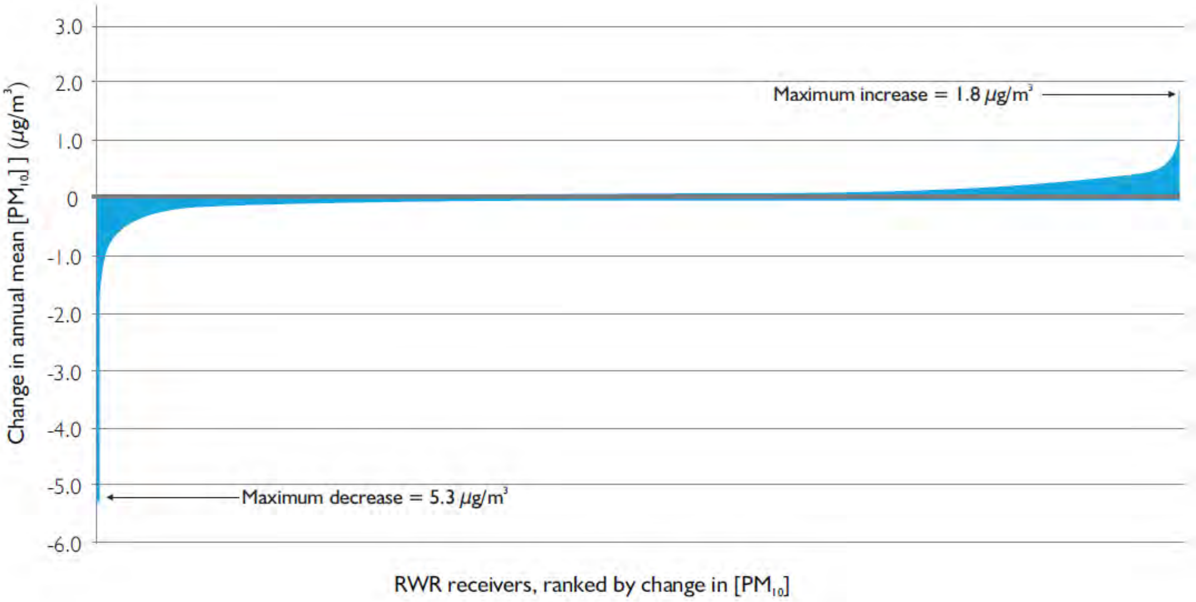

Figure 10-38 Changes in annual mean PM_{10} at RWR receivers (2021-DS)

Contour plots for GRAL New M5 domain

The contour plots for annual mean PM_{10} in 2021 under the 'do minimum' and 'do something' scenarios are presented in **Figure 10-39** and **Figure 10-40**. The change in annual mean PM_{10} with the project in 2021 are shown in **Figure 10-41**. As in the case of NO_2, elevated concentrations of PM_{10} are evident along the major road corridors. The contour plot for the change in concentration with the project in 2021 (**Figure 10-41**) also shows complex changes similar to those for NO_2.

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Figure 10-39 Contour plot showing annual mean PM_{10} without the project (2021-DM)

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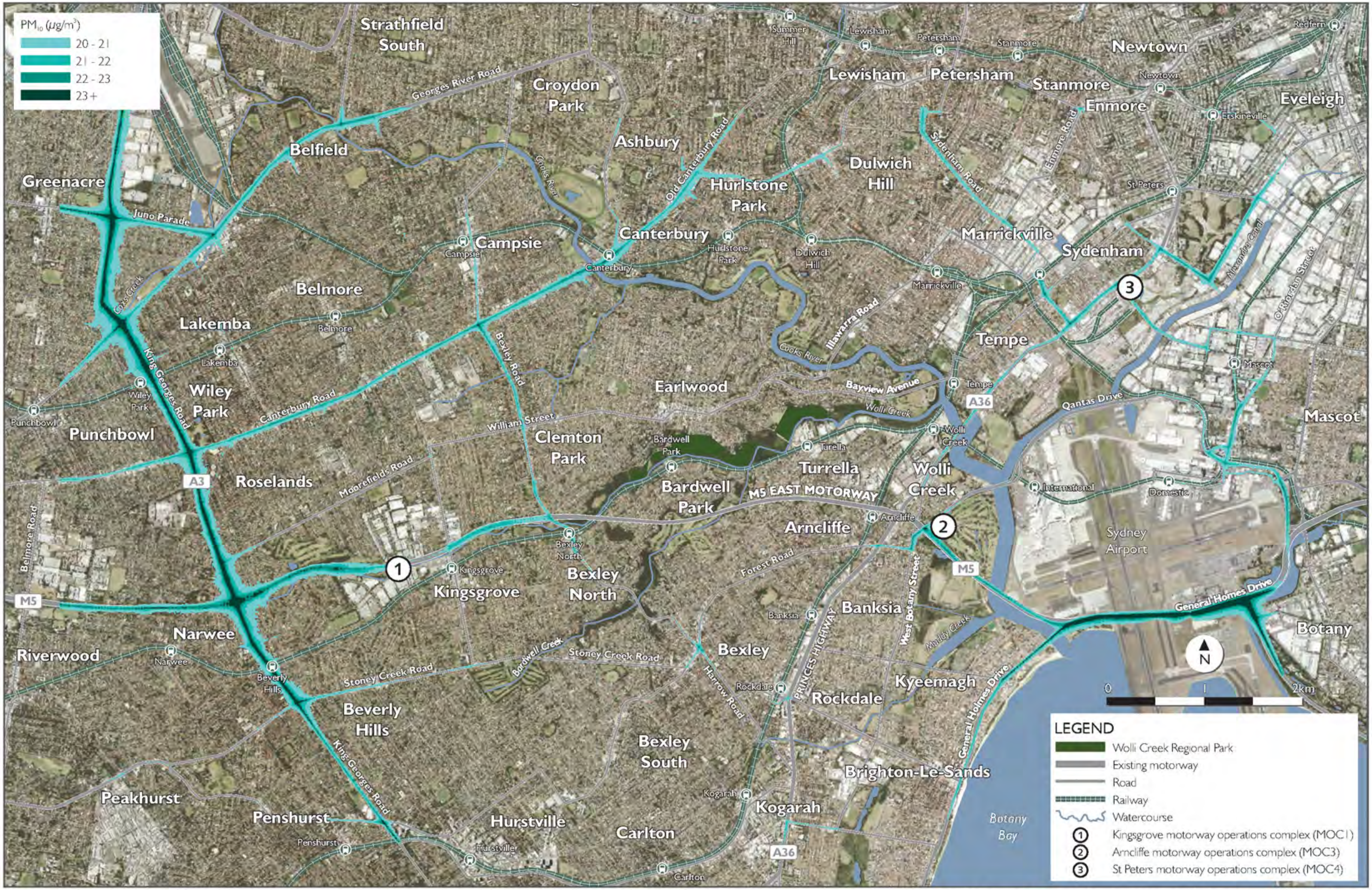

Figure 10-40 Contour plot showing annual mean PM_{10} with the project (2021-DS)

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