Annexure A Pollutant formation, dispersion and transformation

A.1 Overview

This Annexure summarises the processes that are involved in the formation of traffic pollutants, and their subsequent dispersion and transformation in the atmosphere. It is not designed to be comprehensive, but to provide additional contextual information for the assessment.

A.2 Formation of primary pollutants

A.2.1 Combustion

Most road vehicles are powered by internal combustion engines in which energy is derived from the burning of fuel in air. The main products of combustion are carbon dioxide (CO_2) and water vapour. However, several different processes lead to other compounds being present in vehicle exhaust in lower concentrations. The formation of these compounds during combustion is summarised below.

A.2.1.1 Carbon monoxide

Not all of the fuel is completely consumed during combustion. Incomplete combustion usually results from insufficient oxygen in the combustion mixture, and this leads to the production of carbon monoxide (CO). Historically, the main source of CO in urban areas has been petrol vehicles. However, emissions of CO from petrol vehicles have reduced substantially in recent years as a result of emission legislation effectively mandating the fitting of a three-way catalyst (TWC)[1] to exhaust systems. Diesel engines produce little CO as they burn the fuel with excess air in the combustion chamber, even at high engine loads.

A.2.1.2 Hydrocarbons

During combustion the flame is ‘quenched’ by the cylinder walls, leaving behind unburnt and partially burnt fuel that is expelled with the exhaust. The unburnt and partially burnt fuel contains many different organic compounds, referred to collectively as total hydrocarbons (THC). As with CO, hydrocarbon emissions from petrol vehicles have greatly decreased as a result of TWCs.

A.2.1.3 Oxides of nitrogen

At the high temperatures and pressures in the combustion chamber some of the nitrogen in the air is oxidised, forming mainly nitric oxide (NO) with some nitrogen dioxide (NO_2). NO formation is also enhanced by oxygen-rich fuelling conditions and proceeds via two main mechanisms. The main NO mechanism is known as the ‘thermal’ (or Zel’dovich) cycle, and this is responsible for more than 90 per cent of emissions (Heywood, 1988; Vestreng *et al.*, 2009). NO_2 is predominantly a secondary pollutant, being produced by the oxidation of NO in atmospheric photochemical reactions (see Section A.3.3.1). Any NO_2 that is emitted directly from vehicles is referred to as ‘primary NO_2’.

NO and NO_2 are referred to collectively as oxides of nitrogen (NO_X). NO_X emissions from petrol vehicles have also decreased as a consequence of TWCs. However, analyses in Europe have shown that, despite the considerable reductions in vehicle emissions that are calculated in inventories, NO_2 concentrations at many roadside monitoring sites are not decreasing to the same extent. Further analyses have indicated that a significant proportion of ambient NO_2 is emitted directly from vehicle exhaust, and that the direct road traffic contribution to ambient NO_2 has increased (Jenkin, 2004;

[1] Concentrations of pollutants in the exhaust gas depend on the air/fuel mixture. For lean mixtures (*i.e.* where there is an excess of air in the combustion chamber) the exhaust gases contain little CO or HC, but high concentrations of NO_X. Rich mixtures (*i.e.* where there is an excess of fuel) produce high concentrations of CO and HC, with little NO_X. A TWC results in the simultaneous conversion of CO to CO_2, HC to water, and NO_X to nitrogen. The emission rates of these pollutants are typically an order of magnitude lower than those for non-catalyst petrol cars. A closed-loop air-fuel ratio controller is required to maintain stoichiometric conditions for the TWC to work effectively. Precise control is especially important for efficient NO_X reduction, as the NO_X conversion drops dramatically for lean mixtures.

Carslaw and Beevers, 2004; Carslaw, 2005; Hueglin *et al*., 2006; Grice *et al*., 2009). Two contributing factors have been cited:

- The market share of diesel vehicles has increased in many European countries in recent years. Diesel vehicles emit more NO_X than petrol vehicles, and with a larger proportion of NO_2 in NO_X (termed *f*-NO_2).
- The average value of *f*-NO_2 in diesel exhaust has increased. This appears to be linked to the growth in the use of specific after-treatment technologies in modern diesel vehicles which involve *in situ* generation of NO_2, such as catalytically regenerative particle filters (Carslaw, 2005).

Furthermore, it seems likely that real-world NO_X emissions from road vehicles are not decreasing as rapidly as models are predicting (e.g. Rexeis and Hausberger, 2009). Although this does not, in itself, affect actual NO_2 concentrations, it does suggest that NO_X controls have not been sufficiently stringent, or that vehicles are not performing as expected. This issue was widely publicised in 2015, when the USEPA issued a notice of violation of the United States Clean Air Act to Volkswagen, after it was found that the manufacturer had programmed certain diesel cars to activate emission-control systems only during laboratory emission testings. The consequence is that there is now a great deal of interest in the tighter regulation of NO_X and NO_2 emissions from diesel vehicles and the effects of different after-treatment devices.

Historically a fairly low value for *f*-NO_2 (5-10 per cent) has been used in air quality and in-tunnel assessments in NSW. However, primary NO_2 emissions from vehicles in Sydney are not well documented. A recent update of the evidence was provided by Pacific Environment (2015a). Several different data sets and analytical techniques were presented, including emission modelling, the analysis of ambient air quality measurements, and the analysis of emissions from tunnel ventilation outlets. The work focussed on highway traffic conditions, as these were considered to be the most relevant to tunnels in Sydney. The findings suggested that there has been a gradual increase in *f*-NO_2 in recent years, from less than 10 per cent before 2008 to around 15 per cent in 2014.

Time series (2003-2041) of NO_X and NO_2 emission factors for highway traffic in the NSW EPA inventory model (see Annexure C), weighted for the default traffic mix in each year, and the associated values of *f*-NO_2, are shown in Figure A-1. The *f*-NO_2 values for different vehicle types and emission legislation were taken from Pastramas *et al.* (2014). Emission factors are also presented for situations with and without the adoption of the Euro VI regulation for heavy-duty vehicles (HDVs). Although the NO_X emission factors are predicted to decrease with time, there is a sharp increase in *f*-NO_2 after 2008, with a levelling-off at around 12 to 15 per cent (no Euro VI case) between 2020 and 2030.

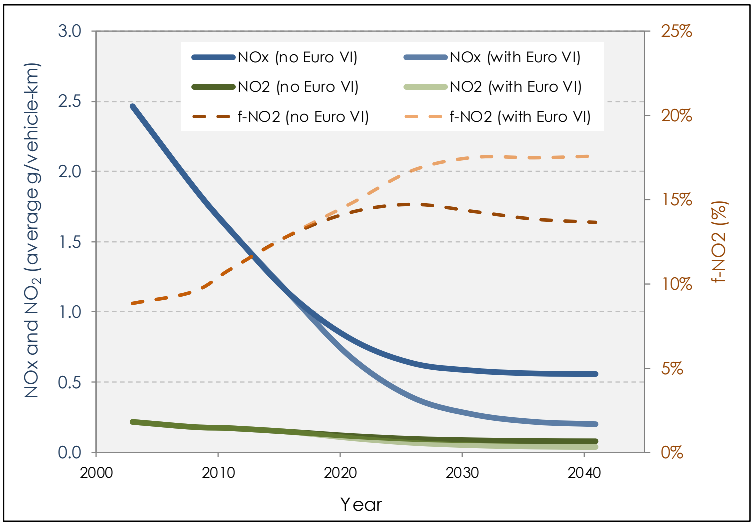

Figure A-1 **Emission factors for NO_X, NO_2 and f-NO_2 from the NSW EPA model for highways/freeways (80 km/h), weighted for default traffic mix (Pacific Environment, 2015a)**

The main reason for the increase in *f*-NO_2 is the increased market penetration of diesel cars into the Sydney vehicle fleet. There is insufficient information on the types and distributions of exhaust after-treatment devices fitted to vehicles in Sydney to determine the contributions of different technologies to primary NO_2.

A.2.1.4 Particulate matter

Incomplete combustion also results in the production of particulate matter (PM). Diesel vehicles represent the main (exhaust) source of PM from road transport, although studies indicate that gasoline-powered vehicles with direct fuel injection also contribute to PM emissions (PIARC, 2012). Particles in diesel exhaust cover a range of sizes and the shape of the size distribution depends on whether the weighting is by number or mass, as shown in Figure A-2. There are three distinct size modes: the nucleation mode (sometimes referred to as 'nuclei' or 'nanoparticles'), the accumulation mode, and the coarse mode. The nucleation mode has traditionally been defined as particles with a diameter of less than 50 nanometres, but other size cut-offs have been used. Accumulation mode particles range in size from around 50 nanometres to around 1 micrometre, with particles smaller than 0.1 micrometres being referred to as ultrafine particles. The coarse mode consists of particles larger than around 1 micrometre.

The usual means of complying with the stringent PM mass emission limits for modern diesel vehicles is through the use of a diesel particulate filter which physically captures particles in the exhaust stream.

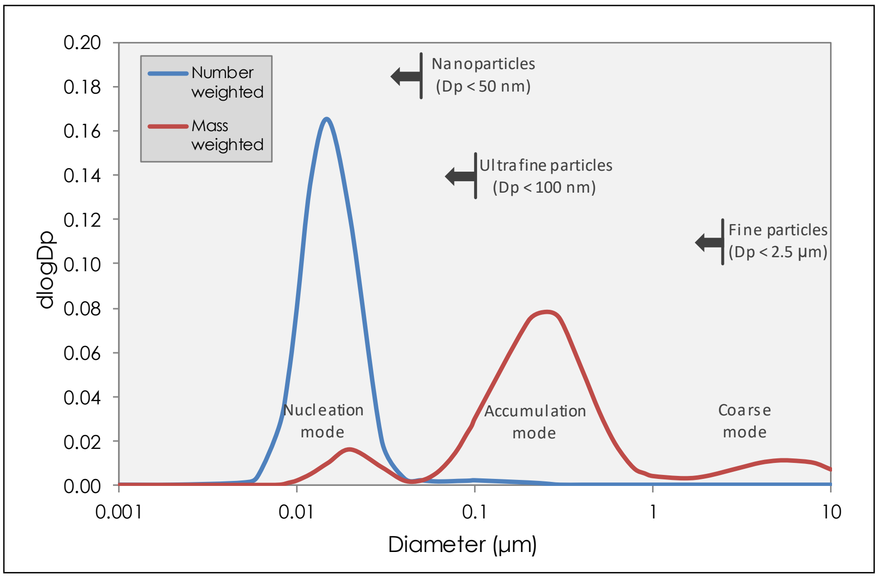

Figure A-2 Typical particle size distributions in vehicle exhaust; the y-axis is a normalised log scale (adapted from Kittelson, 1998)

A.2.2 Evaporation

Volatile organic compounds (VOCs) are emitted from the fuel systems of petrol vehicles as a result of evaporation. The compounds which are emitted are mainly light hydrocarbons (C_4-C_6) (CONCAWE, 1987). Evaporative emissions from diesel-fuelled vehicles are considered to be negligible due to the low volatility of diesel fuel.

There are several different mechanisms of evaporation. 'Diurnal losses' result from the thermal expansion and emission of vapour, mainly in the fuel tank, in response to changes in ambient temperature during the day. 'Hot-soak losses' occur when a warm engine is turned off and heat is dissipated into the fuel system. Whilst a vehicle is being driven the engine provides a continuous input of heat into the fuel system, resulting in 'running losses'.

Evaporative emissions are dependent upon four major factors: the vehicle design, the ambient temperature, the volatility of the petrol and the driving conditions. Emissions are decreasing as a result of new cars being equipped with sealed fuel injection systems and activated carbon canisters in fuel tank vents (Krasenbrink *et al*., 2005).

A.2.3 Abrasion and resuspension

As well as being present in vehicle exhaust, PM is generated by various abrasion processes including tyre wear and brake wear.

Tyre wear is a complex process. The amount, size, and chemical composition of the emitted PM is influenced by various factors including tyre characteristics, the type of road surface, vehicle characteristics and vehicle operation. Tyres contain a vast array of organic compounds and several important inorganic constituents. Although some research has been carried out to characterise wear particles, the understanding remains incomplete (Thorpe and Harrison, 2008).

Brake wear particles are composed of metals (iron, copper, lead, etc.), organic material, and silicon compounds which are used as binders in brake pads, but again composition varies greatly (Thorpe and Harrison, 2008). Test track and wind tunnel measurements have revealed that typically 50 per cent of the brake wear debris escapes the vehicle and enters the atmosphere, although the actual proportion depends on the severity of the braking and the design of the vehicle (Sanders *et al*., 2003). It appears that most airborne brake wear particles are quite coarse, although a substantial proportion has a diameter of less than 2.5 micrometres (Garg *et al*., 2000; Abu-Allaban *et al*., 2003; Iijimia *et al*., 2007).

Another process – the resuspension of material previously deposited on the road surface – occurs as a result of tyre shear, vehicle-generated turbulence, and the action of the wind. Studies in the United States have indicated that resuspension is responsible for between 30 per cent and 70 per cent of total PM_{10} in urban areas (Zimmer *et al*., 1992; Gaffney *et al*., 1995; Kleeman and Cass, 1999). Large contributions of resuspension have also been observed in some European studies (notably in Scandinavia), although the conditions in these studies (e.g. responses to climate such as the use of studded tyres and grit on roads in winter) are not necessarily representative of those in Sydney.

It is possible that non-exhaust PM is less important for tunnels than for surface roads, as under normal operating conditions in many road tunnels there is probably less braking and cornering than on surface roads. This is likely to result in less material being deposited on roads in tunnels than on roads in the external environment, resulting in a smaller contribution from resuspension. However, these effects are not well quantified at present.

A.2.4 Construction dust and odour

Dust emissions occur as a result of construction activities, and these can lead to elevated PM_{10} concentrations and nuisance. A potential source of PM (both airborne and on the road surface), especially during the project construction phase, is fugitive dust from uncovered loads. However, the Protection of the Environment Operations (Waste) Regulation 2014 requires waste transported by a vehicle to be covered during its transportation. Exhaust emissions from diesel-powered construction equipment can also be substantial.

Where construction activities involve, for example, the excavation of waste and its subsequent exposure to the atmosphere, this is likely to result in odour emissions which also need to be managed.

Construction-related air quality issues need to be considered and managed on a site-by-site basis.

A.3 Pollutant dispersion and transformation

A.3.1 Spatial distribution of pollution in an urban area

Once pollutants have been released into the atmosphere they are subject to various physical dispersion processes. These processes, in combination with a varying density of emission sources and chemical transformations (see Section A.3.3) result in a very uneven distribution of pollution across an urban area.

Figure A-3 shows a simplified representation of pollutant concentrations in and around an urban area with a high density of population and activity in the centre and a lower density in the surrounding districts. Regional background pollution originates from a range of sources, extends over a wide area, and is relatively constant outside the urban area. Within the urban area there is an additional ‘urban background' component which is influenced by area-wide emission sources such as domestic and commercial heating, as well as general contributions from transport and industry. Alongside heavily-trafficked roads there is likely to be a significant local contribution to the concentration. This local traffic contribution is more pronounced for some pollutants (notably NO_X) than others (such as PM).

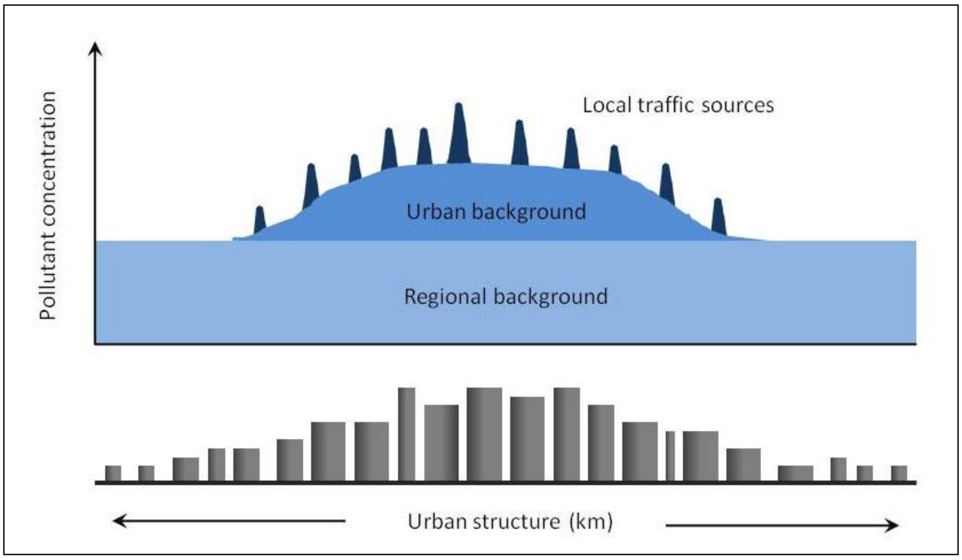

Figure A-3 Simplified representation of urban structure and pollution levels (adapted from Keuken *et al*., 2005)

The general dispersion and transformation of pollutants is influenced to a large extent by the local meteorology. For example, the temperature inversions and low wind speeds associated with stable high-pressure systems can restrict dispersion and lead to high concentrations. High temperatures in summer promote the formation of ozone and other photochemical pollutants, and extreme weather events are often associated with peak levels of pollution. The frequency and severity of pollution events in Sydney are strongly influenced by the regional terrain and the presence of the sea, which affect the circulation of air (DSEWPC, 2011).

Dispersion is also influenced by the local topography (terrain) and by the presence of local obstacles such as buildings. 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, and generates drainage flows at night and upslope flows during the day.

Buildings generate turbulence and can create complicated air flow patterns including areas of accelerated flow and wakes. The influence of buildings on the plume from, say, a tunnel ventilation outlet is known as 'building downwash'. This can occur when the aerodynamic turbulence induced by nearby buildings causes a pollutant emitted from the elevated outlet to be rapidly mixed to the ground. This will depend on a number of factors such as the height and speed at which the plume is released, as well as the height of the nearest buildings and their distance from the outlet. Whether or not a plume is directly influenced by building downwash will also depend on the speed of the ambient air at the time the plume is released. In other words, if wind speeds are low, the effect the building has on the plume may be negligible. These are important considerations for the design of tunnel ventilation outlets.

In the vicinity of roads, vehicle-induced turbulence needs to be considered; the turbulence caused by the moving vehicles is likely to be more significant than that caused by buildings.

A.3.2 Concentration gradients near roads

Traffic pollutants undergo rapid changes in the near-road environment, and concentration gradients in the vicinity of roads have been examined in various studies. Some examples of the results for different pollutants and periods of the day are shown in Figure A-4. The figure is based on the findings of Gordon *et al.* (2012), who used a mobile laboratory to measure the concentration gradients of ultrafine particles

(UFP), black carbon (BC), CO_2, NO, and NO_2 at varying distances from a major highway in Toronto, Canada.

For primary pollutants such as NO and BC, concentrations decay exponentially with increasing distance from the road. Reviews have shown that these typically decrease to background levels between around 100 and 500 metres from roads (e.g. Karner *et al*., 2010; Zhou and Levy, 2007).

Many primary pollutants react together, and with pollutants from other sources, to form secondary pollutants (a substantial proportion of NO_2 is secondary). For these the situation is more complex; because of the time required for their formation, the concentrations of secondary pollutants are not always highest near the emission source.

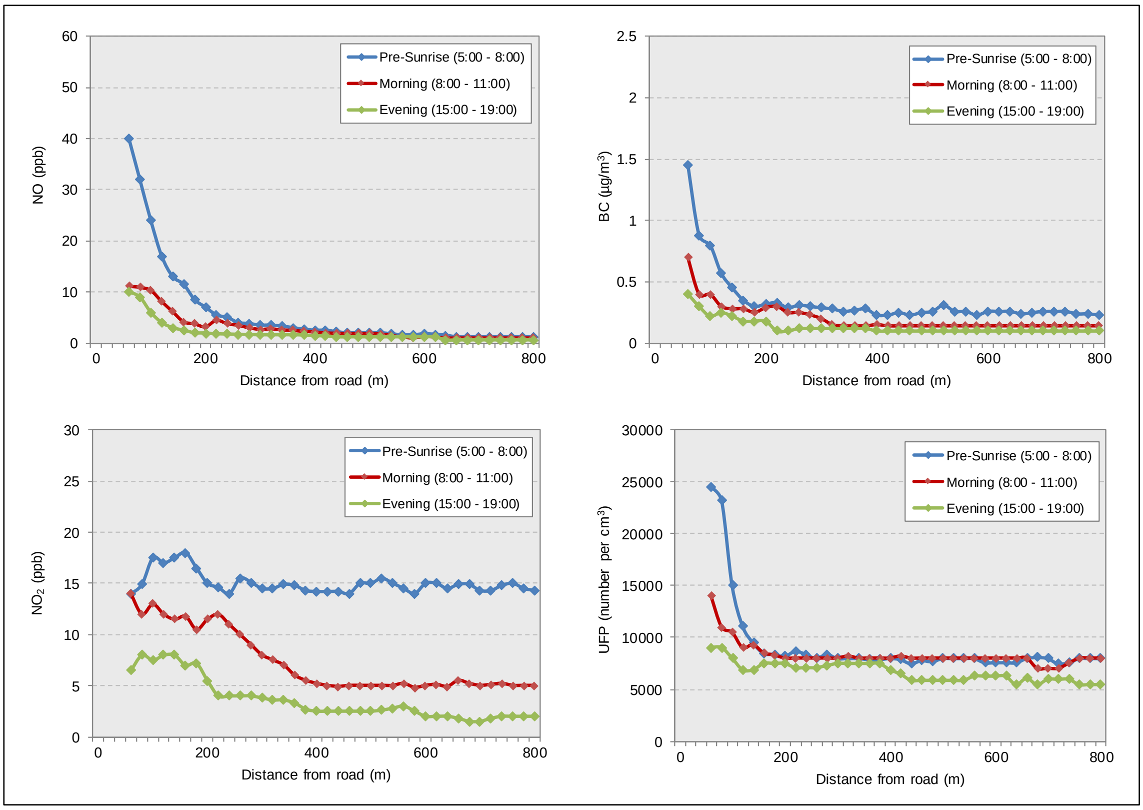

Figure A-4 Median concentrations of pollutants in the vicinity of a major highway (adapted from Gordon et al., 2012)

A.3.3 Pollutant transformation

A.3.3.1 Nitrogen dioxide

Some of the most important reactions for near-road air quality are those that lead to the formation and destruction of NO_2. Under the majority of atmospheric conditions, the main mechanism for NO_2 formation in the atmosphere is through rapid reaction of NO with ozone (O_3):

Equation A1

$$\mathbf{NO + O_3 \rightarrow NO_2 + O_2}$$

Where this is the only important reaction (e.g. at night-time), NO is transformed into NO_2 until either all the NO has been converted to NO_2 or until all the O_3 has been used up. At polluted locations comparatively close to sources of NO_X (such as roads) NO is in large excess and it is the availability of O_3 which limits the quantity of NO_2 that can be produced by this reaction. The timescale for consumption of O_3 depends on the concentration of NO. Under normal ambient daytime conditions the reverse process also occurs – the destruction of NO_2 by photolysis to form NO and O_3, as shown in Equation A2 and Equation A3:

Equation A2

$$\mathbf{NO_2 + sunlight \rightarrow NO + O}$$

Equation A3

$$\mathbf{O + O_2\ (+M) \rightarrow O_3\ (+M)}$$

where **M** is a third body, most commonly nitrogen.

Dilution processes decrease the NO_2 concentration with distance from the road, whereas chemical reactions tend to favour NO_2 production. As a result, the decay rate of NO_2 is lower than that of NO in near-road environments (see Figure A-4). However, the NO_2/NO_X ratio increases with increasing distance from the roadway until it reaches the background level.

It is worth noting that inside a road tunnel there is usually a high concentration of NO from vehicle exhaust, and any available oxidant, principally O_3, is removed relatively quickly. Once the O_3 is removed, NO_2 formation via Equation A1 will stop (Barrefors, 1996). As there is little natural sunlight inside a road tunnel, the destruction of NO_2 via Equation A2 is also limited. Consequently, much of the NO_2 in tunnel air is primary in origin.

A.3.3.2 Particulate matter

The fate of freshly emitted particles in the atmosphere depends upon their size. Nucleation mode particles have a short lifetime in the atmosphere since they readily transform into larger particles and deposit efficiently onto surfaces. Accumulation mode particles are too large to be subject to rapid diffusion and too small to settle from the air rapidly under gravity. Their further growth is inhibited because they do not coagulate quickly and there are diffusion barriers to their growth by condensation. Particles in the accumulation mode can therefore have a long atmospheric lifetime (typically seven to 30 days). For coarse particles, gravitational settling velocities become appreciable and therefore atmospheric lifetimes are shorter than for accumulation mode particles.

A substantial fraction of the fine PM mass, especially at background locations, is secondary in nature. Secondary particles are formed by atmospheric reactions involving both inorganic and organic gaseous precursors, several of which are emitted by road vehicles.

The formation of secondary inorganic aerosol is comparatively well understood, although some mechanistic details still remain to be determined (USEPA, 2009). This aerosol is composed mainly of ammonium sulfate ($(NH_4)_2SO_4$) and ammonium nitrate (NH_4NO_3), with some sodium nitrate. These compounds originate from the conversion of sulfur oxides (SO_X) and NO_X in the atmosphere to sulfuric and nitric acids, which are then neutralised by atmospheric ammonium (NH_4^+). The precursor to atmospheric ammonium is ammonia (NH_3). SO_X and NO_X typically arise from combustion sources. NH_3 emissions are dominated by agricultural sources, such as the decomposition of urea and uric acid in livestock waste (AQEG, 2005).

Secondary organic aerosol is linked to the formation and transformation of low-volatility organic compounds in the atmosphere. The formation of these compounds is governed by a complex series of reactions involving a large number of organic species (Kroll and Seinfeld, 2008). As a result of this complexity a great deal of uncertainty exists around the process of formation (USEPA, 2009).

The formation of secondary particles happens slowly; the overall oxidation rates of SO_2 and NO_2 are around one per cent per hour and five per cent per hour respectively. The slowness of these processes – and the fact that the resulting particles are small and therefore have a relatively long atmospheric lifetime – means that secondary particles are usually observed many kilometres downwind of the source of the precursors.

Particles are removed from the atmosphere by both dry deposition and wet deposition processes. Dry deposition is caused by gravitational sedimentation, interception/impaction, diffusion or turbulence, although other processes can occur. In wet deposition, atmospheric water (raindrops, snow, *etc.*) scavenges airborne particles, with subsequent deposition on the earth's surface.

Annexure B Review of standards and criteria relating to emissions and air quality

B.1 Overview

This Annexure provides supplementary information, including an international context, on key legislative instruments and guidelines of relevance to the project.

B.2 National emission standards for new vehicles

B.2.1 Exhaust emissions

For emission testing purposes, the legislation distinguishes between the following:

- Light-duty vehicles. These have a gross vehicle mass (GVM) of less than 3500 kilograms, and are subdivided into:
    - Light-duty passenger vehicles, including cars, sports utility vehicles (SUVs), four-wheel drive (4WD) vehicles and 'people movers'.
    - Light-duty commercial vehicles, including vans and utility vehicles used for commercial purposes.

  The light-duty vehicle legislation also distinguishes between petrol and diesel vehicles.
- Heavy-duty vehicles, with a GVM of more than 3500 kilograms.

Exhaust emissions are inherently variable, and so the best way to ensure that an emission test is reproducible is to perform it under standardised laboratory conditions. Light-duty vehicles are tested using a power-absorbing chassis dynamometer. The emissions from heavy-duty vehicles are regulated by engine dynamometer testing, given that the same engine model could be used in many different vehicles.

The Australian Design Rules (ADRs) set limits on the exhaust emissions of carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NO_X) and particulate matter (PM). Some of the pollutants in vehicle exhaust are not regulated, including specific 'air toxics' and the greenhouse gases carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The specific emission limits which apply to light-duty and heavy-duty vehicles, and their timetable for adoption in the ADRs, are listed on the Australian Government website[1]. Although the test procedures have changed with time, the exhaust emission limits have been tightened significantly in recent years. There has been a greater alignment with the international vehicle emissions standards set by the UNECE[2], although the Australian standards have delayed introduction dates (DIT, 2010).

Australia is currently implementing the Euro 5[3] emission standards for new light-duty vehicle models (cars and light commercial vehicles). New vehicle models have been required to comply with these standards since November 2013. The introduction in Australia of Euro 6 emissions standards is currently on hold and is being reviewed by the Ministerial Forum on Vehicle Emissions. With full implementation of Euro 6, the World Harmonized Light-duty Vehicle Test Cycle (WLTC) will replace the current test cycle (Mock et al., 2014).

In the case of heavy-duty vehicles the Euro V standards are currently being implemented in Australia, and the Euro VI standards are currently under discussion. Although the Euro VI standards will reduce

[1] http://www.infrastructure.gov.au/roads/environment/emission/

[2] United Nations Economic Commission for Europe.

[3] In accordance with the European legislation, a slightly different notation is used in this Report to refer to the emission standards for LDVs, HDVs and two-wheel vehicles. For LDVs and two-wheel vehicles, Arabic numerals are used (e.g. Euro 1, Euro 2…etc.), whereas for HDVs Roman numerals are used (e.g. Euro I, Euro II…etc.).

the limit on NO_X emissions by 77 per cent relative to Euro V, and by 89 per cent relative to Euro IV, advanced test protocols that improve real-world conformity to NO_X limits should result in reductions that are closer to 95 per cent (Muncrief, 2015).

The ADRs do not mandate the use of particular technology. However, it was necessary for vehicle manufacturers to fit catalytic converters to light-duty petrol vehicles in order to meet the emission limits introduced by ADR37/00. For light-duty diesel vehicles, particulate traps will generally be required for compliance with the very low PM emission limits at the Euro 5 stage. For Euro 6/VI the required NO_X reductions will be achieved with combustion improvements (high-pressure fuel injection and advanced air/fuel management), exhaust gas recirculation, closed-loop selective catalyst reaction systems and lean NO_X trap (LNT) technology. To support the introduction of new technologies there is usually a need for improved fuel quality (e.g. reduced fuel sulfur content). Fuel regulations therefore tend to be updated to support new emission standards.

The European Commission is introducing a mandatory test procedure for 'real driving emissions' (RDE), to be applied during the type approval of light-duty vehicles. These are measured on the road by a portable emission measurement system (PEMS), rather than in the laboratory. The RDE initiative complements the introduction of the WLTC and procedures. The new RDE procedure will require exhaust emission control systems to perform under a broad range of different operating conditions.

Several shortcomings of the regulations have been identified in the European Union. For heavy-duty vehicles the Euro V standards did not achieve the anticipated reductions in NO_X emissions (Ligterink et al., 2009). Although the Euro 5 standards have resulted in dramatic reductions in PM emissions from light-duty diesels, real-world NO_X emissions from Euro V trucks and buses have continued to far exceed certification limits (Carslaw et al., 2011).

B.2.2 Evaporative emissions

The test procedure for evaporative emissions involves placing a vehicle inside a gas-tight measuring chamber equipped with sensors to monitor the temperature and volatile organic compounds (VOC) concentrations, and following a prescribed operational procedure. The chamber is known as a SHED (Sealed Housing for Evaporative Determination). The limits for evaporative emissions are specified in the ADRs.

B.3 In-tunnel limits – international practice

Guidelines for the calculation of the fresh air requirements of tunnel ventilation systems are presented by PIARC[4] (2019)[5]. Three types of value are defined:

- Design values: These determine the required capacity of the tunnel ventilation system. The ventilation capacity for normal tunnel operation is defined by the air demand required to dilute vehicle emissions to maintain allowable in-tunnel air quality.
- Set points: These are used for the incremental operation of the tunnel ventilation system. For example, tunnel sensors trigger mechanical ventilation in stages before the measured concentration of a gas reaches its limit value (Highways Agency et al., 1999). Set points are generally lower than design values, and are selected so that the design conditions are not exceeded, taking into account the time lag between the traffic conditions and the ventilation system.
- Threshold values: These ensure safe operation of the tunnel, and must not be exceeded. If a threshold value is attained, immediate action is required.

[4] Formerly, the Permanent International Association of Road Congress (PIARC), is now called the World Road Association and is an international forum for the discussion of all aspects of roads and road networks.

[5] The 2019 PIARC report replaces the 2012 R05 (revised version) PIARC report "Road Tunnels: Vehicle Emissions and Air Demand for Ventilation". The main changes concern the emission data up to 2030 for Euro 4, 5 and 6 vehicles as well as an update of the factors for non-exhaust particle emissions.

It is prudent for design modelling to include predictions for a range of traffic speeds, and to establish worst case conditions. However, PIARC notes that the application of overly stringent design values can result in over-sizing of the ventilation system, and thresholds or set points that are too low can cause excessive operational energy use and cost. Nevertheless, the PIARC document states that the emission factors it provides for designing tunnel ventilation tend to be conservative (they include a margin of safety).

Table B-1 provides a summary of the PIARC in-tunnel CO and visibility limits for ventilation design, tunnel operation, and tunnel closure. The 100 part per million (ppm) value for CO corresponds to a World Health Organisation (WHO) recommendation for short-term (15-minute) exposure, and is widely used for ventilation design. Exposure at this concentration should not persist for more than 15 minutes, although the length of most tunnels is such that the exposure duration is much less than 15 minutes. In such cases, a higher level of CO may be allowed in the tunnel. The limits for visibility are designed for the purpose of safe driving rather than the protection of health. The limit values for in-tunnel CO and visibility in a number of countries are shown in Table B-2. The national limits for CO in each country are broadly similar to the values recommended by PIARC.

PIARC has not released definitive recommendations for nitrogen dioxide (NO_2) in tunnels, and there are scientific and technical challenges in managing compliance with NO_2 limits. Based on the findings of health studies PIARC has proposed an in-tunnel limit for NO_2 of 1 ppm as the design value, defined as an average value along the length of the tunnel (PIARC, 2019).

It is noted by PIARC that many countries do not apply a NO_2 limit specifically for tunnels, but occupational short-term exposure limits apply. These are typically higher than the 1 ppm proposed by PIARC. Some countries have introduced NO_2 as the target pollutant for in-tunnel air quality monitoring, with the threshold value normally following national and/or WHO recommendations. Depending on the situation, either NO_2 or NO_X inside the tunnel, or NO_2 outside the tunnel, can be taken as the design parameter for ventilation sizing.

Table B-1 CO and visibility limit values (PIARC, 2019)

Traffic situation	CO conc. (ppm)	Visibility	
		Extinction coefficient (/m)	Transmission *s* (beam length: 100 m)
Free-flowing peak traffic 50-100 km/h	70	0.005	60
Daily congested traffic, stopped on all lanes	70	0.007	50
Exceptional congested traffic, stopped on all lanes	90	0.009	40
Planned maintenance work in a tunnel under traffic[(a)]	20	0.003	75
Threshold for closing the tunnel[(b)]	200	0.012	30

(a) National workplace guidelines should be considered.
(b) To be used for tunnel operation only, and not for ventilation design.

Table B-2 In-tunnel CO and visibility limits for ventilation design and tunnel closure

Country	Condition for ventilation design	Limit values for ventilation design		Limit values for tunnel closure	
		CO (ppm)	Visibility (/m)	CO (ppm)	Visibility (/m)
Austria	Regular congestion	100	0.007	150[a]	0.012[a]
				100[b]	-
France	Free-flow and congested	50	0.005	-	-
Germany	Regular congestion	70	0.005	200	0.012
	Occasional congestion	100	0.007	-	-
Hong Kong	5-min average	100	-	-	-
Japan	60 km/h	50-100	<0.009	150	0.012
	80 km/h	50-100	<0.007		
Norway[c]	Mid-tunnel	75	-	100[d]	-
Switzerland	Any	70	0.005	200[e]	0.012[e]
UK[f]	Tunnel <500 m	10	PIARC	-	-
	Tunnel 500 m to 1000 m	50	PIARC	-	-
	Tunnel 1000 m to 2500 m	35	PIARC	-	-
USA	Fluid peak traffic, 60 km/h	100	<0.009	150	0.012
	Fluid peak traffic, 80-100 km/h	100	<0.007		
	Congested traffic	100	<0.009		

(a) If exceeded for more than 1 minute.
(b) If exceeded for more than 10 minutes.
(c) In Norway, NO/NO_2 and particulate matter are also used for design and control purposes.
(d) If exceeded at tunnel mid-point for more than 15 minutes.
(e) If exceeded for more than 3 minutes.
(f) Limit values for tunnels longer than 2500 m are derived from first principles.

Sources: Norwegian Public Roads Administration (2004), ASTRA (2003), CETU (2010), MEPC (1993), RABT (2003), RVS (2004)

Examples of in-tunnel NO_2 values for ventilation control from several countries are summarised in Table B-3. It is noted in PIARC (2019) that the WHO limits aim at improving air quality in general, and are not intended to be applied to peak exposures. Nevertheless, different values have been adopted for different timeframes and some of these are quite stringent. In the UK, consideration was given to lowering the NO_2 limit to one ppm, but tunnel operators stated that it would not be feasible to comply with this limit (Tarada, 2007). PIARC adds that passage through a tunnel typically only lasts for a few minutes and therefore stringent NO_2 thresholds should only be considered where it might be warranted by traffic conditions and/or ambient conditions.

The CO, NO_2 and PM concentrations in the ambient fresh air used for dilution are normally relatively low, but should be checked for tunnels in urban areas, where ambient CO concentrations are typically between one ppm and five ppm. A typical ambient peak NO_2 concentration would be 200 µg/m^3. The situation can be modified, however, when air from the portal of one bore enters the portal of the adjacent bore as 'fresh air', although simple structural design features (e.g. anti-recirculation walls) can minimise or even eliminate such effects (PIARC, 2019).

For longitudinally ventilated tunnels in which traffic demands are high, or may change suddenly, PIARC recommends a minimum air flow speed of 1.0-1.5 m/s.

Table B-3 International in-tunnel NO_2 limits

Country	NO_2 (ppm)	Notes	Source
PIARC	1.0	Averaged over tunnel length	PIARC (2019)
Belgium	0.2	1 hour	WHO (2006)
	0.5	<20 minutes	PIARC (2012)
France	0.4	15 minutes, average for length of tunnel	CETU (2010)
Hong Kong	1.0	5 minutes, ventilation control	Hong Kong EPD (1995)
Norway[a]	0.75	15 minutes, tunnel mid-point	Norwegian Public Roads Administration (2004)
Sweden[b]	0.2	1 hour	WHO (2006)
UK[c]	4	Tunnel <500 m	Highways Agency *et al.* (1999)
	3	Tunnel 500 m to 1000 m	
	1.5	Tunnel 1000 m to 2500 m	

(a) Resulting in tunnel closure.
(b) PIARC states that Sweden is in the process of abandoning the WHO threshold.
(c) Design and control. Limit values for tunnels longer than 2500 m are derived from first principles.

B.4 Ambient air quality standards and goals

B.4.1 Criteria pollutants

The metrics, criteria and goals set out for criteria pollutants in the NSW Approved Methods (NSW EPA, 2016) are listed in Table B-4. The pollutants shaded in grey were not included in the assessment (see section 5.5.3).

Table B-4 Impact assessment criteria for 'criteria pollutants' in NSW Approved Methods (NSW EPA, 2016)

Pollutant or metric	Criterion: Concentration	Criterion: Averaging period	Calculation	Source
Carbon monoxide (CO)	87 ppm or 100 mg/m^3	15 minutes		WHO (2000)
	25 ppm or 30 mg/m^3	1 hour	One hour clock mean	WHO (2000)
	9 ppm or 10 mg/m^3	8 hours	Rolling mean of 1-hour clock means	NEPC (1998)
Nitrogen dioxide (NO_2)	120 ppb or 246 µg/m^3	1 hour	One hour clock mean	NEPC (1998)
	30 ppb or 62 µg/m^3	1 year	Calendar year mean	NEPC (1998)
Particulate matter <10 µm (PM_{10})	50 µg/m^3	24 hours	Calendar day mean	NEPC (2016)
	25 µg/m^3	1 year	Calendar year mean	NEPC (2016)
Particulate matter <2.5 µm ($PM_{2.5}$)	25 µg/m^3	24 hours	Calendar day mean	NEPC (2016)
	8 µg/m^3	1 year	Calendar year mean	NEPC (2016)
Sulfur dioxide (SO_2)	250 ppb or 712 µg/m^3	10 minutes		NHMRC (1996)
	200 ppb or 570 µg/m^3	1 hour	One hour clock mean	NEPC (1998)
	80 ppb or 228 µg/m^3	1 day	Calendar day mean	NEPC (1998)
	20 ppb or 60 µg/m^3	1 year	Calendar year mean	NEPC (1998)
Lead (Pb)	0.5 µg/m^3	1 year	Calendar year mean	NEPC (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	NEPC (1998)
	80 ppb or 171 µg/m^3	4 hours	Rolling mean of 1-hour clock means	NEPC (1998)
Hydrogen fluoride (HF)(a)	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) 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.

For the criteria pollutants included in the assessment, the impact assessment criteria in the NSW Approved Methods (NSW EPA, 2016) and the AAQ NEPM from February 2016 are compared with the WHO guidelines (WHO, 2000) and the standards in other countries/organisations in Table B-5. For CO the NSW standards are numerically lower than, or equivalent to, those in most other countries and organisations. The NSW standards for NO_2 are higher than in the other countries and organisations except for the United States. In the case of PM_{10}, the NSW standard for the 24-hour mean is lower than, or equivalent to, the standards in force elsewhere, whereas the annual mean standard is in the middle of the range of values for other locations. The $PM_{2.5}$ standards are lower than, or equivalent to, those used elsewhere.

Such comparisons do not necessarily mean that the Australian standards are more or less stringent than those elsewhere. For example, to a large degree the lower standards in Australia for PM are made possible by relatively low natural background concentrations and the absence of significant anthropogenic transboundary pollution (which is a major issue in Europe). Moreover there are differences in implementation. For example, there is no legal requirement for compliance with the standards and goals in Australia, whereas there is in some other countries and regions.

Table B-5 Comparison of international health-related ambient air quality standards and criteria[(a)]

Country/Region/ Organisation	CO			NO_2			PM_{10}		$PM_{2.5}$	
	15 min. (mg/m³)	1 hour (mg/m³)	8 hours (mg/m³)	1 hour (µg/m³)	1 day (µg/m³)	1 year (µg/m³)	24-hours (µg/m³)	1 year (µg/m³)	24-hours (µg/m³)	1 year (µg/m³)
NSW Approved Methods	100(0)	30(0)	10(0)	246(0)	-	62	50(0)	25	25(0)	8
AAQ NEPM	-	-	10(1)[(b)]	246(1)[(b)]	-	62	50(0)	25	25(0)/20(0)[(c)]	8/7[(c)]
WHO	100(0)	30(0)	10(0)	200	-	40	50[(d)]	20	25[(d)]	10
Canada	-	-	-	-	-	-	120[(e,f)]	-[(e)]	28/27[(g)]	10/8.8[(g)]
European Union	-	-	10(0)	200(18)	-	40	50(35)	40	-	25[(h)]
Japan	-	-	22(0)	-	75-115	-	-	-	-	-
New Zealand	-	-	10(1)	200(9)	-	-	50(1)	-	-	-
UK	-	-	10(0)[(i)]	200(18)	-	40	50(35)	40	-	25
UK (Scotland)	-	-	10(0)[(j)]	200(18)	-	40	50(7)	18	-	12
United States (USEPA)	-	39(1)	10(1)	190[(k)]	-	100	150(1)	-	35[(l,m)]	12[(l)]
United States (California)	-	22(0)	10(0)	344(0)	-	57	50	20	-	12

(a) Numbers in brackets shows allowed exceedances per year for short-term standards. Non-health standards (e.g. for vegetation) have been excluded.
(b) One day per year.
(c) Goal by 2025.
(d) Stated as 99th percentile.
(e) Although there is no national standard, some provinces have standards.
(f) As a goal.
(g) By 2015/2020.
(h) The 25 µg/m³ value is initially a target, but became a limit in 2015. There is also an indicative 'Stage 2' limit of 20 µg/m³ for 2020.
(i) Maximum daily running 8-hour mean.
(j) Running 8-hour mean.
(k) 98th percentile, averaged over 3 years.
(l) Averaged over three years.
(m) Stated as 98th percentile.

B.4.2 Air toxics

The investigation levels in the National Environment Protection (Air Toxics) Measure (Air Toxics NEPM) are summarised in Table B-6. 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 B-6 Investigation levels for air toxics

Source	Substance	Concentration	Averaging period
Air toxics NEPM (investigation levels)	Benzene	0.003 ppm	1 year(a)
	Toluene	1.0 ppm 0.1 ppm	24 hours 1 year(a)
	Xylenes	0.25 ppm 0.20 ppm	24 hours 1 year(d)
	PAHs(b) (as b(a)p)(c)	0.3 ng/m^3 (d)	1 year(a)
	Formaldehyde	0.04 ppm	24 hours

(a) Arithmetic mean of concentrations of 24-hour monitoring results

(b) PAH – polycyclic aromatic hydrocarbons

(c) b(a)p – benzo(a)pyrene, the most widely studied PAH and used as an indicator compound

(d) ng/m^3 – nanograms per cubic metre

The NSW Approved Methods (NSW EPA, 2016) specify air quality impact assessment criteria and odour assessment criteria for many other substances (mostly hydrocarbons), including air toxics, and these are too numerous to reproduce here. The SEARs for the project require an evaluation of benzene, toluene, ethylbenzene and xylenes (BTEX compounds). The impact assessment criteria in the NSW Approved Methods (NSW EPA, 2016) for priority air toxics and BTEX compounds are given in Table B-7.

Table B-7 Impact assessment criteria for air toxics

Source	Substance	Concentration	Averaging period
NSW Approved Methods (impact assessment criteria)	Benzene	0.009 ppm or 29 µg/m^3	1 hour
	Toluene(a)	0.09 ppm or 360 µg/m^3	1 hour
	Ethylbenzene	1.8 ppm or 8000 µg/m^3	1 hour
	Xylenes(a)	0.04 ppm or 190 µg/m^3	1 hour
	PAHs (as b(a)p)	0.4 µg/m^3	1 hour
	1,3-butadiene	0.018 ppm or 40 µg/m^3	1 hour
	Acetaldehyde(a)	0.023 ppm or 42 µg/m^3	1 hour
	Formaldehyde	0.018 ppm or 20 µg/m^3	1 hour

(a) Odour criterion

Annexure C Description and evaluation of NSW EPA emission model

C.1 Overview

A spatial emissions inventory was developed for the road traffic sources in the GRAL domain. The modelling of emissions was required for the following components:

- Emissions from the proposed ventilation outlets of the project tunnel. These were calculated using the emission factors provided by PIARC (2019). This part of the work is described in Annexure K and is not considered further here.

- Emissions from the traffic on the surface road network, including any new roads associated with the project. These were calculated on a link-by-link basis using an emission model[1] developed by NSW EPA (2012b). A description of the NSW EPA model, and an evaluation of its performance, is provided in the following sections.

C.2 NSW EPA model

C.2.1 Hot running exhaust emissions

The NSW EPA method for calculating hot running exhaust emissions involves the use of matrices of 'base composite' emission factors for the following cases:

- Six pollutants (carbon monoxide (CO), oxides of nitrogen (NO_X), nitrogen dioxide (NO_2), particulate matter with effective diameters less than 10 micrometres (PM_{10}) and 2.5 micrometres ($PM_{2.5}$), total hydrocarbons (THC))[2].
- Nine vehicle types: petrol passenger vehicles, diesel passenger vehicles, light-duty commercial petrol vehicles (≤3500 kilograms), light-duty commercial diesel vehicles (≤3500 kilograms), heavy-duty commercial petrol vehicles (>3500 kilograms), rigid trucks (3.5 to 25 tonne, diesel), articulated trucks (>25 tonne, diesel), heavy public transport buses (diesel only), and motorcycles. The composite emission factor for each vehicle type takes into account vehicle kilometres travelled (VKT) by age and the emission factors for specific emission standards.
- Five road types (residential, arterial, commercial arterial, commercial highway, highway/ freeway), to allow for differences in traffic composition and driving patterns.
- Nine model years (2003, 2008, 2011, 2016, 2021, 2026, 2031, 2036 and 2041). The year defines the composition of the fleet for each type of vehicle, allowing for technological changes. The base year for the inventory is 2008, and therefore the data for years after 2008 are projections.

The road types used in the NSW Greater Metropolitan Region (GMR) emissions inventory have been mapped to Transport for NSW functional classes by NSW EPA (Table C-1). Further information on the mapping of these categories is provided in the inventory report (NSW EPA, 2012b).

Each base composite emission factor is defined for a VKT-weighted average speed (the base speed) associated with the corresponding road type. Dimensionless correction factors – in the form of 6^{th}-order polynomial functions – are then applied to the base emission factors to take into account the actual speed on a road. According to NSW EPA, the speed correction factors are valid up to 110 kilometres per hour for light-duty vehicles, and up to 100 kilometres per hour for heavy-duty vehicles.

Emission factors have also been provided by NSW EPA for heavy-duty vehicles with and without the implementation of the Euro VI regulation. Given the uncertainty in the implementation of Euro VI in

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[1] The model used for this assessment was a simplified version of the full inventory model that was developed by NSW EPA for use in the Transport for NSW air quality screening model TRAQ.

[2] It is assumed that $PM_{2.5}$ is equivalent to PM_{10}, which is appropriate for exhaust emissions. The NO_2 emission factors were not used in the assessment.

Australia, the (higher) 'without Euro VI' emission factors were used in the assessment.

Table C-1 Road types used in the NSW EPA emissions inventory model

NSW GMR inventory road type	Transport for NSW functional class	Definition/description
Local/residential	Local road	Secondary road with prime purpose of access to property. Low congestion and low level of heavy vehicles. Generally one lane each way, undivided with speed limit up to 50 kilometres per hour. Regular intersections, mostly unsignalised, and low intersection delays.
Arterial	Sub-arterial and arterial	Connection from local roads to arterials. May provide support role to arterial roads for movement of traffic during peak periods. Distribute traffic within residential, commercial and industrial areas. Speed limit 50 to 70 kilometres per hour, one to two lanes. Regular intersections, mostly uncontrolled. Lower intersection delays than residential roads, but significant congestion impact at high volume:capacity ratio (V/C).
Commercial arterial	Arterial	Major road for purpose of regional and inter-regional traffic movement. Provides connection between motorways and sub-arterials/collectors. May be subject to high congestion in peak periods. Speed limit 60 to 80 kilometres per hour, typically dual carriageway. Regular intersections, many signalised, characterised by stop-start flow, moderate to high intersection delays and queuing with higher V/C.
Commercial highway	Arterial	Major road for purpose of regional and inter-regional traffic movement. Provides connection between motorways and sub-arterials/collectors. May be subject to moderate congestion in peak periods. Speed limit 70 to 90 kilometres per hour, predominantly dual carriageway. Fewer intersections than commercial arterial, with smoother flow but subject to some congestion at high V/C.
Highway/freeway	Motorway	High volume road with primary purpose of inter-regional traffic movement with strict access control (ie no direct property access). Speed limit 80 to 110 kilometres per hour, predominantly two or more lanes and divided carriageway. Relatively free-flowing when not congested, slowing with congestion approaching V/C limit but minimal stopping.

The emission factor for a given traffic speed is calculated as follows:

Equation C1

$$\mathbf{EF_{HotSpd} = EF_{HotBasSpd} \times \frac{SCF_{Spd}}{SCF_{BasSpd}}}$$

Where:

$\mathbf{EF_{HotSpd}}$	is the composite emission factor (in grams per kilometre) for the defined speed
$\mathbf{EF_{HotBasSpd}}$	is the composite emission factor (in grams per kilometre) for the base speed
$\mathbf{SCF_{Spd}}$	is the speed-correction factor for the defined speed
$\mathbf{SCF_{BasSpd}}$	is the speed-correction factor for the base speed

Each speed-correction factor is a sixth order polynomial: $\mathbf{SCF = aV^6 + bV^5 + \ldots + fV + g}$, where **a** to **g** are constants and **V** is the speed in kilometres per hour.

Some examples of the resulting emission factors are shown in the figures below. Figure C-1 shows how oxides of nitrogen (NO_X) emissions (mass per vehicle-kilometre) from petrol cars vary as a function of average speed[3] on different road types. The figures show that some types of road, notably arterial roads, are associated with higher emissions for a given average speed than others. Figure C-2 shows how emissions (again, per vehicle-kilometre) of different pollutants from petrol cars will decrease in the

[3] 'Average speed' should not be confused with 'constant speed'. The former is calculated for a driving cycle which includes periods of acceleration, deceleration, cruise, and idle, as encountered in real-world traffic.

future as emission-control technology improves. Particulate matter (PM) emissions from petrol vehicles are projected to be dominated by non-exhaust particles. Because these are unregulated the reduction in emissions in the future will be lower than for the other pollutants.

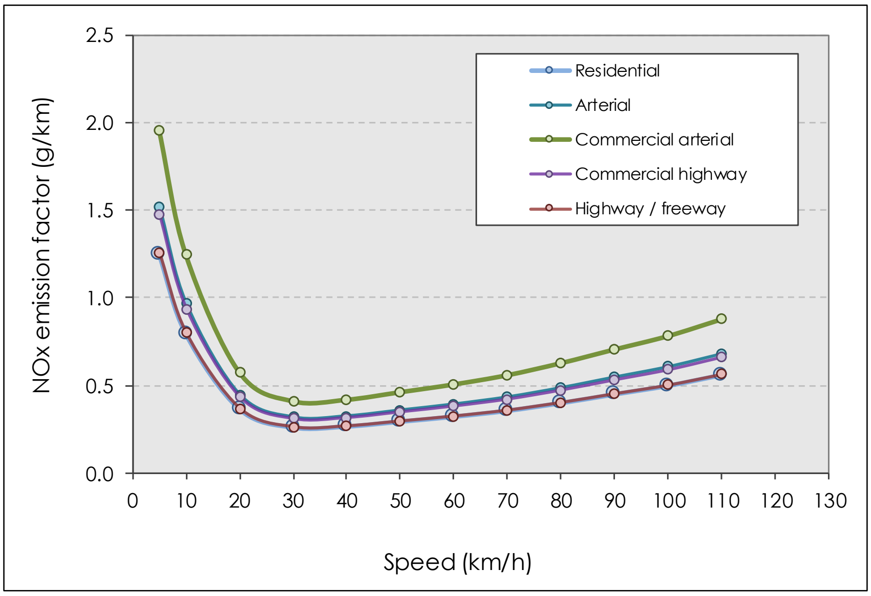

Figure C-1 **NO_x emission factors for petrol cars in 2014**

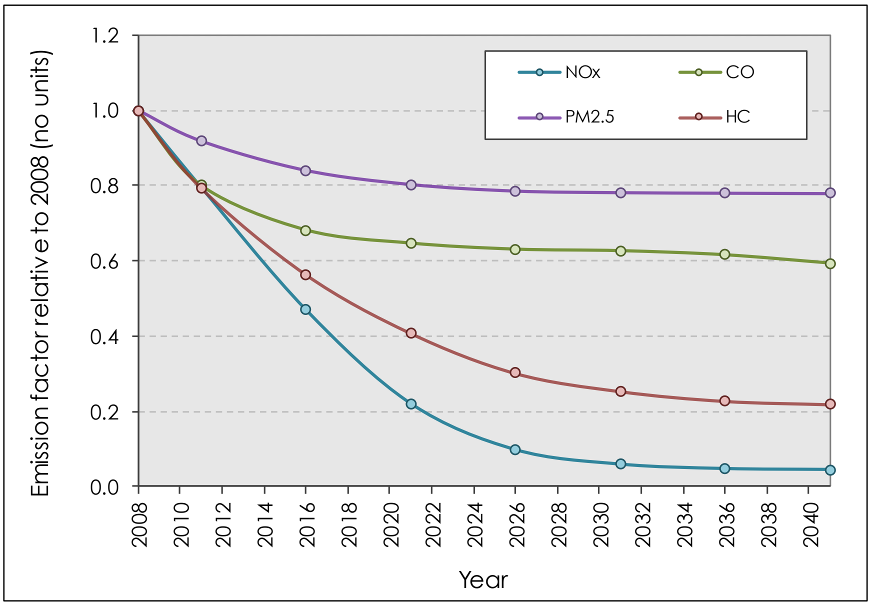

Figure C-2 **Emission factors for petrol cars at 80 kilometres per hour, normalised to 2008**

C.2.2 Gradient factors

NSW EPA has not developed any factors to allow for the effects of road gradient on hot running emissions. For this assessment, gradient factors were determined using the emission rates in PIARC (2019). For each gradient and speed, the gradient correction factor was determined by dividing the corresponding PIARC emission rate by the emission rate for zero gradient.

The gradient correction is introduced as follows:

Equation C2

$$\mathbf{EF_{HotGradCor} = EF_{HotSpd} \times G}$$

Where:

$EF_{HotGradCor}$ is the composite emission factor (in g/km), corrected for road gradient

G is the road gradient correction factor. Different values of **G** are used for each pollutant, vehicle type and speed.

No gradient corrections were applied to THC (any vehicles) or to PM emissions from petrol vehicles.

C.2.3 Cold-start emissions

The method for calculating cold-start emissions involves the application of adjustments to the base hot emission factors to represent the extra emissions which occur during ‘cold running’. The adjustments take into account the distance driven from the start of a trip, the parking duration and the ambient temperature. Cold-start emissions are only calculated for light-duty vehicles, and no cold-start adjustment is made for PM. The amount of ‘cold running’ is dependent on the road type, and no cold running is assumed for highways.

Cold-start emissions are therefore calculated as follows:

Equation C3

$$\mathbf{EF_{Cold} = EF_{HotBasSpd} \times (CS\text{-}1)}$$

Where:

EF_{Cold} is the cold-start emission factor (in grams per kilometre)

CS is a cold start adjustment factor (>1). Different values of **CS** are used for each pollutant, vehicle type, road type and year.

C.2.4 Non-exhaust PM emissions

The method for non-exhaust PM_{10} and $PM_{2.5}$ emissions was taken from the EMEP/EEA Air Pollutant Emission Inventory Guidebook (EEA, 2016), and included tyre wear, brake wear and road surface wear. Emission factors (in grams per kilometre) were provided for each vehicle type, road type and year. Information was required for parameters such as vehicle load and number of axles, and the assumptions used for vehicles in the NSW GMR are described in NSW EPA (2012b).

C.2.5 Evaporative emissions

Evaporative emissions of volatile organic compounds (VOCs) are not included in the version of the NSW EPA model described here, although they are included in the more detailed full inventory model. The calculation of evaporative emissions is relatively complex, as it requires an understanding of temperature profiles, fuel vapour pressure, fuel composition, and operational patterns. Moreover, it is difficult to allocate evaporative emissions to traffic activity on specific road links, as running losses are only one component (for example, evaporative emissions also occur when vehicles are stationary). For these reasons evaporative emissions have been excluded from the assessment. Ambient concentrations of VOCs are also very low, and the inclusion of evaporative emissions would be unlikely to result in adverse impacts on air quality.

C.3 Fleet data

In order to combine the emission factors in the models with traffic data, information was also required on the following:

- The fuel split (petrol/diesel) for cars. This was assumed to be the same for all road types.
- The fuel split (petrol/diesel) for light commercial vehicles (LCVs). This was also assumed to be the same for all road types.
- The sub-division of heavy-duty vehicles (HDVs) into rigid heavy goods vehicles (HGVs), articulated HGVs and buses. This was dependent on road type. For example, the proportion of HGVs on major roads is typically higher than that on minor roads.

The fuel splits were originally provided by NSW EPA for the road types included in the emission model. More recently, Transport for NSW has provided a revised fleet model to support the calculation of in-tunnel emissions (O'Kelly, 2016). The fuel splits for cars and LCVs from the Transport for NSW work were used by ERM to update the fleet data provided by NSW EPA. Figure C-3 and Figure C-4 compare the projections - shown as the percentage of diesel vehicles in the fleet - for cars and LCVs respectively. For cars, in the years between around 2012 and 2027 the percentage of diesel vehicles estimated by Transport for NSW is very similar to that estimated by NSW EPA. Between 2027 and 2037 the projections diverge, with the diesel percentage in the Transport for NSW fleet model being higher than that in the NSW EPA fleet model. In the case of LCVs, the Transport for NSW fleet model has a consistently larger percentage of diesel vehicles than the NSW EPA model between 2012 and 2037. The difference also increases with time, from around 10 percentage points in 2012 to around 30 percentage points in 2037.

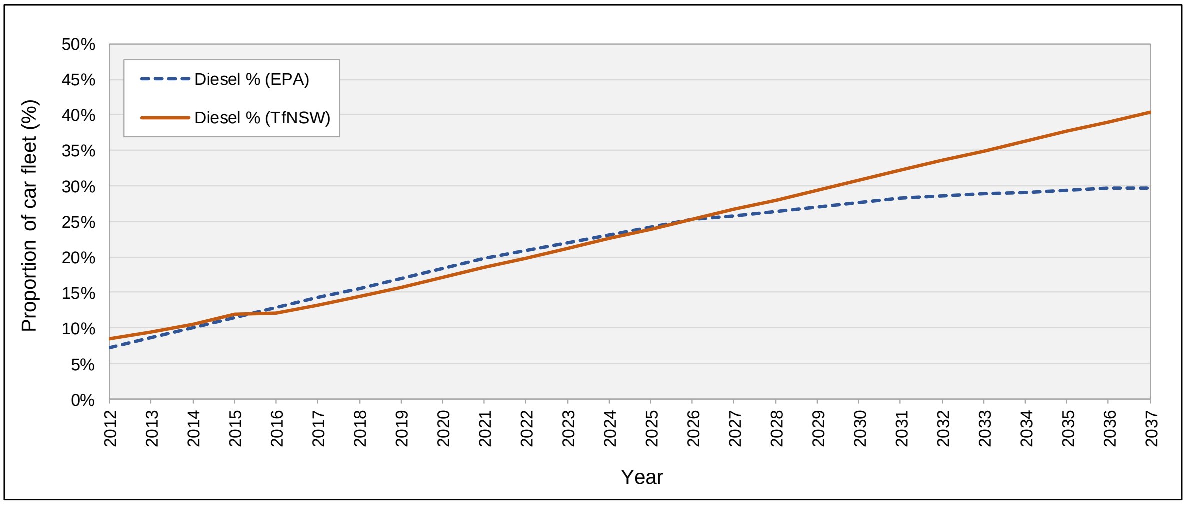

Figure C-3 Fuel split for cars: original NSW EPA data and Transport for NSW data

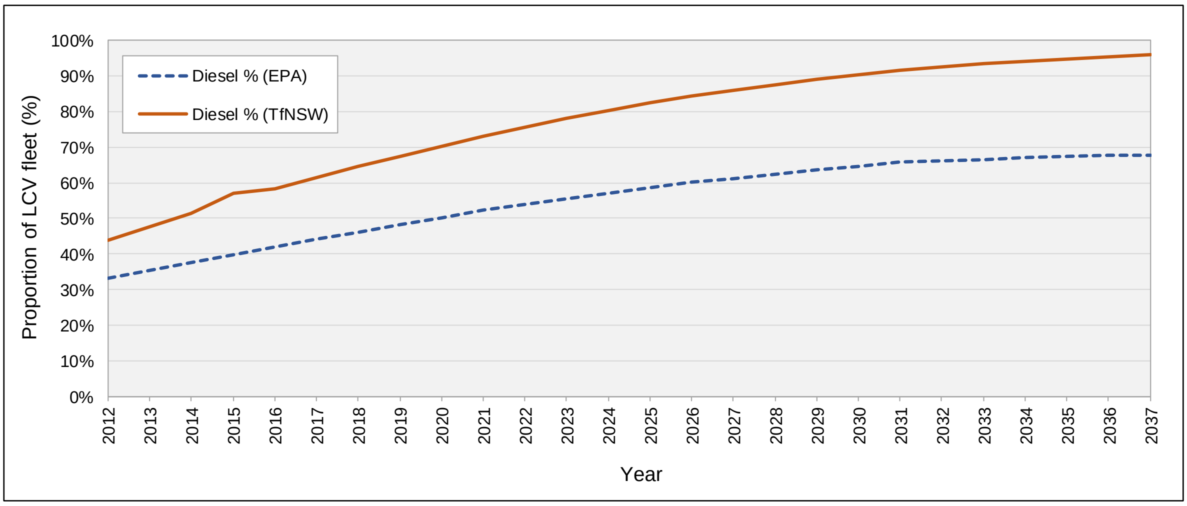

Figure C-4 **Fuel split for LCVs: original NSW EPA data and Transport for NSW data**

The Transport for NSW fleet model did not differentiate between different types of road. For the sub-division of HDVs the default traffic mix information provided by NSW EPA was therefore used. The sub-division of HDVs into rigid HGVs, articulated HGVs and buses is shown in Figure C-5.

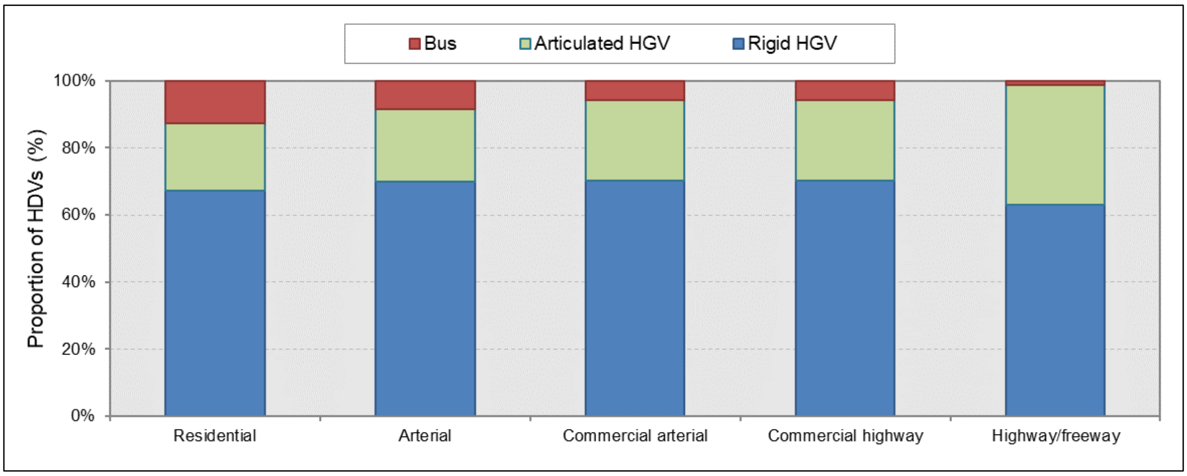

Figure C-5 **Vehicle type split by road type for HDVs (year = 2027)**

C.4 Model validation

C.4.1 Overall model performance

The accuracy of the NSW EPA model[4] in representing vehicle emissions (CO, NO_X, NO_2, PM_{10} and $PM_{2.5}$) was investigated using measurements from the ventilation outlets of the Lane Cove Tunnel during October and November 2013, as described in Pacific Environment (2014). The ventilation conditions in the tunnel result in all vehicle emissions being released from the ventilation outlets. No pollution is released from the tunnel portals. This makes it possible to compare the predicted mass emission rate (in g/h) for the traffic in each direction of the tunnel with the observed emission rate in the corresponding ventilation outlet. The measurement equipment is shown in Figure C-6. Laboratory-grade instruments compliant with Australian Standards were used for measuring in-stack concentrations, and these are summarised in Table C-2. The air flows in the stacks were measured using pitot tubes; to minimise artefacts, the measurements were taken at a point approximately two metres from the stack walls.

Figure C-6 Air pollution measurements at Lane Cove Tunnel outlet

Table C-2 Instruments used for in-stack pollution measurements

Pollutant(s)	Method	Instrument	Range/limit of detection
CO	Non-dispersive infrared (NDIR) gas filter correlation spectroscopy	Ecotech EC9830A	0-200 ppm / 50 ppb
$NO/NO_2/NO_X$	Chemiluminescence detection (CLD)	Ecotech EC9841AS	0-1,000 ppm / 10 ppb
PM_{10}	Tapered Element Oscillating Microbalance (TEOM)	Thermo Scientific TEOM 1400ab	0-5 g/m³ / 0.06 µg/m³
$PM_{2.5}$	TEOM	Thermo Scientific TEOM 1400ab	0-5 g/m³ / 0.06 µg/m³
THC/NMHC	Flame ionisation detector (FID)	Baseline-Mocon Series 9000	1-200 ppm / 60 ppb

[4] It should be noted that this work excludes the changes to the fuel splits for cars and LCVs following the Transport for NSW fleet model revision in 2016.

The predicted and observed total (ie for all traffic) emission rates in the Lane Cove Tunnel were compared using a linear regression approach. The regression plots are shown in Figure C-7. Separate results are shown for each pollutant and each direction in the tunnel; the eastbound tunnel is predominantly uphill, and the westbound tunnel is predominantly downhill. In each graph the dashed red line represents a 1:1 ratio between the predicted and observed emission rates, and the solid lines show the linear regression fits to the data, forced through the origin[5]. The average quotients of the predicted and observed values are given in Table C-3.

Some general patterns were apparent in the results:

- On average, the model **overestimated** emissions of each pollutant in the tunnel, and by a factor of between 1.7 and 3.3.

  This overestimation is likely to be due, at least in part, to the following:

  - The over-prediction built into the PIARC gradient factors, as well as other conservative assumptions.
  - The tunnel environment itself affecting emissions. The piston effect and any forced ventilation in the direction of the traffic flow may combine to produce an effective tail wind that reduces aerodynamic drag on the vehicles in the tunnel (John et al., 1999; Corsmeier et al., 2005).
  - A possible overestimation of the age of the vehicle fleet in the tunnel.

  However, the differences between the predicted and observed emission rates are influenced not only by errors in the emission factors in the model, but also errors in the assumptions concerning the fleet composition and age distribution.

- There was a strong correlation between the predicted and observed emission rates for CO, NO_X, PM_{10} and $PM_{2.5}$, with an R^2 value of between 0.75 and 0.88. The strong correlations were due in large part to the narrow range of operational conditions (ie traffic composition, speed) in the Lane Cove Tunnel. In fact, the modelled emission rates were more or less directly proportional to the traffic volume.
- Different regression slopes were obtained for the eastbound and westbound directions. The eastbound tunnel has a net uphill gradient which would increase engine load and emissions, whereas in the downhill westbound tunnel engines would tend to be under lower load, with some newer vehicles with electronic fuel injection possibly having very low fuelling on downgrades. Such effects may not be adequately reflected in the gradient adjustment approach in the model.
- In the westbound tunnel the NO_2 data had more scatter than the NO_X data, and a low correlation coefficient was obtained. This is in part due to the relatively low emissions in the westbound tunnel and is possibly also a consequence of the measurement technique (chemiluminescence), which does not generally respond well to NO_2 concentrations which fluctuate rapidly on short timescales. The NO_X measurements are less affected by this problem, and ought to be more reliable.

[5] As the outlet emission rates were adjusted for the background contribution, and there were no other in-tunnel emission sources, it was considered acceptable to run the regression model with the constant constrained to zero.

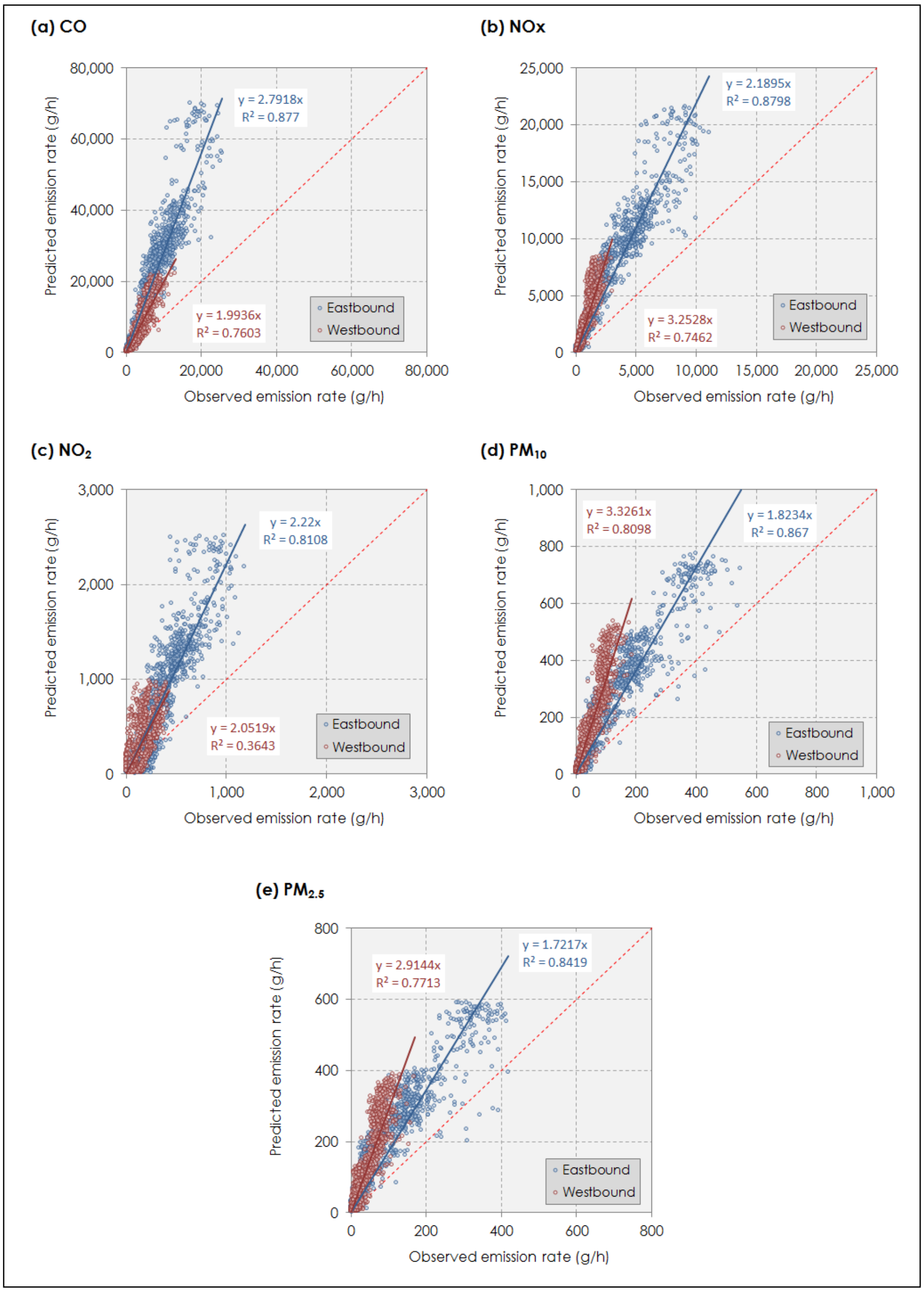

Figure C-7 Predicted vs observed emission rates – NSW EPA model

Table C-3 Summary of predicted vs observed emission rates – NSW EPA model

Model	Predicted emission rate / observed emission rate				
	CO	NO_X	NO_2	PM_{10}	$PM_{2.5}$
Eastbound					
NSW EPA	2.79	2.19	2.22	1.82	1.72
Westbound					
NSW EPA	1.99	3.25	2.06	3.32	2.91

C.4.2 Emission factors by vehicle type

A multiple linear regression (MLR) approach was used to determine mean emission factors (in grams per kilometre) for LDVs and HDVs based on the adjusted outlet emission rates (CO, NO_X, PM_{10} and $PM_{2.5}$). Multiple linear regression can be used to test how well a dependent variable can be predicted on the basis of multiple independent variables. The inputs to the MLR were the hourly mean emission factor for the traffic (dependent variable) and the corresponding numbers of LDVs and HDVs in the tunnel each hour (independent variables). A similar MLR method has been used in various studies to derive emission factors (e.g. Imhof et al., 2005; Colberg et al., 2005). The following regression model was applied to derive the emission factors:

Equation C4

$$\mathbf{EF_{total} = (N_{LDV} \times EF_{LDV}) + (N_{HDV} \times EF_{HDV}) + c}$$

where:

$\mathbf{EF_{total}}$	=	the hourly mean emission factor for all traffic in the tunnel, as determined from the tunnel ventilation outlet measurements (gram per kilometre per hour)
$\mathbf{N_{LDV}}$	=	the number of LDVs in the tunnel per hour (vehicles per hour)
$\mathbf{N_{HDV}}$	=	the number of HDVs in the tunnel per hour (vehicles per hour)
$\mathbf{EF_{LDV}}$	=	the emission factor per LDV in the tunnel (grams per vehicle-kilometre)
$\mathbf{EF_{HDV}}$	=	the emission factor per HDV in the tunnel (grams per vehicle-kilometre)
c	=	a constant (intercept on y-axis)

The hourly mean emission factor for all traffic in the tunnel was obtained by dividing the emission rate by the length of the main line tunnel (3.61 kilometres), with the on- and off-ramps being ignored. The emissions on the ramps were negligible (less than around two per cent) compared with the emissions on the main lines. As the outlet emission rates had already been adjusted to allow for the background contribution, and as there were no other in-tunnel emission sources it was considered acceptable to run the regression model with the constant constrained to zero.

The overall mean observed and predicted emission factors for LDVs, HDVs and all traffic (weighted for traffic volume) are shown in Table C-4, and the predicted/observed ratios are given in Table C-5.

It has already been observed that the NSW EPA model overestimated emissions in the Lane Cove Tunnel. It was noted in Pacific Environment (2014) that this is due in large part to the use of conservative gradient scaling factors. These additional results show that:

- For LDVs the predicted emissions were higher than the observed emissions in both the eastbound and westbound tunnels.
- For HDVs, emissions of CO, NO_X, PM_{10} and $PM_{2.5}$ in the eastbound tunnel were underestimated by the model, whereas emissions of NO_2 were overestimated. In the westbound tunnel the predicted emissions were considerably higher than the observed emissions, especially for NO_2.

Table C-4 Emission factors by vehicle type and direction

Direction	Pollutant	LDV (g/vehicle.km)		HDV (g/vehicle.km)		All traffic (g/vehicle.km)[(a)]	
		Observed	NSW EPA	Observed	NSW EPA	Observed	NSW EPA
Eastbound	CO	1.47	4.61	3.66	1.09	1.62	4.48
	NO_X	0.29	1.18	8.42	6.93	0.61	1.39
	NO_2	0.06	0.14	0.37	0.85	0.08	0.16
	PM_{10}	0.01	0.04	0.36	0.31	0.03	0.05
	$PM_{2.5}$	0.01	0.03	0.32	0.27	0.02	0.04
Westbound	CO	0.72[(b)]	1.53	-[(c)]	0.48	0.78	1.49
	NO_X	0.13	0.51	1.07	2.78	0.18	0.60
	NO_2	0.03	0.06	0.03	0.34	0.03	0.07
	PM_{10}	0.01	0.03	0.08	0.21	0.01	0.04
	$PM_{2.5}$	0.01	0.02	0.07	0.17	0.01	0.03

(a) Weighted for traffic volume.
(b) Based on regression for LDV only (see point (c) below).
(c) Multiple regression analysis did not result in a valid emission rate.

Table C-5 Predicted/observed emission factors by vehicle type and direction

Direction	Pollutant	LDV (predicted/observed)	HDV (predicted/observed)	All traffic (predicted/observed)[(a)]
Eastbound	CO	3.1	0.3	2.8
	NO_X	4.0	0.8	2.3
	NO_2	2.4	2.3	2.1
	PM_{10}	3.0	0.9	1.9
	$PM_{2.5}$	3.2	0.8	1.9
Westbound	CO	N/A	N/A	1.9
	NO_X	3.8	2.6	3.2
	NO_2	2.2	11.6	2.2
	PM_{10}	3.9	2.7	3.3
	$PM_{2.5}$	3.3	2.6	2.9

(a) Weighted for traffic volume.

Annexure D Existing air quality and background concentrations

D.1 Introduction and objectives

This Annexure provides the results of a thorough analysis of the air quality monitoring data from multiple monitoring stations in a large area of Sydney and in the Beaches Link model domain.

The data were used for the following purposes:

(A) To define long-term trends and patterns in air quality in Sydney.

(B) To define background concentrations[1] in the 2016 base year. Only monitoring stations with data for 2016 (partially or in full) were used to derive background concentrations.

(C) To describe the project-specific air quality monitoring for Western Harbour Tunnel and Beaches Link.

(D) To develop empirical methods for converting modelled NO_X to NO_2, and maximum 1-hour CO to maximum 8-hour CO. These were based on all available data for all stations.

(E) To evaluate model performance. This involved a comparison of model predictions with roadside measurements for the 2016 base year. However, there was only one roadside station in the GRAL domain, and this limited the extent to which model performance could be evaluated.

This Annexure focusses on items (A), (B) and (C). Items (D) and (E) are presented in Annexures E and H, respectively. However, all the stations used in the analysis are identified here.

D.2 Monitoring stations

The siting and classification of air quality monitoring stations is governed, as far as practicable, by the requirements of *Australian Standard AS/NZS 3580.1.1:2007 - Methods for sampling and analysis of ambient air - Guide to siting air monitoring equipment*. The Standard recognises that air quality is monitored for different purposes, and for convenience it classifies monitoring stations as follows based on functional requirements:

- Peak stations. These are located where the highest concentrations and exposures are expected to occur (such as near busy roads or industrial sources).
- Neighbourhood stations. These are located in areas which have a broadly uniform land use and activity (e.g. residential areas or commercial zones).
- Background stations. These stations are located in urban or rural areas to provide information on air quality away from specific sources of pollution such as major roads or industry.

The Standard also recognises that, in practice, a given station may serve more than one function.

Considerations when siting a monitoring station include the possibility of restricted airflow caused by vicinity to buildings, trees, walls, *etc.*, and chemical interference due to, for example, local industrial emissions.

[1] When predicting the impact of any new or modified source of air pollution, it is necessary to take into account the ways in which the emissions from the source will interact with existing pollutant levels. Defining these existing levels and the interactions can be challenging, especially in a large urban area such as Sydney where there is a complex mix of sources. Pollutant concentrations can fluctuate a great deal on short time scales, and substantial concentration gradients can occur in the vicinity of sources such as busy roads. Meteorological conditions and local topography are also very important; cold nights and clear skies can create temperature inversions which trap air pollution near ground level, and local topography can increase the frequency and strength of these inversions. In the case of particulate matter, dust storms, natural bush fires and planned burning activities are often associated with the highest concentrations (SEC, 2011).

Air pollutants and meteorological parameters – such as temperature, wind speed and wind direction – are usually measured automatically and continuously, and such monitoring is conducted at several locations across Sydney.

All the monitoring stations used in the air quality assessment, in one way or another, are listed in Table D-1, and the application of each station is identified. For the purpose of the analysis the air quality monitoring data were separated according to station type. The locations of the background stations are shown in Figure D-1, along with the modelling domain for GRAL. The corresponding map for the roadside and near-road stations is provided in Figure D-2. Several of the stations listed in Table D-1 were further away from the GRAL domain, and are not shown in the Figures, but were still included in some aspects of the assessment (e.g. trend analysis, NO_X-to-NO_2 conversion).

Until relatively recently, almost all of the air quality monitoring in Sydney has focussed on background locations within urban agglomerations but away from specific sources such as major roads. The monitoring stations in Sydney that are operated by the Department of Planning, Environment and Industry (DPIE)) are located in such environments, and these have provided a long and vital record of regional air quality. The closest active DPIE monitoring stations with a long monitoring record to the GRAL domain are those at Rozelle and Lindfield. The Rozelle station was the only background station was inside the GRAL domain. The DPIE Lindfield station was slightly outside the domain. DPIE has also established a station at Macquarie Park, around 3 kilometres from the western boundary of the GRAL domain, but the monitoring only began in 2017. A DPIE station was established in Sydney CBD within the GRAL domain, but the monitoring only began in 2019. The other DPIE stations were further away from the domain, but were still considered to be important in terms of characterising air quality in Sydney.

Transport for NSW has established several long-term monitoring stations in response to community concerns relating to the ventilation outlet of the M5 East Tunnel, and to monitor operational compliance of the tunnel with ambient air quality standards. Four of the M5 East stations (CBMS, T1, U1, X1) are in the vicinity of the M5 East ventilation outlet. Stations U1 and X1 are located on a ridge to the north of the outlet, in the region of the predicted maximum impact. However, the impacts of the outlet at the monitoring stations are very small in practice, and these could effectively be considered as urban background stations. Two M5 East stations (F1 and M1) are much closer to busy roads near the M5 East tunnel portals.

Consideration was also given to shorter time series data from other Transport for NSW air quality monitoring stations. Several monitoring stations were established for the NorthConnex project (the stations are identified in AECOM, 2014a), with data being available from December 2013 to January 2015. Data were also available from an additional Transport for NSW roadside station (‘Aristocrat’), located near the junction of Epping Road and Longueville Road. The Aristocrat station was only operational between 2008 and 2009, but given the low number of roadside monitoring stations in Sydney until recently, the data were still considered to be valuable to the analysis.

Transport for NSW established a WestConnex (WCX) monitoring network to address some of the gaps in the DPIE and Transport for NSW monitoring in terms of pollutants and locations, and TfNSW engaged Pacific Environment (now ERM) to operate and maintain the network. The WestConnex network includes monitoring stations at both urban background and near-road stations. Five new monitoring stations were introduced in the M4 East (now known as WestConnex M4) area, seven new stations in the New M5 (now known as WestConnex M8) area, and two new stations in the M4-M5 Link area to support the development and assessment of the respective projects. Some of the WestConnex monitoring stations were subsequently relocated or decommissioned. Of the WestConnex stations, only the station near to City West Link was inside the GRAL domain for the Beaches Link project.

Three project-specific monitoring stations for Western Harbour Tunnel and Beaches Link were established by Transport for NSW in 2017. One of these was at a background location, and the other two were at locations near busy roads. Given the date of deployment, the time period covered was too short for these to be included in the development of background concentrations and model evaluation. However, the data from the stations are presented in this Annexure.

Table D-1 Air quality monitoring stations

Organisation	Project	Station name	Location	Station type	Easting	Northing	Period covered in analysis	Application					
								Air quality trends	Background concentrations	Project monitoring	NO_X to NO_2 conversion	CO 1h to 8h conversion	Model performance
DPIE	N/A	Chullora	Southern Sydney TAFE - Worth St	Urban background	319315	6248145	Jan 2004 to Dec 2019	✓	✓	✓[b]	✓	✓	-
		Earlwood	Beaman Park	Urban background	327663	6245576	Jan 2004 to Dec 2019	✓	✓	✓[b]	✓	-	-
		Lindfield	Bradfield Road	Urban background	328802	6260577	Jan 2004 to Dec 2019	✓	✓	✓[b]	✓	-	-
		Liverpool	Rose Street	Urban background	306573	6243485	Jan 2004 to Dec 2019	✓	✓	-	✓	✓	-
		Macquarie Park	Macquarie University Sport Fields	Urban background	325695	6262277	Oct 2017 to Dec 2019	-	-	✓[b]	✓	-	-
		Prospect	William Lawson Park	Urban background	306901	6258703	Jan 2004 to Dec 2019	✓	✓	-	✓	✓	-
		Randwick	Randwick Barracks	Urban background	337588	6244021	Jan 2004 to Dec 2019	✓	✓	✓[b]	✓	-	-
		Rozelle	Rozelle Hospital	Urban background	330169	6251372	Jan 2004 to Dec 2019	✓	✓	✓[b]	✓	✓	-
		Cook & Philip	Cook and Philip Park	Urban background	334729	6250503	Sep 2019 to Dec 2019	-	-	-	-	-	-
TfNSW	Lane Cove Tunnel	Aristocrat	Longueville road / Epping Road	Peak (roadside)	330661	6257118	Oct 2008 to Nov 2009	-	-	-	✓	✓	-
	M5 East Tunnel	M5E: CBMS	Gipps Street, Bardwell Valley	Urban background	327713	6243517	Jan 2008 to Dec 2018	✓	✓	-	✓	✓	-
		M5E: T1	Thompson Street, Turrella	Urban background	328820	6244172	Jan 2008 to Dec 2018	✓	✓	-	✓	✓	-
		M5E: U1	Jackson Place, Earlwood	Urban background	328277	6244422	Jan 2008 to Dec 2018	✓	✓	-	✓	✓	-
		M5E: X1	Wavell Parade, Earlwood	Urban background	327923	6244507	Jan 2008 to Dec 2018	✓	✓	-	✓	✓	-
		M5E: F1	Flat Rock Rd, Kingsgrove (M5 East)	Peak (roadside)	325204	6243339	Jan 2008 to Oct 2017	-	-	-	✓	✓	-
		M5E: M1	M5 East tunnel portal	Peak (roadside)	329258	6243283	Jan 2008 to Oct 2017	-	-	-	✓	✓	-
	NorthConnex	NCx:01	Headen Sports Park	Urban background	322016	6266696	Dec 2013 to Jan 2015	-	-	-	✓	✓	-
		NCx:02	Rainbow Farm Reserve	Urban background	318901	6262641	Dec 2013 to Jan 2015	-	-	-	✓	✓	-
		NCx:03	James Park	Urban background	325165	6269440	Dec 2013 to Jan 2015	-	-	-	✓	✓	-
		NCx:04	Observatory Park	Peak (roadside)	320643	6264950	Dec 2013 to Jan 2015	-	-	-	✓	✓	-
		NCx:05	Brickpit Park	Peak (roadside)	323027	6266847	Dec 2013 to Jan 2015	-	-	-	✓	✓	-
	WHTBL	WHTBL:01	Reserve Street, Bantry Bay	Urban background	337216	6260688	Oct 2017 to Jan 2019	-	-	✓	✓	-	-
		WHTBL:02	Hope Street, Seaforth	Peak (near-road)[a]	338307	6259481	Oct 2017 to Jan 2019	-	-	✓	✓	-	-
		WHTBL:03	Rhodes Avenue, Naremburn	Peak (near-road)[a]	333652	6256571	Oct 2017 to Jan 2019	-	-	✓	✓	-	-
WCX	WestConnex M4 East	M4E:01	Wattle Street, Haberfield	Peak (roadside)	327563	6250234	Aug 2014 to Mar 2016	-	-	-	✓	✓	-
		M4E:02	Edward Street, Concord	Peak (near-road)[a]	323764	6251146	Sep 2014 to Mar 2016	-	-	-	✓	✓	-
		M4E:03	Bill Boyce Reserve, Homebush	Peak (near-road)[a]	322467	6251602	Sep 2014 to Mar 2016	-	-	-	✓	✓	-
		M4E:04	Concord Oval, Concord	Peak (roadside)	325030	6250752	Nov 2014 to Sep 2017	-	-	-	✓	✓	-
		M4E:05	St Lukes Park, Concord	Urban background	325187	6251158	Nov 2014 to Sep 2017	-	✓	-	✓	✓	-
	WestConnex New M5	New M5:01	St Peters Public School, Church St	Urban Background	331330	6246007	Aug 2015 to Dec 2017	-	✓	-	✓	✓	-
		New M5:02	Princes Highway, St Peters	Peak (roadside)	331661	6246053	Jul 2015 to Apr 2016	-	-	-	✓	-	-
		New M5:03	West Botany St, Arncliffe	Peak (roadside)	329182	6243268	Aug 2015 to Jun 2016	-	-	-	✓	-	-
		New M5:04	Bestic St, Rockdale	Urban Background	329175	6241749	Jul 2015 to Sep 2016	-	✓	-	✓	-	-
		New M5:05	Bexley Rd, Kingsgrove	Peak (roadside)	325359	6243491	Jul 2015 to Apr 2016	-	-	-	✓	-	-
		New M5:06	Beverly Hills Park, Beverly Hills	Urban Background	323296	6242297	Jul 2015 to Sep 2016	-	✓	-	✓	-	-
		New M5:07	Canal Rd, St Peters	Peak (road/industrial)	331520	6245420	Jul 2015 to Apr 2016	-	-	-	✓	-	-
	WestConnex M4-M5 Link	M4-M5:01	City West Link, Rozelle	Peak (roadside)	331142	6250768	Apr 2016 to Dec 2017	-	-	-	✓	-	✓
		M4-M5:02	Ramsay Street, Haberfield	Peak (roadside)	327363	6250306	Apr 2016 to Dec 2017	-	-	-	✓	-	-

(a) Due to practical constraints at this location, the monitoring station is some distance from the closest major road (M4 motorway). Nevertheless, the monitoring station should adequately characterise exposure to air pollution at nearby properties.

(b) For comparison against WHTBL monitoring data.

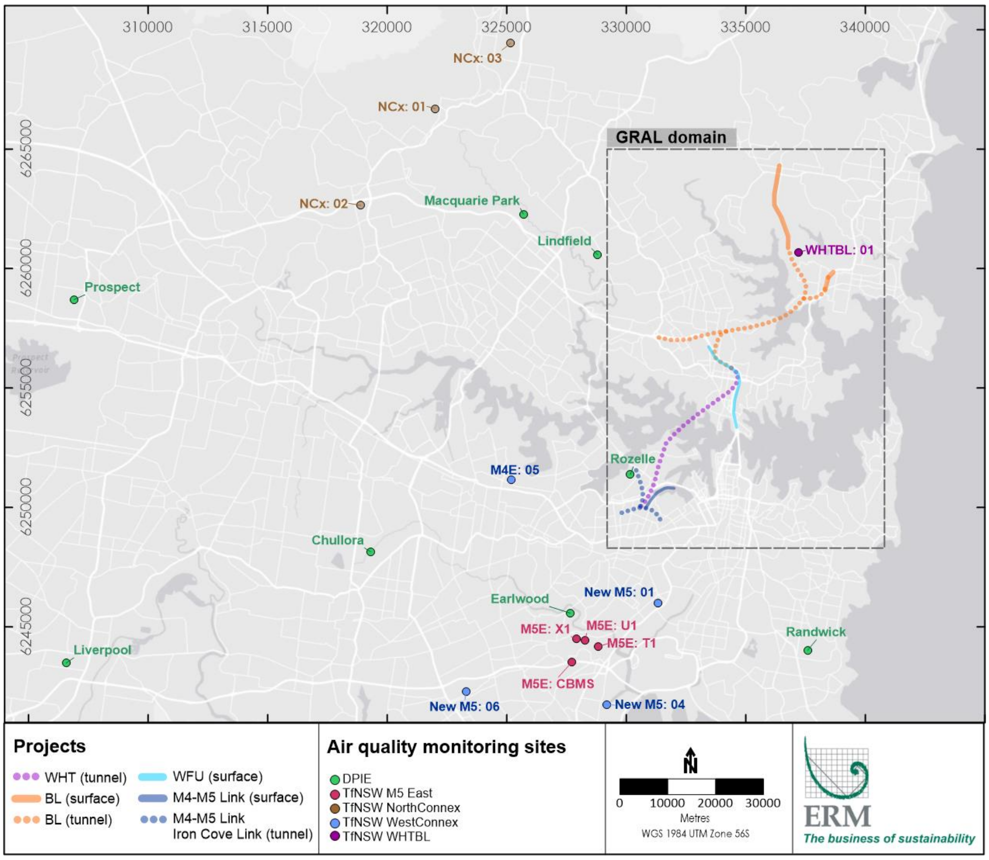

Figure D-1 Locations of background air quality monitoring stations

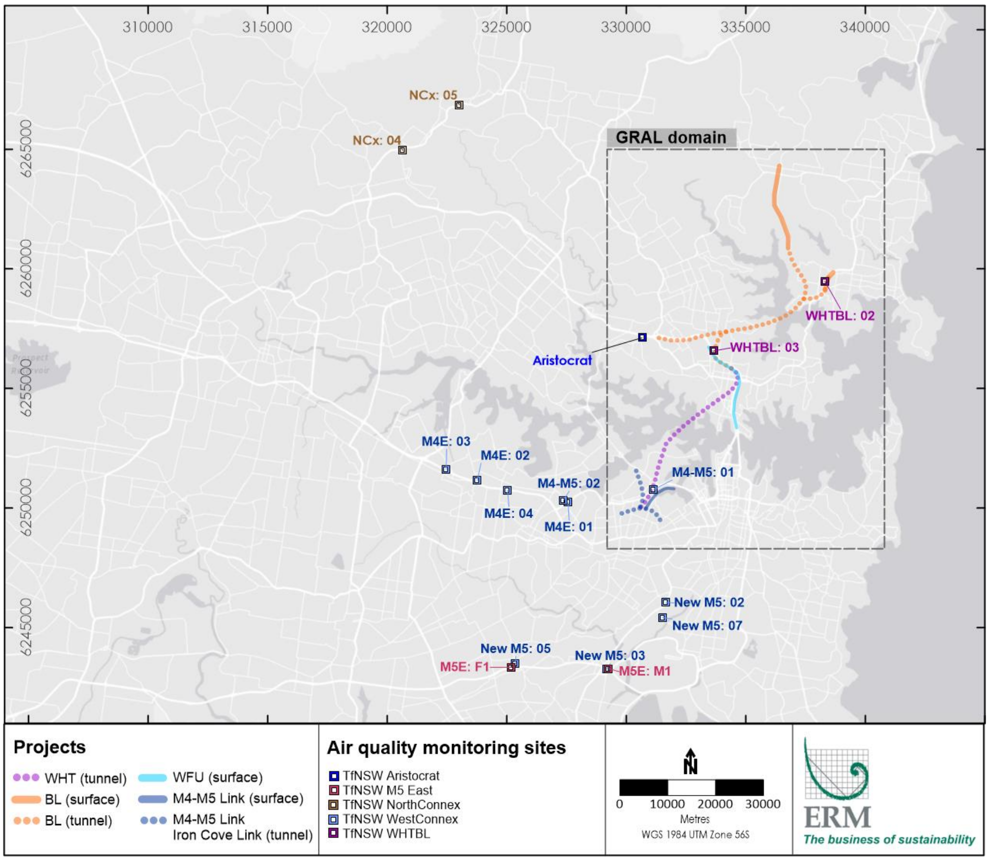

Figure D-2 Locations of road air quality monitoring stations

D.3 Measured parameters and methods

The parameters measured at each station are given in Table D-2. The coverage of pollutants was variable. NO, NO_2 and NO_X were measured at all stations, and CO was measured at most stations. Ozone was measured at the DPIE and WCX stations, but not at the Transport for NSW M5 East and Aristocrat stations. PM_{10} was measured at all stations except Aristocrat. $PM_{2.5}$ was measured at fewer stations, and there was only a longer-term record of $PM_{2.5}$ at three DPIE stations. Although not shown in Table D-2, hydrocarbons[2] are measured continuously at the WCX and Transport for NSW WHTBL stations. Hydrocarbons are not measured routinely at the DPIE and Transport for NSW M5 East stations.

Table D-2 Parameters by monitoring station

Monitoring station		Pollutants					Meteorological parameters			
		CO	NO, NO_2, NO_X	O_3	PM_{10} (a)	$PM_{2.5}$ (a)	WS, WD (b)	Temp.	Humidity	Solar radiation
DPIE	Chullora	✓	✓	✓	✓†	✓§	✓	✓	✓	✓
	Earlwood	-	✓	✓	✓†	✓§	✓	✓	✓	-
	Lindfield	-	✓	✓	✓†	-	✓	✓	✓	-
	Liverpool	✓	✓	✓	✓†	✓§	✓	✓	✓	✓
	Macquarie Park	✓	✓	✓	✓†	✓‡	✓	✓	✓	✓
	Prospect	✓	✓	✓	✓†	✓‡	✓	✓	✓	✓
	Randwick	-	✓	✓	✓†	-	✓	✓	✓	-
	Rozelle	✓	✓	✓	✓†	✓‡	✓	✓	✓	✓
	Cook & Philip	✓	✓	✓	✓†	✓‡	✓	✓	✓	✓
RMS	Aristocrat	✓	✓	-	-	-	✓	✓	✓	✓
	M5E: CBMS	✓	✓	-	✓†	-	✓	✓	✓	✓
	M5E: T1	✓	✓	-	✓†	-	✓	✓	✓	✓
	M5E: U1	✓	✓	-	✓†	-	✓	✓	✓	✓
	M5E: X1	✓	✓	-	✓†	-	✓	✓	✓	✓
	M5E: F1	✓	✓	-	✓†	-	✓	✓	✓	✓
	M5E: M1	✓	✓	-	✓†	-	✓	✓	✓	✓
	NCx:01	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	NCx:02	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	NCx:03	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	NCx:04	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	NCx:05	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	WHTBL:01	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	WHTBL:02	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	WHTBL:03	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
WCX	M4E:01	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	M4E:02	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	M4E:03	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	M4E:04	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	M4E:05	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	New M5:01	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	New M5:02	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	New M5:03	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	New M5:04	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	New M5:05	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	New M5:06	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	New M5:07	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	M4-M5:01	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	M4-M5:02	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓

(a) † TEOM; ‡ BAM; § TEOM/BAM depending on year
(b) WS = wind speed; WD = wind direction

2 Total hydrocarbons, methane, and non-methane hydrocarbons.

The pollutant measurements at each station were conducted in accordance with the relevant Australian Standards[3]. The methods used were, in general terms:

- CO - gas filter correlation infrared (GFC-IR)
- $NO/NO_2/NO_X$ - chemiluminescence detection (CLD)
- O_3 - non-dispersive ultra-violet (NDUV) spectroscopy
- $PM_{10}/PM_{2.5}$ - tapered-element oscillating microbalance (TEOM) and/or beta-attenuation monitor (BAM)

In the case of PM, it is well documented that the measurements are sensitive to the technique used. The data used in this analysis were collected using different instruments, and this clearly introduces some uncertainty in the results. For example, TEOMs were used at the Transport for NSW M5 East stations, whereas BAMs were used at the WestConnex and WHTBL stations. For the measurement of $PM_{2.5}$ at the DPIE stations, TEOMs were used until early 2012. A combination of TEOMs and BAMs were used during 2012, when a decision was made to replace the continuous TEOM $PM_{2.5}$ monitors with the USEPA equivalent-method BAM. However, for traceability, in this assessment all data were used as received.

D.4 Data processing and analysis

The monitoring data were used in the form provided, with the following exceptions:

- For gases, any volumetric concentrations (*e.g.* ppm or ppb) were converted to mass units (*e.g.* mg/m^3 or $\mu g/m^3$). For consistency, an ambient pressure of 1 atmosphere and a temperature of 0^oC were assumed throughout for the conversions. In the NSW Approved Methods, for some pollutants a conversion temperature of 25^oC is used, which gives slightly lower mass concentrations. The use of 0^oC is therefore slightly conservative.

- For PM_{10} and $PM_{2.5}$, the data on days with bush fires and/or dust storms were removed, as the inclusion of the high concentrations that occurred on some of these days could have obscured any underlying trends. The days that were affected by such events were identified by DPIE.

All measurements were initially analysed using an averaging period of one-hour. The data were then further averaged, where appropriate, according to the time periods for the criteria in the NSW Approved Methods. Values were only deemed to be valid where the data capture rate was greater than 75 per cent[4] in any given period.

D.5 Long-term trends at background stations

In this part of the analysis the long-term trends in air pollution at background monitoring stations in Sydney were investigated. Only the DPIE and Transport for NSW monitoring stations with a multi-year record were considered (i.e. Chullora, Earlwood, Lindfield, Liverpool, Prospect, Randwick, Rozelle, CBMS, T1, U1 and X1).

The trend analysis was based mainly on measurements conducted during the 16-year period between 1 January 2004 and 31 December 2019, the principal aims being (i) to understand the temporal and spatial patterns in the data and (ii) to establish background pollutant concentrations for use in the project assessment (2016 base year), taking into account factors such as those identified in section F.1.

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[3] Full details of the methods and procedures used at the WCX monitoring stations are presented in monthly monitoring reports for the M4 East network, and these are available on request from WCX.

[4] Clause 18 (5) of the AAQ NEPM specifies that the annual report for a pollutant must include the percentage of data available in the reporting period. An average concentration can be valid only if it is based on at least 75 per cent of the expected samples in the averaging period. The 75 per cent data availability criterion is specified as an absolute minimum requirement for data completeness (PRC, 2001).

This approach was in accordance with the NSW Approved Methods, which states:

> 'Including background concentrations in the assessment enables the total impact of the proposal to be assessed. The background concentrations of air pollutants are ideally obtained from ambient monitoring data collected at the proposed station. As this is extremely rare, data is typically obtained from a monitoring station as close as possible to the proposed location where the sources of air pollution resemble the existing sources at the proposal station.' (NSW EPA, 2016)

Trends were determined for the following pollutants and metrics, as these are especially relevant to road transport:

- CO – one-hour mean
- CO – rolling 8-hour mean
- NO_X – annual mean
- NO_X – one-hour mean
- PM_{10} – annual mean
- PM_{10} – 24-hour mean
- $PM_{2.5}$ – annual mean
- $PM_{2.5}$ – 24-hour mean

The Mann–Kendall nonparametric test was used to determine the statistical significance of trends at the 90 per cent confidence level.

Trends in NO_2 and O_3 were also investigated, as these were required for the testing of different NO_X-to-NO_2 conversion methods (see Annexure E).

For air toxics the NSW Approved Methods do not require the consideration of background concentrations. However, some data have been presented to demonstrate that prevailing concentrations in Sydney are very low.

D.5.1 Carbon monoxide

D.5.1.1 Annual mean concentration

In NSW there is no air quality criterion for the annual mean CO concentration, but the trends and patterns are still of interest. The annual mean CO concentrations at the DPIE and Transport for NSW M5 East monitoring stations are shown in Figure D-3, and the corresponding statistics are provided in Table D-3.

At the DPIE stations the annual mean CO concentrations were quite variable. Concentrations decreased between 2004 and the start of 2008, but then began to increase again during 2008, and continued to do so until around 2010. These changes coincided with a programme of instrument replacement. Between 2010 and 2018 CO concentrations then generally decreased again. A more systematic – and perhaps more representative – downward trend in CO was apparent in the data from the Transport for NSW M5 East background stations, where there was a net overall decrease of between around 20 and 30 per cent between 2008 and 2019. The Mann-Kendall test showed that there was a significant downward trend in annual mean CO concentration at three stations.

After 2008, the trend in CO at the only monitoring station inside the GRAL domain (Rozelle) was similar to that at the RMS stations. The long-term mean (2009-2019) at Rozelle was 0.33 mg/m^3, compared with 0.27-0.37 mg/m^3 at the Transport for NSW background stations. For comparison, the mean CO concentrations at the Transport for NSW roadside stations (F1 and M1) during the same period were 0.48 and 0.42 mg/m^3 respectively.

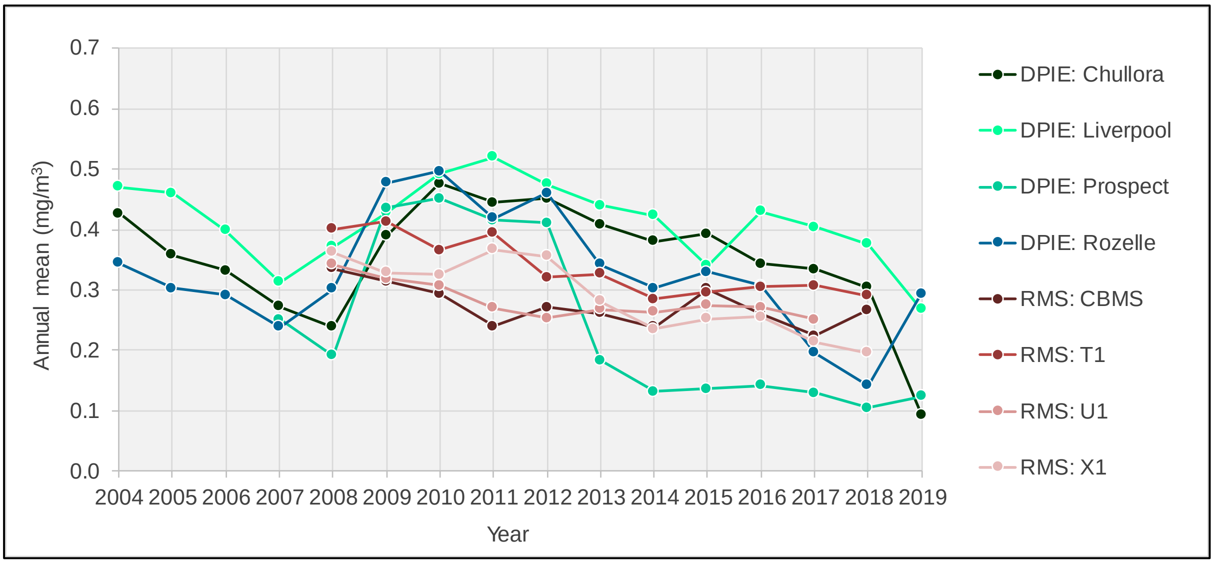


Figure D-3 Trend in annual mean CO concentration

Table D-3 Annual mean CO concentration at DPIE and Transport for NSW background stations

Year	Annual mean concentration (mg/m^3)(a)										
	DPIE Chullora	DPIE Earlwood	DPIE Lindfield	DPIE Liverpool	DPIE Prospect	DPIE Randwick	DPIE Rozelle	RMS CBMS	RMS T1	RMS U1	RMS X1
2004	0.43	-	-	0.47	-	-	0.34	-	-	-	-
2005	0.36	-	-	0.46	-	-	0.30	-	-	-	-
2006	0.33	-	-	0.40	-	-	0.29	-	-	-	-
2007	0.27	-	-	0.31	0.25	-	0.24	-	-	-	-
2008	0.24	-	-	0.37	0.19	-	0.30	0.34	0.40	0.34	0.36
2009	0.39	-	-	0.43	0.44	-	0.48	0.31	0.41	0.32	0.33
2010	0.48	-	-	0.49	0.45	-	0.50	0.29	0.37	0.31	0.33
2011	0.44	-	-	0.52	0.42	-	0.42	0.24	0.39	0.27	0.37
2012	0.45	-	-	0.48	0.41	-	0.46	0.27	0.32	0.25	0.36
2013	0.41	-	-	0.44	0.18	-	0.34	0.26	0.33	0.27	0.28
2014	0.38	-	-	0.42	0.13	-	0.30	0.24	0.28	0.26	0.24
2015	0.39	-	-	0.34	0.14	-	0.33	0.30	0.30	0.27	0.25
2016	0.34	-	-	0.43	0.14	-	0.31	0.26	0.30	0.27	0.26
2017	0.33	-	-	0.40	0.13	-	0.20	0.22	0.31	0.25	0.21
2018	0.30	-	-	0.38	0.10	-	0.14	0.27	0.29	-	0.20
2019	0.09	-	-	0.27	0.12	-	0.29	-	-	-	-
Mean (2009-19)	**0.37**	-	-	**0.42**	**0.24**	-	**0.34**	**0.27**	**0.33**	**0.28**	**0.37**
Mean (2004-19)	**0.35**	-	-	**0.41**	-	-	**0.33**	-	-	-	-
Significance(b)	◄►	-	-	◄►	▼	-	◄►	◄►	▼	◄►	▼

(a) Only years with >75 per cent complete data shown

(b) ▼ = significantly decreasing, ▲ = significantly increasing, ◄► = stable/no trend

D.5.1.2 Maximum one-hour mean concentration

The trends in the maximum one-hour mean CO concentration by year are shown in Figure D-4 and Table D-4. All maximum values were well below the air quality criterion of 30 mg/m^3. The patterns at all background stations were broadly similar, with a general downward trend. Maximum values rose slightly in 2019. The trend was statistically significant at all but one of the stations.

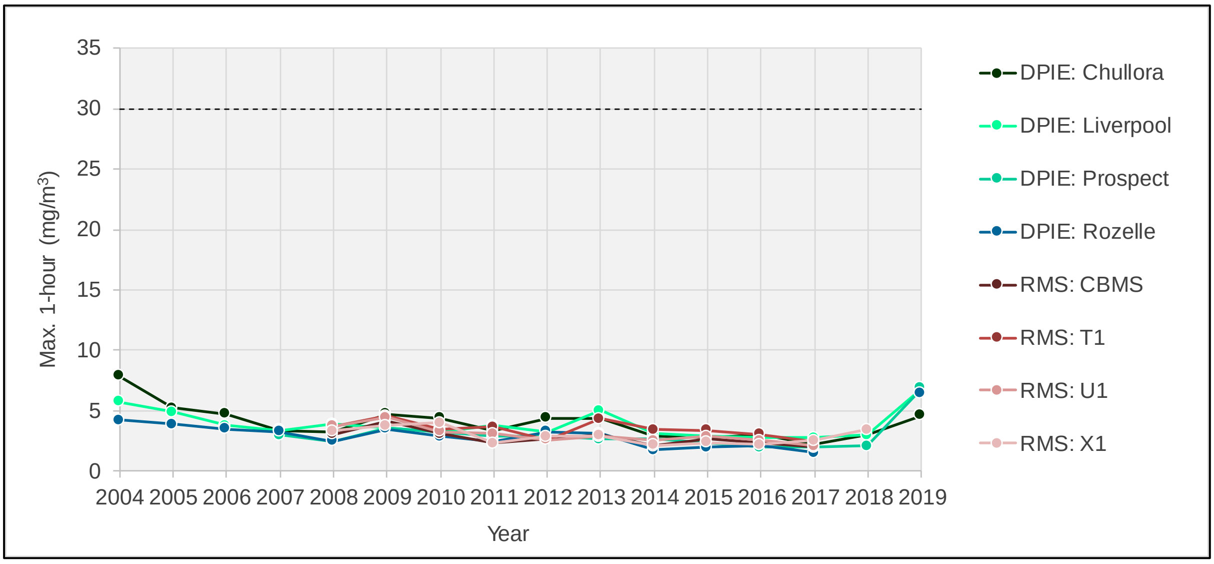


Figure D-4 Trend in maximum one-hour mean CO concentration

Table D-4 Maximum one-hour mean CO at DPIE and Transport for NSW background stations

Year	Annual mean concentration (mg/m³)[(a)]										
	DPIE Chullora	DPIE Earlwood	DPIE Lindfield	DPIE Liverpool	DPIE Prospect	DPIE Randwick	DPIE Rozelle	RMS CBMS	RMS T1	RMS U1	RMS X1
2004	7.87	-	-	5.75	-	-	4.25	-	-	-	-
2005	5.25	-	-	4.87	-	-	3.87	-	-	-	-
2006	4.75	-	-	3.75	-	-	3.50	-	-	-	-
2007	3.37	-	-	3.37	3.00	-	3.25	-	-	-	-
2008	3.25	-	-	3.87	2.50	-	2.50	3.03	3.66	3.69	3.30
2009	4.75	-	-	3.62	3.62	-	3.50	4.18	4.55	4.47	3.77
2010	4.37	-	-	3.25	3.25	-	2.87	3.10	3.43	3.24	3.98
2011	3.37	-	-	3.75	2.87	-	2.50	2.29	3.65	3.09	2.33
2012	4.37	-	-	3.25	2.87	-	3.25	2.73	2.57	2.58	2.87
2013	4.37	-	-	5.00	2.62	-	3.12	3.00	4.36	2.89	2.95
2014	2.87	-	-	3.12	2.62	-	1.75	2.06	3.45	2.56	2.15
2015	2.75	-	-	2.87	2.37	-	2.00	2.68	3.37	2.88	2.34
2016	3.00	-	-	2.75	2.00	-	2.12	2.36	3.06	2.52	2.22
2017	2.25	-	-	2.75	2.00	-	1.50	1.99	2.44	2.06	2.54
2018	3.00	-	-	3.00	2.08	-	-	-	-	-	-
2019	4.63	-	-	6.88	6.88	-	6.50	-	-	-	-
Mean (2009-19)	**3.61**	-	-	**3.66**	**3.02**	-	**2.91**	**2.74**	**3.46**	**3.00**	**2.90**
Mean (2004-19)	**4.01**	-	-	**3.87**	-	-	**3.10**	-	-	-	-
Significance[(b)]	▼	-	-	▼	▼	-	▼	▼	◀▶	▼	▼

(a) Only years with >75 per cent complete data shown

(b) ▼ = significantly decreasing, ▲ = significantly increasing, ◀▶ = stable/no trend

D.5.1.3 Maximum rolling 8-hour mean concentration

The trends in the maximum rolling 8-hour mean CO concentration by year are shown in Figure D-5 and Table D-5. All maximum values were well below the air quality criterion of 10 mg/m³; the long-term averages were between 2 and 3 mg/m³. For comparison, the long-term mean values at the Transport for NSW roadside stations (F1 and M1) were 3.1 and 2.3 mg/m³ respectively. The patterns at all background stations were broadly similar; there was a general downward trend that was statistically significant at all but one of the stations. Although there was some spatial variation in CO, it was not systematic, and the between-station variation was small compared with the criterion.

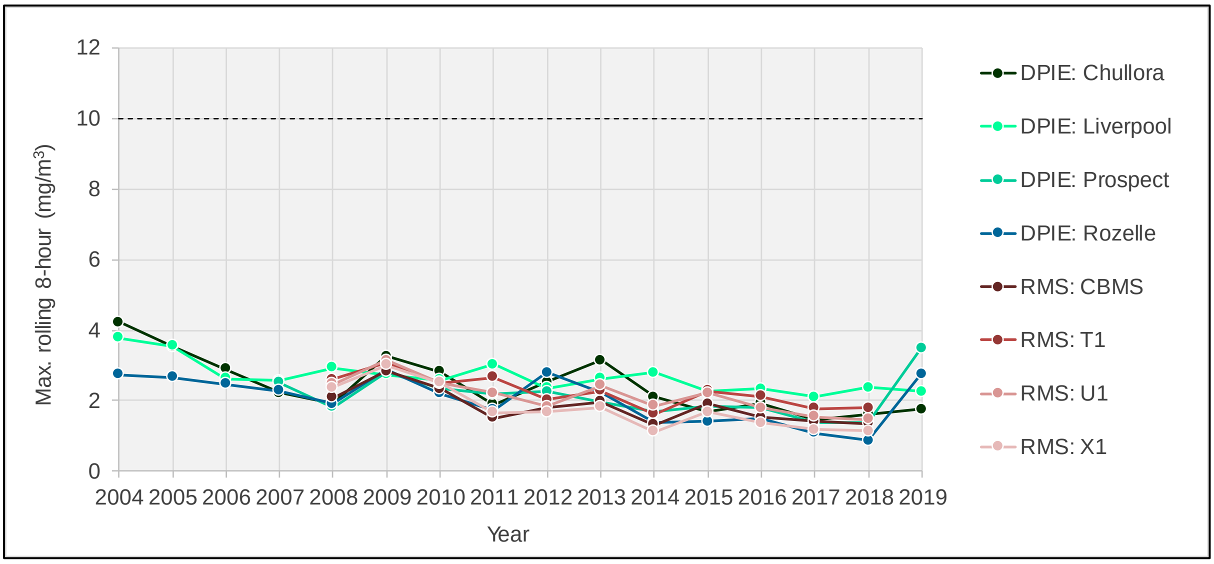


Figure D-5 Trend in maximum rolling 8-hour mean CO concentration

Table D-5 Maximum rolling 8-hour mean CO at DPIE and Transport for NSW background stations

Year	Annual mean concentration (mg/m³)[(a)]										
	DPIE Chullora	DPIE Earlwood	DPIE Lindfield	DPIE Liverpool	DPIE Prospect	DPIE Randwick	DPIE Rozelle	RMS CBMS	RMS T1	RMS U1	RMS X1
2004	4.22	-	-	3.78	-	-	2.73	-	-	-	-
2005	3.53	-	-	3.54	-	-	2.66	-	-	-	-
2006	2.89	-	-	2.62	-	-	2.46	-	-	-	-
2007	2.22	-	-	2.57	2.52	-	2.28	-	-	-	-
2008	1.93	-	-	2.93	1.82	-	1.91	2.08	2.60	2.46	2.38
2009	3.27	-	-	2.75	2.83	-	2.87	2.84	3.10	3.14	3.01
2010	2.82	-	-	2.59	2.35	-	2.21	2.33	2.51	2.50	2.51
2011	1.89	-	-	3.03	2.18	-	1.73	1.51	2.67	2.23	1.66
2012	2.53	-	-	2.36	2.25	-	2.79	1.81	2.02	1.83	1.68
2013	3.14	-	-	2.62	1.96	-	2.23	1.97	2.27	2.43	1.82
2014	2.11	-	-	2.80	1.68	-	1.37	1.31	1.61	1.84	1.13
2015	1.70	-	-	2.27	1.84	-	1.41	1.91	2.27	2.22	1.69
2016	1.93	-	-	2.34	1.80	-	1.50	1.52	2.13	1.79	1.38
2017	1.45	-	-	2.11	1.37	-	1.08	1.41	1.78	1.53	1.18
2018	1.62	-	-	2.37	1.37	-	0.87	1.35	1.79	1.53	1.18
2019	1.75	-	-	2.25	3.50	-	2.75	-	-	-	-
Mean (2008-19)	**2.20**	-	-	**2.50**	**2.10**	-	**1.89**	**1.82**	**2.25**	**2.13**	**1.78**
Mean (2009-19)	**2.44**	-	-	**2.68**	-	-	**2.05**	-	-	-	-
Significance[(b)]	▼	-	-	▼	▼	-	▼	◀▶	▼	▼	▼

(a) Only years with >75 per cent complete data shown

(b) ▼ = significantly decreasing, ▲ = significantly increasing, ◀▶ = stable/no trend

D.5.1.4 Exceedances of air quality criteria

Between 2004 and 2019 there were no exceedances of the rolling 8-hour mean criterion for CO of 10 mg/m³, or the one-hour criterion of 30 mg/m³, at any of the background stations.

D.5.2 Nitrogen oxides

D.5.2.1 Annual mean concentration

The annual mean NO_X concentrations at the monitoring stations are shown in Figure D-6, and the corresponding statistics are provided in Table D-6. There are no air quality criteria for NO_X in NSW, but it is important to understand NO_X in order to characterise NO_2 (see Annexure E).

The T1 station had a systematically higher NO_X concentration than the other Transport for NSW stations, which all had very similar concentrations. Given that all the Transport for NSW stations are relatively close together, the measurements at the T1 station could have been influenced by a local source. The station is alongside Thompson Street, but the traffic volume is likely to be very low. However, concentrations may have been affected by truck movements at a factory (manufacture of crop protection products) across the road. In any case, it is possible the T1 station was not representative of background NO_X concentrations in this part of Sydney.

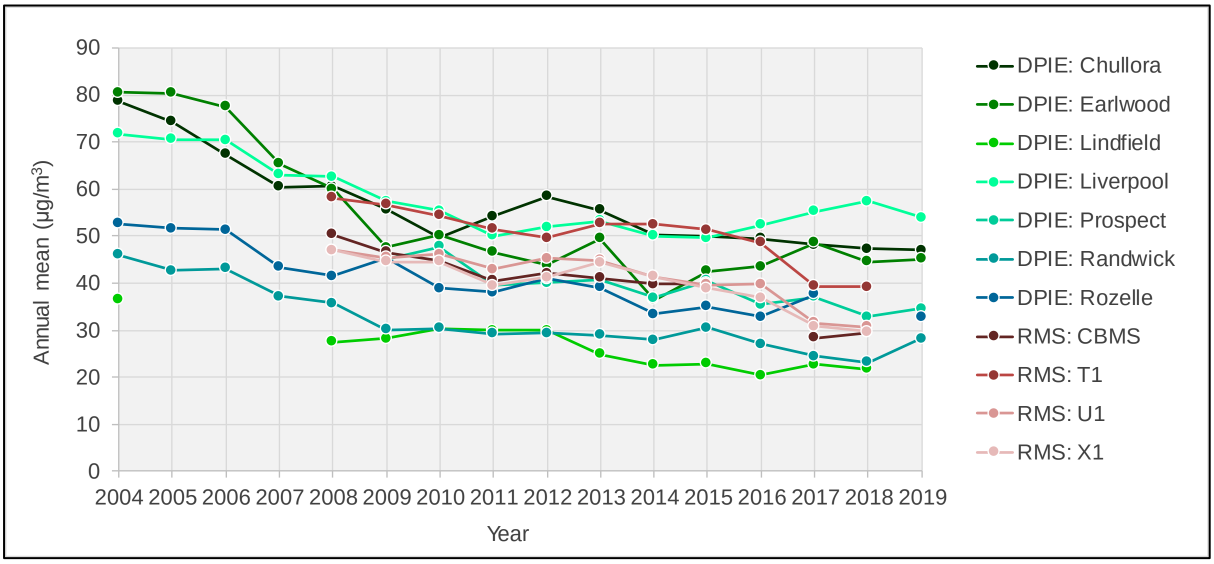


Figure D-6 Trend in annual mean NO_X concentration

Table D-6 Annual mean NO_X concentration at DPIE and Transport for NSW background stations

Year	Annual mean concentration (µg/m³)[(a)]										
	DPIE Chullora	DPIE Earlwood	DPIE Lindfield	DPIE Liverpool	DPIE Prospect	DPIE Randwick	DPIE Rozelle	RMS CBMS	RMS T1	RMS U1	RMS X1
2004	78.7	80.6	36.6	71.8	-	46.0	52.7	-	-	-	-
2005	74.4	80.5	-	70.7	-	42.7	51.7	-	-	-	-
2006	67.5	77.5	-	70.5	-	43.2	51.3	-	-	-	-
2007	60.4	65.5	-	63.0	-	37.2	43.4	-	-	-	-
2008	60.7	60.0	27.5	62.7	-	35.8	41.5	50.3	58.2	47.0	47.1
2009	55.7	47.5	28.2	57.5	45.1	30.1	45.4	46.7	56.7	45.5	44.6
2010	49.7	50.2	30.4	55.4	47.7	30.4	38.9	44.8	54.3	46.2	44.6
2011	54.3	46.5	29.9	50.0	39.5	29.2	38.0	40.5	51.5	42.9	39.4
2012	58.5	43.8	30.0	52.0	40.1	29.4	40.9	42.2	49.6	45.3	41.3
2013	55.6	49.4	24.8	53.3	40.8	28.9	39.1	41.0	52.7	44.8	44.4
2014	50.2	36.5	22.6	50.1	36.9	27.9	33.5	39.8	52.5	41.4	41.4
2015	50.1	42.6	22.9	49.6	40.5	30.6	35.1	39.9	51.3	39.7	38.9
2016	49.4	43.6	20.4	52.4	35.5	27.1	32.8	-	48.7	39.7	36.9
2017	48.2	48.7	22.7	55.2	37.0	24.5	37.6	28.3	39.4	31.5	30.9
2018	47.3	44.5	21.7	57.4	32.8	23.2	-	29.5	39.2	30.6	29.7
2019	47.0	45.1	-	54.0	34.6	28.2	32.6	-	-	-	-
Mean (2009-19)	**51.5**	**45.3**	**25.4**	**53.4**	**39.1**	**28.1**	**37.4**	**40.3**	**50.4**	**41.3**	**39.9**
Mean (2004-19)	**56.7**	**53.9**	**26.5**	**57.8**	**-**	**32.1**	**41.0**	-	-	-	-
Significance[(b)]	▼	▼	▼	▼	◄►	▼	▼	▼	▼	▼	▼

(a) Only years with >75 per cent complete data shown

(b) ▼ = significantly decreasing, ▲ = significantly increasing, ◄► = stable/no trend

There has been a general tendency for annual mean NO_X concentrations to decrease. At the DPIE stations concentrations decreased by between 27 per cent and 46 per cent between 2004 and 2019. The Mann-Kendall test showed that the downward trend in concentrations was statistically significant at all stations except Prospect, although this station had a shorter time series. There is, however, a suggestion of a levelling-off of concentrations at some stations in recent years.

There was a pronounced spatial variation in the annual mean NO_X concentration when the results were considered for a consistent time period (e.g. 2009-2019). For example, at the DPIE Chullora, Earlwood and Liverpool stations the long-term mean concentration during this period was around 50 µg/m³, compared with around 40 µg/m³ at Prospect and Rozelle, and 30 µg/m³ at Randwick and Lindfield. The long-term concentration at the Transport for NSW T1 station was around 50 µg/m³, with concentrations at the Transport for NSW stations CBMS, U1 and X1 being slightly lower (around 40 µg/m³). This spatial variation was taken into account in the derivation of background NO_X concentrations for the Beaches Link project.

Although not shown, the long-term mean (2008-2018) NO_X concentrations at the Transport for NSW roadside stations (F1 and M1) were substantially higher than those at the background stations, and very similar at 97.1 and 97.3 µg/m³ respectively. The road increment (the average roadside concentration minus the average background concentration) remained relatively stable, at around 50-60 µg/m³, between 2008 and 2018 (there was a slight downward trend overall). This illustrates the ongoing contribution of NO_X emissions from road transport.

D.5.2.2 Maximum one-hour mean concentration

The long-term trends in the maximum one-hour mean NO_X concentration are shown in Figure D-7**.** Again, there are no air quality criteria for NO_X, and these are largely of interest in relation to the one-hour criterion for NO_2. As with the annual mean concentration, there has been a general downward trend in peak concentrations, with some levelling-off in recent years.

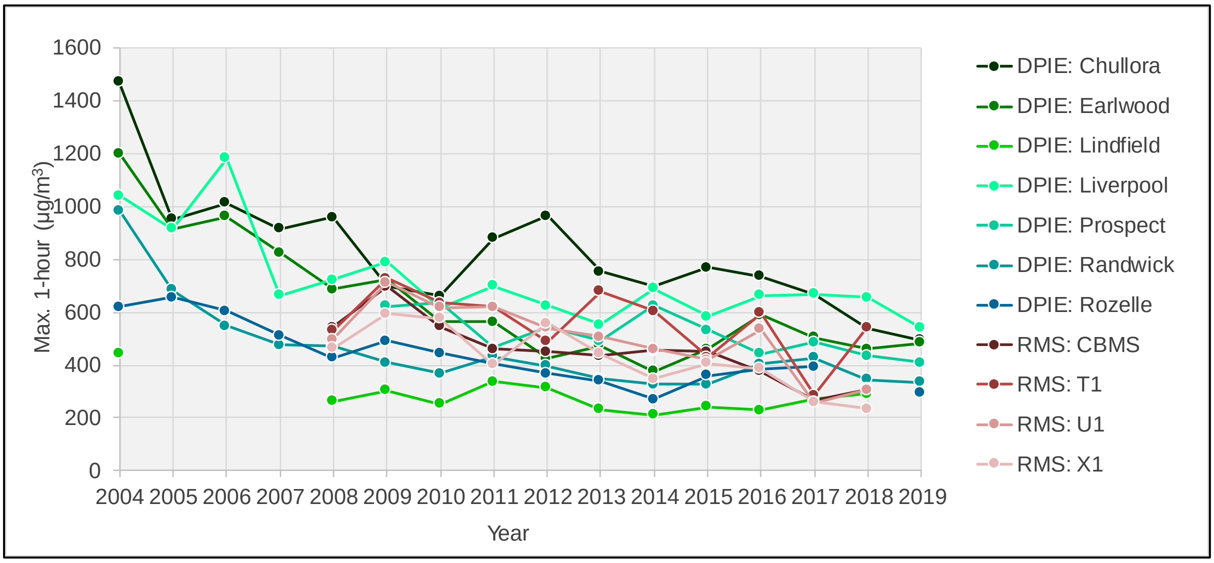


Figure D-7 Trend in maximum one-hour mean NO_X concentration

For comparison, the maximum one-hour mean NO_X concentrations at the Transport for NSW roadside stations (F1 and M1) in 2016 were 1043 and 696 µg/m³ respectively. These values are similar to or higher than the upper end of the range of values for the background stations.

D.5.3 Nitrogen dioxide

D.5.3.1 Annual mean concentration

The long-term trends in annual mean NO_2 concentrations are shown in Figure D-8, and the corresponding statistics are provided in Table D-7. The concentrations at all stations were well below the NSW air quality assessment criterion of 62 µg/m³.

The NO_2 concentrations at the DPIE stations exhibited a systematic downward trend, with a reduction of between around 15 per cent and 30 per cent between 2004 and 2019 depending on the station. The trend was statistically significant at six of the seven stations. However, in recent years the concentrations at some stations appear to have stabilised. At the Transport for NSW background stations there was a significant downward trend at two stations (CBMS, T1) but no trend at the other two (U1, X1). As with NO_X, there was some spatial variation in NO_2 concentrations, but the pattern across the monitoring stations was not quite the same. Nevertheless, concentrations were again generally highest at the Chullora station and lowest at Lindfield and Randwick, although concentrations increased markedly at Randwick between 2014 and 2016.

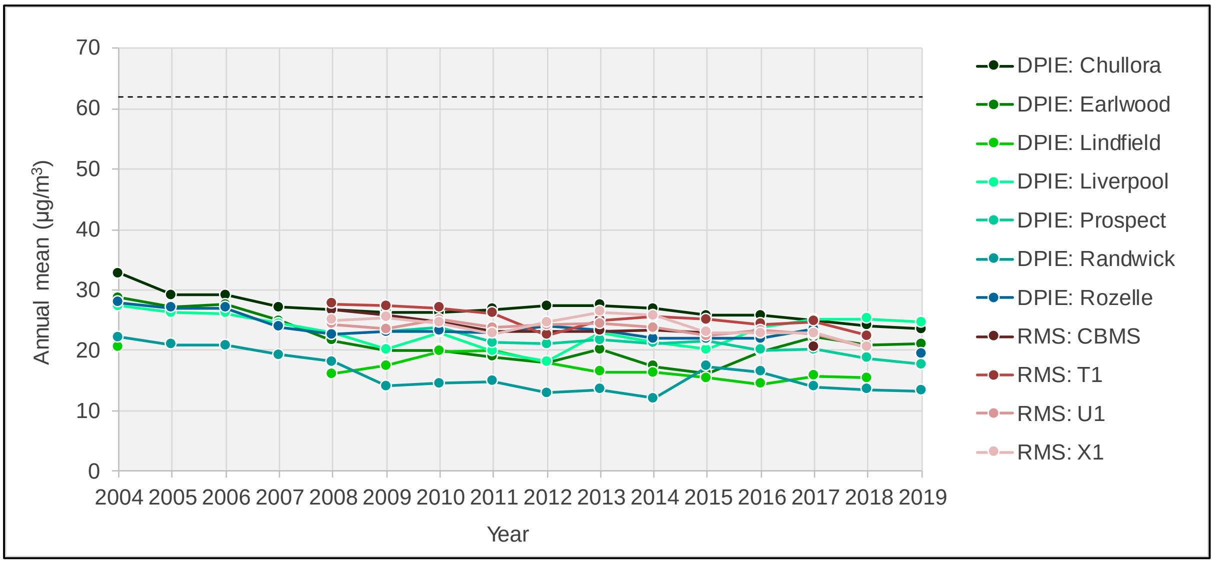


Figure D-8 Trend in annual mean NO_2 concentration

Table D-7 Annual mean NO_2 concentration at DPIE and Transport for NSW background stations

Year	Annual mean concentration (µg/m³)[(a)]										
	DPIE Chullora	DPIE Earlwood	DPIE Lindfield	DPIE Liverpool	DPIE Prospect	DPIE Randwick	DPIE Rozelle	RMS CBMS	RMS T1	RMS U1	RMS X1
2004	32.8	28.7	20.4	27.4	-	22.2	27.9	-	-	-	-
2005	29.1	27.1	-	26.2	-	20.9	27.0	-	-	-	-
2006	29.2	27.6	-	26.1	-	20.8	27.0	-	-	-	-
2007	27.1	24.9	-	24.5	-	19.2	23.9	-	-	-	-
2008	26.7	21.7	16.1	22.9	-	18.1	22.6	26.7	27.7	24.3	25.0
2009	26.3	19.9	17.4	20.1	23.1	14.1	23.1	25.7	27.4	23.5	25.4
2010	26.2	20.1	19.8	22.9	23.7	14.6	23.2	24.8	27.1	25.1	24.5
2011	26.8	18.9	20.0	19.9	21.3	14.8	22.9	23.1	26.1	23.8	22.8
2012	27.4	18.1	18.0	18.1	21.1	13.0	24.0	23.1	22.5	24.2	24.7
2013	27.5	20.2	16.5	22.9	21.7	13.5	23.4	23.2	25.0	24.5	26.3
2014	26.9	17.3	16.3	21.3	21.1	12.1	21.9	23.4	25.5	23.7	25.7
2015	25.8	16.2	15.4	20.2	21.6	17.4	21.9	22.9	25.1	22.4	23.0
2016	25.8	19.8	14.4	23.8	20.1	16.4	21.9	-	24.3	23.3	22.8
2017	25.0	22.2	15.8	25.1	20.1	13.9	23.5	20.4	24.7	22.6	22.9
2018	24.1	21.0	15.5	25.2	18.7	13.5	-	-	22.4	20.5	20.5
2019	23.6	21.0	-	24.6	17.7	13.3	19.5	-	-	-	-
Mean (2009-19)	**25.9**	**19.5**	**16.9**	**22.2**	**20.9**	**14.2**	**22.5**	**23.7**	**25.3**	**23.4**	**24.0**
Mean (2004-19)	**26.9**	**21.5**	**17.1**	**23.2**	**-**	**16.1**	**23.6**	**-**	**-**	**-**	**-**
Significance[(b)]	▼	▼	▼	▼	◀▶	▼	▼	▼	▼	◀▶	◀▶

(a) Only years with >75 per cent complete data shown.
(b) ▼ = significantly decreasing, ▲ = significantly increasing, ◀▶ = stable/no trend

The long-term (2008-2018) average NO_2 concentrations at the Transport for NSW roadside stations (F1 and M1) were 34 and 37 µg/m³ respectively, and therefore around 10 to 13 µg/m³ higher than those at the Transport for NSW background stations. Even so, the NO_2 concentrations at roadside were also well below the NSW assessment criterion.

D.5.3.2 Maximum one-hour mean concentration

The trends in the maximum one-hour mean NO_2 concentration by year are given in Error! Reference source not found.. The within-station variation for this metric is similar to the between-site variation, but when viewed overall the values have been quite stable with time (broadly varying around 1000 µg/m³), and are all below the NSW air quality assessment criterion of 246 µg/m³. The maximum one-hour mean NO_2 concentrations at the Transport for NSW roadside stations (F1 and M1) in 2016 were 144 µg/m³ and 165 µg/m³ respectively. As with NO_X, these values are similar to or higher than the highest values for the background stations.

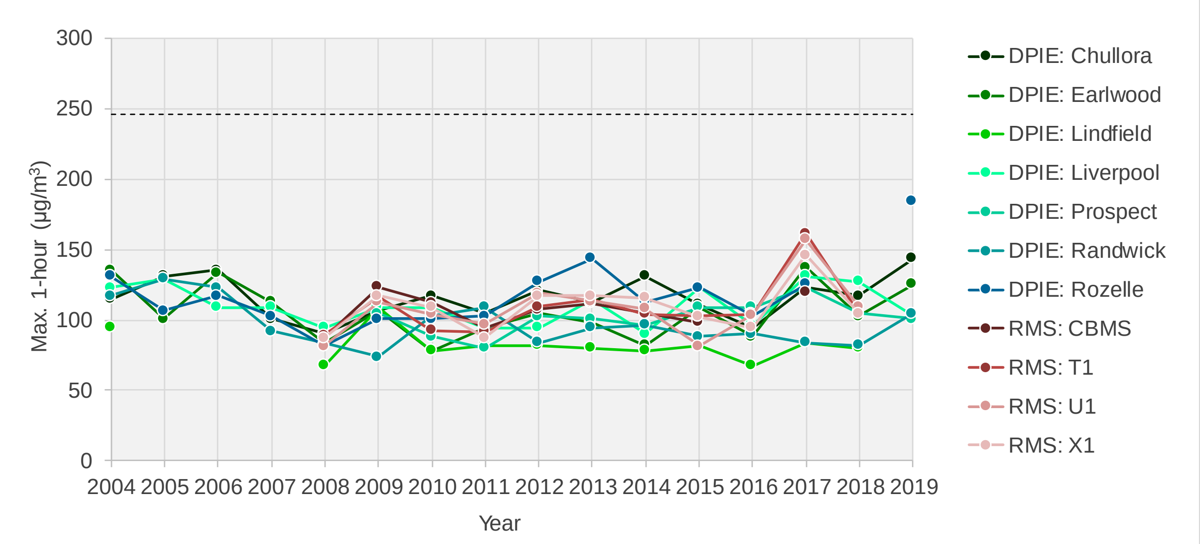


Figure D-9 Trend in maximum one-hour mean NO_2 concentration

D.5.3.3 Exceedances of air quality criteria

There were no exceedances of the annual mean criterion for NO_2 of 62 µg/m³ (Table D-7). In fact, annual mean concentrations were well below the criterion at all stations and in all years. There were also no exceedances of the one-hour mean criterion for NO_2 (246 µg/m³).

D.5.4 Ozone

D.5.4.1 Annual mean concentration

Annual mean ozone concentrations at the DPIE stations - presented in Figure D-10 and Table D-8 - were relatively stable between 2004 and 2019, being typically around 30-35 µg/m³. The main exception was the Randwick station, where the typical annual mean concentration was substantially higher, at closer to 40 µg/m³. This is likely to be due to the coastal nature of Randwick, with easterly winds having low concentrations of ozone-scavenging species, notably NO_X (see Figure D-6).

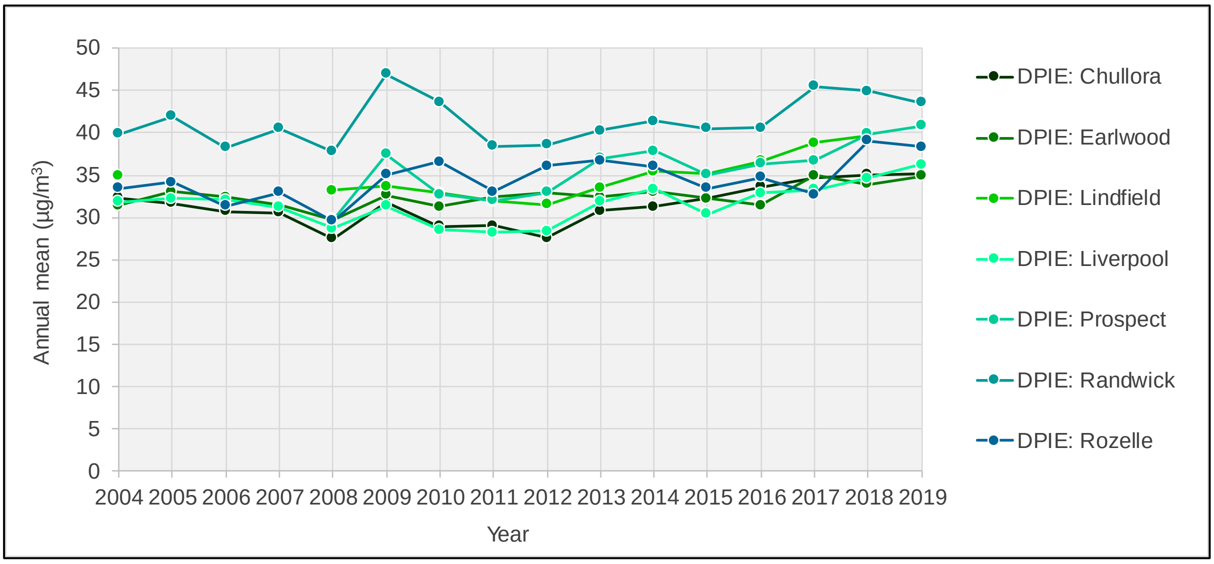


Figure D-10 Trend in annual mean O_3 concentration

Table D-8 Annual mean O_3 concentration at DPIE background stations

Year	Annual mean concentration (µg/m³) (a)						
	Chullora	Earlwood	Lindfield	Liverpool	Prospect	Randwick	Rozelle
2004	32.3	31.5	35.0	31.8	-	39.8	33.5
2005	31.6	33.0	-	32.2	-	42.0	34.2
2006	30.7	32.4	-	32.0	-	38.3	31.3
2007	30.5	31.4	-	31.2	-	40.5	32.9
2008	27.5	29.7	33.2	28.7	29.8	37.8	29.6
2009	31.8	32.7	33.7	31.3	37.5	46.9	35.1
2010	28.9	31.3	32.9	28.6	32.8	43.6	36.6
2011	29.0	32.4	31.9	28.2	32.0	38.4	33.0
2012	27.5	33.0	31.5	28.4	33.0	38.6	36.1
2013	30.8	32.4	33.5	31.8	37.0	40.3	36.8
2014	31.3	33.0	35.4	33.4	37.9	41.4	36.0
2015	32.3	32.2	35.1	30.4	35.0	40.5	33.5
2016	33.6	31.4	36.7	32.9	36.3	40.6	34.7
2017	34.7	34.9	38.8	33.3	36.7	45.5	32.7
2018	35.1	33.9	39.6	34.7	39.9	44.9	-
2019	35.1	34.9	-	36.2	40.8	43.5	38.4
Mean (2009-19)	**31.8**	**32.9**	**34.9**	**31.7**	**36.3**	**42.2**	**35.6**
Mean (2004-19)	**31.4**	**32.5**	**34.8**	**31.6**	**-**	**41.4**	**34.6**
Significance(b)	◀▶	◀▶	◀▶	◀▶	▲	◀▶	▲

(a) Only years with >75 per cent complete data shown

(b) ▼ = significantly decreasing, ▲ = significantly increasing, ◀▶ = stable/no trend

D.5.4.2 Exceedances of air quality criteria

Table D-9 and Table D-10 show that there were exceedances of the rolling 4-hour mean and 1-hour mean standards for ozone at several monitoring stations.

Table D-9 Exceedances of rolling 4-hour mean O_3 standard

Year	Number of exceedances of rolling 4-hour standard per year (171 µg/m³)						
	Chullora	Earlwood	Lindfield	Liverpool	Prospect	Randwick	Rozelle
2004	**7**	**1**	**5**	**11**	-	**2**	**2**
2005	**1**	0	-	**6**	-	0	0
2006	**10**	**4**	-	**17**	-	0	**2**
2007	0	0	-	**7**	-	**2**	0
2008	0	0	0	**1**	**2**	0	0
2009	**6**	**7**	**3**	**10**	**18**	0	0
2010	0	0	0	**1**	**7**	0	0
2011	**4**	**3**	**1**	**5**	**13**	0	0
2012	0	0	0	0	0	0	0
2013	**3**	**3**	0	**6**	**6**	0	0
2014	0	0	0	**3**	**5**	0	0
2015	0	**1**	**1**	0	0	**2**	0
2016	0	**2**	**4**	**3**	0	**3**	0
2017	**11**	**14**	**9**	**9**	**6**	**13**	**5**
2018	**2**	0	0	**12**	**8**	0	-
2019	**10**	**13**	**-**	**27**	**34**	**13**	**10**

Table D-10 Exceedances of 1-hour O_3 standard

Year	Number of exceedances of 1-hour standard per year (214 µg/m³)						
	Chullora	Earlwood	Lindfield	Liverpool	Prospect	Randwick	Rozelle
2004	**2**	0	**1**	**5**	-	**2**	0
2005	0	0	-	**3**	-	0	0
2006	**3**	**2**	-	**11**	-	0	0
2007	0	0	-	**3**	-	0	0
2008	0	0	0	0	**1**	0	0
2009	**3**	**3**	**1**	**3**	**4**	0	0
2010	0	0	0	0	**3**	0	0
2011	**1**	0	0	**1**	**5**	0	0
2012	0	0	0	0	0	0	0
2013	**1**	**1**	0	**5**	**2**	0	0
2014	0	0	0	**1**	**2**	0	0
2015	0	0	0	0	0	**1**	0
2016	0	0	**1**	0	**1**	0	0
2017	**5**	**2**	**1**	**5**	**2**	**4**	**3**
2018	0	0	0	**1**	**1**	0	-
2019	**5**	**5**	**-**	**8**	**12**	**5**	**6**

D.5.5 PM_{10}

D.5.5.1 Annual mean concentration

Annual mean PM_{10} concentrations at the DPIE and Transport for NSW stations are given in Figure D-11 and Table D-11. Concentrations at the DPIE stations showed a net decrease between 2004 and 2016, by as much as 21 to 23 per cent in the case of the Chullora and Earlwood stations.

In recent years the annual mean PM_{10} concentration at the DPIE stations has increased, from around 20 µg/m³ in 2018 except at Lindfield where the concentration is substantially lower (around 15 to

16 µg/m³) to around 25 µg/m³ and above in the case of Liverpool and Prospect in 2019. The concentration at the Transport for NSW stations in 2018 have increased slightly to around 16-17 µg/m³. These values can be compared with the air quality criterion of 25 µg/m³ in the NSW Approved Methods.

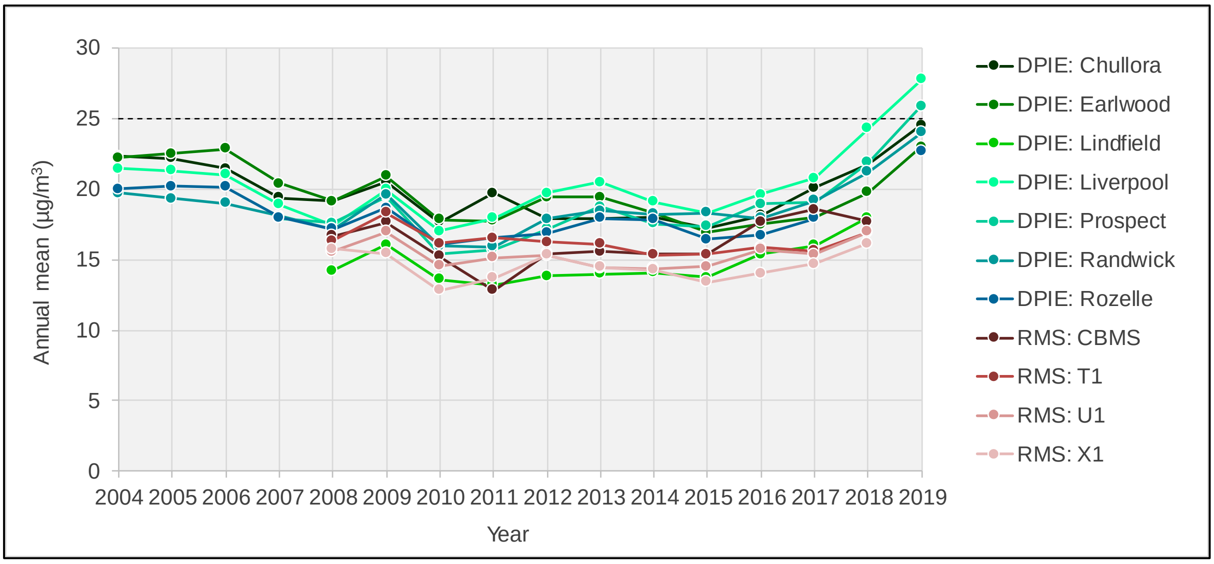


Figure D-11 Trend in annual mean PM_{10} concentration

Table D-11 Annual mean PM_{10} concentration at DPIE and Transport for NSW background stations

Year	Annual mean concentration (µg/m³)[(a)]										
	DPIE Chullora	DPIE Earlwood	DPIE Lindfield	DPIE Liverpool	DPIE Prospect	DPIE Randwick	DPIE Rozelle	RMS CBMS	RMS T1	RMS U1	RMS X1
2004	22.3	22.2	-	21.4	-	19.7	20.0	-	-	-	-
2005	22.2	22.5	-	21.3	-	19.3	20.2	-	-	-	-
2006	21.5	22.8	-	21.0	-	19.0	20.2	-	-	-	-
2007	19.4	20.4	-	18.9	18.0	18.1	18.0	-	-	-	-
2008	19.1	19.1	14.2	17.4	17.6	17.2	17.2	16.7	16.4	15.6	15.8
2009	20.5	20.9	16.1	20.0	19.5	19.6	18.7	17.7	18.3	17.0	15.5
2010	17.7	17.9	13.6	17.0	15.4	16.0	16.1	15.2	16.2	14.6	12.8
2011	19.7	17.7	13.2	18.0	15.7	15.9	16.6	12.8	16.6	15.2	13.7
2012	17.9	19.4	13.8	19.7	17.2	17.9	16.9	15.5	16.2	15.3	15.4
2013	17.9	19.4	14.0	20.5	18.8	18.5	17.9	15.6	16.1	14.4	14.5
2014	18.1	18.3	14.1	19.1	17.6	18.2	17.8	15.4	15.3	14.4	14.3
2015	17.3	16.9	13.8	18.3	17.4	18.3	16.5	15.4	15.4	14.5	13.4
2016	18.1	17.5	15.4	19.6	19.0	17.9	16.7	17.7	15.9	15.7	14.0
2017	20.1	18.0	16.0	20.8	19.0	19.2	17.9	18.6	15.6	15.4	14.7
2018	21.8	19.8	18.0	24.3	21.9	21.2	-	17.7	16.9	17.0	16.2
2019	24.6	23.0	-	27.8	25.9	24.0	22.7	-	-	-	-
Mean (2009-19)	**19.4**	**19.0**	**14.8**	**20.5**	**18.8**	**18.8**	**17.8**	**16.2**	**16.3**	**15.4**	**14.6**
Mean (2004-19)	**19.9**	**19.8**	**-**	**20.3**	**-**	**18.8**	**18.2**	**-**	**-**	**-**	**-**
Significance[(b)]	▲	▲	◀▶	▲	▲	▲	▲	◀▶	◀▶	◀▶	◀▶

(a) Only years with >75 per cent complete data shown

(b) ▼ = significantly decreasing, ▲ = significantly increasing, ◀▶ = stable/no trend

D.5.5.2 24-hour mean concentration

The maximum 24-hour mean PM_{10} concentrations are shown in Figure D-12. These show a large variation from year to year at most stations, and 2009, 2016, 2018 and 2019 in particular had a large variation between stations. In 2016 the peak concentrations were largely due to hazard reduction burning in May. In 2009 and 2018 these were largely due to significant dust storm events. In 2019 these were largely due to hazard reduction burning in May and widespread bushfires from October to December.

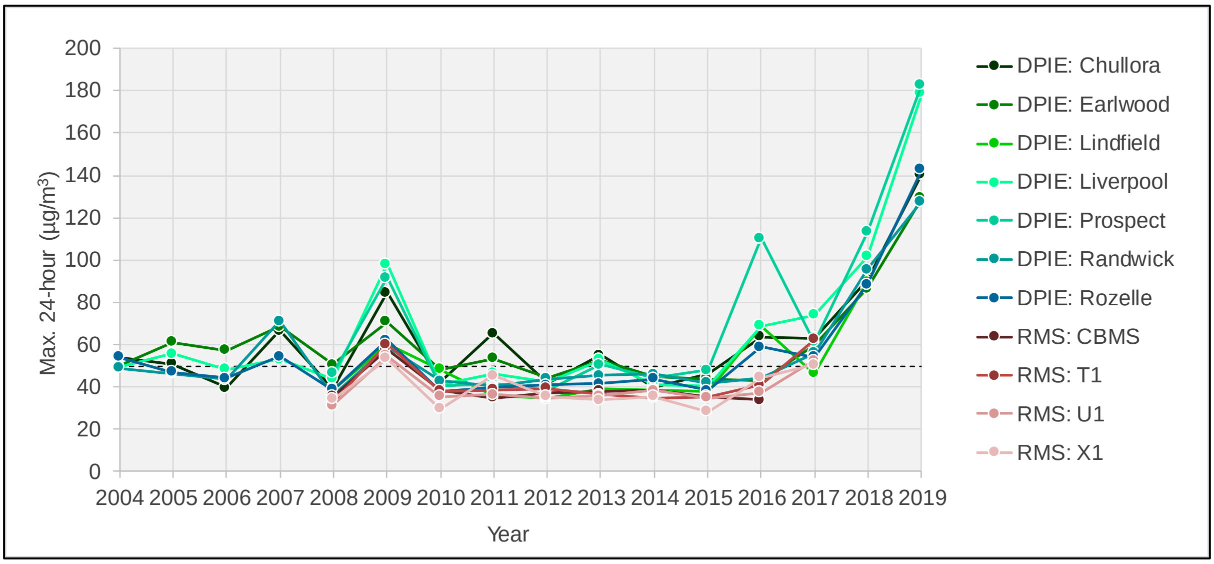


Figure D-12 Trend in maximum 24-hour mean PM_{10} concentration

D.5.5.3 Exceedances of air quality criteria

Prior to 2019, there were no exceedances of the annual mean criterion for PM_{10} in the NSW Approved Methods of 25 µg/m³. In 2019, there were two exceedances of the annual mean criterion for PM_{10} at Liverpool (27.8 µg/m³) and Prospect (25.9 µg/m³), notably due to the widespread bushfires in the spring and summer of 2019.

Table D-12 shows that there were multiple exceedances of the 24-hour criterion of 50 µg/m³, notably 2009, 2016 and 2019 due to events such as dust storms, hazard reduction burns and bushfires.

Table D-12 Exceedances of 24-hour PM_{10} standard

Year	Number of exceedances of 24-hour criterion per year (50 µg/m³)[(a)]						
	Chullora	Earlwood	Lindfield	Liverpool	Prospect	Randwick	Rozelle
2004	**3**	**1**	0	1	-	**1**	**1**
2005	**1**	**2**	**1**	**2**	-	0	0
2006	0	**5**	-	0	-	0	0
2007	**2**	**3**	0	**1**	0	**1**	**1**
2008	0	**1**	0	0	0	0	0
2009	**2**	**4**	**1**	**3**	**3**	**2**	**2**
2010	0	0	0	0	0	0	0
2011	**8**	**1**	0	0	0	0	0
2012	0	0	0	0	0	0	0
2013	**1**	**2**	0	**1**	**1**	0	0
2014	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0
2016	**1**	0	**1**	**3**	**4**	0	**1**
2017	**4**	**1**	0	**2**	**1**	**1**	**1**
2018	**7**	**5**	4	**13**	**8**	**5**	-
2019	**17**	**14**	-	**26**	**21**	**16**	**15**

(a) Note that extreme events reported by DPIE are included.

D.5.6 $PM_{2.5}$

D.5.6.1 Annual mean concentration

An extensive time series of $PM_{2.5}$ measurements was only available for three stations: Chullora, Earlwood and Liverpool (Figure D-13, Table D-13). Concentrations at these stations had a broadly similar pattern, with a reduction between 2004 and 2012 followed by a substantial increase in 2013 and then stabilisation. It is important to recognise that during 2012 DPIE made a decision to replace its continuous TEOM $PM_{2.5}$ monitors with USEPA-equivalent BAMs. This is the main reason for the increase in the measured concentrations. It is well documented that there are considerable uncertainties in the measurement of $PM_{2.5}$, and the results are instrument-specific (e.g. AQEG, 2012). The increases meant that background $PM_{2.5}$ concentrations at the three stations between 2013 and 2016 were very close to, or above, the NSW criterion of 8 µg/m³, as well as being above the AAQ NEPM long-term goal of 7 µg/m³. In 2018 and 2019, the annual average $PM_{2.5}$ exceeded the NSW criterion at the three long-term monitoring stations.

Shorter time series of $PM_{2.5}$ (2015 to 2019) were also available for the Rozelle and Prospect stations, and for several WCX stations (not shown). Mean concentrations at Prospect were similar to those at the long-term stations. However, the concentrations at Rozelle were noticeably lower at around 7 µg/m³. The measurements at four WCX background stations in 2016 had a slightly wider range (between 6.7 µg/m³ and 9.2 µg/m³). In 2019, the annual average $PM_{2.5}$ NSW criterion was exceeded at all stations.

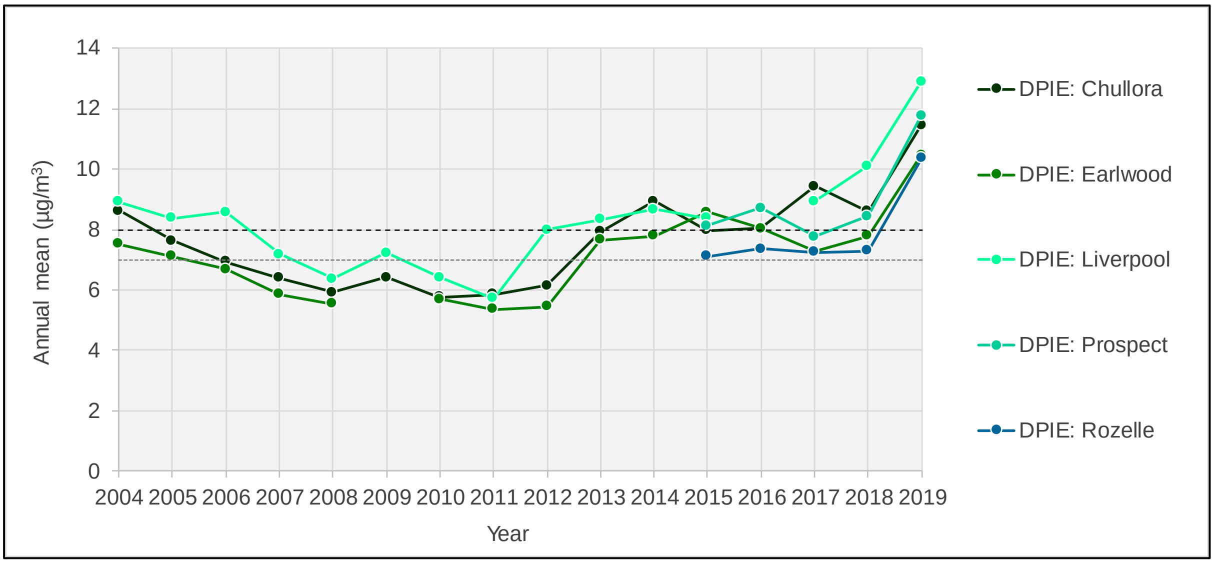


Figure D-13 Long-term trends in annual mean $PM_{2.5}$ concentration

Table D-13 Annual mean $PM_{2.5}$ concentration at DPIE background stations

Year	Annual mean concentration (µg/m³) (a)						
	Chullora	Earlwood	Lindfield	Liverpool	Prospect	Randwick	Rozelle
2004	8.6	7.5	-	8.9	-	-	-
2005	7.6	7.1	-	8.4	-	-	-
2006	6.9	6.7	-	8.6	-	-	-
2007	6.4	5.9	-	7.2	-	-	-
2008	5.9	5.5	-	6.4	-	-	-
2009	6.4	-	-	7.2	-	-	-
2010	5.8	5.7	-	6.4	-	-	-
2011	5.9	5.3	-	5.7	-	-	-
2012	6.1	5.5	-	8.0	-	-	-
2013	7.9	7.7	-	8.3	-	-	-
2014	8.9	7.8	-	8.7	-	-	-
2015	8.0	8.6	-	8.4	8.1	-	7.1
2016	8.0	8.0	-	-	8.7	-	7.4
2017	9.4	7.3	-	8.9	7.8	-	7.2
2018	8.6	7.8	-	10.1	8.4	7.6	7.3
2019	11.5	10.5	-	12.9	11.8	11.0	10.3
Mean (2004-19)	**7.6**	**7.1**	**-**	**8.3**	**-**	**-**	**-**
Significance(b)	▲	▲	-	▲	-	-	-

(a) Only years with >75 per cent complete data shown

(b) ▼ = significantly decreasing, ▲ = significantly increasing, ◄► = stable/no trend

Overall, the data indicated that there was likely to be some spatial variation in $PM_{2.5}$ concentrations across the GRAL domain, although it would not be very pronounced.

D.5.6.2 24-hour mean concentration

The maximum 24-hour mean $PM_{2.5}$ concentrations at the three long-term and two short-term $PM_{2.5}$ monitoring stations are shown in Figure D-14. There has been no systematic trend in the maximum value. The maximum concentrations have tended to be close to the NSW criterion of 25 µg/m³, and in some cases significantly above it, largely due to hazard reduction burns and bushfires. In most years the maximum concentrations have been above the NEPM long-term goal of 20 µg/m³.

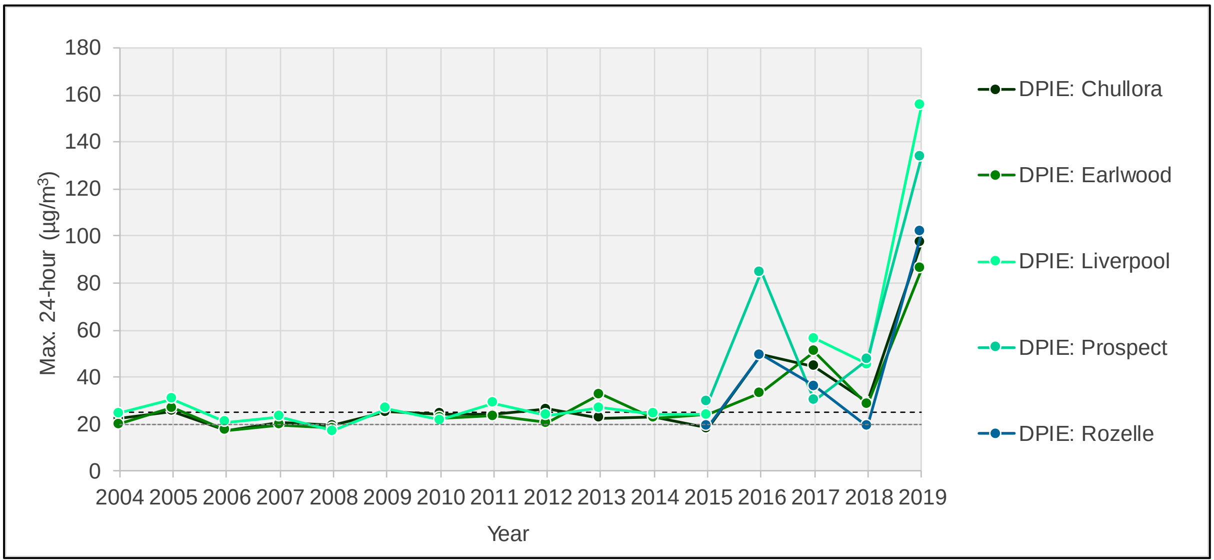


Figure D-14 Trend in maximum 24-hour mean $PM_{2.5}$ concentration

D.5.6.3 Exceedances of air quality criteria

As noted earlier, there have been some exceedances of the NSW criterion for annual mean $PM_{2.5}$ of 8 µg/m³, and these also seem likely to occur in the future given the recent trend in concentrations.

Table D-14 summarises the exceedances of the NSW criterion for 24-hour mean $PM_{2.5}$ of 25 µg/m³, as well as the long-term NEPM goal of 20 µg/m³.

Table D-14 Exceedances of 24-hour $PM_{2.5}$ criterion

Year	Number of exceedances of 24-hour criterion per year (25 µg/m³) (exceedances of the NEPM goal of 20 µg/m³ are given in brackets)[a]						
	Chullora	Earlwood	Lindfield	Liverpool	Prospect	Randwick	Rozelle
2004	0 (3)	0 (1)	-	0 (**7**)	-	-	-
2005	**2** (**4**)	**2** (**4**)	-	**2** (**7**)	-	-	-
2006	0 (0)	0 (0)	-	0 (**2**)	-	-	-
2007	0 (**1**)	0 (0)	-	0 (**2**)	-	-	-
2008	0 (0)	0 (0)	-	0 (0)	-	-	-
2009	**1** (**1**)	-	-	**1** (**3**)	-	-	-
2010	0 (**3**)	0 (**1**)	-	0 (**2**)	-	-	-
2011	0 (**1**)	0 (**2**)	-	**1** (**3**)	-	-	-
2012	**1** (**5**)	0 (1)	-	0 (3)	-	-	-
2013	0 (**2**)	**1** (**6**)	-	**1** (**8**)	-	-	-
2014	0 (**3**)	0 (**1**)	-	0 (**5**)	-	-	-
2015	0 (0)	0 (**6**)	-	0 (**6**)	**1** (**5**)	-	0 (0)
2016	**5 (7)**	**5 (8)**	-	**0 (2)**	**5 (10)**	**-**	**4 (7)**
2017	**8 (18)**	**2 (4)**	-	**3 (10)**	**3 (8)**	-	**2 (3)**
2018	**3 (11)**	**1 (5)**	-	**8 (11)**	**4 (7)**	**1 (3)**	-
2019	**19 (24)**	**19 (24)**	-	**29 (33)**	**20 (26)**	**15 (21)**	**18 (25)**

(a) Note that extreme events reported by DPIE are included.

D.5.7 Air toxics

Fewer data were available to characterise the concentrations of air toxics in Sydney. The main sources of data used in the assessment were the following:

- An Ambient Air Quality Research Project that was conducted between 1996 and 2001 (NSW EPA, 2002). The project investigated concentrations of 81 air toxics, including dioxins, VOCs, PAHs and heavy metals. More than 1,400 samples were collected at 25 sites. Three air toxics – benzene, 1,3-butadiene and benzo(α)pyrene – were identified as requiring ongoing assessment to ensure they remain at acceptable levels in the future.
- An additional round of data collection between October 2008 and October 2009. The five NEPM air toxics and additional VOCs were monitored at two sites in Sydney:
  - Turrella: formaldehyde, acetaldehyde, 19 PAHs including benzo(a)pyrene, and 41 VOCs including benzene, toluene and xylenes.
  - Rozelle: formaldehyde, acetaldehyde, 41 VOCs including benzene, toluene and xylenes.

  This study collected 24-hour concentrations of formaldehyde, acetaldehyde, and 34 organic compounds every sixth day, and 19 PAHs at one location on the same days. Sixty-one samples were collected at each location during the sampling period.
- Measurements conducted to support the WestConnex M4 East, New M5 and M4-M5 Link projects: benzene, toluene, ethylbenzene and xylenes.

The findings of the first two studies were summarised by DECCW (2010), and some results for selected pollutants are given in Table D-15. In the 1996-2001 monitoring campaign the concentrations of most compounds were very low. Some 23 compounds were not, or rarely, detected. Annual average concentrations of benzene were below the Air Toxics NEPM investigation level (0.003 ppm or 3 ppb) at all sites. The maximum annual concentrations of toluene and xylenes were less than 5 per cent of the investigation levels, and maximum 24-hour concentrations were less than 2 per cent and 4 per cent of the investigation levels respectively. The 2008-09 monitoring campaign also found low concentrations of all compounds, with many observations below detection limits. Concentrations of the five pollutants in the Air Toxics NEPM were low compared to the respective investigation levels.

The concentrations of the pollutants in Table D-15 generally halved between the two campaigns. Improved engine technology and a greater proportion of the vehicle fleet being fitted with catalysts reduced emissions from road vehicles. Benzene concentrations showed a larger decrease as a result of a reduction in the maximum allowed benzene concentration in automotive fuels (DECCW, 2010).

Table D-15 Average concentrations of selected organic pollutants

Pollutant	Concentration (ppb)				
	1996-2001			2008-2009	
	Sydney CBD	Rozelle	St Marys	Turrella	Rozelle
Benzene	2.3	1.1	0.4	0.4	0.3
Toluene	4.2	2.2	0.8	1.8	0.9
Xylene (m + p)	2.2	1.0	0.4	0.7	0.5
Xylene (o)	0.8	0.4	0.1	0.3	0.2
1,3-butadiene	0.4	0.2	0.1	<0.1	<0.1

Source: (DECCW, 2010)

In the 2008-2009 campaign the highest benzo(a)pyrene concentration was 0.4 ng/m^3, and the average for the year was 0.12 ng/m^3. Concentrations of formaldehyde were low: the highest concentration was only 11 per cent of the investigation level (DECCW, 2010).

The results clearly showed levels of air toxics were below the monitoring investigation levels, and well below levels observed in overseas cities. There were no occasions on which any of the air toxics monitored exceeded the monitoring investigation levels at any location. The results for benzo(a)pyrene, with levels of approximately 65 per cent of the NEPM monitoring investigation level, were the most significant (NEPC, 2011b).

To support the air quality assessments for the M4 East, New M5 and M4-M5 Link projects, Pacific Environment measured the concentrations of BTEX compounds (benzene, toluene, ethylbenzene and xylenes) at each of the project-specific air quality monitoring stations (five stations for the M4 East, seven stations for the New M5, and three stations for the M4-M5 Link) (Oswald, 2015a, 2015b; Phillips, 2017). The sites included background and roadside locations. Samples of air were obtained and analysed for BTEX compounds during four rounds of sampling between September and October of 2015 for the M4 East and New M5, and between January and February of 2017 for the M4-M5 Link. The results are summarised in Table D-16. In many cases the concentration for a given compound was lower than the corresponding limit of reporting (LOR)[5]. The results were therefore similar to those from the earlier studies, and confirmed that the concentrations of air toxics in Sydney remain very low.

Table D-16 Results of BTEX sampling for the M4 East, New M5 and M4-M5 Link projects

Compound(s)	Range of concentrations measured		
	M4 East sites (5)	New M5 sites (7)	M4-M5 Link sites (3)
Benzene	All measurements <1.6 µg/m^3 (a) (<0.5 ppb)	All measurements <1.6 µg/m^3 (a) (<0.5 ppb)	All measurements <1.6 µg/m^3 (a) (<0.5 ppb)
Toluene	<1.9 µg/m^3 (a) to 6.8 µg/m^3 (<0.5 to 1.7 ppb)	<1.9 µg/m^3 (a) to 6.8 µg/m^3 (<0.5 to 1.7 ppb)	<1.9 µg/m^3 (a) to 5.3 µg/m^3 (<0.5 to 1.4 ppb)
Ethylbenzene	All measurements <2.2 µg/m^3 (a) (<0.5 ppb)	All measurements <2.2 µg/m^3 (a) (<0.5 ppb)	All measurements <2.2 µg/m^3 (a) (<0.5 ppb)
Total xylenes(b)	All measurements <6.6 µg/m^3 (a) (<1.4 ppb)	All measurements <6.6 µg/m^3 (a) (<1.4 ppb)	All measurements <6.6 µg/m^3 (a) (<1.4 ppb)

(a) Limit of reporting
(b) Sum of meta-, para- and ortho- isomers

D.6 Seasonal patterns

Seasonal patterns in air quality in Sydney were described in the EISs for the WestConnex projects, most recently by Pacific Environment (2017). Monthly mean concentrations were analysed to provide additional data on seasonal patterns in air pollution. This analysis showed the following:

- There is a strong seasonal influence on CO, NO_X and NO_2 concentrations, with values being much higher in winter than in summer. This is due to a combination of winter-time factors such as an increase in combustion for heating purposes, elevated ‘cold start’ emissions from road vehicles, and more frequent and persistent temperature inversions in the atmosphere reducing the effectiveness of dispersion. Another contributing factor may be the reaction of NO_2 with the hydroxyl radical (OH) acting as a sink for NO_X. Concentrations of OH are highest in the summer.
- Ozone concentrations are highest in the late spring and early summer, when photochemical activity is high, and lowest in the autumn and winter.

[5] The LOR represents the lowest concentration at which a compound can be detected in the samples during laboratory analysis.

- For PM_{10} there is a weaker seasonal effect than for the gaseous pollutants, with concentrations tending to be higher in summer and lower in winter.
- For $PM_{2.5}$ concentrations there are some differences between seasons, but they are not systematic.

It was desirable to ensure that such seasonal effects were represented in the assumed background concentrations for the Beaches Link project.

D.7 Directional patterns

D.7.1 Overview

In the EIS for the M4-M5 Link (Pacific Environment, 2017), polar plots for each of the DPIE background monitoring stations were created using the *Openair* software (Carslaw, 2015). These plots covered the period from 2004 to 2015. They were not used directly in the determination of background concentrations, but they did assist (qualitatively) in the understanding of pollutant sources. A feature of several of the plots was an apparent influence of road traffic at background locations, which suggested a degree of conservatism in the modelling approach. For the closest stations to the Beaches Link domain (Earlwood, Lindfield, Randwick and Rozelle), the findings are summarised below.

Earlwood

For the Earlwood station NO_X and NO_2 concentrations were highest when the winds were strong and from an easterly direction. This influence was especially strong during winter, hinting that this was an effect of combustion for heating purposes. PM_{10} concentrations were highest when the winds were strong and from a westerly direction (especially in winter and spring). $PM_{2.5}$ concentrations, while more evenly distributed than PM_{10}, were high when the winds were strong from a southerly direction (especially in summer). The reasons for these patterns were not investigated further, but different sources and effects were evidently influencing PM_{10} and $PM_{2.5}$.

Lindfield

For Lindfield the analysis for NO_X and NO_2 indicated the presence of a local ground-level source, as well as a diffuse source further afield to the north. This probably reflected the population distribution around the monitoring station. There was also an influence further way and to the west, which may have been the M2 Motorway and Lane Cove Road. PM_{10} concentrations were high when there was a strong westerly wind. This may have been due to wind-blown dust from open land immediately to the west of the monitoring station. There were no strong seasonal effects at the Lindfield station, apart from higher concentrations from the west under high wind speed conditions in spring, and higher concentrations from the south under high wind speed conditions in the summer. Again, these effects were not investigated further.

Randwick

At Randwick NO_X and NO_2 concentrations were highest when the wind speed was low and the wind was coming from the west. There was no seasonal effect for NO_X. This indicated the presence of a road near to the monitoring station, which could have been Anzac Parade and/or Avoca Street. Sydney Airport, around 5 kilometres to the west of the monitoring station, may also have affected NO_X concentrations in this area. The highest PM_{10} concentrations occurred when the wind speed was high and the wind was from three distinct directions. Given that these directions coincided with open land and land under development, this seems to be a confirmation that high PM_{10} concentrations are associated with wind-blown dust from local sources.

Rozelle

At the Rozelle station there were multiple combustion sources affecting CO concentrations. These were likely to be associated with the University of Sydney campus immediately to the south-west, and roads within 500 metres (Victoria Road to the north-east, and Darling Street to the south-west). The highest NO_X/NO_2 concentrations occurred when winds were along an east-west axis, which suggested contributions from the University campus and residential areas. The peak associated with easterly winds may also have been linked to Victoria Road. The highest PM_{10} concentrations at the monitoring station were associated with strong southerly winds, especially in summer. As at the other DPIE monitoring stations, this seemed to be due to wind-blown dust from open land to the south of the station.

D.8 Assumed background concentrations

D.8.1 Overview

Various approaches can be used to define long-term (annual mean) and short-term (*e.g.* 1-hour, 24-hour) background concentrations. The selection of a suitable method is strongly dependent on the quantity and quality of available data, and this varies from project to project.

Firstly, it is important that that the same year is used for background air quality data and the meteorological data used in the dispersion modelling, given the influence of the latter on the former. The year selected for the meteorological data was 2016. This was also the base year for the assessment, which permitted model evaluation for this year. Becasue there was a general downward trend, or stabilisation, in pollutant concentrations between 2004 and 2016 (see section D.5), the concentrations in 2016 were considered to be appropriate for use in the Beaches Link assessment. On balance, it was considered that the concentrations in 2016 would represent typical (but probably slightly conservative) background concentrations in the future.

The approaches for establishing background concentrations in the Beaches Link assessment, and for combining these with model predictions, were similar to those developed to support the EISs for the WestConnex M4 East, New M5 and M4-M5 Link projects (Pacific Environment, 2015b; Pacific Environment, 2015c; Pacific Environment, 2017a). Three types of background concentration data were required:

- For community receptors, time series of background concentrations for the whole of 2016, and using time intervals that corresponded to the air quality criteria (e.g. 1-hour average, 24-hour average). These profiles were used in the ‘contemporaneous’ assessment for each receptor.
- For RWR receptors, annual mean background concentrations.
- For RWR receptors, short-term background concentrations.

The general approaches used, and the results for the various pollutants and metrics, are described in sections D9.2, D9.3 and D9.4. The various approaches are summarised in section D9.5, and some limitations are discussed in section D9.5.

D.8.2 Synthetic background profiles for community receptors (contemporaneous assessment)

D.8.2.1 General approach

A contemporaneous approach used for community receptors in the Beaches Link assessment. This was broadly consistent with the ‘Level 2’ method described in the NSW Approved methods. The approach requires that existing background concentrations of a pollutant in the vicinity of a proposal should be included in the assessment as follows (NSW EPA, 2016):

- At least one year of continuous ambient pollutant measurements should be obtained for a suitable background station. The background data should be contemporaneous with the meteorological data used in the dispersion modelling.
- At each receptor, each individual dispersion model prediction is added to the corresponding measured background concentration (*e.g.* the first hourly average dispersion model prediction is added to the first hourly average background concentration) to obtain total hourly predictions.
- At each receptor, the maximum concentration for the relevant averaging period is determined.

The unstated assumption is that one of the paired project-background concentration combinations will result in a realistic estimate of the maximum concentration that could be expected.

For the Beaches Link project this approach was applied to the short-term concentration metrics for CO (1-hour mean, rolling 8-hour mean), NO_X (1-hour mean), PM_{10} (24-hour mean) and $PM_{2.5}$ (24-hour mean). NO_X (1-hour mean) was used in place of NO_2 for the reasons given in Annexure E.

An important consideration was the actual stations to be included in the calculation of the synthetic profiles, and the annual mean concentration maps were used to identify these. The stations listed below reflected the ranges of annual mean concentrations in the GRAL domain, and it was assumed that these stations would also represent the range of short-term concentrations.

- DPIE Lindfield
- DPIE Randwick
- DPIE Rozelle
- WCX M4E:05
- WCX NewM5:01

Gap-filling techniques were used to ensure that a complete time series of concentrations was available. The approach for each pollutant is described in the relevant section below. To maintain a margin of safety, in each synthetic profile the concentration for a given time step (e.g. 1 hour or 24 hours) was taken as the maximum of the values from all the relevant stations.

D.8.2.2 Carbon monoxide: one-hour mean

Figure D-15 shows examples of one-hour mean CO concentration profiles at three stations during June of 2016. Peak concentrations generally occurred simultaneously at the different stations, indicating a regional background influence. This synthetic background profile for 2016, which was constructed using the data from these stations, is shown in Figure D-16.

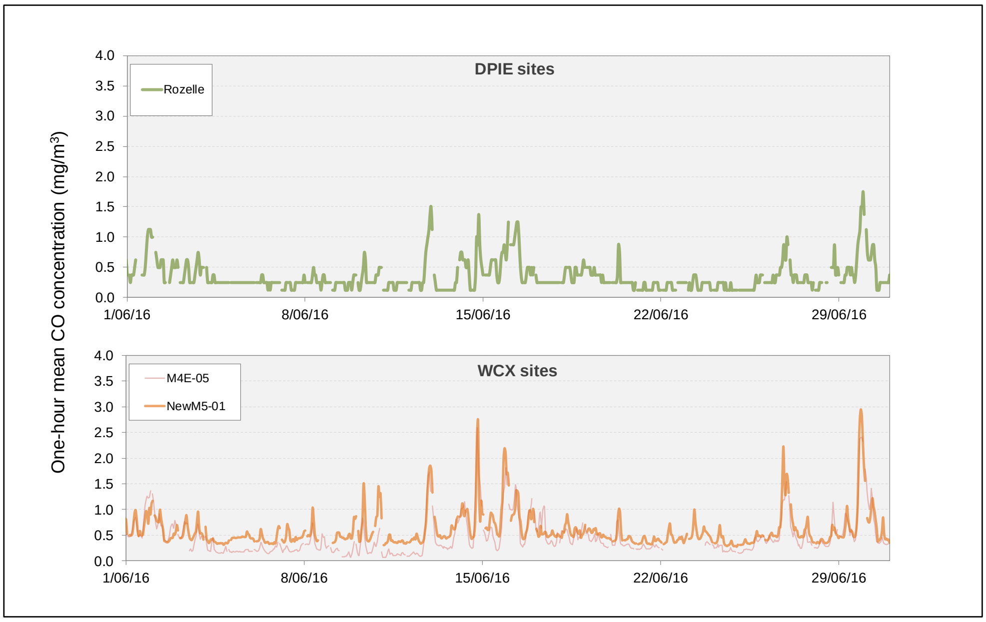


Figure D-15 One-hour mean CO concentration at DPIE and WCX stations (example for June 2016)

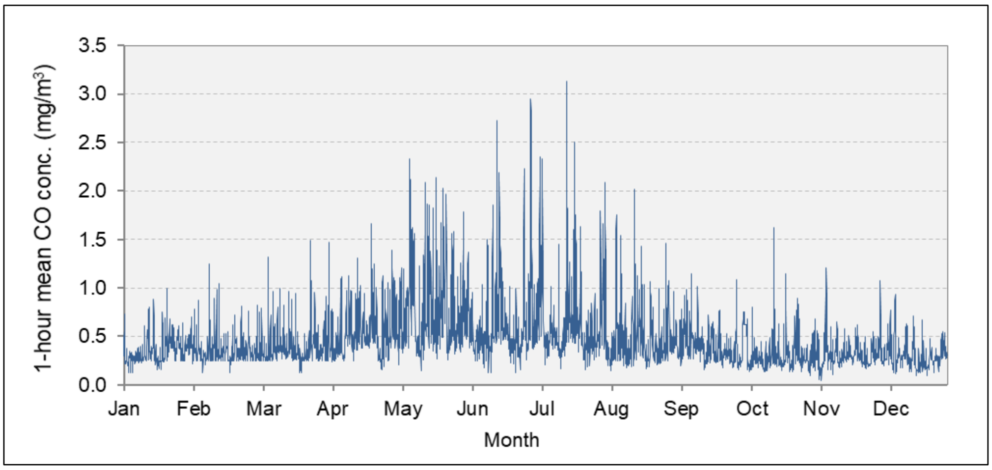


Figure D-16 **Synthetic background concentration profile for one-hour mean CO in 2016**

D.8.2.3 Carbon monoxide: rolling 8-hour mean

The synthetic profile for the rolling 8-hour mean CO concentration was constructed using the data from the three stations in Figure D-15. This profile is shown in Figure D-17.

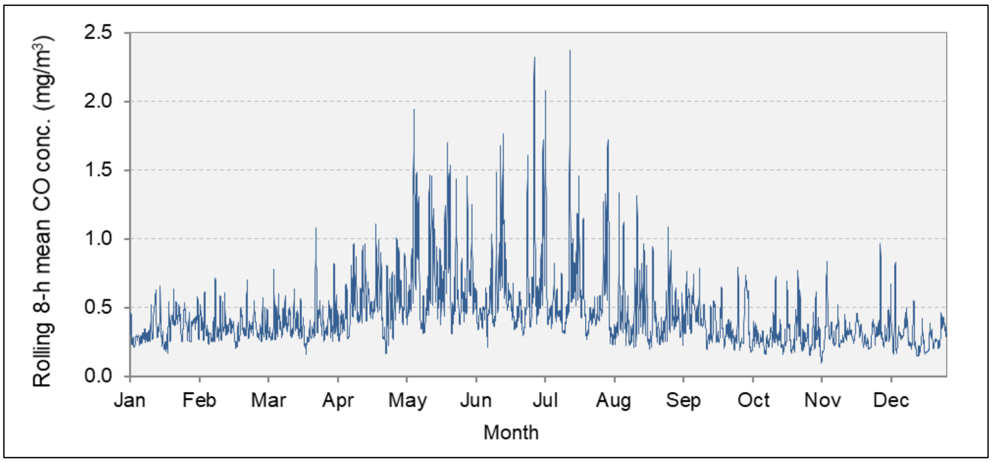


Figure D-17 **Synthetic background concentration profile for rolling 8-hour mean CO in 2016**

D.8.2.4 NO_X: one-hour mean

Figure D-18 shows examples (for June 2016) of one-hour concentration profiles at the relevant DPIE and WCX background stations. As with CO, peak concentrations regularly occurred simultaneously at the different stations, indicating a regional influence.

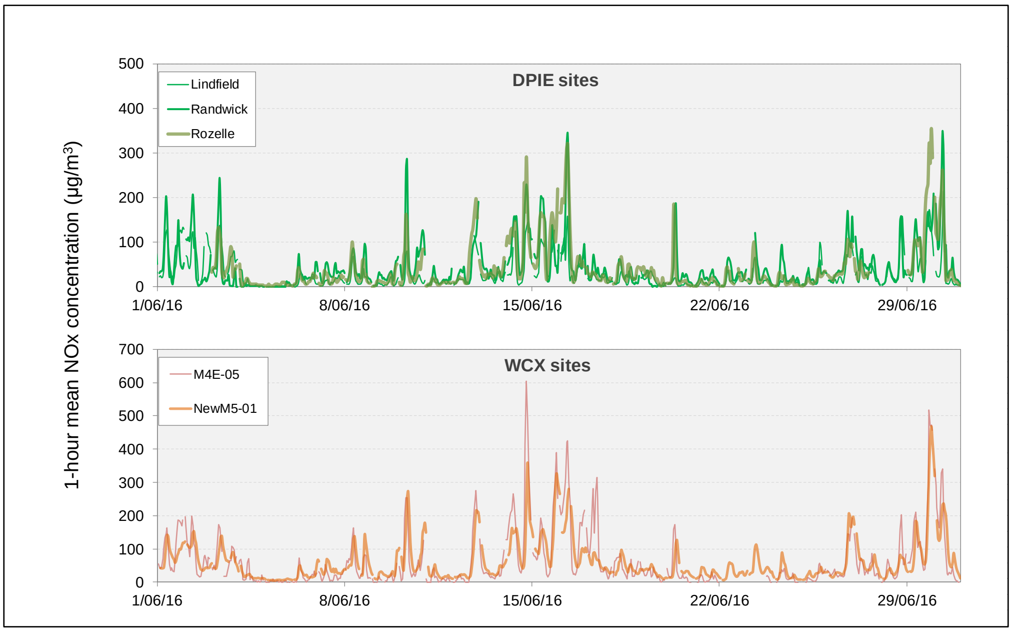


Figure D-18 One-hour mean NO_X concentration at DPIE and WCX stations (example for June 2016)

The four synthetic background concentration profile is shown in Figure D-19. For the Beaches Link GRAL domain, a single synthetic profile would be dominated by the stations outside the domain which have relatively high annual mean concentrations (i.e. the two WCX sites - M4E:05 and NewM5:01). Whilst the concentration profiles for these sites would be reasonably accurate for the south-west corner of the GRAL domain, it is likely that for most of the domain the synthetic profile would be quite conservative.

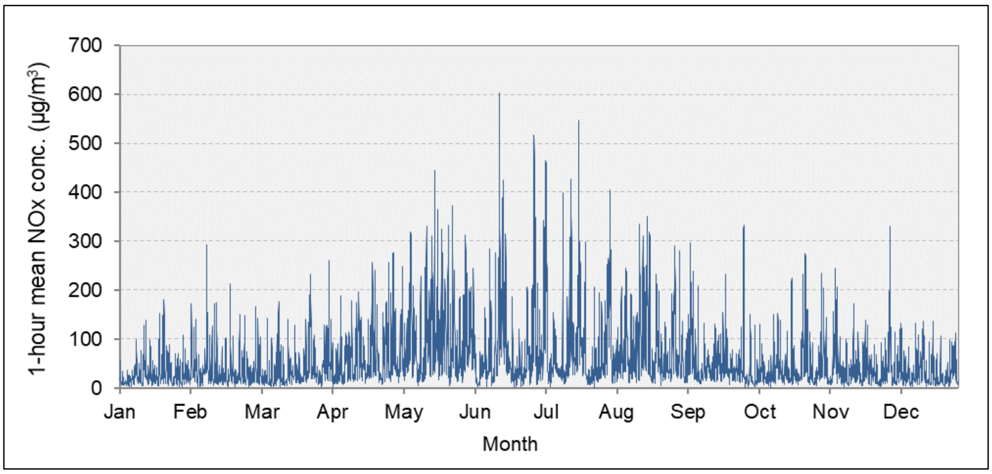


Figure D-19 Synthetic background concentration profile for one-hour mean NO_X in 2016

D.8.2.5 PM_{10}: 24-hour mean

Figure D-20 shows the concentration profiles for 24-hour mean PM_{10} in 2016 at three DPIE stations and two WCX stations. As before, the strong similarities between the peaks and troughs in the profiles at the three stations show that the stations are characterising the same (*i.e.* regional) patterns in PM_{10}.The synthetic background concentration profile for 24-hour PM_{10} is shown in Figure D-21. There were seven exceedances of the criterion of 50 µg/m³, when regional events such as dust storms, bush fires and hazard reduction burns are included.

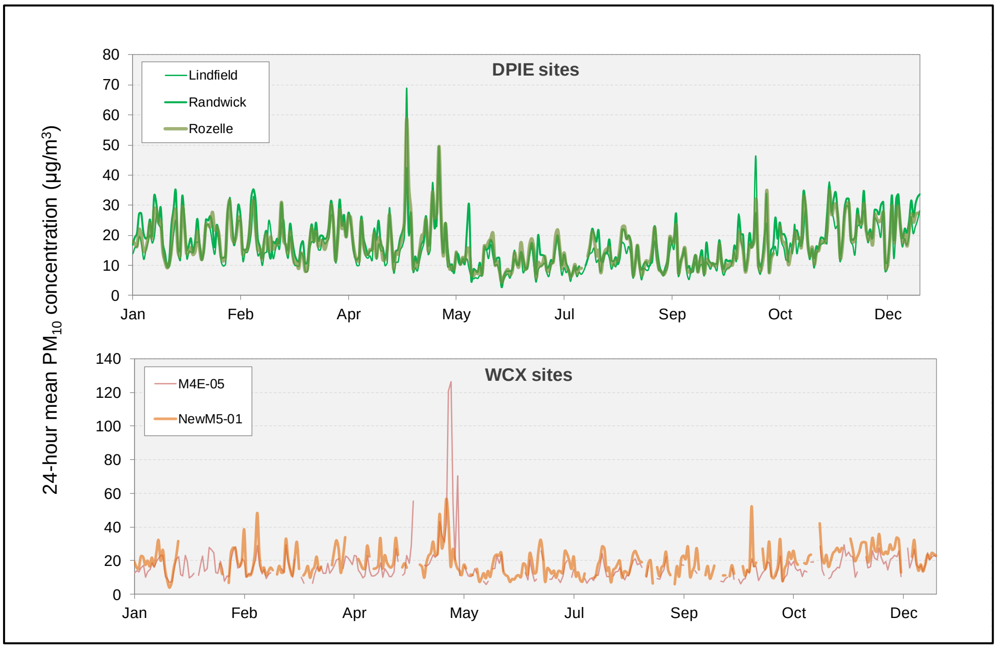


Figure D-20 24-hour mean PM_{10} concentration at DPIE and WCX stations in 2016

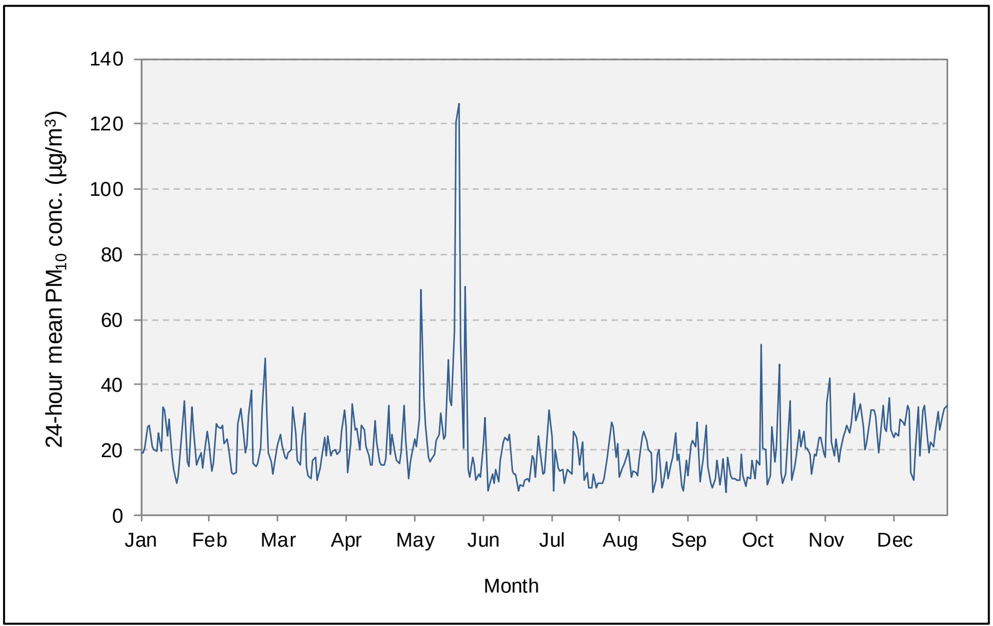


Figure D-21 Synthetic background concentration profile for 24-hour mean PM_{10} in 2016

D.8.2.6 $PM_{2.5}$: 24-hour mean

The synthetic background profile for 24-hour $PM_{2.5}$ in 2016 was based on the data from three DPIE and WCX stations. The concentrations from the these stations are shown in Figure D-22, and the synthetic profile is given in Figure D-23. There were seven exceedances of the criterion of 25 µg/m³, when regional events such as dust storms, bush fires and hazard reduction burns are included.

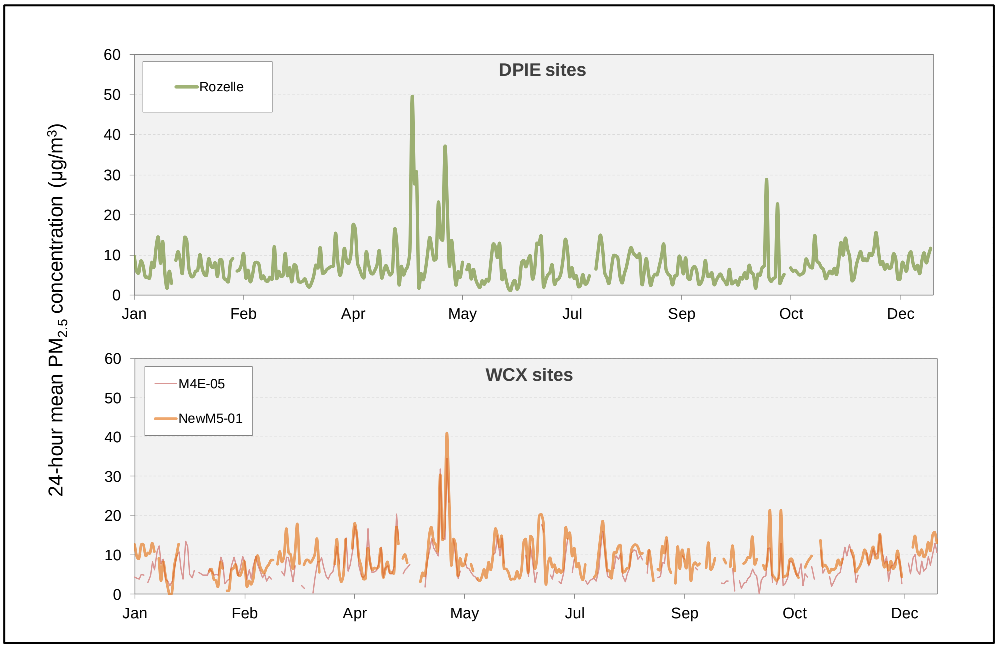


Figure D-22 24-hour mean $PM_{2.5}$ concentration at DPIE and WCX stations in 2016

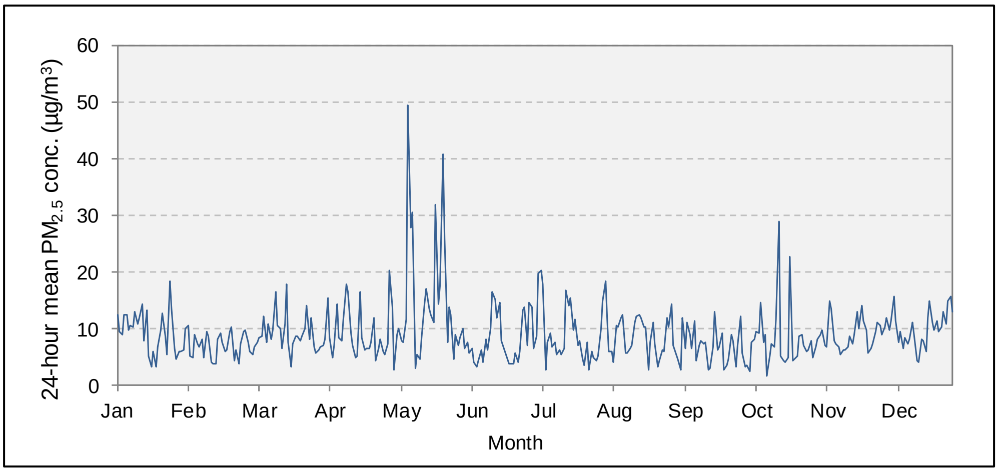


Figure D-23 Synthetic background concentration profile for 24-hour mean $PM_{2.5}$ in 2016

D.8.3 Annual mean background concentrations at RWR receptors

In the case of annual mean concentrations it is relatively straightforward to define background values. For smaller projects it has often been sufficient to use a single background value, and to assume that this is representative of the whole study area. However, for a project such as Beaches Link, which covers a large geographical area and features different types of land use, it was considered important to allow for spatial variation in annual mean concentrations where possible. Maps of background annual mean concentrations of the most important road transport pollutants (NO_X, PM_{10} and $PM_{2.5}$) were therefore developed for the GRAL domain. When developing these maps the data from any non-background stations were excluded.

The background maps were created in the Golden Software Surfer package using a geostatistical Kriging method, whereby gridded values are interpolated based on the statistical relationship of the surrounding measured values. Clearly, the absence of monitoring data for much of the GRAL domain meant that there was some uncertainity in the extrapolation. For the creation of the background maps the data from all background stations in Sydney with relevant measurements were used.

To determine background pollutant concentrations for any discrete receptor location within the GRAL domain, the ‘grid residual’ function in Surfer was used. This function calculates the difference between the grid value and a specified data value at any x-y location. By setting the data value for a given x-y point to zero, it can be used to return the estimated concentration for the point. Although this approach did not allow for localised influences on background concentrations, it was considered to be better than the alternatives (e.g. using a single annual mean value for the whole domain).

D.8.3.1 NO_X: annual mean

It was noted in the trend analysis that there was a spatial variation in NO_X concentrations. To allow for this spatial variation, the data from the DPIE, Transport for NSW and WCX background monitoring stations were used to determine a background map for annual mean NO_X across Sydney in 2016, as shown in Figure D-24. The area covered by the GRAL domain, as used in the air quality assessment, is identified in the Figure. The Figure shows that there was a decreasing NO_X concentration gradient across Sydney, from the south-west to the north-east. This was also the case for the GRAL domain, with concentrations decreasing from around 40 $\mu g/m^3$ in the south-west to around 18 $\mu g/m^3$ in the north-east.

Because there were no measurements in the GRAL domain during 2016, except at Rozelle in the south-west, the size of the NO_X gradient was somewhat uncertain. However, data from the Western Harbour Tunnel and Beaches Link background monitoring station (WHTBL:01) from October 2017 to January 2019 were compared statistically with those from several DPIE stations during the same period (Table D-17).

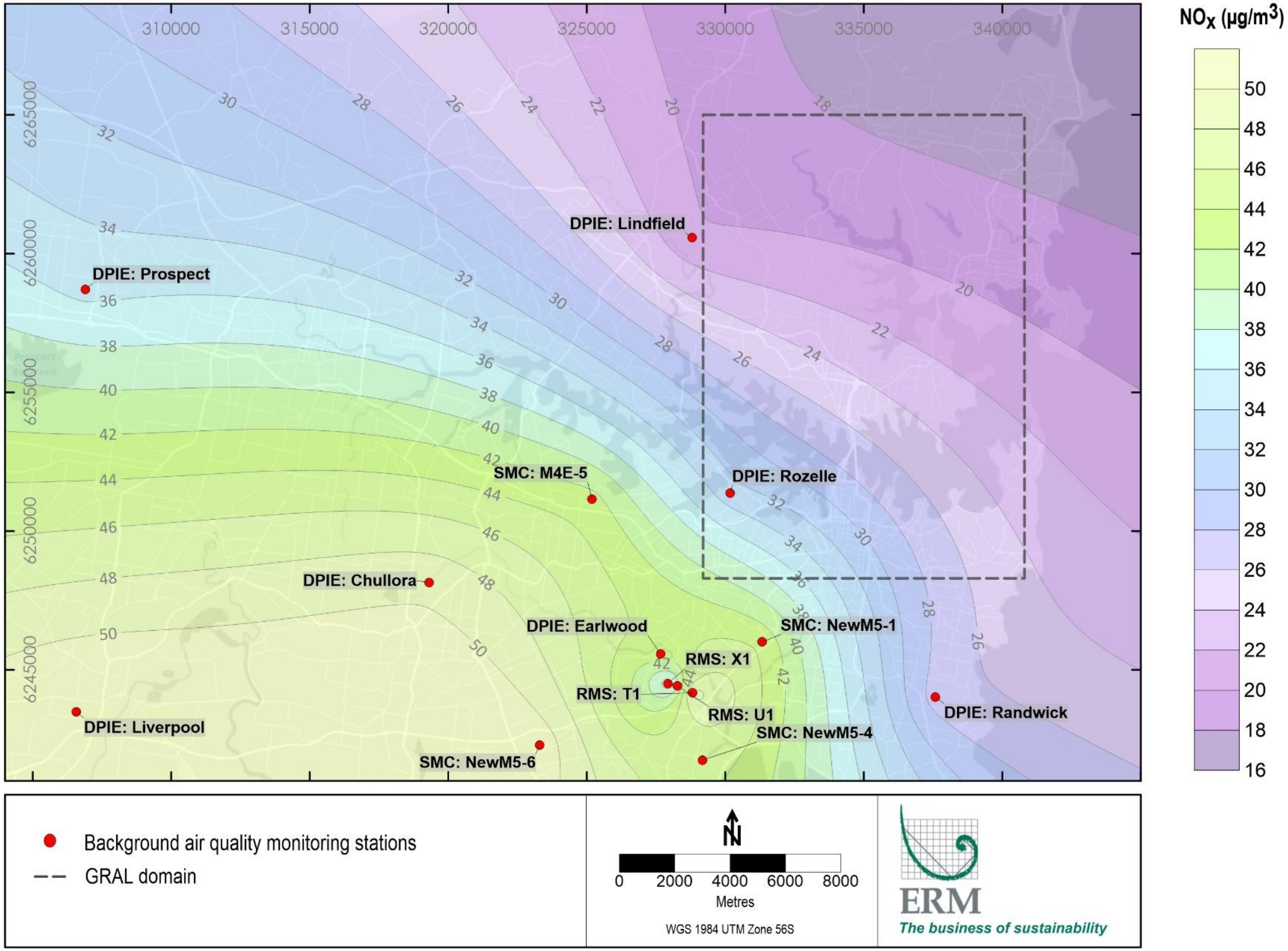


Figure D-24 **Background map for annual mean NO_X concentration across Sydney in 2016**

Table D-17 **NO_X concentrations at DPIE and WHTBL stations (October 2017 to January 2019)**

Statistic	NO_X concentration (µg/m^3)						
	Chullora	Earlwood	Lindfield	Macquarie Park	Randwick	Rozelle	WHTBL:01
Mean	41.5	37.3	18.7	14.6	18.3	28.0	**14.2**
Median	20.5	16.4	10.3	8.2	4.1	14.4	**8.7**
Max	539.8	459.7	291.4	262.7	344.8	554.1	**139.5**
98th%ile	213.4	227.8	98.7	71.8	137.5	143.7	**64.0**

The WHTBL:01 station is in the north-east of the GRAL domain, and the background map suggests that the annual mean NO_X concentration in 2016 at this location would be 0.4-4.5 µg/m^3 lower than those at Lindfield and Macquarie Park, and around 4-14 µg/m^3 lower than those at Randwick and Rozelle. Although the mean and median values for Randwick in Table D-17 are rather low, the statistics otherwise provide evidence that the background NO_X concentration gradient in the GRAL domain is reasonably accurate.

D.8.3.2 PM_{10}: annual mean

The background map for annual mean PM_{10} in Sydney in 2016 is shown in Figure D-25. Although there was a localised concentration low points to the north-west of Sydney Airport (which may have been real or may have been related to differences in the PM_{10} measurement technique), the concentration gradient in the GRAL domain was not affected given that it was several kilometres away.

Compared with NO_X, the concentration gradient for PM_{10} across the GRAL domain was quite small ranging from around 16 µg/m^3 in the north-west to around 17.5 µg/m^3 in the south. As with NO_X, the size of the PM_{10} gradient was somewhat uncertain, and again the data from the WHTBL:01 station from October 2017 to January 2019 were compared statistically with those from the DPIE stations during the same period (Table D-18).

Table D-18 **PM_{10} concentrations at DPIE and WHTBL stations (October 2017 to January 2019)**

Statistic	PM_{10} concentration (µg/m^3)						
	Chullora	Earlwood	Lindfield	Macquarie Park	Randwick	Rozelle	WHTBL:01
Mean	21.7	19.8	18.1	17.3	21.5	19.1	**18.6**
Median	19.0	17.7	15.8	14.6	19.3	17.0	**16.0**
Max	397.7	385.2	261.7	278.4	327.0	309.9	**323.0**
98th%ile	59.6	49.1	50.0	53.7	53.6	45.3	**47.0**

The background map suggests that the annual mean PM_{10} concentration in 2016 at the WHTBL:01 station would be slightly higher than those at Lindfield and Macquarie Park, around 1.9 µg/m^3 lower than those at Randwick, and around 0.5 µg/m^3 lower those at Rozelle. Whilst the values in Table D-18 do not match this pattern exactly, when allowing for differences in year and time of year they do indicate that the background PM_{10} gradient in the GRAL domain is reasonably accurate.

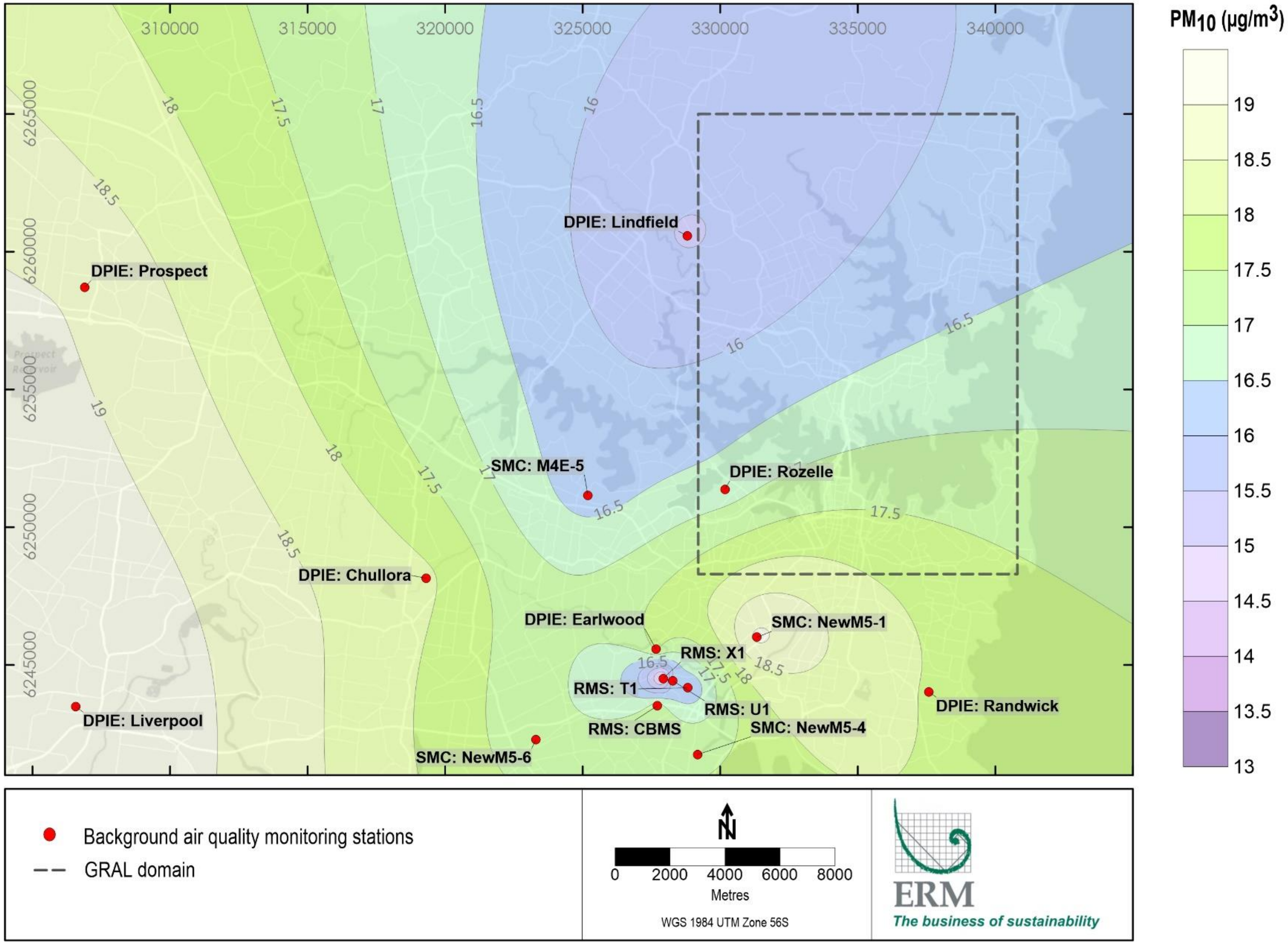


Figure D-25 **Background map for annual mean PM_{10} concentration across Sydney in 2016**

D.8.3.3 $PM_{2.5}$: annual mean

The background map for annual mean $PM_{2.5}$ in Sydney in 2016 is shown in Figure D-26. This was based on a smaller number of stations than the maps for NO_X and PM_{10}. The concentration range across the GRAL domain was small, ranging from just below 7 µg/m^3 in the west to around 8.3 µg/m^3 in the south-east.

The data from the WHTBL:01 station for October 2017 to January 2019 were compared statistically with those from the DPIE stations during the same period (Table D-19). However, the data were not very extensive. For example, $PM_{2.5}$ is not measured at Lindfield, and was not measured at Macquarie Park and Randwick in 2016. The background map suggests that the annual mean $PM_{2.5}$ concentration in 2016 at the WHTBL:01 station would be around 0.8 µg/m^3 higher than that at Rozelle. Overall, the data from the WHTBL:01 station do provide a definite confirmation of the $PM_{2.5}$ gradient in the GRAL domain.

Table D-19 $PM_{2.5}$ concentrations at DPIE and WHTBL stations (October 2017 to January 2019)

Statistic	$PM_{2.5}$ concentration (µg/m^3)						
	Chullora	Earlwood	Lindfield	Macquarie Park	Randwick	Rozelle	WHTBL:01
Mean	8.6	7.6	-	6.8	7.6	7.3	**8.1**
Median	7.2	6.4	-	5.6	6.4	6.5	**7.0**
Max	116.4	164.0	-	183.0	98.1	134.7	**118.0**
98th%ile	27.8	23.2	-	20.9	23.9	20.7	**23.0**

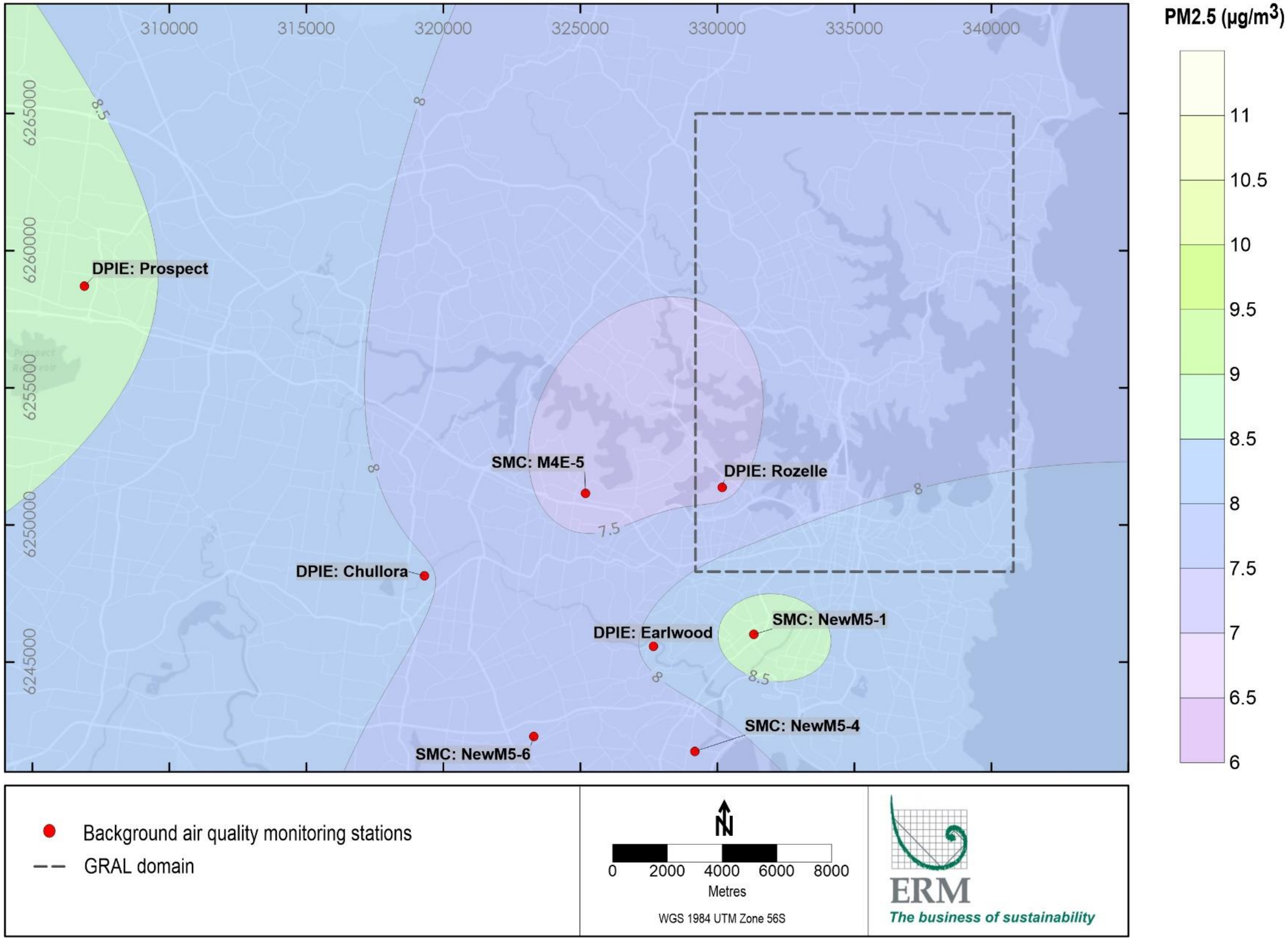


Figure D-26 **Background map for annual mean $PM_{2.5}$ concentration across Sydney in 2016**

D.8.4 Background concentrations for short-term metrics at RWR receptors

In the WestConnex assessments the background concentrations for short-term metrics at all RWR receptors were taken to be single values - either the 98th percentile (M4 East, New M5) or the maximum (M4-M5 Link) of the synthetic profile - that did not vary in space. This corresponds to the 'Level 1' method in the NSW Approved Methods. In the case of the M4-M5 Link assessment, this contributed to an over-prediction of concentrations at some RWR receptors (Pacific Environment, 2017). However, given the limited amount of air quality monitoring data in the GRAL domain, it was also necessary to retain this approach for the Beaches Link project. It should be noted that the approaches described below for RWR receptors were also applied to the development of the contour plots for the corresponding pollutant metrics.

D.8.4.1 CO

For RWR receptors the maximum 1-hour CO concentration from GRAL was added to the maximum 1-hour background concentration from the synthetic profile (3.13 mg/m³). The result from the above calculation was also used to derive the maximum rolling 8-hour CO concentration using a relationship based on the data from the air quality monitoring stations in Sydney between 2004 and 2016 (Figure D-27). This relationship is expressed in Equation D1.

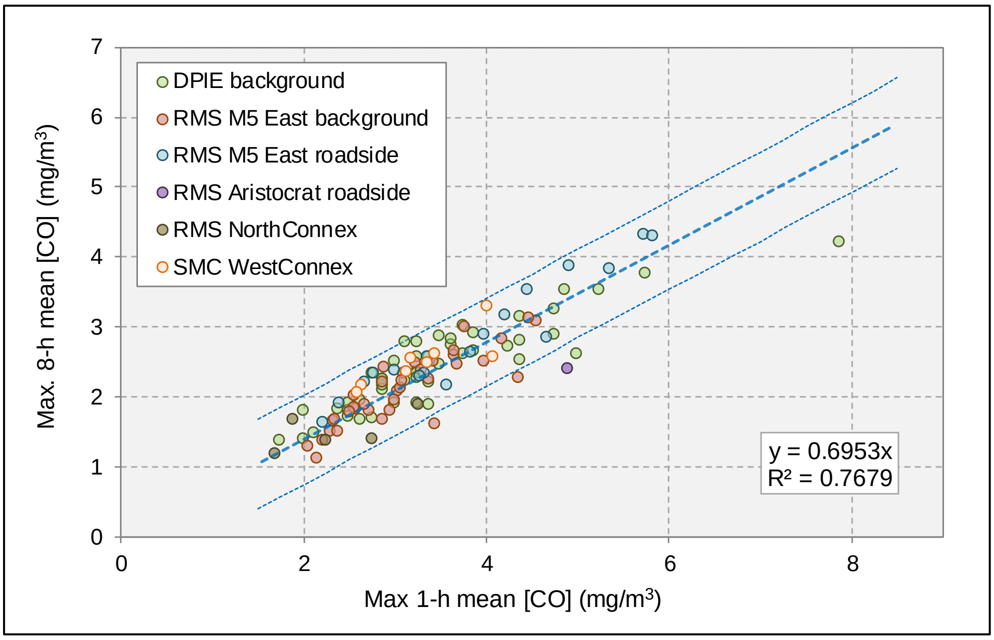


Figure D-27 Relationship between maximum rolling 8-hour mean CO and maximum 1-hour mean CO (dotted blue lines show 95 per cent prediction intervals)

Equation D1

$$[CO]_{8h,max} = 0.6953 \times [CO]_{1h,max}$$

Where:

$[CO]_{8h,max}$ = maximum rolling 8-hour CO concentration (including background) (mg/m³)

$[CO]_{1h,max}$ = maximum 1-hour CO concentration (including background) (mg/m³)

D.8.4.2 NO_X, PM_{10} and $PM_{2.5}$

For NO_X the maximum 1-hour concentration from GRAL was added to the maximum 1-hour concentration from the synthetic background profile (603.8 μg/m³), and the resulting total was converted to NO_2 using the empirical approach described in Annexure E.

For PM_{10} and $PM_{2.5}$ the maximum 24-hour concentration from GRAL was added to the 98th percentile 24-hour concentration from the synthetic background profile (48.04 μg/m³ for PM_{10} and 22.06 μg/m³ for $PM_{2.5}$).

D.8.5 Summary of background concentration approaches

The approaches used to characterise background concentrations for community and RWR receptors, and some basic statistics, are provided in Table D-20.

Table D-20 Characteristics of assumed background concentrations (year = 2016)

Pollutant/ metric	Averaging period	Form	Units	Statistical descriptors		
				Mean	Max.	98th percentile
Community receptors – contemporaneous assessment						
CO	1-hour	Synthetic profile	mg/m³	0.45	3.13	1.38
	8 hour (rolling)	Synthetic profile	mg/m³	0.45	2.37	1.24
NO_X	Annual, 1-hour	Synthetic profile	μg/m³	54.7	603.8	239.9
PM_{10}	Annual, 24-hour	Synthetic profile	μg/m³	21.2	126.2	48.02
$PM_{2.5}$	Annual, 24-hour	Synthetic profile	μg/m³	9.1	49.4	22.06
RWR receptors – statistical assessment						
CO	1-hour	Maximum	mg/m³	-	3.13	-
	8 hour (rolling)	Not applicable (see Equation D1)				
NO_X	Annual	Map	μg/m³	Spatially varying	-	-
	1-hour	Maximum	μg/m³	-	603.8	-
PM_{10}	Annual	Map	μg/m³	Spatially varying	-	-
	24-hour	Maximum	μg/m³	-	-	43.6
$PM_{2.5}$	Annual	Map	μg/m³	Spatially varying	-	-
	24-hour	Maximum	μg/m³	-	-	22.8

D.9 Limitations

It is important to understand the limitations of the various approaches for combining model predictions with background concentrations, and the inherent uncertainty in the overall results.

For annual mean concentrations the approaches used were considered to be robust, taking into account the spatial variation in the background concentration with reasonable accuracy. However, for short-term metrics there is always more uncertainty in both the model predictions and the background. Measured short-term concentration peaks vary considerably in terms of the magnitude, time of occurrence and location. It is well know that models do not accurately predict peak concentrations in both time and space. Secondly, it is very difficult to define both the spatial and temporal variation in short-term background concentrations in great detail, especially where the monitoring data are not very extensive.

The uncertainty in the prediction of short-term concentrations relates to both the contemporaneous and statistical approaches used in this assessment, as noted below.

D.9.1 'Contemporaneous' approach

The contemporaneous approach gives a good representation of the *temporal* variation in model predictions and background concentrations. As the temporal variation in concentrations is generally more pronounced than the spatial variation, it is usually considered to be more important to focus on this.

The main shortcoming of the contemporaneous approach is that a single background profile is applied across a wide geographic area, whereas peak concentrations vary spatially. For example, for NO_X the monitoring data for all stations and years were analysed to determine the relationships between the annual mean concentration and various short-term concentration metrics (eg. maximum, 98th percentile). The relationship between the annual mean concentration and the maximum 1-hour concentration was found to be strong (Figure D-28, R^2 = 0.74). For the annual mean and the 98th percentile 1-hour concentration the relationship was very strong (Figure D-29, R^2 = 0.90). Given that the annual mean NO_X concentration varies spatially, it can be inferred that the peak concentrations would also vary spatially. Consequently, it is likely that that the synthetic profile would underestimate peak concentrations and some locations, and would over estimate concentrations at other locations (given the conservative nature of the synthetic profile, the latter would be more likely to occur). A similar logic applies to 24-hour concentrations of PM_{10} and $PM_{2.5}$.

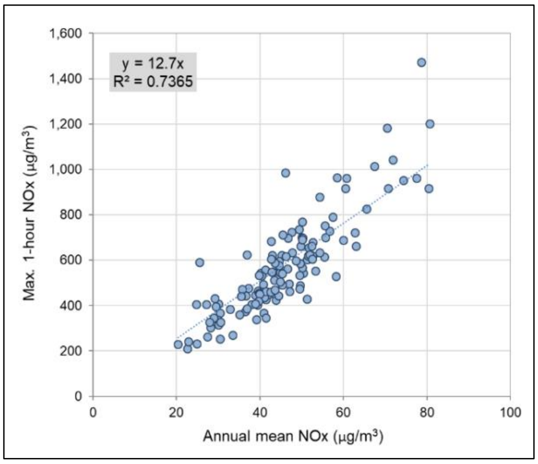


Figure D-28 Relationship between annual mean and maximum 1-hour NO_X

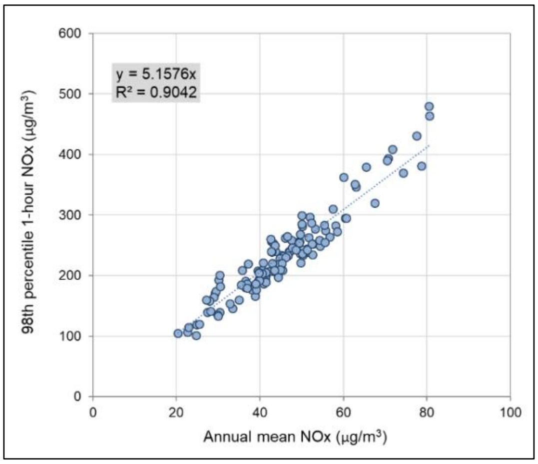


Figure D-29 Relationship between annual mean and 98th percentile 1-hour NO_X

D.9.2 'Statistical' approach

For RWR receptors a single (98th percentile) value was used for short-term background concentrations. Given the very small number of values such an approach can be very conservative, and can result in unrealistically high cumulative concentrations; it is very unlikely that these few high background values will coincide in space and time with the maximum predicted values.

For NO_X, consideration was given to the use of the relationship between the annual mean concentration and the 98th percentile 1-hour or 24-hour concentration (eg. Figure D-29) in conjunction with the annual mean map to give a spatially-varying 98th percentile background for the RWR receptors. However, this would have been inconsistent with the contemporaneous assessment for the community receptors, and it is possible that the use of the 98th percentile background could have meant that the maximum total NO_2 concentrations at most RWR receptors would have been underestimated. Specifically, it was found that, in the contemporaneous assessment, the maximum total concentration very frequently coincided in time with the maximum background concentration. For the community receptors there would therefore be a poor relationship between the results for the contemporaneous and statistical approaches when the background for the latter is linked to the annual mean (basically, there would be a lot more variation in the results for the statistical approach). The use of the single maximum background concentration for NO_X across the domain generally gave slightly higher results than the contemporaneous approach (see Figure D-30). In some cases the NO_2 prediction was markedly higher. Nevertheless, as noted earlier, the contemporaneous approach has some spatial uncertainty.

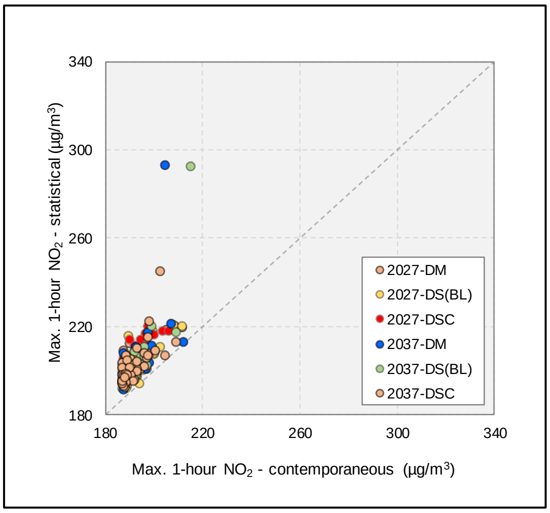


Figure D-30 Comparison between statistical and contemporaneous approaches for calculating 1-hour NO_2 at community receptors (maximum background NOx)

For $PM_{2.5}$ and PM_{10} the relationships between the annual mean and peak concentrations were much weaker than for NO_X. Therefore, there 98th percentile was used for background $PM_{2.5}$ and PM_{10} at RWR receptors (Figure D-31 and **Error! Reference source not found.**).

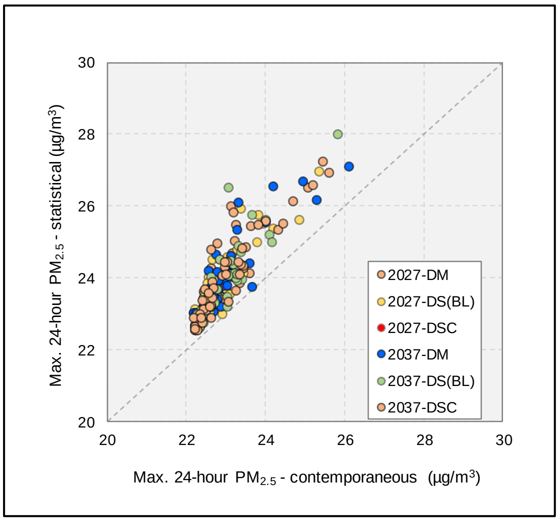


Figure D-31 Comparison between statistical and contemporaneous approaches for calculating maximum 24-hour $PM_{2.5}$ at community receptors (98th percentile background $PM_{2.5}$)

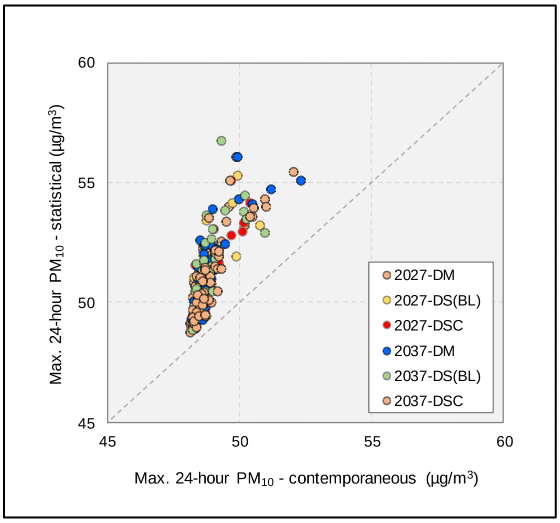


Figure D-32 Comparison between statistical and contemporaneous approaches for calculating maximum 24-hour PM_{10} at community receptors (98th percentile background PM_{10})

D.10 Measurements at project stations

As noted earlier, three project-specific monitoring stations for the Western Harbour Tunnel and Beaches Link Projects were established in 2017 (see Table D-1). One of these was at a background location, and the other two were at locations near busy roads. Given the date of deployment, the time period covered was too short for these to be included directly in the development of background concentrations and for model evaluation. However, the data from the stations from October 2017 to January 2019 are presented in this Annexure.

For background air quality, the data from the WHTBL:01 station have been compared with the the range of measurements at the DPIE stations, and these comparisons are shown in Figure D-33 to Figure D-38. Some basic statistics are also provided in Table D-21. Only the DPIE stations closest to the Beaches Link project (i.e. Chullora, Earlwood, Lindfield, Macquarie Park, Randwick and Rozelle) were included in the evaluation. The Liverpool and Prospect stations, which were much further to the west, were excluded. This work expanded upon the comparisons between WHTBL:01 and the DPIE stations earlier in this Annexure.

Each figure shows the following:

- The 1-hour time series for the one project background station and the two project roadside stations.
- For station WHTBL:01, the comparison with the DPIE data for the daily mean and daily maximum concentrations. The 24-hour averaging period was chosen as a convenient way of representing the whole monitoring period while retaining some of the temporal detail.

It is worth noting that background stations are located so as to characterise regional air quality, and therefore the data ought to show similar patterns from station to station, albeit with some variation in absolute concentrations. The data from roadside stations are, on the other hand, dependent on additional factors, such as the type of road (level in hierarchy), the level of traffic, and the distance between the road and the monitoring station, and are inherently more variable.

Given that the various monitoring stations are located at a range of stations across Sydney, differences in concentration are to be expected. It is therefore more helpful to consider the general patterns in the data than features of specific stations.

The statistics for the near-road project monitoring stations (e.g. NO_X) indicate that station WHTBL:03 was more strongly influenced by road traffic emissions that station WHTBL:02.

Average CO and $PM_{2.5}$ concentrations at WHTBL:01 were towards the upper end of the range at the DPIE stations. It is worth observing that all the measured 1-hour CO concentrations at WHTBL:01 were well below the corresponding criterion of 30 mg/m^3, and any differences between the DPIE and WHTBL data would not have had a material impact on the outcomes of the assessment for this pollutant.

For NO_X, NO_2 and PM_{10}, the measurements at the WHTBL:01 background were generally towards the lower end of the range of values at the DPIE sites. This has already been noted earlier with the respect to the concentration gradients in Sydney. Based on the dataset at WHTBL:01, it seems that the the use of the DPIE stations could result in rather conservative maximum concentrations of these pollutants in the air quality assessment, at least in the northern part of the GRAL domain. For example, between October 2017 and January 2019 the highest 1-hour average NO_X concentration at an DPIE station used in the synthetic profile (Rozelle) was 554 µg/m^3, compared with 140 µg/m^3 at the WHTBL:01 station.

Ozone concentrations at WHTBL:01 were higher than those st the DPIE stations, which is unsurprising given the relatively low NO_X at this station. NO_X, NO_2 and ozone are linked by chemical reactions in the atmosphere, and concentrations of NO_X and ozone typically have an inverse relationship (see section B.3.3 of Annexure B).

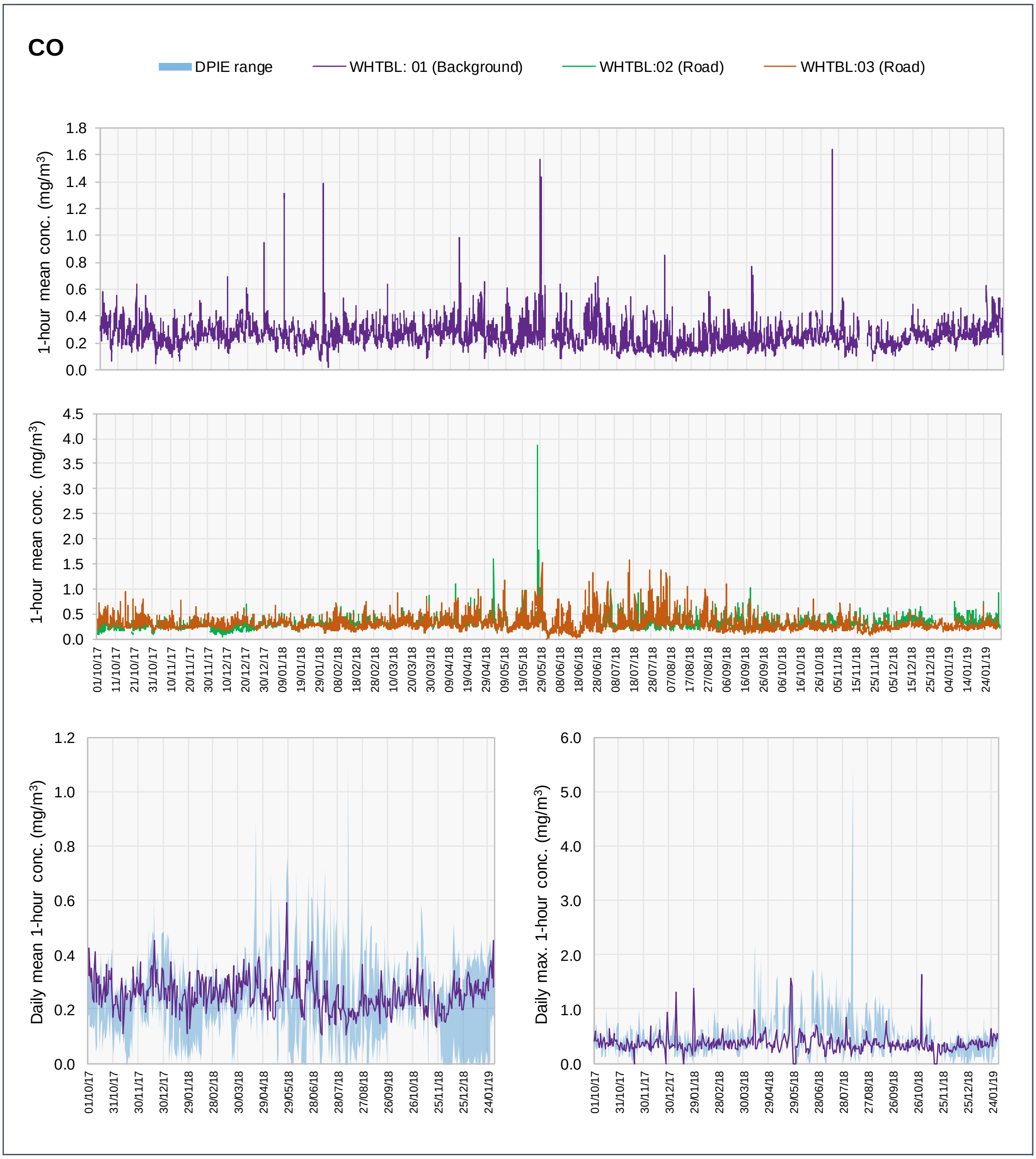


Figure D-33 CO concentrations at project monitoring stations (blue shading shows range of values at DPIE stations)

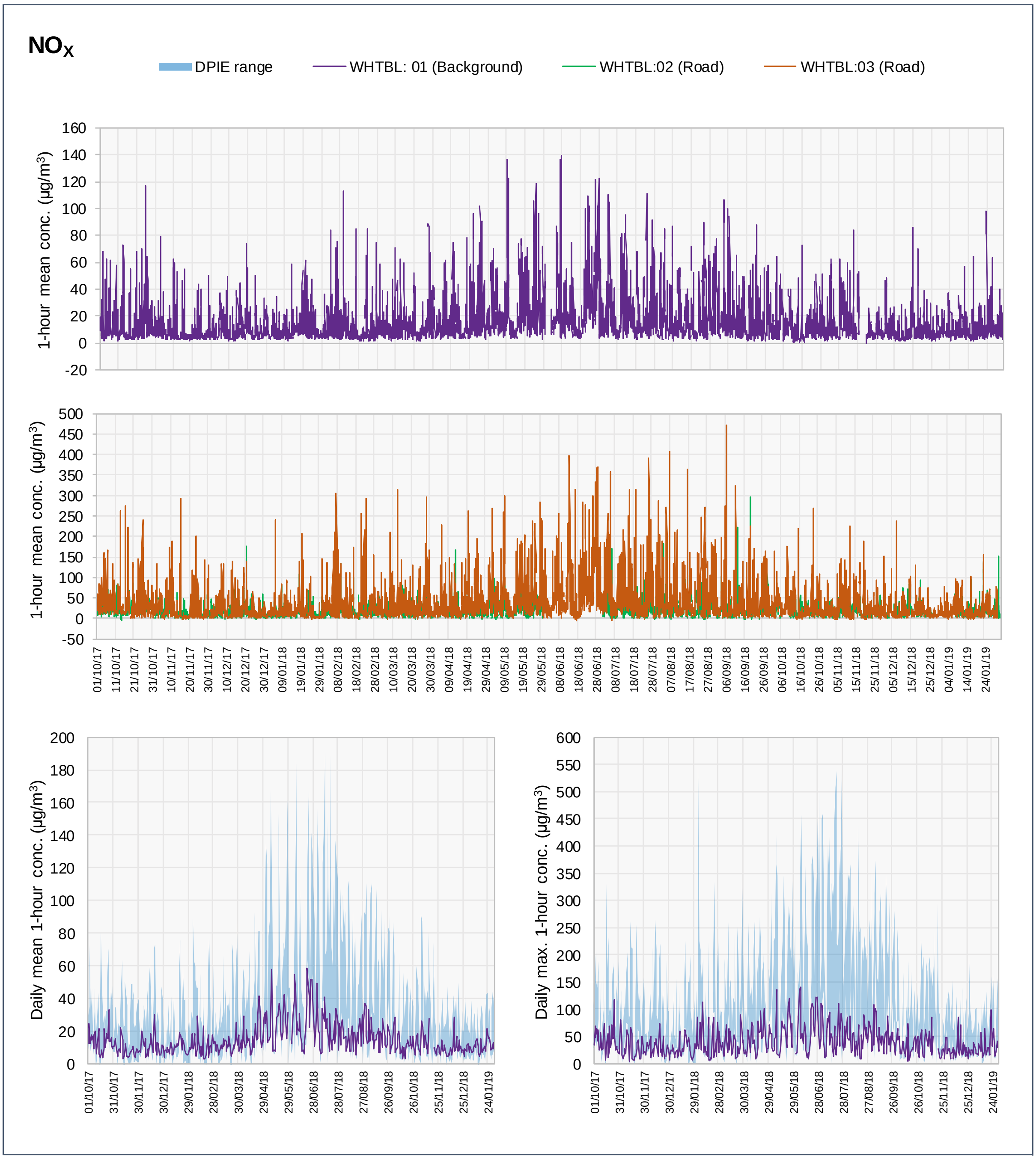


Figure D-34 NO_X concentrations at project monitoring stations (blue shading shows range of values at DPIE stations)

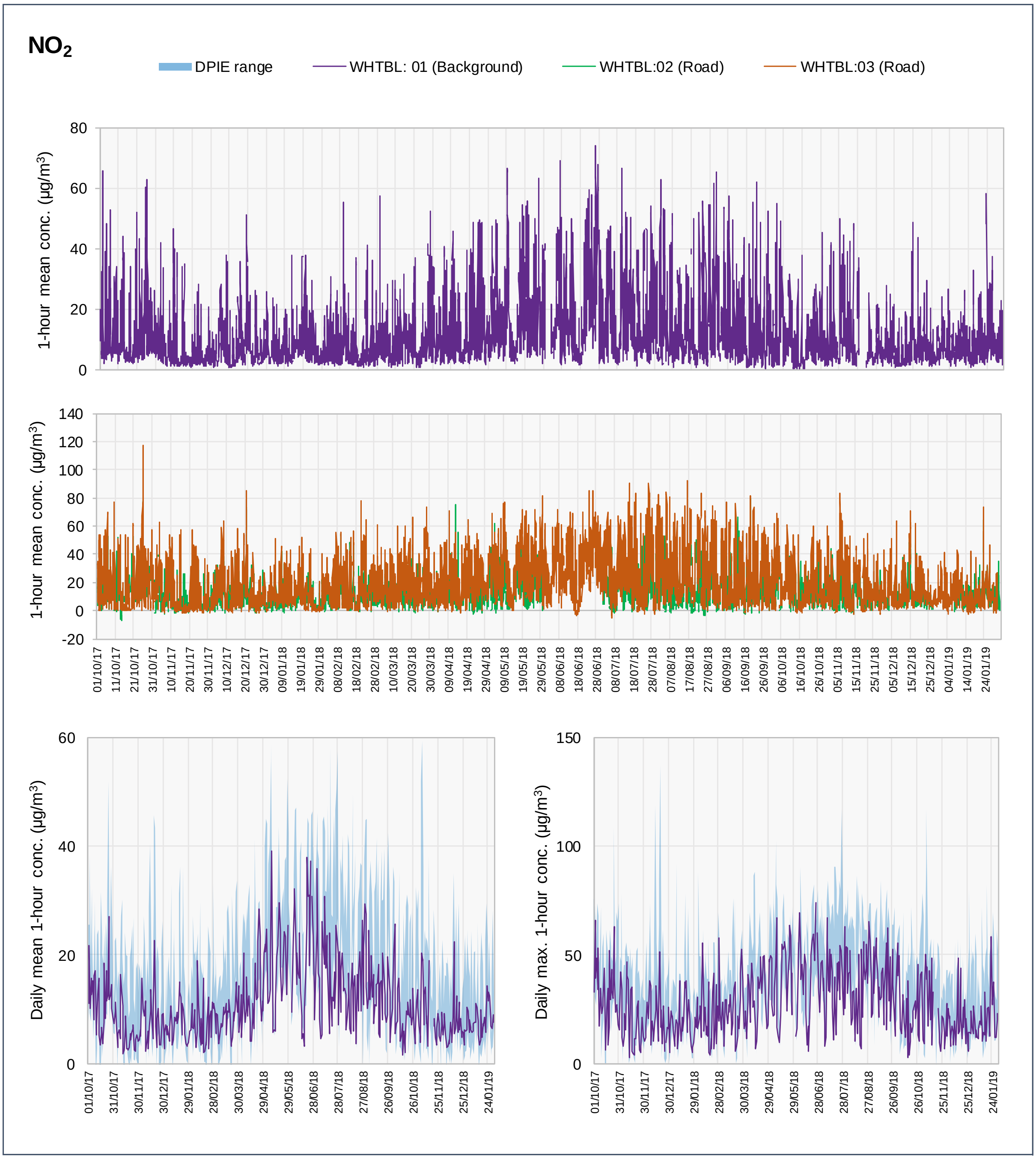


Figure D-35 **NO_2 concentrations at project monitoring stations (blue shading shows range of values at DPIE stations)**

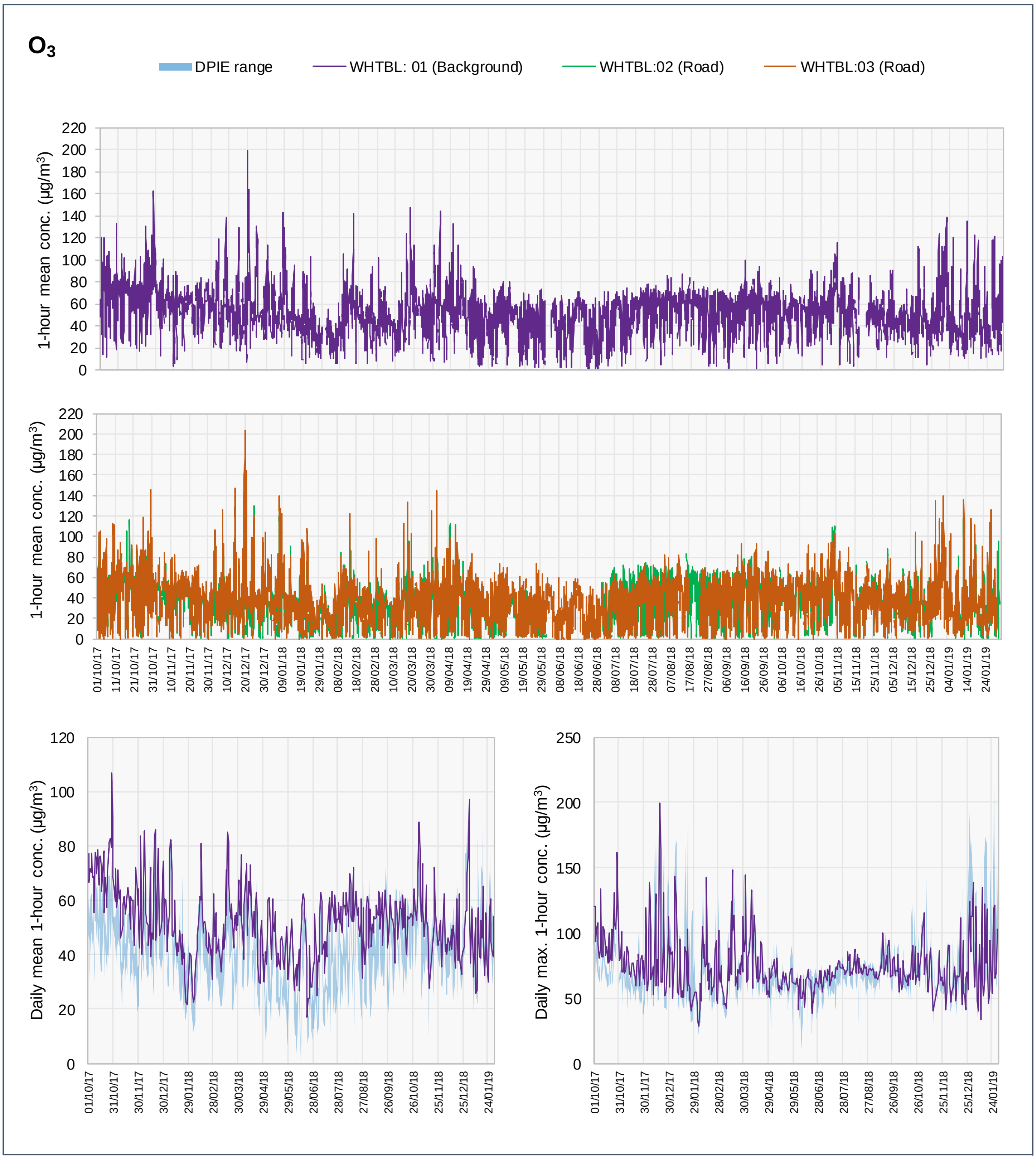


Figure D-36 **O_3 concentrations at project monitoring stations (blue shading shows range of values at DPIE stations)**

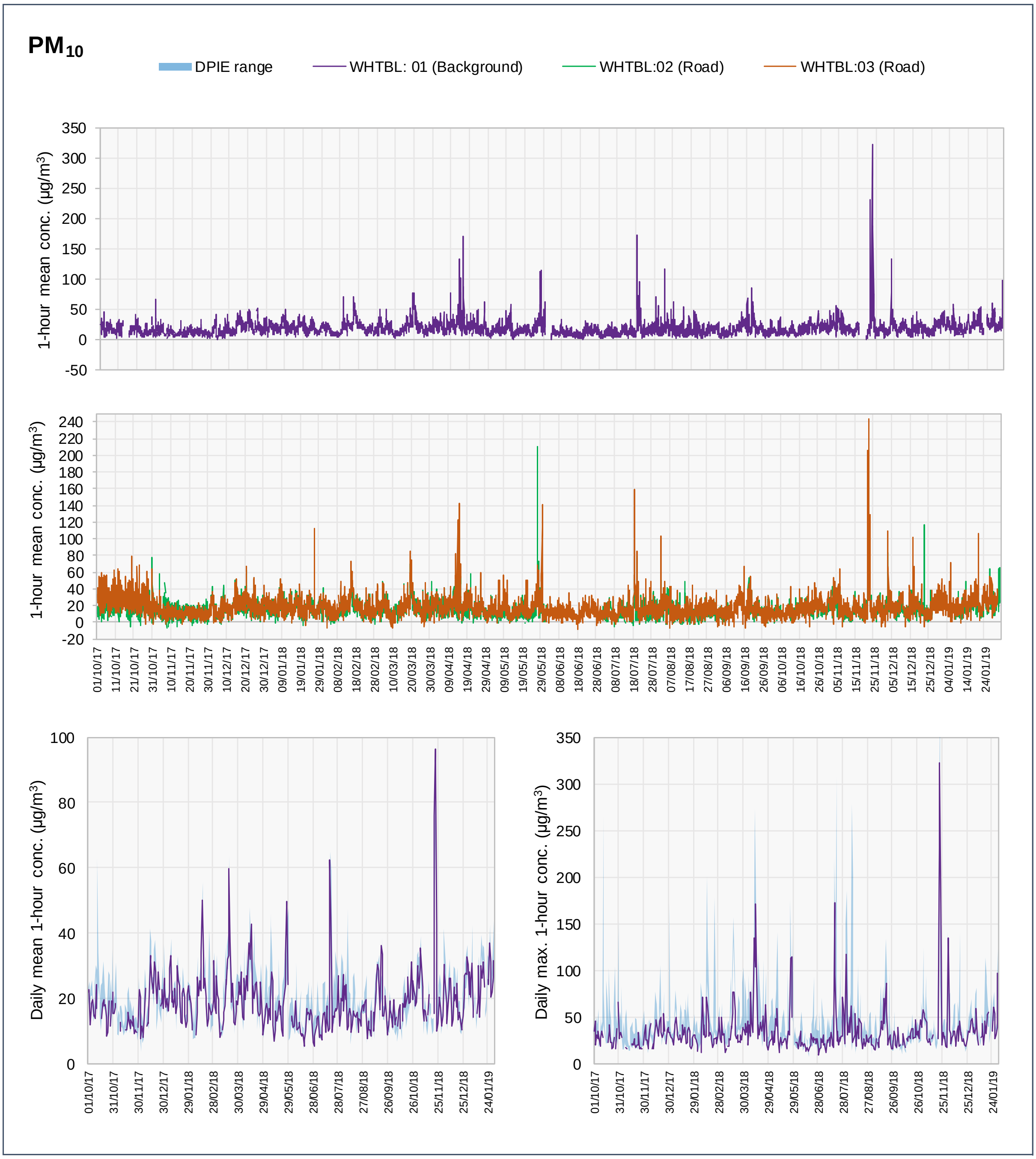


Figure D-37 PM_{10} concentrations at project monitoring stations (blue shading shows range of values at DPIE stations)

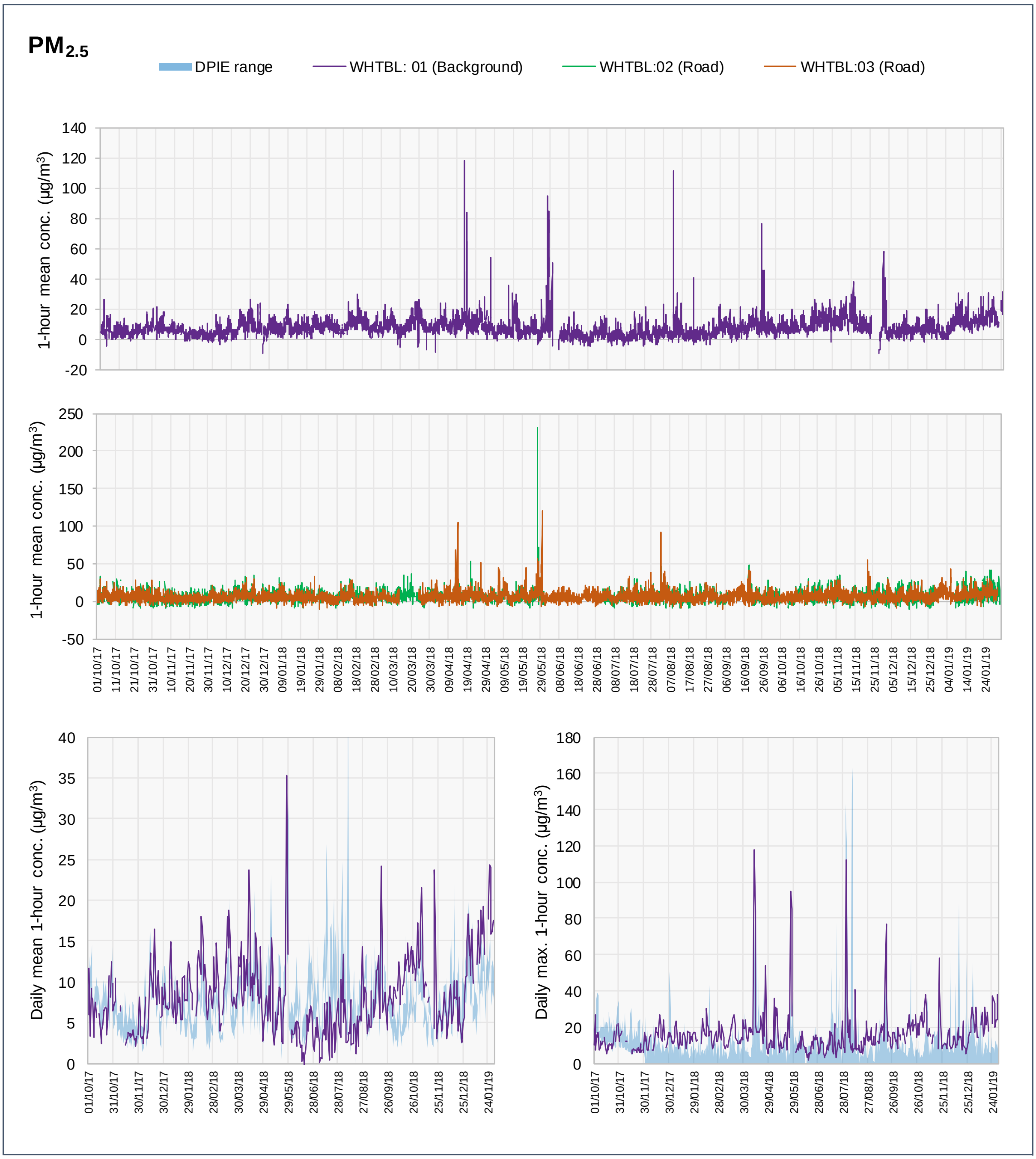


Figure D-38 **$PM_{2.5}$ concentrations at project monitoring stations (blue shading shows range of values at DPIE stations)**

Table D-21 Pollutant concentrations at WHTBL stations (October 2017 - January 2019)

Statistic	1-hour concentration			24-hour concentration		
	WHTBL:01 (Background)	WHTBL:02 (Road)	WHTBL:03 (Road)	WHTBL:01 (Background)	WHTBL:02 (Road)	WHTBL:03 (Road)
CO (mg/m^3)						
Mean	0.25	0.32	0.29	0.25	0.32	0.29
Median	0.24	0.30	0.27	0.25	0.31	0.28
Max	1.64	3.86	1.57	0.59	1.03	0.65
98th%ile	0.46	0.60	0.68	0.38	0.48	0.50
NO_X ($\mu g/m^3$)						
Mean	14.2	20.3	34.5	14.1	20.3	34.4
Median	8.7	15.4	19.5	11.5	19.0	27.5
Max	139.5	297.2	472.3	58.3	59.6	174.9
98th%ile	64.0	73.6	175.4	40.8	45.7	114.7
NO_2 ($\mu g/m^3$)						
Mean	10.9	13.0	18.9	10.8	13.0	18.9
Median	6.9	10.3	13.9	9.0	11.8	16.5
Max	74.1	79.5	117.8	39.2	33.8	52.3
98th%ile	44.7	41.6	61.9	29.6	28.7	46.1
O_3 ($\mu g/m^3$)						
Mean	52.2	33.5	37.9	52.3	33.4	37.9
Median	52.5	33.4	38.0	52.2	33.6	37.8
Max	199.9	181.5	203.3	106.7	81.5	89.6
98th%ile	101.6	81.1	91.0	82.4	60.9	66.3
PM_{10} ($\mu g/m^3$)						
Mean	18.6	15.5	17.7	18.8	15.5	17.7
Median	16.0	14.1	15.7	17.1	14.3	16.2
Max	323.0	210.1	243.6	96.5	50.3	77.4
98th%ile	47.0	39.1	46.5	37.6	28.7	34.0
$PM_{2.5}$ ($\mu g/m^3$)						
Mean	8.1	6.3	6.6	8.2	6.5	6.6
Median	7.0	5.3	5.7	7.6	6.1	5.8
Max	118.0	231.4	120.8	35.3	46.7	25.6
98th%ile	23.0	24.1	21.6	18.8	13.8	15.9

Annexure E NO_X-to-NO_2 conversion

E.1 Overview

Some atmospheric pollutants have slow chemical reaction rates, and for air quality modelling on an urban scale they can essentially be treated as inert (Denby, 2011). This is not the case for NO_2 since it is rapidly formed through the atmospheric reaction of NO with O_3, and is destroyed by sunlight during the day (see Annexure B). This is one reason why air pollution models are generally configured to predict NO_X concentrations, with the spread of NO_X being simulated as though it were a non-reactive gas (NZMfE, 2008). However, as air quality criteria address NO_2 rather than NO_X it is necessary to estimate NO_2 concentrations from the modelled NO_X concentrations. Many different approaches to this conversion have been developed over the years, and this Annexure describes some of these. The approach used for the Beaches Link assessment is also detailed.

The estimation of NO_2 concentrations near roads is not straightforward; it requires an understanding of NO_2 formation and destruction, and here there are a number of challenges. These include:

- How to account for the amount of primary NO_2 emitted in vehicle exhaust. This is dependent on the composition of the traffic, and is changing as the vehicle fleet evolves.
- How to account for the amount of conversion of NO to NO_2 in the atmosphere following release from the source, as this is dependent on the local atmospheric conditions, including the amount of ozone available.
- How to determine cumulative NO_2 concentrations, or in other words how to combine the road traffic contribution and the background (non-road) contribution.
- How to provide a realistic estimate of the change (whether this be an increment or decrement) in the NO_2 concentration that results from a road project.

The challenges are also greater for the 1-hour air quality criterion than for the annual mean criterion. For example, the maximum predicted NO_X concentration will not occur during the same hour of the year at all locations in the model domain.

In order to ensure that an appropriate and pragmatic method was selected for the Beaches Link assessment, a review of the literature and data was carried out. This Annexure presents the findings of the review and contains the following:

- A brief summary of the available guidance relating to the estimation of NO_2 concentrations.
- A review of the methods that are commonly used for estimating NO_2 concentrations. These either involve the use of empirical data or the modelling of atmospheric chemistry. In practice empirical approaches tend to be applied, as local knowledge on the inputs required for modelling chemistry is often incomplete.
- An analysis of the NO_X and NO_2 data from ambient air quality monitoring stations in Sydney, including the monitoring stations that were established specifically for the Western Harbour Tunnel and Beaches Link projects. This analysis was used to estimate NO_X-to-NO_2 conversion methods for the specific purpose of the Beaches Link assessment, and more widely for complex road projects in Sydney.

E.2 Guidance on NO_2 estimation

E.2.1 New South Wales

Guidance on the conversion of NO_X to NO_2 is provided in the NSW Approved Methods (NSW EPA, 2016). Three methods are described, from Method 1, the most simple, to Method 3, the most complex.

E.2.2 North America

The USEPA's Guideline on Air Quality Models (GAQM) provides recommendations on the use of air quality models to determine compliance with National Ambient Air Quality Standards (NAAQS). The Guideline is published as Appendix W of 40 CFR Part 51. In this case, three 'Tiers' of assessment are provided, with Tier1 being the simplest and Tier 3 the most complex. Additional guidance on the assessment of 1-hour NO_2 concentrations has recently been provided in the following:

- Applicability of Appendix W Modeling Guidance for the 1-hour NO_2 National Ambient Air Quality Standard, June 28, 2010[1].
- Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO_2 National Ambient Air Quality Standard, March 1, 2011[2].

Other recent guidelines from North America include:

- Modeling Compliance of the Federal 1-Hour NO_2 NAAQS (CAPCOA, 2011).
- Air Quality Model Guideline (Alberta Government, 2013).
- Guidelines for Air Quality Dispersion Modelling in British Columbia (BCMoE, 2008).

E.2.3 New Zealand

The following documents provide guidance on the estimation of NO_2 for air quality assessments in New Zealand:

- Good Practice Guide for Atmospheric Dispersion Modelling (NZMfE, 2004).
- Good Practice Guide for Assessing Discharges to Air from Industry (NZMfE, 2008), which updates the 2004 document.

E.2.4 United Kingdom

Guidance documents from the UK include:

- Review of background air-quality data and methods to combine these with process contributions (Environment Agency, 2006).
- Review of methods for NO to NO_2 conversion in plumes at short ranges (Environment Agency, 2007). This report focusses on the regulation of large industrial point sources.
- Local Air Quality Management Technical Guidance LAQM.TG(16) (Defra, 2016). This document is designed to support UK local authorities in carrying out their duties with respect to air quality management. A number of tools have been developed to support the guidance, including background maps of air pollutants, with year adjustment factors and a calculator that can be used to derive NO_2 from NO_X which is predicted when modelling emissions from roads.

E.3 Estimation methods

E.3.1 General approaches

In some assessments the road traffic and background concentrations to NO_2 at any given receptor have simply been added together to give the cumulative concentration, i.e.:

Equation E1

$$[NO_2]_{total} = [NO_2]_{road} + [NO_2]_{background}$$

Where:

$[NO_2]_{total}$	is the total estimated NO_2 concentration at the receptor
$[NO_2]_{road}$	is the modelled NO_2 concentration at the receptor due to a road (or roads) in the modelling domain

[1] http://www.epa.gov/scram001/guidance/clarification/ClarificationMemo_AppendixW_Hourly-NO2-NAAQS_FINAL_06-28-2010.pdf

[2] http://www.epa.gov/region7/air/nsr/nsrmemos/appwno2_2.pdf

$[NO_2]_{background}$ is the existing background NO_2 concentration at the receptor due to emissions from all sources other than roads

As the background is often assumed to be fixed, in this formulation the NO_2 increment or decrement associated with a project is simply the change in the value of $[NO_2]_{road}$ for model runs with and without the project. This has to be determined in some way from the road NO_X increment. However, there is a flaw in this approach. Although the road and background contributions to NO_X are additive, this is not the case for NO_2. The potential for oxidising NO to NO_2 is dependent on the amount of ozone that is available, which in turn is dependent on the NO concentration. The higher the existing background NO concentration, the less ozone that is available and the smaller the possibility of oxidising the NO from road vehicles to NO_2.

For any given model prediction/scenario it is therefore more appropriate to determine the total NO_2 concentration from the total NO_X concentration. This can be expressed as follows:

Equation E2

$$[NO_X]_{total} = [NO_X]_{road} + [NO_X]_{background}$$

Equation E3

$$[NO_2]_{total} = f([NO_X]_{total})$$

Where $f([NO_X]_{total})$ is the method used to convert total NO_X to total NO_2.

The NO_2 increment or decrement associated with the project is then calculated as follows:

Equation E4

$$[NO_2]_{project} = [NO_2]_{total\ (with\ project)} - [NO_2]_{total\ (without\ project)}$$

E.3.2 Specific methods

Several methods are available for characterising the transformation of NO to NO_2. These include:

- Total conversion method:
  - Assuming that all NO_X from the emission source being modelled is present as NO_2 (i.e. there is always total conversion of NO to NO_2. This is 'Method 1' in the NSW Approved Methods and the USEPA's 'Tier 1' approach).
- NO_2/NO_X ratio methods, including:
  - Assuming a constant NO_2/NO_X ratio. This is the USEPA's 'Tier 2' approach, which is referred to as the 'ambient ratio method' (ARM).
  - Assuming a variable NO_2/NO_X ratio to all for influences such as the season and distance from source.

  NO_X to NO_2 conversion methods that use ambient ratios are usually based on empirical data. Empirical relationships fall within the 'Method 3' in the NSW Approved Methods.
- Reactant-limited methods, whereby the instantaneous conversion of NO is constrained only by the amount of oxidant(s) available. Such methods include:
  - The 'ozone limiting method (OLM)', in which NO to NO_2 conversion is limited by the amount of ozone available (known as 'ozone titration'). This is 'Method 2' in the NSW Approved Methods, and is a USEPA Tier 3 approach.
  - The plume volume molar ratio method (PVMRM), which is also based on ozone titration. This is a USEPA 'Tier 3' approach. It is not mentioned in the NSW Approved Methods.
- Reactive plume methods. These use complex or simplified atmospheric photochemical reaction schemes which derive NO_2 concentrations from first principles. Such approaches have been incorporated into some of the latest generation of air pollution models.

The different methods presented in the literature are summarised in the following Sections.

E.3.3 Total conversion of NO to NO_2

E.3.3.1 Description

The most basic – and most conservative – method for estimating the NO_2 concentration at a receptor is based on the assumption that all emitted NO is oxidised to NO_2, or in other words all modelled NO_X from roads is present as NO_2:

Equation E5

$$[NO_2]_{road} = [NO_X]_{road}$$

Equation E6

$$[NO_2]_{total} = [NO_2]_{road} + [NO_2]_{background}$$

This approach is often used as a screening step; if compliance with air quality standards is obtained using this approach, then it can be assumed that there will be negligible risk of exceedances in reality and more detailed calculations for NO_2 are not required. If, on the other hand, the estimated NO_2 concentrations are close to or higher than the air quality standards then more detailed, less conservative methods should subsequently be applied.

E.3.3.2 Application in NSW Approved Methods

For annual mean concentrations the modelled NO_x concentration is converted to NO_2 (assuming 100% conversion of NO), and the result is then simply added to the background NO_2 concentration.

For 1-hour means, the cumulative concentration can be determined in one of two ways:

- Level 1 (maximum): The maximum modelled 1-hour mean NO_2 concentration is added to the maximum background 1-hour mean NO_2 concentration.
- Level 2 (contemporaneous): Using contemporaneous assessment of model predictions and ambient concentrations. The cumulative NO_2 concentration is determined by adding the modelled 1-hour mean NO_2 concentration with the contemporaneous background 1-hour mean NO_2 concentration.

E.3.3.3 Limitations and performance

This method represents a worst case situation. It does not allow for the availability of ozone or NO_2 destruction through photolysis, and will overestimate NO_2 concentrations. The overestimation will be largest at high NO_X concentrations where NO_2 formation is ozone-limited. This is explored further in Section G5. The total conversion method is therefore of limited use where an accurate estimate of NO_2 is required.

E.3.4 NO_2/NO_X ratio methods

E.3.4.1 Description

Constant ratio

In the USEPA's ARM, the predicted NO_X concentration for a receptor is multiplied by an empirically derived NO_2/NO_X ratio to determine the NO_2 concentration at the receptor. The NO_2/NO_X ratio is based upon average NO_2 and NO_X concentrations in ambient air at a representative site. For example, in the USEPA 'Tier 2' approach the modelled annual mean NO_X concentrations is multiplied by a default NO_2/NO_X ratio of 0.75. For 1-hour concentrations a NO_2/NO_X ratio of 0.80 is used.

Variable ratio

ARM2

A new empirical method, known as ARM2, has recently been developed by the American Petroleum Institute in response to the frequent observation that hourly NO_2 concentrations estimated using the existing USEPA three-tier approach are much higher than observed concentrations. ARM2 is based on an empirical fit to the 98th percentiles of the binned 1-hour NO_2/NO_X and NO_X values collected from different monitoring stations between 2001 and 2010 (RTP, 2013; Podrez, 2015). The USEPA has approved the use of ARM2 for regulatory 1-hour NO_2 assessments under certain circumstances.

Janssen method

The NSW Approved Methods refer to the approach of Janssen et al. (1988). This involves the use of an empirical equation for estimating the oxidation rate of NO in power plant plumes. The equation is dependent on distance downwind from the source, and has the following form:

Equation E7

$$[NO_2]/[NO_X] = A\,(1 - \exp(-\alpha x))$$

Where:

x = the distance from the source

A and **α** are classified according to the O_3 concentration, wind speed and season; Janssen et al. (1988) provide values for **A** and **α**.

Given that this method requires the distance from the source to be quantified, the method is not suitable for complex road networks.

Defra method

An empirical approach to calculating NO_2 from NO_X concentrations at roadside sites was developed by Defra in the UK in 2002, and has most recently been updated in 2017. The approach takes account of the difference between fresh emissions of NO_X, the background NO_X, the concentration of O_3, and the different proportions of primary NO_2 emissions in different years. The approach has been incorporated into a spreadsheet which is available from the Defra web site[3].

E.3.4.2 Limitations and performance

The ARM2 method has some advantages over other USEPA Tier 3 methods. For example, it does not require ambient ozone data. The performance of the ARM2 method is comparable to that of the OLM and the PVMRM. However, all three methods over-predict NO_2/NO_X ratios (RTP, 2013).

According to NZMfE (2004) the Janssen approach is based upon the rate of diffusion of O_3 into the emission plume rather than the rates of reaction. It is therefore probably only applicable to the particular power station studied, and is of questionable application to other sources. Although the Approved Methods describe the application of the Janssen method to determine annual mean and 1-hour mean concentrations, its lack of applicability to road networks means that it has not been explored in detail in this Annexure. There is little information on how the NO_2/NO_X ratio changes with distance from the road; monitoring data are usually only available for roadside and/or background locations.

Given that it has been developed to represent vehicle fleets and near-road atmospheres in the UK, it is unlikely that the Defra calculator is suitable for use in Sydney, although this ought to be investigated further. However, this was beyond the scope of the Beaches Link assessment.

E.3.5 Reactant-limited methods

E.3.5.1 Description

Ozone limiting method

The USEPA's ozone limiting method (OLM) is one of several reactant-limited approaches. It uses a simple approach to the reaction chemistry of NO and O_3 in order to estimate NO_2 concentrations. It is assumed that all the available O_3 in the atmosphere will react with the NO from the source until either

[3] https://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html#NOxNO2calc

all the O_3 is consumed or all the NO is used up (Cole and Summerhays, 1979; Tikvart, 1996). A slightly different approach to the OLM has been developed for use in New Zealand (NZMfE, 2008).

Plume volume molar ratio method

The plume volume molar ratio method (PVMRM) extends the basic chemistry of the OLM. The PVMRM determines the conversion rate for NO_x to NO_2 based on a calculation of the number of NO_x moles emitted into the plume, and the number of O_3 moles contained within the volume of the plume between the source and receptor. The ratio between the two molar quantities is multiplied by the NO_X concentration to calculate the NO_2 concentration.

Both the OLM and PVMRM require two key model inputs, namely the NO_2/NO_X emission ratio at the source and background ozone concentrations.

E.3.5.2 Implementation in NSW Approved Methods

The USEPA version of the OLM is represented by the equation (NSW EPA, 2016):

Equation E8

$$[NO_2]_{total} = \{0.1 \times [NO_X]_{road}\} + MIN\{(0.9) \times [NO_X]_{road} \text{ or } (46/48) \times [O_3]_{background}\} + [NO_2]_{background}$$

Where:

$[NO_2]_{total}$	=	predicted concentration of NO_2 in µg/m^3
$[NO_X]_{road}$	=	dispersion model prediction of NO_X from roads in µg/m^3
MIN	=	minimum of the two quantities within the braces
$[O_3]_{background}$	=	background ambient O_3 concentration in µg/m^3
(46/48)	=	molecular weight of NO_2 divided by the molecular weight of O_3 in µg/m^3
$[NO_2]_{background}$	=	background ambient NO_2 concentration in µg/m^3

The method involves an initial comparison of the estimated maximum NO_X concentration and the ambient O_3 concentration to determine the limiting factor to NO_2 formation:

- If the O_3 concentration is greater than the maximum NO_X concentration, then total NO_X to NO_2 conversion is assumed.
- If the maximum NO_X concentration is greater than the ozone concentration, the formation of NO_2 is limited by the ambient ozone concentration.

The OLM – in the above form – is based on the assumption that 10% of the initial NO_X emissions are NO_2. The emitted NO reacts with ambient ozone to form additional NO_2. If the ozone concentration is greater than 90% of the predicted NO_X concentration, all the NO_X is assumed to be converted to NO_2. Otherwise, NO_2 concentrations are calculated on the assumption of total conversion of the ozone. The predicted NO_2 concentration is then added to the background NO_2 concentration.

The following approaches are presented in the Approved methods for the ‘maximum’ and ‘contemporaneous’ calculations:

- Level 1 (maximum): The maximum 1-hour and annual average background concentrations of NO_2 and O_3 ($[NO_2]_{background}$, $[O_3]_{background}$) are used in Equation E8.
- Level 2 (contemporaneous): Continuous 1-hour average background concentrations of NO_2 and O_3 are obtained for the same period as the dispersion modelling predictions (usually one year). The value of $[NO_2]_{total}$ is then calculated for every hour of the dispersion model simulation by substituting the hourly values of $[NO_X]_{road}$, $[NO_2]_{background}$ and $[O_3]_{background}$ into Equation E8.

As before, the Level 1 approach is used as a screening step. The OLM is usually applied using the Level 2 approach, and this has the advantage of yielding various statistics for NO_2, including:

- The annual mean concentration (based on the 1-hour predictions for a year).
- The maximum concentration.
- Percentile concentration values.
- The frequency with which the 1-hour NO_2 criterion is exceeded.

In the NSW EPA's submission to the EIS for the NorthConnex project in Sydney, it is stated that that an average value for the NO_2/NO_X ratio of 16%[4] would be more appropriate than 10%. The OLM equation should therefore be adjusted as follows (AECOM, 2014b):

Equation E9

$$[NO_2]_{total} = \{0.16 \times [NO_X]_{road}\} + MIN\ \{(0.84) \times [NO_X]_{road} \text{ or } (46/48) \times [O_3]_{background}\} + [NO_2]_{background}$$

The effect of the adjustment is to increase the amount of NO_2 emitted directly, potentially increasing the NO_2 concentrations that are predicted under low ambient O_3 concentrations.

E.3.5.3 Limitations and performance

Several limitations of the OLM have been noted in the literature. For example:

- The approach is known to be conservative:
  - The method assumes that the atmospheric conversion of NO to NO_2 occurs instantaneously. In reality, the reaction requires time. This assumption therefore leads to an overestimate of NO_2 concentrations close to the source (NZMfE, 2004).
  - The method assumes that all ozone is available to the emission source being evaluated. The OLM will be too conservative when, for example, a new source is to be located in close proximity to existing sources. The new source will be competing with the existing sources for the available ozone, and the rate of conversion of NO to NO_2 will not be as great as if the new source was in an isolated location (NZMfE, 2004).
  - Ozone is assumed to be uniformly and continuously mixed across the cross section of the plume. The OLM does not account for the molar ratio of NO to ozone in the plume (reactions occur in proportion to the moles of each gas rather than in proportion to the concentrations assumed by the OLM), nor does it account for the gradual entrainment and mixing of ambient ozone in the plume.
  - Situations in which the OLM has been demonstrated to substantially overestimate NO_2 concentrations include during daylight hours when the photochemical equilibrium reverses the oxidation of NO by O_3, and during stable, night-time conditions when both NO_2 and O_3 are removed by reaction with vegetation and other surfaces (NZMfE, 2004).
- The OLM model requires a record of 1-hour average background concentrations over a year. Apart from the expense of obtaining such information at a single location, there are significant problems in locating the monitoring site relative to existing emission sources and a proposed new emission source because of the perceived difficulty of accounting for scavenging of O_3 by NO (NZMfE, 2004).
- The USEPA states that the OLM should only be used on a 'plume-by-plume' basis. This is a severe limitation in relation to road projects.

Some of these limitations also apply to the PVMRM. Because of the different methods used, there are cases where PVMRM will perform better than OLM, and vice versa. The PVMRM better simulates the NO to NO_2 conversion chemistry during plume expansion, and works well for isolated elevated point sources. However, OLM may be the better choice for low-level releases and area sources. For low-level releases the modelled plume may extend below ground level, but the PVMRM will still use the full

[4] This is the upper bound of the estimated ratio used for the in-tunnel modelling in Annexure K for primary NO_2. The in-tunnel modelling considers the ratio variations for different traffic speeds and different tunnel grades.

volume of the plume to estimate the NO_X-to-NO_2 conversion. This may again lead to overly conservative NO_2 concentrations.

E.3.6 Reactive plume models

Various photochemical reaction schemes are applied in regional-scale and urban-scale air pollution models. One of the most commonly used is the Generic Reaction Scheme (Azzi *et al.*, 1992). More detailed photochemical models and schemes have been developed in recent years, including the EMEP scheme (Simpson *et al*., 2003), the Carbon Bond-IV mechanism (Gery *et al*., 1989), and the CB05 photochemical mechanism (Yarwood *et al*., 2005).

However, the use of such models is uncommon for regulatory local air quality assessments. A major drawback of these methods is that the near-source chemical reactions may not be well described. Many of the atmospheric chemistry schemes developed for regional and global models include reactions on timescales that are much longer than the residence times of pollutants in urban areas, and as such introduce an additional complexity and computational time that is unnecessary (Denby, 2011). As noted by the Environment Agency (2007) in the UK, care is required to select a chemical mechanism, and advanced photochemical modelling requires a comprehensive set of emissions data for a wide range of compounds (notably hydrocarbons), as well as the appropriate meteorological data. These are major constraints for any regulatory work.

E.4 Development of empirical conversion methods for Sydney

E.4.1 Overview

Various guidance documents recommend the use of local monitoring data, where available, to estimate NO_2 from modelled NO_X. Functions have been fitted to NO_X and NO_2 monitoring data for many years, notably in the form of the ‘Derwent-Middleton’ equation (Derwent and Middleton, 1996), and this continues to be the case (e.g. Podrez, 2015).

Both NO_X and NO_2 have been measured for several years at a range of stations across Sydney, as described in Annexure E. A substantial amount of data from these stations was used to develop empirical NO_X-to-NO_2 conversion functions for the WestConnex M4 East and New M5 projects (Pacific Environment, 2015b; Pacific Environment, 2015c), with separate approaches for annual mean and 1-hour mean NO_2. These functions were also used for the Western Harbour Tunnel assessment. One reason for the analysis was to quantify and address the conservatism in some of the other methods in use, whereby exceedances of NO_2 air quality standards can be predicted for a given NO_X concentration, even where the monitoring data show that this situation is extremely uncommon for real-world receptor locations.

The methods that were developed are described below.

E.4.2 Methods used in the project assessment

E.4.2.1 Annual mean concentrations

Figure E-1 shows the relationship between the annual mean concentrations of NO_X and NO_2 at the monitoring stations in Sydney across all years. As the values shown are measurements, they equate to **$[NO_X]_{total}$** and **$[NO_2]_{total}$**. In the low-NO_X range of the graph there is an excess of ozone and therefore NO_2 formation is limited by the availability of NO. In the high-NO_X range there is an excess of NO, and therefore NO_2 formation is limited by the availability of ozone. The Figure also shows that there is not a large amount of scatter in the data, and for this reason a central-estimate approach was considered to be appropriate.

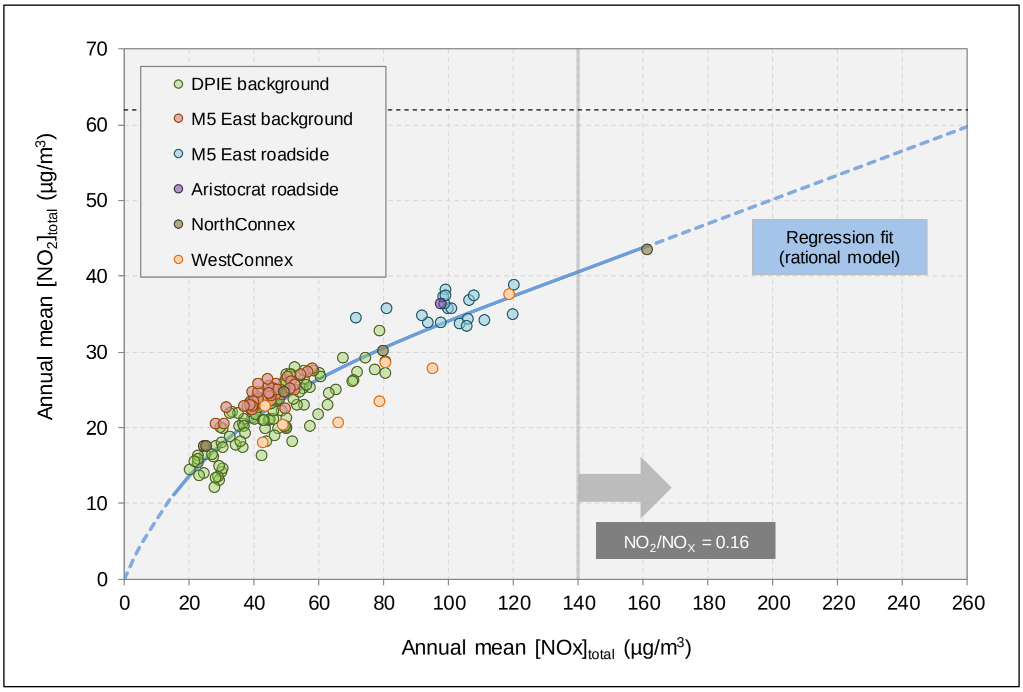


Figure E-1 Annual mean NO_X and NO_2 concentrations at monitoring stations in Sydney

The solid blue in Figure E-1 represents a regression model fit to the data (i.e. the central-estimate situation) which will give the most likely NO_2 concentration for a given NO_X concentration. The function giving the best fit (the rational model) was selected from a large number of alternatives using curve-fitting software. This function, which was used in the Beaches Link assessment, is described by the following equations:

For **$[NO_X]_{total}$** values less than or equal to 140 µg/m³:

Equation E10

$$[NO_2]_{total} = \frac{a + b[NOx]_{total}}{1 + c[NOx]_{total} + d([NOx]_{total})^2}$$

Where:

a = -7.6313 x 10^{-4}

b = 9.9470 x 10^{-1}

c = 2.3750 x 10^{-2}

d = -4.5287 x 10^{-5}

For **$[NO_X]_{total}$** greater than 140 µg/m³ it has been assumed that the available ozone has been consumed and so NO_2 is linearly proportional to NO_X with a NO_2/NO_X ratio of 0.16, representing the current f-NO_2 value for vehicle exhaust quoted by NSW EPA in its response to the EIS for the NorthConnex project (AECOM, 2014b):

Equation E11

$$\mathbf{[NO_2]_{total} = 40.513 + (0.16 \times ([NO_X]_{total} - 140))}$$

The work presented in Pacific Environment (2015a) suggests that an annual average value for f-NO_2 of 0.16 is an overestimate for the 2016 vehicle fleet, but is likely to be more representative for future years.

The dashed blue line represents the extrapolation of the function to values below and above the range of measurements. Given the absence of high annual mean NO_X concentrations, the extrapolation to concentrations above the measurement range is rather uncertain, but on the basis of the primary NO_2 assumption it is likely to be rather conservative.

Given that the total NO_X concentration was used to determine the total NO_2 concentration, in order to determine the change in NO_2 associated with the project the background NO_2 concentration was subtracted. That is:

Equation E13

$$\mathbf{[NO_2]_{project} = [NO_2]_{total} - [NO_2]_{background}}$$

Where both $\mathbf{[NO_2]_{total}}$ and $\mathbf{[NO_2]_{background}}$ were determined using Equations E10 and E11.

For a given project contribution to NO_X at a receptor, the higher the background NO_X the lower the project NO_2 increment will tend to be, as less ozone will generally be available for converting the NO from the project to NO_2.

The use of the function could theoretically lead to exceedances of the annual mean criterion for NO_2 in NSW of 62 µg/m^3. However, a very high annual mean NO_X concentration – more than 260 µg/m^3 - would be required. This is much higher than the measurements in Sydney have yielded to date.

E.4.2.2 One-hour mean concentrations

For the maximum 1-hour mean NO_2 concentrations the situation was more complicated. One-hour mean NO_X and NO_2 concentrations are much more variable than annual mean concentrations. Patterns in the hourly data can be most easily visualised by plotting the 1-hour mean NO_2/NO_X ratio against the 1-hour mean NO_X concentration, as shown for the various monitoring stations, including the Western Harbour Tunnel and Beaches Link stations, in Figure E-2 to Figure E-7.

In each dataset it is clear that for low NO_x concentrations there is a wide range of possible NO_2/NO_x ratios, whereas for higher NO_X concentrations the range is much more constrained. A distinct outer envelope can be fitted to the data which includes all (or very nearly all) the measurement points, and this envelope has a strong inverse relationship with the NO_X concentration. In the envelope the NO_2/NO_X ratio is highest (1.0) at low NO_X concentrations, representing complete, or near-complete, conversion of NO to NO_2. At the high end of the NO_X concentration range the ratio is much lower and levels out at a value of around 0.1. The highest NO_X concentrations occur mostly during the winter months when temperature inversions prevent the effective dispersion of pollution.

Although the range and variability of the data varied by station type, the general patterns in the data were quite consistent. It was therefore considered appropriate to combine the datasets. In particular, the outer envelope of the $NO_X:NO_2$ ratio was very consistent, and so it was also considered appropriate to define one (conservative) approach to reflect this envelope.

The derivation of a conversion method from these data for the Beaches Link assessment was adapted from that recommended by BCMoE (2008)[5]. This method involved the following steps:

- The range of NO_X concentrations for which the NO_2/NO_X ratio is equal to 1.0 is estimated.
- The NO_X concentration for which NO_2/NO_X is equal to 0.1 is estimated.
- An exponential equation of the following form is fitted to the upper envelope of the scatter:

  $$\mathbf{NO_2/NO_X = a \times [NOx]^b}$$

  where **a** and **b** are selected through an iterative process to produce a curve that fits the upper bound of the envelope of the scatter.

  The equation is defined so that the NO_2/NO_x ratio never exceeds unity or falls below 0.1.
- The equation is checked to ensure that NO_2 does not decrease with an increase in NO_X.

[5] BCMoE (2008) recommends that the ozone limiting method should only be applied if adequate monitoring data are not available to establish representative NO/NO_2 ratios.

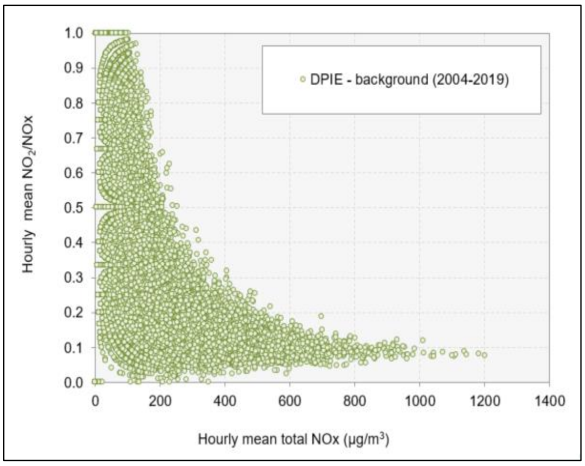


Figure E-2 Hourly mean NO_2/NO_X vs NO_X at DPIE (background) stations

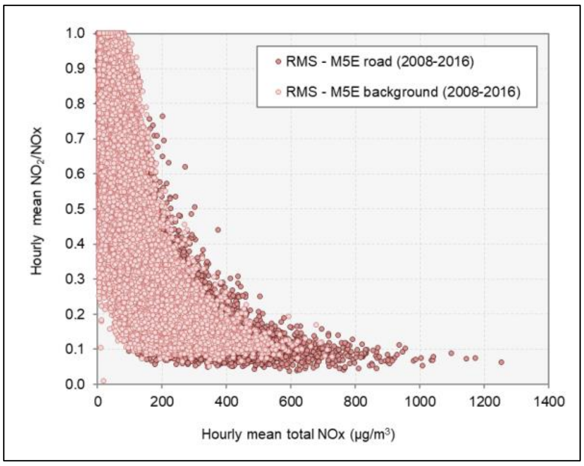


Figure E-3 Hourly mean NO_2/NO_X vs NO_X at Roads and Maritime M5 East (road and background) stations

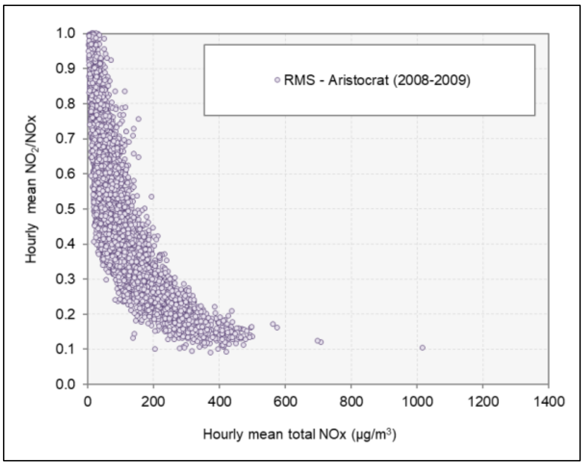


Figure E-4 Hourly mean NO_2/NO_X vs NO_X at Roads and Maritime Aristocrat (road) station

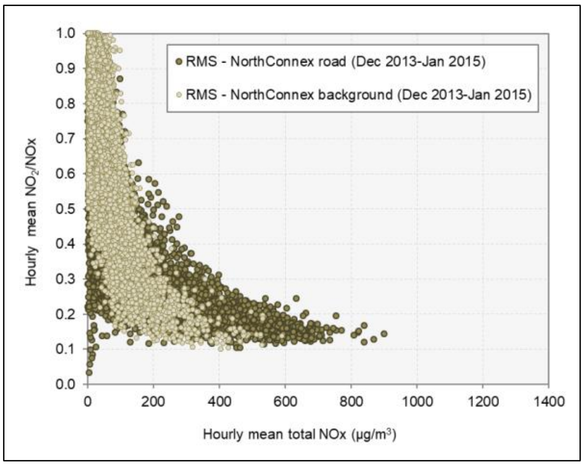


Figure E-5 Hourly mean NO_2/NO_X vs NO_X at Roads and Maritime NorthConnex (road and background) stations

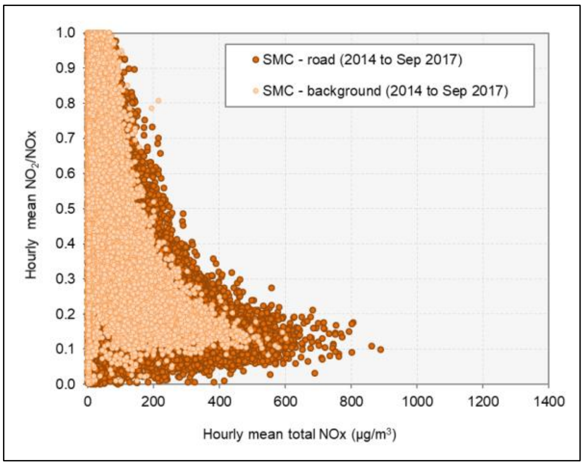


Figure E-6 Hourly mean NO_2/NO_X and NO_X at SMC (road and background) stations

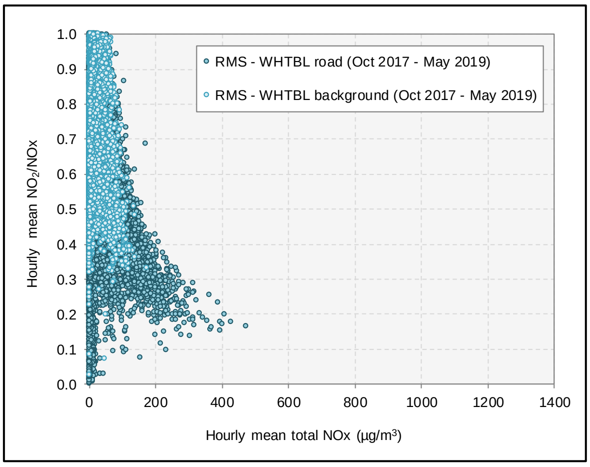


Figure E-7 Hourly mean NO_2/NO_X and NO_X at Roads and Maritime WHTBL stations

The data from all Sydney monitoring stations between 2004 and 2019 – a total of more than 1.3 million data points – are shown in Figure E-8, and the steps described above have been applied. Around 20% of the data points were for roadside monitoring stations.

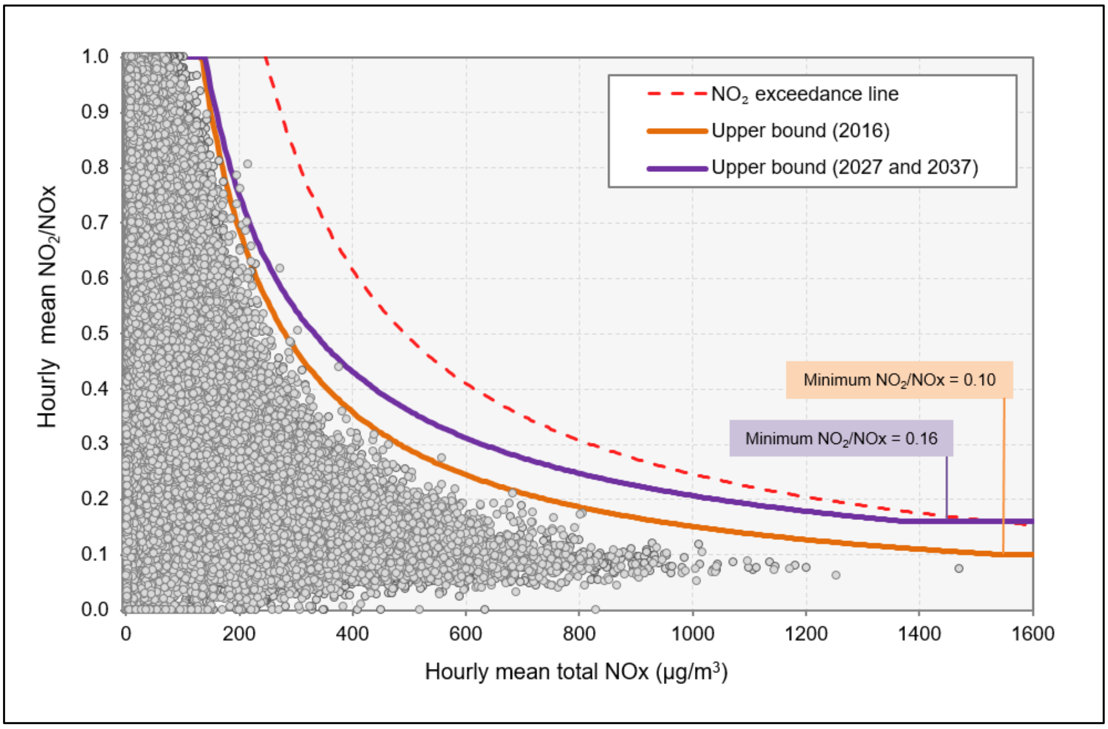


Figure E-8 **Hourly mean NO_2/NO_X ratio vs NO_X for monitoring stations at various locations in Sydney**

The solid orange line in Figure E-8 represents the outer envelope of all data points, and approximates to a conservative upper bound estimate for 2016, or in other words the maximum NO_2/NO_X ratio for a given NO_X concentration in 2016. This is described by the following equations:

For $[NO_X]_{total}$ values less than or equal to 130 µg/m³:

Equation E14

$$\frac{[NO_2]_{total}}{[NOx]_{total}} = 1.0$$

For $[NO_X]_{total}$ values greater than 130 µg/m³ and less than or equal to 1,555 µg/m³:

Equation E15

$$\frac{[NO_2]_{total}}{[NOx]_{total}} = a \times [NOx]_{total}^{\,b}$$

where:

a = 100
b = -0.94

For $[NO_X]_{total}$ values greater than 1,555 µg/m³ a cut-off for the NO_2/NO_X ratio of 0.10 has been assumed. That is:

Equation E16

$$\frac{[NO_2]_{total}}{[NOx]_{total}} = 0.1$$

The dashed red line in Figure E-8 shows the NO_2/NO_X ratio that would be required for an exceedance of the NO_2 criterion of 246 µg/m^3 at each NO_X concentration. It is clear from Figure E-8 that an exceedance of the 1-hour criterion for NO_2 cannot be predicted using the upper bound curve for 2016 across a wide range of NO_X concentrations.

For future years it is possible that the upper bound estimate for 2016 will not be appropriate, given that primary NO_2 emissions could increase. An exploratory analysis by Pacific Environment indicated that, on average for highway traffic in Sydney, *f*-NO_2 could increase to 0.16 by around 2030 (Pacific Environment, 2015a). Although the increase in *f*-NO_2 would be combined with lower overall NO_X emissions, it could be expected that for high ambient NO_X concentrations the ambient NO_2/NO_X ratio could exceed 0.1. Here, it has therefore been assumed that a minimum value for the NO_2/NO_X ratio of 0.16 would be appropriate for the 2027 and 2037 scenarios, and a corresponding (conservative) upper bound function is shown as a purple line in Figure E-8.

This function, which is essentially arbitrary, is described by the following equations:

For $\mathbf{[NO_X]_{total}}$ values less than or equal to 140 µg/m^3, Equation E14 applies.

For $\mathbf{[NO_X]_{total}}$ values greater than 140 µg/m^3 and less than or equal to 1375 µg/m^3, Equation 15 applies with the following coefficients:

a = 52

b = -0.80

For $\mathbf{[NO_X]_{total}}$ values greater than 1375 µg/m^3 a cut-off for the NO_2/NO_X ratio of 0.16 has been assumed. That is:

Equation E17

$$\frac{[NO_2]_{total}}{[NOx]_{total}} = 0.16$$

Even this assumption would only result in an exceedance of the NO_2 criterion at very high NO_X concentrations (above around 1500 µg/m^3). If a more conservative estimate for the minimum ambient NO_2/NO_X ratio of 0.20 were to be assumed, the total NO_X concentration required for NO_2 exceedance in Figure E-8 would be around 1000 µg/m^3.

Given that the background NO_X concentrations developed for the Beaches Link assessment were also slightly conservative (see Annexure E), it is likely that there will be a conservative overall estimate of NO_2 using this approach.

E.4.2.3 Limitations and performance

The general limitations of empirical methods for NO_X-to-NO_2 conversion include the following:

- They do not make any allowance for future changes, such as a potential increase in primary NO_2 emissions or changes in ozone concentrations. Here, this has been addressed as in part through the use of a more conservative function for converting NO_X to NO_2 than the ambient measurements in Sydney to date would suggest.
- They do not differentiate between receptor locations at different distances from emission sources.
- They are only useful for the general locations where they were developed. The methods will not provide the correct dynamic response to changes in emissions, boundary conditions or meteorology unless these influences are implicitly included in their formulation (Denby, 2011).

However, despite, or as a result of, their empirical nature such models can give satisfactory results, especially for annual mean concentrations as there is a clear dependence of NO_2 on NO_X concentrations (Denby, 2011).

E.5 Comparison of methods

As part of the analysis for the M4 East project the functions for calculating NO_2 from NO_X based on the monitoring data from Sydney (up to and including 2016) were compared with some alternative approaches (Pacific Environment, 2015b). The results of these comparisons for both annual mean and 1-hour mean NO_2 concentration are given below.

E.5.1 Annual mean NO_2 concentrations

The following methods for calculating annual mean NO_2 concentrations were compared:

- The central-estimate approach based on the Sydney monitoring data (see Section G.4.2.1).
- The complete conversion method (see Section G.3.3).
- The USEPA constant ambient ratio method (ARM), with a NO_2/NO_X ratio of 0.75 (see Section G.3.4.1).
- The ozone limiting method (OLM), with an *f*-NO_2 value of 0.16 (see Section G.3.5.1).

In order to compare the different methods for annual mean NO_2 it was necessary to assume background concentrations of NO_X, NO_2 and, in the case of the OLM, O_3. The synthetic profiles for the M4 East modelling domain (and associated annual mean concentrations) described in Pacific Environment (2015b) were used for this purpose.

In the case of the OLM, the conversion method was applied to the contemporaneous hourly background data and project increment data for one year. An example dataset from another road project was used to provide the NO_X project increments. This project had an hourly time series for more than 500 receptor points. However, many of the receptors had similar concentrations and therefore a much smaller sample was extracted. The sample included a wide range of NO_X concentrations. The results of the comparison are shown in Figure E-9.

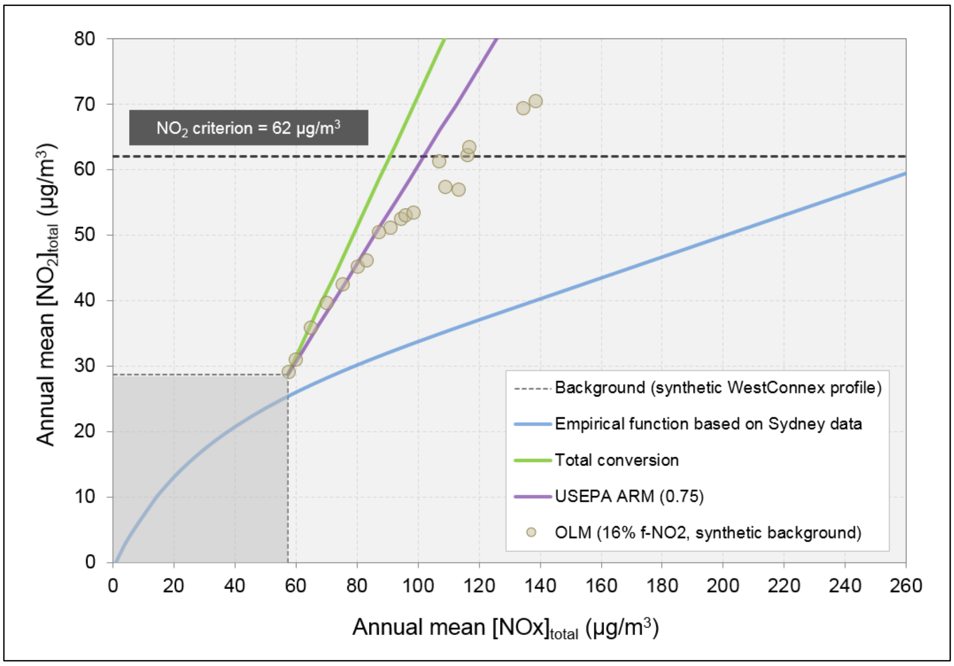


Figure E-9 Comparison of methods for calculating annual mean NO_2 concentration

The total conversion method gave the highest NO_2 concentrations, and for the conditions defined here it resulted in an exceedance of the NO_2 criterion of 62 µg/m³ when the total NO_X concentration was around 90 µg/m³. The ARM and the OLM gave quite similar results, and also resulted in exceedances of the NO_2 criterion when the total NO_X concentration was around 100-120 µg/m³. All three of these methods gave much higher NO_2 concentrations than the envelope and regression functions based on the Sydney monitoring data.

It is also worth repeating that work in the United States has shown that the performance of the ARM2, PVMRM, and OLM methods is very similar (RTP, 2013).

Although the concentrations in the synthetic background profiles were quite conservative, the results show that that the annual mean NO_2 concentrations predicted using the total conversion, ARM and OLM methods are unrealistically high, and would tend to result in an improbable number of exceedance of the NO_2 criterion. These methods were therefore considered to be unsuitable for the Beaches Link assessment.

E.5.2 One-hour mean NO_2 concentrations

In the case of 1-hour mean NO_2 concentrations, only the OLM was compared with the empirical method. Again, the synthetic background profiles for the M4 East modelling domain were used, and an *f*-NO_2 value of 0.16 was assumed.

For the road contribution to NO_X, the same example dataset as that mentioned above for annual mean concentrations was used. The hourly results for ten receptors from the dataset, with representative NO_X concentrations across the range, are shown in Figure E-10. It can be seen that the OLM predicted NO_2/NO_X ratios for many 1-hour periods that were higher than those predicted by the conservative upper bound function. The OLM gave a small number of exceedances of the NO_2 criterion of 246 µg/m³. This work shows that the OLM will yield overly conservative maximum NO_2 concentrations for road projects in Sydney.

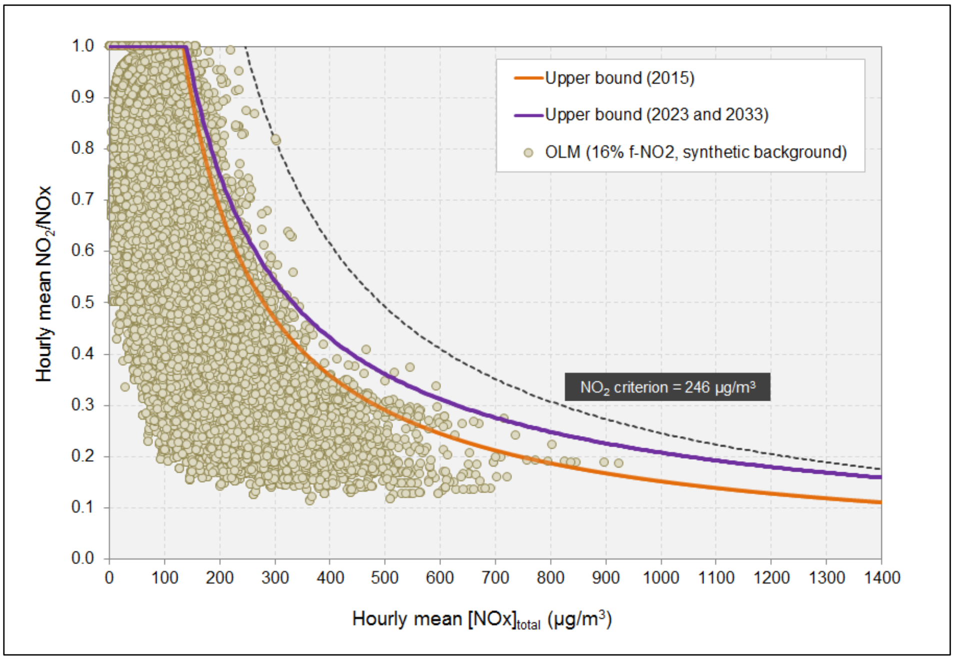


Figure E-10 **Comparison of OLM and empirical methods for calculating 1-hour mean NO_2 concentration**

Annexure F Analysis of meteorological data and GRAMM evaluation

F.1 Introduction

The project GRAMM domain covers an area with diverse land use types, including a mixture of ocean coast, harbour and near-coastal inland locations which will have different local meteorological characteristics.

Whilst meteorology may not always be the main driver of predicted concentrations near to roads where the peak impacts could be expected to occur, it is nevertheless important to characterise the meteorology as accurately as possible within the GRAL domain. It is worth noting that the Beaches Link (and Western Harbour Tunnel) project corridor is aligned along a broad SW-NE axis through the GRAL domain, and with most receptors located along this axis.

F.2 Analysis of meteorological data

F.2.1 Monitoring stations

There were few meteorological stations within the GRAL domain. The only stations located within the domain were DPIE Rozelle, BoM Fort Denison and BoM Wedding Cake West. However, when setting up GRAMM it is possible to include meteorological stations outside of the GRAL domain but within the GRAMM domain. For this reason, a number of other meteorological stations have been considered as a part of the wider analysis of meteorological data. These stations were a mixture of DPIE, BoM and Transport for NSW (including WestConnex) owned stations. These are listed below.

- DPIE meteorological stations:
  - Chullora
  - Earlwood
  - Lindfield
  - Randwick
  - Rozelle
- BoM meteorological stations:
  - Canterbury Racecourse Automatic Weather Station (AWS) (Station No. 066194)
  - Fort Denison (Station No. 066022)
  - Little Bay (The Coast Golf Club) (Station No. 066051)
  - Manly (North Head) (Station No. 066197)
  - Sydney Airport AMO (Station No. 066037)
  - Sydney Olympic Park AWS (Archery Centre) (Station No. 066212)
- WestConnex (WCX) and Transport for NSW meteorological stations:
  - WCX M4E:04 (roadside site)
  - WCX M4E:05
  - WCX NewM5: 01
  - WCX NewM5:06
  - Transport for NSW T1
  - Transport for NSW X1
  - Transport for NSW F1 (roadside site)
  - Transport for NSW M1 (roadside site)

F.2.2 Summary statistics

Some of the stations listed in the previous section were not carried through for further consideration in the GRAMM modelling given their distance from the project, data availability and siting issues. For example, all WCX sites were excluded as some are located at roadside and they also had limited data availability to inform a long-term site representativeness analysis. The data from these sites may be useful, however, to provide an idea of the general wind patterns in the area and have been discussed in this context in subsequent sections.

Table F-1 provides a summary of the annual data recovery, average wind speed and percentage of calms (wind speeds < 0.5 m/s) for ten of the remaining DPIE and BoM meteorological stations to be considered for further analysis. The parameters that were obtained were wind speed, wind direction, temperature and cloud cover for the years 2009 to 2016 inclusive.

The table shows a generally high percentage of data recovery at each station. The NSW Approved Methods require a meteorological dataset for modelling to be at least 90 per cent complete to be deemed acceptable for a Level 2 (detailed) impact assessment.

There was a high level of year-on-year consistency in the annual average wind speed and annual percentage of calms at each meteorological station. The wind speeds at the BoM Fort Denison, BoM Manly (North Head) and BoM Sydney Airport station were relatively high, with annual averages of 4.1 m/s to 5.7 m/s. This is not unusual given the exposed nature of these stations and their proximity to large coastal waterbodies (Sydney Harbour and Botany Bay). Wind speeds at Chullora, Earlwood, Lindfield and Rozelle were the lowest, with annual averages between 0.7 m/s and 2.2 m/s.

There was also a fairly good year-on-year consistency in the annual percentage of calms at each station, although the values at the OEH Chullora, Earlwood and Lindfield stations showed an increasing trend between 2009 and 2016. There were few calm conditions at Fort Denison and Sydney Airport. OEH Lindfield showed very high percentages of calms throughout the whole period. This is likely due to its location on elevated terrain within the Lane Cove National Park.

F.3 Rationale for selection of reference station and year for modelling

The measurements from the DPIE Randwick, BoM Fort Denison and BoM Manly (North Head) stations in 2016 were chosen as the reference meteorological data for modelling across the GRAMM domain. The reasons for the selection of these stations and the year are given below.

F.3.1 Introduction

The meteorological stations located within the GRAMM domain are owned and operated by various organisations, and each organisation uses different instrumentation. Notably, the DPIE stations use a sonic anemometer and the BoM stations use a cup and vane system. It is important to understand that these differences in instrumentation are likely to contribute to the variability in the measurements (e.g. BoM wind speeds may be higher on average due to a higher stall speed using the cup and vane instrumentation compared with a DPIE sonic anemometer).

It is also known that several of the sites in the GRAMM domain are affected by siting effects/issues that are likely to result in localised meteorological effects which mean that the measurements may not be representative of the GRAL domain. For example, the DPIE station at Lindfield is located on elevated terrain within the Lane Cove National Park, and an analysis of the average wind speeds recorded at this site appears to reflect the influence of the siting. BoM stations such as Fort Denison and Manly (North Head) will be less affected by obstacles such as trees, but are located close to large water bodies or at elevated locations, and have particularly high wind speeds. The use of these data in GRAMM would obviously have an effect on the resultant wind fields in the GRAL domain, as the area has both inland and coastal characteristics.

The above issues also need to be considered with the GRAMM modelling process in mind. GRAMM, unlike other common meteorological models (CALMET etc.), uses a different process to develop meteorological wind fields for use in GRAL. The common and recommended GRAMM process will be implemented for the Beaches Link GRAMM modelling. In short, this includes an initial GRAMM run using a synthetic meteorological file (with a range of meteorological conditions). The resultant GRAMM wind fields will then be matched to selected meteorological station data using the GRAMM 'Match-to-Observations' (MtO) function. Whilst a 'radius of influence' cannot be set for different stations, weighting factors for wind speed and direction can be defined by the user to gain the 'best fit' of data across the domain. This means that all meteorological data included in the matching process will affect the wind fields across the entire GRAMM domain, and to a greater or lesser degree depending on the weighting factors. The weighting factors are based on user judgment, taking into account, for example, the representativeness of the data for the study area. The final wind fields for GRAL will then be a 'compromise' of the meteorological data used in the MtO process. It is then important to select the most appropriate stations to represent the domain, along with appropriate weighting factors.

For the reasons stated above, a basic multi-criteria analysis has been used to select the most appropriate meteorological stations for the Beaches Link GRAMM modelling.

Table F-1 Summary of data recovery, average wind speed and percentage calms

Site and parameter	2009	2010	2011	2012	2013	2014	2015	2016
Chullora – DPIE								
Data recovery (%)	100	100	100	100	97	100	99	100
Average wind speed (m/s)	2.3	2.2	2.1	1.9	1.9	1.8	1.7	1.7
Annual calms (%)	7.6	7.0	7.4	10.4	11.5	11.6	12.7	13.6
Earlwood – DPIE								
Data recovery (%)	100	100	97	100	99	100	100	99
Average wind speed (m/s)	1.6	1.6	1.4	1.4	1.4	1.3	1.3	1.3
Annual calms (%)	18.1	16.8	17.5	22.0	23.1	22.0	23.6	24.6
Lindfield – DPIE								
Data recovery (%)	99	98	100	100	100	99	99	100
Average wind speed (m/s)	1.2	1.0	0.9	0.9	0.9	0.9	0.8	0.7
Annual calms (%)	33.2	38.0	39.6	42.4	41.3	43.1	46.3	49.8
Randwick – DPIE								
Data recovery (%)	99	98	98	99	99	97	96	98
Average wind speed (m/s)	2.2	1.9	2.4	2.6	2.6	2.6	2.6	2.6
Annual calms (%)	11.5	14.5	10.7	9.3	10.5	9.4	9.1	9.6
Rozelle – DPIE								
Data recovery (%)	69	94	100	100	98	99	97	99
Average wind speed (m/s)	1.8	1.8	1.8	1.7	1.8	1.7	1.7	1.7
Annual calms (%)	21.7	23.1	21.3	24.9	23.1	22.1	24.7	24.0
Canterbury Racecourse AWS – BoM								
Data recovery (%)	61	88	91	89	89	90	90	89
Average wind speed (m/s)	3.3	3.2	3.3	3.3	3.3	3.3	3.2	3.3
Annual calms (%)	9.4	8.4	8.0	8.7	8.8	8.6	9.1	9.0
Fort Denison AWS – BoM								
Data recovery (%)	97	96	100	100	98	100	99	100
Average wind speed (m/s)	4.3	4.4	4.4	4.4	4.4	4.3	4.2	4.3
Annual calms (%)	1.6	0.8	0.5	0.2	0.4	0.3	0.3	0.4
Manly (North Head) – BoM								
Data recovery (%)	N/A	99	100	100	99	100	100	100
Average wind speed (m/s)	N/A	5.1	5.1	4.2	4.2	4.1	4.1	4.1
Annual calms (%)	N/A	0.2	0.3	0.2	0.2	N/A	0.3	0.1
Sydney Airport AMO – BoM								
Data recovery (%)	67	66	100	100	100	100	100	100
Average wind speed (m/s)	5.7	5.7	5.7	5.6	5.7	5.5	5.5	5.5
Annual calms (%)	0.3	0.2	0.2	0.3	0.1	0.1	0.2	0.1
Sydney Olympic Park AWS (Archery Centre) – BoM								
Data recovery (%)	N/A	N/A	31[(b)]	90	89	90	89	100
Average wind speed (m/s)	N/A	N/A	2.9	2.7	2.7	2.6	2.6	2.4
Annual calms (%)	N/A	N/A	8.8	11.1	11.4	10.2	12.0	12.0

F.3.2 Year selection

The selection of a meteorological year is linked to the selection of the ambient air quality monitoring (background) year, as the two years need to be the same in any assessment. In both cases the selected year should also be taken as the base year for the assessment. One of the main purposes of including a base year is to enable the dispersion modelling methodology to be verified against real-world air pollution monitoring data.

The base year for the Beaches Link tunnel air quality assessment was taken to be 2016. The main reasons for this can be summarised as follows:

- There is often an expectation that the most recent air quality data (for a complete year) are used in an assessment. The last complete year of validated data at the time the assessment process began 2016.
- The use of 2016 data allowed for a roadside monitoring station (M4-M5:01 – City West Link) to be included in the dispersion model evaluation.
- The air quality monitoring data for 2016 were representative of the longer-term trends.
- The long-term wind speed and direction analysis for the selected meteorological stations showed consistency across the monitored years.

F.3.3 Station selection

F.3.3.1 Analysis of average wind speeds

To provide an overview of all the available meteorological data in the Beaches Link GRAMM domain for 2016, Figure F-1 shows a contour plot of annual average wind speeds based on all of the meteorological stations within the study area. It is important to keep in mind that the plot shows annual average wind speeds from each site interpolated over the GRAMM domain area. Therefore, areas with few or no measurements will be influenced by the closest meteorological station(s). As noted in the previous section, many of these stations (mostly the WCX and Transport for NSW stations) have not been considered for the GRAMM modelling. Basic wind speed data has been shown here however to provide some context of the overall patterns in the area.

Figure F-1 shows that BoM Sydney Airport, Manly, Little Bay, Wedding Cake West and Fort Denison drive the higher average wind speeds in eastern part of the GRAMM domain, which is unsurprising given their proximity to the coast and (in the case of Sydney Airport) local activities. The first third of the domain (from west to east) shows average wind speeds of around 1.5 m/s to 3.5 m/s, with the project corridor falling mostly within this range and just above this range closer to the eastern project corridor.

Figure F-2 shows the monthly average wind speeds in 2016 for the stations presented in Figure F-1. Again, it shows that a large number of stations within the GRAMM domain have average wind speeds between 1.5 and 3 m/s.

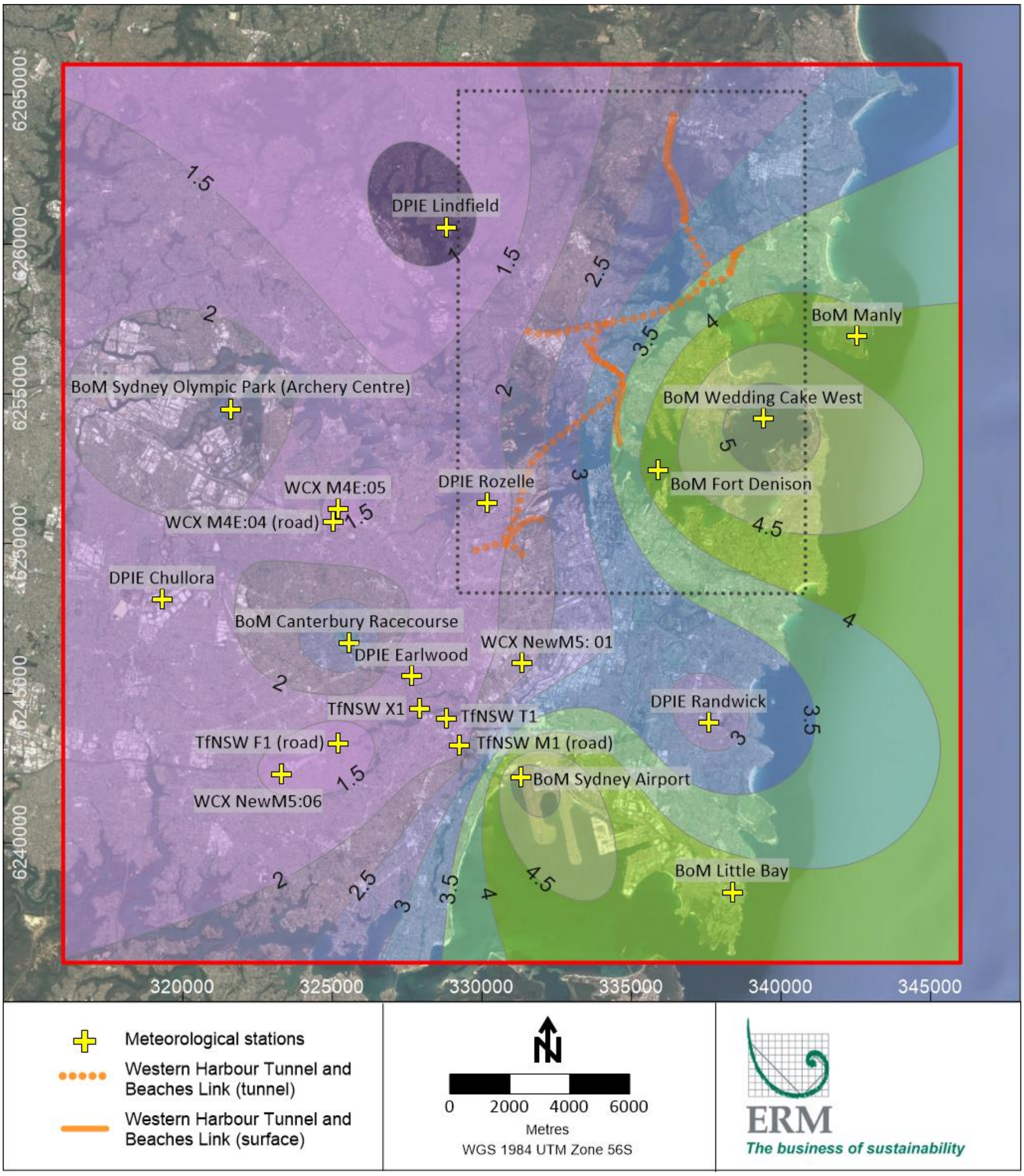


Figure F-1 Contour plot of average wind speed in the GRAMM domain in 2016

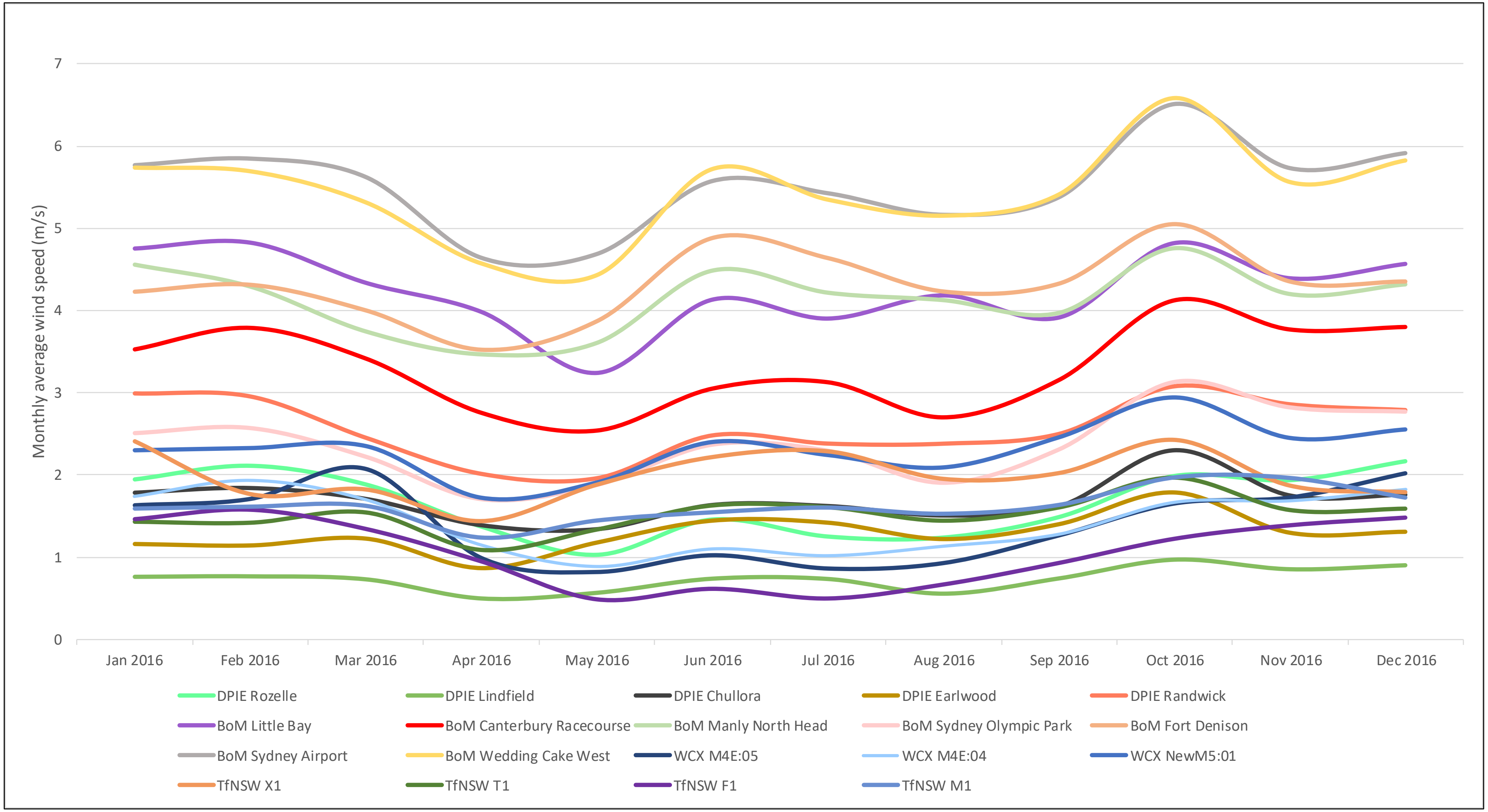


Figure F-2 **Monthly average wind speed in 2016**

F.3.3.2 Analysis of wind directions

Annual and seasonal wind roses were created for all ten meteorological stations presented in Table F-1.

The wind patterns across all of the stations in 2016 are quite varied and the reasons will include those mentioned previously (different instrumentation, siting issues etc.). Stations Earlwood, Lindfield, Randwick, BoM Fort Denison and BoM Manly (North Head) showed most similar patterns to each other with dominant wind directions from the west, west north-west and north-eastern directions. With the exception of Chullora, these stations are also closest to the project.

Previous years of data have also been analysed as wind roses for all meteorological stations. These data have not been included here for practicality purposes but are discussed in subsequent sections for the meteorological stations selected for the GRAMM modelling.

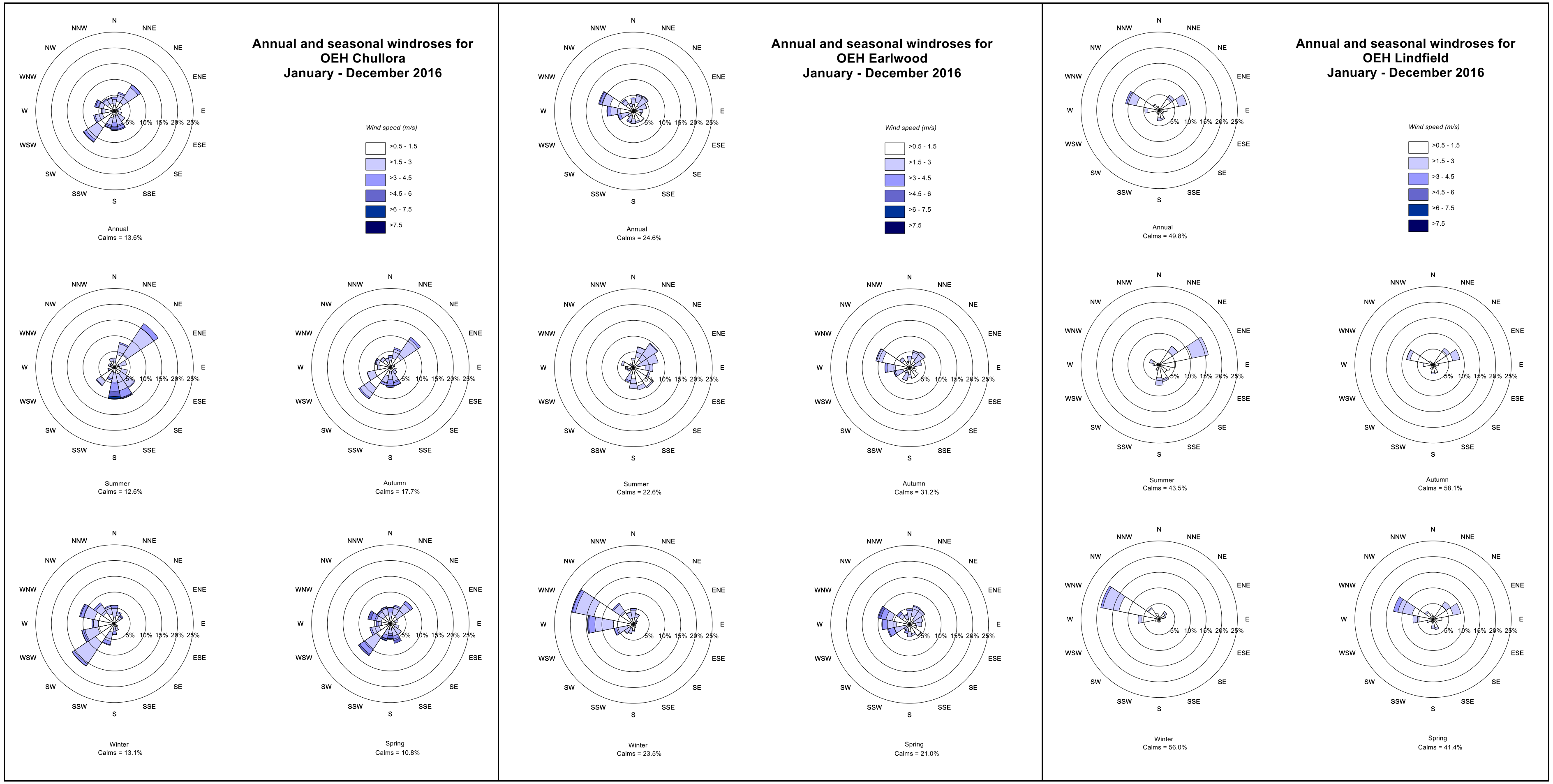


Figure F-3 Annual and seasonal wind roses for DPIE meteorological stations Chullora, Earlwood and Lindfield (2016)

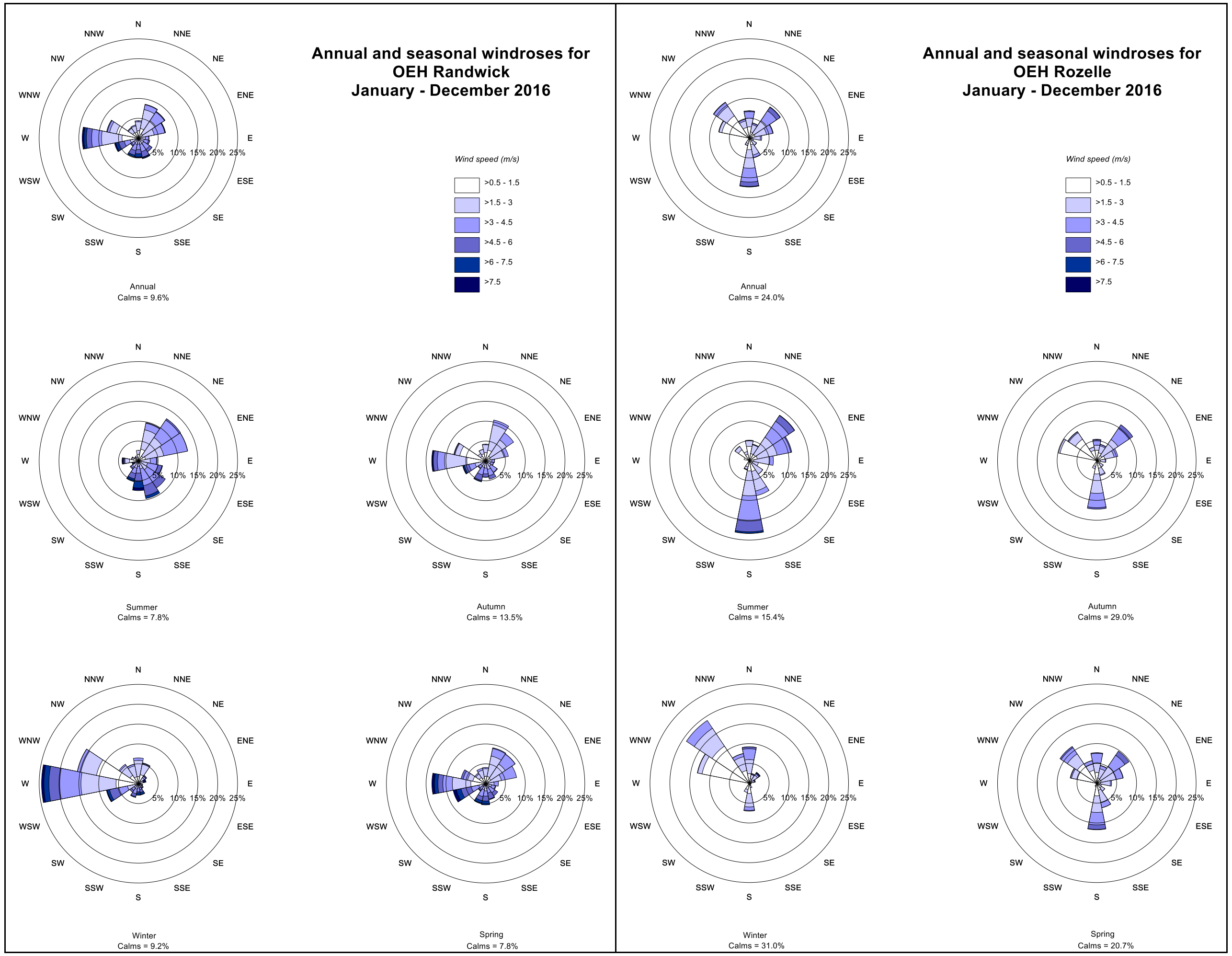


Figure F-4 Annual and seasonal wind roses for DPIE meteorological stations Randwick and Rozelle (2016)

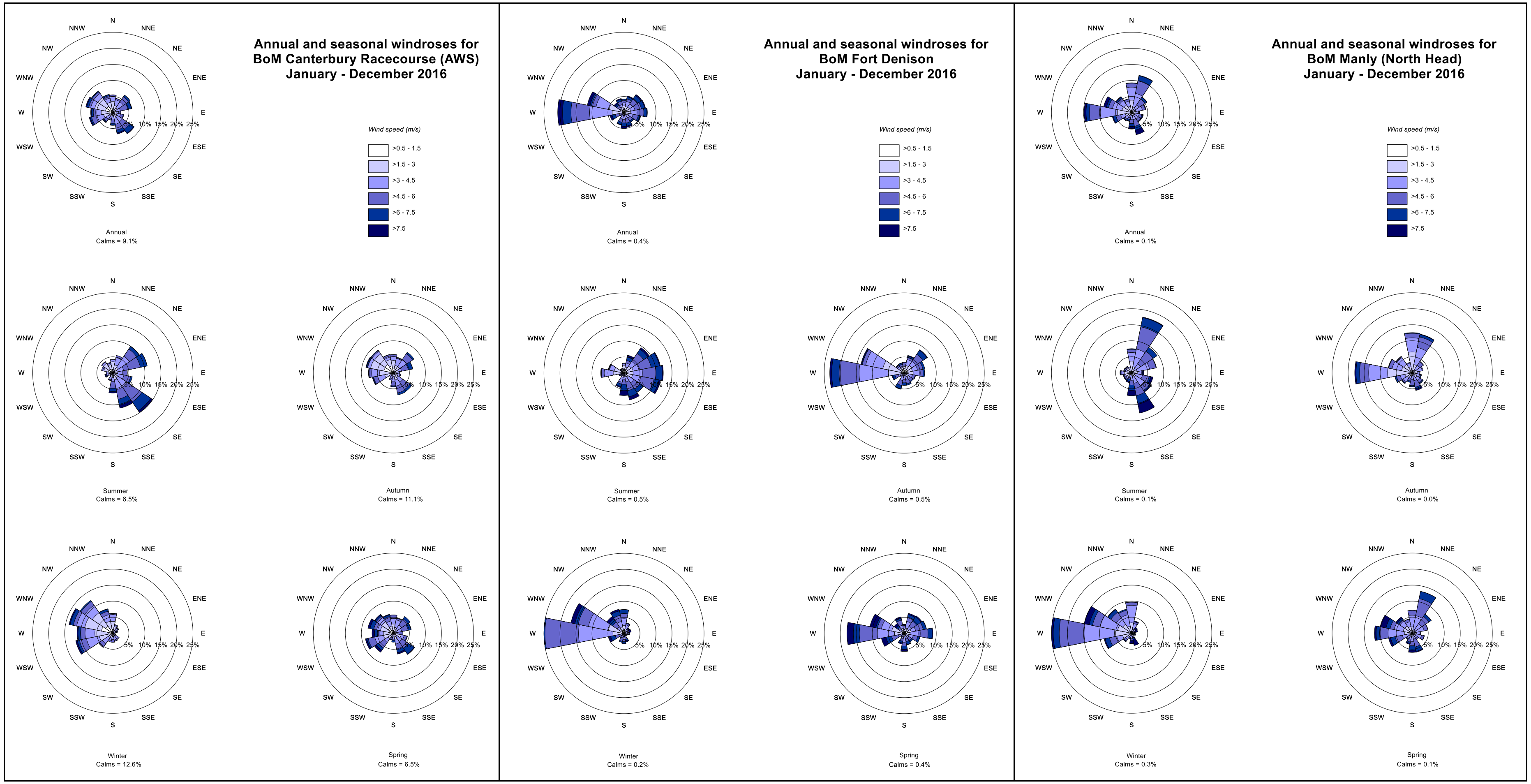


Figure F-5 Annual and seasonal wind roses for BoM meteorological stations Canterbury Racecourse (AWS), Fort Denison and Manly (North Head), (2016)

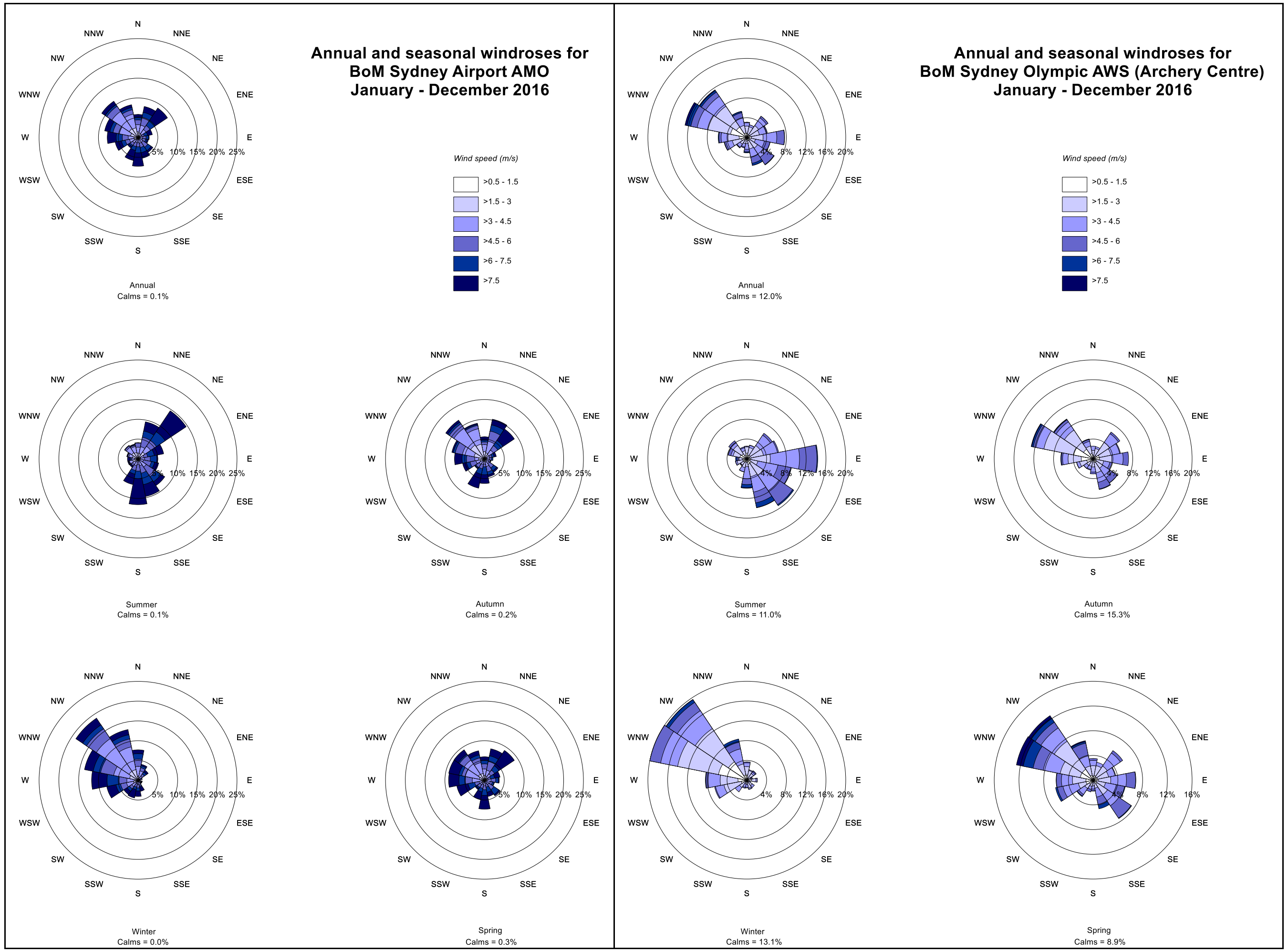


Figure F-6 Annual and seasonal wind roses for BoM meteorological stations Sydney Airport AMO and Sydney Olympic Park (Archery Centre) (2016)

F.3.3.3 Determination of meteorological stations for GRAMM modelling

Based on the consideration of station siting, wind speed and wind direction analysis, stations were included/excluded from additional consideration in the GRAMM modelling for the reasons provided in Table F-1 below.

Table F-2 Consideration of meteorological stations for use in GRAMM modelling

Station	Further consideration for use in modelling
DPIE – Rozelle	Considered in GRAMM modelling given its location within the GRAL domain and proximity to sensitive locations within Rozelle. This station has known siting issues being located on a hill and in proximity to trees. The wind speed and direction is likely affected at this site and this is reflected in the wind speed analysis shown in previous section as well as through the wind rose analysis which shows dissimilar wind patterns when compared to other sites in the general area. Due to the reasons stated above, Rozelle was included in the GRAMM modelling but with lower weighting factors.
DPIE – Lindfield, Chullora, Earlwood	Excluded from further consideration given their distance from the GRAL domain, land use (inland, located in National Park, away from water bodies) and siting issues stated on the Department of Planning, Industry and Environment website.
DPIE – Randwick	Considered in GRAMM modelling given its proximity to the GRAL domain and its location inland but also slightly coastal. Average wind speeds at this site appear to be representative of general project corridor. This station is located outside of the GRAL domain but appears to be well sited and wind speeds/directions are consistent throughout the past years. Higher weightings will therefore be applied in the modelling for this station.
BoM Manly North Head	Considered in GRAMM modelling given their proximity to the GRAL domain and representative of higher wind speeds along the coast which represents the most eastern section of the GRAL domain but may not be entirely representative of the project corridor area. For the reasons stated above, these stations were included in the modelling but with a lower overall weighting and a lower wind direction weighting.
BoM Fort Denison	
BoM Sydney Olympic Park (Archery Centre)	Excluded from further consideration given its distance from the GRAL domain and the dominant wind direction patterns observed which differ from the dominant patterns observed at sites closer to the GRAL domain.
BoM Sydney Airport	Excluded from further consideration given the nature of the very localised land use (higher wind speeds driven by airport activities and location in exposed ocean). Inclusion of these data may result in an overestimate of higher wind speeds as modelled by GRAMM and which could ultimately lead to an underestimate of higher GRAL concentrations.
BoM Wedding Cake West	
WCX M4E:05	Excluded from further consideration given distance from the GRAL domain, roadside location of some sites, and (for the WCX stations) lack of historical data to provide a long-term representativeness analysis to show that 2016 is an appropriate year.
WCX M4E:04 (road)	
WCX NewM5:01	
Transport for NSW X1	
Transport for NSW T1	
Transport for NSW F1 (road)	
Transport for NSW M1 (road)	

Based on the analysis, the majority of meteorological stations were not considered representative and therefore removed from further analysis. Reasons included such things as proximity to vastly different land-use, too far in-land, instrument siting issues or distance from the GRAL domain. Data was not generally excluded for a single one of these attributes, but a number of them combined. BoM Wedding Cake West characterised an exposed location and recorded the highest average wind speed of all the sites across the domain. This is clearly seen in Figure F-1 which shows it is not representative of the project corridor. These high wind speeds were also likely to lead to an underestimate of pollutant concentrations and so was not considered a conservative option. It would also result in an over representation of coastal sites, which are considered by including BoM Manly and BoM Fort Denison. This left the five remaining sites to be considered, DPIE Lindfield, DPIE Rozelle, DPIE Randwick, BoM Fort Denison and BoM Manly.

The average monthly wind speeds for each of these five sites, as well as BoM Wedding Cake West, is shown in Figure F-7. Again, it is clear that BoM Wedding Cake West is significantly higher than the remaining sites. The figure also shows that DPIE Lindfield is significantly lower, and also not representative of the project corridor. The remaining four sites provided a reasonable spread of speeds across the domain, predominantly within the range of wind speeds representative of the project corridor.

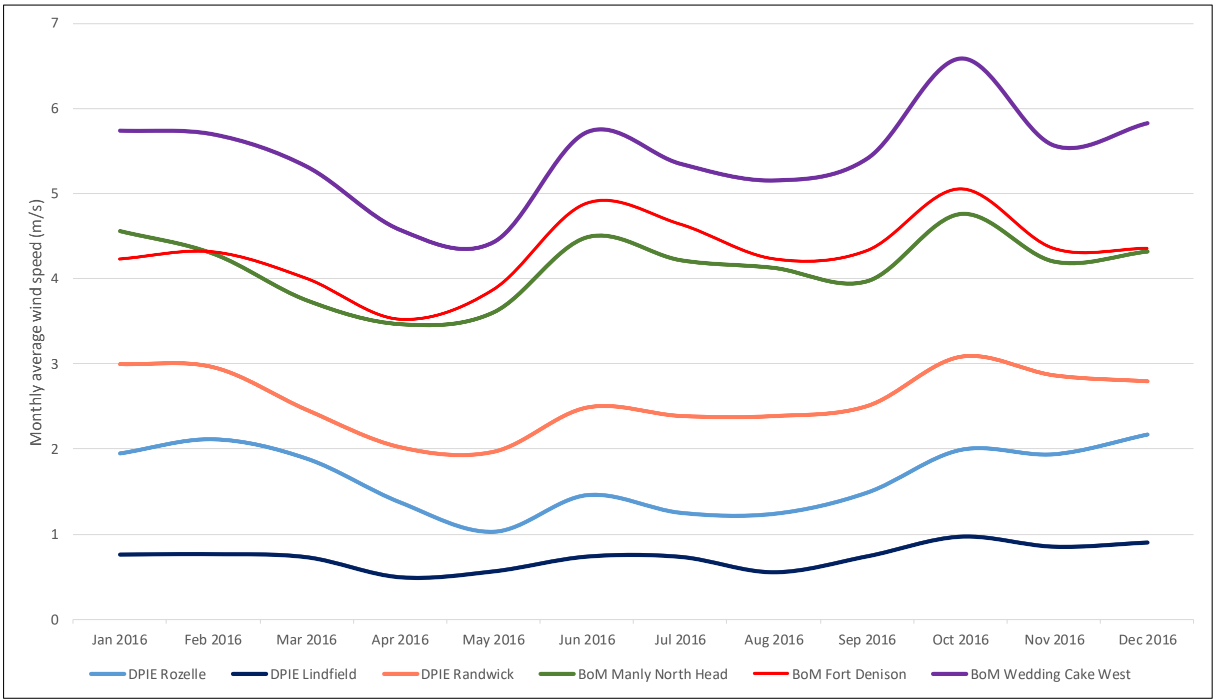


Figure F-7 Monthly average wind speeds in 2016

The remaining five sites were then further evaluated using a matrix to determine their 'weighting' within the GRAMM model. That is, the amount of influence they would have on the final GRAMM output to be used in the GRAL dispersion model. The weighting factors takes into account four main aspects, wind speed, wind direction, siting factors and representativeness of the project corridor.

An evaluation matrix was developed and each aspect scored. While not within the GRAL domain, DPIE Randwick scored highly in the evaluation process and therefore received a higher weighting in terms of influencing the data in GRAMM. Likewise, DPIE Lindfield scored poorly on almost all aspects and was subsequently excluded from further GRAMM analysis. The remaining three sites scored relatively low on one or two aspects and were therefore included but given a low weighting so they had minimal influence across the domain. DPIE Rozelle also scored poorly on wind direction and so was given a lower weighting.

The above assessment has therefore resulted in the following stations being selected for the GRAMM modelling:

- Rozelle – DPIE
- Randwick – DPIE
- Fort Denison – BoM
- BoM Manly – BoM

Table F-3 presents the weighting factors applied in the GRAMM MtO modelling for the four stations selected. These factors were based on the analysis provided above.

Table F-3 Weighting factors applied to meteorological stations in GRAMM modelling

Station	Overall MtO weighting factor	Directional MtO weighting factor
Randwick – DPIE	1	1
Rozelle – DPIE	0.2	0.05
Fort Denison – BoM	0.2	0.2
Manly (North Head) – BoM	0.2	0.2

F.4 Meteorological model evaluation

F.4.1 GRAL optimisation study

Pacific Environment (2017b) examined the performance of the GRAMM-GRAL system in an urban area of Sydney. The main objectives of the study were to assess the performance of GRAMM (version: July 2016) and GRAL (version: August 2016) against meteorological measurements and air quality measurements respectively. GRAMM and GRAL were also compared against other models that are commonly used in Australia: CALMET version 6.334 for meteorology, and CAL3QHCR version 2.0 for dispersion. The study provided recommendations regarding the configuration and application of GRAMM and GRAL to the assessment urban road networks/projects in Australia.

The recommendations on GRAMM modelling from that project have been considered in the GRAMM set up for the Beaches Link project. The main outcome was the use of the Match to Observations (MtO) function, with recommendations regarding testing and input data. These recommendations have been adopted in the GRAMM modelling for this project, and are detailed below.

F.4.2 Wind speed

Table F-4 provides, for 2016, a comparison between the predicted and measured annual average wind speed, standard deviation of wind speed, and percentage of calms at DPIE Randwick, DPIE Rozelle, BoM Fort Denison and BoM Manly (North Head). To enable a direct comparison, the table contains statistics that cover only the time periods for which valid data were available at all monitoring stations. The results show that there was a good agreement between the predicted and observed meteorology at the DPIE Randwick site, but a lesser agreement at DPIE Rozelle, BoM Fort Denison and BoM Manly. This is unsurpising given the weighting factors applied for these stations (DPIE Randwick had the highest weighting, then BoM Fort Denison and BoM Manly and Rozelle with the lowest).

The MtO function applies a ‘comprimise’ across the model domain using the meteorological data included in the matching process. This explains why the agreement of observations and predictions at DPIE Randwick, albiet very strong, is not exact.

Table F-4 Summary statistics – observed and predicted (2016)

Site	Observed			Predicted		
	Annual average wind speed (m/s)	Standard deviation wind speed (m/s)	% calms	Annual average wind speed (m/s)	Standard deviation wind speed (m/s)	% calms
DPIE Randwick	2.6	1.7	9.6	2.5	1.6	5.3
DPIE Rozelle	1.6	1.3	24.2	1.8	1.8	3.7
BoM Fort Denison	4.3	2.1	0.5	3.5	2.6	4.7
BoM Manly (North Head)	4.2	1.9	0.1	3.4	2.2	4.4

Time series, regression and percentile plots of wind speed in 2016 for DPIE Randwick, DPIE Rozelle, BoM Fort Denison and BoM Manly (North Head) are shown in Figure F-8.

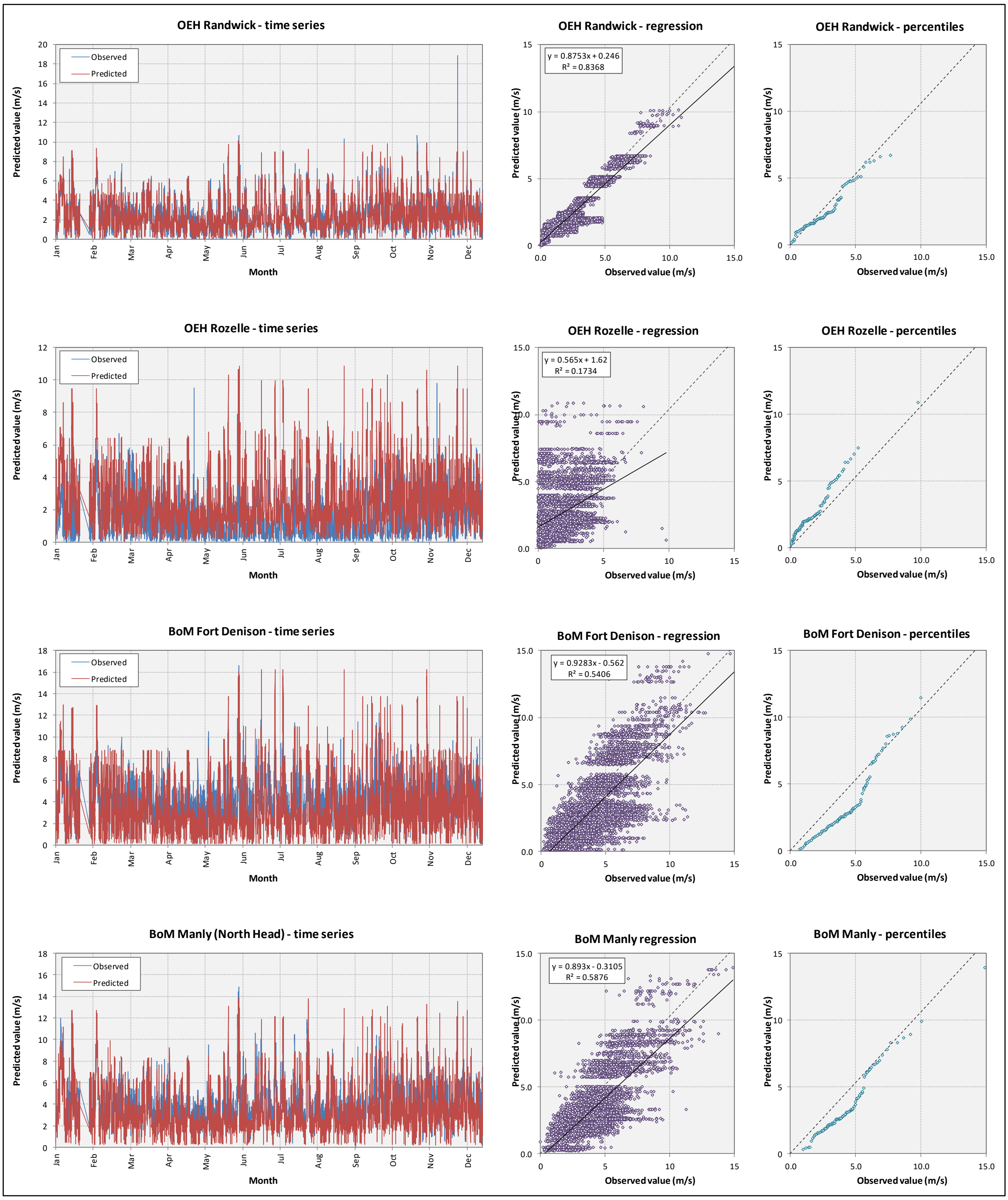


Figure F-8 **GRAMM predicted and observed hourly average wind speed (time series, regression and percentile plots) (2016)**

The results of the regression analysis (predicted wind speed versus observed wind speed) are summarised below. For the correlation coefficient (r), and the associated coefficient of determination (R2), the strength of any relationship was described according to the scheme by Evans (1996) (for R^2: 0.00-0.04 = “very weak”, 0.04-0.16 = “weak”, 0.16-0.36 = “moderate”, 0.36-0.64 = “strong”, 0.64-1.00 = “very strong”).

- DPIE Randwick R^2 = 0.84
- DPIE Rozelle R^2 = 0.17
- BoM Fort Denison R^2 = 0.54
- BoM Manly (North Head) R^2 = 0.58

The analysis showed a very good agreement between the predicted and observed wind speeds at the DPIE Randwick station, which was the site with the highest weightings applied in the MtO function (1 for overall weighting and 1 for wind direction weighting). It is therefore unsurprising that there is a very strong agreement between the observed and predicted wind speeds at the DPIE Randwick site.

There was a strong agreement at BoM Fort Denison and BoM Manly (North Head) although the performance was not as strong at these locations as at DPIE Randwick. This reflects the lower weighting applied at these locations compared to at Randwick.

There was a moderate agreement at DPIE Rozelle which is to be expected and again shows that the lower weighting factor has been applied successfully in the MtO process by taking the data from the site into account but not allowing it to have a significant influence.

The percentile plots shown in Figure F-8 demonstrates a slight under-prediction of mid-rangewind speeds at DPIE Randwick but an overall very strong agreement of the wind speed range at this site. There is an over prediction at Rozelle at the lower wind speeds, and an under prediction at the low wind speeds at BoM Fort Denison and BoM Manly.

Whilst meteorological conditions are an important aspect of any dispersion modelling excercise, it may not always be the most important aspect in determining predicted concentrations in near-source environments such as this. Annexure H of the report provides a validation of the GRAL predictions as compared with measured data. The analysis showed a reasonably good agreement between the pattterns in the predictions and measurements). Although GRAMM may not be predicting meteorology accurately at all locations across the domain, the GRAL model (for which GRAMM is an input), is predicting results at an appropriate level at locations across the study area (see Annexure H).

Summaries of the average temporal patterns in wind speed at DPIE Randwick, DPIE Rozelle, BoM Fort Denison and BoM Manly (North Head) are provided in Figure F-9 to Figure F-12. These plots reflect the discussions provided above and show:

- A very strong agreement between the observed and predicted average wind speeds at DPIE Randwick. There is a tendency for GRAMM to underestimate the higher wind speeds during the middle of the day, but this will add a level of conservatism to the modelling. Times of peak traffic volumes when wind speeds are often lower, show better agreement.
- GRAMM has over-predicted average wind speeds at DPIE Rozelle which again is a reflection of the weighting factors applied. Typical diurnal and monthly average wind speeds patterns have been picked up by the model.
- GRAMM has under-predicted average wind speeds at BoM Fort Denison and BoM Manly which again is a reflection of the weighting factors used, and is unsurprising for these very exposed coastal monitoring stations. Typical diurnal and monthly wind speed patters are again reflected in the GRAMM results.

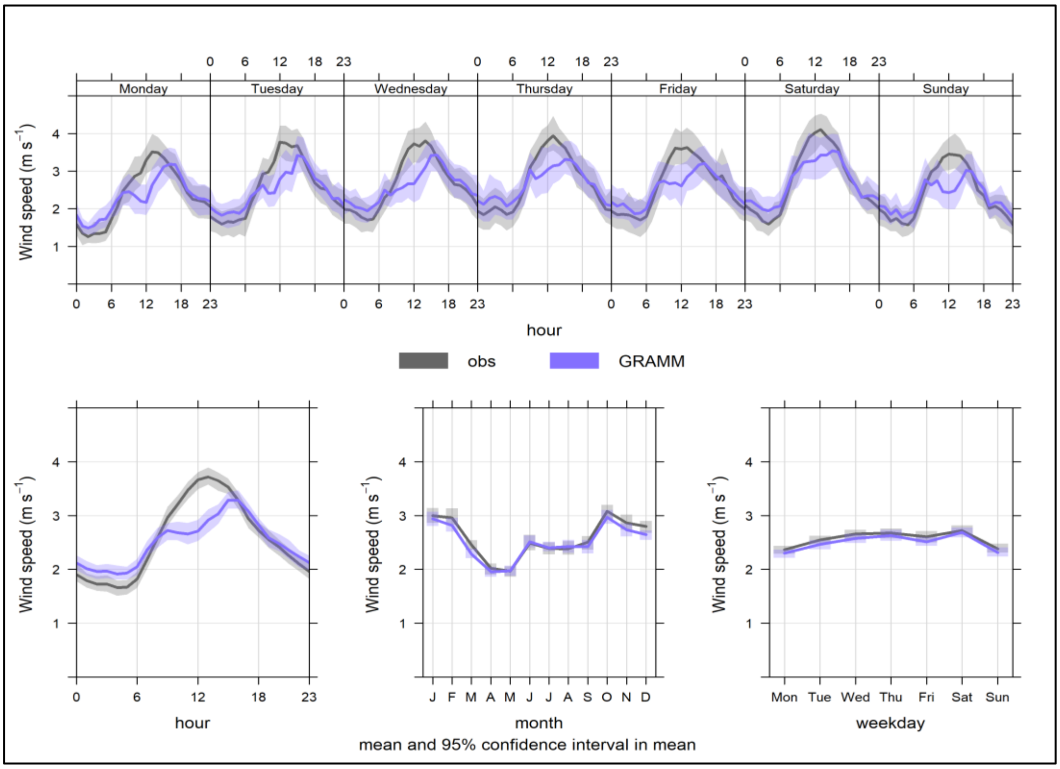


Figure F-9 **Openair timeVariation plot of observed vs predicted wind speeds at DPIE Randwick (2016)**

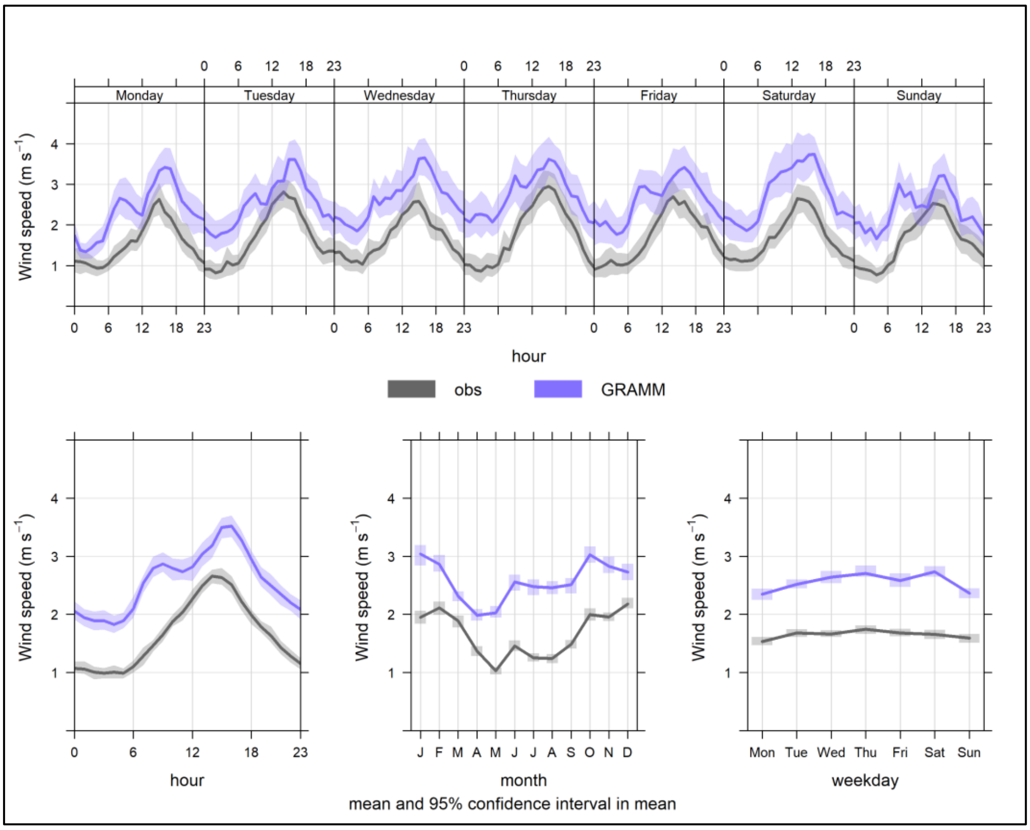


Figure F-10 **Openair timeVariation plot of observed vs predicted wind speeds at DPIE Rozelle (2016)**

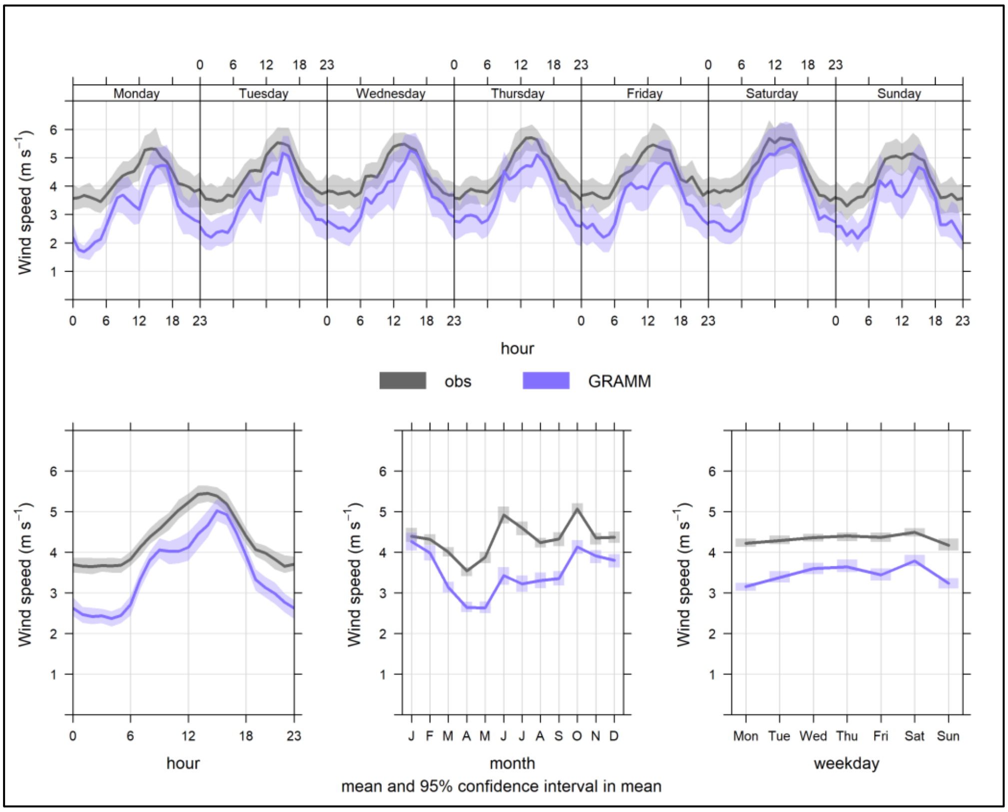


Figure F-11 **Openair timeVariation plot of observed vs predicted wind speeds at BoM Fort Denison (2016)**

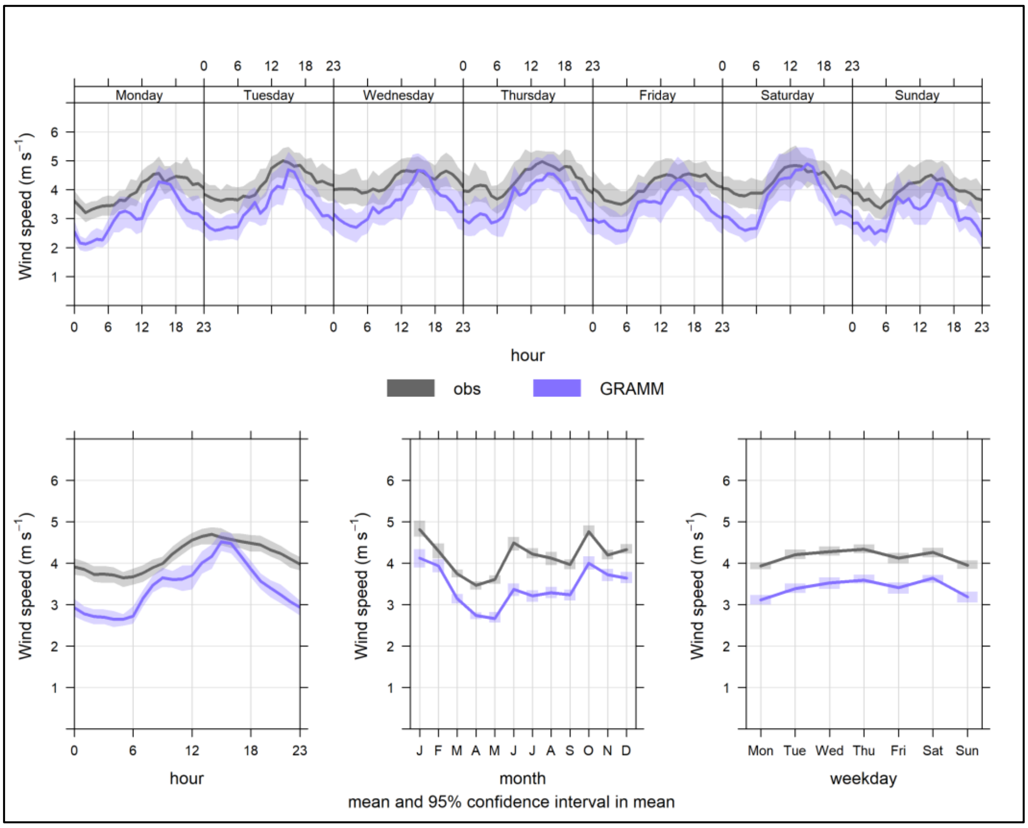


Figure F-12 **Openair timeVariation plot of observed vs predicted wind speeds at BoM Manly (North Head) (2016)**

F.4.3 Wind direction

Annual and seasonal wind roses for the measured and predicted winds in 2016 for DPIE Randwick, DPIE Rozelle, BoM Fort Denison and BoM Manly (North Head) are provided in Figure F-13 to Figure F-16.

The measured and predicted winds for the four sites reflect the discussion above regarding the weighting factors used in the MtO process. There is a good agreement of the prominent wind directions at DPIE Randwick between the observed and predicted results.

The agreement of wind directions at DPIE Rozelle is poor. There is some agreement of winds from the northeast but the overall dominant winds do not agree. As discussed in Section F.3, there are known siting issues at the DPIE Rozelle station and the prominent wind patterns seen at this site at dissimilar to patterns seen at other weather stations in the wider area. This implies that the wind patterns seen at this site are very localised. Given that the MtO function applies all input meteorological data across the domain as a ‘compromise’, the fact that GRAMM has not picked up these prominent winds, is the desired effect.

There is a fair level of agreement between the observed and predicted dominant winds at the BoM Fort Denison and BoM Manly (North Head) sites.

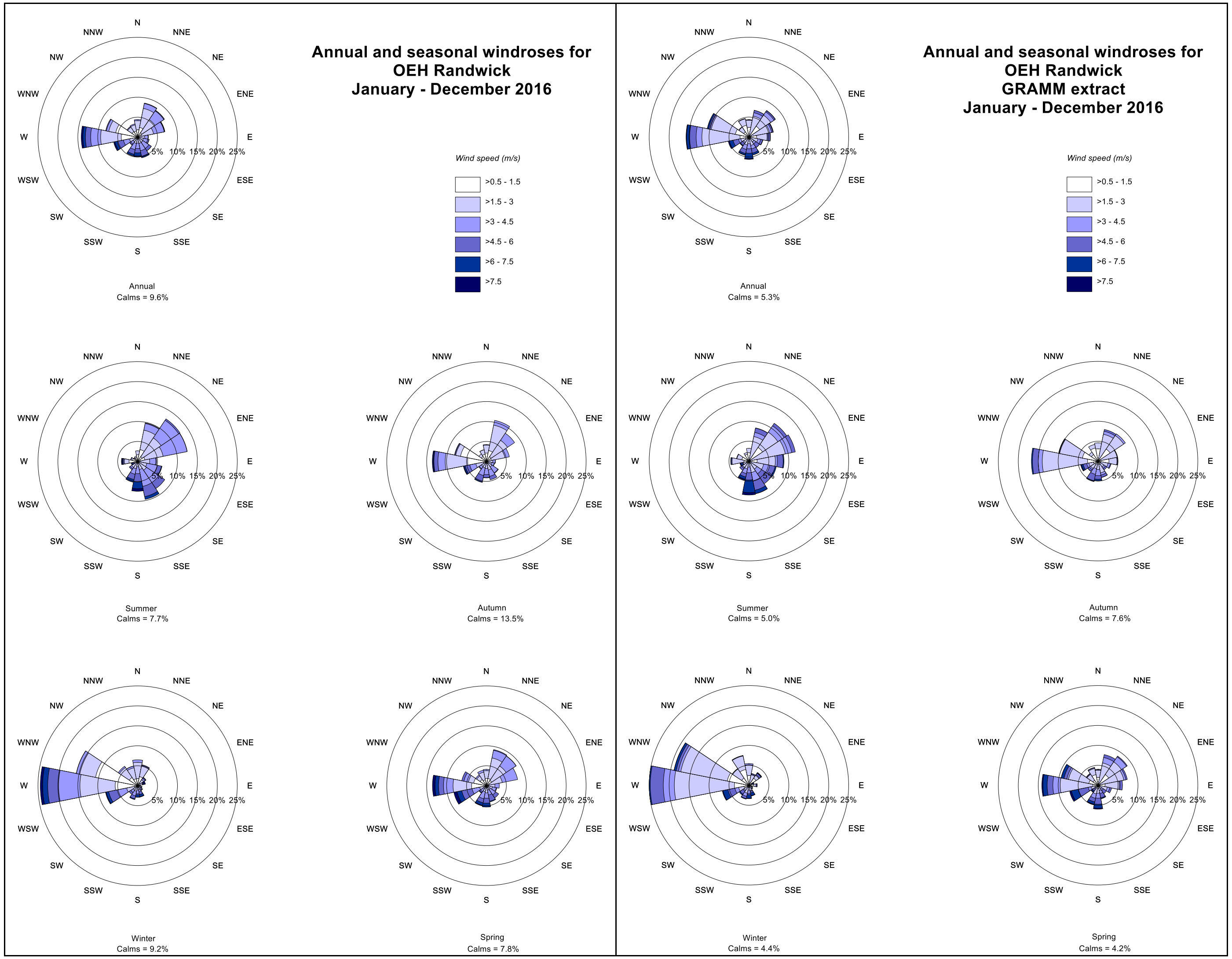


Figure F-13 Annual and seasonal wind roses for observed and predicted winds at DPIE Randwick (2016)

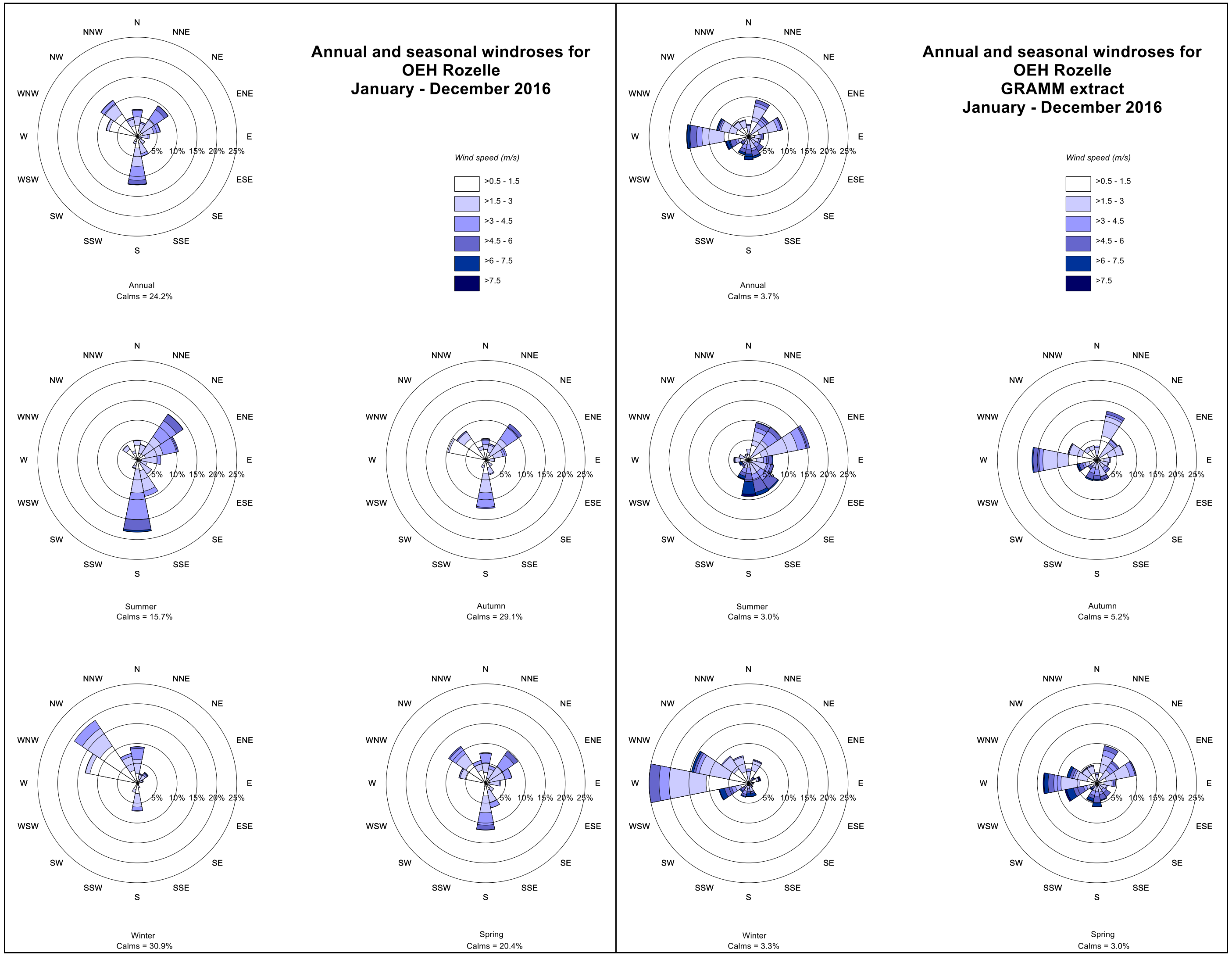


Figure F-14 Annual and seasonal wind roses for observed and predicted winds at DPIE Rozelle (2016)

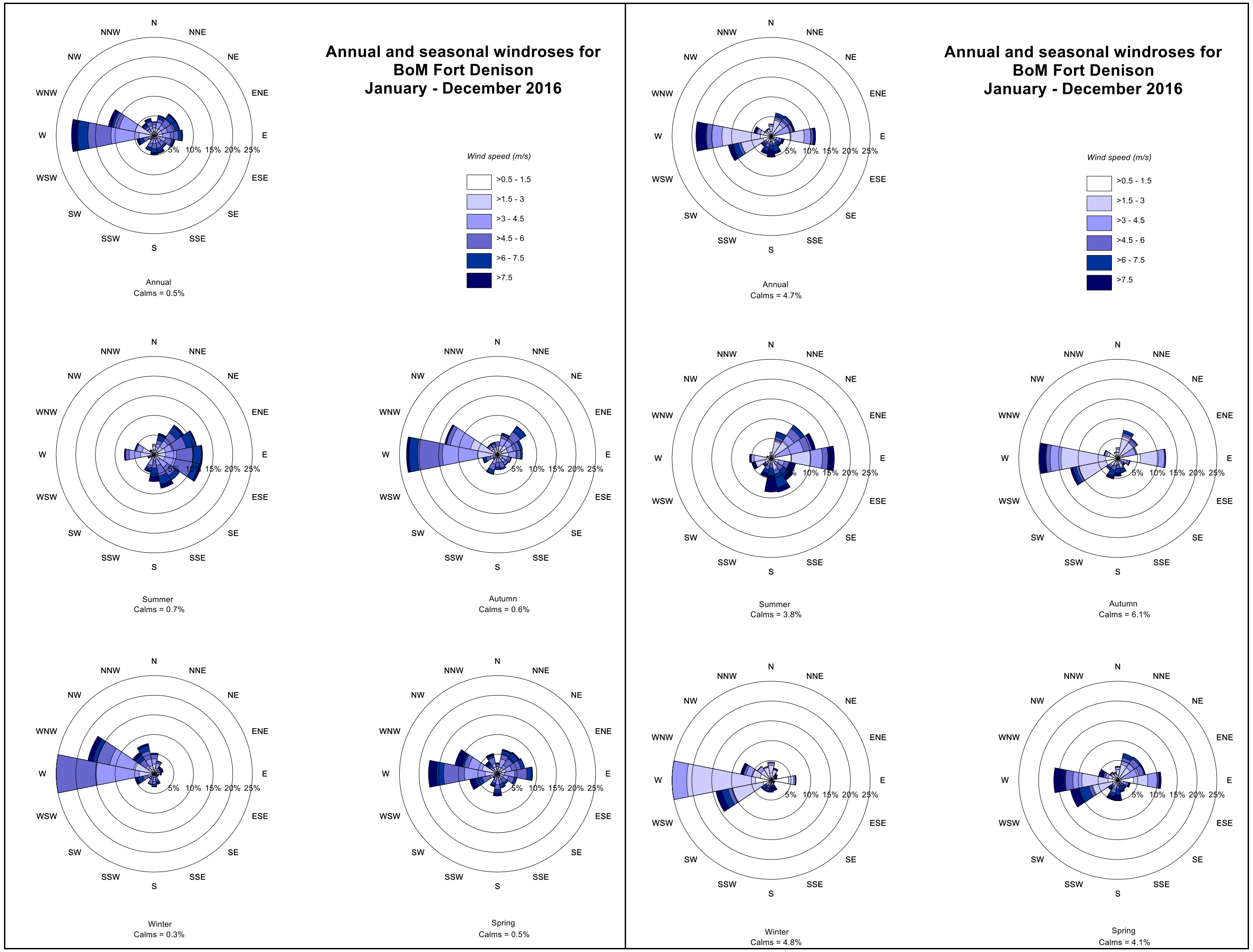


Figure F-15 Annual and seasonal wind roses for observed and predicted winds at BoM Fort Denison (2016)

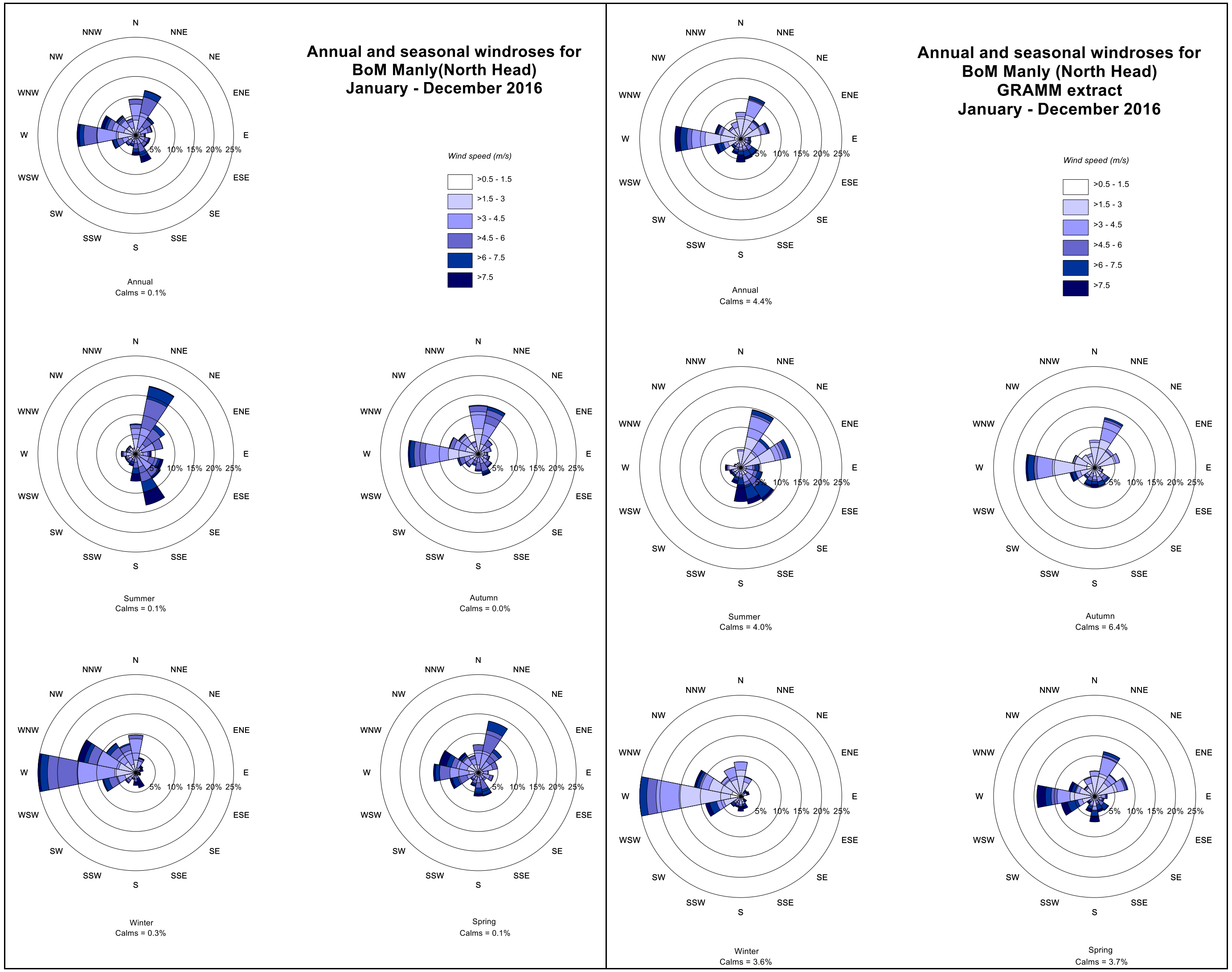


Figure F-16 Annual and seasonal wind roses for observed and predicted winds at BoM Manly (North Head) (2016)

Annexure G Ventilation outlet parameters

This Annexure provides the following parameters for all ventilation outlets in the various scenarios:

- Outlet locations and dimensions
- Air flows and temperatures for the expected traffic scenarios
- Emissions for the expected traffic scenarios
- In-stack concentrations for the expected traffic scenarios
- Parameters for the regulatory worst case scenarios

G.1 Outlet locations and dimensions

The locations and dimensions of the ventilation outlets included in the assessment are given in Table G-1.

Table G-1 Ventilation outlet locations and dimensions

Ventilation outlet	Tunnel project	Location	Traffic direction	Ventilation outlet code	Outlet location (MGA94)		Ground elevation (m)	Outlet height above ground elevation (m)	Outlet diameter[b] (m)
					X	Y	Z[a]		
Exiting and other outlets									
A	Lane Cove Tunnel	Marden Street, Artarmon	EB	LCT-1	331472	6256858	74.1	60.0	8.7
B	Cross City Tunnel	Darling Harbour	EB/WB	CCT-1	333656	6250352	3.1	65.0	6.1
C	M4-M5 Link/Iron Cove Link	Rozelle Rail Yards (mid)	Various	ROZ-1	330939	6250656	2.8	35.0	15.0
D	M4-M5 Link/Iron Cove Link	Rozelle Rail Yards (west)	Various	ROZ-3	330906	6250633	3.0	35.0	12.0
E	Iron Cove Link	Rozelle near Iron Cove	NB	ICL-1	330391	6251650	23.9	20.0	7.0
Project outlets									
F	Western Harbour Tunnel: Rozelle	Rozelle Rail Yards (east)	SB	ROZ-2	330972	6250679	2.7	35.0	14.0
G	Western Harbour Tunnel: Warringah Freeway	Warringah Freeway, Cammeray	NB	CAM-1	334735	6255558	73.1	30.0	11.7
H	Beaches Link: Warringah Freeway	Warringah Freeway, Cammeray	SB	CAM-2	334732	6255569	71.0	30.0	10.5
I	Beaches Link: Gore Hill Freeway	Artarmon, Punch Street	WB	GOR-1	332656	6256995	65.6	25.0	6.8
J	Beaches Link: Wakehurst Parkway	Wakehurst Parkway. Killarney Heights	NB	WAK-1	336865	6261176	117.4	25.0	7.6
K	Beaches Link: Burnt Bridge Creek Deviation	Burnt Bridge Creek Deviation, Balgowlah	EB	BAL-1	338469	6259442	31.0	20.0	7.8

(a) Taken from GRAMM terrain file (5 metre resolution).
(b) Effective circular diameter.

G.2 Air flows and temperatures - expected traffic scenarios

Table G-2 Ventilation air flows and temperatures: 2016-BY

Ventilation outlet	Tunnel project	Location	GRAL source group	Time period(s) (hour start)	Air flow (m^3/s)	Exit velocity (m/s)	Outlet temp. (ºC)
A	Lane Cove Tunnel	Marden Street, Artarmon	A-1	Hours 00 to 04, 20 to 23	335	5.58	24.1
			A-2	Hours 05, 11 to 19	400	6.67	26.3
			A-3	Hours 06 to 10	470	7.83	25.3
B	Cross City Tunnel	Darling Harbour	B-1	Hours 00 to 23	222	7.47	22.2

Table G-3 Ventilation air flows and temperatures: 2027-DM

Ventilation outlet	Tunnel project	Location	GRAL source group	Time period(s) (hour start)*	Air flow (m^3/s)	Exit velocity (m/s)	Outlet temp. (ºC)
A	Lane Cove Tunnel	Marden Street, Artarmon	A-1	Hours 00 to 04, 20 to 23	335	5.58	24.1
			A-2	Hours 05, 11 to 19	400	6.67	26.3
			A-3	Hours 06 to 10	470	7.83	25.3
B	Cross City Tunnel	Darling Harbour	B-1	Hours 00 to 23	222	7.47	22.2
C	M4-M5 Link/Iron Cove Link	Rozelle Rail Yards (mid)	C-1	Hours 05, 22	830	4.70	18.2
			C-2	Hours 06, 14 to 21	1030	5.83	
			C-3	Hours 07 to 13	1130	6.40	
D	M4-M5 Link/Iron Cove Link	Rozelle Rail Yards (west)	D-1	Hours 01 to 04	500	4.42	18.2
			D-2	Hours 00, 23	620	5.48	
E	Iron Cove Link	Rozelle near Iron Cove	E-1	Hours 00 to 04	250	6.49	17.3
			E-2	Hours 05 to 06, 22 to 23	360	9.35	
			E-3	Hours 07 to 21	470	12.21	

* For time periods not listed, air flow = 0.

Table G-4 Ventilation air flows and temperatures: 2027-DS(BL)

Ventilation outlet	Tunnel project	Location	GRAL source group	Time period(s) (hour start)*	Air flow (m^3/s)	Exit velocity (m/s)	Outlet temp. (°C)
A	Lane Cove Tunnel	Marden Street, Artarmon	A-1	Hours 00 to 04, 20 to 23	335	5.58	24.1
			A-2	Hours 05, 11 to 19	400	6.67	26.3
			A-3	Hours 06 to 10	470	7.83	25.3
B	Cross City Tunnel	Darling Harbour	B-1	Hours 00 to 23	222	7.47	22.2
C	M4-M5 Link/Iron Cove Link	Rozelle Rail Yards (mid)	C-1	Hours 05, 22	830	4.70	18.2
			C-2	Hours 06, 14 to 21	1030	5.83	
			C-3	Hours 07 to 13	1130	6.40	
D	M4-M5 Link/Iron Cove Link	Rozelle Rail Yards (west)	D-1	Hours 01 to 04	500	4.42	18.2
			D-2	Hours 00, 23	620	5.48	
E	Iron Cove Link	Rozelle near Iron Cove	E-1	Hours 00 to 04	250	6.49	17.3
			E-2	Hours 05 to 06, 22 to 23	360	9.35	
			E-3	Hours 07 to 21	470	12.21	
H	Beaches Link: Warringah Freeway	Warringah Freeway, Cammeray	H-1	Hours 00 to 06, 18 to 23	300	3.49	24.4
			H-2	Hours 09 to 14	580	6.74	
			H-3	Hours 15 to 17	470	5.47	
I	Beaches Link: Gore Hill Freeway	Artarmon, Punch Street	I-1	Hours 00 to 06, 18 to 23	270	7.50	24.4
			I-2	Hours 09 to 17	410	11.39	
			I-3	Hours 07 to 08	390	10.83	
J	Beaches Link: Wakehurst Parkway	Wakehurst Parkway. Killarney Heights	J-1	Hours 00 to 06, 18 to 23	310	6.89	24.4
			J-2	Hours 07 to 08	440	9.78	
			J-3	Hours 09 to 17	480	10.67	
K	Beaches Link: Burnt Bridge Creek Deviation	Burnt Bridge Creek Deviation, Balgowlah	K-1	Hours 00 to 08, 19 to 23	380	7.92	24.4
			K-2	Hours 09 to 15, 18	460	9.58	
			K-3	Hours 16 to 17	540	11.25	

* For time periods not listed, air flow = 0.

Table G-5 Ventilation air flows and temperatures: 2027-DSC

Ventilation outlet	Tunnel project	Location	GRAL source group	Time period(s) (hour start)*	Air flow (m^3/s)	Exit velocity (m/s)	Outlet temp. (ºC)
A	Lane Cove Tunnel	Marden Street, Artarmon	A-1	Hours 00 to 04, 20 to 23	335	5.58	24.1
			A-2	Hours 05, 11 to 19	400	6.67	26.3
			A-3	Hours 06 to 10	470	7.83	25.3
B	Cross City Tunnel	Darling Harbour	B-1	Hours 00 to 23	222	7.47	22.2
C	M4-M5 Link/Iron Cove Link	Rozelle Rail Yards (mid)	C-1	Hours 00, 04, 06, 08 to 21, 23	810	5.58	21.8
			C-2	Hours 05, 07, 22	1000	6.67	
D	M4-M5 Link/Iron Cove Link	Rozelle Rail Yards (west)	D-1	Hours 06 to 21	550	4.86	21.8
			D-2	Hours 01 to 03	700	6.19	
E	Iron Cove Link	Rozelle near Iron Cove	E-1	Hours 00 to 04, 23	280	7.27	20.3
			E-2	Hours 05 to 07, 22	380	9.87	
			E-3	Hours 08 to 21	470	12.21	
F	Western Harbour Tunnel: Rozelle	Rozelle Rail Yards (east)	F-1	Hours 00 to 06, 18 to 23	710	4.61	24.4
			F-2	Hours 09 to 14	1040	6.75	
			F-3	Hours 07 to 08, 15 to 17	1000	6.49	
G	Western Harbour Tunnel: Warringah Freeway	Warringah Freeway, Cammeray	G-1	Hours 00 to 06, 18 to 23	650	6.02	24.4
			G-2	Hours 07 to 08, 15 to 17	920	8.52	
			G-3	Hours 09 to 14	870	8.06	
H	Beaches Link: Warringah Freeway	Warringah Freeway, Cammeray	H-1	Hours 00 to 06, 18 to 23	360	4.19	24.4
			H-2	Hours 09 to 17	680	7.91	
			H-3	Hours 07 to 08	560	6.51	
I	Beaches Link: Gore Hill Freeway	Artarmon, Punch Street	I-1	Hours 00 to 06, 18 to 23	250	6.94	24.4
			I-2	Hours 07, 15 to 17	420	11.67	
			I-3	Hours 08 to 14	360	10.00	
J	Beaches Link: Wakehurst Parkway	Wakehurst Parkway. Killarney Heights	J-1	Hours 00 to 06, 18 to 23	310	6.89	24.4
			J-2	Hours 07 to 08	450	10.00	
			J-3	Hours 09 to 17	490	10.89	
K	Beaches Link: Burnt Bridge Creek Deviation	Burnt Bridge Creek Deviation, Balgowlah	K-1	Hours 00 to 06, 18 to 23	380	7.92	24.4
			K-2	Hours 07 to 14	480	10.00	
			K-3	Hours 15 to 17	550	11.46	

* For time periods not listed, air flow = 0.

Table G-6 Ventilation air flows and temperatures: 2037-DM

Ventilation outlet	Tunnel project	Location	GRAL source group	Time period(s) (hour start)*	Air flow (m^3/s)	Exit velocity (m/s)	Outlet temp. (ºC)
A	Lane Cove Tunnel	Marden Street, Artarmon	A-1	Hours 00 to 04, 20 to 23	335	5.58	24.1
			A-2	Hours 05, 11 to 19	400	6.67	26.3
			A-3	Hours 06 to 10	470	7.83	25.3
B	Cross City Tunnel	Darling Harbour	B-1	Hours 00 to 23	222	7.47	22.2
C	M4-M5 Link/Iron Cove Link	Rozelle Rail Yards (mid)	C-1	Hours 05, 22	840	4.75	19.5
			C-2	Hours 06, 14 to 21	1050	5.94	
			C-3	Hours 07 to 13	1180	6.68	
D	M4-M5 Link/Iron Cove Link	Rozelle Rail Yards (west)	D-1	Hours 01 to 03	530	4.69	19.5
			D-2	Hours 00, 04, 23	630	5.57	
E	Iron Cove Link	Rozelle near Iron Cove	E-1	Hours 00 to 04	250	6.49	17.6
			E-2	Hours 05 to 06, 22 to 23	360	9.35	
			E-3	Hours 07 to 21	470	12.21	

* For time periods not listed, air flow = 0.

Table G-7 Ventilation air flows and temperatures: 2037-DS(BL)

Ventilation outlet	Tunnel project	Location	GRAL source group	Time period(s) (hour start)*	Air flow (m^3/s)	Exit velocity (m/s)	Outlet temp. (ºC)
A	Lane Cove Tunnel	Marden Street	A-1	Hours 00 to 04, 20 to 23	335	5.58	24.1
			A-2	Hours 05, 11 to 19	400	6.67	26.3
			A-3	Hours 06 to 10	470	7.83	25.3
B	Cross City Tunnel	Darling Harbour	B-1	Hours 00 to 23	222	7.47	22.2
C	M4-M5 Link/Iron Cove Link	Rozelle Rail Yards (mid)	C-1	Hours 05, 23	840	4.75	19.5
			C-2	Hours 06, 14 to 21	1050	5.94	
			C-3	Hours 07 to 13	1180	6.68	
D	M4-M5 Link/Iron Cove Link	Rozelle Rail Yards (west)	D-1	Hours 01 to 03	530	4.69	19.5
			D-2	Hours 00, 04, 23	630	5.57	
E	Iron Cove Link	Rozelle near Iron Cove	E-1	Hours 00 to 04	250	6.49	17.6
			E-2	Hours 05 to 06, 22 to 23	360	9.35	
			E-3	Hours 07 to 21	470	12.21	
H	Beaches Link: Warringah Freeway	Warringah Freeway, Cammeray	H-1	Hours 00 to 06, 18 to 23	300	3.49	24.4
			H-2	Hours 09, 15 to 17	580	6.74	
			H-3	Hours 07 to 08, 10 to 14	480	5.58	
I	Beaches Link: Gore Hill Freeway	Artarmon, Punch Street	I-1	Hours 00 to 06, 15 to 23	270	7.50	24.4
			I-2	Hours 10 to 14	420	11.67	
			I-3	Hours 07 to 9	360	10.00	
J	Beaches Link: Wakehurst Parkway	Wakehurst Parkway. Killarney Heights	J-1	Hours 00 to 06, 15 to 23	310	6.89	24.4
			J-2	Hours 07 to 08	460	10.22	
			J-3	Hours 09 to 17	510	11.33	
K	Beaches Link: Burnt Bridge Creek Deviation	Burnt Bridge Creek Deviation, Balgowlah	K-1	Hours 00 to 08, 18 to 23	380	7.92	24.4
			K-2	Hours 09 to 14	480	10.00	
			K-3	Hours 15 to 17	560	11.67	

* For time periods not listed, air flow = 0.

Table G-8 Ventilation air flows and temperatures: 2037-DSC

Ventilation outlet	Tunnel project	Location	GRAL source group	Time period(s) (hour start)*	Air flow (m^3/s)	Exit velocity (m/s)	Outlet temp. (ºC)
A	Lane Cove Tunnel	Marden Street, Artarmon	A-1	Hours 00 to 04, 20 to 23	335	5.58	24.1
			A-2	Hours 05, 11 to 19	400	6.67	26.3
			A-3	Hours 06 to 10	470	7.83	25.3
B	Cross City Tunnel	Darling Harbour	B-1	Hours 00 to 23	222	7.47	22.2
C	M4-M5 Link/Iron Cove Link	Rozelle Rail Yards (mid)	C-1	Hours 00, 04, 06, 08 to 21, 23	810	4.58	21.8
			C-2	Hours 05, 07, 22	1000	5.66	
D	M4-M5 Link/Iron Cove Link	Rozelle Rail Yards (west)	D-1	Hours 06 to 21	550	4.86	21.8
			D-2	Hours 01 to 03	700	6.19	
E	Iron Cove Link	Rozelle near Iron Cove	E-1	Hours 00 to 04, 23	280	7.27	20.3
			E-2	Hours 05 to 07, 22	380	9.87	
			E-3	Hours 08 to 21	470	12.21	
F	Western Harbour Tunnel: Rozelle	Rozelle Rail Yards (east)	F-1	Hours 00 to 05, 18 to 23	740	4.81	24.4
			F-2	Hours 06 to 17	1050	6.82	
G	Western Harbour Tunnel: Warringah Freeway	Warringah Freeway, Cammeray	G-1	Hours 00 to 06, 18 to 23	680	6.30	24.4
			G-2	Hours 07 to 17	920	8.52	
H	Beaches Link: Warringah Freeway	Warringah Freeway, Cammeray	H-1	Hours 00 to 06, 18 to 23	360	4.19	24.4
			H-2	Hours 09 to 16	710	8.26	
			H-3	Hours 07 to 08	580	6.74	
I	Beaches Link: Gore Hill Freeway	Artarmon, Punch Street	I-1	Hours 00 to 05, 18 to 23	260	7.22	24.4
			I-2	Hours 06, 09, 15	440	12.22	
			I-3	Hours 07 to 08, 10 to 14, 16 to 17	360	10.00	
J	Beaches Link: Wakehurst Parkway	Wakehurst Parkway. Killarney Heights	J-1	Hour 18	320	7.11	24.4
			J-2	Hours 00 to 06, 19 to 23	470	10.44	
			J-3	Hours 07 to 17	520	11.56	
K	Beaches Link: Burnt Bridge Creek Deviation	Burnt Bridge Creek Deviation, Balgowlah	K-1	Hours 00 to 14, 18 to 23	390	8.13	24.4
			K-2	Hours 9 to 14	490	10.21	
			K-3	Hours 15 to 17	560	11.67	

* For time periods not listed, air flow = 0.

G.3 Emissions – expected traffic scenarios

The diurnal emission profiles for each ventilation outlet and pollutant are presented in the following sections. The emission rate for each hour of the day represents the total from the outlet; where a ventilation facility was sub-divided into several outlets, the total emission rate was divided by the number of outlets. The average emission rate for each GRAL source group (see Section 8.4.6) is also provided.

NB(1): These average emission rates for source groups are used in conjunction with emission modulation factors in GRAL (not shown). This approach results in exactly the same hourly emission profiles as those shown in the tables.

NB(2): The same presentational format has been used for each ventilation outlet, and where a particular outlet is not relevant to a scenario the corresponding table contains no values.

G.3.1 Outlet A (Lane Cove Tunnel: Marden Street)

Table G-9 Outlet A, 2016-BY

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.145	0.274	0.004	0.003	0.017
01	0.137	0.207	0.004	0.003	0.016
02	0.129	0.139	0.004	0.003	0.015
03	0.158	0.229	0.006	0.004	0.018
04	0.434	0.546	0.013	0.012	0.050
05	1.418	1.759	0.045	0.040	0.165
06	2.412	3.260	0.079	0.072	0.280
07	2.530	3.661	0.087	0.079	0.283
08	2.166	3.141	0.070	0.064	0.242
09	1.869	2.644	0.057	0.051	0.200
10	1.772	2.404	0.051	0.046	0.190
11	1.654	2.298	0.046	0.041	0.177
12	1.608	2.316	0.044	0.040	0.172
13	1.493	2.254	0.042	0.038	0.160
14	1.438	2.311	0.041	0.037	0.154
15	1.529	2.519	0.043	0.039	0.182
16	1.567	2.784	0.044	0.040	0.187
17	1.400	2.756	0.041	0.037	0.167
18	1.052	2.111	0.033	0.029	0.122
19	0.680	1.363	0.021	0.019	0.079
20	0.483	0.962	0.015	0.013	0.056
21	0.359	0.753	0.011	0.009	0.042
22	0.262	0.568	0.008	0.006	0.030
23	0.195	0.401	0.006	0.005	0.023
Average emission rates by source group used in GRAL **(kg/h)**					
A-1	***0.921***	***1.632***	***0.028***	***0.023***	***0.107***
A-2	***4.983***	***8.090***	***0.144***	***0.129***	***0.564***
A-3	***7.739***	***10.879***	***0.248***	***0.225***	***0.860***

Table G-10 Outlet A, 2027-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.922	2.145	0.048	0.032	0.086
01	0.874	1.618	0.041	0.027	0.081
02	0.825	1.091	0.042	0.027	0.077
03	1.008	1.797	0.065	0.043	0.094
04	2.771	4.280	0.148	0.113	0.257
05	9.052	13.777	0.489	0.390	0.841
06	15.395	25.534	0.867	0.708	1.430
07	16.219	25.333	0.933	0.748	1.386
08	13.886	21.735	0.752	0.609	1.186
09	12.252	16.572	0.614	0.483	0.953
10	11.614	15.064	0.543	0.432	0.903
11	10.846	14.404	0.497	0.390	0.843
12	10.544	14.513	0.470	0.372	0.820
13	9.789	14.124	0.454	0.356	0.761
14	9.430	14.480	0.443	0.348	0.733
15	10.008	16.739	0.476	0.379	0.892
16	10.256	18.498	0.490	0.391	0.914
17	9.162	18.314	0.453	0.366	0.816
18	6.712	16.535	0.356	0.286	0.623
19	4.339	10.675	0.227	0.183	0.403
20	3.082	7.537	0.163	0.125	0.286
21	2.294	5.896	0.116	0.088	0.213
22	1.669	4.448	0.083	0.060	0.155
23	1.247	3.141	0.064	0.045	0.116
Average emission rates by source group used in GRAL **(kg/h)**					
A-1	***0.454***	***0.986***	***0.024***	***0.017***	***0.042***
A-2	***2.504***	***4.224***	***0.121***	***0.096***	***0.212***
A-3	***3.854***	***5.791***	***0.206***	***0.166***	***0.325***

Table G-11 Outlet A, 2027-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	1.015	2.384	0.052	0.036	0.094
01	0.961	1.798	0.045	0.029	0.090
02	0.908	1.212	0.046	0.030	0.085
03	1.109	1.998	0.072	0.048	0.103
04	3.049	4.757	0.163	0.125	0.284
05	9.958	15.315	0.539	0.430	0.927
06	16.937	28.384	0.956	0.780	1.577
07	18.444	26.631	1.054	0.843	1.524
08	15.792	22.849	0.850	0.687	1.305
09	14.006	18.206	0.690	0.544	1.050
10	13.277	16.549	0.611	0.486	0.995
11	12.398	15.823	0.558	0.439	0.929
12	12.053	15.943	0.529	0.419	0.903
13	11.191	15.516	0.511	0.400	0.839
14	10.780	15.907	0.497	0.391	0.808
15	11.070	17.687	0.531	0.422	0.982
16	11.344	19.546	0.546	0.435	1.006
17	10.134	19.352	0.505	0.407	0.899
18	7.384	18.380	0.392	0.316	0.688
19	4.773	11.866	0.250	0.201	0.444
20	3.391	8.378	0.180	0.138	0.316
21	2.524	6.554	0.127	0.097	0.235
22	1.837	4.944	0.091	0.067	0.171
23	1.372	3.491	0.070	0.050	0.128
Average emission rates by source group used in GRAL **(kg/h)**					
A-1	***0.499***	***1.096***	***0.026***	***0.019***	***0.046***
A-2	***2.808***	***4.593***	***0.135***	***0.107***	***0.234***
A-3	***4.359***	***6.257***	***0.231***	***0.186***	***0.358***

Table G-12 Outlet A, 2027-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	1.090	2.259	0.053	0.036	0.092
01	1.032	1.704	0.046	0.030	0.087
02	0.975	1.149	0.047	0.031	0.082
03	1.190	1.893	0.074	0.049	0.101
04	3.274	4.508	0.166	0.128	0.277
05	10.694	14.511	0.550	0.440	0.904
06	18.189	26.894	0.976	0.798	1.537
07	18.624	25.826	1.047	0.838	1.487
08	15.946	22.158	0.844	0.682	1.273
09	14.625	17.451	0.698	0.551	1.023
10	13.864	15.863	0.618	0.493	0.970
11	12.946	15.167	0.565	0.445	0.905
12	12.587	15.282	0.535	0.424	0.880
13	11.686	14.872	0.517	0.405	0.817
14	11.257	15.247	0.503	0.397	0.787
15	11.912	16.886	0.543	0.433	0.957
16	12.206	18.660	0.559	0.447	0.980
17	10.905	18.475	0.517	0.418	0.876
18	7.930	17.415	0.401	0.323	0.670
19	5.126	11.243	0.255	0.206	0.433
20	3.642	7.938	0.184	0.141	0.308
21	2.710	6.210	0.130	0.099	0.229
22	1.972	4.684	0.093	0.068	0.167
23	1.474	3.308	0.071	0.051	0.125
Average emission rates by source group used in GRAL **(kg/h)**					
A-1	***0.536***	***1.039***	***0.027***	***0.020***	***0.045***
A-2	***2.979***	***4.382***	***0.137***	***0.109***	***0.228***
A-3	***4.514***	***6.011***	***0.232***	***0.187***	***0.349***

Table G-13 Outlet A, 2037-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.873	1.997	0.053	0.035	0.081
01	0.827	1.506	0.045	0.029	0.077
02	0.781	1.016	0.047	0.030	0.072
03	0.953	1.673	0.073	0.047	0.088
04	2.622	3.985	0.165	0.124	0.243
05	8.564	12.827	0.546	0.426	0.793
06	14.565	23.773	0.969	0.772	1.349
07	15.830	21.669	1.065	0.830	1.301
08	13.554	18.591	0.859	0.676	1.114
09	11.819	14.561	0.689	0.527	0.887
10	11.204	13.236	0.610	0.471	0.840
11	10.462	12.655	0.558	0.426	0.785
12	10.171	12.751	0.528	0.406	0.763
13	9.443	12.409	0.510	0.388	0.708
14	9.097	12.722	0.497	0.380	0.682
15	9.837	14.095	0.547	0.423	0.837
16	10.080	15.577	0.563	0.437	0.858
17	9.006	15.422	0.520	0.409	0.766
18	6.350	15.395	0.398	0.312	0.588
19	4.105	9.939	0.253	0.199	0.380
20	2.916	7.017	0.182	0.136	0.270
21	2.171	5.489	0.129	0.096	0.201
22	1.579	4.141	0.092	0.066	0.146
23	1.180	2.924	0.071	0.049	0.109
Average emission rates by source group used in GRAL **(kg/h)**					
A-1	***0.429***	***0.918***	***0.026***	***0.019***	***0.040***
A-2	***2.420***	***3.716***	***0.137***	***0.106***	***0.199***
A-3	***3.721***	***5.102***	***0.233***	***0.182***	***0.305***

Table G-14 Outlet A, 2037-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.956	2.123	0.057	0.038	0.086
01	0.906	1.601	0.049	0.031	0.082
02	0.856	1.080	0.050	0.032	0.077
03	1.045	1.779	0.079	0.051	0.094
04	2.873	4.237	0.178	0.133	0.259
05	9.384	13.638	0.589	0.460	0.846
06	15.960	25.277	1.046	0.833	1.439
07	17.521	23.128	1.156	0.901	1.387
08	15.001	19.843	0.932	0.734	1.187
09	13.346	15.527	0.755	0.579	0.944
10	12.652	14.114	0.669	0.518	0.894
11	11.814	13.495	0.612	0.468	0.835
12	11.486	13.597	0.579	0.446	0.812
13	10.664	13.233	0.559	0.426	0.754
14	10.273	13.566	0.545	0.417	0.726
15	10.820	14.198	0.597	0.461	0.893
16	11.087	15.690	0.615	0.476	0.915
17	9.905	15.533	0.568	0.445	0.818
18	6.958	16.368	0.429	0.337	0.627
19	4.498	10.567	0.274	0.215	0.406
20	3.196	7.461	0.197	0.147	0.288
21	2.378	5.836	0.139	0.104	0.214
22	1.731	4.403	0.100	0.071	0.156
23	1.293	3.109	0.077	0.053	0.117
Average emission rates by source group used in GRAL **(kg/h)**					
A-1	***0.470***	***0.976***	***0.029***	***0.020***	***0.042***
A-2	***2.691***	***3.886***	***0.149***	***0.115***	***0.212***
A-3	***4.138***	***5.438***	***0.253***	***0.198***	***0.325***

Table G-15 Outlet A, 2037-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	1.018	2.074	0.059	0.039	0.085
01	0.964	1.565	0.050	0.032	0.081
02	0.911	1.055	0.052	0.033	0.076
03	1.112	1.738	0.081	0.052	0.093
04	3.058	4.140	0.182	0.137	0.256
05	9.990	13.326	0.603	0.471	0.836
06	16.990	24.697	1.070	0.854	1.422
07	18.483	21.519	1.191	0.927	1.372
08	15.825	18.463	0.960	0.755	1.175
09	14.762	14.071	0.798	0.611	0.929
10	13.994	12.791	0.707	0.547	0.881
11	13.067	12.230	0.646	0.494	0.822
12	12.704	12.322	0.612	0.471	0.800
13	11.795	11.992	0.591	0.450	0.742
14	11.362	12.295	0.576	0.440	0.715
15	12.420	13.457	0.633	0.490	0.879
16	12.727	14.871	0.652	0.506	0.901
17	11.370	14.723	0.602	0.473	0.805
18	7.407	15.993	0.439	0.345	0.620
19	4.789	10.325	0.280	0.220	0.401
20	3.402	7.290	0.201	0.151	0.285
21	2.532	5.702	0.143	0.106	0.212
22	1.842	4.302	0.102	0.073	0.154
23	1.377	3.038	0.078	0.054	0.115
Average emission rates by source group used in GRAL **(kg/h)**					
A-1	***0.501***	***0.954***	***0.029***	***0.021***	***0.042***
A-2	***2.990***	***3.654***	***0.157***	***0.121***	***0.209***
A-3	***4.447***	***5.086***	***0.263***	***0.205***	***0.321***

G.3.2 Outlet B (Cross City Tunnel: Darling Harbour)

Table G-16 Outlet B, 2016-BY

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.310	1.040	0.009	0.004	0.023
01	0.253	0.751	0.006	0.003	0.019
02	0.179	0.488	0.006	0.003	0.014
03	0.153	0.378	0.006	0.003	0.012
04	0.169	0.328	0.008	0.004	0.013
05	0.306	0.582	0.016	0.010	0.023
06	0.950	2.276	0.037	0.025	0.072
07	1.483	3.550	0.056	0.038	0.112
08	1.525	3.752	0.063	0.040	0.115
09	1.506	3.570	0.059	0.038	0.114
10	1.476	3.263	0.056	0.035	0.112
11	1.473	3.239	0.054	0.033	0.111
12	1.517	3.431	0.054	0.033	0.115
13	1.469	3.409	0.053	0.032	0.111
14	1.463	3.567	0.054	0.034	0.111
15	1.556	4.070	0.057	0.036	0.118
16	1.426	4.138	0.053	0.034	0.108
17	1.313	4.104	0.048	0.031	0.099
18	1.155	3.953	0.042	0.028	0.087
19	0.879	3.142	0.031	0.021	0.066
20	0.601	2.357	0.021	0.015	0.045
21	0.503	2.043	0.017	0.012	0.038
22	0.473	1.819	0.015	0.009	0.036
23	0.411	1.503	0.012	0.006	0.031
Average emission rates by source group used in GRAL **(kg/h)**					
B-1	***0.939***	***2.531***	***0.035***	***0.022***	***0.071***
B-2	-	-	-	-	-
B-3	-	-	-	-	-

Table G-17 Outlet B, 2027-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.647	1.899	0.028	0.012	0.037
01	0.528	2.106	0.019	0.008	0.030
02	0.373	1.420	0.018	0.007	0.021
03	0.319	2.340	0.020	0.008	0.018
04	0.352	5.571	0.027	0.012	0.020
05	0.639	0.000	0.051	0.027	0.037
06	1.986	0.000	0.119	0.069	0.114
07	3.099	0.000	0.180	0.106	0.178
08	3.185	0.000	0.203	0.112	0.183
09	3.147	0.000	0.189	0.107	0.181
10	3.083	0.000	0.178	0.099	0.177
11	3.078	0.000	0.173	0.093	0.177
12	3.169	0.000	0.173	0.093	0.182
13	3.069	0.000	0.169	0.090	0.177
14	3.056	0.000	0.173	0.095	0.176
15	3.250	0.000	0.183	0.101	0.187
16	2.978	0.000	0.169	0.094	0.171
17	2.744	0.000	0.153	0.087	0.158
18	2.412	0.000	0.134	0.078	0.139
19	1.836	0.000	0.099	0.060	0.106
20	1.257	9.812	0.068	0.042	0.072
21	1.051	7.675	0.056	0.033	0.060
22	0.987	5.790	0.047	0.025	0.057
23	0.858	4.088	0.039	0.018	0.049
Average emission rates by source group used in GRAL **(kg/h)**					
B-1	***0.545***	***1.284***	***0.031***	***0.017***	***0.031***
B-2	-	-	-	-	-
B-3	-	-	-	-	-

Table G-18 Outlet B, 2027-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.487	2.257	0.023	0.010	0.037
01	0.397	1.629	0.016	0.007	0.030
02	0.281	1.058	0.015	0.006	0.021
03	0.240	0.820	0.016	0.006	0.018
04	0.265	0.713	0.022	0.010	0.020
05	0.481	1.263	0.042	0.022	0.037
06	1.494	4.938	0.099	0.057	0.114
07	2.331	7.703	0.149	0.087	0.178
08	2.396	8.141	0.168	0.092	0.183
09	2.368	7.746	0.156	0.088	0.181
10	2.320	7.080	0.147	0.081	0.177
11	2.316	7.028	0.143	0.076	0.177
12	2.384	7.445	0.143	0.076	0.182
13	2.309	7.397	0.140	0.074	0.177
14	2.299	7.740	0.143	0.078	0.176
15	2.445	8.831	0.152	0.083	0.187
16	2.241	8.979	0.139	0.077	0.171
17	2.064	8.905	0.126	0.072	0.158
18	1.815	8.577	0.111	0.064	0.139
19	1.381	6.817	0.082	0.049	0.106
20	0.945	5.114	0.056	0.034	0.072
21	0.791	4.434	0.046	0.027	0.061
22	0.743	3.948	0.039	0.021	0.057
23	0.646	3.261	0.032	0.015	0.049
Average emission rates by source group used in GRAL **(kg/h)**					
B-1	***0.410***	***1.526***	***0.026***	***0.014***	***0.031***
B-2	-	-	-	-	-
B-3	-	-	-	-	-

Table G-19 Outlet B, 2027-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.666	1.967	0.029	0.013	0.038
01	0.543	1.420	0.019	0.008	0.031
02	0.384	0.922	0.019	0.007	0.022
03	0.328	0.715	0.020	0.008	0.019
04	0.362	0.621	0.028	0.012	0.021
05	0.658	1.101	0.053	0.028	0.038
06	2.042	4.304	0.123	0.071	0.118
07	3.186	6.714	0.186	0.109	0.184
08	3.275	7.096	0.209	0.115	0.189
09	3.236	6.751	0.195	0.110	0.187
10	3.171	6.171	0.184	0.102	0.183
11	3.165	6.126	0.178	0.096	0.183
12	3.259	6.489	0.178	0.096	0.188
13	3.156	6.447	0.174	0.093	0.182
14	3.142	6.747	0.179	0.098	0.181
15	3.342	7.698	0.189	0.104	0.193
16	3.062	7.826	0.174	0.097	0.177
17	2.821	7.762	0.157	0.090	0.163
18	2.481	7.476	0.138	0.081	0.143
19	1.888	5.942	0.102	0.062	0.109
20	1.292	4.457	0.070	0.043	0.075
21	1.081	3.864	0.058	0.034	0.062
22	1.015	3.441	0.048	0.026	0.059
23	0.883	2.842	0.040	0.018	0.051
Average emission rates by source group used in GRAL **(kg/h)**					
B-1	***0.561***	***1.330***	***0.032***	***0.018***	***0.032***
B-2	-	-	-	-	-
B-3	-	-	-	-	-

Table G-20 Outlet B, 2037-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.642	1.751	0.033	0.014	0.037
01	0.524	1.263	0.022	0.009	0.030
02	0.370	0.821	0.021	0.008	0.021
03	0.316	0.636	0.023	0.009	0.018
04	0.349	0.553	0.032	0.013	0.020
05	0.634	0.980	0.060	0.030	0.037
06	1.969	3.830	0.138	0.077	0.114
07	3.072	5.975	0.209	0.119	0.177
08	3.158	6.315	0.236	0.126	0.182
09	3.120	6.009	0.220	0.120	0.180
10	3.057	5.492	0.207	0.112	0.176
11	3.052	5.452	0.201	0.104	0.176
12	3.142	5.775	0.201	0.104	0.181
13	3.042	5.738	0.197	0.101	0.176
14	3.029	6.004	0.201	0.106	0.175
15	3.222	6.851	0.213	0.114	0.186
16	2.953	6.965	0.196	0.106	0.170
17	2.720	6.908	0.178	0.098	0.157
18	2.392	6.654	0.156	0.088	0.138
19	1.820	5.288	0.115	0.068	0.105
20	1.246	3.967	0.079	0.047	0.072
21	1.042	3.439	0.065	0.037	0.060
22	0.979	3.062	0.055	0.028	0.056
23	0.851	2.529	0.045	0.020	0.049
Average emission rates by source group used in GRAL **(kg/h)**					
B-1	***0.541***	***1.184***	***0.036***	***0.019***	***0.031***
B-2	-	-	-	-	-
B-3	-	-	-	-	-

Table G-21 Outlet B, 2037-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.649	1.761	0.033	0.014	0.037
01	0.529	1.271	0.022	0.009	0.030
02	0.374	0.826	0.021	0.008	0.021
03	0.319	0.640	0.023	0.009	0.018
04	0.353	0.556	0.032	0.013	0.020
05	0.641	0.985	0.060	0.031	0.037
06	1.990	3.853	0.140	0.078	0.114
07	3.106	6.010	0.211	0.120	0.178
08	3.193	6.352	0.238	0.127	0.183
09	3.154	6.044	0.222	0.121	0.181
10	3.090	5.524	0.209	0.112	0.177
11	3.085	5.483	0.202	0.105	0.177
12	3.176	5.809	0.203	0.105	0.182
13	3.076	5.771	0.198	0.102	0.176
14	3.062	6.039	0.203	0.107	0.176
15	3.258	6.891	0.215	0.115	0.187
16	2.985	7.006	0.197	0.107	0.171
17	2.750	6.948	0.179	0.099	0.158
18	2.418	6.693	0.157	0.089	0.139
19	1.840	5.319	0.116	0.068	0.105
20	1.259	3.990	0.080	0.047	0.072
21	1.053	3.459	0.065	0.038	0.060
22	0.989	3.080	0.055	0.029	0.057
23	0.860	2.544	0.045	0.020	0.049
Average emission rates by source group used in GRAL **(kg/h)**					
B-1	***0.546***	***1.190***	***0.036***	***0.019***	***0.031***
B-2	-	-	-	-	-
B-3	-	-	-	-	-

Table G-22 Outlet B, 2037-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.669	1.801	0.034	0.018	0.038
01	0.546	1.300	0.023	0.012	0.031
02	0.386	0.845	0.022	0.012	0.022
03	0.329	0.655	0.024	0.013	0.019
04	0.364	0.569	0.033	0.017	0.021
05	0.661	1.008	0.062	0.033	0.038
06	2.053	3.941	0.143	0.077	0.117
07	3.203	6.148	0.217	0.116	0.182
08	3.293	6.498	0.244	0.131	0.187
09	3.253	6.182	0.228	0.122	0.185
10	3.188	5.651	0.215	0.115	0.181
11	3.182	5.609	0.208	0.111	0.181
12	3.276	5.942	0.208	0.112	0.186
13	3.172	5.904	0.204	0.109	0.181
14	3.159	6.178	0.208	0.112	0.180
15	3.360	7.049	0.221	0.118	0.191
16	3.079	7.166	0.203	0.109	0.175
17	2.836	7.108	0.184	0.099	0.161
18	2.494	6.846	0.161	0.086	0.142
19	1.898	5.441	0.120	0.064	0.108
20	1.299	4.082	0.082	0.044	0.074
21	1.087	3.539	0.067	0.036	0.062
22	1.021	3.151	0.056	0.030	0.058
23	0.887	2.603	0.047	0.025	0.050
Average emission rates by source group used in GRAL **(kg/h)**					
B-1	***0.564***	***1.218***	***0.037***	***0.020***	***0.032***
B-2	-	-	-	-	-
B-3	-	-	-	-	-

G.3.3 Outlet C (M4-M5 Link/ICL: Rozelle (mid))

Table G-23 Outlet C, 2016-BY

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
C-1	***-***	***-***	***-***	***-***	***-***
C-2	***-***	***-***	***-***	***-***	***-***
C-3	***-***	***-***	***-***	***-***	***-***

Table G-24 Outlet C, 2027-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.000	0.000	0.000	0.000	0.000
01	0.000	0.000	0.000	0.000	0.000
02	0.000	0.000	0.000	0.000	0.000
03	0.000	0.000	0.000	0.000	0.000
04	0.000	0.000	0.000	0.000	0.000
05	0.897	1.339	0.125	0.085	0.054
06	1.766	3.703	0.298	0.204	0.106
07	2.530	4.968	0.435	0.298	0.152
08	2.415	4.331	0.392	0.269	0.145
09	2.343	4.037	0.369	0.253	0.141
10	2.337	3.919	0.361	0.247	0.140
11	2.340	3.870	0.357	0.245	0.140
12	2.363	3.847	0.357	0.244	0.142
13	2.226	3.751	0.342	0.234	0.134
14	2.005	3.634	0.322	0.220	0.120
15	1.816	3.634	0.309	0.212	0.109
16	1.762	3.699	0.311	0.213	0.106
17	1.631	3.123	0.272	0.186	0.098
18	1.555	2.746	0.244	0.167	0.093
19	1.531	2.623	0.235	0.161	0.092
20	1.496	2.564	0.228	0.157	0.090
21	1.414	2.456	0.216	0.148	0.085
22	0.907	1.258	0.123	0.084	0.054
23	0.000	0.000	0.000	0.000	0.000
Average emission rates by source group used in GRAL **(kg/h)**					
C-1	***3.248***	***4.674***	***0.446***	***0.305***	***0.195***
C-2	***5.990***	***11.273***	***0.974***	***0.667***	***0.359***
C-3	***8.513***	***14.772***	***1.344***	***0.921***	***0.511***

Table G-25 Outlet C, 2027-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.000	0.000	0.000	0.000	0.000
01	0.000	0.000	0.000	0.000	0.000
02	0.000	0.000	0.000	0.000	0.000
03	0.000	0.000	0.000	0.000	0.000
04	0.000	0.000	0.000	0.000	0.000
05	0.897	1.339	0.125	0.085	0.054
06	1.766	3.703	0.298	0.204	0.106
07	2.530	4.968	0.435	0.298	0.152
08	2.415	4.331	0.392	0.269	0.145
09	2.343	4.037	0.369	0.253	0.141
10	2.337	3.919	0.361	0.247	0.140
11	2.340	3.870	0.357	0.245	0.140
12	2.363	3.847	0.357	0.244	0.142
13	2.226	3.751	0.342	0.234	0.134
14	2.005	3.634	0.322	0.220	0.120
15	1.816	3.634	0.309	0.212	0.109
16	1.762	3.699	0.311	0.213	0.106
17	1.631	3.123	0.272	0.186	0.098
18	1.555	2.746	0.244	0.167	0.093
19	1.531	2.623	0.235	0.161	0.092
20	1.496	2.564	0.228	0.157	0.090
21	1.414	2.456	0.216	0.148	0.085
22	0.907	1.258	0.123	0.084	0.054
23	0.000	0.000	0.000	0.000	0.000
Average emission rates by source group used in GRAL **(kg/h)**					
C-1	***3.248***	***4.674***	***0.446***	***0.305***	***0.195***
C-2	***5.990***	***11.273***	***0.974***	***0.667***	***0.359***
C-3	***8.513***	***14.772***	***1.344***	***0.921***	***0.511***

Table G-26 Outlet C, 2027-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.380	0.676	0.060	0.041	0.023
01	0.000	0.000	0.000	0.000	0.000
02	0.000	0.000	0.000	0.000	0.000
03	0.000	0.000	0.000	0.000	0.000
04	0.341	0.571	0.052	0.036	0.020
05	0.864	1.431	0.131	0.089	0.052
06	1.674	2.957	0.268	0.184	0.100
07	3.449	5.417	0.527	0.361	0.207
08	2.684	4.295	0.417	0.286	0.161
09	2.305	3.667	0.353	0.242	0.138
10	2.134	3.378	0.324	0.222	0.128
11	2.043	3.252	0.309	0.212	0.123
12	2.028	3.207	0.305	0.209	0.122
13	1.951	3.154	0.298	0.204	0.117
14	1.776	3.059	0.285	0.195	0.107
15	1.766	3.171	0.294	0.202	0.106
16	1.848	3.427	0.320	0.219	0.111
17	1.474	2.700	0.249	0.171	0.088
18	1.267	2.229	0.203	0.139	0.076
19	1.168	2.016	0.183	0.126	0.070
20	1.112	1.890	0.173	0.118	0.067
21	1.072	1.820	0.165	0.113	0.064
22	0.891	1.482	0.136	0.093	0.053
23	0.429	0.785	0.068	0.047	0.026
Average emission rates by source group used in GRAL **(kg/h)**					
C-1	***5.490***	***9.251***	***0.907***	***0.593***	***0.220***
C-2	***6.244***	***9.996***	***0.997***	***0.652***	***0.250***
C-3	***-***	***-***	***-***	***-***	***-***

Table G-27 Outlet C, 2037-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.000	0.000	0.000	0.000	0.000
01	0.000	0.000	0.000	0.000	0.000
02	0.000	0.000	0.000	0.000	0.000
03	0.000	0.000	0.000	0.000	0.000
04	0.000	0.000	0.000	0.000	0.000
05	0.619	1.070	0.118	0.077	0.025
06	1.388	3.136	0.322	0.210	0.056
07	2.348	4.687	0.520	0.340	0.094
08	2.222	4.060	0.466	0.305	0.089
09	2.084	3.632	0.424	0.277	0.083
10	2.034	3.454	0.405	0.264	0.081
11	2.019	3.377	0.397	0.259	0.081
12	2.003	3.327	0.392	0.256	0.080
13	1.931	3.278	0.382	0.250	0.077
14	1.804	3.239	0.370	0.242	0.072
15	1.684	3.292	0.363	0.237	0.067
16	1.555	3.322	0.358	0.234	0.062
17	1.383	2.734	0.298	0.195	0.055
18	1.305	2.471	0.271	0.177	0.052
19	1.290	2.351	0.261	0.171	0.052
20	1.303	2.313	0.259	0.169	0.052
21	1.259	2.210	0.247	0.162	0.050
22	0.823	1.190	0.144	0.094	0.033
23	0.000	0.000	0.000	0.000	0.000
Average emission rates by source group used in GRAL **(kg/h)**					
C-1	***2.596***	***4.068***	***0.472***	***0.309***	***0.104***
C-2	***5.188***	***10.027***	***1.100***	***0.719***	***0.208***
C-3	***7.530***	***13.277***	***1.535***	***1.004***	***0.301***

Table G-28 Outlet C, 2037-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.000	0.000	0.000	0.000	0.000
01	0.000	0.000	0.000	0.000	0.000
02	0.000	0.000	0.000	0.000	0.000
03	0.000	0.000	0.000	0.000	0.000
04	0.000	0.000	0.000	0.000	0.000
05	0.619	1.070	0.118	0.077	0.025
06	1.388	3.136	0.322	0.210	0.056
07	2.348	4.687	0.520	0.340	0.094
08	2.222	4.060	0.466	0.305	0.089
09	2.084	3.632	0.424	0.277	0.083
10	2.034	3.454	0.405	0.264	0.081
11	2.019	3.377	0.397	0.259	0.081
12	2.003	3.327	0.392	0.256	0.080
13	1.931	3.278	0.382	0.250	0.077
14	1.804	3.239	0.370	0.242	0.072
15	1.684	3.292	0.363	0.237	0.067
16	1.555	3.322	0.358	0.234	0.062
17	1.383	2.734	0.298	0.195	0.055
18	1.305	2.471	0.271	0.177	0.052
19	1.290	2.351	0.261	0.171	0.052
20	1.303	2.313	0.259	0.169	0.052
21	1.259	2.210	0.247	0.162	0.050
22	0.823	1.190	0.144	0.094	0.033
23	0.000	0.000	0.000	0.000	0.000
Average emission rates by source group used in GRAL **(kg/h)**					
C-1	***2.596***	***4.068***	***0.472***	***0.309***	***0.104***
C-2	***5.188***	***10.027***	***1.100***	***0.719***	***0.208***
C-3	***7.530***	***13.277***	***1.535***	***1.004***	***0.301***

Table G-29 Outlet C, 2037-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.333	0.604	0.068	0.044	0.013
01	0.000	0.000	0.000	0.000	0.000
02	0.000	0.000	0.000	0.000	0.000
03	0.000	0.000	0.000	0.000	0.000
04	0.298	0.510	0.059	0.039	0.012
05	0.000	0.000	0.000	0.000	0.000
06	1.465	2.642	0.304	0.199	0.059
07	0.000	0.000	0.000	0.000	0.000
08	2.349	3.839	0.473	0.309	0.094
09	2.017	3.277	0.401	0.262	0.081
10	1.868	3.019	0.367	0.240	0.075
11	1.788	2.906	0.351	0.229	0.072
12	1.774	2.867	0.347	0.226	0.071
13	1.708	2.819	0.338	0.221	0.068
14	1.555	2.734	0.323	0.211	0.062
15	1.545	2.834	0.334	0.218	0.062
16	1.617	3.063	0.363	0.237	0.065
17	1.290	2.413	0.283	0.185	0.052
18	1.109	1.993	0.231	0.151	0.044
19	1.022	1.802	0.208	0.136	0.041
20	0.973	1.689	0.196	0.128	0.039
21	0.938	1.626	0.188	0.123	0.038
22	0.000	0.000	0.000	0.000	0.000
23	0.375	0.702	0.078	0.051	0.015
Average emission rates by source group used in GRAL **(kg/h)**					
C-1	***4.805***	***8.268***	***0.982***	***0.642***	***0.192***
C-2	***5.464***	***8.934***	***1.080***	***0.706***	***0.219***
C-3	***-***	***-***	***-***	***-***	***-***

G.3.4 Outlet D (M4-M5 Link/ICL: Rozelle (west))

Table G-30 Outlet D, 2016-BY

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
D-1	***-***	***-***	***-***	***-***	***-***
D-2	***-***	***-***	***-***	***-***	***-***
D-3	***-***	***-***	***-***	***-***	***-***

Table G-31 Outlet D, 2027-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.348	0.530	0.049	0.034	0.021
01	0.181	0.333	0.028	0.019	0.011
02	0.129	0.259	0.021	0.014	0.008
03	0.130	0.261	0.021	0.014	0.008
04	0.215	0.420	0.034	0.023	0.013
05	0.000	0.000	0.000	0.000	0.000
06	0.000	0.000	0.000	0.000	0.000
07	0.000	0.000	0.000	0.000	0.000
08	0.000	0.000	0.000	0.000	0.000
09	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	0.000
23	0.416	0.678	0.061	0.042	0.025
Average emission rates by source group used in GRAL **(kg/h)**					
D-1	***0.590***	***1.146***	***0.093***	***0.064***	***0.035***
D-2	***1.374***	***2.174***	***0.198***	***0.135***	***0.082***
D-3	***-***	***-***	***-***	***-***	***-***

Table G-32 Outlet D, 2027-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.348	0.530	0.049	0.034	0.021
01	0.181	0.333	0.028	0.019	0.011
02	0.129	0.259	0.021	0.014	0.008
03	0.130	0.261	0.021	0.014	0.008
04	0.215	0.420	0.034	0.023	0.013
05	0.000	0.000	0.000	0.000	0.000
06	0.000	0.000	0.000	0.000	0.000
07	0.000	0.000	0.000	0.000	0.000
08	0.000	0.000	0.000	0.000	0.000
09	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	0.000
23	0.416	0.678	0.061	0.042	0.025
Average emission rates by source group used in GRAL **(kg/h)**					
D-1	***0.590***	***1.146***	***0.093***	***0.064***	***0.035***
D-2	***1.374***	***2.174***	***0.198***	***0.135***	***0.082***
D-3	***-***	***-***	***-***	***-***	***-***

Table G-33 Outlet D, 2027-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.000	0.000	0.060	0.041	0.000
01	0.238	0.449	0.000	0.000	0.014
02	0.221	0.403	0.000	0.000	0.013
03	0.216	0.386	0.000	0.000	0.013
04	0.000	0.000	0.052	0.036	0.000
05	0.000	0.000	0.131	0.089	0.000
06	1.033	1.825	0.268	0.184	0.062
07	2.129	3.344	0.527	0.361	0.128
08	1.657	2.651	0.417	0.286	0.099
09	1.423	2.264	0.353	0.242	0.085
10	1.318	2.085	0.324	0.222	0.079
11	1.261	2.007	0.309	0.212	0.076
12	1.252	1.980	0.305	0.209	0.075
13	1.205	1.947	0.298	0.204	0.072
14	1.097	1.888	0.285	0.195	0.066
15	1.090	1.958	0.294	0.202	0.065
16	1.141	2.116	0.320	0.219	0.068
17	0.910	1.667	0.249	0.171	0.055
18	0.782	1.376	0.203	0.139	0.047
19	0.721	1.245	0.183	0.126	0.043
20	0.686	1.167	0.173	0.118	0.041
21	0.662	1.123	0.165	0.113	0.040
22	0.000	0.000	0.136	0.093	0.000
23	0.000	0.000	0.068	0.047	0.000
Average emission rates by source group used in GRAL **(kg/h)**					
D-1	***4.132***	***6.895***	***0.680***	***0.445***	***0.165***
D-2	***0.810***	***1.486***	***0.135***	***0.088***	***0.032***
D-3	***-***	***-***	***-***	***-***	***-***

Table G-34 Outlet D, 2037-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.255	0.460	0.050	0.033	0.010
01	0.187	0.301	0.001	0.023	0.000
02	0.148	0.239	0.000	0.018	0.000
03	0.169	0.262	0.000	0.020	0.000
04	0.285	0.439	0.000	0.034	0.000
05	0.000	0.000	0.000	0.000	0.000
06	0.000	0.000	0.000	0.000	0.000
07	0.000	0.000	0.000	0.000	0.000
08	0.000	0.000	0.000	0.000	0.000
09	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	0.000
23	0.317	0.554	0.000	0.040	0.000
Average emission rates by source group used in GRAL **(kg/h)**					
D-1	***0.605***	***0.962***	***0.111***	***0.073***	***0.024***
D-2	***1.029***	***1.743***	***0.195***	***0.128***	***0.041***
D-3	***-***	***-***	***-***	***-***	***-***

Table G-35 Outlet D, 2037-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.255	0.460	0.050	0.033	0.010
01	0.187	0.301	0.001	0.023	0.000
02	0.148	0.239	0.000	0.018	0.000
03	0.169	0.262	0.000	0.020	0.000
04	0.285	0.439	0.000	0.034	0.000
05	0.000	0.000	0.000	0.000	0.000
06	0.000	0.000	0.000	0.000	0.000
07	0.000	0.000	0.000	0.000	0.000
08	0.000	0.000	0.000	0.000	0.000
09	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	0.000
23	0.317	0.554	0.000	0.040	0.000
Average emission rates by source group used in GRAL **(kg/h)**					
D-1	***0.605***	***0.962***	***0.111***	***0.073***	***0.024***
D-2	***1.029***	***1.743***	***0.195***	***0.128***	***0.041***
D-3	***-***	***-***	***-***	***-***	***-***

Table G-36 Outlet D, 2037-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.000	0.000	0.000	0.000	0.000
01	0.000	0.000	0.000	0.000	0.000
02	0.000	0.000	0.000	0.000	0.000
03	0.000	0.000	0.000	0.000	0.000
04	0.000	0.000	0.000	0.000	0.000
05	0.000	0.000	0.000	0.000	0.000
06	0.904	1.631	0.188	0.123	0.036
07	0.000	0.000	0.000	0.000	0.000
08	1.450	2.370	0.292	0.191	0.058
09	1.245	2.023	0.248	0.162	0.050
10	1.153	1.864	0.227	0.148	0.046
11	1.104	1.794	0.216	0.141	0.044
12	1.095	1.770	0.214	0.140	0.044
13	1.054	1.740	0.209	0.136	0.042
14	0.960	1.688	0.200	0.130	0.038
15	0.954	1.750	0.206	0.135	0.038
16	0.998	1.891	0.224	0.146	0.040
17	0.796	1.490	0.175	0.114	0.032
18	0.685	1.230	0.142	0.093	0.027
19	0.631	1.112	0.128	0.084	0.025
20	0.601	1.043	0.121	0.079	0.024
21	0.579	1.004	0.116	0.076	0.023
22	0.000	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000	0.000
Average emission rates by source group used in GRAL **(kg/h)**					
D-1	***3.616***	***6.162***	***0.737***	***0.482***	***0.145***
D-2	***0.708***	***1.328***	***0.146***	***0.095***	***0.028***
D-3	***-***	***-***	***-***	***-***	***-***

G.3.5 Outlet E (Iron Cove Link: Rozelle)

Table G-37 Outlet E, 2016-BY

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
E-1	***-***	***-***	***-***	***-***	***-***
E-2	***-***	***-***	***-***	***-***	***-***
E-3	***-***	***-***	***-***	***-***	***-***

Table G-38 Outlet E, 2027-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.111	0.258	0.014	0.009	0.007
01	0.079	0.177	0.010	0.007	0.005
02	0.064	0.143	0.008	0.005	0.004
03	0.058	0.152	0.008	0.005	0.003
04	0.072	0.226	0.010	0.007	0.004
05	0.143	0.533	0.022	0.015	0.009
06	0.264	0.945	0.043	0.030	0.016
07	0.442	1.342	0.069	0.048	0.026
08	0.473	1.314	0.070	0.048	0.028
09	0.545	1.318	0.076	0.052	0.033
10	0.591	1.330	0.079	0.054	0.035
11	0.624	1.338	0.082	0.056	0.037
12	0.645	1.344	0.084	0.058	0.039
13	0.647	1.353	0.085	0.058	0.039
14	0.647	1.387	0.086	0.059	0.039
15	0.631	1.511	0.091	0.062	0.038
16	0.629	1.691	0.099	0.068	0.038
17	0.568	1.393	0.080	0.055	0.034
18	0.518	1.199	0.068	0.047	0.031
19	0.479	1.096	0.061	0.042	0.029
20	0.440	1.031	0.056	0.038	0.026
21	0.396	0.975	0.051	0.035	0.024
22	0.269	0.681	0.034	0.023	0.016
23	0.139	0.320	0.017	0.012	0.008
Average emission rates by source group used in GRAL **(kg/h)**					
E-1	***0.276***	***0.689***	***0.036***	***0.024***	***0.017***
E-2	***0.735***	***2.231***	***0.105***	***0.072***	***0.044***
E-3	***1.986***	***4.709***	***0.274***	***0.187***	***0.119***

Table G-39 Outlet E, 2027-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.111	0.258	0.014	0.009	0.007
01	0.079	0.177	0.010	0.007	0.005
02	0.064	0.143	0.008	0.005	0.004
03	0.058	0.152	0.008	0.005	0.003
04	0.072	0.226	0.010	0.007	0.004
05	0.143	0.533	0.022	0.015	0.009
06	0.264	0.945	0.043	0.030	0.016
07	0.442	1.342	0.069	0.048	0.026
08	0.473	1.314	0.070	0.048	0.028
09	0.545	1.318	0.076	0.052	0.033
10	0.591	1.330	0.079	0.054	0.035
11	0.624	1.338	0.082	0.056	0.037
12	0.645	1.344	0.084	0.058	0.039
13	0.647	1.353	0.085	0.058	0.039
14	0.647	1.387	0.086	0.059	0.039
15	0.631	1.511	0.091	0.062	0.038
16	0.629	1.691	0.099	0.068	0.038
17	0.568	1.393	0.080	0.055	0.034
18	0.518	1.199	0.068	0.047	0.031
19	0.479	1.096	0.061	0.042	0.029
20	0.440	1.031	0.056	0.038	0.026
21	0.396	0.975	0.051	0.035	0.024
22	0.269	0.681	0.034	0.023	0.016
23	0.139	0.320	0.017	0.012	0.008
Average emission rates by source group used in GRAL **(kg/h)**					
E-1	***0.276***	***0.689***	***0.036***	***0.024***	***0.017***
E-2	***0.735***	***2.231***	***0.105***	***0.072***	***0.044***
E-3	***1.986***	***4.709***	***0.274***	***0.187***	***0.119***

Table G-40 Outlet E, 2027-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.124	0.311	0.015	0.010	0.007
01	0.100	0.225	0.013	0.009	0.006
02	0.084	0.189	0.011	0.007	0.005
03	0.082	0.199	0.011	0.007	0.005
04	0.098	0.299	0.014	0.009	0.006
05	0.169	0.613	0.025	0.017	0.010
06	0.291	1.029	0.048	0.033	0.017
07	0.303	1.115	0.050	0.034	0.018
08	0.484	1.367	0.074	0.051	0.029
09	0.610	1.393	0.085	0.058	0.037
10	0.641	1.379	0.087	0.060	0.038
11	0.658	1.379	0.089	0.061	0.039
12	0.669	1.383	0.090	0.062	0.040
13	0.659	1.372	0.090	0.062	0.040
14	0.649	1.381	0.091	0.062	0.039
15	0.574	1.403	0.088	0.060	0.034
16	0.575	1.458	0.092	0.063	0.035
17	0.498	1.306	0.077	0.053	0.030
18	0.494	1.229	0.071	0.048	0.030
19	0.475	1.194	0.066	0.045	0.029
20	0.464	1.178	0.064	0.043	0.028
21	0.436	1.132	0.059	0.040	0.026
22	0.299	0.790	0.039	0.027	0.018
23	0.158	0.382	0.020	0.014	0.009
Average emission rates by source group used in GRAL **(kg/h)**					
E-1	***0.387***	***0.963***	***0.052***	***0.034***	***0.015***
E-2	***0.956***	***3.192***	***0.153***	***0.100***	***0.038***
E-3	***2.028***	***4.771***	***0.302***	***0.198***	***0.081***

Table G-41 Outlet E, 2037-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.089	0.212	0.014	0.009	0.004
01	0.065	0.147	0.010	0.007	0.003
02	0.054	0.120	0.009	0.006	0.002
03	0.048	0.123	0.008	0.005	0.002
04	0.060	0.186	0.011	0.007	0.002
05	0.117	0.432	0.024	0.015	0.005
06	0.226	0.793	0.049	0.032	0.009
07	0.382	1.101	0.079	0.052	0.015
08	0.400	1.106	0.080	0.052	0.016
09	0.454	1.082	0.083	0.054	0.018
10	0.474	1.075	0.084	0.055	0.019
11	0.489	1.074	0.086	0.056	0.020
12	0.500	1.081	0.087	0.057	0.020
13	0.507	1.093	0.089	0.058	0.020
14	0.512	1.122	0.091	0.060	0.020
15	0.476	1.191	0.092	0.060	0.019
16	0.486	1.330	0.103	0.067	0.019
17	0.428	1.089	0.081	0.053	0.017
18	0.393	0.986	0.071	0.046	0.016
19	0.373	0.920	0.065	0.043	0.015
20	0.352	0.867	0.061	0.040	0.014
21	0.322	0.806	0.055	0.036	0.013
22	0.219	0.536	0.035	0.023	0.009
23	0.121	0.288	0.019	0.013	0.005
Average emission rates by source group used in GRAL **(kg/h)**					
E-1	***0.228***	***0.567***	***0.038***	***0.025***	***0.009***
E-2	***0.614***	***1.844***	***0.115***	***0.075***	***0.025***
E-3	***1.571***	***3.822***	***0.289***	***0.189***	***0.063***

Table G-42 Outlet E, 2037-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.089	0.212	0.014	0.009	0.004
01	0.065	0.147	0.010	0.007	0.003
02	0.054	0.120	0.009	0.006	0.002
03	0.048	0.123	0.008	0.005	0.002
04	0.060	0.186	0.011	0.007	0.002
05	0.117	0.432	0.024	0.015	0.005
06	0.226	0.793	0.049	0.032	0.009
07	0.382	1.101	0.079	0.052	0.015
08	0.400	1.106	0.080	0.052	0.016
09	0.454	1.082	0.083	0.054	0.018
10	0.474	1.075	0.084	0.055	0.019
11	0.489	1.074	0.086	0.056	0.020
12	0.500	1.081	0.087	0.057	0.020
13	0.507	1.093	0.089	0.058	0.020
14	0.512	1.122	0.091	0.060	0.020
15	0.476	1.191	0.092	0.060	0.019
16	0.486	1.330	0.103	0.067	0.019
17	0.428	1.089	0.081	0.053	0.017
18	0.393	0.986	0.071	0.046	0.016
19	0.373	0.920	0.065	0.043	0.015
20	0.352	0.867	0.061	0.040	0.014
21	0.322	0.806	0.055	0.036	0.013
22	0.219	0.536	0.035	0.023	0.009
23	0.121	0.288	0.019	0.013	0.005
Average emission rates by source group used in GRAL **(kg/h)**					
E-1	***0.228***	***0.567***	***0.038***	***0.025***	***0.009***
E-2	***0.614***	***1.844***	***0.115***	***0.075***	***0.025***
E-3	***1.571***	***3.822***	***0.289***	***0.189***	***0.063***

Table G-43 Outlet E, 2037-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.098	0.253	0.016	0.011	0.004
01	0.080	0.183	0.013	0.009	0.003
02	0.067	0.154	0.011	0.007	0.003
03	0.065	0.162	0.011	0.007	0.003
04	0.078	0.243	0.015	0.010	0.003
05	0.135	0.498	0.027	0.018	0.005
06	0.232	0.838	0.051	0.033	0.009
07	0.241	0.907	0.053	0.035	0.010
08	0.385	1.112	0.078	0.051	0.015
09	0.486	1.133	0.090	0.059	0.019
10	0.510	1.122	0.092	0.060	0.020
11	0.524	1.122	0.094	0.062	0.021
12	0.533	1.125	0.096	0.062	0.021
13	0.525	1.116	0.095	0.062	0.021
14	0.517	1.123	0.096	0.063	0.021
15	0.457	1.142	0.093	0.061	0.018
16	0.458	1.187	0.098	0.064	0.018
17	0.397	1.062	0.082	0.053	0.016
18	0.394	1.000	0.075	0.049	0.016
19	0.379	0.972	0.070	0.046	0.015
20	0.369	0.959	0.067	0.044	0.015
21	0.347	0.921	0.063	0.041	0.014
22	0.238	0.643	0.041	0.027	0.010
23	0.126	0.311	0.021	0.014	0.005
Average emission rates by source group used in GRAL **(kg/h)**					
E-1	***0.309***	***0.783***	***0.053***	***0.034***	***0.012***
E-2	***0.761***	***2.597***	***0.155***	***0.101***	***0.030***
E-3	***1.615***	***3.882***	***0.306***	***0.200***	***0.065***

G.3.6 Outlet F (Western Harbour Tunnel: Rozelle (east))

Table G-44 Outlet F, 2016-BY

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
F-1	**-**	**-**	**-**	**-**	**-**
F-2	**-**	**-**	**-**	**-**	**-**
F-3	**-**	**-**	**-**	**-**	**-**

Table G-45 Outlet F, 2027-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
F-1	**-**	**-**	**-**	**-**	**-**
F-2	**-**	**-**	**-**	**-**	**-**
F-3	**-**	**-**	**-**	**-**	**-**

Table G-46 Outlet F, 2027-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
F-1	**-**	**-**	**-**	**-**	**-**
F-2	**-**	**-**	**-**	**-**	**-**
F-3	**-**	**-**	**-**	**-**	**-**

Table G-47 Outlet F, 2027-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.824	1.280	0.064	0.044	0.056
01	0.824	1.280	0.064	0.044	0.056
02	0.824	1.280	0.064	0.044	0.056
03	0.824	1.280	0.064	0.044	0.056
04	0.824	1.280	0.064	0.044	0.056
05	0.824	1.280	0.064	0.044	0.056
06	0.824	1.280	0.064	0.044	0.056
07	2.769	2.860	0.282	0.195	0.187
08	2.769	2.860	0.282	0.195	0.187
09	2.407	2.537	0.237	0.164	0.163
10	2.407	2.537	0.237	0.164	0.163
11	2.407	2.537	0.237	0.164	0.163
12	2.407	2.537	0.237	0.164	0.163
13	2.407	2.537	0.237	0.164	0.163
14	2.407	2.537	0.237	0.164	0.163
15	2.147	2.393	0.213	0.147	0.145
16	2.147	2.393	0.213	0.147	0.145
17	2.147	2.393	0.213	0.147	0.145
18	0.824	1.280	0.064	0.044	0.056
19	0.824	1.280	0.064	0.044	0.056
20	0.824	1.280	0.064	0.044	0.056
21	0.824	1.280	0.064	0.044	0.056
22	0.824	1.280	0.064	0.044	0.056
23	0.824	1.280	0.064	0.044	0.056
Average emission rates by source group used in GRAL **(kg/h)**					
F-1	***2.965***	***4.607***	***0.231***	***0.160***	***0.201***
F-2	***9.967***	***10.296***	***1.014***	***0.700***	***0.674***
F-3	***8.353***	***8.961***	***0.823***	***0.569***	***0.565***

Table G-48 Outlet F, 2037-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
F-1	**-**	**-**	**-**	**-**	**-**
F-2	**-**	**-**	**-**	**-**	**-**
F-3	**-**	**-**	**-**	**-**	**-**

Table G-49 Outlet F, 2037-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
F-1	**-**	**-**	**-**	**-**	**-**
F-2	**-**	**-**	**-**	**-**	**-**
F-3	**-**	**-**	**-**	**-**	**-**

Table G-50 Outlet F, 2037-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.800	1.326	0.073	0.049	0.051
01	0.800	1.326	0.073	0.049	0.051
02	0.800	1.326	0.073	0.049	0.051
03	0.800	1.326	0.073	0.049	0.051
04	0.800	1.326	0.073	0.049	0.051
05	0.800	1.326	0.073	0.049	0.051
06	0.800	1.326	0.073	0.049	0.051
07	2.903	2.953	0.339	0.225	0.185
08	2.903	2.953	0.339	0.225	0.185
09	2.522	2.649	0.285	0.189	0.161
10	2.522	2.649	0.285	0.189	0.161
11	2.522	2.649	0.285	0.189	0.161
12	2.522	2.649	0.285	0.189	0.161
13	2.522	2.649	0.285	0.189	0.161
14	2.522	2.649	0.285	0.189	0.161
15	2.382	2.594	0.277	0.184	0.152
16	2.382	2.594	0.277	0.184	0.152
17	2.377	2.580	0.277	0.184	0.152
18	0.800	1.326	0.073	0.049	0.051
19	0.800	1.326	0.073	0.049	0.051
20	0.800	1.326	0.073	0.049	0.051
21	0.800	1.326	0.073	0.049	0.051
22	0.800	1.326	0.073	0.049	0.051
23	0.800	1.326	0.073	0.049	0.051
Average emission rates by source group used in GRAL **(kg/h)**					
F-1	***2.881***	***4.774***	***0.264***	***0.175***	***0.184***
F-2	***9.189***	***9.676***	***1.054***	***0.700***	***0.587***
F-3	***0.000***	***0.000***	***0.000***	***0.000***	***0.000***

G.3.7 Outlet G (Western Harbour Tunnel: Warringah Freeway)

Table G-51 Outlet G, 2016-BY

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
G-1	**-**	**-**	**-**	**-**	**-**
G-2	**-**	**-**	**-**	**-**	**-**
G-3	**-**	**-**	**-**	**-**	**-**

Table G-52 Outlet G, 2027-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
G-1	**-**	**-**	**-**	**-**	**-**
G-2	**-**	**-**	**-**	**-**	**-**
G-3	**-**	**-**	**-**	**-**	**-**

Table G-53 Outlet G, 2027-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
G-1	**-**	**-**	**-**	**-**	**-**
G-2	**-**	**-**	**-**	**-**	**-**
G-3	**-**	**-**	**-**	**-**	**-**

Table G-54 Outlet G, 2027-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	1.511	1.642	0.094	0.065	0.102
01	1.511	1.642	0.094	0.065	0.102
02	1.511	1.642	0.094	0.065	0.102
03	1.511	1.642	0.094	0.065	0.102
04	1.511	1.642	0.094	0.065	0.102
05	1.511	1.642	0.094	0.065	0.102
06	1.511	1.642	0.094	0.065	0.102
07	4.804	3.931	0.304	0.210	0.325
08	4.804	3.931	0.304	0.210	0.325
09	4.283	3.488	0.272	0.188	0.290
10	4.282	3.488	0.272	0.188	0.290
11	4.282	3.488	0.272	0.188	0.290
12	4.282	3.488	0.272	0.188	0.290
13	4.282	3.488	0.272	0.188	0.290
14	4.282	3.488	0.272	0.188	0.290
15	4.010	3.611	0.265	0.183	0.271
16	4.011	3.612	0.265	0.183	0.271
17	4.010	3.612	0.265	0.183	0.271
18	1.511	1.642	0.094	0.065	0.102
19	1.511	1.642	0.094	0.065	0.102
20	1.511	1.642	0.094	0.065	0.102
21	1.511	1.642	0.094	0.065	0.102
22	1.511	1.642	0.094	0.065	0.102
23	1.511	1.642	0.094	0.065	0.102
Average emission rates by source group used in GRAL **(kg/h)**					
G-1	***5.441***	***5.910***	***0.337***	***0.233***	***0.368***
G-2	***17.296***	***14.150***	***1.096***	***0.757***	***1.170***
G-3	-	-	-	-	-

Table G-55 Outlet G, 2037-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
G-1	-	-	-	-	-
G-2	-	-	-	-	-
G-3	-	-	-	-	-

Table G-56 Outlet G, 2037-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
G-1	-	-	-	-	-
G-2	-	-	-	-	-
G-3	-	-	-	-	-

Table G-57 Outlet G, 2037-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	1.484	1.671	0.104	0.069	0.095
01	1.484	1.671	0.104	0.069	0.095
02	1.484	1.671	0.104	0.069	0.095
03	1.484	1.671	0.104	0.069	0.095
04	1.484	1.671	0.104	0.069	0.095
05	1.484	1.671	0.104	0.069	0.095
06	1.484	1.671	0.104	0.069	0.095
07	5.160	4.052	0.364	0.242	0.330
08	5.160	4.052	0.364	0.242	0.330
09	4.384	3.521	0.308	0.205	0.280
10	4.385	3.521	0.308	0.205	0.280
11	4.385	3.521	0.308	0.205	0.280
12	4.385	3.521	0.308	0.205	0.280
13	4.385	3.521	0.308	0.205	0.280
14	4.385	3.521	0.308	0.205	0.280
15	4.079	3.578	0.298	0.198	0.260
16	4.079	3.578	0.298	0.198	0.260
17	4.079	3.577	0.298	0.198	0.260
18	1.485	1.671	0.104	0.069	0.095
19	1.484	1.671	0.104	0.069	0.095
20	1.484	1.671	0.104	0.069	0.095
21	1.484	1.671	0.104	0.069	0.095
22	1.484	1.671	0.104	0.069	0.095
23	1.484	1.671	0.104	0.069	0.095
Average emission rates by source group used in GRAL **(kg/h)**					
G-1	***5.344***	***6.017***	***0.375***	***0.249***	***0.341***
G-2	***15.992***	***13.079***	***1.136***	***0.755***	***1.021***
G-3	***-***	***-***	***-***	***-***	***-***

G.3.8 Outlet H (Beaches Link: Warringah Freeway)

Table G-58 Outlet H, 2016-BY

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
H-1	**-**	**-**	**-**	**-**	**-**
H-2	**-**	**-**	**-**	**-**	**-**
H-3	**-**	**-**	**-**	**-**	**-**

Table G-59 Outlet H, 2027-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
H-1	**-**	**-**	**-**	**-**	**-**
H-2	**-**	**-**	**-**	**-**	**-**
H-3	**-**	**-**	**-**	**-**	**-**

Table G-60 Outlet H, 2027-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.584	0.664	0.040	0.028	0.039
01	0.584	0.664	0.040	0.028	0.039
02	0.584	0.664	0.040	0.028	0.039
03	0.584	0.664	0.040	0.028	0.039
04	0.584	0.664	0.040	0.028	0.039
05	0.584	0.664	0.040	0.028	0.039
06	0.657	0.733	0.045	0.031	0.044
07	2.852	2.259	0.227	0.157	0.193
08	2.994	2.348	0.237	0.164	0.203
09	2.151	1.709	0.162	0.112	0.146
10	2.025	1.629	0.153	0.106	0.137
11	2.025	1.629	0.153	0.106	0.137
12	2.025	1.629	0.153	0.106	0.137
13	2.025	1.629	0.153	0.106	0.137
14	2.025	1.629	0.153	0.106	0.137
15	1.537	1.384	0.117	0.081	0.104
16	1.548	1.389	0.118	0.081	0.105
17	1.558	1.394	0.119	0.082	0.105
18	0.622	0.694	0.043	0.030	0.042
19	0.584	0.664	0.040	0.028	0.039
20	0.584	0.664	0.040	0.028	0.039
21	0.584	0.664	0.040	0.028	0.039
22	0.584	0.664	0.040	0.028	0.039
23	0.584	0.664	0.040	0.028	0.039
Average emission rates by source group used in GRAL **(kg/h)**					
H-1	***2.132***	***2.419***	***0.147***	***0.102***	***0.144***
H-2	***10.523***	***8.293***	***0.835***	***0.577***	***0.712***
H-3	***6.768***	***5.608***	***0.512***	***0.354***	***0.458***

Table G-61 Outlet H, 2027-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.646	0.771	0.045	0.031	0.044
01	0.646	0.771	0.045	0.031	0.044
02	0.646	0.771	0.045	0.031	0.044
03	0.646	0.771	0.045	0.031	0.044
04	0.646	0.771	0.045	0.031	0.044
05	0.646	0.771	0.045	0.031	0.044
06	0.727	0.855	0.051	0.035	0.049
07	3.346	2.683	0.272	0.188	0.226
08	3.489	2.772	0.282	0.195	0.236
09	2.396	1.977	0.187	0.129	0.162
10	2.261	1.879	0.177	0.122	0.153
11	2.261	1.879	0.177	0.122	0.153
12	2.261	1.879	0.177	0.122	0.153
13	2.261	1.879	0.177	0.122	0.153
14	2.261	1.879	0.177	0.122	0.153
15	1.819	1.685	0.142	0.098	0.123
16	1.829	1.690	0.143	0.098	0.124
17	1.840	1.694	0.143	0.099	0.125
18	0.692	0.816	0.049	0.034	0.047
19	0.646	0.771	0.045	0.031	0.044
20	0.646	0.771	0.045	0.031	0.044
21	0.646	0.771	0.045	0.031	0.044
22	0.646	0.771	0.045	0.031	0.044
23	0.646	0.771	0.045	0.031	0.044
Average emission rates by source group used in GRAL **(kg/h)**					
H-1	***2.360***	***2.811***	***0.166***	***0.115***	***0.160***
H-2	***12.303***	***9.819***	***0.997***	***0.689***	***0.833***
H-3	***7.675***	***6.577***	***0.599***	***0.414***	***0.519***

Table G-62 Outlet H, 2037-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
H-1	***-***	***-***	***-***	***-***	***-***
H-2	***-***	***-***	***-***	***-***	***-***
H-3	***-***	***-***	***-***	***-***	***-***

Table G-63 Outlet H, 2037-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.549	0.654	0.043	0.029	0.035
01	0.549	0.654	0.043	0.029	0.035
02	0.549	0.654	0.043	0.029	0.035
03	0.549	0.654	0.043	0.029	0.035
04	0.549	0.654	0.043	0.029	0.035
05	0.549	0.654	0.043	0.029	0.035
06	0.619	0.722	0.048	0.032	0.040
07	2.760	2.186	0.246	0.164	0.176
08	2.898	2.273	0.257	0.171	0.185
09	2.085	1.669	0.175	0.116	0.133
10	1.964	1.590	0.165	0.110	0.125
11	1.964	1.590	0.165	0.110	0.125
12	1.964	1.590	0.165	0.110	0.125
13	1.964	1.590	0.165	0.110	0.125
14	1.964	1.590	0.165	0.110	0.125
15	1.477	1.351	0.126	0.084	0.094
16	1.487	1.356	0.127	0.085	0.095
17	1.497	1.361	0.128	0.085	0.096
18	0.592	0.698	0.046	0.031	0.038
19	0.549	0.654	0.043	0.029	0.035
20	0.549	0.654	0.043	0.029	0.035
21	0.549	0.654	0.043	0.029	0.035
22	0.549	0.654	0.043	0.029	0.035
23	0.549	0.654	0.043	0.029	0.035
Average emission rates by source group used in GRAL **(kg/h)**					
H-1	***2.007***	***2.384***	***0.157***	***0.104***	***0.128***
H-2	***10.186***	***8.026***	***0.906***	***0.602***	***0.650***
H-3	***6.546***	***5.475***	***0.553***	***0.368***	***0.418***

Table G-64 Outlet H, 2037-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.612	0.763	0.049	0.033	0.039
01	0.612	0.763	0.049	0.033	0.039
02	0.612	0.763	0.049	0.033	0.039
03	0.612	0.763	0.049	0.033	0.039
04	0.612	0.763	0.049	0.033	0.039
05	0.612	0.763	0.049	0.033	0.039
06	0.682	0.831	0.054	0.036	0.044
07	3.426	2.736	0.308	0.205	0.219
08	3.565	2.823	0.319	0.212	0.228
09	2.409	1.982	0.209	0.139	0.154
10	2.278	1.887	0.198	0.132	0.145
11	2.278	1.887	0.198	0.132	0.145
12	2.278	1.887	0.198	0.132	0.145
13	2.278	1.887	0.198	0.132	0.145
14	2.278	1.887	0.198	0.132	0.145
15	1.829	1.694	0.162	0.107	0.117
16	1.839	1.699	0.163	0.108	0.117
17	1.856	1.718	0.164	0.109	0.118
18	0.656	0.807	0.052	0.035	0.042
19	0.612	0.763	0.049	0.033	0.039
20	0.612	0.763	0.049	0.033	0.039
21	0.612	0.763	0.049	0.033	0.039
22	0.612	0.763	0.049	0.033	0.039
23	0.612	0.763	0.049	0.033	0.039
Average emission rates by source group used in GRAL **(kg/h)**					
H-1	***2.234***	***2.777***	***0.179***	***0.119***	***0.143***
H-2	***12.584***	***10.006***	***1.128***	***0.750***	***0.803***
H-3	***7.729***	***6.612***	***0.676***	***0.449***	***0.494***

G.3.9 Outlet I (Beaches Link: Gore Hill Freeway)

Table G-65 Outlet I, 2016-BY

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
I-1	**-**	**-**	**-**	**-**	**-**
I-2	**-**	**-**	**-**	**-**	**-**
I-3	**-**	**-**	**-**	**-**	**-**

Table G-66 Outlet I, 2027-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
I-1	**-**	**-**	**-**	**-**	**-**
I-2	**-**	**-**	**-**	**-**	**-**
I-3	**-**	**-**	**-**	**-**	**-**

Table G-67 Outlet I, 2027-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.401	0.520	0.026	0.018	0.027
01	0.401	0.520	0.026	0.018	0.027
02	0.401	0.520	0.026	0.018	0.027
03	0.401	0.520	0.026	0.018	0.027
04	0.401	0.520	0.026	0.018	0.027
05	0.401	0.520	0.026	0.018	0.027
06	0.398	0.517	0.026	0.018	0.027
07	1.681	1.443	0.131	0.091	0.114
08	1.676	1.438	0.130	0.090	0.113
09	1.200	1.077	0.088	0.061	0.081
10	1.208	1.083	0.090	0.062	0.082
11	1.208	1.083	0.090	0.062	0.082
12	1.208	1.083	0.090	0.062	0.082
13	1.208	1.083	0.090	0.062	0.082
14	1.208	1.083	0.090	0.062	0.082
15	1.000	0.938	0.072	0.050	0.068
16	0.999	0.938	0.072	0.049	0.068
17	0.998	0.937	0.071	0.049	0.068
18	0.399	0.519	0.026	0.018	0.027
19	0.401	0.520	0.026	0.018	0.027
20	0.401	0.520	0.026	0.018	0.027
21	0.401	0.520	0.026	0.018	0.027
22	0.401	0.520	0.026	0.018	0.027
23	0.401	0.520	0.026	0.018	0.027
Average emission rates by source group used in GRAL **(kg/h)**					
I-1	***1.444***	***1.871***	***0.094***	***0.065***	***0.098***
I-2	***6.043***	***5.186***	***0.470***	***0.325***	***0.409***
I-3	***4.094***	***3.722***	***0.300***	***0.208***	***0.277***

Table G-68 Outlet I, 2027-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.375	0.484	0.025	0.017	0.025
01	0.375	0.484	0.025	0.017	0.025
02	0.375	0.484	0.025	0.017	0.025
03	0.375	0.484	0.025	0.017	0.025
04	0.375	0.484	0.025	0.017	0.025
05	0.375	0.484	0.025	0.017	0.025
06	0.370	0.480	0.024	0.016	0.025
07	1.492	1.330	0.115	0.080	0.101
08	1.486	1.325	0.114	0.079	0.101
09	1.106	0.984	0.082	0.057	0.075
10	1.124	1.006	0.084	0.058	0.076
11	1.124	1.006	0.084	0.058	0.076
12	1.124	1.006	0.084	0.058	0.076
13	1.124	1.006	0.084	0.058	0.076
14	1.124	1.006	0.084	0.058	0.076
15	0.912	0.859	0.066	0.045	0.062
16	0.911	0.858	0.065	0.045	0.062
17	0.910	0.858	0.065	0.045	0.062
18	0.372	0.482	0.024	0.017	0.025
19	0.375	0.484	0.025	0.017	0.025
20	0.375	0.484	0.025	0.017	0.025
21	0.375	0.484	0.025	0.017	0.025
22	0.375	0.484	0.025	0.017	0.025
23	0.375	0.484	0.025	0.017	0.025
Average emission rates by source group used in GRAL **(kg/h)**					
I-1	***1.348***	***1.740***	***0.088***	***0.061***	***0.091***
I-2	***5.360***	***4.779***	***0.414***	***0.286***	***0.363***
I-3	***3.784***	***3.435***	***0.279***	***0.193***	***0.256***

Table G-69 Outlet I, 2037-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
I-1	-	-	-	-	-
I-2	-	-	-	-	-
I-3	-	-	-	-	-

Table G-70 Outlet I, 2037-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.379	0.517	0.028	0.019	0.024
01	0.379	0.517	0.028	0.019	0.024
02	0.379	0.517	0.028	0.019	0.024
03	0.379	0.517	0.028	0.019	0.024
04	0.379	0.517	0.028	0.019	0.024
05	0.379	0.517	0.028	0.019	0.024
06	0.376	0.515	0.028	0.018	0.024
07	1.805	1.521	0.158	0.105	0.115
08	1.808	1.533	0.157	0.104	0.115
09	1.229	1.126	0.101	0.067	0.078
10	1.234	1.130	0.102	0.068	0.079
11	1.234	1.130	0.102	0.068	0.079
12	1.234	1.130	0.102	0.068	0.079
13	1.234	1.130	0.102	0.068	0.079
14	1.234	1.130	0.102	0.068	0.079
15	0.985	0.930	0.080	0.053	0.063
16	0.985	0.929	0.080	0.053	0.063
17	0.984	0.929	0.080	0.053	0.063
18	0.377	0.516	0.028	0.018	0.024
19	0.379	0.517	0.028	0.019	0.024
20	0.379	0.517	0.028	0.019	0.024
21	0.379	0.517	0.028	0.019	0.024
22	0.379	0.517	0.028	0.019	0.024
23	0.379	0.517	0.028	0.019	0.024
Average emission rates by source group used in GRAL **(kg/h)**					
I-1	***1.362***	***1.861***	***0.101***	***0.067***	***0.087***
I-2	***4.956***	***4.424***	***0.417***	***0.277***	***0.316***
I-3	***3.544***	***3.345***	***0.287***	***0.191***	***0.226***

Table G-71 Outlet I, 2037-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.362	0.497	0.027	0.018	0.023
01	0.362	0.497	0.027	0.018	0.023
02	0.362	0.497	0.027	0.018	0.023
03	0.362	0.497	0.027	0.018	0.023
04	0.362	0.497	0.027	0.018	0.023
05	0.362	0.497	0.027	0.018	0.023
06	0.358	0.494	0.026	0.017	0.023
07	1.493	1.350	0.131	0.087	0.095
08	1.483	1.331	0.130	0.086	0.095
09	1.094	0.984	0.091	0.060	0.070
10	1.102	0.990	0.092	0.061	0.070
11	1.102	0.990	0.092	0.061	0.070
12	1.102	0.990	0.092	0.061	0.070
13	1.102	0.990	0.092	0.061	0.070
14	1.102	0.990	0.092	0.061	0.070
15	0.896	0.872	0.073	0.049	0.057
16	0.895	0.871	0.073	0.049	0.057
17	0.894	0.871	0.073	0.048	0.057
18	0.359	0.495	0.027	0.018	0.023
19	0.362	0.497	0.027	0.018	0.023
20	0.362	0.497	0.027	0.018	0.023
21	0.362	0.497	0.027	0.018	0.023
22	0.362	0.497	0.027	0.018	0.023
23	0.362	0.497	0.027	0.018	0.023
Average emission rates by source group used in GRAL **(kg/h)**					
I-1	***1.301***	***1.789***	***0.097***	***0.064***	***0.083***
I-2	***5.356***	***4.826***	***0.470***	***0.312***	***0.342***
I-3	***3.716***	***3.419***	***0.308***	***0.205***	***0.237***

G.3.10 Outlet J (Beaches Link: Wakehurst Parkway)

Table G-72 Outlet J, 2016-BY

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
J-1	**-**	**-**	**-**	**-**	**-**
J-2	**-**	**-**	**-**	**-**	**-**
J-3	**-**	**-**	**-**	**-**	**-**

Table G-73 Outlet J, 2027-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
J-1	**-**	**-**	**-**	**-**	**-**
J-2	**-**	**-**	**-**	**-**	**-**
J-3	**-**	**-**	**-**	**-**	**-**

Table G-74 Outlet J, 2027-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.629	0.701	0.040	0.028	0.043
01	0.629	0.701	0.040	0.028	0.043
02	0.629	0.701	0.040	0.028	0.043
03	0.629	0.701	0.040	0.028	0.043
04	0.629	0.701	0.040	0.028	0.043
05	0.629	0.701	0.040	0.028	0.043
06	0.629	0.701	0.040	0.028	0.043
07	1.369	1.137	0.088	0.061	0.093
08	1.369	1.137	0.088	0.061	0.093
09	2.091	1.540	0.137	0.094	0.142
10	2.093	1.542	0.137	0.095	0.142
11	2.093	1.542	0.137	0.095	0.142
12	2.093	1.542	0.137	0.095	0.142
13	2.093	1.542	0.137	0.095	0.142
14	2.093	1.542	0.137	0.095	0.142
15	2.650	1.959	0.178	0.123	0.179
16	2.648	1.952	0.177	0.123	0.179
17	2.649	1.947	0.177	0.123	0.179
18	0.612	0.661	0.039	0.027	0.041
19	0.629	0.701	0.040	0.028	0.043
20	0.629	0.701	0.040	0.028	0.043
21	0.629	0.701	0.040	0.028	0.043
22	0.629	0.701	0.040	0.028	0.043
23	0.629	0.701	0.040	0.028	0.043
Average emission rates by source group used in GRAL **(kg/h)**					
J-1	***2.259***	***2.512***	***0.144***	***0.100***	***0.153***
J-2	***6.883***	***5.186***	***0.448***	***0.310***	***0.466***
J-3	***9.537***	***7.030***	***0.639***	***0.441***	***0.645***

Table G-75 Outlet J, 2027-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.641	0.720	0.041	0.028	0.043
01	0.641	0.720	0.041	0.028	0.043
02	0.641	0.720	0.041	0.028	0.043
03	0.641	0.720	0.041	0.028	0.043
04	0.641	0.720	0.041	0.028	0.043
05	0.641	0.720	0.041	0.028	0.043
06	0.641	0.720	0.041	0.028	0.043
07	1.602	1.310	0.104	0.072	0.108
08	1.602	1.310	0.104	0.072	0.108
09	2.174	1.612	0.144	0.099	0.147
10	2.175	1.614	0.144	0.099	0.147
11	2.175	1.614	0.144	0.099	0.147
12	2.175	1.614	0.144	0.099	0.147
13	2.175	1.614	0.144	0.099	0.147
14	2.175	1.614	0.144	0.099	0.147
15	2.714	2.057	0.185	0.128	0.184
16	2.713	2.049	0.185	0.128	0.184
17	2.713	2.044	0.185	0.128	0.184
18	0.631	0.695	0.040	0.028	0.043
19	0.641	0.720	0.041	0.028	0.043
20	0.641	0.720	0.041	0.028	0.043
21	0.641	0.720	0.041	0.028	0.043
22	0.641	0.720	0.041	0.028	0.043
23	0.641	0.720	0.041	0.028	0.043
Average emission rates by source group used in GRAL **(kg/h)**					
J-1	***2.304***	***2.585***	***0.148***	***0.102***	***0.156***
J-2	***7.313***	***5.536***	***0.482***	***0.333***	***0.495***
J-3	***9.768***	***7.380***	***0.667***	***0.461***	***0.661***

Table G-76 Outlet J, 2037-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
J-1	-	-	-	-	-
J-2	-	-	-	-	-
J-3	-	-	-	-	-

Table G-77 Outlet J, 2037-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.599	0.689	0.043	0.029	0.038
01	0.599	0.689	0.043	0.029	0.038
02	0.599	0.689	0.043	0.029	0.038
03	0.599	0.689	0.043	0.029	0.038
04	0.599	0.689	0.043	0.029	0.038
05	0.599	0.689	0.043	0.029	0.038
06	0.599	0.689	0.043	0.029	0.038
07	1.366	1.137	0.097	0.065	0.087
08	1.366	1.137	0.097	0.065	0.087
09	2.040	1.544	0.148	0.098	0.130
10	2.041	1.545	0.148	0.098	0.130
11	2.041	1.545	0.148	0.098	0.130
12	2.041	1.545	0.148	0.098	0.130
13	2.041	1.545	0.148	0.098	0.130
14	2.041	1.545	0.148	0.098	0.130
15	2.670	1.987	0.198	0.132	0.171
16	2.675	1.984	0.198	0.132	0.171
17	2.675	1.968	0.198	0.132	0.171
18	0.596	0.669	0.042	0.028	0.038
19	0.599	0.689	0.043	0.029	0.038
20	0.599	0.689	0.043	0.029	0.038
21	0.599	0.689	0.043	0.029	0.038
22	0.599	0.689	0.043	0.029	0.038
23	0.599	0.689	0.043	0.029	0.038
Average emission rates by source group used in GRAL **(kg/h)**					
J-1	***2.157***	***2.474***	***0.155***	***0.103***	***0.138***
J-2	***6.739***	***5.194***	***0.487***	***0.324***	***0.430***
J-3	***9.624***	***7.127***	***0.713***	***0.474***	***0.615***

Table G-78 Outlet J, 2037-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.620	0.719	0.045	0.030	0.040
01	0.620	0.719	0.045	0.030	0.040
02	0.620	0.719	0.045	0.030	0.040
03	0.620	0.719	0.045	0.030	0.040
04	0.620	0.719	0.045	0.030	0.040
05	0.620	0.719	0.045	0.030	0.040
06	0.620	0.719	0.045	0.030	0.040
07	1.631	1.342	0.119	0.079	0.104
08	1.631	1.342	0.119	0.079	0.104
09	2.185	1.641	0.160	0.106	0.140
10	2.186	1.642	0.160	0.106	0.140
11	2.186	1.642	0.160	0.106	0.140
12	2.186	1.642	0.160	0.106	0.140
13	2.186	1.642	0.160	0.106	0.140
14	2.186	1.642	0.160	0.106	0.140
15	2.807	2.090	0.210	0.140	0.179
16	2.811	2.086	0.210	0.140	0.179
17	2.810	2.070	0.210	0.140	0.179
18	0.617	0.698	0.044	0.030	0.039
19	0.620	0.719	0.045	0.030	0.040
20	0.620	0.719	0.045	0.030	0.040
21	0.620	0.719	0.045	0.030	0.040
22	0.620	0.719	0.045	0.030	0.040
23	0.620	0.719	0.045	0.030	0.040
Average emission rates by source group used in GRAL **(kg/h)**					
J-1	***2.230***	***2.583***	***0.161***	***0.107***	***0.142***
J-2	***7.370***	***5.641***	***0.538***	***0.358***	***0.471***
J-3	***10.113***	***7.495***	***0.756***	***0.503***	***0.646***

G.3.11 Outlet K (Beaches Link: Burnt Bridge Creek Deviation)

Table G-79 Outlet K, 2016-BY

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
K-1	**-**	**-**	**-**	**-**	**-**
K-2	**-**	**-**	**-**	**-**	**-**
K-3	**-**	**-**	**-**	**-**	**-**

Table G-80 Outlet K, 2027-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
K-1	**-**	**-**	**-**	**-**	**-**
K-2	**-**	**-**	**-**	**-**	**-**
K-3	**-**	**-**	**-**	**-**	**-**

Table G-81 Outlet K, 2027-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.619	0.792	0.045	0.031	0.042
01	0.619	0.792	0.045	0.031	0.042
02	0.619	0.792	0.045	0.031	0.042
03	0.619	0.792	0.045	0.031	0.042
04	0.619	0.792	0.045	0.031	0.042
05	0.619	0.792	0.045	0.031	0.042
06	0.619	0.792	0.045	0.031	0.042
07	1.090	1.089	0.082	0.057	0.074
08	1.090	1.089	0.082	0.057	0.074
09	1.520	1.347	0.117	0.081	0.103
10	1.487	1.320	0.115	0.079	0.101
11	1.487	1.320	0.115	0.079	0.101
12	1.487	1.320	0.115	0.079	0.101
13	1.487	1.320	0.115	0.079	0.101
14	1.487	1.320	0.115	0.079	0.101
15	1.786	1.645	0.146	0.101	0.121
16	1.929	1.751	0.157	0.109	0.131
17	2.052	1.835	0.167	0.116	0.139
18	0.894	1.042	0.066	0.045	0.060
19	0.619	0.792	0.045	0.031	0.042
20	0.619	0.792	0.045	0.031	0.042
21	0.619	0.792	0.045	0.031	0.042
22	0.619	0.792	0.045	0.031	0.042
23	0.619	0.792	0.045	0.031	0.042
Average emission rates by source group used in GRAL **(kg/h)**					
K-1	***2.229***	***2.852***	***0.161***	***0.111***	***0.151***
K-2	***4.812***	***4.467***	***0.368***	***0.254***	***0.326***
K-3	***6.921***	***6.277***	***0.564***	***0.390***	***0.468***

Table G-82 Outlet K, 2027-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.635	0.807	0.046	0.032	0.043
01	0.635	0.807	0.046	0.032	0.043
02	0.635	0.807	0.046	0.032	0.043
03	0.635	0.807	0.046	0.032	0.043
04	0.635	0.807	0.046	0.032	0.043
05	0.635	0.807	0.046	0.032	0.043
06	0.635	0.807	0.046	0.032	0.043
07	1.201	1.177	0.092	0.063	0.081
08	1.201	1.177	0.092	0.063	0.081
09	1.594	1.410	0.124	0.086	0.108
10	1.568	1.397	0.122	0.084	0.106
11	1.568	1.397	0.122	0.084	0.106
12	1.568	1.397	0.122	0.084	0.106
13	1.568	1.397	0.122	0.084	0.106
14	1.568	1.397	0.122	0.084	0.106
15	1.926	1.782	0.159	0.110	0.130
16	2.062	1.873	0.170	0.117	0.140
17	2.184	1.957	0.180	0.124	0.148
18	0.909	1.056	0.067	0.047	0.061
19	0.635	0.807	0.046	0.032	0.043
20	0.635	0.807	0.046	0.032	0.043
21	0.635	0.807	0.046	0.032	0.043
22	0.635	0.807	0.046	0.032	0.043
23	0.635	0.807	0.046	0.032	0.043
Average emission rates by source group used in GRAL **(kg/h)**					
K-1	***2.285***	***2.903***	***0.167***	***0.115***	***0.155***
K-2	***5.098***	***4.722***	***0.393***	***0.271***	***0.345***
K-3	***7.408***	***6.734***	***0.610***	***0.422***	***0.501***

Table G-83 Outlet K, 2037-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
Average emission rates by source group used in GRAL **(kg/h)**					
K-1	-	-	-	-	-
K-2	-	-	-	-	-
K-3	-	-	-	-	-

Table G-84 Outlet K, 2037-DS(BL)

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.575	0.773	0.047	0.031	0.037
01	0.575	0.773	0.047	0.031	0.037
02	0.575	0.773	0.047	0.031	0.037
03	0.575	0.773	0.047	0.031	0.037
04	0.575	0.773	0.047	0.031	0.037
05	0.575	0.773	0.047	0.031	0.037
06	0.575	0.773	0.047	0.031	0.037
07	1.054	1.072	0.089	0.059	0.067
08	1.054	1.072	0.089	0.059	0.067
09	1.469	1.347	0.127	0.084	0.094
10	1.438	1.320	0.124	0.082	0.092
11	1.438	1.320	0.124	0.082	0.092
12	1.438	1.320	0.124	0.082	0.092
13	1.438	1.320	0.124	0.082	0.092
14	1.438	1.320	0.124	0.082	0.092
15	1.696	1.599	0.156	0.104	0.108
16	1.826	1.686	0.167	0.111	0.117
17	1.937	1.751	0.177	0.118	0.124
18	0.829	1.002	0.069	0.046	0.053
19	0.575	0.773	0.047	0.031	0.037
20	0.575	0.773	0.047	0.031	0.037
21	0.575	0.773	0.047	0.031	0.037
22	0.575	0.773	0.047	0.031	0.037
23	0.575	0.773	0.047	0.031	0.037
Average emission rates by source group used in GRAL **(kg/h)**					
K-1	***2.069***	***2.782***	***0.170***	***0.113***	***0.132***
K-2	***4.637***	***4.437***	***0.397***	***0.264***	***0.296***
K-3	***6.550***	***6.043***	***0.601***	***0.399***	***0.418***

Table G-85 Outlet K, 2037-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.593	0.802	0.049	0.033	0.038
01	0.593	0.802	0.049	0.033	0.038
02	0.593	0.802	0.049	0.033	0.038
03	0.593	0.802	0.049	0.033	0.038
04	0.593	0.802	0.049	0.033	0.038
05	0.593	0.802	0.049	0.033	0.038
06	0.593	0.802	0.049	0.033	0.038
07	1.162	1.159	0.100	0.067	0.074
08	1.162	1.159	0.100	0.067	0.074
09	1.570	1.418	0.136	0.090	0.100
10	1.539	1.391	0.134	0.089	0.098
11	1.539	1.391	0.134	0.089	0.098
12	1.539	1.391	0.134	0.089	0.098
13	1.539	1.391	0.134	0.089	0.098
14	1.539	1.391	0.134	0.089	0.098
15	1.817	1.688	0.168	0.112	0.116
16	1.947	1.775	0.179	0.119	0.124
17	2.058	1.841	0.189	0.126	0.131
18	0.846	1.032	0.071	0.047	0.054
19	0.593	0.802	0.049	0.033	0.038
20	0.593	0.802	0.049	0.033	0.038
21	0.593	0.802	0.049	0.033	0.038
22	0.593	0.802	0.049	0.033	0.038
23	0.593	0.802	0.049	0.033	0.038
Average emission rates by source group used in GRAL **(kg/h)**					
K-1	***2.136***	***2.887***	***0.178***	***0.118***	***0.136***
K-2	***4.975***	***4.689***	***0.430***	***0.286***	***0.318***
K-3	***6.987***	***6.365***	***0.644***	***0.428***	***0.446***

G.4 In-stack concentrations – expected traffic scenarios

The diurnal profiles for the concentrations of pollutants in each ventilation outlet are presented in the following sections.

G.4.1 Outlet A (Lane Cove Tunnel: Marden Street)

Table G-86 Outlet A, 2016-BY

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.431	0.817	0.013	0.010	0.050
01	0.409	0.617	0.011	0.008	0.047
02	0.386	0.416	0.011	0.008	0.045
03	0.471	0.685	0.018	0.013	0.055
04	1.296	1.631	0.040	0.035	0.150
05	3.546	4.397	0.112	0.100	0.411
06	5.133	6.936	0.169	0.154	0.596
07	5.383	7.789	0.185	0.167	0.601
08	4.609	6.683	0.149	0.136	0.515
09	3.976	5.627	0.122	0.109	0.426
10	3.769	5.114	0.108	0.098	0.404
11	4.136	5.746	0.116	0.104	0.443
12	4.021	5.790	0.110	0.099	0.431
13	3.733	5.634	0.106	0.094	0.400
14	3.596	5.776	0.103	0.092	0.385
15	3.823	6.298	0.107	0.096	0.456
16	3.918	6.960	0.110	0.099	0.467
17	3.500	6.891	0.102	0.093	0.417
18	2.629	5.278	0.081	0.073	0.305
19	1.700	3.407	0.052	0.047	0.197
20	1.442	2.872	0.045	0.038	0.167
21	1.073	2.247	0.032	0.027	0.125
22	0.781	1.695	0.023	0.018	0.091
23	0.583	1.197	0.017	0.014	0.068

Table G-87 Outlet A, 2027-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	2.753	6.402	0.142	0.096	0.256
01	2.609	4.829	0.121	0.080	0.242
02	2.464	3.256	0.125	0.082	0.229
03	3.008	5.365	0.195	0.129	0.279
04	8.272	12.775	0.441	0.338	0.768
05	22.629	34.442	1.221	0.976	2.102
06	32.755	54.327	1.845	1.506	3.043
07	34.508	53.900	1.984	1.591	2.948
08	29.546	46.245	1.599	1.296	2.524
09	26.068	35.260	1.305	1.029	2.027
10	24.712	32.051	1.156	0.919	1.922
11	27.114	36.009	1.242	0.976	2.108
12	26.360	36.282	1.176	0.931	2.050
13	24.473	35.309	1.136	0.889	1.903
14	23.576	36.199	1.106	0.870	1.833
15	25.020	41.848	1.190	0.948	2.230
16	25.639	46.246	1.225	0.979	2.285
17	22.906	45.786	1.132	0.916	2.041
18	16.779	41.336	0.890	0.716	1.559
19	10.847	26.686	0.567	0.456	1.008
20	9.201	22.498	0.487	0.373	0.855
21	6.848	17.599	0.345	0.263	0.636
22	4.983	13.276	0.246	0.180	0.463
23	3.723	9.375	0.190	0.134	0.346

Table G-88 Outlet A, 2027-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	2.854	6.337	0.171	0.114	0.257
01	2.704	4.780	0.146	0.094	0.244
02	2.554	3.223	0.151	0.096	0.230
03	3.118	5.311	0.236	0.152	0.281
04	8.576	12.647	0.532	0.398	0.773
05	23.460	34.096	1.474	1.149	2.115
06	33.958	53.781	2.226	1.773	3.061
07	37.279	49.208	2.460	1.918	2.950
08	31.918	42.220	1.983	1.562	2.526
09	28.397	33.036	1.607	1.232	2.008
10	26.919	30.029	1.423	1.102	1.903
11	29.536	33.738	1.529	1.169	2.088
12	28.715	33.993	1.448	1.115	2.030
13	26.660	33.082	1.399	1.065	1.885
14	25.682	33.916	1.362	1.042	1.816
15	27.049	35.494	1.493	1.152	2.233
16	27.719	39.224	1.537	1.189	2.288
17	24.763	38.834	1.420	1.112	2.044
18	17.396	40.921	1.073	0.843	1.568
19	11.246	26.418	0.684	0.538	1.014
20	9.539	22.272	0.588	0.440	0.860
21	7.100	17.422	0.416	0.310	0.640
22	5.166	13.143	0.297	0.212	0.466
23	3.860	9.280	0.229	0.158	0.348

Table G-89 Outlet A, 2027-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	3.253	6.743	0.160	0.109	0.275
01	3.082	5.086	0.136	0.090	0.260
02	2.911	3.429	0.141	0.092	0.246
03	3.554	5.651	0.220	0.145	0.300
04	9.773	13.456	0.496	0.382	0.826
05	26.736	36.277	1.375	1.101	2.259
06	38.700	57.221	2.077	1.699	3.270
07	39.626	54.949	2.227	1.783	3.163
08	33.928	47.145	1.795	1.452	2.709
09	31.118	37.129	1.485	1.173	2.176
10	29.498	33.750	1.315	1.048	2.063
11	32.366	37.918	1.413	1.113	2.264
12	31.466	38.205	1.338	1.061	2.201
13	29.214	37.181	1.292	1.014	2.043
14	28.143	38.118	1.259	0.992	1.968
15	29.779	42.214	1.358	1.082	2.392
16	30.516	46.651	1.399	1.116	2.451
17	27.263	46.186	1.292	1.044	2.190
18	19.825	43.538	1.002	0.808	1.675
19	12.816	28.108	0.638	0.515	1.083
20	10.871	23.696	0.548	0.421	0.919
21	8.091	18.536	0.388	0.297	0.684
22	5.888	13.983	0.277	0.203	0.498
23	4.399	9.874	0.213	0.151	0.372

Table G-90 Outlet A, 2037-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	2.605	5.960	0.158	0.105	0.241
01	2.468	4.496	0.135	0.087	0.229
02	2.331	3.031	0.140	0.089	0.216
03	2.846	4.995	0.218	0.140	0.264
04	7.826	11.894	0.492	0.369	0.725
05	21.410	32.068	1.365	1.064	1.983
06	30.990	50.582	2.062	1.642	2.870
07	33.681	46.103	2.267	1.766	2.768
08	28.837	39.556	1.827	1.438	2.370
09	25.146	30.980	1.466	1.122	1.886
10	23.838	28.161	1.297	1.003	1.788
11	26.155	31.638	1.394	1.065	1.962
12	25.428	31.878	1.320	1.015	1.907
13	23.608	31.023	1.275	0.970	1.771
14	22.742	31.805	1.242	0.949	1.706
15	24.593	35.238	1.367	1.058	2.093
16	25.201	38.941	1.408	1.092	2.144
17	22.514	38.554	1.300	1.021	1.916
18	15.876	38.486	0.994	0.780	1.470
19	10.263	24.847	0.634	0.498	0.951
20	8.706	20.947	0.544	0.407	0.806
21	6.479	16.385	0.386	0.287	0.600
22	4.715	12.361	0.275	0.196	0.437
23	3.523	8.728	0.212	0.146	0.326

Table G-91 Outlet A, 2037-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	2.854	6.337	0.171	0.114	0.257
01	2.704	4.780	0.146	0.094	0.244
02	2.554	3.223	0.151	0.096	0.230
03	3.118	5.311	0.236	0.152	0.281
04	8.576	12.647	0.532	0.398	0.773
05	23.460	34.096	1.474	1.149	2.115
06	33.958	53.781	2.226	1.773	3.061
07	37.279	49.208	2.460	1.918	2.950
08	31.918	42.220	1.983	1.562	2.526
09	28.397	33.036	1.607	1.232	2.008
10	26.919	30.029	1.423	1.102	1.903
11	29.536	33.738	1.529	1.169	2.088
12	28.715	33.993	1.448	1.115	2.030
13	26.660	33.082	1.399	1.065	1.885
14	25.682	33.916	1.362	1.042	1.816
15	27.049	35.494	1.493	1.152	2.233
16	27.719	39.224	1.537	1.189	2.288
17	24.763	38.834	1.420	1.112	2.044
18	17.396	40.921	1.073	0.843	1.568
19	11.246	26.418	0.684	0.538	1.014
20	9.539	22.272	0.588	0.440	0.860
21	7.100	17.422	0.416	0.310	0.640
22	5.166	13.143	0.297	0.212	0.466
23	3.860	9.280	0.229	0.158	0.348

Table G-92 Outlet A, 2037-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	3.039	6.192	0.175	0.116	0.254
01	2.879	4.671	0.150	0.096	0.241
02	2.719	3.149	0.154	0.099	0.228
03	3.319	5.189	0.241	0.155	0.278
04	9.129	12.357	0.544	0.408	0.764
05	24.975	33.314	1.507	1.177	2.090
06	36.150	52.548	2.277	1.816	3.026
07	39.325	45.785	2.534	1.972	2.919
08	33.670	39.283	2.042	1.606	2.499
09	31.408	29.939	1.698	1.301	1.977
10	29.774	27.214	1.504	1.163	1.874
11	32.668	30.575	1.616	1.234	2.056
12	31.760	30.806	1.530	1.177	1.999
13	29.487	29.980	1.478	1.124	1.856
14	28.406	30.736	1.439	1.100	1.788
15	31.049	33.642	1.584	1.226	2.198
16	31.817	37.178	1.631	1.265	2.252
17	28.425	36.808	1.506	1.184	2.012
18	18.519	39.982	1.098	0.863	1.550
19	11.971	25.812	0.700	0.551	1.002
20	10.155	21.761	0.601	0.450	0.850
21	7.558	17.022	0.426	0.317	0.633
22	5.500	12.841	0.304	0.217	0.460
23	4.109	9.068	0.234	0.162	0.344

G.4.2 Outlet B (Cross City Tunnel: Darling Harbour)

Table G-93 Outlet B, 2016-BY

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.396	4.685	0.039	0.020	0.106
01	1.139	3.381	0.026	0.013	0.086
02	0.805	2.197	0.026	0.012	0.061
03	0.687	1.703	0.028	0.013	0.052
04	0.760	1.479	0.038	0.019	0.057
05	1.379	2.622	0.072	0.043	0.104
06	4.281	10.250	0.168	0.111	0.324
07	6.681	15.990	0.253	0.171	0.505
08	6.868	16.900	0.285	0.180	0.519
09	6.785	16.079	0.266	0.172	0.513
10	6.648	14.697	0.251	0.160	0.503
11	6.637	14.589	0.243	0.149	0.502
12	6.833	15.455	0.243	0.149	0.517
13	6.617	15.355	0.238	0.145	0.500
14	6.588	16.068	0.244	0.152	0.498
15	7.008	18.333	0.258	0.163	0.530
16	6.422	18.639	0.237	0.152	0.486
17	5.916	18.487	0.215	0.141	0.447
18	5.202	17.806	0.189	0.126	0.393
19	3.958	14.151	0.140	0.097	0.299
20	2.709	10.615	0.096	0.067	0.205
21	2.266	9.204	0.079	0.054	0.171
22	2.129	8.195	0.066	0.041	0.161
23	1.851	6.769	0.055	0.029	0.140

Table G-94 Outlet B, 2027-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	2.916	8.554	0.126	0.056	0.168
01	2.379	9.486	0.085	0.037	0.137
02	1.682	6.396	0.082	0.033	0.097
03	1.435	10.540	0.088	0.035	0.083
04	1.587	25.097	0.122	0.053	0.091
05	2.880	0.000	0.231	0.121	0.166
06	8.944	0.000	0.537	0.311	0.515
07	13.958	0.000	0.812	0.479	0.803
08	14.348	0.000	0.914	0.504	0.826
09	14.175	0.000	0.852	0.483	0.816
10	13.889	0.000	0.804	0.447	0.799
11	13.866	0.000	0.779	0.418	0.798
12	14.275	0.000	0.780	0.419	0.822
13	13.824	0.000	0.762	0.407	0.796
14	13.764	0.000	0.781	0.427	0.792
15	14.641	0.000	0.827	0.456	0.843
16	13.416	0.000	0.759	0.425	0.772
17	12.359	0.000	0.688	0.394	0.711
18	10.867	0.000	0.604	0.353	0.625
19	8.269	0.000	0.448	0.271	0.476
20	5.660	44.196	0.306	0.187	0.326
21	4.735	34.572	0.252	0.150	0.272
22	4.447	26.081	0.211	0.114	0.256
23	3.866	18.416	0.175	0.081	0.223

Table G-95 Outlet B, 2027-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	2.922	7.932	0.148	0.063	0.168
01	2.385	5.724	0.099	0.041	0.137
02	1.686	3.719	0.096	0.037	0.097
03	1.439	2.883	0.103	0.040	0.082
04	1.591	2.505	0.143	0.060	0.091
05	2.887	4.439	0.270	0.137	0.166
06	8.965	17.355	0.629	0.352	0.514
07	13.990	27.073	0.951	0.542	0.802
08	14.381	28.614	1.071	0.570	0.824
09	14.208	27.223	0.998	0.547	0.814
10	13.921	24.883	0.941	0.506	0.798
11	13.897	24.700	0.912	0.474	0.797
12	14.307	26.166	0.913	0.474	0.820
13	13.855	25.997	0.892	0.461	0.794
14	13.795	27.204	0.914	0.483	0.791
15	14.675	31.039	0.968	0.517	0.841
16	13.446	31.557	0.889	0.482	0.771
17	12.387	31.299	0.806	0.446	0.710
18	10.892	30.147	0.707	0.400	0.624
19	8.288	23.959	0.524	0.307	0.475
20	5.673	17.973	0.358	0.212	0.325
21	4.745	15.582	0.295	0.170	0.272
22	4.457	13.875	0.248	0.129	0.256
23	3.875	11.460	0.205	0.092	0.222

Table G-96 Outlet B, 2027-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	2.998	8.861	0.130	0.057	0.173
01	2.447	6.394	0.087	0.038	0.141
02	1.730	4.154	0.084	0.034	0.100
03	1.476	3.220	0.091	0.036	0.085
04	1.632	2.798	0.126	0.054	0.094
05	2.962	4.959	0.238	0.125	0.171
06	9.197	19.387	0.553	0.320	0.531
07	14.352	30.244	0.836	0.493	0.828
08	14.754	31.965	0.942	0.519	0.851
09	14.576	30.412	0.878	0.497	0.841
10	14.282	27.798	0.828	0.461	0.824
11	14.258	27.593	0.802	0.431	0.822
12	14.678	29.231	0.803	0.431	0.847
13	14.214	29.042	0.785	0.419	0.820
14	14.152	30.390	0.804	0.440	0.816
15	15.055	34.674	0.852	0.470	0.868
16	13.795	35.252	0.782	0.438	0.796
17	12.708	34.965	0.709	0.406	0.733
18	11.174	33.678	0.622	0.364	0.645
19	8.503	26.765	0.461	0.279	0.490
20	5.820	20.078	0.315	0.193	0.336
21	4.868	17.407	0.259	0.155	0.281
22	4.573	15.500	0.218	0.117	0.264
23	3.975	12.802	0.180	0.083	0.229

Table G-97 Outlet B, 2037-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	2.891	7.886	0.147	0.063	0.167
01	2.359	5.691	0.099	0.041	0.136
02	1.668	3.697	0.095	0.037	0.096
03	1.423	2.866	0.102	0.040	0.082
04	1.573	2.490	0.142	0.059	0.091
05	2.856	4.413	0.268	0.136	0.165
06	8.867	17.254	0.624	0.349	0.512
07	13.838	26.916	0.944	0.538	0.798
08	14.225	28.448	1.063	0.566	0.821
09	14.053	27.065	0.990	0.543	0.811
10	13.770	24.739	0.934	0.503	0.795
11	13.747	24.557	0.905	0.470	0.793
12	14.152	26.014	0.906	0.470	0.817
13	13.705	25.846	0.886	0.457	0.791
14	13.645	27.046	0.907	0.480	0.787
15	14.516	30.859	0.961	0.513	0.838
16	13.301	31.373	0.882	0.478	0.767
17	12.252	31.118	0.800	0.443	0.707
18	10.773	29.972	0.702	0.397	0.622
19	8.198	23.820	0.520	0.304	0.473
20	5.612	17.869	0.356	0.210	0.324
21	4.694	15.492	0.293	0.169	0.271
22	4.409	13.794	0.246	0.128	0.254
23	3.833	11.394	0.203	0.091	0.221

Table G-98 Outlet B, 2037-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	2.922	7.932	0.148	0.063	0.168
01	2.385	5.724	0.099	0.041	0.137
02	1.686	3.719	0.096	0.037	0.097
03	1.439	2.883	0.103	0.040	0.082
04	1.591	2.505	0.143	0.060	0.091
05	2.887	4.439	0.270	0.137	0.166
06	8.965	17.355	0.629	0.352	0.514
07	13.990	27.073	0.951	0.542	0.802
08	14.381	28.614	1.071	0.570	0.824
09	14.208	27.223	0.998	0.547	0.814
10	13.921	24.883	0.941	0.506	0.798
11	13.897	24.700	0.912	0.474	0.797
12	14.307	26.166	0.913	0.474	0.820
13	13.855	25.997	0.892	0.461	0.794
14	13.795	27.204	0.914	0.483	0.791
15	14.675	31.039	0.968	0.517	0.841
16	13.446	31.557	0.889	0.482	0.771
17	12.387	31.299	0.806	0.446	0.710
18	10.892	30.147	0.707	0.400	0.624
19	8.288	23.959	0.524	0.307	0.475
20	5.673	17.973	0.358	0.212	0.325
21	4.745	15.582	0.295	0.170	0.272
22	4.457	13.875	0.248	0.129	0.256
23	3.875	11.460	0.205	0.092	0.222

Table G-99 Outlet B, 2037-DSC

Hour start	NO_X (mg/m^3)	CO (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_{10} (mg/m^3)	THC (mg/m^3)
00	3.014	8.114	0.152	0.081	0.172
01	2.460	5.855	0.102	0.055	0.140
02	1.739	3.804	0.098	0.053	0.099
03	1.484	2.949	0.106	0.057	0.084
04	1.641	2.562	0.147	0.079	0.093
05	2.978	4.541	0.278	0.149	0.169
06	9.246	17.753	0.646	0.346	0.526
07	14.429	27.695	0.977	0.523	0.821
08	14.832	29.271	1.100	0.589	0.844
09	14.654	27.849	1.025	0.549	0.834
10	14.358	25.455	0.967	0.518	0.817
11	14.334	25.268	0.937	0.502	0.816
12	14.757	26.767	0.938	0.503	0.840
13	14.290	26.594	0.917	0.491	0.813
14	14.228	27.828	0.939	0.503	0.810
15	15.136	31.752	0.994	0.533	0.861
16	13.869	32.281	0.913	0.489	0.789
17	12.776	32.018	0.828	0.444	0.727
18	11.234	30.839	0.726	0.389	0.639
19	8.548	24.510	0.538	0.288	0.486
20	5.851	18.386	0.368	0.197	0.333
21	4.894	15.940	0.303	0.162	0.279
22	4.597	14.194	0.254	0.136	0.262
23	3.997	11.723	0.210	0.113	0.227

G.4.3 Outlet C (M4-M5 Link/ICL: Rozelle (mid))

Table G-100 Outlet C, 2016-BY

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-101 Outlet C, 2027-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	1.081	1.613	0.150	0.103	0.065
06	1.715	3.595	0.289	0.198	0.103
07	2.239	4.397	0.385	0.264	0.134
08	2.137	3.833	0.347	0.238	0.128
09	2.074	3.572	0.327	0.224	0.124
10	2.068	3.469	0.319	0.219	0.124
11	2.070	3.425	0.316	0.217	0.124
12	2.091	3.404	0.316	0.216	0.125
13	1.970	3.319	0.303	0.207	0.118
14	1.946	3.529	0.312	0.214	0.117
15	1.763	3.528	0.300	0.205	0.106
16	1.711	3.591	0.302	0.207	0.103
17	1.583	3.032	0.264	0.181	0.095
18	1.510	2.666	0.237	0.163	0.091
19	1.486	2.547	0.228	0.156	0.089
20	1.453	2.489	0.222	0.152	0.087
21	1.373	2.384	0.210	0.144	0.082
22	1.093	1.516	0.148	0.102	0.066
23	-	-	-	-	-

Table G-102 Outlet C, 2027-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	0.737	1.274	0.141	0.092	0.029
06	1.322	2.987	0.306	0.200	0.053
07	1.990	3.972	0.441	0.288	0.080
08	1.883	3.440	0.395	0.258	0.075
09	1.766	3.078	0.359	0.235	0.071
10	1.724	2.927	0.343	0.224	0.069
11	1.711	2.862	0.336	0.220	0.068
12	1.698	2.819	0.332	0.217	0.068
13	1.636	2.778	0.324	0.212	0.065
14	1.718	3.085	0.352	0.230	0.069
15	1.604	3.135	0.345	0.226	0.064
16	1.481	3.164	0.341	0.223	0.059
17	1.317	2.604	0.284	0.186	0.053
18	1.243	2.353	0.258	0.169	0.050
19	1.229	2.239	0.249	0.163	0.049
20	1.241	2.203	0.247	0.161	0.050
21	1.199	2.104	0.236	0.154	0.048
22	0.980	1.417	0.172	0.112	0.039
23	-	-	-	-	-

Table G-103 Outlet C, 2027-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.470	0.835	0.074	0.050	0.028
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	0.421	0.705	0.064	0.044	0.025
05	0.864	1.431	0.131	0.089	0.052
06	2.066	3.650	0.331	0.227	0.124
07	3.449	5.417	0.527	0.361	0.207
08	3.313	5.302	0.515	0.353	0.199
09	2.845	4.527	0.436	0.299	0.171
10	2.635	4.170	0.399	0.274	0.158
11	2.523	4.014	0.381	0.261	0.151
12	2.503	3.960	0.377	0.258	0.150
13	2.409	3.894	0.368	0.252	0.145
14	2.193	3.776	0.352	0.241	0.132
15	2.180	3.915	0.363	0.249	0.131
16	2.281	4.231	0.395	0.270	0.137
17	1.819	3.334	0.308	0.211	0.109
18	1.564	2.752	0.251	0.172	0.094
19	1.442	2.489	0.226	0.155	0.086
20	1.372	2.334	0.213	0.146	0.082
21	1.323	2.246	0.204	0.140	0.079
22	0.891	1.482	0.136	0.093	0.053
23	0.529	0.969	0.085	0.058	0.032

Table G-104 Outlet C, 2037-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	0.737	1.274	0.141	0.092	0.029
06	1.322	2.987	0.306	0.200	0.053
07	1.990	3.972	0.441	0.288	0.080
08	1.883	3.440	0.395	0.258	0.075
09	1.766	3.078	0.359	0.235	0.071
10	1.724	2.927	0.343	0.224	0.069
11	1.711	2.862	0.336	0.220	0.068
12	1.698	2.819	0.332	0.217	0.068
13	1.636	2.778	0.324	0.212	0.065
14	1.718	3.085	0.352	0.230	0.069
15	1.604	3.135	0.345	0.226	0.064
16	1.481	3.164	0.341	0.223	0.059
17	1.317	2.604	0.284	0.186	0.053
18	1.243	2.353	0.258	0.169	0.050
19	1.229	2.239	0.249	0.163	0.049
20	1.241	2.203	0.247	0.161	0.050
21	1.199	2.104	0.236	0.154	0.048
22	0.980	1.417	0.172	0.112	0.039
23	-	-	-	-	-

Table G-105 Outlet C, 2037-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	0.737	1.274	0.141	0.092	0.029
06	1.322	2.987	0.306	0.200	0.053
07	1.990	3.972	0.441	0.288	0.080
08	1.883	3.440	0.395	0.258	0.075
09	1.766	3.078	0.359	0.235	0.071
10	1.724	2.927	0.343	0.224	0.069
11	1.711	2.862	0.336	0.220	0.068
12	1.698	2.819	0.332	0.217	0.068
13	1.636	2.778	0.324	0.212	0.065
14	1.718	3.085	0.352	0.230	0.069
15	1.604	3.135	0.345	0.226	0.064
16	1.481	3.164	0.341	0.223	0.059
17	1.317	2.604	0.284	0.186	0.053
18	1.243	2.353	0.258	0.169	0.050
19	1.229	2.239	0.249	0.163	0.049
20	1.241	2.203	0.247	0.161	0.050
21	1.199	2.104	0.236	0.154	0.048
22	0.980	1.417	0.172	0.112	0.039
23	-	-	-	-	-

Table G-106 Outlet C, 2037-DSC

Hour start	NO_X (mg/m^3)	CO (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_{10} (mg/m^3)	THC (mg/m^3)
00	0.411	0.746	0.083	0.055	0.016
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	0.368	0.630	0.073	0.048	0.015
05	0.000	0.000	0.000	0.000	0.000
06	1.808	3.262	0.376	0.246	0.072
07	0.000	0.000	0.000	0.000	0.000
08	2.900	4.739	0.585	0.382	0.116
09	2.490	4.046	0.495	0.324	0.100
10	2.306	3.727	0.453	0.296	0.092
11	2.208	3.588	0.433	0.283	0.088
12	2.191	3.539	0.428	0.280	0.088
13	2.108	3.480	0.418	0.273	0.084
14	1.919	3.375	0.399	0.261	0.077
15	1.908	3.499	0.412	0.270	0.076
16	1.996	3.782	0.448	0.293	0.080
17	1.592	2.979	0.349	0.228	0.064
18	1.369	2.460	0.285	0.186	0.055
19	1.262	2.224	0.257	0.168	0.050
20	1.201	2.086	0.242	0.158	0.048
21	1.158	2.008	0.232	0.151	0.046
22	0.000	0.000	0.000	0.000	0.000
23	0.463	0.866	0.096	0.063	0.019

G.4.4 Outlet D (M4-M5 Link/ICL: Rozelle (west))

Table G-107 Outlet D, 2016-BY

Hour start	NO_X (mg/m^3)	CO (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_{10} (mg/m^3)	THC (mg/m^3)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-108 Outlet D, 2027-DM

Hour start	NO_X (mg/m^3)	CO (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_{10} (mg/m^3)	THC (mg/m^3)
00	0.561	0.855	0.079	0.054	0.034
01	0.362	0.667	0.056	0.039	0.022
02	0.259	0.518	0.042	0.028	0.016
03	0.260	0.522	0.041	0.028	0.016
04	0.430	0.840	0.067	0.046	0.026
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	0.670	1.093	0.098	0.067	0.040

Table G-109 Outlet D, 2027-DS(BL)

Hour start	NO_X (mg/m^3)	CO (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_{10} (mg/m^3)	THC (mg/m^3)
00	0.405	0.730	0.079	0.052	0.016
01	0.353	0.568	0.002	0.043	0.000
02	0.279	0.451	0.000	0.034	0.000
03	0.319	0.494	0.000	0.038	0.000
04	0.453	0.697	0.000	0.054	0.000
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	0.503	0.880	0.000	0.063	0.000

Table G-110 Outlet D, 2027-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	0.340	0.641	0.000	0.000	0.020
02	0.315	0.576	0.000	0.000	0.019
03	0.309	0.551	0.000	0.000	0.019
04	-	-	-	-	-
05	-	-	-	-	-
06	1.878	3.319	0.488	0.334	0.113
07	3.871	6.080	0.958	0.656	0.232
08	3.013	4.821	0.759	0.520	0.181
09	2.587	4.116	0.643	0.440	0.155
10	2.396	3.792	0.588	0.403	0.144
11	2.294	3.650	0.562	0.385	0.138
12	2.276	3.600	0.555	0.380	0.137
13	2.190	3.540	0.542	0.371	0.131
14	1.994	3.433	0.518	0.355	0.120
15	1.982	3.560	0.535	0.367	0.119
16	2.074	3.847	0.581	0.398	0.124
17	1.654	3.031	0.454	0.311	0.099
18	1.422	2.502	0.369	0.253	0.085
19	1.311	2.263	0.333	0.228	0.079
20	1.248	2.122	0.314	0.215	0.075
21	1.203	2.042	0.301	0.206	0.072
22	-	-	-	-	-
23	-	-	-	-	-

Table G-111 Outlet D, 2037-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.405	0.730	0.079	0.052	0.016
01	0.353	0.568	0.002	0.043	0.000
02	0.279	0.451	0.000	0.034	0.000
03	0.319	0.494	0.000	0.038	0.000
04	0.453	0.697	0.000	0.054	0.000
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	0.503	0.880	0.000	0.063	0.000

Table G-112 Outlet D, 2037-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.405	0.730	0.079	0.052	0.016
01	0.353	0.568	0.002	0.043	0.000
02	0.279	0.451	0.000	0.034	0.000
03	0.319	0.494	0.000	0.038	0.000
04	0.453	0.697	0.000	0.054	0.000
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	0.503	0.880	0.000	0.063	0.000

Table G-113 Outlet D, 2037-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	0.000	0.000	0.000	0.000	0.000
02	0.000	0.000	0.000	0.000	0.000
03	0.000	0.000	0.000	0.000	0.000
04	-	-	-	-	-
05	-	-	-	-	-
06	1.644	2.966	0.342	0.223	0.066
07	0.000	0.000	0.000	0.000	0.000
08	2.636	4.309	0.531	0.347	0.105
09	2.264	3.679	0.450	0.294	0.091
10	2.097	3.389	0.412	0.269	0.084
11	2.007	3.262	0.394	0.257	0.080
12	1.992	3.218	0.389	0.254	0.080
13	1.917	3.164	0.380	0.248	0.077
14	1.745	3.069	0.363	0.237	0.070
15	1.734	3.181	0.375	0.245	0.069
16	1.815	3.438	0.407	0.266	0.073
17	1.448	2.709	0.318	0.208	0.058
18	1.245	2.237	0.259	0.169	0.050
19	1.147	2.022	0.234	0.153	0.046
20	1.092	1.896	0.220	0.144	0.044
21	1.053	1.825	0.211	0.138	0.042
22	-	-	-	-	-
23	-	-	-	-	-

G.4.5 Outlet E (Iron Cove Link: Rozelle)

Table G-114 Outlet E, 2016-BY

Hour start	NO_X (mg/m^3)	CO (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_{10} (mg/m^3)	THC (mg/m^3)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-115 Outlet E, 2027-DM

Hour start	NO_X (mg/m^3)	CO (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_{10} (mg/m^3)	THC (mg/m^3)
00	0.444	1.030	0.055	0.037	0.027
01	0.315	0.710	0.039	0.027	0.019
02	0.254	0.574	0.032	0.022	0.015
03	0.233	0.607	0.031	0.021	0.014
04	0.288	0.905	0.041	0.028	0.017
05	0.398	1.480	0.062	0.042	0.024
06	0.734	2.626	0.120	0.082	0.044
07	0.940	2.855	0.148	0.101	0.056
08	1.007	2.796	0.150	0.102	0.060
09	1.160	2.804	0.161	0.110	0.070
10	1.258	2.830	0.169	0.116	0.075
11	1.327	2.847	0.175	0.120	0.080
12	1.372	2.860	0.179	0.123	0.082
13	1.376	2.879	0.180	0.124	0.083
14	1.376	2.951	0.184	0.126	0.083
15	1.342	3.214	0.193	0.132	0.080
16	1.337	3.599	0.211	0.145	0.080
17	1.208	2.964	0.171	0.117	0.073
18	1.103	2.551	0.145	0.099	0.066
19	1.020	2.331	0.131	0.090	0.061
20	0.935	2.194	0.120	0.082	0.056
21	0.842	2.074	0.109	0.074	0.051
22	0.749	1.892	0.094	0.064	0.045
23	0.387	0.888	0.048	0.033	0.023

Table G-116 Outlet E, 2027-DS(BL)

Hour start	NO_X (mg/m^3)	CO (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_{10} (mg/m^3)	THC (mg/m^3)
00	0.358	0.847	0.058	0.038	0.014
01	0.261	0.587	0.041	0.027	0.010
02	0.216	0.481	0.035	0.023	0.009
03	0.193	0.490	0.033	0.021	0.008
04	0.241	0.743	0.045	0.029	0.010
05	0.324	1.200	0.066	0.043	0.013
06	0.628	2.203	0.137	0.090	0.025
07	0.812	2.342	0.168	0.110	0.032
08	0.851	2.353	0.170	0.111	0.034
09	0.967	2.303	0.176	0.115	0.039
10	1.009	2.287	0.179	0.117	0.040
11	1.039	2.285	0.182	0.119	0.042
12	1.064	2.300	0.186	0.121	0.043
13	1.078	2.325	0.189	0.124	0.043
14	1.089	2.388	0.194	0.127	0.044
15	1.012	2.535	0.195	0.127	0.040
16	1.035	2.831	0.219	0.143	0.041
17	0.910	2.317	0.172	0.113	0.036
18	0.835	2.097	0.150	0.098	0.033
19	0.794	1.958	0.139	0.091	0.032
20	0.750	1.846	0.129	0.084	0.030
21	0.684	1.715	0.117	0.076	0.027
22	0.608	1.488	0.098	0.064	0.024
23	0.335	0.799	0.054	0.035	0.013

Table G-117 Outlet E, 2027-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.441	1.110	0.054	0.037	0.026
01	0.357	0.803	0.045	0.031	0.021
02	0.299	0.677	0.038	0.026	0.018
03	0.292	0.709	0.038	0.026	0.018
04	0.351	1.066	0.049	0.034	0.021
05	0.445	1.612	0.067	0.046	0.027
06	0.766	2.709	0.126	0.086	0.046
07	0.798	2.934	0.132	0.090	0.048
08	1.029	2.908	0.157	0.107	0.062
09	1.298	2.963	0.181	0.124	0.078
10	1.363	2.935	0.185	0.127	0.082
11	1.400	2.935	0.189	0.129	0.084
12	1.423	2.943	0.192	0.131	0.085
13	1.402	2.919	0.191	0.131	0.084
14	1.381	2.938	0.193	0.132	0.083
15	1.221	2.986	0.187	0.128	0.073
16	1.224	3.103	0.196	0.134	0.073
17	1.060	2.778	0.164	0.112	0.064
18	1.051	2.615	0.151	0.103	0.063
19	1.011	2.541	0.141	0.096	0.061
20	0.987	2.507	0.135	0.093	0.059
21	0.927	2.409	0.126	0.086	0.056
22	0.787	2.079	0.102	0.070	0.047
23	0.565	1.365	0.071	0.048	0.034

Table G-118 Outlet E, 2037-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.358	0.847	0.058	0.038	0.014
01	0.261	0.587	0.041	0.027	0.010
02	0.216	0.481	0.035	0.023	0.009
03	0.193	0.490	0.033	0.021	0.008
04	0.241	0.743	0.045	0.029	0.010
05	0.324	1.200	0.066	0.043	0.013
06	0.628	2.203	0.137	0.090	0.025
07	0.812	2.342	0.168	0.110	0.032
08	0.851	2.353	0.170	0.111	0.034
09	0.967	2.303	0.176	0.115	0.039
10	1.009	2.287	0.179	0.117	0.040
11	1.039	2.285	0.182	0.119	0.042
12	1.064	2.300	0.186	0.121	0.043
13	1.078	2.325	0.189	0.124	0.043
14	1.089	2.388	0.194	0.127	0.044
15	1.012	2.535	0.195	0.127	0.040
16	1.035	2.831	0.219	0.143	0.041
17	0.910	2.317	0.172	0.113	0.036
18	0.835	2.097	0.150	0.098	0.033
19	0.794	1.958	0.139	0.091	0.032
20	0.750	1.846	0.129	0.084	0.030
21	0.684	1.715	0.117	0.076	0.027
22	0.608	1.488	0.098	0.064	0.024
23	0.335	0.799	0.054	0.035	0.013

Table G-119 Outlet E, 2037-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.358	0.847	0.058	0.038	0.014
01	0.261	0.587	0.041	0.027	0.010
02	0.216	0.481	0.035	0.023	0.009
03	0.193	0.490	0.033	0.021	0.008
04	0.241	0.743	0.045	0.029	0.010
05	0.324	1.200	0.066	0.043	0.013
06	0.628	2.203	0.137	0.090	0.025
07	0.812	2.342	0.168	0.110	0.032
08	0.851	2.353	0.170	0.111	0.034
09	0.967	2.303	0.176	0.115	0.039
10	1.009	2.287	0.179	0.117	0.040
11	1.039	2.285	0.182	0.119	0.042
12	1.064	2.300	0.186	0.121	0.043
13	1.078	2.325	0.189	0.124	0.043
14	1.089	2.388	0.194	0.127	0.044
15	1.012	2.535	0.195	0.127	0.040
16	1.035	2.831	0.219	0.143	0.041
17	0.910	2.317	0.172	0.113	0.036
18	0.835	2.097	0.150	0.098	0.033
19	0.794	1.958	0.139	0.091	0.032
20	0.750	1.846	0.129	0.084	0.030
21	0.684	1.715	0.117	0.076	0.027
22	0.608	1.488	0.098	0.064	0.024
23	0.335	0.799	0.054	0.035	0.013

Table G-120 Outlet E, 2037-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.352	0.903	0.058	0.038	0.014
01	0.285	0.653	0.047	0.031	0.011
02	0.238	0.551	0.041	0.027	0.010
03	0.233	0.577	0.040	0.026	0.009
04	0.280	0.867	0.052	0.034	0.011
05	0.354	1.312	0.071	0.046	0.014
06	0.610	2.204	0.133	0.087	0.024
07	0.635	2.387	0.140	0.091	0.025
08	0.820	2.366	0.167	0.109	0.033
09	1.034	2.411	0.192	0.125	0.041
10	1.086	2.388	0.197	0.129	0.043
11	1.115	2.388	0.201	0.131	0.045
12	1.133	2.394	0.203	0.133	0.045
13	1.116	2.375	0.203	0.133	0.045
14	1.100	2.390	0.205	0.134	0.044
15	0.973	2.429	0.198	0.130	0.039
16	0.975	2.524	0.208	0.136	0.039
17	0.844	2.260	0.174	0.113	0.034
18	0.837	2.128	0.160	0.104	0.033
19	0.806	2.067	0.149	0.098	0.032
20	0.786	2.040	0.143	0.094	0.031
21	0.738	1.960	0.133	0.087	0.030
22	0.627	1.691	0.109	0.071	0.025
23	0.450	1.111	0.075	0.049	0.018

G.4.6 Outlet F (Western Harbour Tunnel: Rozelle (east))

Table G-121 Outlet F, 2016-BY

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-122 Outlet F, 2027-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-123 Outlet F, 2027-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-124 Outlet F, 2027-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.160	1.803	0.090	0.062	0.079
01	1.160	1.803	0.090	0.062	0.079
02	1.160	1.803	0.090	0.062	0.079
03	1.160	1.803	0.090	0.062	0.079
04	1.160	1.803	0.090	0.062	0.079
05	1.160	1.803	0.090	0.062	0.079
06	1.160	1.803	0.090	0.062	0.079
07	2.662	2.750	0.271	0.187	0.180
08	2.662	2.750	0.271	0.187	0.180
09	2.407	2.537	0.237	0.164	0.163
10	2.407	2.537	0.237	0.164	0.163
11	2.407	2.537	0.237	0.164	0.163
12	2.407	2.537	0.237	0.164	0.163
13	2.407	2.537	0.237	0.164	0.163
14	2.407	2.537	0.237	0.164	0.163
15	2.147	2.393	0.213	0.147	0.145
16	2.147	2.393	0.213	0.147	0.145
17	2.147	2.393	0.213	0.147	0.145
18	1.160	1.803	0.090	0.062	0.079
19	1.160	1.803	0.090	0.062	0.079
20	1.160	1.803	0.090	0.062	0.079
21	1.160	1.803	0.090	0.062	0.079
22	1.160	1.803	0.090	0.062	0.079
23	1.160	1.803	0.090	0.062	0.079

Table G-125 Outlet F, 2037-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-126 Outlet F, 2037-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-127 Outlet F, 2037-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.081	1.792	0.099	0.066	0.069
01	1.081	1.792	0.099	0.066	0.069
02	1.081	1.792	0.099	0.066	0.069
03	1.081	1.792	0.099	0.066	0.069
04	1.081	1.792	0.099	0.066	0.069
05	1.081	1.792	0.099	0.066	0.069
06	1.081	1.792	0.099	0.066	0.069
07	2.764	2.812	0.323	0.215	0.177
08	2.764	2.812	0.323	0.215	0.177
09	2.401	2.523	0.271	0.180	0.153
10	2.401	2.523	0.271	0.180	0.153
11	2.401	2.523	0.271	0.180	0.153
12	2.401	2.523	0.271	0.180	0.153
13	2.401	2.523	0.271	0.180	0.153
14	2.401	2.523	0.271	0.180	0.153
15	2.269	2.470	0.264	0.175	0.145
16	2.269	2.470	0.264	0.175	0.145
17	2.264	2.457	0.264	0.175	0.145
18	1.081	1.792	0.099	0.066	0.069
19	1.081	1.792	0.099	0.066	0.069
20	1.081	1.792	0.099	0.066	0.069
21	1.081	1.792	0.099	0.066	0.069
22	1.081	1.792	0.099	0.066	0.069
23	1.081	1.792	0.099	0.066	0.069

G.4.7 Outlet G (Western Harbour Tunnel: Warringah Freeway)

Table G-128 Outlet G, 2016-BY

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-129 Outlet G, 2027-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-130 Outlet G, 2027-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-131 Outlet G, 2027-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	2.325	2.526	0.144	0.100	0.157
01	2.325	2.526	0.144	0.100	0.157
02	2.325	2.526	0.144	0.100	0.157
03	2.325	2.526	0.144	0.100	0.157
04	2.325	2.526	0.144	0.100	0.157
05	2.325	2.526	0.144	0.100	0.157
06	2.325	2.526	0.144	0.100	0.157
07	5.222	4.272	0.331	0.229	0.353
08	5.222	4.272	0.331	0.229	0.353
09	4.923	4.009	0.312	0.216	0.333
10	4.922	4.009	0.312	0.216	0.333
11	4.922	4.009	0.312	0.216	0.333
12	4.922	4.009	0.312	0.216	0.333
13	4.922	4.009	0.312	0.216	0.333
14	4.922	4.009	0.312	0.216	0.333
15	4.610	4.151	0.304	0.210	0.312
16	4.610	4.152	0.304	0.210	0.312
17	4.610	4.151	0.304	0.210	0.312
18	2.325	2.526	0.144	0.100	0.157
19	2.325	2.526	0.144	0.100	0.157
20	2.325	2.526	0.144	0.100	0.157
21	2.325	2.526	0.144	0.100	0.157
22	2.325	2.526	0.144	0.100	0.157
23	2.325	2.526	0.144	0.100	0.157

Table G-132 Outlet G, 2037-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-133 Outlet G, 2037-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-134 Outlet G, 2037-DSC

Hour start	NO_X (mg/m^3)	CO (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_{10} (mg/m^3)	THC (mg/m^3)
00	2.183	2.458	0.153	0.102	0.139
01	2.183	2.458	0.153	0.102	0.139
02	2.183	2.458	0.153	0.102	0.139
03	2.183	2.458	0.153	0.102	0.139
04	2.183	2.458	0.153	0.102	0.139
05	2.183	2.458	0.153	0.102	0.139
06	2.183	2.458	0.153	0.102	0.139
07	5.609	4.404	0.396	0.263	0.358
08	5.609	4.404	0.396	0.263	0.358
09	4.766	3.827	0.335	0.223	0.304
10	4.766	3.827	0.335	0.223	0.304
11	4.766	3.827	0.335	0.223	0.304
12	4.766	3.827	0.335	0.223	0.304
13	4.766	3.827	0.335	0.223	0.304
14	4.766	3.827	0.335	0.223	0.304
15	4.434	3.889	0.324	0.215	0.283
16	4.434	3.889	0.324	0.216	0.283
17	4.434	3.888	0.324	0.216	0.283
18	2.183	2.458	0.153	0.102	0.139
19	2.183	2.458	0.153	0.102	0.139
20	2.183	2.458	0.153	0.102	0.139
21	2.183	2.458	0.153	0.102	0.139
22	2.183	2.458	0.153	0.102	0.139
23	2.183	2.458	0.153	0.102	0.139

G.4.8 Outlet H (Beaches Link: Warringah Freeway)

Table G-135 Outlet H, 2016-BY

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-136 Outlet H, 2027-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-137 Outlet H, 2027-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.830	2.178	0.143	0.095	0.117
01	1.830	2.178	0.143	0.095	0.117
02	1.830	2.178	0.143	0.095	0.117
03	1.830	2.178	0.143	0.095	0.117
04	1.830	2.178	0.143	0.095	0.117
05	1.830	2.178	0.143	0.095	0.117
06	2.063	2.406	0.161	0.107	0.132
07	4.759	3.769	0.424	0.282	0.304
08	4.997	3.919	0.443	0.295	0.319
09	4.345	3.477	0.365	0.242	0.277
10	4.091	3.313	0.344	0.229	0.261
11	4.091	3.313	0.344	0.229	0.261
12	4.091	3.313	0.344	0.229	0.261
13	4.091	3.313	0.344	0.229	0.261
14	4.091	3.313	0.344	0.229	0.261
15	3.076	2.815	0.263	0.175	0.196
16	3.098	2.825	0.265	0.176	0.198
17	3.120	2.835	0.267	0.177	0.199
18	1.974	2.325	0.154	0.102	0.126
19	1.830	2.178	0.143	0.095	0.117
20	1.830	2.178	0.143	0.095	0.117
21	1.830	2.178	0.143	0.095	0.117
22	1.830	2.178	0.143	0.095	0.117
23	1.830	2.178	0.143	0.095	0.117

Table G-138 Outlet H, 2027-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.794	2.141	0.126	0.087	0.121
01	1.794	2.141	0.126	0.087	0.121
02	1.794	2.141	0.126	0.087	0.121
03	1.794	2.141	0.126	0.087	0.121
04	1.794	2.141	0.126	0.087	0.121
05	1.794	2.141	0.126	0.087	0.121
06	2.019	2.376	0.142	0.098	0.137
07	4.920	3.946	0.399	0.276	0.333
08	5.131	4.076	0.415	0.287	0.347
09	4.279	3.531	0.334	0.231	0.290
10	4.037	3.356	0.316	0.218	0.273
11	4.037	3.356	0.316	0.218	0.273
12	4.037	3.356	0.316	0.218	0.273
13	4.037	3.356	0.316	0.218	0.273
14	4.037	3.356	0.316	0.218	0.273
15	3.248	3.008	0.253	0.175	0.220
16	3.266	3.018	0.255	0.176	0.221
17	3.286	3.025	0.256	0.177	0.222
18	1.922	2.266	0.135	0.093	0.130
19	1.794	2.141	0.126	0.087	0.121
20	1.794	2.141	0.126	0.087	0.121
21	1.794	2.141	0.126	0.087	0.121
22	1.794	2.141	0.126	0.087	0.121
23	1.794	2.141	0.126	0.087	0.121

Table G-139 Outlet H, 2037-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-140 Outlet H, 2037-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.830	2.178	0.143	0.095	0.117
01	1.830	2.178	0.143	0.095	0.117
02	1.830	2.178	0.143	0.095	0.117
03	1.830	2.178	0.143	0.095	0.117
04	1.830	2.178	0.143	0.095	0.117
05	1.830	2.178	0.143	0.095	0.117
06	2.063	2.406	0.161	0.107	0.132
07	4.759	3.769	0.424	0.282	0.304
08	4.997	3.919	0.443	0.295	0.319
09	4.345	3.477	0.365	0.242	0.277
10	4.091	3.313	0.344	0.229	0.261
11	4.091	3.313	0.344	0.229	0.261
12	4.091	3.313	0.344	0.229	0.261
13	4.091	3.313	0.344	0.229	0.261
14	4.091	3.313	0.344	0.229	0.261
15	3.076	2.815	0.263	0.175	0.196
16	3.098	2.825	0.265	0.176	0.198
17	3.120	2.835	0.267	0.177	0.199
18	1.974	2.325	0.154	0.102	0.126
19	1.830	2.178	0.143	0.095	0.117
20	1.830	2.178	0.143	0.095	0.117
21	1.830	2.178	0.143	0.095	0.117
22	1.830	2.178	0.143	0.095	0.117
23	1.830	2.178	0.143	0.095	0.117

Table G-141 Outlet H, 2037-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.700	2.118	0.136	0.090	0.109
01	1.700	2.118	0.136	0.090	0.109
02	1.700	2.118	0.136	0.090	0.109
03	1.700	2.118	0.136	0.090	0.109
04	1.700	2.118	0.136	0.090	0.109
05	1.700	2.118	0.136	0.090	0.109
06	1.895	2.309	0.151	0.100	0.121
07	4.825	3.853	0.433	0.288	0.308
08	5.022	3.976	0.449	0.299	0.321
09	4.153	3.418	0.360	0.239	0.265
10	3.928	3.254	0.342	0.227	0.251
11	3.928	3.254	0.342	0.227	0.251
12	3.928	3.254	0.342	0.227	0.251
13	3.928	3.254	0.342	0.227	0.251
14	3.928	3.254	0.342	0.227	0.251
15	3.153	2.920	0.279	0.185	0.201
16	3.171	2.930	0.280	0.186	0.202
17	3.199	2.962	0.282	0.188	0.204
18	1.821	2.241	0.145	0.097	0.116
19	1.700	2.118	0.136	0.090	0.109
20	1.700	2.118	0.136	0.090	0.109
21	1.700	2.118	0.136	0.090	0.109
22	1.700	2.118	0.136	0.090	0.109
23	1.700	2.118	0.136	0.090	0.109

G.4.9 Outlet I (Beaches Link: Gore Hill Freeway)

Table G-142 Outlet I, 2016-BY

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-143 Outlet I, 2027-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-144 Outlet I, 2027-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.402	1.916	0.104	0.069	0.090
01	1.402	1.916	0.104	0.069	0.090
02	1.402	1.916	0.104	0.069	0.090
03	1.402	1.916	0.104	0.069	0.090
04	1.402	1.916	0.104	0.069	0.090
05	1.402	1.916	0.104	0.069	0.090
06	1.392	1.908	0.102	0.068	0.089
07	4.298	3.621	0.375	0.249	0.274
08	4.305	3.650	0.374	0.249	0.275
09	2.925	2.681	0.241	0.160	0.187
10	2.939	2.690	0.243	0.162	0.188
11	2.939	2.690	0.243	0.162	0.188
12	2.939	2.690	0.243	0.162	0.188
13	2.939	2.690	0.243	0.162	0.188
14	2.939	2.690	0.243	0.162	0.188
15	2.736	2.582	0.222	0.147	0.175
16	2.735	2.581	0.221	0.147	0.175
17	2.733	2.580	0.221	0.147	0.175
18	1.396	1.911	0.103	0.068	0.089
19	1.402	1.916	0.104	0.069	0.090
20	1.402	1.916	0.104	0.069	0.090
21	1.402	1.916	0.104	0.069	0.090
22	1.402	1.916	0.104	0.069	0.090
23	1.402	1.916	0.104	0.069	0.090

Table G-145 Outlet I, 2027-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.501	1.935	0.098	0.068	0.102
01	1.501	1.935	0.098	0.068	0.102
02	1.501	1.935	0.098	0.068	0.102
03	1.501	1.935	0.098	0.068	0.102
04	1.501	1.935	0.098	0.068	0.102
05	1.501	1.935	0.098	0.068	0.102
06	1.481	1.921	0.095	0.066	0.100
07	3.552	3.167	0.275	0.190	0.240
08	3.538	3.155	0.272	0.188	0.239
09	3.072	2.733	0.228	0.157	0.208
10	3.123	2.794	0.233	0.161	0.211
11	3.123	2.794	0.233	0.161	0.211
12	3.123	2.794	0.233	0.161	0.211
13	3.123	2.794	0.233	0.161	0.211
14	3.123	2.794	0.233	0.161	0.211
15	2.533	2.386	0.182	0.126	0.171
16	2.531	2.384	0.182	0.126	0.171
17	2.529	2.383	0.182	0.125	0.171
18	1.489	1.926	0.096	0.067	0.101
19	1.501	1.935	0.098	0.068	0.102
20	1.501	1.935	0.098	0.068	0.102
21	1.501	1.935	0.098	0.068	0.102
22	1.501	1.935	0.098	0.068	0.102
23	1.501	1.935	0.098	0.068	0.102

Table G-146 Outlet I, 2037-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-147 Outlet I, 2037-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.402	1.916	0.104	0.069	0.090
01	1.402	1.916	0.104	0.069	0.090
02	1.402	1.916	0.104	0.069	0.090
03	1.402	1.916	0.104	0.069	0.090
04	1.402	1.916	0.104	0.069	0.090
05	1.402	1.916	0.104	0.069	0.090
06	1.392	1.908	0.102	0.068	0.089
07	4.298	3.621	0.375	0.249	0.274
08	4.305	3.650	0.374	0.249	0.275
09	2.925	2.681	0.241	0.160	0.187
10	2.939	2.690	0.243	0.162	0.188
11	2.939	2.690	0.243	0.162	0.188
12	2.939	2.690	0.243	0.162	0.188
13	2.939	2.690	0.243	0.162	0.188
14	2.939	2.690	0.243	0.162	0.188
15	2.736	2.582	0.222	0.147	0.175
16	2.735	2.581	0.221	0.147	0.175
17	2.733	2.580	0.221	0.147	0.175
18	1.396	1.911	0.103	0.068	0.089
19	1.402	1.916	0.104	0.069	0.090
20	1.402	1.916	0.104	0.069	0.090
21	1.402	1.916	0.104	0.069	0.090
22	1.402	1.916	0.104	0.069	0.090
23	1.402	1.916	0.104	0.069	0.090

Table G-148 Outlet I, 2037-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.391	1.912	0.104	0.069	0.089
01	1.391	1.912	0.104	0.069	0.089
02	1.391	1.912	0.104	0.069	0.089
03	1.391	1.912	0.104	0.069	0.089
04	1.391	1.912	0.104	0.069	0.089
05	1.391	1.912	0.104	0.069	0.089
06	1.378	1.902	0.101	0.067	0.088
07	3.393	3.068	0.298	0.198	0.217
08	3.370	3.025	0.295	0.196	0.215
09	3.039	2.734	0.252	0.167	0.194
10	3.062	2.749	0.256	0.170	0.196
11	3.062	2.749	0.256	0.170	0.196
12	3.062	2.749	0.256	0.170	0.196
13	3.062	2.749	0.256	0.170	0.196
14	3.062	2.749	0.256	0.170	0.196
15	2.490	2.421	0.203	0.135	0.159
16	2.485	2.420	0.203	0.135	0.159
17	2.483	2.418	0.202	0.135	0.159
18	1.383	1.905	0.102	0.068	0.088
19	1.391	1.912	0.104	0.069	0.089
20	1.391	1.912	0.104	0.069	0.089
21	1.391	1.912	0.104	0.069	0.089
22	1.391	1.912	0.104	0.069	0.089
23	1.391	1.912	0.104	0.069	0.089

G.4.10 Outlet J (Beaches Link: Wakehurst Parkway)

Table G-149 Outlet J, 2016-BY

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-150 Outlet J, 2027-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-151 Outlet J, 2027-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.933	2.222	0.139	0.092	0.123
01	1.933	2.222	0.139	0.092	0.123
02	1.933	2.222	0.139	0.092	0.123
03	1.933	2.222	0.139	0.092	0.123
04	1.933	2.222	0.139	0.092	0.123
05	1.933	2.222	0.139	0.092	0.123
06	1.933	2.222	0.139	0.092	0.123
07	2.970	2.472	0.211	0.140	0.190
08	2.970	2.472	0.211	0.140	0.190
09	4.435	3.357	0.321	0.214	0.283
10	4.436	3.359	0.322	0.214	0.283
11	4.436	3.359	0.322	0.214	0.283
12	4.436	3.359	0.322	0.214	0.283
13	4.436	3.359	0.322	0.214	0.283
14	4.436	3.359	0.322	0.214	0.283
15	5.236	3.896	0.388	0.258	0.334
16	5.245	3.890	0.388	0.258	0.335
17	5.245	3.859	0.388	0.258	0.335
18	1.923	2.156	0.137	0.091	0.123
19	1.933	2.222	0.139	0.092	0.123
20	1.933	2.222	0.139	0.092	0.123
21	1.933	2.222	0.139	0.092	0.123
22	1.933	2.222	0.139	0.092	0.123
23	1.933	2.222	0.139	0.092	0.123

Table G-152 Outlet J, 2027-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	2.067	2.323	0.133	0.092	0.140
01	2.067	2.323	0.133	0.092	0.140
02	2.067	2.323	0.133	0.092	0.140
03	2.067	2.323	0.133	0.092	0.140
04	2.067	2.323	0.133	0.092	0.140
05	2.067	2.323	0.133	0.092	0.140
06	2.067	2.323	0.133	0.092	0.140
07	3.559	2.911	0.232	0.160	0.241
08	3.559	2.911	0.232	0.160	0.241
09	4.830	3.582	0.319	0.220	0.327
10	4.833	3.587	0.319	0.221	0.327
11	4.833	3.587	0.319	0.221	0.327
12	4.833	3.587	0.319	0.221	0.327
13	4.833	3.587	0.319	0.221	0.327
14	4.833	3.587	0.319	0.221	0.327
15	5.538	4.198	0.378	0.261	0.375
16	5.537	4.182	0.378	0.261	0.375
17	5.538	4.171	0.378	0.261	0.375
18	2.036	2.240	0.130	0.090	0.138
19	2.067	2.323	0.133	0.092	0.140
20	2.067	2.323	0.133	0.092	0.140
21	2.067	2.323	0.133	0.092	0.140
22	2.067	2.323	0.133	0.092	0.140
23	2.067	2.323	0.133	0.092	0.140

Table G-153 Outlet J, 2037-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-154 Outlet J, 2037-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.933	2.222	0.139	0.092	0.123
01	1.933	2.222	0.139	0.092	0.123
02	1.933	2.222	0.139	0.092	0.123
03	1.933	2.222	0.139	0.092	0.123
04	1.933	2.222	0.139	0.092	0.123
05	1.933	2.222	0.139	0.092	0.123
06	1.933	2.222	0.139	0.092	0.123
07	2.970	2.472	0.211	0.140	0.190
08	2.970	2.472	0.211	0.140	0.190
09	4.435	3.357	0.321	0.214	0.283
10	4.436	3.359	0.322	0.214	0.283
11	4.436	3.359	0.322	0.214	0.283
12	4.436	3.359	0.322	0.214	0.283
13	4.436	3.359	0.322	0.214	0.283
14	4.436	3.359	0.322	0.214	0.283
15	5.236	3.896	0.388	0.258	0.334
16	5.245	3.890	0.388	0.258	0.335
17	5.245	3.859	0.388	0.258	0.335
18	1.923	2.156	0.137	0.091	0.123
19	1.933	2.222	0.139	0.092	0.123
20	1.933	2.222	0.139	0.092	0.123
21	1.933	2.222	0.139	0.092	0.123
22	1.933	2.222	0.139	0.092	0.123
23	1.933	2.222	0.139	0.092	0.123

Table G-155 Outlet J, 2037-DSC

Hour start	NO_X (mg/m^3)	CO (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_{10} (mg/m^3)	THC (mg/m^3)
00	1.936	2.247	0.140	0.093	0.124
01	1.936	2.247	0.140	0.093	0.124
02	1.936	2.247	0.140	0.093	0.124
03	1.936	2.247	0.140	0.093	0.124
04	1.936	2.247	0.140	0.093	0.124
05	1.936	2.247	0.140	0.093	0.124
06	1.936	2.247	0.140	0.093	0.124
07	3.471	2.855	0.253	0.168	0.222
08	3.471	2.855	0.253	0.168	0.222
09	4.649	3.491	0.340	0.226	0.297
10	4.651	3.494	0.340	0.226	0.297
11	4.651	3.494	0.340	0.226	0.297
12	4.651	3.494	0.340	0.226	0.297
13	4.651	3.494	0.340	0.226	0.297
14	4.651	3.494	0.340	0.226	0.297
15	5.397	4.019	0.404	0.269	0.345
16	5.406	4.012	0.404	0.269	0.345
17	5.404	3.981	0.404	0.269	0.345
18	1.930	2.183	0.139	0.092	0.123
19	1.936	2.247	0.140	0.093	0.124
20	1.936	2.247	0.140	0.093	0.124
21	1.936	2.247	0.140	0.093	0.124
22	1.936	2.247	0.140	0.093	0.124
23	1.936	2.247	0.140	0.093	0.124

G.4.11 Outlet K (Beaches Link: Burnt Bridge Creek Deviation)

Table G-156 Outlet K, 2016-BY

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-157 Outlet K, 2027-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-158 Outlet K, 2027-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.513	2.034	0.125	0.083	0.097
01	1.513	2.034	0.125	0.083	0.097
02	1.513	2.034	0.125	0.083	0.097
03	1.513	2.034	0.125	0.083	0.097
04	1.513	2.034	0.125	0.083	0.097
05	1.513	2.034	0.125	0.083	0.097
06	1.513	2.034	0.125	0.083	0.097
07	2.195	2.233	0.185	0.123	0.140
08	2.195	2.233	0.185	0.123	0.140
09	3.060	2.806	0.264	0.175	0.195
10	2.995	2.750	0.259	0.172	0.191
11	2.995	2.750	0.259	0.172	0.191
12	2.995	2.750	0.259	0.172	0.191
13	2.995	2.750	0.259	0.172	0.191
14	2.995	2.750	0.259	0.172	0.191
15	3.029	2.855	0.279	0.185	0.193
16	3.260	3.011	0.299	0.199	0.208
17	3.458	3.127	0.317	0.210	0.221
18	1.727	2.088	0.143	0.095	0.110
19	1.513	2.034	0.125	0.083	0.097
20	1.513	2.034	0.125	0.083	0.097
21	1.513	2.034	0.125	0.083	0.097
22	1.513	2.034	0.125	0.083	0.097
23	1.513	2.034	0.125	0.083	0.097

Table G-159 Outlet K, 2027-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.670	2.122	0.122	0.084	0.113
01	1.670	2.122	0.122	0.084	0.113
02	1.670	2.122	0.122	0.084	0.113
03	1.670	2.122	0.122	0.084	0.113
04	1.670	2.122	0.122	0.084	0.113
05	1.670	2.122	0.122	0.084	0.113
06	1.670	2.122	0.122	0.084	0.113
07	2.502	2.452	0.191	0.132	0.169
08	2.502	2.452	0.191	0.132	0.169
09	3.321	2.938	0.258	0.178	0.225
10	3.266	2.910	0.253	0.175	0.221
11	3.266	2.910	0.253	0.175	0.221
12	3.266	2.910	0.253	0.175	0.221
13	3.266	2.910	0.253	0.175	0.221
14	3.266	2.910	0.253	0.175	0.221
15	3.502	3.240	0.288	0.199	0.237
16	3.750	3.405	0.309	0.213	0.254
17	3.972	3.558	0.327	0.226	0.269
18	1.893	2.200	0.140	0.097	0.128
19	1.670	2.122	0.122	0.084	0.113
20	1.670	2.122	0.122	0.084	0.113
21	1.670	2.122	0.122	0.084	0.113
22	1.670	2.122	0.122	0.084	0.113
23	1.670	2.122	0.122	0.084	0.113

Table G-160 Outlet K, 2037-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table G-161 Outlet K, 2037-DS(BL)

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.513	2.034	0.125	0.083	0.097
01	1.513	2.034	0.125	0.083	0.097
02	1.513	2.034	0.125	0.083	0.097
03	1.513	2.034	0.125	0.083	0.097
04	1.513	2.034	0.125	0.083	0.097
05	1.513	2.034	0.125	0.083	0.097
06	1.513	2.034	0.125	0.083	0.097
07	2.195	2.233	0.185	0.123	0.140
08	2.195	2.233	0.185	0.123	0.140
09	3.060	2.806	0.264	0.175	0.195
10	2.995	2.750	0.259	0.172	0.191
11	2.995	2.750	0.259	0.172	0.191
12	2.995	2.750	0.259	0.172	0.191
13	2.995	2.750	0.259	0.172	0.191
14	2.995	2.750	0.259	0.172	0.191
15	3.029	2.855	0.279	0.185	0.193
16	3.260	3.011	0.299	0.199	0.208
17	3.458	3.127	0.317	0.210	0.221
18	1.727	2.088	0.143	0.095	0.110
19	1.513	2.034	0.125	0.083	0.097
20	1.513	2.034	0.125	0.083	0.097
21	1.513	2.034	0.125	0.083	0.097
22	1.513	2.034	0.125	0.083	0.097
23	1.513	2.034	0.125	0.083	0.097

Table G-162 Outlet K, 2037-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.521	2.056	0.127	0.084	0.097
01	1.521	2.056	0.127	0.084	0.097
02	1.521	2.056	0.127	0.084	0.097
03	1.521	2.056	0.127	0.084	0.097
04	1.521	2.056	0.127	0.084	0.097
05	1.521	2.056	0.127	0.084	0.097
06	1.521	2.056	0.127	0.084	0.097
07	2.372	2.365	0.205	0.136	0.151
08	2.372	2.365	0.205	0.136	0.151
09	3.205	2.894	0.278	0.185	0.205
10	3.141	2.839	0.272	0.181	0.201
11	3.141	2.839	0.272	0.181	0.201
12	3.141	2.839	0.272	0.181	0.201
13	3.141	2.839	0.272	0.181	0.201
14	3.141	2.839	0.272	0.181	0.201
15	3.245	3.014	0.300	0.199	0.207
16	3.477	3.170	0.320	0.213	0.222
17	3.675	3.288	0.338	0.225	0.235
18	1.727	2.106	0.144	0.096	0.110
19	1.521	2.056	0.127	0.084	0.097
20	1.521	2.056	0.127	0.084	0.097
21	1.521	2.056	0.127	0.084	0.097
22	1.521	2.056	0.127	0.084	0.097
23	1.521	2.056	0.127	0.084	0.097

G.5 Parameters for regulatory worst case scenario

Table G-163 Ventilation outlet assumptions for regulatory worst case (RWC-2037-DSC scenario)

Ventilation outlet	Air flow (m^3/s)	CSA (m^2)	Effective outlet diameter (m)	Exit velocity (m/s)	Temp. (^0C)	Emission rate (kg/hour)				
						PM_{10}	$PM_{2.5}$	NO_X	CO	VOC/THC
Exiting and other outlets										
A (Lane Cove Tunnel: Marden St)	470	60	8.74	7.8	25.0	1.860	1.860	33.826	67.651	6.765
B (Cross City Tunnel: Darling Harbour)	222	29.7	6.15	7.5	25.0	0.879	0.879	15.974	31.948	3.195
C (M4-M5 Link/ICL: Rozelle (mid))	1,000	177	15.00	5.7	25.0	3.960	3.960	72.009	144.018	14.402
D (M4-M5 Link/ICL: Rozelle (west))	700	113	12.00	6.2	25.0	2.772	2.772	50.406	100.813	10.081
E (ICL: Rozelle)	470	38.5	7.00	12.2	25.0	1.862	1.862	33.846	67.692	6.769
Project outlets										
F (Western Harbour Tunnel: Rozelle (east))	1,050	154.0	14.00	6.8	25.0	4.159	4.159	75.620	151.240	15.124
G (Western Harbour Tunnel: Warringah Freeway)	920	108	11.73	8.5	25.0	3.644	3.644	66.252	132.503	13.250
H (Beaches Link: Warringah Freeway)	710	86	10.46	8.3	25.0	2.813	2.813	51.146	102.292	10.229
I (Beaches Link: Gore Hill Freeway)	440	36	6.77	12.2	25.0	1.742	1.742	31.674	63.348	6.335
J (Beaches Link: Wakehurst Parkway)	520	45	7.57	11.6	25.0	2.060	2.060	37.454	74.909	7.491
K (Beaches Link: Burnt Bridge Creek Deviation)	560	48	7.82	11.7	25.0	2.218	2.218	40.332	80.663	8.066

Annexure H Dispersion model evaluation

H.1 GRAL optimisation study

Pacific Environment (2017b) examined the performance of the GRAMM-GRAL system in an urban area of Sydney. The main objectives of the study were to assess the performance of GRAMM (version: July 2016) and GRAL (version: August 2016) against meteorological measurements and air quality measurements respectively. GRAMM and GRAL were also compared against other models that are commonly used in Australia: CALMET version 6.334 for meteorology, and CAL3QHCR version 2.0 for dispersion. The study provided recommendations regarding the configuration and application of GRAMM and GRAL to the assessment urban road networks/projects in Australia.

The study area was located near Parramatta Road in Western Sydney, where the terrain was relatively flat and there were few large buildings. The dispersion modelling part of the study involved the analysis of monitoring data and model predictions for an overall period of four months (November 2016 to February 2017). Measurements from both roadside and background continuous monitoring stations, as well as multiple passive sampling locations, were used in the assessment. The evaluation of GRAL and CAL3QHCR focussed on the dispersion of oxides of nitrogen (NO_X) from surface roads.

The study took advantage of the two existing air pollution monitoring stations that were established for the WestConnex M4 East project:

- Concord Oval (roadside), adjacent to Parramatta Road. The average weekday traffic volume on Parramatta Road near this location was around 80,000 vehicles per day.
- St Lukes Park (background), around 180 metres from the nearest heavily trafficked road (Gipps Street, with around 26,000 vehicles per day). The station was approximately 450 metres to the north-east of the Concord Oval station.

The continuous monitoring data were analysed as 1-hour averages.

Ogawa passive samplers were used to measure fortnightly-average NO_X and NO_2 concentrations simultaneously at 17 locations, including co-location with the continuous analysers for calibration. The Ogawa samplers were deployed over two periods (i.e. two rounds of sampling). A third round of sampling was included at Concord Oval and St Lukes Park only, the reason for this being to increase the number of data points available for sampler calibration.

All the main roads in the dispersion model domain were included in the models. Traffic volumes by lane and by hour at specific junctions, and for the whole dispersion model evaluation period, were obtained from the Sydney Coordinated Adaptive Traffic System (SCATS). Traffic surveys were also carried out at seven locations (four video camera sites and three automatic tube count sites) to obtain additional data on traffic composition. Average traffic speeds between specific node points on the network were estimated using the Google Maps Distance Matrix application programming interface (API).

The study showed that the combination of GRAMM and GRAL is capable of giving good average predictions which reflect the spatial distribution of concentrations near roads with reasonable accuracy. The model chain gives results that are at least as good as those produced by other models that are currently in use in Australia. For example, Figure H-1 compares the performance of GRAL and CAL3QHCR with respect to the prediction of two-week average NO_X concentrations at the passive sampling locations. The slight overestimation of GRAM is desirable in an air quality assessment context. As with all air pollution models, the prediction of short-term (1-hour) concentrations remains a challenge. This is not surprising given the complexity of the processes involved.

Another challenge for the study was the treatment of short-term average NO_2 concentrations. This was because of the need to simulate several complex processes, including adequate representation of background concentrations, quantification of primary NO_2 (which is especially uncertain), and the short-term chemical formation of NO_2 through its reaction with ozone. The latter point was particularly important for this study; the time scales for atmospheric mixing and chemical reactions are very similar, which makes this task difficult.

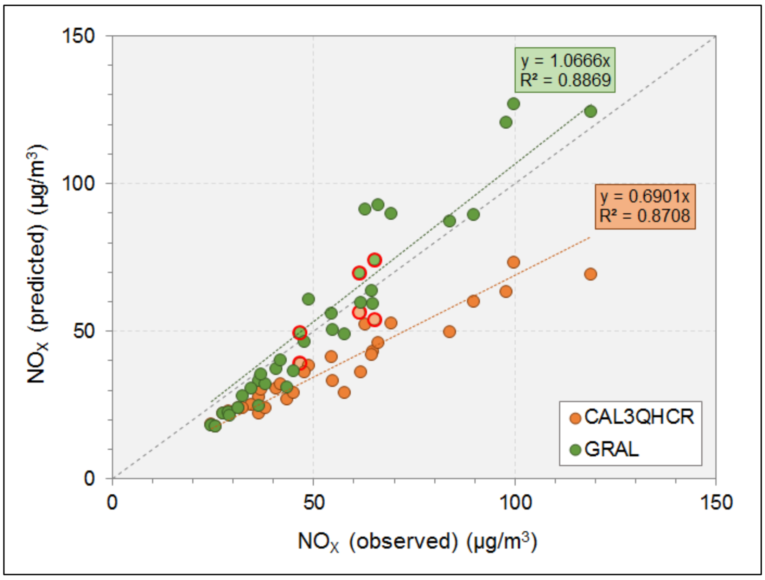


Figure H-1 Model evaluation at passive sampling locations (red circles show Concord Oval) (Pacific Environment, 2017b)

H.2 Evaluation for WestConnex projects

The performance of the GRAMM-GRAL system was also evaluated in the air quality assessments for the WestConnex M4 East, New M5 (now WestConnex M8) and M4-M5 Link projects. The most comprehensive of these evaluations was reported for the M4-M5 Link air quality assessment (Pacific Environment, 2017). The evaluation involved comparing the predicted and measured concentrations at multiple air quality monitoring stations in 2015. The monitoring stations considered in the evaluation included a mixture of background and near-road sites.

The emphasis was on NO_X and NO_2, as the road traffic increment for CO and PM_{10} tends to be small relative to the background. $PM_{2.5}$ was not assessed as there were insufficient measurements to provide a detailed characterisation of background concentrations.

In order to cover different characteristics of the data, three statistical metrics were used: the annual mean concentration, the maximum short-term concentration (one hour or 24-hour, depending on the pollutant), and the 98th percentile[1] short-term concentration.

The results can be summarised as follows:

- For annual mean concentrations of all pollutants, there was, broadly speaking, a reasonably good agreement between the measured concentrations and those predicted by GRAL. An example of the results is shown in Figure H-2. However, there was a general overestimation of concentrations, and this was attributed to GRAL itself
- Maximum and 98th percentile concentrations are inherently difficult to predict, and there was a clear tendency towards the overestimation of these
- A more detailed temporal assessment of NO_X revealed a pronounced overestimation of concentrations at night-time and during peak traffic periods, although the seasonal variation in concentrations was, on average, well reproduced
- For annual mean and maximum 1-hour NO_2 the model with empirical NO_X-to-NO_2 conversion methods gave more realistic predictions than the ozone limiting method.

[1] The selection of the 98th percentile was arbitrary. The intention of using this statistic was to provide an indication of the performance of GRAL at high concentrations, but with the most extreme values excluded.

Overall, the results supported the application of GRAL in the assessment, along with the empirical conversion methods for NO_2, noting that the results tend to be quite conservative. The results suggested that the estimated concentrations ought to be conservative for most of the modelling domain.

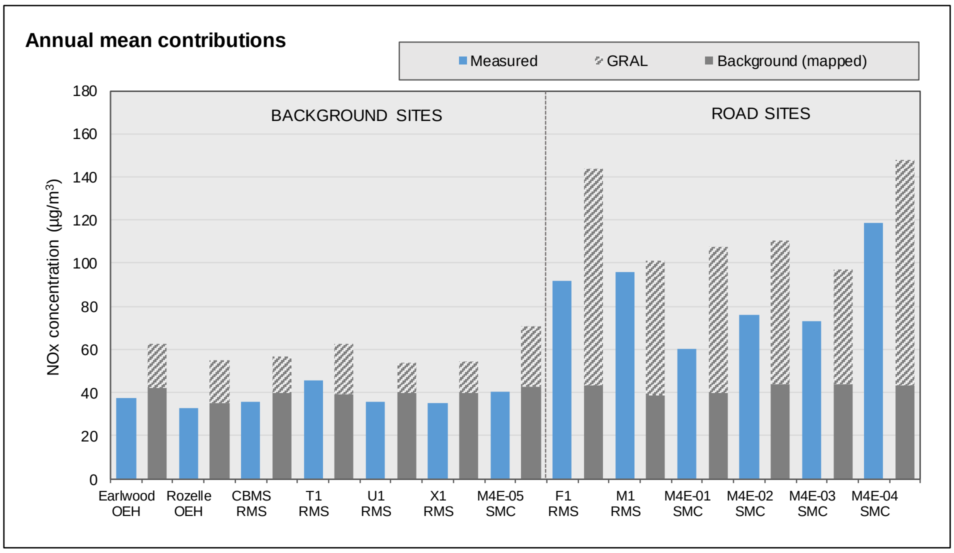


Figure H-2 **Comparison between measured and predicted annual mean NO_X concentrations (Pacific Environment, 2017)**

H.3 Project-specific evaluation

H.3.1 Approach

A similar model evaluation approach to that conducted for the WestConnex projects was also conducted for the Beaches Link project, based on the monitoring data and model predictions for the 2016 base year. The characteristics of the monitoring stations inside the GRAL domain are summarised in Table H-1, and for those located near roads the two-way traffic volumes are also given. The monitoring data available for model evaluation were quite limited. Only five stations were located inside the GRAL domain, and of these only one background station had full data for 2016. One roadside site had data for April-December 2016. These two stations were therefore the only ones used in the evaluation. The performance of GRAL was not investigated at the project-specific monitoring stations as no data from these were available for 2016.

Table H-1 Characteristics of monitoring stations in the GRAL domain

Station code	Organisation (project)	Station name	Location	Station type	Nearest busy road(s) (road sites only)			Monitoring data for 2016
					Road(s)	Distance to kerb (m)	Traffic vol. (approx. vpd)	
M01	DPIE (-)	Rozelle	Rozelle Hospital, Rozelle	Background	-	-	-	Jan-Dec
M05	WestConnex (M4-M5 Link)	M4-M5:01	City West Link, Rozelle	Peak (road)	City West Link	5	~60,000	Apr-Dec
M02	Transport for NSW (Western Harbour Tunnel and Beaches Link)	WHTBL:01	Reserve Street, Bantry Bay	Background	-	-	-	None[(a)]
M03		WHTBL:02	Hope Street, Seaforth	Peak (road)	Manly Road	35	~65,000	None[(a)]
M04		WHTBL:03	Rhodes Avenue, Naremburn	Peak (road)	Gore Hill Freeway	22	~100,000	None[(a)]

(a) Monitoring commenced in October 2017.

GRAL was configured to predict hourly concentrations of NO_X, NO_2, CO and PM_{10} at the two stations. For PM_{10}, daily average concentrations were also calculated, and these are presented here.

A number of different approaches were used to account for the background contribution to the predicted concentrations, and to compare the effects of different assumptions:

- For annual mean NO_X and PM_{10}, a background concentration map was used (see Annexure D).
- For short-term metrics the contemporaneous method was used, based on both 'average' and 'maximum' synthetic background profiles. The average synthetic background profiles were constructed in a similar way to those described in Annexure D, but to enable a more direct comparison with the monitoring data, they were calculated using an average value for each hour of the year across several monitoring stations rather than the maximum value used in the assessment (where an element of conservatism was required for short-term concentrations).
- NO_2 was calculated using the empirical methods described in Annexure E. The ozone limiting method (OLM, see Annexure E) was also applied for comparison, as this is widely used in NSW.

In the following sections, the results of the evaluation are presented by pollutant.

H.3.2 Results for NOx

Figure H-3 and Figure H-4 show examples of the modelled 1-hour mean NO_X concentrations for the background station (Rozelle) and the roadside station (M4-M5:01, alongside the City West Link), along with the measured NO_X concentrations at these stations. The modelled concentration includes both the background contribution and the GRAL prediction. At the road station there was a much larger modelled contribution from GRAL.

In Figure H-5 the measured and predicted NO_X concentrations are compared for each of the monitoring stations. The mapped background concentration (as an annual mean) was only used in conjunction with the mean GRAL prediction. It should be noted that, for the roadside site, monitoring data were only available from April to December of 2016, whereas the mapped background was for the full year. Figure H-6 shows the background concentrations and GRAL contributions separately for mean NO_X.

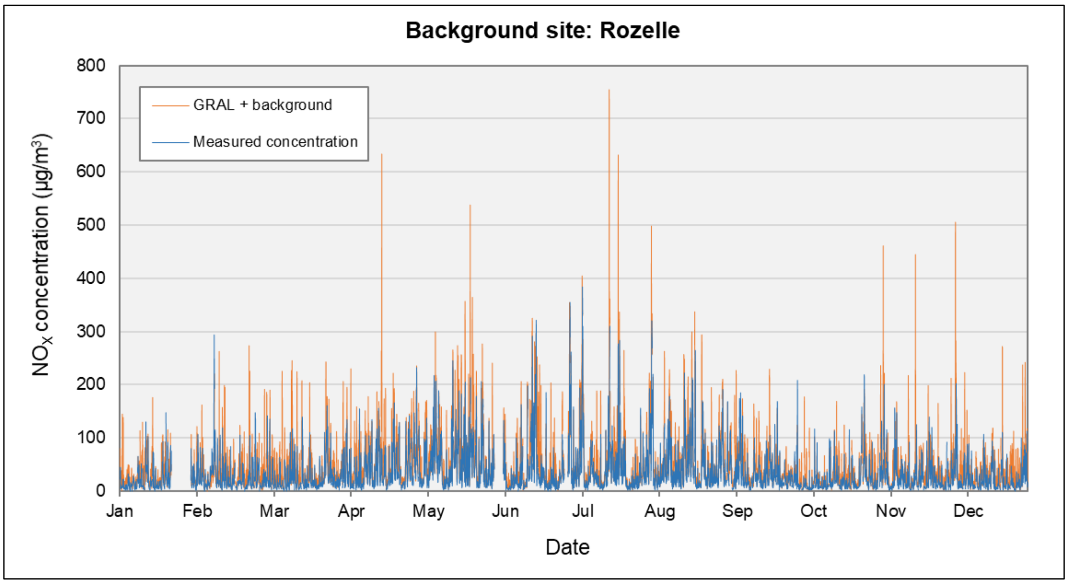


Figure H-3 **Measured 1-hour mean NO_X concentrations and GRAL predictions (including background) for the DPIE Rozelle background monitoring station**

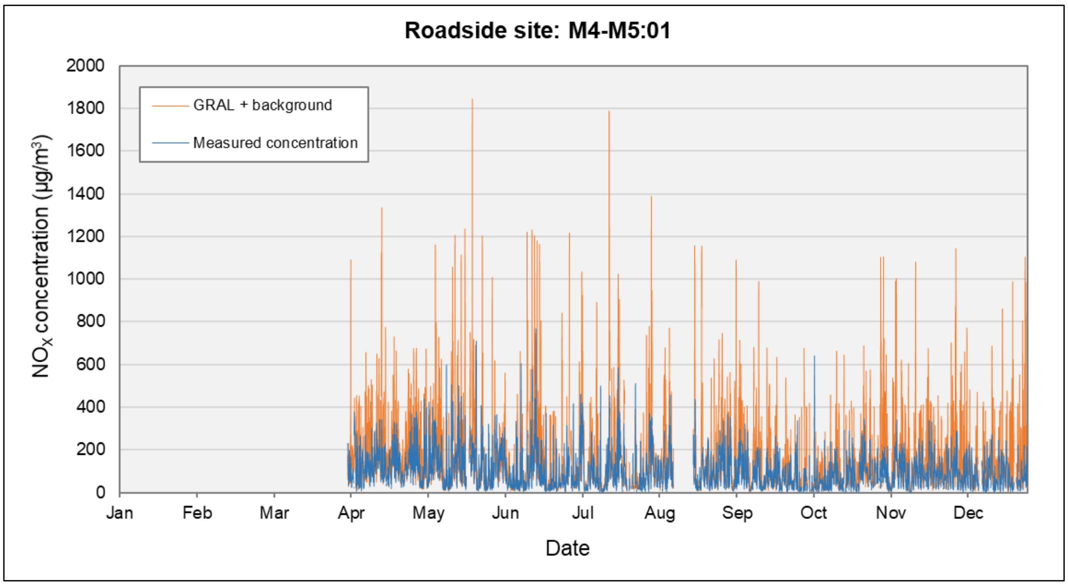
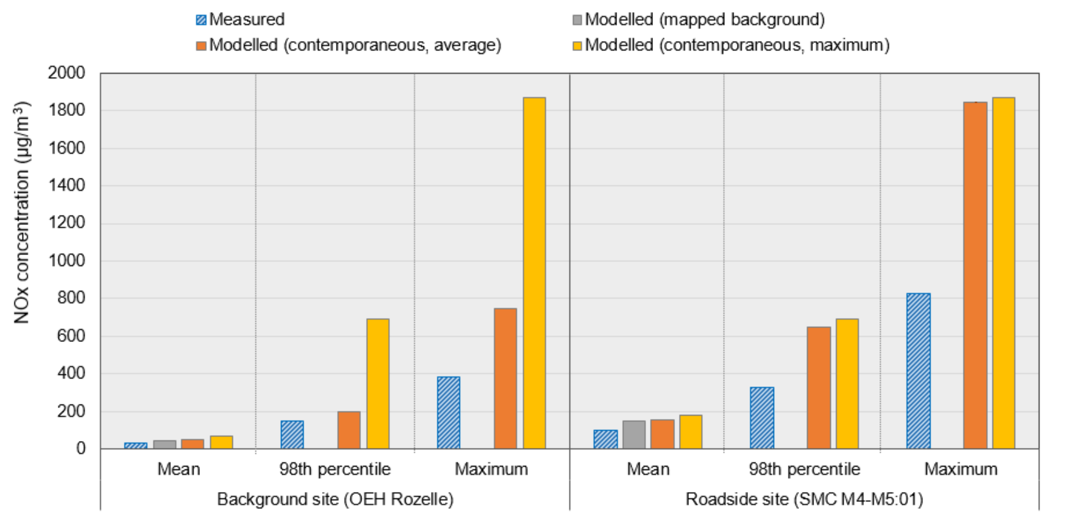


Figure H-4 **Measured 1-hour mean NO_X concentrations and GRAL predictions (including background) for the M4-M5:01 (City West Link) monitoring station**



Site type	Metric (based on 1-hour measurements)	Measured concentration (µg/m³)	Predicted concentration (µg/m³)			Predicted/measured		
			GRAL + mapped background	GRAL + contemporaneous background		GRAL + mapped background	GRAL + contemporaneous background	
				'Average' approach	'Maximum' approach		'Average' approach	'Maximum' approach
Background site (OEH Rozelle)	Mean	33.2	47.5	48.0	70.1	1.4	1.4	2.1
	98th percentile	151.9	-	201.8	693.5	-	1.3	4.6
	Maximum	383.8	-	750.5	1871.7	-	2.0	4.9
Roadside site (SMC M4-M5:01)	Mean	100.0	151.7	157.0	180.5	1.5	1.6	1.8
	98th percentile	329.6	-	650.1	693.5	-	2.0	2.1
	Maximum	829.5	-	1844.7	1871.7	-	2.2	2.3

Figure H-5 **Comparison between measured and predicted total NO_X concentrations**

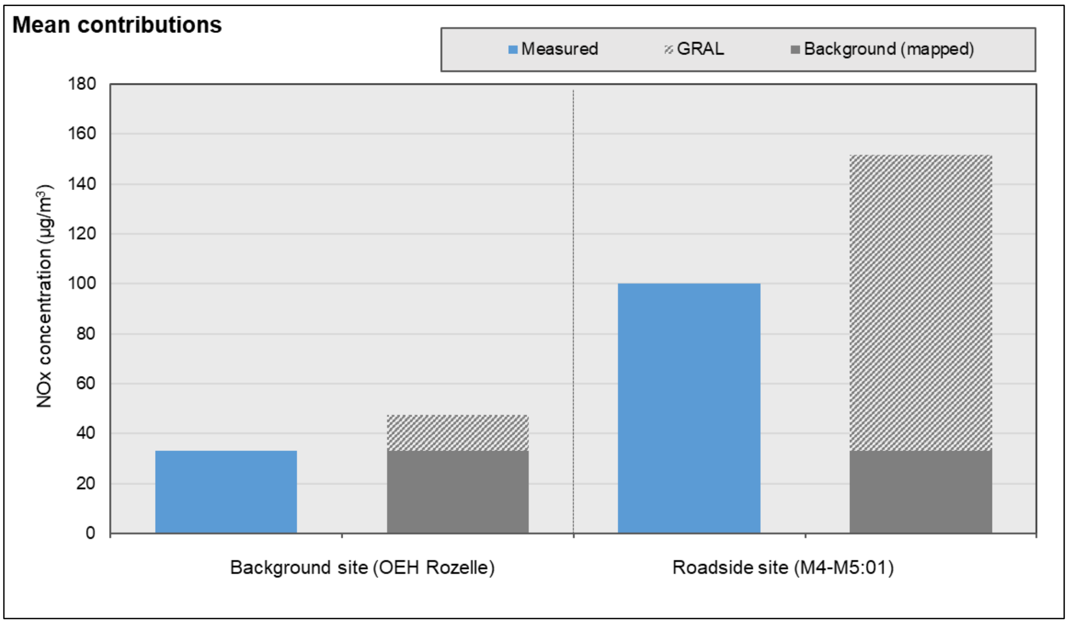


Figure H-6 Contributions to modelled mean NO_X concentrations

Based on the mapped background, mean NO_X concentrations were overestimated at both the background and roadside sites.

For the purpose of the air quality assessment it was assumed that the background stations were not influenced by road transport sources, and therefore in principle the concentrations predicted by GRAL at these stations should have been zero. In practice, dispersion models will often give non-zero values at background stations, and this was also the case here. This overestimation of mean NO_X at the background site was around 14 µg/m^3, or 40 per cent, based on the mapped background. At the background stations the bulk of the overestimation was due to GRAL. Using the 'average' synthetic profile the 98th percentile concentration at the background site was overestimated by around 30 per cent. However, using the 'maximum' synthetic profile the overestimation of the 98th percentile was much larger (a factor of 4.6). This was because the maximum concentrations in the synthetic background profile for NO_X were much higher than the measurements at Rozelle. The maximum concentration was also overestimated, by a factor of 2.0 using the average synthetic background profile and by a factor of 4.9 using the maximum synthetic profile. The inference from these results is that, while mean NO_X concentrations at locations away from roads were probably slightly overestimated, it is likely that there would have been a considerable overestimation of high percentile and maximum 1-hour NO_X concentrations at many such locations, essentially as a result of the inherent conservatism in the 'maximum' synthetic background profile. As noted earlier, maximum pollutant concentrations are inherently very difficult to predict, and the comparisons here reflect this.

At the roadside site the mean NO_X concentration was overestimated by around 50 per cent based on the mapped background. The contemporaneous approaches were more conservative. The synthetic profiles also resulted in the overestimation of 98th percentile and maximum NO_X concentration by around a factor of two.

Because there is generally a stronger road traffic signal for NO_X than for other criteria pollutants, the model performance at the M4-M5:01 roadside station was examined in detail using the 'timeVariation' function in the Openair software (Carslaw, 2015). Figure H-7 shows the results from the timeVariation function for the predicted ('GRAL') and monitored ('MON') hourly NO_X concentrations. The hours with low numbers of values (typically less than 20) associated with, for example, periods of instrument calibration, have been removed from the datasets.

The variation of a pollutant by time of day and day of week can reveal useful information concerning the likely sources. For example, road vehicle emissions tend to follow regular patterns both on a daily and weekly basis. The timeVariation function produces four plots: day of the week variation, mean hour of day variation, a combined hour of day – day of week plot, and a monthly plot. Also shown on the plots is the 95 per cent confidence interval in the mean. For model evaluation it is important to consider the difference between observations and modelled values over these different time scales (Carslaw, 2015).

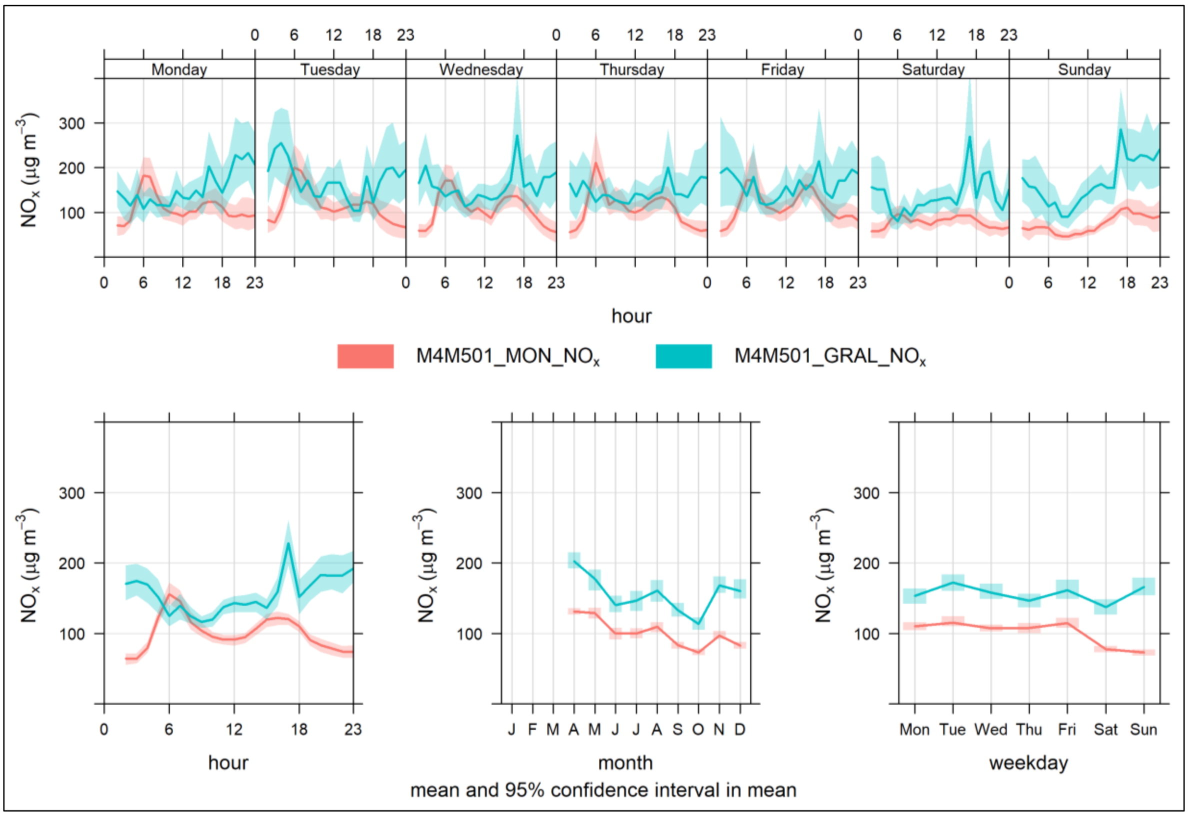


Figure H-7 Time variation of measured and predicted total NO_X concentrations at the M4-M5:01 roadside monitoring station

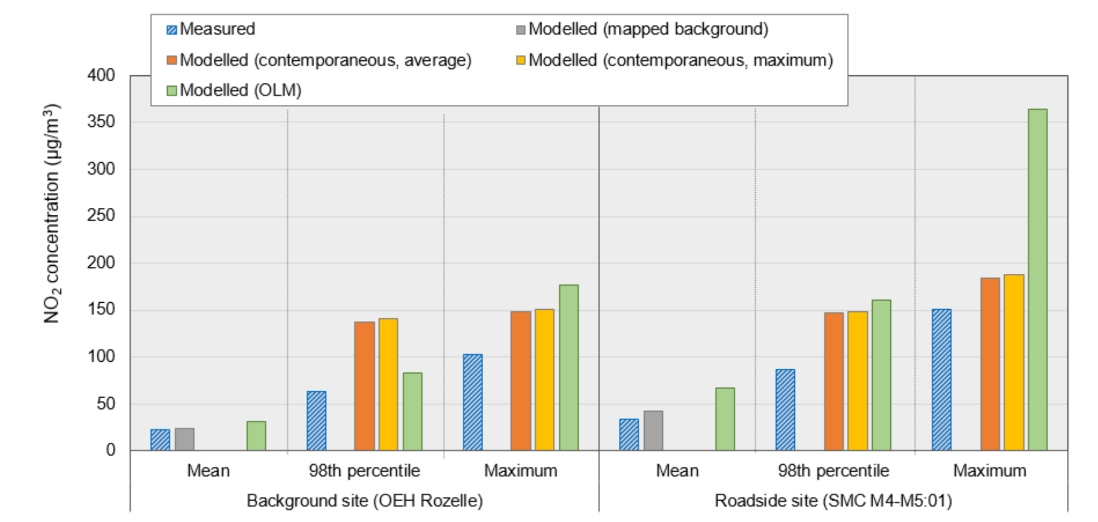
The plot shows the following:

- There was a pronounced overestimation of NO_X concentrations, especially at night-time and during the peak afternoon traffic periods
- The inter-peak concentrations were reasonably well reproduced, although there was still a marked overestimation during some periods
- The seasonal pattern in NO_X was well reproduced, although again there was a consistent overestimation of the monthly average concentration
- The overestimation was larger at the weekend than on weekdays. This is likely to be due in large part to the assumption of weekday traffic volumes on every day of the year in the modelling.

Overall, the results for NO_X suggest that the estimated total annual mean and short-term NO_X concentrations ought to be quite conservative for most of the modelling domain. The selected approaches should introduce a clear margin of safety into the Beached Link assessment.

H.3.3 Results for NO_2

Figure H-8 shows the measured and predicted NO_2 concentrations. NO_2 concentration calculated using the OLM for converting NO_X to NO_2 are shown for comparison with the empirical methods used in the assessment. The mean NO_2 values were obtained using a background map for NO_X. The OLM calculations were contemporaneous, based on the synthetic (average) background profiles for NO_2 and O_3, and the *f*-NO_2 value of 0.16 recommended by NSW EPA.



Site type	Metric (based on 1-hour measurements)	Measured concentration (µg/m³)	Predicted concentration (µg/m³)			Predicted/measured		
			GRAL + mapped background NOx with annual NO_2 conversion	GRAL + contemporaneous background with 1h NO_2 conversion: 'Average' approach	GRAL + contemporaneous background with 1h NO_2 conversion: 'Maximum' approach	GRAL + mapped background NOx with annual NO_2 conversion	GRAL + contemporaneous background with 1h NO_2 conversion: 'Average' approach	GRAL + contemporaneous background with 1h NO_2 conversion: 'Maximum' approach
Background site (OEH Rozelle)	Mean	22.0	23.3	-	-	1.1	-	-
	98th percentile	63.6	-	137.5	140.3	-	2.2	2.2
	Maximum	102.6	-	148.8	150.1	-	1.4	1.5
Roadside site (SMC M4-M5:01)	Mean	33.9	42.4	-	-	1.3	-	-
	98th percentile	86.5	-	147.5	148.1	-	1.7	1.7
	Maximum	150.4	-	184.5	187.2	-	1.2	1.2

Figure H-8 Comparison between measured and predicted total NO_2 concentrations

For mean NO_2 the predicted concentrations based on the use of background maps for NO_X were slightly higher than the measured values (30 per cent higher at the roadside site). When the OLM was used to determine NO_2 for each hour of the year, the predicted mean concentration was double the measurement at the roadside location. The predicted maximum 1-hour mean NO_2 concentration at the roadside site was only 20 per cent higher than the measured value, whereas again the OLM gave a large over-prediction. These findings reinforce the statements in Annexure E concerning the unsuitability of the OLM for road projects.

The results for the 98th percentile 1-hour mean concentration were interesting, as the OLM gave results that were similar to the empirical method developed for the assessment. The latter is designed to give a conservative estimate for the maximum NO_2 concentration for each hour of the year, so that the overall maximum for the year is not underestimated. This means that the whole distribution is skewed towards high values. Although this is useful for determining the maximum value during a year, it is clearly not well suited to the estimation of other NO_2 statistics such as means and percentiles.

H.3.4 Results for CO

Figure H-9 and Figure H-10 show examples of the 1-hour mean CO concentrations predicted by GRAL for the background and roadside stations. The GRAL predictions include the background contribution. The GRAL concentration was, however, generally much lower than the measured background. The measured background at Rozelle also had a slight offset on the y-axis, indicating that there is a degree of uncertainty in the measured data. However, this would not have had a large impact on the results of the evaluation. At the roadside station there was a larger contribution from GRAL than at Rozelle, although the difference was not great.

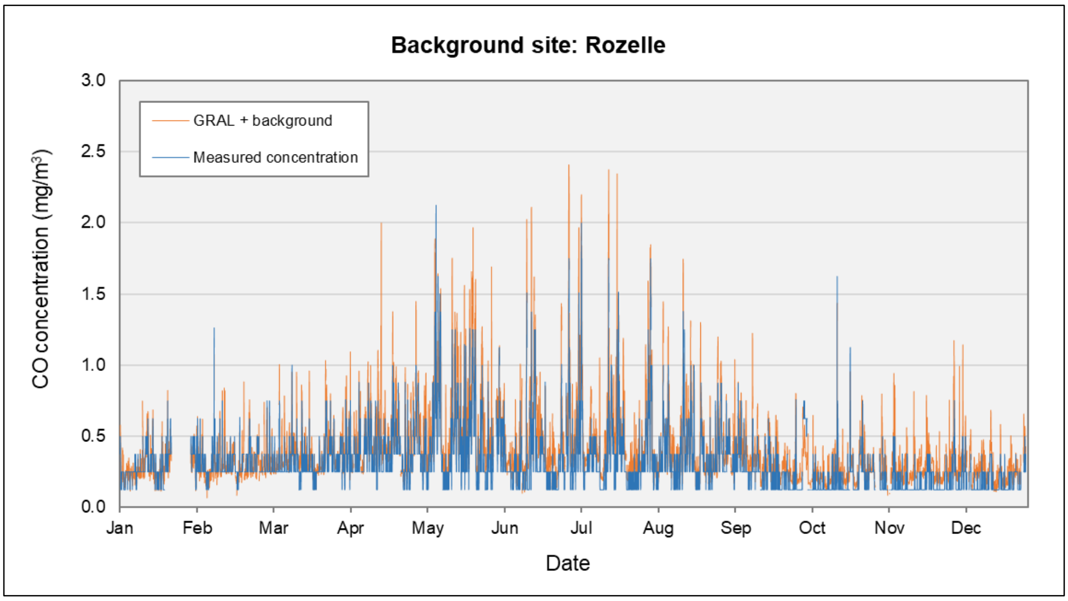


Figure H-9 **Measured 1-hour mean CO concentrations and GRAL predictions (including background) for the DPIE Rozelle background monitoring station**

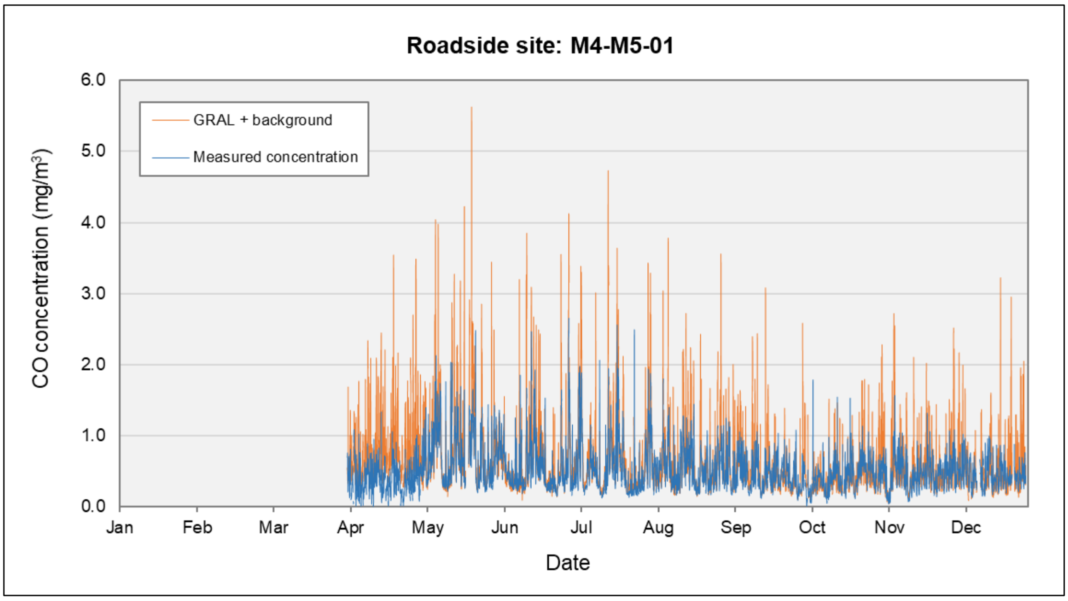
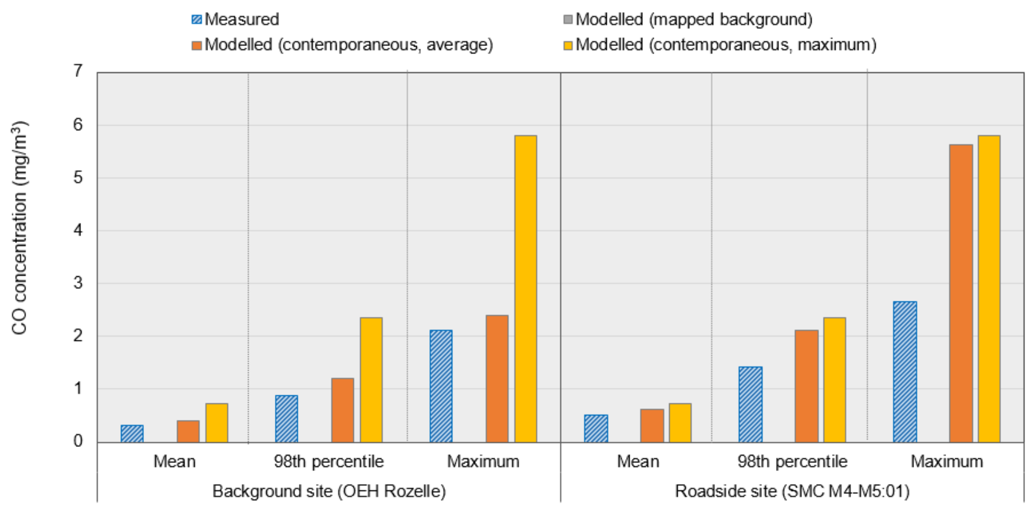


Figure H-10 **Measured 1-hour mean CO concentrations and GRAL predictions (including background) for the M4-M5:01 (City West Link) monitoring station**

The statistics for the measured and predicted total CO concentrations are compared in Figure H-11. For mean concentrations the predictions based on the average synthetic profile generally showed a good agreement with the measurement. When the maximum synthetic background profile was used – as in the Beaches Link assessment – the predictions were considerably higher. As with NO_X, the results for the maximum and 98th percentile concentrations were more variable. At the roadside site the maximum concentration was overestimated by a factor of two.

In Figure H-12 the background and GRAL contributions to the mean CO concentration are shown separately. The background here is simply an average for the synthetic CO profile. At the roadside site the background contributed 60 per cent of the total CO concentration.



Site type	Metric (based on 1-hour measurements)	Measured concentration (µg/m³)	Predicted concentration (µg/m³)			Predicted/measured		
			GRAL + mapped background	GRAL + contemporaneous background		GRAL + mapped background	GRAL + contemporaneous background	
				'Average' approach	'Maximum' approach		'Average' approach	'Maximum' approach
Background site (OEH Rozelle)	Mean	0.3	-	0.4	0.7	-	1.3	2.3
	98th percentile	0.9	-	1.2	2.4	-	1.4	2.7
	Maximum	2.1	-	2.4	5.8	-	1.1	2.7
Roadside site (SMC M4-M5:01)	Mean	0.5	-	0.6	0.7	-	1.2	1.4
	98th percentile	1.4	-	2.1	2.4	-	1.5	1.7
	Maximum	2.7	-	5.6	5.8	-	2.1	2.2

Figure H-11 Comparison between measured and predicted total CO concentrations

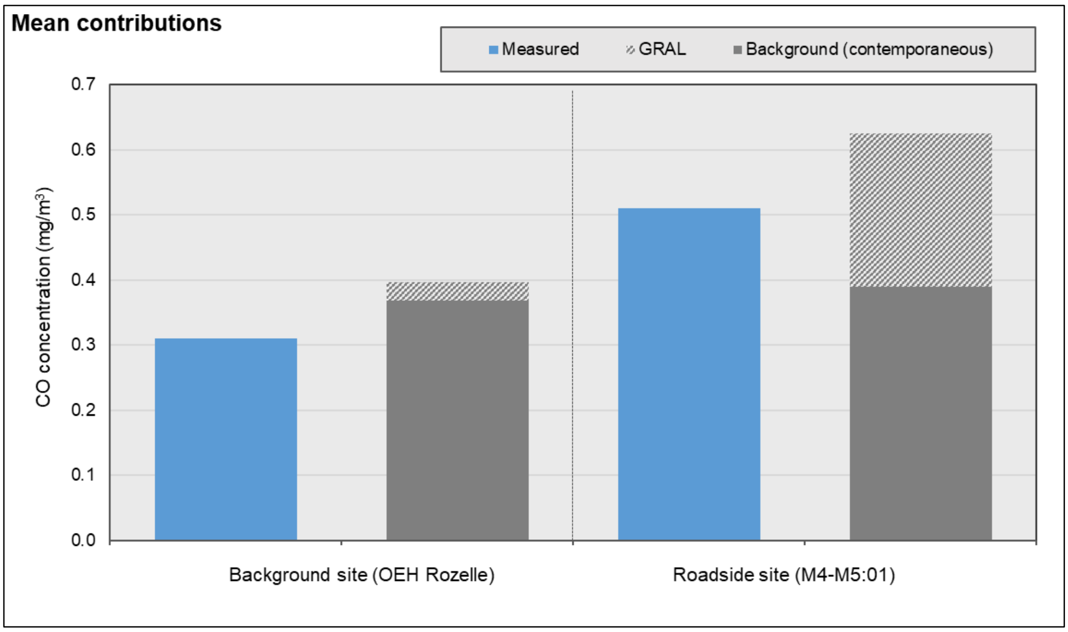


Figure H-12 Contributions to modelled mean CO concentrations

H.3.5 Results for PM_{10}

Figure H-13 compares the measured 24-hour mean PM_{10} concentrations with those predicted by GRAL for the background station, and Figure H-14 shows the results for the roadside station. Unsurprisingly, given the large background contribution, there was a good agreement between the model predictions and the measurements.

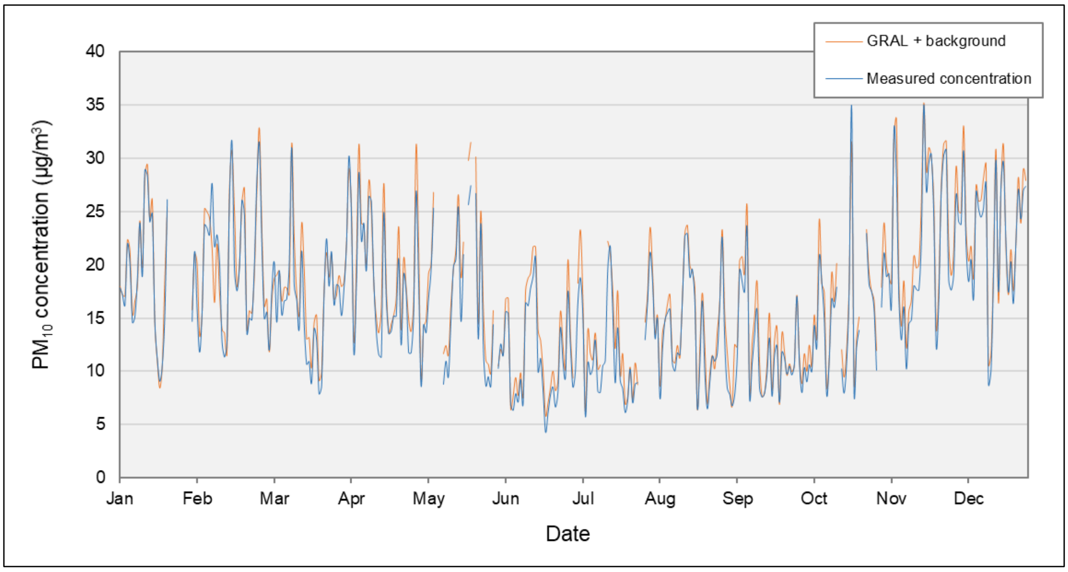


Figure H-13 Measured 24-hour mean PM_{10} concentrations and GRAL predictions (including background) for the DPIE Rozelle background monitoring station

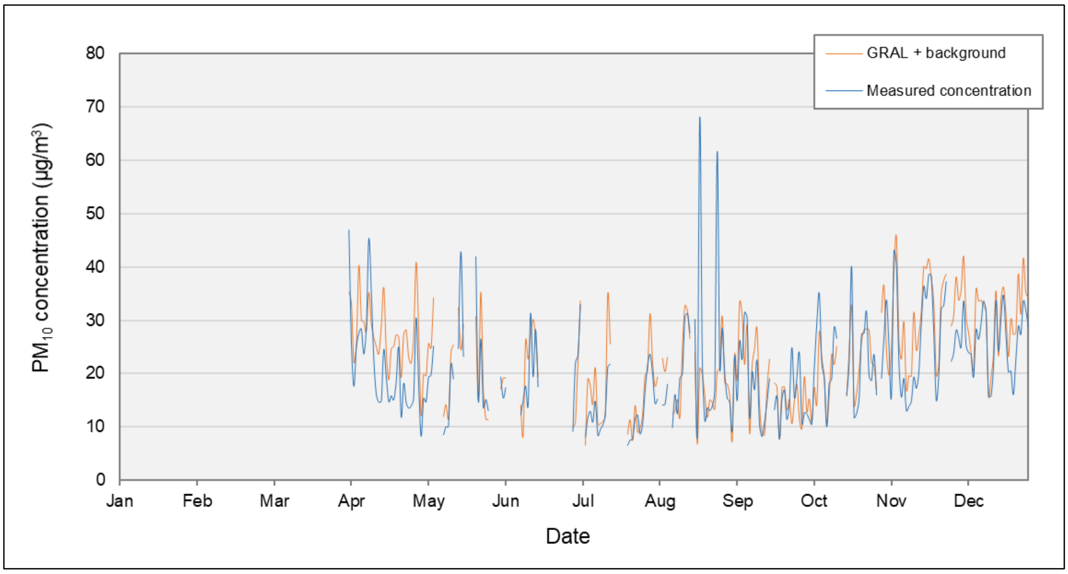
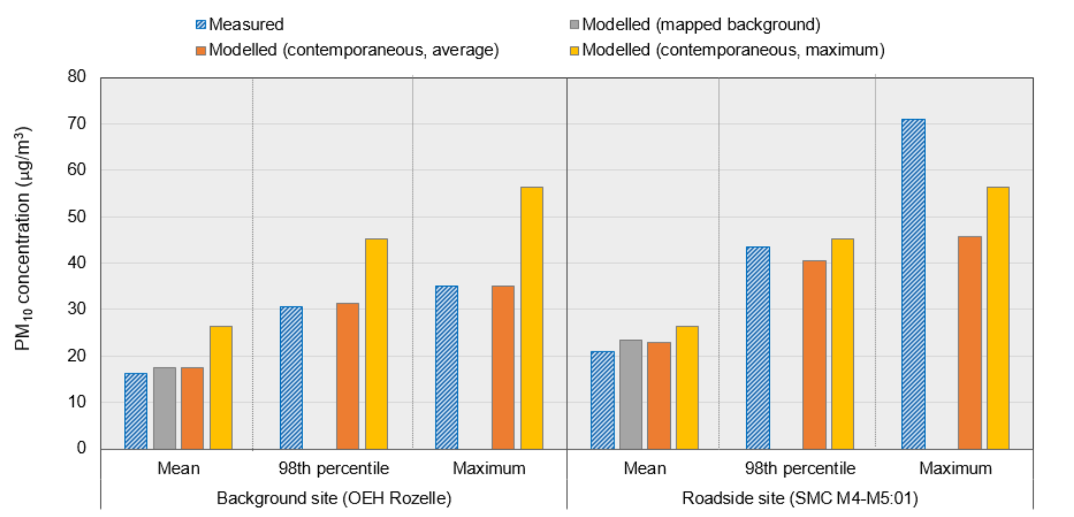


Figure H-14 Measured 24-hour mean PM_{10} concentrations and GRAL predictions (including background) for the M4-M5:01 (City West Link) monitoring station

The summary plots and statistics for the PM_{10} comparisons are provided in Figure H-15. As with NO_X, calculations based on the contemporaneous background approaches are also included for comparison with the mapped background approach. The average contemporaneous approach gave similar predictions to the mapping approach. In Figure H-16 the background and GRAL contributions to the mean PM_{10} concentration are shown separately.



Site type	Metric (based on 1-hour measurements)	Measured concentration (µg/m³)	Predicted concentration (µg/m³)			Predicted/measured		
			GRAL + mapped background	GRAL + contemporaneous background		GRAL + mapped background	GRAL + contemporaneous background	
				'Average' approach	'Maximum' approach		'Average' approach	'Maximum' approach
Background site (OEH Rozelle)	Mean	16.3	17.6	17.5	26.3	1.1	1.1	1.6
	98th percentile	30.7	-	31.4	45.3	-	1.0	1.5
	Maximum	35.0	-	35.1	56.3	-	1.0	1.6
Roadside site (SMC M4-M5:01)	Mean	20.8	23.3	22.9	26.3	1.1	1.1	1.3
	98th percentile	43.6	-	40.5	45.3	-	0.9	1.0
	Maximum	70.9	-	45.6	56.3	-	0.6	0.8

Figure H-15 Comparison between measured and predicted total PM_{10} concentrations

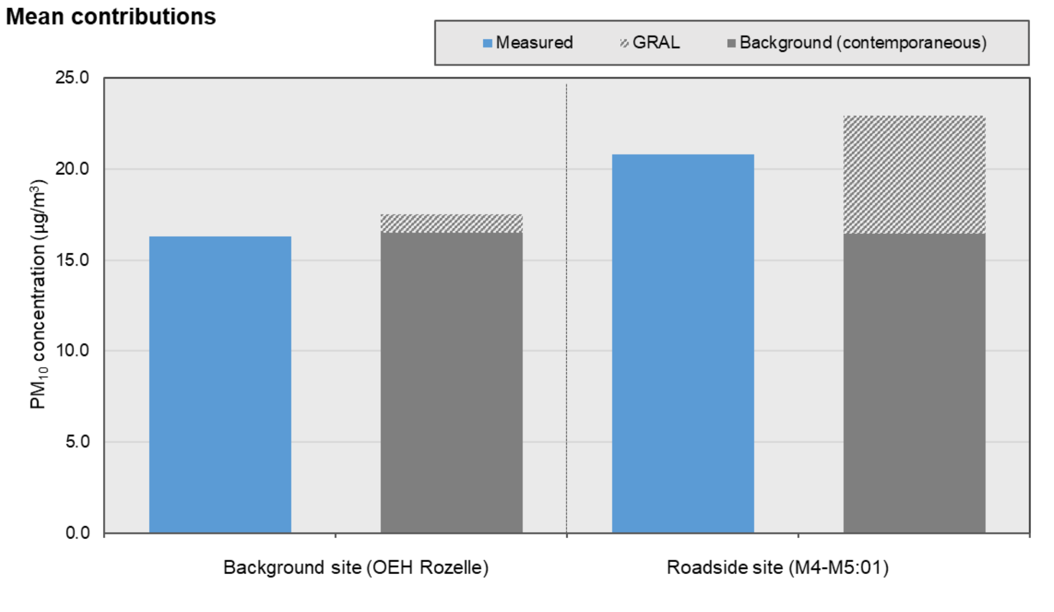


Figure H-16 Contributions to modelled mean PM_{10} concentrations

The importance of the background for PM_{10} is clear; at the roadside site the background contribution was 72 per cent of the total. At the background station the predicted concentration represented the combination of the values from the monitoring stations and a small GRAL contribution, so it is not surprising that they agree well with the measurements (i.e. the measured and predicted values are hardly independent). The model overestimated the mean PM_{10} concentrations at the roadside site by just 10 per cent.

The maximum and 98th percentile 24-hour mean PM_{10} concentrations were not systematically overestimated when the average synthetic background profile was used, and in fact the agreement with measurements was quite good. This is again largely due to the high background contribution. However, the maximum synthetic profile, as used in the assessment, gave markedly higher values. The exception to this was the maximum concentration at the roadside side, which was underestimated by around 40%. It is possible that the maximum values in the monitoring data were affected by atypical local activity, or by a regional event such as a bushfire.

In general, the results suggest that the use of GRAL and the background mapping approach should give good (and slightly conservative) estimates of the annual PM_{10} concentration.

Annexure I Dispersion modelling results - all sources

This Annexure provides all results of the dispersion modelling for the **expected traffic** scenarios. The following notes apply:

- Data are not presented for the 2016-BY scenario, as this scenario was designed primarily for model evaluation.
- For community receptors the Figures presented in the main body of the report have not been duplicated. The results for these receptors have been tabulated.
- In the Tables any grey shading indicates where no value was obtained. For example, where the top ten increases in concentration are ranked, there may have been fewer than ten receptors that actually had an increase in concentration.
- For short-term air quality criteria, such as the maximum 1-hour NO_2 concentrations, the contour plots should be viewed as indicative. This is a consequence of the difficulties associated with the prediction of short-term concentrations.

> **NB:** Larger-scale contour plots for air pollutants in the vicinity of each tunnel ventilation outlet in the expected traffic scenarios are provided in Annexure J

I.1 Carbon monoxide (maximum 1-hour mean)

Table I-1 Maximum 1-hour mean CO concentration at community receptors

Receptor	Maximum 1-hour CO concentration (mg/m³)							Change relative to Do Minimum (mg/m³)				Change relative to Do Minimum (%)			
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
CR01	-	3.85	3.82	3.66	3.60	3.62	3.44	-0.03	-0.19	0.02	-0.16	-0.7%	-4.9%	0.5%	-4.5%
CR02	-	3.26	3.23	3.27	3.17	3.26	3.27	-0.04	0.01	0.08	0.09	-1.1%	0.3%	2.6%	2.9%
CR03	-	3.19	3.30	3.19	3.25	3.33	3.28	0.11	0.00	0.07	0.03	3.5%	0.1%	2.2%	0.9%
CR04	-	3.18	3.17	3.23	3.30	3.19	3.26	-0.01	0.05	-0.10	-0.04	-0.2%	1.5%	-3.1%	-1.1%
CR05	-	3.18	3.19	3.13	3.21	3.14	3.16	0.02	-0.04	-0.07	-0.06	0.5%	-1.4%	-2.2%	-1.7%
CR06	-	3.23	3.19	3.20	3.16	3.25	3.19	-0.04	-0.02	0.09	0.02	-1.2%	-0.8%	2.8%	0.8%
CR07	-	3.14	3.20	3.14	3.21	3.14	3.16	0.06	0.00	-0.07	-0.05	1.8%	0.1%	-2.2%	-1.5%
CR08	-	3.23	3.33	3.22	3.17	3.23	3.19	0.10	0.00	0.06	0.02	3.2%	-0.1%	2.0%	0.6%
CR09	-	3.21	3.20	3.23	3.16	3.14	3.18	-0.01	0.02	-0.02	0.02	-0.2%	0.6%	-0.6%	0.7%
CR10	-	3.38	3.37	3.31	3.23	3.19	3.21	0.00	-0.07	-0.04	-0.02	-0.1%	-2.0%	-1.4%	-0.7%
CR11	-	3.32	3.27	3.26	3.28	3.42	3.23	-0.05	-0.06	0.14	-0.06	-1.4%	-1.7%	4.1%	-1.7%
CR12	-	3.22	3.16	3.21	3.21	3.20	3.25	-0.06	-0.02	-0.01	0.04	-1.9%	-0.5%	-0.4%	1.1%
CR13	-	3.15	3.18	3.13	3.21	3.22	3.22	0.03	-0.01	0.01	0.01	1.1%	-0.4%	0.4%	0.3%
CR14	-	3.35	3.30	3.17	3.42	3.28	3.29	-0.05	-0.19	-0.14	-0.13	-1.5%	-5.6%	-4.0%	-3.8%
CR15	-	3.22	3.21	3.13	3.17	3.19	3.14	-0.01	-0.09	0.01	-0.03	-0.4%	-2.7%	0.4%	-1.0%
CR16	-	3.35	3.26	3.35	3.26	3.19	3.33	-0.10	0.00	-0.07	0.07	-2.9%	-0.1%	-2.1%	2.1%
CR17	-	3.41	3.20	3.23	3.41	3.24	3.24	-0.21	-0.18	-0.16	-0.17	-6.1%	-5.3%	-4.8%	-4.9%
CR18	-	3.17	3.17	3.27	3.18	3.14	3.20	0.01	0.10	-0.04	0.02	0.2%	3.2%	-1.1%	0.8%
CR19	-	3.31	3.24	3.22	3.19	3.32	3.19	-0.06	-0.08	0.13	0.00	-1.9%	-2.5%	4.0%	-0.1%
CR20	-	3.20	3.17	3.19	3.20	3.18	3.15	-0.03	-0.01	-0.02	-0.05	-0.8%	-0.2%	-0.7%	-1.6%
CR21	-	3.34	3.29	3.17	3.20	3.20	3.20	-0.05	-0.17	0.00	0.00	-1.6%	-5.1%	-0.1%	-0.1%
CR22	-	3.23	3.29	3.21	3.25	3.14	3.15	0.05	-0.02	-0.11	-0.10	1.6%	-0.7%	-3.4%	-3.0%
CR23	-	3.17	3.23	3.21	3.37	3.27	3.15	0.06	0.04	-0.09	-0.22	1.9%	1.3%	-2.8%	-6.4%
CR24	-	3.16	3.16	3.13	3.18	3.15	3.13	0.00	-0.03	-0.03	-0.05	-0.1%	-1.0%	-0.9%	-1.4%
CR25	-	3.20	3.30	3.29	3.41	3.23	3.25	0.09	0.09	-0.19	-0.16	3.0%	2.7%	-5.5%	-4.7%
CR26	-	3.19	3.18	3.19	3.20	3.22	3.20	-0.01	0.00	0.02	0.00	-0.2%	0.1%	0.6%	-0.1%
CR27	-	3.20	3.13	3.15	3.22	3.16	3.17	-0.07	-0.05	-0.06	-0.04	-2.1%	-1.6%	-1.7%	-1.3%
CR28	-	3.22	3.16	3.19	3.21	3.14	3.18	-0.05	-0.02	-0.06	-0.02	-1.6%	-0.7%	-2.0%	-0.7%
CR29	-	3.23	3.18	3.21	3.13	3.23	3.15	-0.06	-0.02	0.10	0.02	-1.7%	-0.5%	3.1%	0.7%
CR30	-	3.28	3.15	3.18	3.18	3.14	3.16	-0.13	-0.09	-0.03	-0.02	-3.9%	-2.8%	-1.0%	-0.6%
CR31	-	3.20	3.27	3.21	3.19	3.21	3.19	0.08	0.02	0.01	-0.01	2.4%	0.5%	0.4%	-0.2%
CR32	-	3.15	3.16	3.13	3.14	3.13	3.14	0.01	-0.02	-0.01	0.00	0.3%	-0.6%	-0.2%	0.0%
CR33	-	3.13	3.13	3.15	3.15	3.13	3.13	0.00	0.01	-0.02	-0.02	0.0%	0.5%	-0.6%	-0.6%
CR34	-	3.13	3.15	3.13	3.15	3.13	3.13	0.02	0.00	-0.02	-0.02	0.6%	0.0%	-0.5%	-0.5%
CR35	-	3.13	3.14	3.13	3.13	3.13	3.13	0.00	0.00	0.00	0.00	0.1%	0.0%	0.0%	0.0%
CR36	-	3.14	3.13	3.17	3.13	3.14	3.13	-0.01	0.02	0.00	0.00	-0.3%	0.8%	0.2%	0.0%
CR37	-	3.16	3.28	3.39	3.19	3.18	3.40	0.12	0.23	-0.01	0.21	3.9%	7.2%	-0.3%	6.6%
CR38	-	3.23	3.19	3.31	3.16	3.17	3.17	-0.04	0.08	0.01	0.01	-1.2%	2.6%	0.4%	0.3%
CR39	-	3.23	3.27	3.34	3.14	3.17	3.18	0.04	0.11	0.03	0.04	1.4%	3.5%	0.9%	1.2%
CR40	-	3.13	3.15	3.16	3.15	3.15	3.16	0.02	0.03	0.00	0.01	0.5%	0.8%	-0.1%	0.4%
CR41	-	3.13	3.13	3.13	3.13	3.13	3.13	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%
CR42	-	3.13	3.13	3.15	3.13	3.13	3.14	0.00	0.02	0.00	0.01	0.0%	0.6%	0.0%	0.3%

Table I-2 **Maximum 1-hour mean CO concentration at community receptors, ranked by concentration**

Rank	Ranking by concentration (mg/m^3)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	3.85	3.82	3.66	3.60	3.62	3.44
2	-	3.41	3.37	3.39	3.42	3.42	3.40
3	-	3.38	3.33	3.35	3.41	3.33	3.33
4	-	3.35	3.30	3.34	3.41	3.32	3.29
5	-	3.35	3.30	3.31	3.37	3.28	3.28
6	-	3.34	3.30	3.31	3.30	3.27	3.27
7	-	3.32	3.29	3.29	3.28	3.26	3.26
8	-	3.31	3.29	3.27	3.26	3.25	3.25
9	-	3.28	3.28	3.27	3.25	3.24	3.25
10	-	3.26	3.27	3.26	3.25	3.23	3.24

Table I-3 **Maximum 1-hour mean CO concentration at community receptors, ranked by increase and by decrease in concentration**

Rank	Ranking by increase in concentration relative to Do Minimum (mg/m^3)				Ranking by decrease in concentration relative to Do Minimum (mg/m^3)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	0.12	0.23	0.14	0.21	-0.21	-0.19	-0.19	-0.22
2	0.11	0.11	0.13	0.09	-0.13	-0.19	-0.16	-0.17
3	0.10	0.10	0.10	0.07	-0.10	-0.18	-0.14	-0.16
4	0.09	0.09	0.09	0.04	-0.07	-0.17	-0.11	-0.16
5	0.08	0.08	0.08	0.04	-0.06	-0.09	-0.10	-0.13
6	0.06	0.05	0.07	0.03	-0.06	-0.09	-0.09	-0.10
7	0.06	0.04	0.06	0.02	-0.06	-0.08	-0.07	-0.06
8	0.05	0.03	0.03	0.02	-0.05	-0.07	-0.07	-0.06
9	0.04	0.02	0.02	0.02	-0.05	-0.06	-0.07	-0.05
10	0.03	0.02	0.02	0.02	-0.05	-0.05	-0.06	-0.05

Table I-4 **Maximum 1-hour mean CO concentration at community receptors, ranked by percentage increase and by decrease in concentration**

Rank	Ranking by % increase in concentration relative to Do Minimum				Ranking by % decrease in concentration relative to Do Minimum			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	3.9%	7.2%	4.1%	6.6%	-6.1%	-5.6%	-5.5%	-6.4%
2	3.5%	3.5%	4.0%	2.9%	-3.9%	-5.3%	-4.8%	-4.9%
3	3.2%	3.2%	3.1%	2.1%	-2.9%	-5.1%	-4.0%	-4.7%
4	3.0%	2.7%	2.8%	1.2%	-2.1%	-4.9%	-3.4%	-4.5%
5	2.4%	2.6%	2.6%	1.1%	-1.9%	-2.8%	-3.1%	-3.8%
6	1.9%	1.5%	2.2%	0.9%	-1.9%	-2.7%	-2.8%	-3.0%
7	1.8%	1.3%	2.0%	0.8%	-1.7%	-2.5%	-2.2%	-1.7%
8	1.6%	0.8%	0.9%	0.8%	-1.6%	-2.0%	-2.2%	-1.7%
9	1.4%	0.8%	0.6%	0.7%	-1.6%	-1.7%	-2.1%	-1.6%
10	1.1%	0.6%	0.5%	0.7%	-1.5%	-1.6%	-2.0%	-1.5%

Table I-5 Maximum 1-hour mean CO concentration at RWR receptors, ranked by concentration

Rank	Ranking by concentration (mg/m³)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	6.0	5.5	5.5	5.1	4.8	5.0
2	-	5.5	5.2	5.4	4.9	4.8	4.8
3	-	5.4	5.2	5.3	4.8	4.7	4.7
4	-	5.3	5.2	5.2	4.8	4.7	4.6
5	-	5.3	5.2	5.2	4.8	4.7	4.6
6	-	5.3	5.1	5.1	4.8	4.7	4.6
7	-	5.3	5.1	5.1	4.8	4.7	4.6
8	-	5.3	5.1	5.0	4.8	4.7	4.6
9	-	5.3	5.1	5.0	4.8	4.7	4.6
10	-	5.2	5.0	5.0	4.8	4.7	4.6

Table I-6 Maximum 1-hour mean CO concentration at RWR receptors, ranked by increase and by decrease in concentration

Rank	Ranking by increase in concentration relative to Do Minimum (mg/m³)				Ranking by decrease in concentration relative to Do Minimum (mg/m³)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	0.8	0.9	0.8	0.6	-1.0	-1.2	-1.0	-1.1
2	0.8	0.9	0.8	0.5	-1.0	-1.0	-0.9	-0.8
3	0.8	0.9	0.7	0.5	-1.0	-1.0	-0.9	-0.8
4	0.7	0.8	0.6	0.5	-1.0	-0.9	-0.9	-0.8
5	0.7	0.8	0.6	0.5	-0.9	-0.9	-0.7	-0.8
6	0.7	0.7	0.6	0.5	-0.9	-0.8	-0.7	-0.7
7	0.7	0.7	0.6	0.5	-0.9	-0.8	-0.7	-0.7
8	0.7	0.7	0.5	0.5	-0.8	-0.8	-0.7	-0.7
9	0.7	0.7	0.5	0.5	-0.8	-0.8	-0.7	-0.7
10	0.7	0.7	0.5	0.5	-0.8	-0.8	-0.7	-0.7

Table I-7 Maximum 1-hour mean CO concentration at RWR receptors, ranked by percentage increase and by decrease in concentration

Rank	Ranking by % increase in concentration relative to Do Minimum				Ranking by % decrease in concentration relative to Do Minimum			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	22.5%	22.9%	20.9%	14.8%	-20.8%	-22.0%	-20.8%	-22.7%
2	20.3%	21.8%	20.4%	14.8%	-20.8%	-22.0%	-19.5%	-17.8%
3	19.7%	21.3%	17.7%	14.7%	-19.8%	-20.8%	-19.5%	-17.5%
4	19.2%	21.0%	17.1%	13.7%	-19.2%	-18.3%	-18.6%	-17.0%
5	18.6%	19.7%	16.2%	13.6%	-18.5%	-18.1%	-17.4%	-16.9%
6	18.6%	19.3%	16.0%	13.6%	-17.8%	-17.7%	-17.2%	-16.9%
7	18.0%	19.3%	15.2%	13.5%	-17.2%	-17.1%	-17.2%	-16.9%
8	17.7%	19.2%	14.4%	13.5%	-16.8%	-17.0%	-16.8%	-16.5%
9	17.6%	19.0%	14.4%	13.3%	-16.7%	-17.0%	-15.5%	-16.5%
10	17.3%	18.0%	14.4%	13.3%	-16.1%	-16.9%	-15.5%	-15.6%

I.2 Carbon monoxide (maximum rolling 8-hour mean)

Table I-8 Maximum rolling 8-hour mean CO concentration at community receptors

Receptor	Maximum rolling 8-hour CO concentration (mg/m³)							Change relative to Do Minimum (mg/m³)				Change relative to Do Minimum (%)			
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
CR01	-	2.76	2.82	2.77	2.69	2.66	2.73	0.06	0.01	-0.03	0.03	2.1%	0.4%	-1.2%	1.3%
CR02	-	2.50	2.48	2.52	2.49	2.48	2.48	-0.02	0.02	-0.01	-0.02	-0.8%	0.8%	-0.6%	-0.6%
CR03	-	2.47	2.48	2.50	2.49	2.49	2.46	0.01	0.03	-0.01	-0.03	0.4%	1.2%	-0.2%	-1.1%
CR04	-	2.50	2.48	2.51	2.50	2.44	2.47	-0.02	0.01	-0.06	-0.02	-0.9%	0.5%	-2.3%	-1.0%
CR05	-	2.45	2.43	2.46	2.44	2.42	2.44	-0.01	0.01	-0.03	-0.01	-0.6%	0.4%	-1.2%	-0.3%
CR06	-	2.46	2.48	2.42	2.40	2.44	2.42	0.02	-0.04	0.03	0.01	0.9%	-1.7%	1.4%	0.6%
CR07	-	2.40	2.42	2.42	2.41	2.39	2.43	0.01	0.01	-0.02	0.02	0.6%	0.6%	-0.9%	0.8%
CR08	-	2.47	2.50	2.47	2.47	2.42	2.47	0.03	0.00	-0.04	0.00	1.1%	0.0%	-1.7%	0.0%
CR09	-	2.45	2.41	2.45	2.42	2.42	2.41	-0.04	0.00	0.00	-0.01	-1.7%	0.1%	0.0%	-0.3%
CR10	-	2.52	2.48	2.47	2.48	2.46	2.45	-0.04	-0.05	-0.03	-0.04	-1.6%	-2.0%	-1.1%	-1.5%
CR11	-	2.57	2.54	2.55	2.54	2.53	2.52	-0.04	-0.02	-0.01	-0.02	-1.4%	-0.9%	-0.6%	-0.9%
CR12	-	2.45	2.46	2.46	2.45	2.45	2.46	0.01	0.01	0.00	0.02	0.5%	0.5%	-0.1%	0.6%
CR13	-	2.40	2.41	2.41	2.40	2.41	2.42	0.00	0.01	0.01	0.02	0.2%	0.3%	0.2%	0.8%
CR14	-	2.50	2.49	2.45	2.49	2.46	2.45	-0.02	-0.05	-0.03	-0.04	-0.7%	-2.1%	-1.4%	-1.6%
CR15	-	2.44	2.41	2.40	2.42	2.41	2.40	-0.03	-0.04	-0.01	-0.02	-1.1%	-1.5%	-0.3%	-0.9%
CR16	-	2.56	2.59	2.57	2.51	2.54	2.54	0.02	0.01	0.03	0.03	0.8%	0.4%	1.3%	1.2%
CR17	-	2.56	2.48	2.53	2.50	2.50	2.48	-0.08	-0.03	0.00	-0.02	-3.3%	-1.0%	-0.1%	-0.7%
CR18	-	2.43	2.45	2.43	2.43	2.41	2.42	0.01	0.00	-0.02	-0.01	0.6%	-0.1%	-0.6%	-0.3%
CR19	-	2.50	2.54	2.51	2.47	2.51	2.48	0.03	0.01	0.05	0.01	1.3%	0.4%	1.9%	0.5%
CR20	-	2.48	2.44	2.46	2.46	2.46	2.43	-0.04	-0.02	0.00	-0.04	-1.5%	-0.9%	-0.1%	-1.4%
CR21	-	2.55	2.51	2.47	2.44	2.47	2.46	-0.04	-0.08	0.03	0.02	-1.5%	-3.1%	1.3%	0.8%
CR22	-	2.49	2.53	2.45	2.43	2.44	2.46	0.05	-0.03	0.01	0.02	1.9%	-1.3%	0.4%	1.0%
CR23	-	2.53	2.49	2.54	2.54	2.52	2.48	-0.03	0.01	-0.02	-0.06	-1.4%	0.6%	-0.6%	-2.2%
CR24	-	2.43	2.41	2.40	2.41	2.40	2.41	-0.02	-0.03	-0.01	0.00	-0.8%	-1.4%	-0.5%	-0.2%
CR25	-	2.54	2.52	2.53	2.52	2.50	2.49	-0.01	0.00	-0.02	-0.03	-0.5%	-0.1%	-0.8%	-1.3%
CR26	-	2.46	2.50	2.48	2.47	2.44	2.46	0.05	0.02	-0.03	-0.01	1.8%	1.0%	-1.1%	-0.2%
CR27	-	2.43	2.41	2.43	2.41	2.41	2.40	-0.02	0.00	0.00	-0.01	-0.9%	0.0%	0.0%	-0.6%
CR28	-	2.44	2.44	2.48	2.44	2.42	2.43	0.00	0.04	-0.01	-0.01	-0.1%	1.6%	-0.5%	-0.4%
CR29	-	2.41	2.42	2.45	2.40	2.42	2.41	0.01	0.04	0.03	0.01	0.3%	1.7%	1.1%	0.4%
CR30	-	2.45	2.41	2.41	2.42	2.41	2.43	-0.04	-0.05	-0.01	0.01	-1.7%	-2.0%	-0.3%	0.3%
CR31	-	2.51	2.50	2.48	2.44	2.46	2.45	-0.01	-0.03	0.02	0.02	-0.3%	-1.4%	0.9%	0.8%
CR32	-	2.41	2.41	2.39	2.40	2.40	2.40	0.00	-0.02	0.01	0.00	0.0%	-0.6%	0.2%	0.2%
CR33	-	2.39	2.40	2.39	2.40	2.38	2.38	0.01	0.00	-0.02	-0.02	0.3%	-0.2%	-0.9%	-0.8%
CR34	-	2.41	2.40	2.39	2.39	2.39	2.38	-0.01	-0.02	0.00	-0.01	-0.6%	-0.8%	0.0%	-0.5%
CR35	-	2.39	2.39	2.40	2.38	2.38	2.38	0.00	0.00	0.00	0.00	-0.2%	0.2%	0.2%	0.0%
CR36	-	2.40	2.39	2.39	2.39	2.40	2.38	-0.01	-0.01	0.00	-0.01	-0.5%	-0.3%	0.2%	-0.4%
CR37	-	2.51	2.59	2.53	2.47	2.49	2.53	0.08	0.02	0.02	0.06	3.1%	0.8%	0.7%	2.6%
CR38	-	2.51	2.51	2.50	2.43	2.45	2.44	0.00	-0.02	0.02	0.01	-0.1%	-0.7%	0.8%	0.2%
CR39	-	2.47	2.46	2.50	2.44	2.43	2.43	0.00	0.03	-0.01	-0.01	-0.2%	1.3%	-0.4%	-0.4%
CR40	-	2.41	2.40	2.42	2.43	2.39	2.41	-0.01	0.01	-0.04	-0.02	-0.3%	0.3%	-1.7%	-0.8%
CR41	-	2.40	2.40	2.43	2.39	2.39	2.39	0.00	0.03	0.00	0.00	-0.2%	1.3%	-0.1%	-0.1%
CR42	-	2.41	2.40	2.41	2.39	2.40	2.41	-0.02	0.00	0.01	0.01	-0.6%	-0.2%	0.5%	0.6%

Table I-9 **Maximum rolling 8-hour mean CO concentration at community receptors, ranked by concentration**

Rank	Ranking by concentration (mg/m^3)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	2.76	2.82	2.77	2.69	2.66	2.73
2	-	2.57	2.59	2.57	2.54	2.54	2.54
3	-	2.56	2.59	2.55	2.54	2.53	2.53
4	-	2.56	2.54	2.54	2.52	2.52	2.52
5	-	2.55	2.54	2.53	2.51	2.51	2.49
6	-	2.54	2.53	2.53	2.50	2.50	2.48
7	-	2.53	2.52	2.53	2.50	2.50	2.48
8	-	2.52	2.51	2.52	2.49	2.49	2.48
9	-	2.51	2.51	2.51	2.49	2.49	2.48
10	-	2.51	2.50	2.51	2.49	2.48	2.47

Table I-10 **Maximum rolling 8-hour mean CO concentration at community receptors, ranked by increase and by decrease in concentration**

Rank	Ranking by increase in concentration relative to Do Minimum (mg/m^3)				Ranking by decrease in concentration relative to Do Minimum (mg/m^3)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	0.08	0.04	0.05	0.06	-0.08	-0.08	-0.06	-0.06
2	0.06	0.04	0.03	0.03	-0.04	-0.05	-0.04	-0.04
3	0.05	0.03	0.03	0.03	-0.04	-0.05	-0.04	-0.04
4	0.05	0.03	0.03	0.02	-0.04	-0.05	-0.03	-0.04
5	0.03	0.03	0.03	0.02	-0.04	-0.04	-0.03	-0.03
6	0.03	0.02	0.02	0.02	-0.04	-0.04	-0.03	-0.03
7	0.02	0.02	0.02	0.02	-0.04	-0.03	-0.03	-0.02
8	0.02	0.02	0.02	0.02	-0.03	-0.03	-0.03	-0.02
9	0.01	0.01	0.01	0.02	-0.03	-0.03	-0.02	-0.02
10	0.01	0.01	0.01	0.01	-0.02	-0.03	-0.02	-0.02

Table I-11 **Maximum rolling 8-hour mean CO concentration at community receptors, ranked by percentage increase and by decrease in concentration**

Rank	Ranking by % increase in concentration relative to Do Minimum				Ranking by % decrease in concentration relative to Do Minimum			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	3.1%	1.7%	1.9%	2.6%	-3.3%	-3.1%	-2.3%	-2.2%
2	2.1%	1.6%	1.4%	1.3%	-1.7%	-2.1%	-1.7%	-1.6%
3	1.9%	1.3%	1.3%	1.2%	-1.7%	-2.0%	-1.7%	-1.5%
4	1.8%	1.3%	1.3%	1.0%	-1.6%	-2.0%	-1.4%	-1.4%
5	1.3%	1.2%	1.1%	0.8%	-1.5%	-1.7%	-1.2%	-1.3%
6	1.1%	1.0%	0.9%	0.8%	-1.5%	-1.5%	-1.2%	-1.1%
7	0.9%	0.8%	0.8%	0.8%	-1.4%	-1.4%	-1.1%	-1.0%
8	0.8%	0.8%	0.7%	0.8%	-1.4%	-1.4%	-1.1%	-0.9%
9	0.6%	0.6%	0.5%	0.6%	-1.1%	-1.3%	-0.9%	-0.9%
10	0.6%	0.6%	0.4%	0.6%	-0.9%	-1.0%	-0.9%	-0.8%

Table I-12 **Maximum rolling 8-hour mean CO concentration at RWR receptors, ranked by concentration**

Rank	Ranking by concentration (mg/m^3)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	4.2	3.8	3.8	3.5	3.4	3.5
2	-	3.9	3.6	3.7	3.4	3.3	3.4
3	-	3.8	3.6	3.7	3.3	3.3	3.3
4	-	3.7	3.6	3.6	3.3	3.3	3.2
5	-	3.7	3.6	3.6	3.3	3.3	3.2
6	-	3.7	3.6	3.5	3.3	3.3	3.2
7	-	3.7	3.6	3.5	3.3	3.3	3.2
8	-	3.7	3.6	3.5	3.3	3.3	3.2
9	-	3.7	3.5	3.5	3.3	3.2	3.2
10	-	3.6	3.5	3.5	3.3	3.2	3.2

Table I-13 **Maximum rolling 8-hour mean CO concentration at RWR receptors, ranked by increase and by decrease in concentration**

Rank	Ranking by increase in concentration relative to Do Minimum (mg/m^3)				Ranking by decrease in concentration relative to Do Minimum (mg/m^3)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	0.6	0.6	0.6	0.4	-0.7	-0.8	-0.7	-0.7
2	0.5	0.6	0.6	0.4	-0.7	-0.7	-0.6	-0.5
3	0.5	0.6	0.5	0.4	-0.7	-0.7	-0.6	-0.5
4	0.5	0.6	0.4	0.4	-0.7	-0.6	-0.6	-0.5
5	0.5	0.6	0.4	0.4	-0.6	-0.6	-0.5	-0.5
6	0.5	0.5	0.4	0.3	-0.6	-0.6	-0.5	-0.5
7	0.5	0.5	0.4	0.3	-0.6	-0.6	-0.5	-0.5
8	0.5	0.5	0.4	0.3	-0.5	-0.6	-0.5	-0.5
9	0.5	0.5	0.4	0.3	-0.5	-0.6	-0.5	-0.5
10	0.5	0.5	0.4	0.3	-0.5	-0.6	-0.5	-0.5

Table I-14 **Maximum rolling 8-hour mean CO concentration at RWR receptors, ranked by percentage increase and by decrease in concentration**

Rank	Ranking by % increase in concentration relative to Do Minimum				Ranking by % decrease in concentration relative to Do Minimum			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	22.5%	22.9%	20.9%	14.8%	-20.8%	-22.0%	-20.8%	-22.7%
2	20.3%	21.8%	20.4%	14.8%	-20.8%	-22.0%	-19.5%	-17.8%
3	19.7%	21.3%	17.7%	14.7%	-19.8%	-20.8%	-19.5%	-17.5%
4	19.2%	21.0%	17.1%	13.7%	-19.2%	-18.3%	-18.6%	-17.0%
5	18.6%	19.7%	16.2%	13.6%	-18.5%	-18.1%	-17.4%	-16.9%
6	18.6%	19.3%	16.0%	13.6%	-17.8%	-17.7%	-17.2%	-16.9%
7	18.0%	19.3%	15.2%	13.5%	-17.2%	-17.1%	-17.2%	-16.9%
8	17.7%	19.2%	14.4%	13.5%	-16.8%	-17.0%	-16.8%	-16.5%
9	17.6%	19.0%	14.4%	13.3%	-16.7%	-17.0%	-15.5%	-16.5%
10	17.3%	18.0%	14.4%	13.3%	-16.1%	-16.9%	-15.5%	-15.6%

I.3 Nitrogen dioxide (annual mean)

Table I-15 Annual mean NO_2 concentration at community receptors

Receptor	Annual mean NO_2 concentration (µg/m^3)							Change relative to Do Minimum (µg/m^3)				Change relative to Do Minimum (%)			
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
CR01	-	28.2	28.2	27.8	27.9	27.7	27.3	0.0	-0.4	-0.2	-0.6	0.1%	-1.4%	-0.7%	-2.3%
CR02	-	22.7	23.0	22.6	22.3	22.7	22.4	0.3	-0.2	0.4	0.1	1.2%	-0.7%	1.9%	0.4%
CR03	-	22.6	22.9	23.4	22.3	22.4	22.9	0.3	0.9	0.1	0.6	1.4%	3.8%	0.5%	2.5%
CR04	-	21.8	21.8	21.6	21.7	21.6	21.5	-0.1	-0.2	-0.1	-0.2	-0.3%	-1.1%	-0.7%	-0.9%
CR05	-	22.2	21.3	21.6	21.4	21.6	21.2	-0.9	-0.6	0.2	-0.2	-4.2%	-2.7%	0.8%	-1.0%
CR06	-	25.0	25.9	23.2	24.8	26.1	23.8	0.8	-1.8	1.3	-1.1	3.3%	-7.3%	5.2%	-4.2%
CR07	-	19.0	18.7	18.7	18.4	18.6	18.3	-0.3	-0.3	0.2	-0.1	-1.5%	-1.6%	1.1%	-0.4%
CR08	-	25.1	23.9	23.3	24.3	23.8	23.0	-1.2	-1.8	-0.5	-1.4	-4.8%	-7.3%	-2.1%	-5.7%
CR09	-	19.1	18.9	19.3	19.0	18.7	19.0	-0.2	0.2	-0.2	0.1	-0.9%	1.0%	-1.1%	0.4%
CR10	-	22.0	22.0	21.4	22.2	21.1	20.9	0.1	-0.5	-1.1	-1.3	0.3%	-2.4%	-4.9%	-5.8%
CR11	-	26.8	25.8	25.4	26.0	24.9	24.6	-0.9	-1.3	-1.1	-1.5	-3.5%	-4.9%	-4.2%	-5.6%
CR12	-	21.2	20.2	20.3	20.3	19.7	20.1	-0.9	-0.9	-0.6	-0.3	-4.3%	-4.1%	-3.0%	-1.3%
CR13	-	18.0	17.9	17.6	17.8	17.6	17.7	-0.1	-0.3	-0.3	-0.1	-0.3%	-1.9%	-1.5%	-0.8%
CR14	-	26.9	25.3	25.1	26.2	23.8	23.9	-1.6	-1.7	-2.4	-2.3	-5.9%	-6.4%	-9.1%	-8.8%
CR15	-	17.7	17.1	17.0	17.3	17.1	16.8	-0.7	-0.7	-0.2	-0.5	-3.8%	-4.1%	-1.1%	-2.7%
CR16	-	21.7	21.5	22.0	21.4	21.0	21.6	-0.2	0.2	-0.4	0.2	-1.0%	1.1%	-1.8%	1.1%
CR17	-	19.8	19.8	20.0	19.7	19.3	19.8	-0.1	0.1	-0.4	0.1	-0.5%	0.6%	-1.9%	0.7%
CR18	-	19.3	18.7	19.4	18.7	18.8	18.9	-0.6	0.1	0.1	0.2	-3.0%	0.3%	0.7%	1.2%
CR19	-	21.0	20.3	20.2	20.8	20.2	20.0	-0.6	-0.8	-0.6	-0.7	-3.0%	-3.7%	-2.6%	-3.6%
CR20	-	20.5	20.7	20.4	20.4	19.9	19.6	0.2	-0.1	-0.5	-0.8	0.8%	-0.6%	-2.4%	-3.9%
CR21	-	19.2	19.7	19.5	18.9	19.1	19.1	0.5	0.3	0.2	0.2	2.6%	1.7%	1.2%	0.9%
CR22	-	20.2	20.6	20.5	19.7	20.0	19.9	0.4	0.3	0.3	0.2	2.1%	1.4%	1.6%	1.1%
CR23	-	22.3	22.6	22.6	21.9	22.1	22.6	0.3	0.3	0.3	0.7	1.4%	1.5%	1.3%	3.2%
CR24	-	18.3	18.3	18.4	18.0	18.0	17.9	0.0	0.1	0.0	-0.1	0.1%	0.4%	0.0%	-0.6%
CR25	-	20.7	20.2	20.7	20.5	19.7	20.2	-0.5	0.0	-0.8	-0.3	-2.5%	-0.1%	-3.9%	-1.4%
CR26	-	20.0	19.1	19.1	19.9	18.8	18.6	-0.8	-0.8	-1.1	-1.2	-4.1%	-4.2%	-5.6%	-6.3%
CR27	-	17.3	17.4	17.1	17.2	16.7	16.8	0.1	-0.2	-0.5	-0.3	0.6%	-1.0%	-2.7%	-1.9%
CR28	-	32.3	29.8	29.7	33.1	29.2	28.8	-2.6	-2.6	-3.9	-4.3	-7.9%	-8.1%	-11.7%	-13.1%
CR29	-	16.6	16.4	16.4	16.2	16.0	16.0	-0.2	-0.2	-0.2	-0.1	-1.5%	-1.2%	-1.0%	-0.7%
CR30	-	17.2	17.4	17.7	17.6	16.8	17.2	0.3	0.5	-0.8	-0.4	1.5%	3.0%	-4.7%	-2.5%
CR31	-	17.2	18.1	17.6	17.0	17.4	17.5	0.9	0.4	0.4	0.5	5.1%	2.6%	2.2%	3.0%
CR32	-	15.1	15.1	14.9	14.8	14.9	15.1	0.0	-0.1	0.1	0.2	0.1%	-0.9%	0.7%	1.7%
CR33	-	15.2	15.1	15.1	15.0	14.9	14.9	-0.2	-0.1	-0.2	-0.1	-1.1%	-0.5%	-1.0%	-0.7%
CR34	-	16.2	16.4	16.2	15.9	16.5	16.3	0.2	-0.1	0.6	0.4	1.0%	-0.4%	3.6%	2.7%
CR35	-	14.6	14.8	14.8	14.6	14.7	14.7	0.2	0.2	0.1	0.1	1.6%	1.6%	1.0%	0.8%
CR36	-	14.7	14.6	15.1	14.6	14.7	14.7	-0.1	0.4	0.1	0.1	-0.7%	2.8%	0.7%	1.0%
CR37	-	18.5	19.2	18.9	17.6	18.8	18.6	0.7	0.5	1.2	1.0	4.0%	2.6%	6.7%	5.5%
CR38	-	17.6	17.1	16.9	17.4	16.4	16.8	-0.6	-0.8	-0.9	-0.6	-3.2%	-4.3%	-5.5%	-3.2%
CR39	-	17.6	17.1	16.9	17.1	16.8	17.0	-0.5	-0.7	-0.3	-0.2	-2.9%	-3.8%	-2.0%	-1.0%
CR40	-	15.3	15.1	15.3	15.7	15.0	14.9	-0.2	0.0	-0.7	-0.8	-1.3%	0.1%	-4.5%	-4.9%
CR41	-	15.4	15.0	14.9	15.6	14.9	14.9	-0.4	-0.4	-0.7	-0.8	-2.3%	-2.8%	-4.5%	-4.9%
CR42	-	15.5	15.4	15.5	15.3	15.2	15.4	-0.1	0.0	-0.1	0.2	-0.4%	0.1%	-0.4%	1.1%

Table I-16 Annual mean NO_2 concentration at community receptors, ranked by concentration

Rank	Ranking by concentration (µg/m^3)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	32.3	29.8	29.7	33.1	29.2	28.8
2	-	28.2	28.2	27.8	27.9	27.7	27.3
3	-	26.9	25.9	25.4	26.2	26.1	24.6
4	-	26.8	25.8	25.1	26.0	24.9	23.9
5	-	25.1	25.3	23.4	24.8	23.8	23.8
6	-	25.0	23.9	23.3	24.3	23.8	23.0
7	-	22.7	23.0	23.2	22.3	22.7	22.9
8	-	22.6	22.9	22.6	22.3	22.4	22.6
9	-	22.3	22.6	22.6	22.2	22.1	22.4
10	-	22.2	22.0	22.0	21.9	21.6	21.6

Table I-17 Annual mean NO_2 concentration at community receptors, ranked by increase and by decrease in concentration

Rank	Ranking by increase in concentration relative to Do Minimum (µg/m^3)				Ranking by decrease in concentration relative to Do Minimum (µg/m^3)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	0.87	0.86	1.30	0.97	-2.56	-2.60	-3.87	-4.32
2	0.82	0.51	1.17	0.71	-1.59	-1.84	-2.39	-2.32
3	0.74	0.48	0.57	0.56	-1.22	-1.83	-1.11	-1.45
4	0.50	0.44	0.43	0.52	-0.94	-1.73	-1.10	-1.38
5	0.42	0.40	0.37	0.43	-0.94	-1.32	-1.09	-1.28
6	0.32	0.34	0.32	0.25	-0.91	-0.86	-0.95	-1.25
7	0.30	0.33	0.28	0.25	-0.83	-0.85	-0.83	-1.05
8	0.27	0.29	0.24	0.22	-0.67	-0.78	-0.79	-0.79
9	0.25	0.25	0.20	0.21	-0.62	-0.76	-0.71	-0.76
10	0.23	0.23	0.18	0.18	-0.58	-0.72	-0.70	-0.76

Table I-18 Annual mean NO_2 concentration at community receptors, ranked by percentage increase and by decrease in concentration

Rank	Ranking by % increase in concentration relative to Do Minimum				Ranking by % decrease in concentration relative to Do Minimum			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	5.1%	3.8%	6.7%	5.5%	5.1%	3.8%	6.7%	5.5%
2	4.0%	3.0%	5.2%	3.2%	4.0%	3.0%	5.2%	3.2%
3	3.3%	2.8%	3.6%	3.0%	3.3%	2.8%	3.6%	3.0%
4	2.6%	2.6%	2.2%	2.7%	2.6%	2.6%	2.2%	2.7%
5	2.1%	2.6%	1.9%	2.5%	2.1%	2.6%	1.9%	2.5%
6	1.6%	1.7%	1.6%	1.7%	1.6%	1.7%	1.6%	1.7%
7	1.5%	1.6%	1.3%	1.2%	1.5%	1.6%	1.3%	1.2%
8	1.4%	1.5%	1.2%	1.1%	1.4%	1.5%	1.2%	1.1%
9	1.4%	1.4%	1.1%	1.1%	1.4%	1.4%	1.1%	1.1%
10	1.2%	1.1%	1.0%	1.1%	1.2%	1.1%	1.0%	1.1%

Table I-19 Annual mean NO_2 concentration at RWR receptors, ranked by concentration

Rank	Ranking by concentration (µg/m³)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	43.5	40.7	35.5	39.4	40.6	33.8
2	-	38.2	35.7	32.6	37.1	36.5	31.9
3	-	35.7	35.5	32.5	35.0	35.6	31.9
4	-	34.5	35.4	31.8	34.9	34.5	31.4
5	-	34.3	34.7	31.3	34.3	34.1	31.1
6	-	34.1	33.8	31.3	33.8	34.0	31.0
7	-	33.8	33.6	31.2	33.7	34.0	31.0
8	-	33.8	33.5	31.0	33.7	33.6	30.9
9	-	33.7	33.5	31.0	33.5	33.4	30.7
10	-	33.4	33.2	31.0	33.5	33.1	30.6

Table I-20 Annual mean NO_2 concentration at RWR receptors, ranked by increase and by decrease in concentration

Rank	Ranking by increase in concentration relative to Do Minimum (µg/m³)				Ranking by decrease in concentration relative to Do Minimum (µg/m³)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	5.5	3.9	6.0	3.1	-7.2	-7.8	-5.7	-6.2
2	4.0	2.3	3.6	2.9	-6.4	-6.0	-5.3	-6.1
3	2.8	2.2	3.4	2.9	-5.7	-6.0	-5.1	-5.8
4	2.7	2.2	3.2	2.3	-4.9	-5.3	-5.1	-5.7
5	2.5	1.9	2.3	2.2	-4.8	-5.0	-5.0	-5.1
6	2.3	1.9	2.3	2.2	-4.5	-4.8	-4.4	-5.1
7	2.2	1.8	2.3	2.2	-4.4	-4.8	-4.3	-5.0
8	2.1	1.8	2.1	2.1	-4.3	-4.6	-4.1	-5.0
9	2.0	1.8	2.0	2.1	-4.0	-4.4	-4.1	-4.9
10	1.9	1.7	2.0	2.0	-3.8	-4.2	-4.0	-4.9

Table I-21 Annual mean NO_2 concentration at RWR receptors, ranked by percentage increase and by decrease in concentration

Rank	Ranking by % increase in concentration relative to Do Minimum				Ranking by % decrease in concentration relative to Do Minimum			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	20.8%	20.0%	19.8%	16.3%	-22.6%	-24.3%	-20.1%	-22.0%
2	18.4%	12.4%	16.4%	15.5%	-22.5%	-21.1%	-18.4%	-19.1%
3	12.5%	12.3%	13.7%	14.5%	-19.0%	-17.6%	-18.3%	-19.0%
4	10.9%	11.9%	13.6%	13.0%	-16.5%	-17.5%	-18.0%	-18.1%
5	10.1%	11.4%	12.1%	12.6%	-16.5%	-17.4%	-17.7%	-18.0%
6	9.9%	10.6%	11.3%	11.6%	-16.0%	-15.7%	-15.2%	-17.9%
7	9.8%	9.9%	10.9%	10.9%	-14.5%	-14.9%	-15.2%	-17.0%
8	9.4%	9.9%	10.9%	10.9%	-14.3%	-14.9%	-15.0%	-16.6%
9	9.3%	9.8%	10.7%	10.9%	-13.3%	-14.8%	-15.0%	-16.5%
10	9.1%	9.7%	10.5%	10.4%	-13.3%	-14.6%	-14.9%	-16.3%

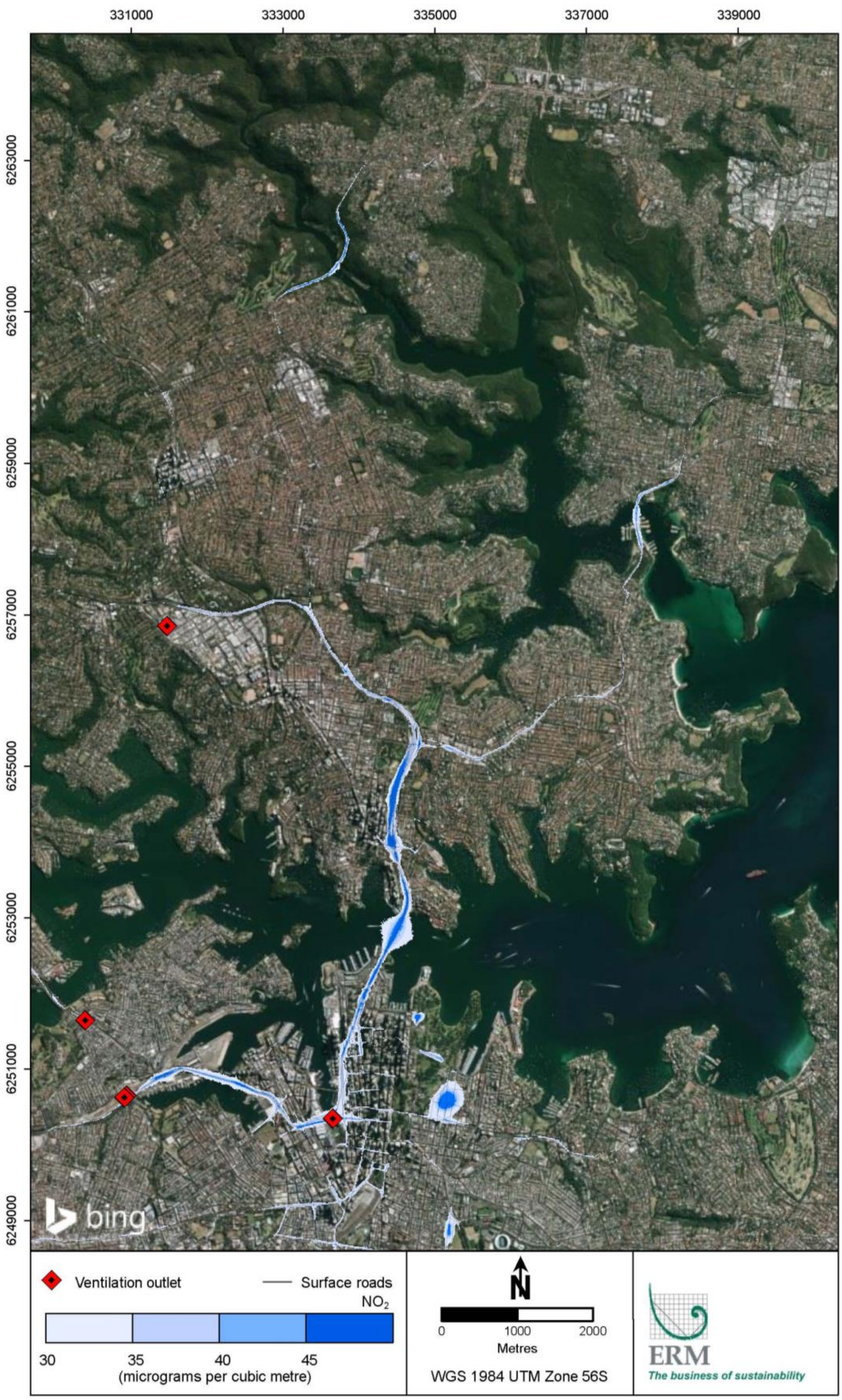


Figure I-1 **Contour plot of annual mean NO_2 concentration in the 2027 Do Minimum scenario (all sources, 2027-DM)**

Figure I-2 **Contour plot of annual mean NO_2 concentration in the 2027 Do Something scenario (all sources, 2027-DS(BL))**

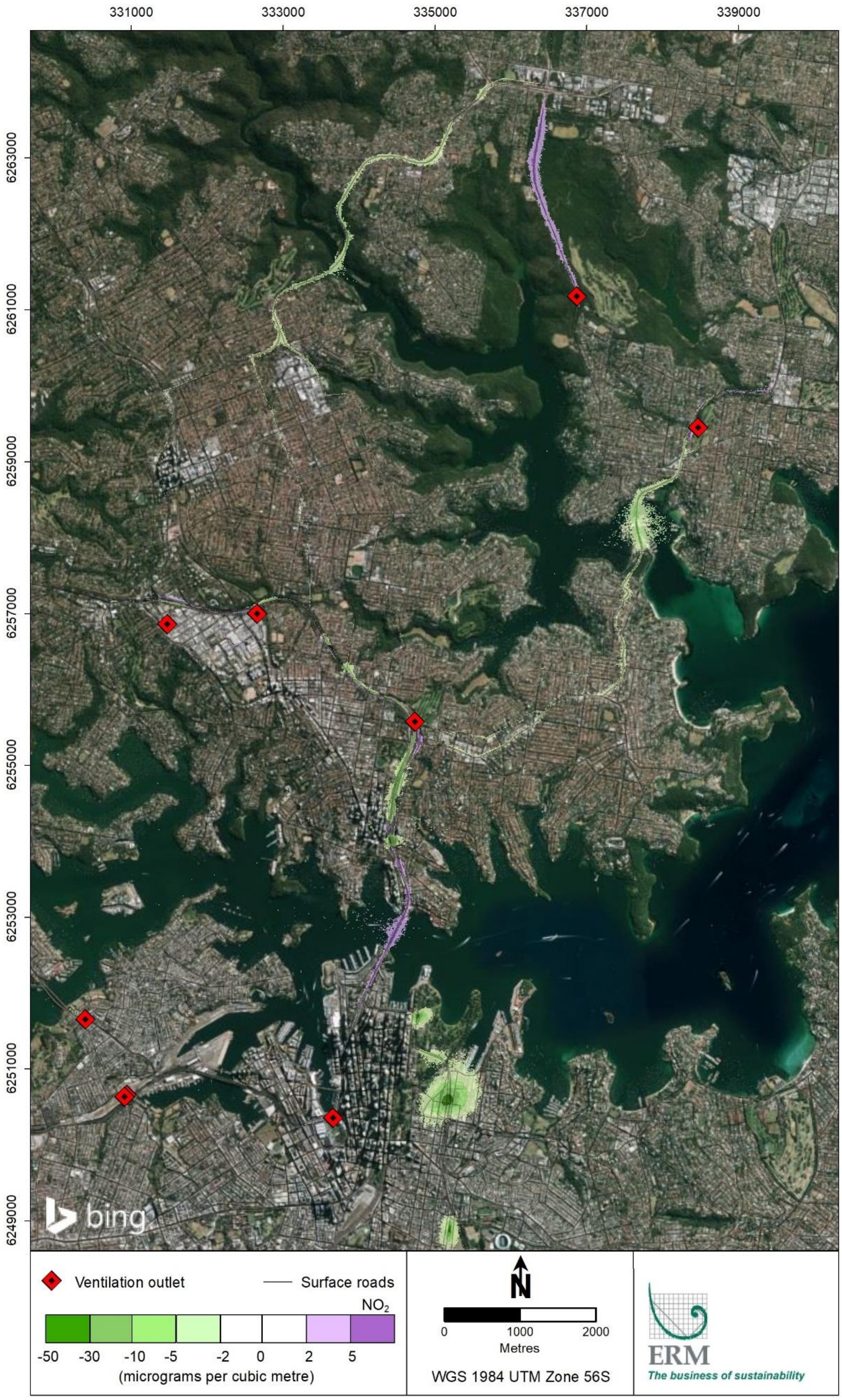


Figure I-3 **Contour plot of change in annual mean NO_2 concentration in the 2027 Do something scenario (all sources, 2027-DS(BL) minus 2027-DM)**

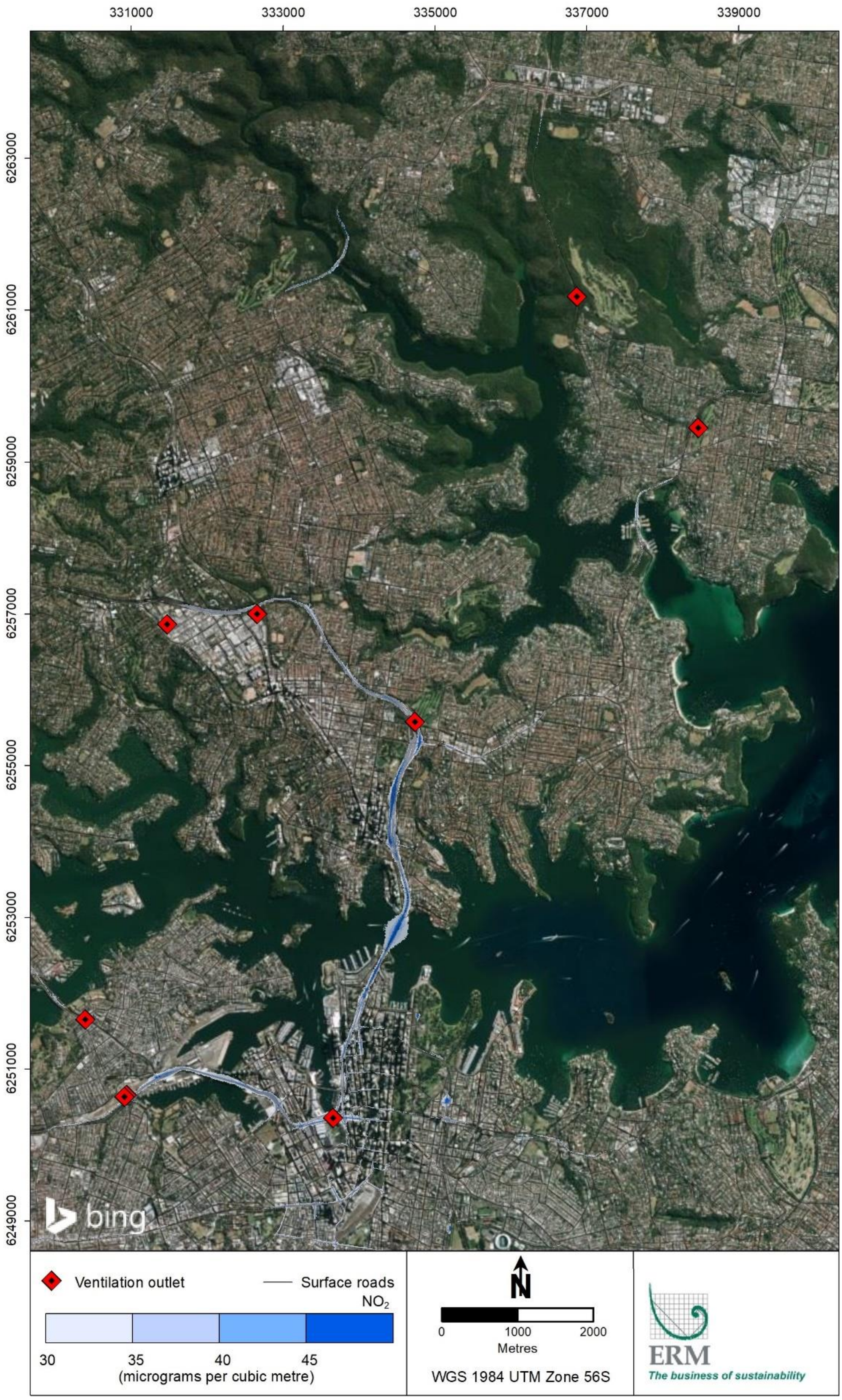


Figure I-4 **Contour plot of annual mean NO_2 concentration in the 2027 cumulative scenario (all sources, 2027-DSC)**

Figure I-5 **Contour plot of change in annual mean NO_2 concentration in the 2027 cumulative scenario (all sources, 2027-DSC minus 2027-DM)**

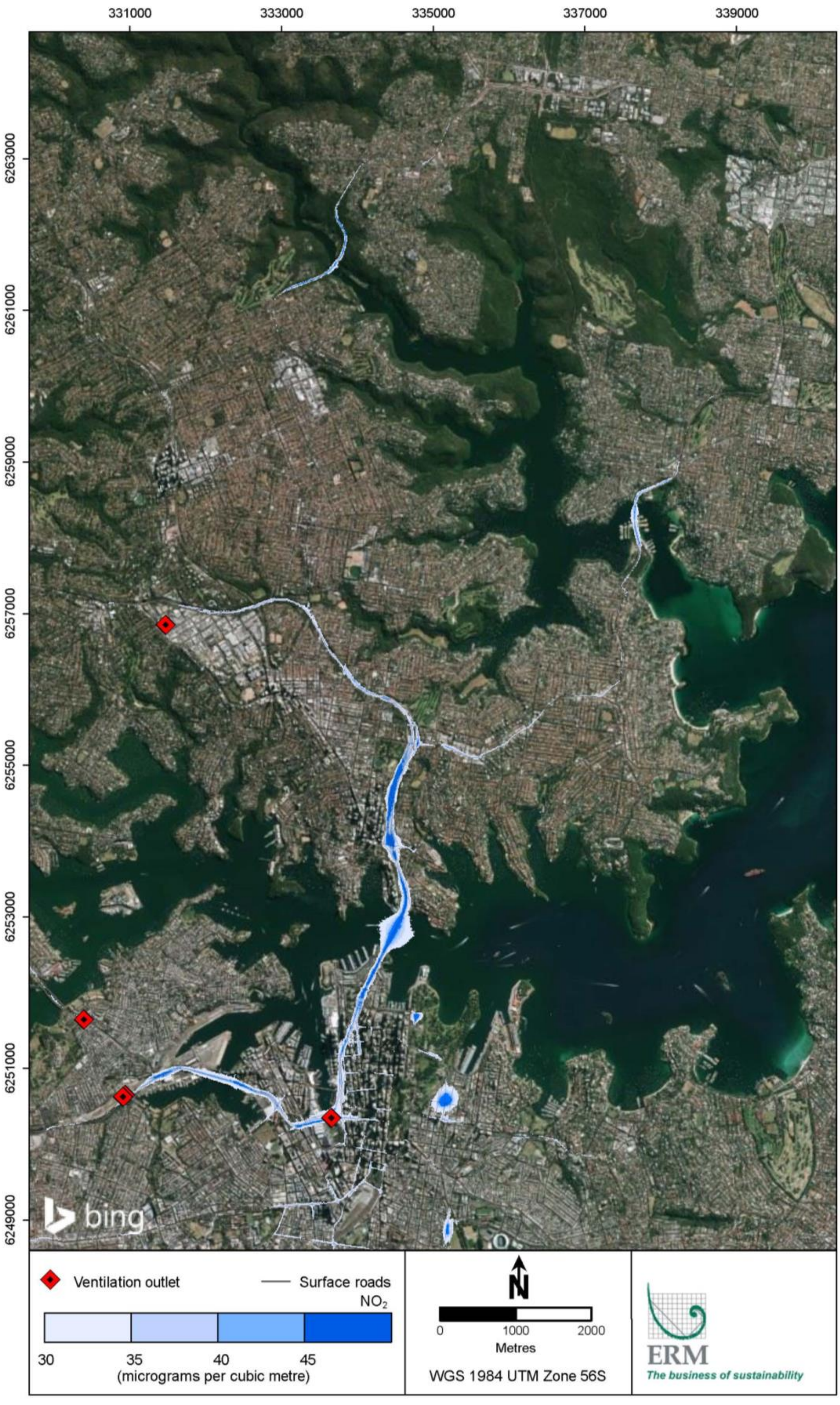


Figure I-6 **Contour plot of annual mean NO_2 concentration in the 2037 Do Minimum scenario (all sources, 2037-DM)**

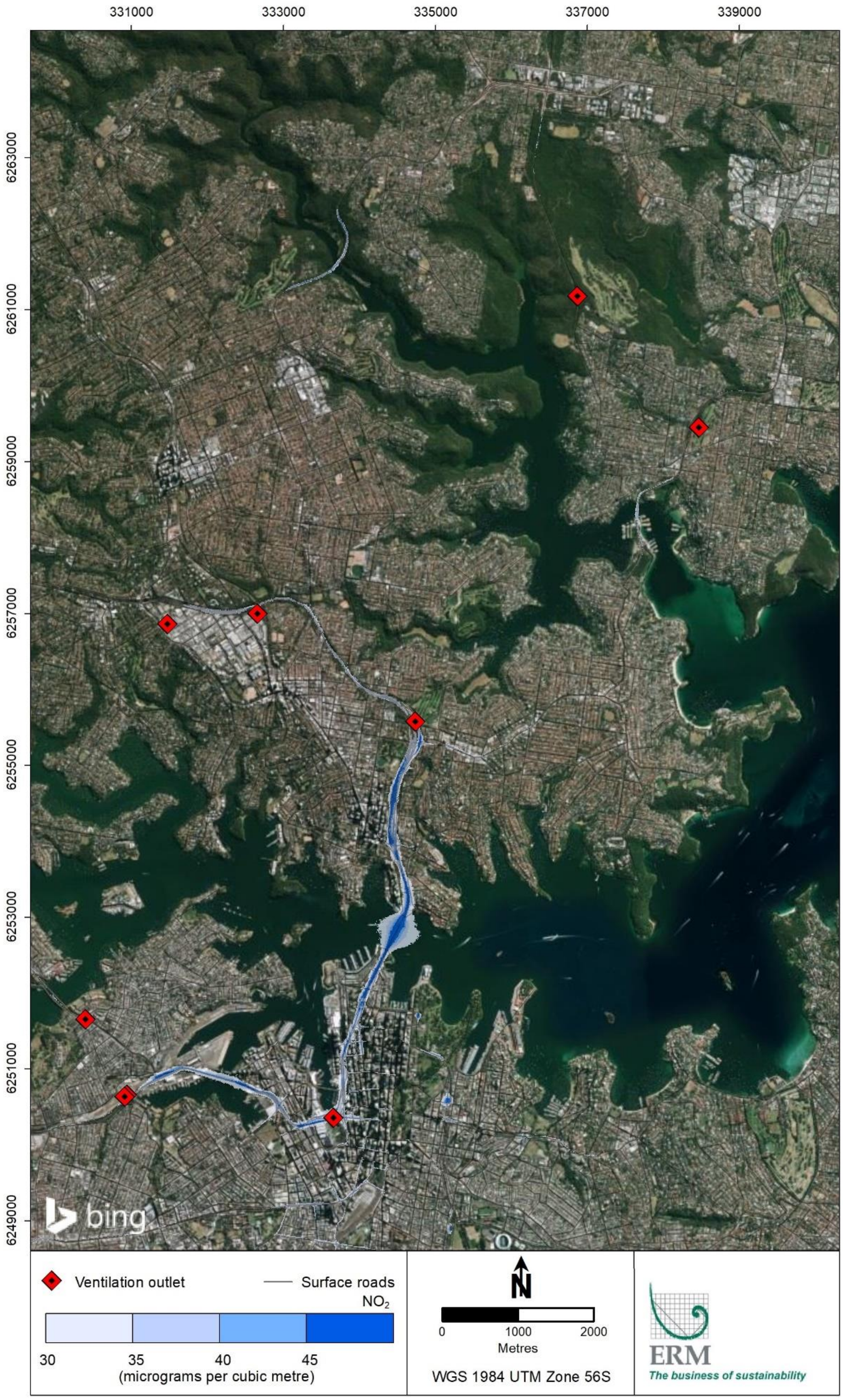


Figure I-7 **Contour plot of annual mean NO_2 concentration in the 2037 Do Something scenario (all sources, 2037-DS(BL))**

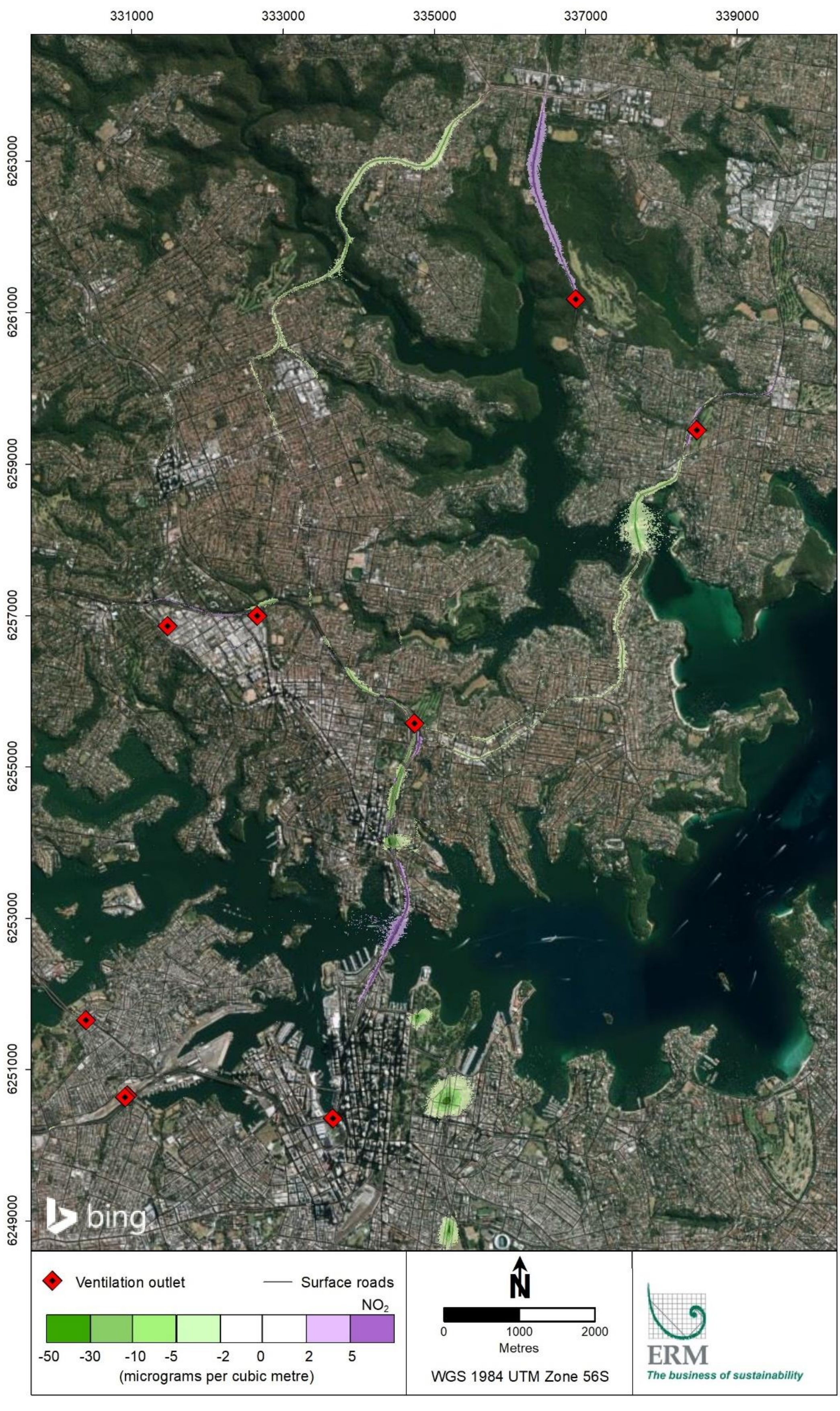


Figure I-8 **Contour plot of change in annual mean NO_2 concentration in the 2037 Do Something scenario (all sources, 2037-DS(BL) minus 2037-DM)**

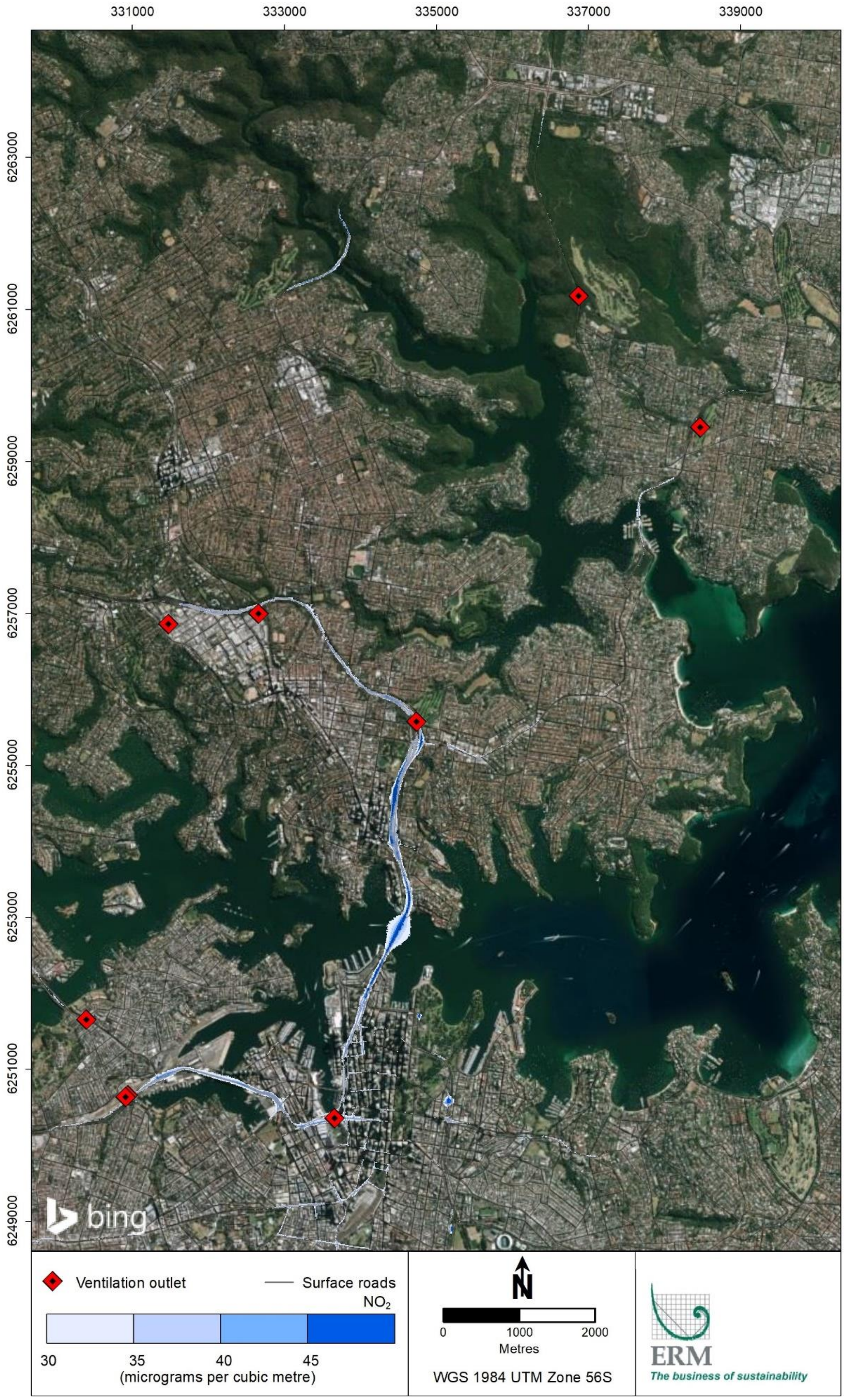


Figure I-9 **Contour plot of annual mean NO_2 concentration in the 2037 cumulative scenario (all sources, 2037-DSC)**

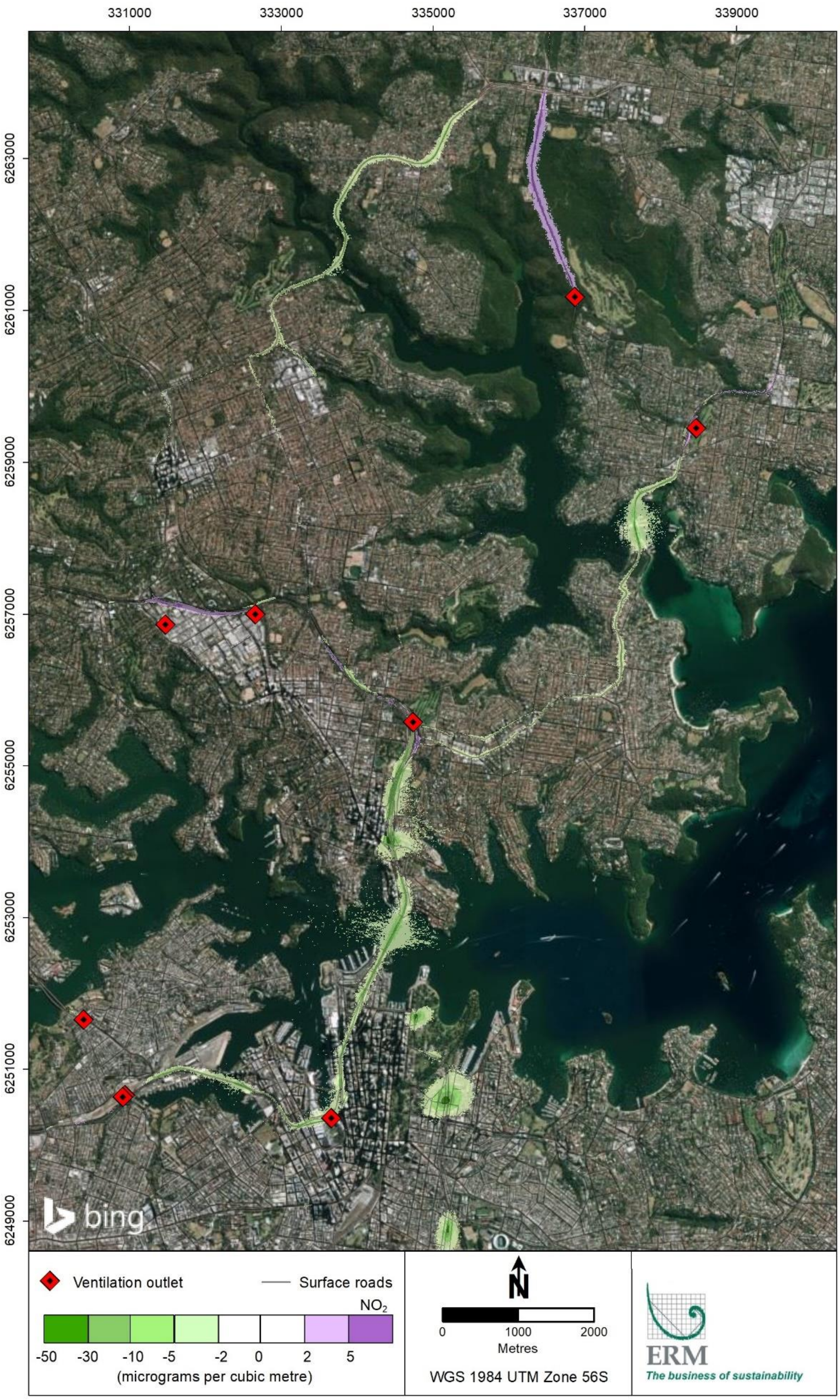


Figure I-10 **Contour plot of change in annual mean NO_2 concentration in the 2037 cumulative scenario (all sources, 2037-DSC minus 2037-DM)**

I.4 Nitrogen dioxide (maximum 1-hour mean)

Table I-22 Maximum 1-hour mean NO_2 concentration at community receptors

Receptor	Maximum 1-hour mean NO_2 concentration (µg/m^3)							Change relative to Do Minimum (µg/m^3)				Change relative to Do Minimum (%)			
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
CR01	-	212.0	207.3	207.3	212.4	209.1	206.5	-4.6	-4.6	-3.3	-5.9	-2.2%	-2.2%	-1.5%	-2.8%
CR02	-	197.2	197.4	195.5	195.7	202.4	193.1	0.3	-1.6	6.7	-2.6	0.1%	-0.8%	3.4%	-1.4%
CR03	-	194.4	195.9	203.3	195.3	195.7	204.1	1.5	8.9	0.4	8.8	0.8%	4.6%	0.2%	4.5%
CR04	-	188.5	189.3	190.2	195.4	192.3	189.0	0.7	1.6	-3.1	-6.4	0.4%	0.9%	-1.6%	-3.3%
CR05	-	189.8	193.8	191.0	189.8	189.1	189.2	4.0	1.2	-0.7	-0.6	2.1%	0.6%	-0.3%	-0.3%
CR06	-	202.7	206.4	201.5	204.8	205.3	200.6	3.7	-1.2	0.5	-4.2	1.8%	-0.6%	0.2%	-2.0%
CR07	-	188.9	188.8	188.3	187.9	187.5	187.1	-0.2	-0.6	-0.3	-0.7	-0.1%	-0.3%	-0.2%	-0.4%
CR08	-	192.8	193.2	191.8	195.0	187.4	193.4	0.4	-1.0	-7.5	-1.5	0.2%	-0.5%	-3.9%	-0.8%
CR09	-	189.9	189.0	189.2	190.8	189.3	195.8	-0.8	-0.7	-1.5	4.9	-0.4%	-0.4%	-0.8%	2.6%
CR10	-	195.0	191.6	191.9	194.7	191.5	193.8	-3.4	-3.1	-3.2	-0.8	-1.7%	-1.6%	-1.6%	-0.4%
CR11	-	205.1	208.6	210.3	207.0	200.0	199.3	3.5	5.1	-7.0	-7.7	1.7%	2.5%	-3.4%	-3.7%
CR12	-	192.3	189.8	193.1	194.1	188.9	191.7	-2.5	0.8	-5.2	-2.4	-1.3%	0.4%	-2.7%	-1.2%
CR13	-	187.7	188.5	189.7	188.1	188.0	188.1	0.8	1.9	0.0	0.1	0.4%	1.0%	0.0%	0.0%
CR14	-	208.6	209.1	208.0	199.1	197.2	201.9	0.5	-0.7	-2.0	2.8	0.2%	-0.3%	-1.0%	1.4%
CR15	-	195.4	196.9	187.7	196.5	194.4	190.2	1.5	-7.7	-2.0	-6.3	0.8%	-3.9%	-1.0%	-3.2%
CR16	-	195.1	193.2	195.8	192.5	201.4	193.2	-1.9	0.7	8.9	0.7	-1.0%	0.3%	4.6%	0.4%
CR17	-	190.0	192.4	194.0	193.5	189.9	193.3	2.5	4.0	-3.6	-0.2	1.3%	2.1%	-1.8%	-0.1%
CR18	-	190.6	187.8	188.0	188.3	188.4	191.0	-2.8	-2.7	0.1	2.6	-1.5%	-1.4%	0.0%	1.4%
CR19	-	190.0	194.0	195.5	194.7	191.7	194.3	4.0	5.5	-2.9	-0.4	2.1%	2.9%	-1.5%	-0.2%
CR20	-	192.0	191.6	193.6	191.2	188.4	189.9	-0.4	1.6	-2.8	-1.3	-0.2%	0.8%	-1.5%	-0.7%
CR21	-	191.8	193.7	196.2	190.3	192.2	194.9	1.9	4.3	1.9	4.5	1.0%	2.3%	1.0%	2.4%
CR22	-	197.2	193.7	192.1	189.6	190.1	190.4	-3.5	-5.1	0.4	0.8	-1.8%	-2.6%	0.2%	0.4%
CR23	-	193.4	198.4	195.5	198.1	195.4	196.0	5.0	2.2	-2.7	-2.0	2.6%	1.1%	-1.3%	-1.0%
CR24	-	193.1	187.6	187.1	189.9	187.1	187.5	-5.6	-6.0	-2.8	-2.4	-2.9%	-3.1%	-1.4%	-1.3%
CR25	-	200.9	189.8	192.9	192.0	188.6	188.1	-11.0	-8.0	-3.5	-3.9	-5.5%	-4.0%	-1.8%	-2.0%
CR26	-	191.0	190.5	190.2	188.3	188.0	188.9	-0.5	-0.8	-0.3	0.6	-0.3%	-0.4%	-0.2%	0.3%
CR27	-	188.8	187.7	188.7	190.0	189.2	189.6	-1.1	-0.1	-0.8	-0.5	-0.6%	-0.1%	-0.4%	-0.2%
CR28	-	196.8	193.1	199.8	197.8	194.6	193.9	-3.6	3.0	-3.1	-3.9	-1.8%	1.5%	-1.6%	-1.9%
CR29	-	188.6	189.0	187.1	188.0	188.2	189.2	0.3	-1.5	0.2	1.2	0.2%	-0.8%	0.1%	0.7%
CR30	-	190.2	189.0	189.4	194.3	193.5	188.7	-1.2	-0.9	-0.8	-5.6	-0.6%	-0.5%	-0.4%	-2.9%
CR31	-	190.2	191.9	190.4	191.9	190.6	188.6	1.7	0.2	-1.3	-3.3	0.9%	0.1%	-0.7%	-1.7%
CR32	-	189.8	187.6	187.3	188.2	187.1	187.1	-2.2	-2.5	-1.0	-1.0	-1.2%	-1.3%	-0.5%	-0.5%
CR33	-	187.2	187.8	188.9	188.0	188.4	187.1	0.5	1.6	0.4	-0.8	0.3%	0.9%	0.2%	-0.4%
CR34	-	187.3	187.9	187.8	187.8	189.5	187.7	0.7	0.5	1.6	-0.2	0.4%	0.3%	0.9%	-0.1%
CR35	-	187.1	190.0	187.1	187.9	187.1	187.1	2.8	0.0	-0.7	-0.7	1.5%	0.0%	-0.4%	-0.4%
CR36	-	187.1	188.6	187.1	187.8	187.8	187.9	1.4	0.0	0.1	0.1	0.8%	0.0%	0.0%	0.1%
CR37	-	195.4	193.5	190.6	189.7	189.5	189.2	-1.9	-4.8	-0.2	-0.4	-1.0%	-2.5%	-0.1%	-0.2%
CR38	-	188.8	188.8	188.8	187.7	189.1	187.9	-0.1	0.0	1.3	0.2	0.0%	0.0%	0.7%	0.1%
CR39	-	188.9	187.8	189.7	189.6	187.1	192.1	-1.0	0.8	-2.5	2.5	-0.5%	0.4%	-1.3%	1.3%
CR40	-	190.3	187.1	187.1	187.1	187.1	187.4	-3.2	-3.2	0.0	0.2	-1.7%	-1.7%	0.0%	0.1%
CR41	-	187.1	187.1	187.6	187.9	188.1	187.6	0.0	0.4	0.2	-0.3	0.0%	0.2%	0.1%	-0.1%
CR42	-	188.5	188.1	188.1	189.3	187.1	189.5	-0.4	-0.4	-2.1	0.2	-0.2%	-0.2%	-1.1%	0.1%

Table I-23 **Maximum 1-hour mean NO_2 concentration at community receptors, ranked by concentration**

Rank		Ranking by concentration (µg/m³)						
		2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1		-	212.0	209.1	210.3	212.4	209.1	206.5
2		-	208.6	208.6	208.0	207.0	205.3	204.1
3		-	205.1	207.3	207.3	204.8	202.4	201.9
4		-	202.7	206.4	203.3	199.1	201.4	200.6
5		-	200.9	198.4	201.5	198.1	200.0	199.3
6		-	197.2	197.4	199.8	197.8	197.2	196.0
7		-	197.2	196.9	196.2	196.5	195.7	195.8
8		-	196.8	195.9	195.8	195.7	195.4	194.9
9		-	195.4	194.0	195.5	195.4	194.6	194.3
10		-	195.4	193.8	195.5	195.3	194.4	193.9

Table I-24 **Maximum 1-hour mean NO_2 concentration at community receptors, ranked by increase and by decrease in concentration**

Rank		Ranking by increase in concentration relative to Do Minimum (µg/m³)					Ranking by decrease in concentration relative to Do Minimum (µg/m³)			
		2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC		2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1		5.0	8.9	8.9	8.8		-11.0	-8.0	-7.5	-7.7
2		4.0	5.5	6.7	4.9		-5.6	-7.7	-7.0	-6.4
3		4.0	5.1	1.9	4.5		-4.6	-6.0	-5.2	-6.3
4		3.7	4.3	1.6	2.8		-3.6	-5.1	-3.6	-5.9
5		3.5	4.0	1.3	2.6		-3.5	-4.8	-3.5	-5.6
6		2.8	3.0	0.5	2.5		-3.4	-4.6	-3.3	-4.2
7		2.5	2.2	0.4	1.2		-3.2	-3.2	-3.2	-3.9
8		1.9	1.9	0.4	0.8		-2.8	-3.1	-3.1	-3.9
9		1.7	1.6	0.4	0.7		-2.5	-2.7	-3.1	-3.3
10		1.5	1.6	0.2	0.6		-2.2	-2.5	-2.9	-2.6

Table I-25 **Maximum 1-hour mean NO_2 concentration at community receptors, ranked by percentage increase and by decrease in concentration**

Rank		Ranking by % increase in concentration relative to Do Minimum					Ranking by % decrease in concentration relative to Do Minimum			
		2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC		2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1		2.6%	4.6%	4.6%	4.5%		-5.5%	-4.0%	-3.9%	-3.7%
2		2.1%	2.9%	3.4%	2.6%		-2.9%	-3.9%	-3.4%	-3.3%
3		2.1%	2.5%	1.0%	2.4%		-2.2%	-3.1%	-2.7%	-3.2%
4		1.8%	2.3%	0.9%	1.4%		-1.8%	-2.6%	-1.8%	-2.9%
5		1.7%	2.1%	0.7%	1.4%		-1.8%	-2.5%	-1.8%	-2.8%
6		1.5%	1.5%	0.2%	1.3%		-1.7%	-2.2%	-1.6%	-2.0%
7		1.3%	1.1%	0.2%	0.7%		-1.7%	-1.7%	-1.6%	-2.0%
8		1.0%	1.0%	0.2%	0.4%		-1.5%	-1.6%	-1.6%	-1.9%
9		0.9%	0.9%	0.2%	0.4%		-1.3%	-1.4%	-1.5%	-1.7%
10		0.8%	0.9%	0.1%	0.3%		-1.2%	-1.3%	-1.5%	-1.4%

Table I-26 Maximum 1-hour mean NO_2 concentration at RWR receptors, ranked by concentration

Rank	Ranking by concentration (µg/m³)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	466.8	474.6	363.5	432.7	485.3	441.7
2	-	409.1	375.8	339.9	406.2	418.9	323.9
3	-	393.6	375.2	320.4	406.2	417.4	317.9
4	-	393.6	364.7	295.0	401.3	415.2	315.5
5	-	393.6	357.9	293.4	394.5	411.8	314.7
6	-	388.0	352.7	289.4	393.0	402.1	301.0
7	-	349.1	352.7	287.1	391.7	389.1	301.0
8	-	345.2	341.7	286.1	387.9	386.2	300.5
9	-	345.2	340.2	286.1	373.4	381.7	298.7
10	-	338.9	338.9	285.3	371.3	381.1	296.7

Table I-27 Maximum 1-hour mean NO_2 concentration at RWR receptors, ranked by increase and by decrease in concentration

Rank	Ranking by increase in concentration relative to Do Minimum (µg/m³)				Ranking by decrease in concentration relative to Do Minimum (µg/m³)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	111.2	95.2	116.6	84.6	-147.7	-110.0	-174.5	-178.2
2	106.9	50.7	102.9	43.0	-123.0	-110.0	-133.1	-176.6
3	101.8	50.1	99.7	42.1	-123.0	-108.2	-124.1	-176.6
4	84.2	48.3	97.4	36.5	-120.9	-104.1	-124.1	-141.9
5	79.2	48.1	96.0	35.9	-116.7	-99.3	-116.3	-133.7
6	79.2	44.0	94.0	34.6	-98.3	-93.0	-116.3	-109.4
7	70.8	41.8	89.2	33.9	-97.6	-91.7	-116.3	-104.7
8	68.6	37.0	79.0	30.0	-91.0	-90.7	-96.8	-104.7
9	65.5	34.4	77.8	28.4	-90.7	-89.1	-96.3	-102.6
10	65.0	33.8	76.7	28.4	-86.1	-88.1	-90.3	-101.7

Table I-28 Maximum 1-hour mean NO_2 concentration at RWR receptors, ranked by percentage increase and by decrease in concentration

Rank	Ranking by % increase in concentration relative to Do Minimum				Ranking by % decrease in concentration relative to Do Minimum			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	48.9%	42.3%	46.7%	23.7%	-35.7%	-33.0%	-44.2%	-45.2%
2	48.2%	22.7%	39.5%	20.3%	-34.6%	-31.3%	-37.7%	-43.5%
3	38.7%	21.8%	39.1%	18.5%	-31.6%	-30.7%	-36.3%	-43.5%
4	33.3%	21.7%	34.5%	16.8%	-31.3%	-29.9%	-36.3%	-39.5%
5	29.7%	20.4%	34.2%	16.6%	-31.3%	-29.0%	-32.4%	-37.9%
6	29.0%	20.0%	34.0%	16.0%	-31.0%	-29.0%	-30.5%	-32.3%
7	29.0%	18.4%	32.2%	14.5%	-29.7%	-28.0%	-29.3%	-32.3%
8	27.5%	16.8%	31.2%	13.1%	-29.4%	-28.0%	-29.2%	-32.0%
9	25.9%	15.5%	30.5%	13.1%	-28.4%	-28.0%	-29.2%	-30.7%
10	25.9%	15.3%	30.5%	12.8%	-28.0%	-27.5%	-29.0%	-29.9%

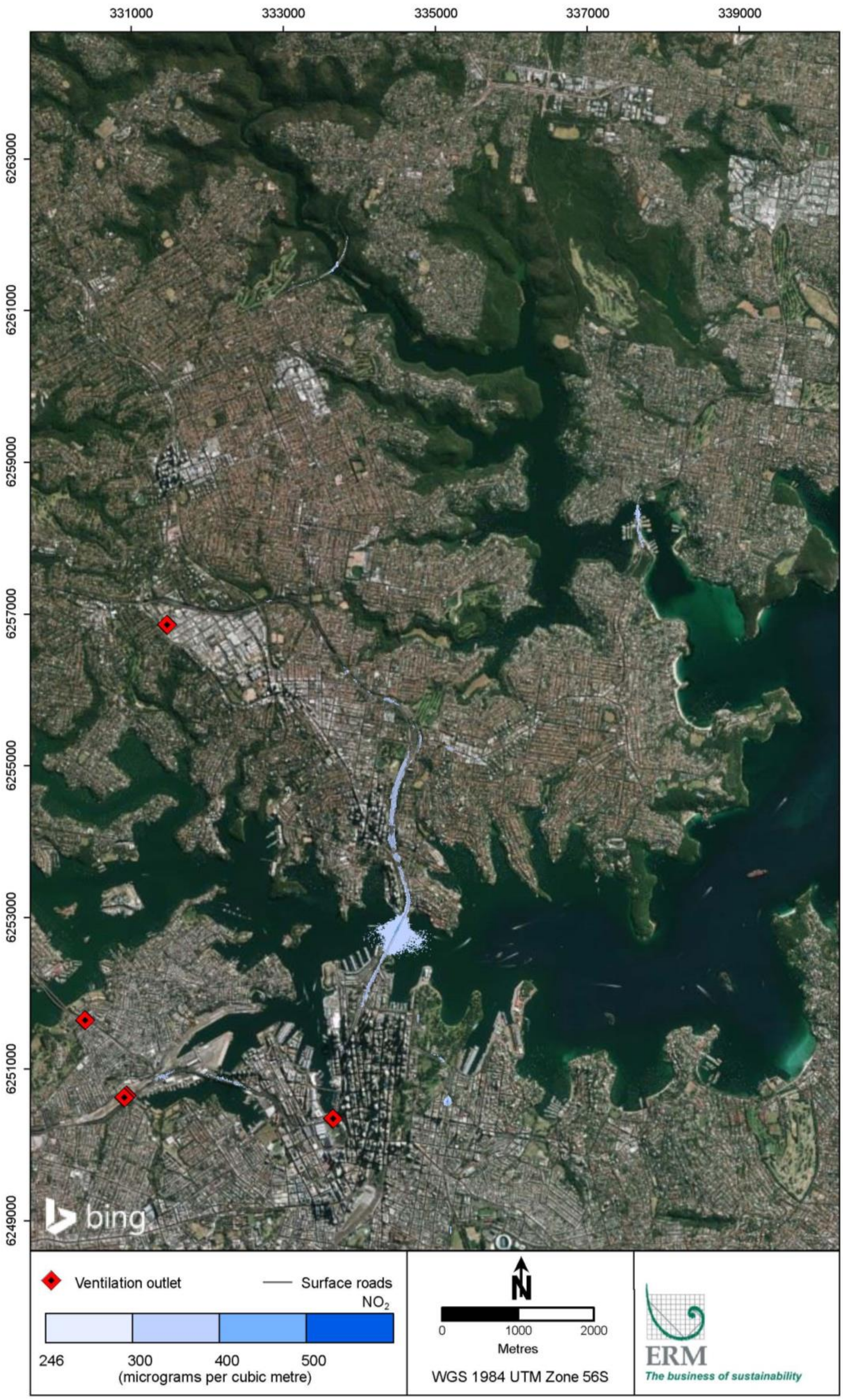


Figure I-11 **Contour plot of maximum 1-hour mean NO_2 concentration in the 2027 Do Minimum scenario (all sources, 2027-DM)**

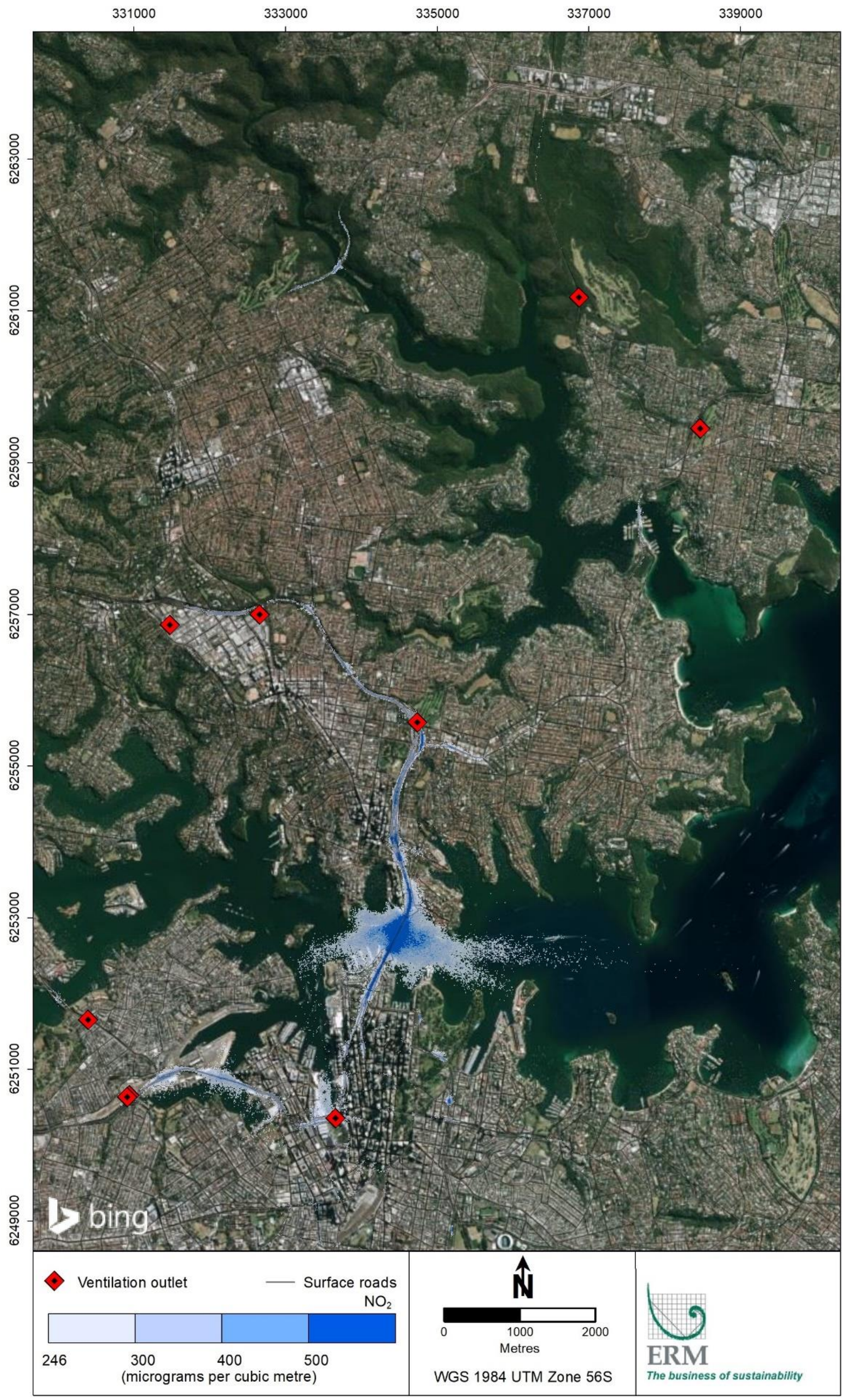


Figure I-12 **Contour plot of maximum 1-hour mean NO_2 concentration in the 2027 Do Something scenario (all sources, 2027-DS(BL))**

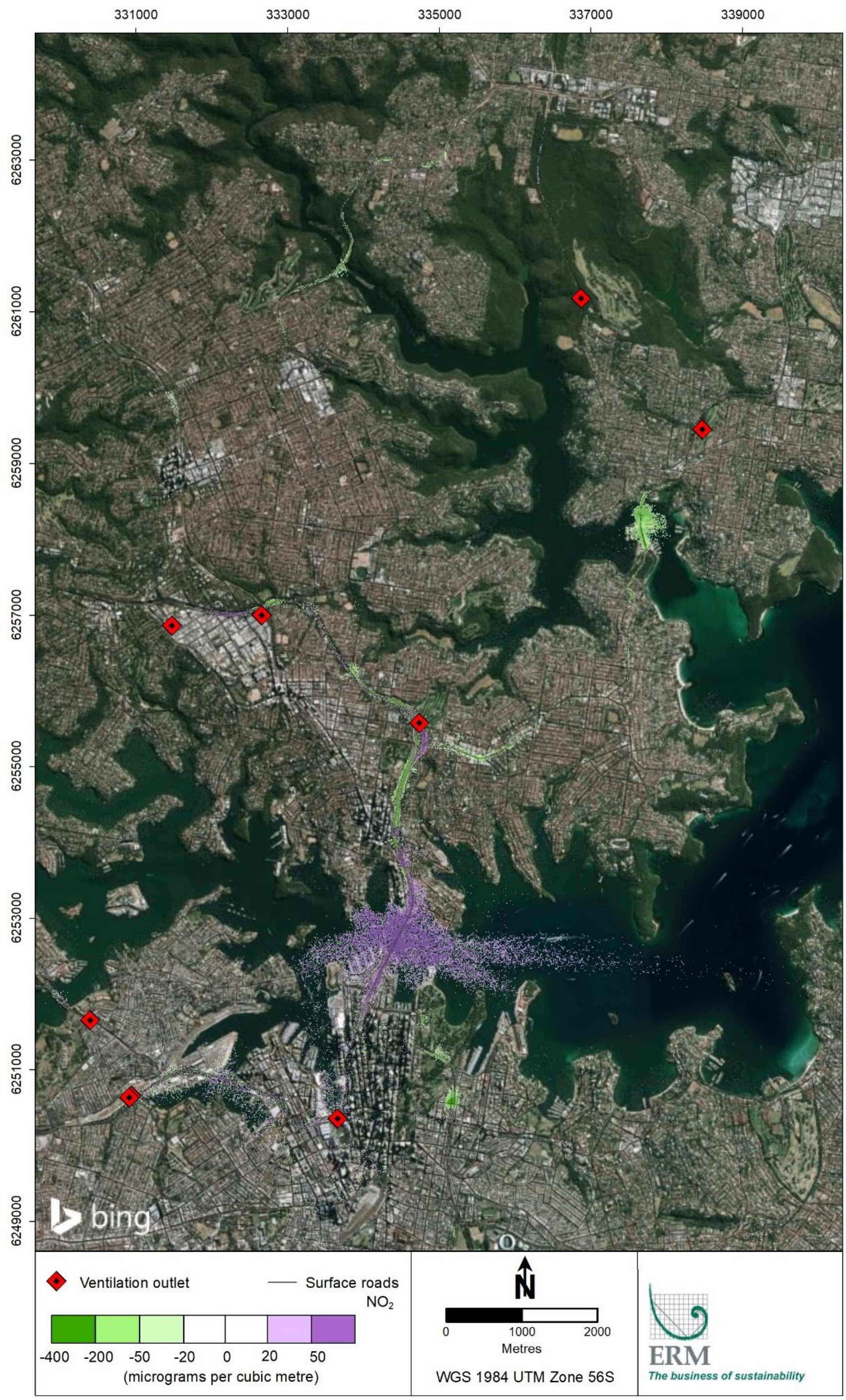


Figure I-13 **Contour plot of change in maximum 1-hour mean NO_2 concentration in the 2027 Do Something scenario (all sources, 2027-DS(BL) minus 2027-DM)**

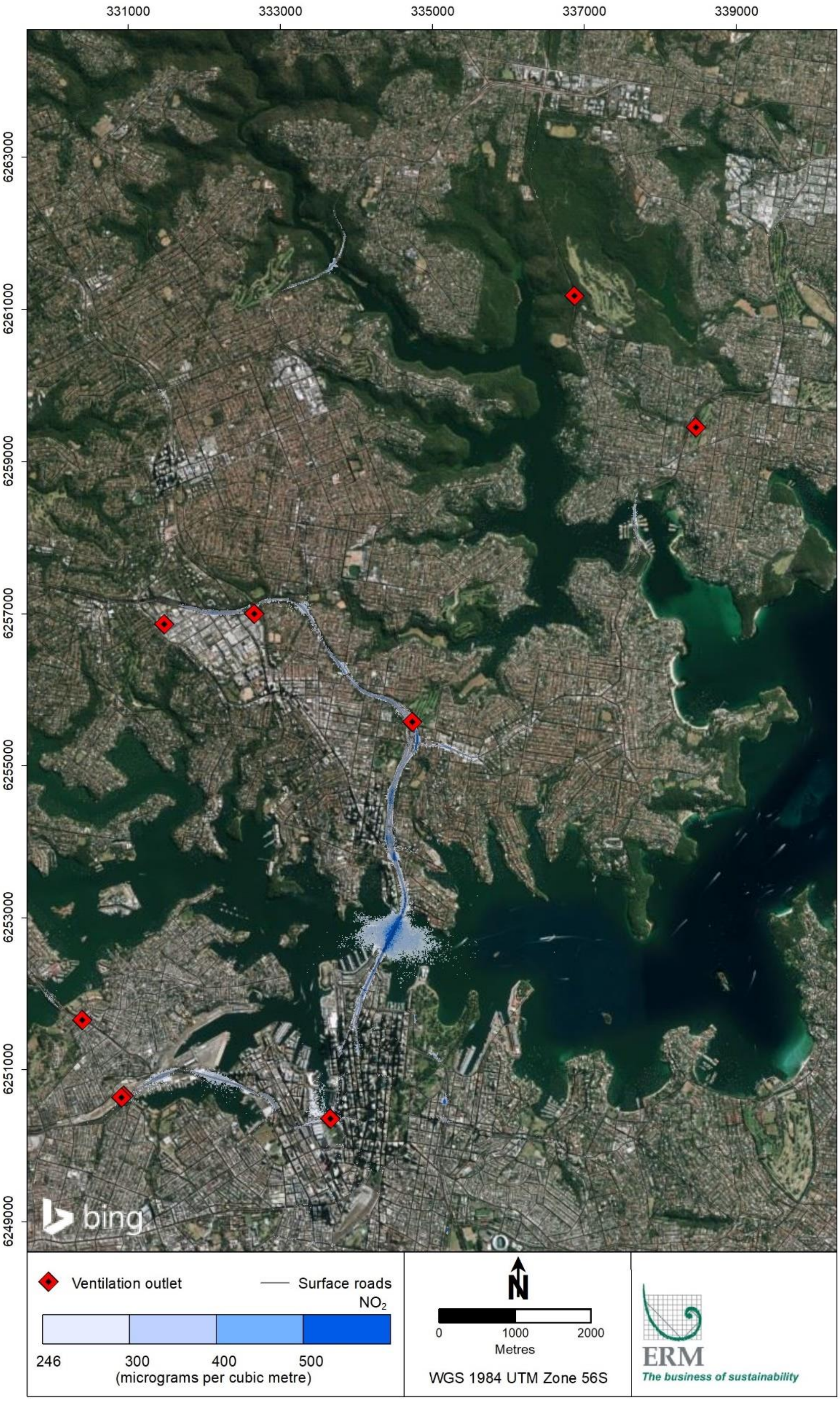


Figure I-14 **Contour plot of maximum 1-hour mean NO_2 concentration in the 2027 cumulative scenario (all sources, 2027-DSC)**

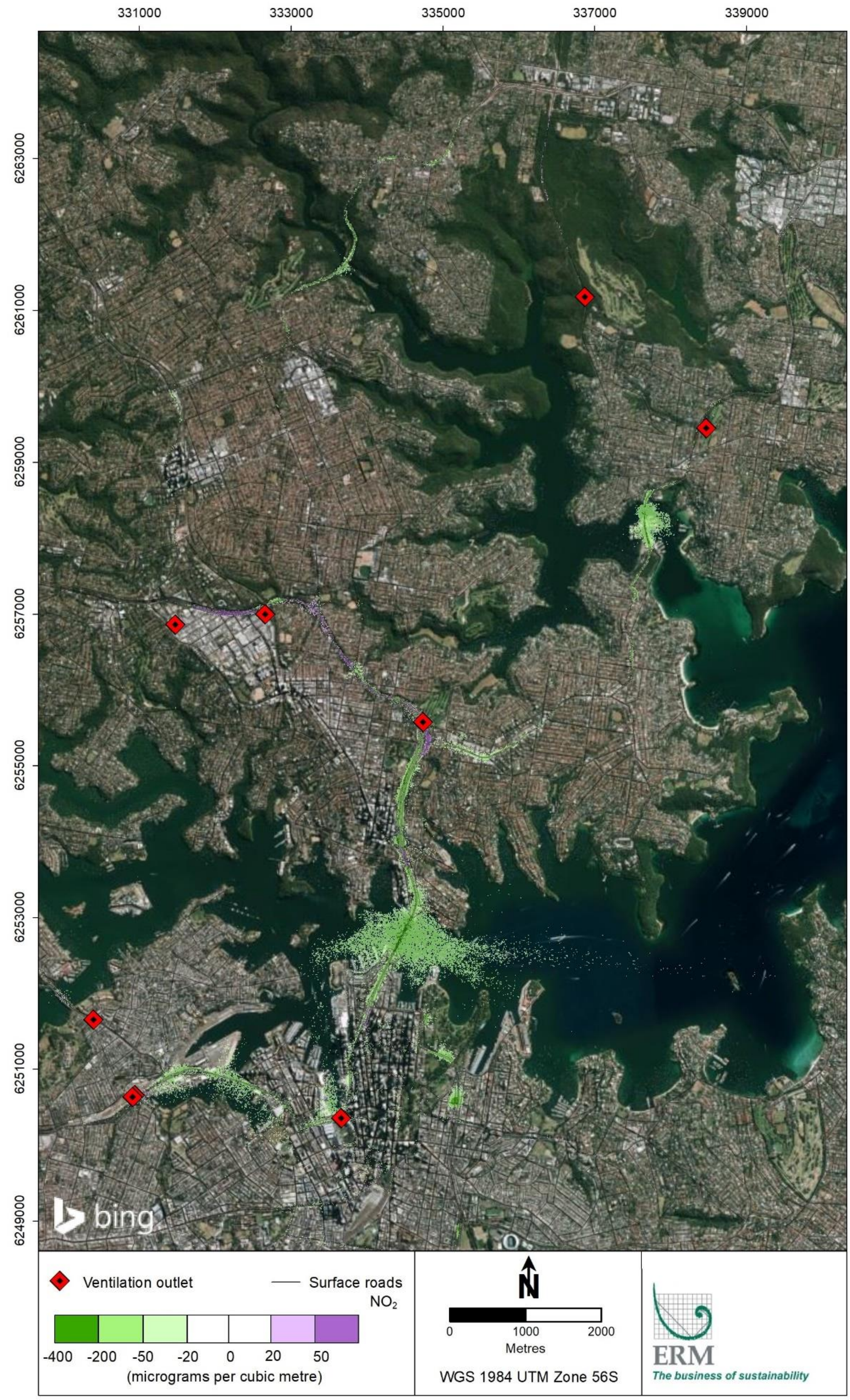


Figure I-15 **Contour plot of change in maximum 1-hour mean NO_2 concentration in the 2027 cumulative scenario (all sources, 2027-DSC minus 2027-DM)**

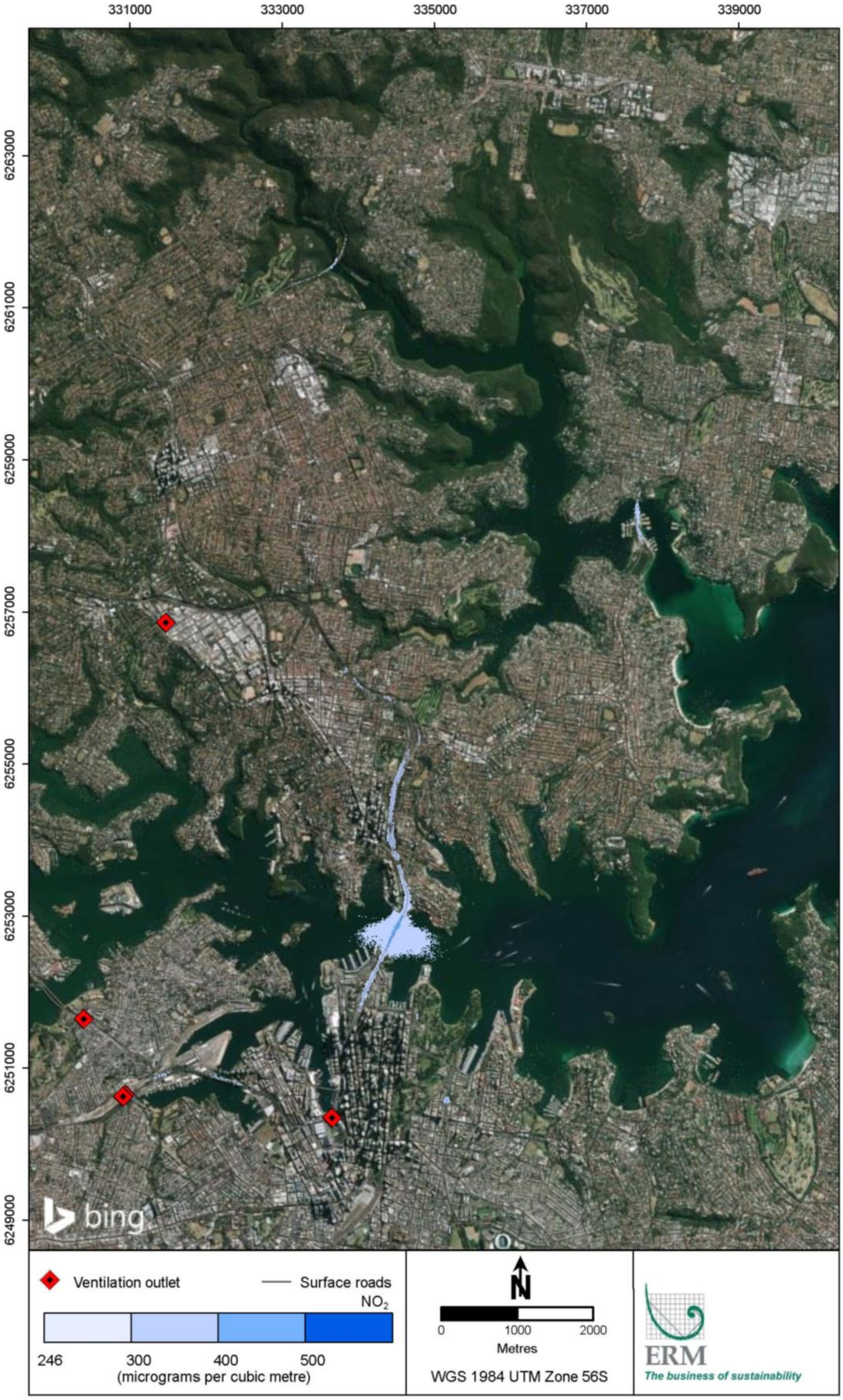


Figure I-16 **Contour plot of maximum 1-hour mean NO_2 concentration in the 2037 Do Minimum scenario (all sources, 2037-DM)**

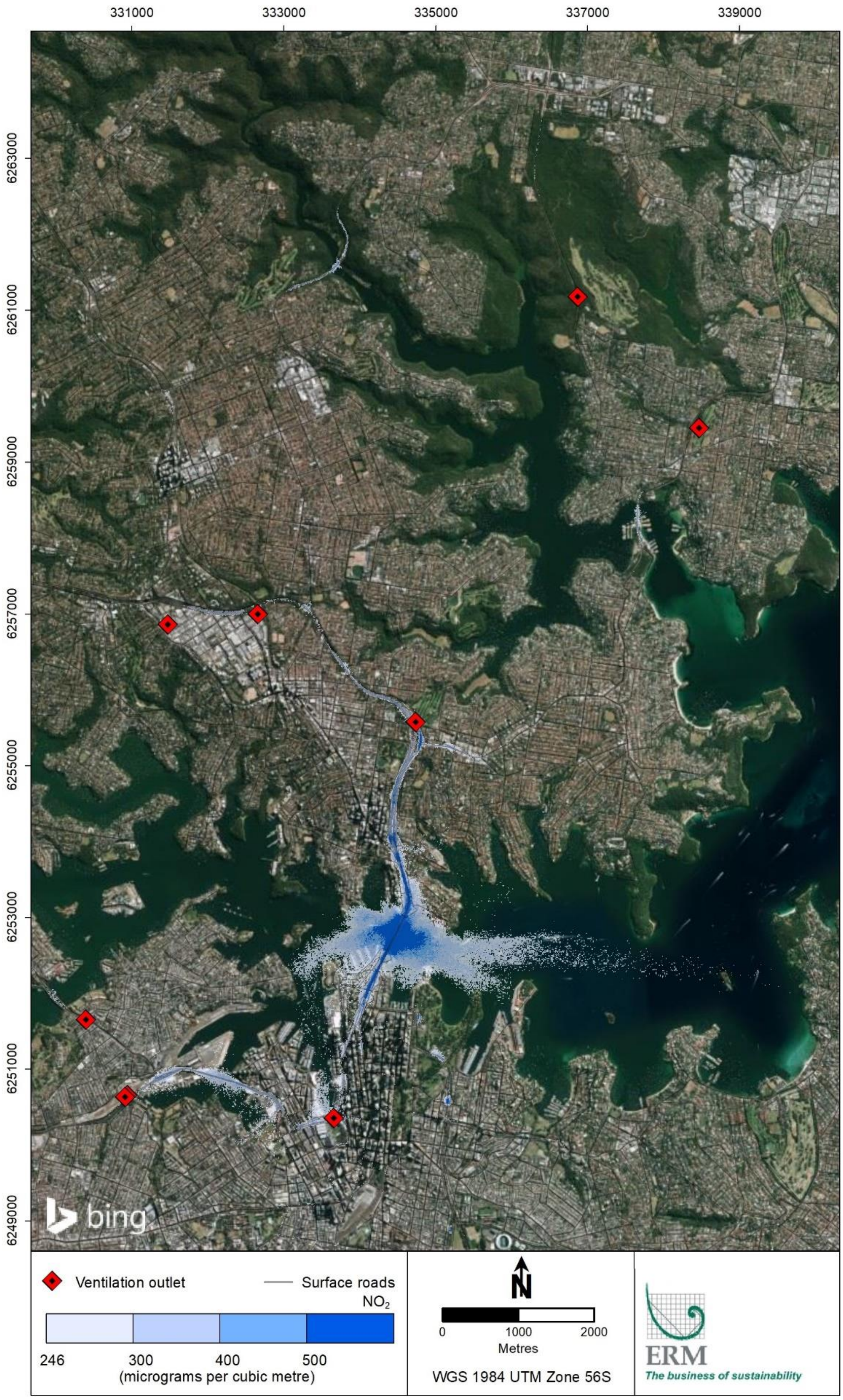


Figure I-17 Contour plot of maximum 1-hour mean NO_2 concentration in the 2037 Do Something scenario (all sources, 2037-DS(BL))

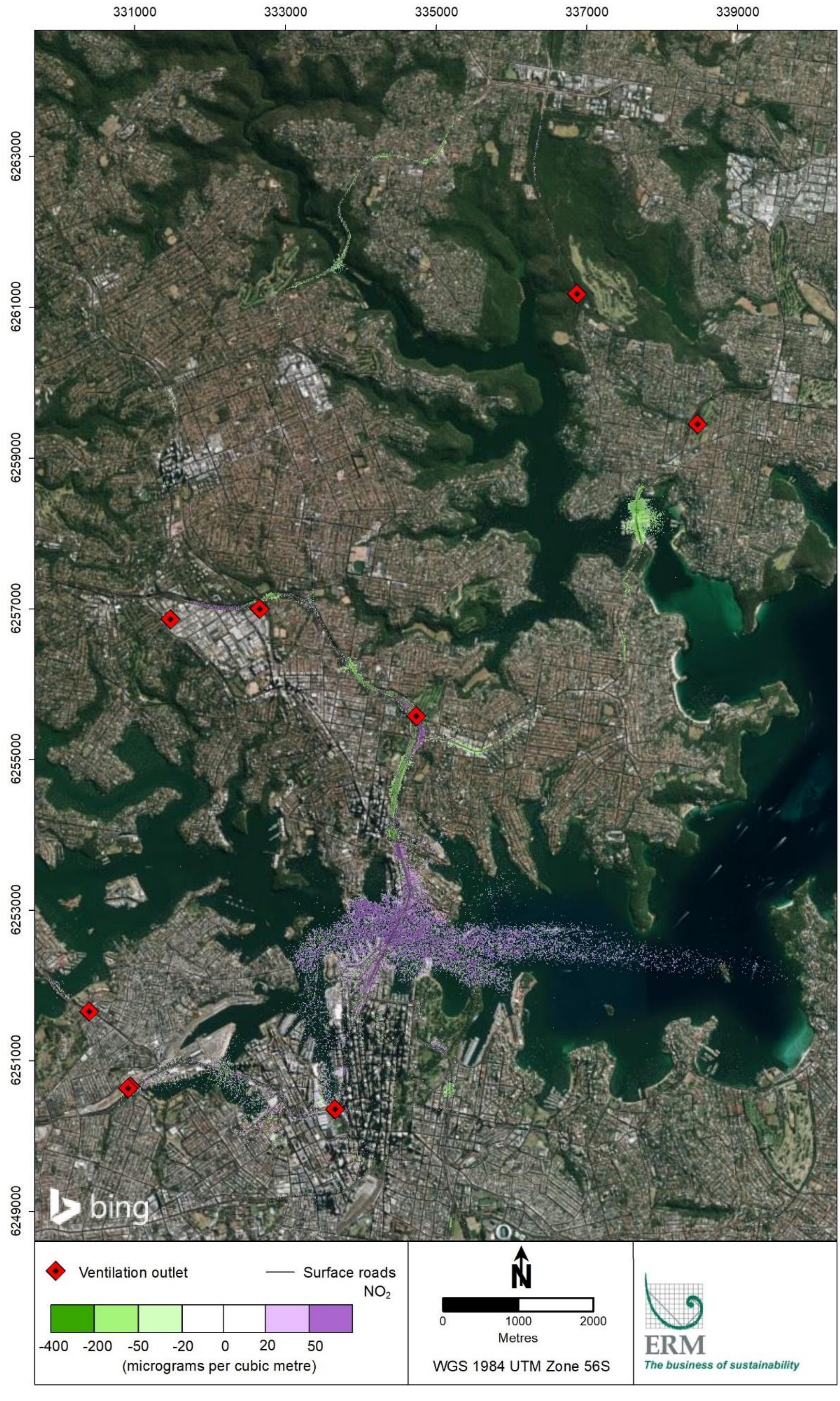


Figure I-18 **Contour plot of change in maximum 1-hour mean NO_2 concentration in the 2037 Do Something scenario (all sources, 2037-DS(BL) minus 2037-DM)**

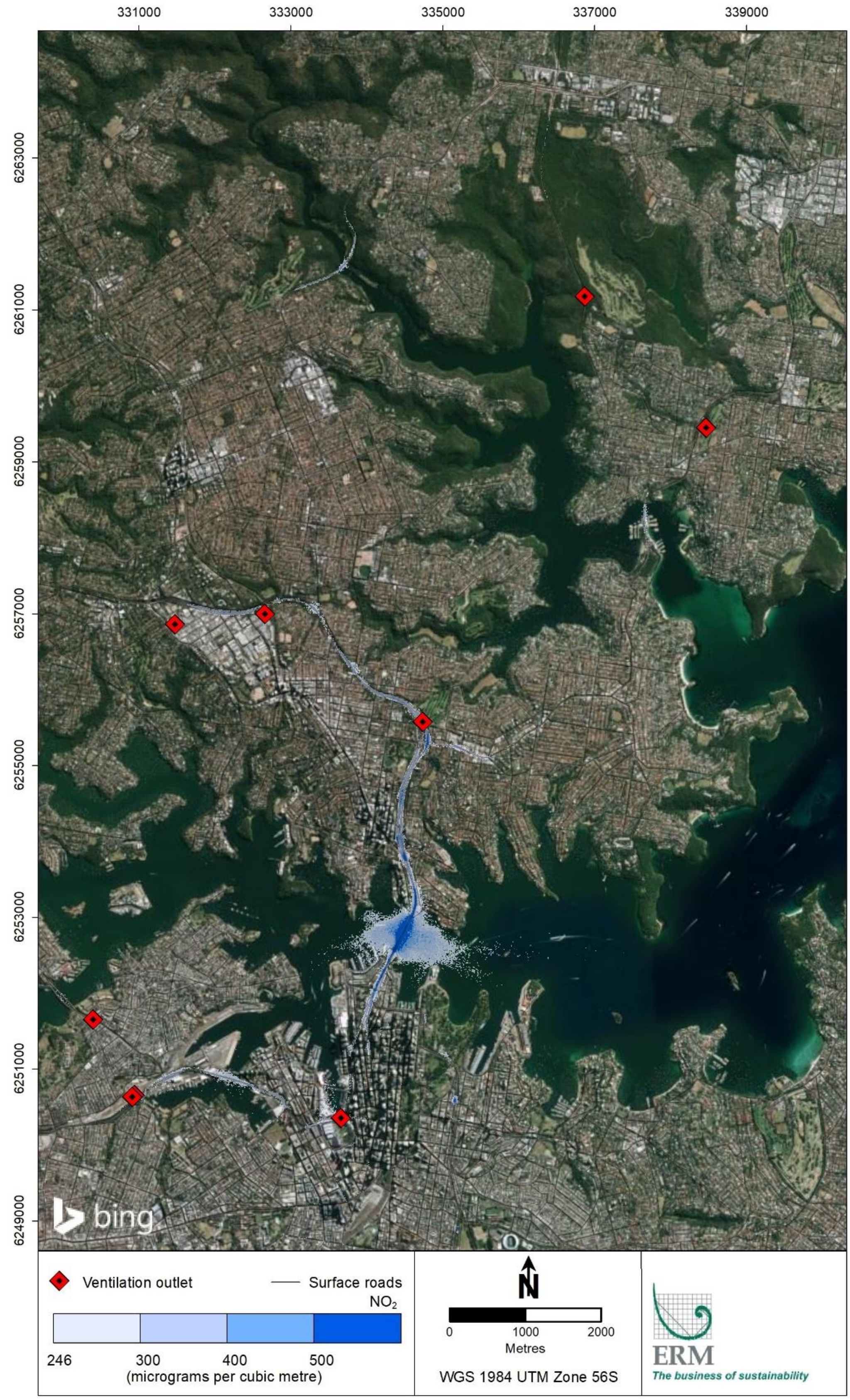


Figure I-19 **Contour plot of maximum 1-hour mean NO_2 concentration in the 2037 cumulative scenario (all sources, 2037-DSC)**

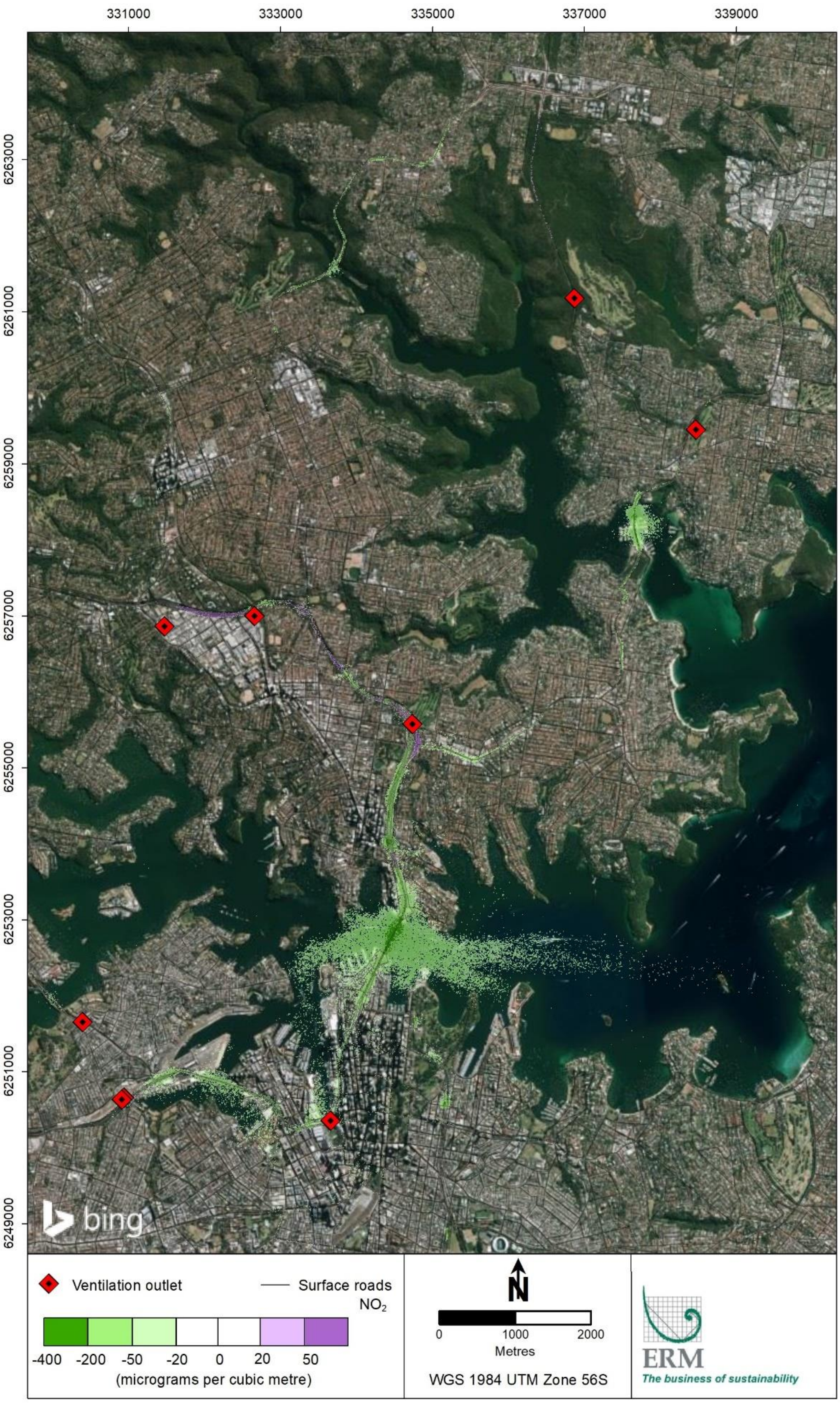


Figure I-20 **Contour plot of change in maximum 1-hour mean NO_2 concentration in the 2037 cumulative scenario (all sources, 2037-DSC minus 2037-DM)**

I.5 PM_{10} (annual mean)

Table I-29 Annual mean PM_{10} concentration at community receptors

Receptor	Annual mean PM_{10} concentration (µg/m^3)							Change relative to Do Minimum (µg/m^3)				Change relative to Do Minimum (%)			
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
CR01	-	20.8	21.0	20.7	21.1	21.1	21.0	0.3	-0.1	0.0	-0.2	1.3%	-0.3%	0.0%	-0.8%
CR02	-	18.6	18.8	18.6	18.7	18.7	18.8	0.2	0.0	0.0	0.1	1.1%	0.0%	0.0%	0.7%
CR03	-	18.6	18.4	18.7	18.5	18.6	19.0	-0.1	0.1	0.1	0.5	-0.6%	0.8%	0.5%	2.6%
CR04	-	17.8	18.0	17.8	18.0	18.0	17.9	0.2	0.0	0.0	0.0	0.9%	-0.1%	0.3%	-0.2%
CR05	-	17.7	17.8	17.8	17.9	17.8	17.9	0.1	0.0	-0.1	0.0	0.3%	0.2%	-0.5%	0.3%
CR06	-	18.9	19.3	18.6	19.3	19.5	18.8	0.3	-0.3	0.3	-0.5	1.8%	-1.6%	1.4%	-2.4%
CR07	-	17.2	17.1	17.2	17.2	17.3	17.1	-0.1	0.0	0.1	-0.1	-0.4%	0.0%	0.5%	-0.5%
CR08	-	18.5	18.5	18.3	18.4	18.5	18.4	0.0	-0.2	0.0	-0.1	0.0%	-1.2%	0.2%	-0.3%
CR09	-	17.2	17.2	17.3	17.2	17.4	17.3	0.0	0.1	0.2	0.1	0.2%	0.5%	0.9%	0.7%
CR10	-	18.1	18.0	17.9	18.1	18.0	18.0	-0.1	-0.2	-0.1	0.0	-0.6%	-1.3%	-0.5%	-0.3%
CR11	-	19.3	18.9	19.0	19.3	19.0	18.9	-0.4	-0.3	-0.3	-0.4	-2.0%	-1.7%	-1.5%	-1.9%
CR12	-	17.9	17.7	17.9	18.0	17.8	17.7	-0.2	0.0	-0.2	-0.3	-0.9%	0.1%	-1.0%	-1.4%
CR13	-	17.3	17.3	17.3	17.4	17.3	17.2	0.0	0.0	-0.1	-0.1	0.1%	0.1%	-0.4%	-0.8%
CR14	-	19.4	18.7	18.7	19.6	19.0	18.8	-0.7	-0.7	-0.6	-0.8	-3.6%	-3.5%	-3.2%	-4.0%
CR15	-	17.1	16.9	17.0	17.1	17.0	17.0	-0.1	0.0	-0.2	-0.2	-0.6%	-0.3%	-1.0%	-0.9%
CR16	-	18.1	18.1	18.1	18.1	18.1	18.4	0.0	0.0	0.1	0.3	0.1%	0.1%	0.5%	1.8%
CR17	-	17.5	17.6	17.5	17.6	17.6	17.6	0.0	-0.1	-0.1	-0.1	0.1%	-0.4%	-0.4%	-0.4%
CR18	-	17.3	17.3	17.3	17.4	17.4	17.4	0.0	0.0	0.0	0.0	-0.2%	0.0%	-0.1%	-0.1%
CR19	-	17.7	17.5	17.6	17.7	17.7	17.6	-0.2	-0.1	0.0	-0.1	-1.3%	-0.8%	0.0%	-0.7%
CR20	-	17.5	17.7	17.5	17.5	17.6	17.7	0.2	0.0	0.1	0.2	1.4%	0.0%	0.4%	1.1%
CR21	-	17.0	17.0	17.0	16.9	17.1	17.0	0.0	0.0	0.2	0.1	-0.2%	0.1%	1.1%	0.6%
CR22	-	17.4	17.4	17.3	17.4	17.5	17.6	0.0	0.0	0.1	0.2	0.1%	0.0%	0.3%	0.9%
CR23	-	17.9	18.2	18.0	18.4	18.3	18.2	0.3	0.1	-0.2	-0.2	1.8%	0.5%	-1.0%	-1.2%
CR24	-	16.8	16.7	16.7	16.7	16.8	16.8	-0.1	-0.1	0.0	0.1	-0.8%	-0.4%	0.3%	0.7%
CR25	-	17.6	17.4	17.6	17.6	17.6	17.6	-0.2	0.0	0.1	0.0	-1.0%	0.0%	0.3%	0.0%
CR26	-	17.5	17.3	17.3	17.5	17.4	17.4	-0.1	-0.2	-0.1	-0.1	-0.8%	-1.0%	-0.4%	-0.4%
CR27	-	16.7	16.6	16.7	16.6	16.6	16.6	-0.1	0.0	-0.1	-0.1	-0.5%	-0.2%	-0.3%	-0.4%
CR28	-	20.8	19.4	19.3	20.8	19.5	19.5	-1.4	-1.5	-1.3	-1.3	-6.6%	-7.3%	-6.3%	-6.1%
CR29	-	17.0	17.0	17.0	17.0	17.0	17.0	0.0	0.0	0.0	0.0	0.0%	-0.1%	0.0%	0.0%
CR30	-	17.0	17.1	17.0	17.0	17.2	17.1	0.0	0.0	0.2	0.1	0.3%	0.0%	0.9%	0.4%
CR31	-	17.0	17.2	17.2	17.0	17.3	17.2	0.1	0.1	0.3	0.2	0.6%	0.8%	1.7%	1.2%
CR32	-	16.5	16.5	16.5	16.6	16.5	16.5	0.0	0.0	-0.1	0.0	0.1%	0.0%	-0.5%	-0.2%
CR33	-	16.5	16.5	16.5	16.5	16.5	16.5	0.0	0.0	0.0	0.0	0.2%	0.1%	-0.1%	-0.2%
CR34	-	16.8	17.0	16.9	16.8	16.9	16.9	0.2	0.1	0.1	0.1	0.9%	0.4%	0.4%	0.7%
CR35	-	16.4	16.4	16.5	16.4	16.4	16.4	0.0	0.1	0.0	0.0	0.0%	0.4%	-0.1%	-0.1%
CR36	-	16.4	16.5	16.5	16.4	16.5	16.5	0.1	0.1	0.0	0.0	0.4%	0.4%	0.1%	0.1%
CR37	-	17.6	17.8	17.7	17.7	17.8	17.6	0.2	0.1	0.1	-0.1	1.2%	0.6%	0.6%	-0.6%
CR38	-	16.7	16.5	16.6	16.7	16.6	16.6	-0.1	-0.1	-0.1	-0.1	-0.8%	-0.7%	-0.8%	-0.7%
CR39	-	16.6	16.6	16.5	16.7	16.6	16.6	0.0	-0.1	0.0	-0.1	-0.2%	-0.4%	-0.3%	-0.5%
CR40	-	16.4	16.3	16.2	16.4	16.3	16.2	0.0	-0.1	-0.1	-0.1	-0.1%	-0.7%	-0.8%	-0.9%
CR41	-	16.4	16.3	16.3	16.4	16.3	16.3	-0.1	-0.1	-0.1	-0.1	-0.6%	-0.7%	-0.6%	-0.8%
CR42	-	16.5	16.5	16.5	16.5	16.5	16.6	0.0	0.0	0.0	0.1	0.3%	-0.1%	0.1%	0.5%

Table I-30 Annual mean PM_{10} concentration at community receptors, ranked by concentration

Rank	Ranking by concentration (µg/m^3)						
	2016-BY	2027-DM	2023-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	20.8	21.0	20.7	21.1	21.1	21.0
2	-	20.8	19.4	19.3	20.8	19.5	19.5
3	-	19.4	19.3	19.0	19.6	19.5	19.0
4	-	19.3	18.9	18.7	19.3	19.0	18.9
5	-	18.9	18.8	18.7	19.3	19.0	18.8
6	-	18.6	18.7	18.6	18.7	18.7	18.8
7	-	18.6	18.5	18.6	18.5	18.6	18.8
8	-	18.5	18.4	18.3	18.4	18.5	18.4
9	-	18.1	18.2	18.1	18.4	18.3	18.4
10	-	18.1	18.1	18.0	18.1	18.1	18.2

Table I-31 Annual mean PM_{10} concentration at community receptors, ranked by increase and by decrease in concentration

Rank	Ranking by increase in concentration relative to Do Minimum (µg/m^3)				Ranking by decrease in concentration relative to Do Minimum (µg/m^3)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	0.35	0.15	0.29	0.49	-1.36	-1.51	-1.30	-1.27
2	0.33	0.14	0.27	0.32	-0.70	-0.69	-0.63	-0.79
3	0.26	0.11	0.18	0.20	-0.40	-0.32	-0.28	-0.47
4	0.24	0.10	0.16	0.19	-0.24	-0.30	-0.18	-0.37
5	0.21	0.09	0.15	0.16	-0.18	-0.23	-0.18	-0.26
6	0.20	0.06	0.11	0.13	-0.16	-0.22	-0.17	-0.21
7	0.17	0.06	0.09	0.12	-0.14	-0.17	-0.14	-0.18
8	0.15	0.06	0.09	0.12	-0.14	-0.14	-0.13	-0.16
9	0.11	0.04	0.08	0.11	-0.13	-0.12	-0.10	-0.15
10	0.06	0.02	0.06	0.09	-0.12	-0.11	-0.09	-0.14

Table I-32 Annual mean PM_{10} concentration at community receptors, ranked by percentage increase and by decrease in concentration

Rank	Ranking by % increase in concentration relative to Do Minimum				Ranking by % decrease in concentration relative to Do Minimum			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	1.8%	0.8%	1.7%	2.6%	-6.6%	-7.3%	-6.3%	-6.1%
2	1.8%	0.8%	1.4%	1.8%	-3.6%	-3.5%	-3.2%	-4.0%
3	1.4%	0.6%	1.1%	1.2%	-2.0%	-1.7%	-1.5%	-2.4%
4	1.3%	0.5%	0.9%	1.1%	-1.3%	-1.6%	-1.0%	-1.9%
5	1.2%	0.5%	0.9%	0.9%	-1.0%	-1.3%	-1.0%	-1.4%
6	1.1%	0.4%	0.6%	0.7%	-0.9%	-1.2%	-1.0%	-1.2%
7	0.9%	0.4%	0.5%	0.7%	-0.8%	-1.0%	-0.8%	-0.9%
8	0.9%	0.4%	0.5%	0.7%	-0.8%	-0.8%	-0.8%	-0.9%
9	0.6%	0.2%	0.5%	0.7%	-0.8%	-0.7%	-0.6%	-0.8%
10	0.4%	0.1%	0.4%	0.6%	-0.6%	-0.7%	-0.5%	-0.8%

Table I-33 **Annual mean PM_{10} concentration at RWR receptors, ranked by concentration**

Rank		Ranking by concentration (µg/m³)						
		2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1		-	26.02	26.88	23.19	26.31	27.10	23.83
2		-	24.56	24.55	22.74	24.81	24.48	23.23
3		-	23.54	23.59	22.62	24.43	23.96	23.12
4		-	23.53	23.58	22.39	23.65	23.88	22.85
5		-	23.28	23.46	22.24	23.61	23.83	22.66
6		-	23.27	23.30	21.90	23.58	23.78	22.49
7		-	23.08	22.97	21.87	23.32	23.29	22.03
8		-	23.06	22.92	21.76	23.30	23.26	22.02
9		-	23.05	22.76	21.64	23.20	23.13	22.02
10		-	22.67	22.54	21.59	22.88	22.93	21.60

Table I-34 **Annual mean PM_{10} concentration at RWR receptors, ranked by increase and by decrease in concentration**

Rank		Ranking by increase in concentration relative to Do Minimum (µg/m³)					Ranking by decrease in concentration relative to Do Minimum (µg/m³)			
		2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC		2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1		2.34	1.02	2.34	1.18		-2.37	-2.83	-2.77	-3.52
2		1.08	0.86	1.33	0.89		-2.32	-2.60	-2.16	-3.11
3		0.86	0.84	1.30	0.82		-2.23	-2.34	-2.05	-2.68
4		0.85	0.74	1.03	0.79		-1.71	-2.09	-2.01	-2.57
5		0.70	0.73	0.97	0.78		-1.65	-1.96	-2.00	-2.57
6		0.69	0.66	0.95	0.78		-1.65	-1.96	-1.84	-2.39
7		0.67	0.60	0.88	0.77		-1.51	-1.95	-1.76	-2.30
8		0.63	0.58	0.79	0.70		-1.48	-1.94	-1.73	-2.29
9		0.61	0.57	0.79	0.70		-1.46	-1.92	-1.72	-2.29
10		0.60	0.55	0.78	0.68		-1.39	-1.92	-1.69	-2.25

Table I-35 **Annual mean PM_{10} concentration at RWR receptors, ranked by percentage increase and by decrease in concentration**

Rank		Ranking by % increase in concentration relative to Do Minimum					Ranking by % decrease in concentration relative to Do Minimum			
		2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC		2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1		11.6%	6.1%	11.2%	7.1%		-10.8%	-12.2%	-11.7%	-14.9%
2		6.5%	4.8%	7.8%	4.5%		-10.3%	-11.7%	-9.6%	-13.7%
3		4.4%	4.3%	6.9%	4.5%		-10.0%	-10.9%	-9.5%	-12.1%
4		3.9%	3.7%	5.2%	4.4%		-8.7%	-9.8%	-9.2%	-12.0%
5		3.4%	3.7%	5.1%	4.3%		-7.9%	-9.4%	-9.1%	-11.2%
6		3.4%	3.6%	4.5%	4.0%		-7.9%	-9.3%	-9.1%	-11.0%
7		3.4%	3.3%	4.3%	3.9%		-7.2%	-9.1%	-8.2%	-10.7%
8		3.4%	3.2%	4.0%	3.7%		-7.2%	-9.1%	-8.0%	-10.7%
9		3.4%	3.0%	3.9%	3.6%		-7.1%	-8.9%	-7.9%	-10.6%
10		3.3%	3.0%	3.7%	3.6%		-7.0%	-8.8%	-7.9%	-10.5%

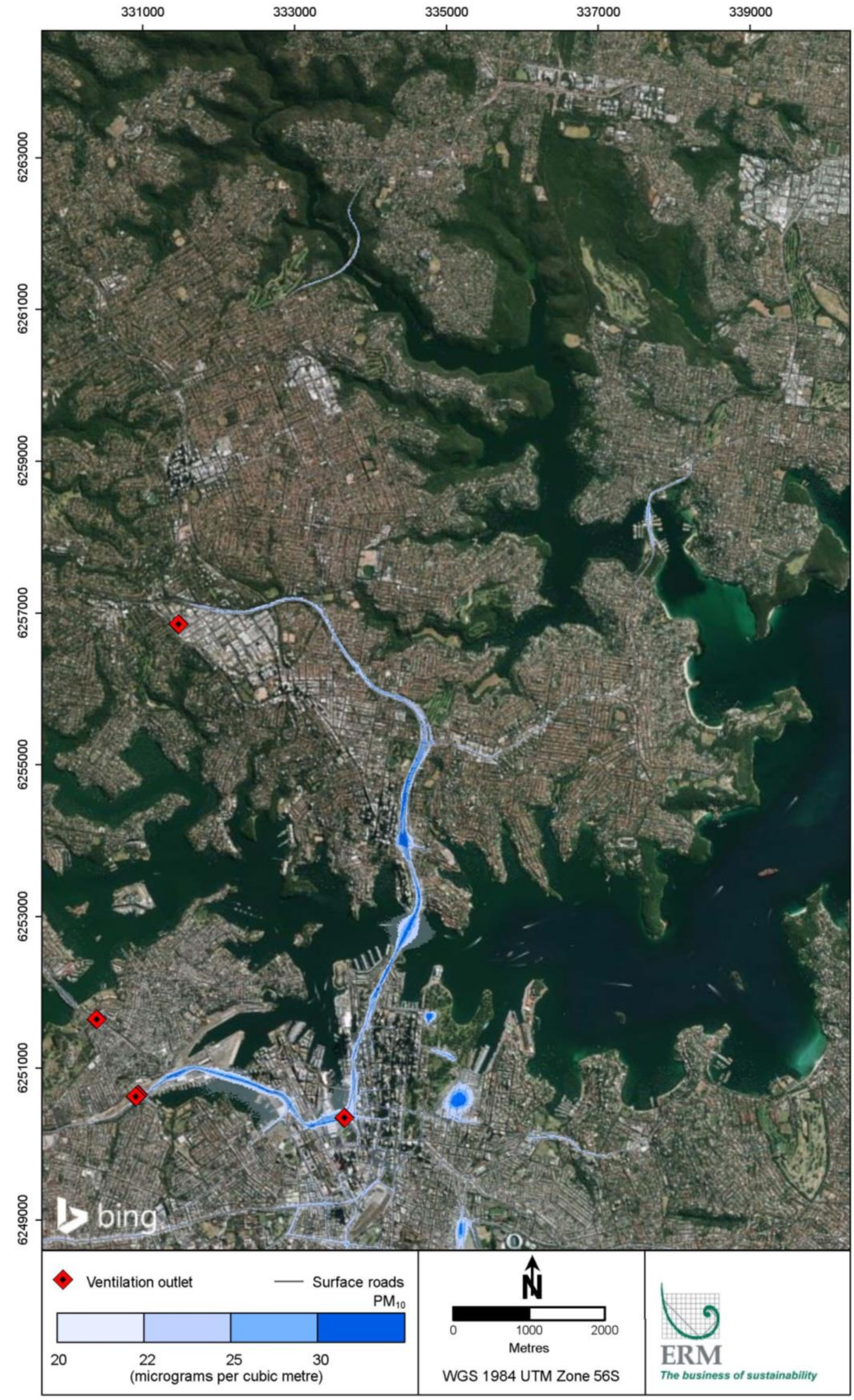


Figure I-21 **Contour plot of annual mean PM_{10} concentration in 2027 Do Minimum scenario (all sources, 2027-DM)**

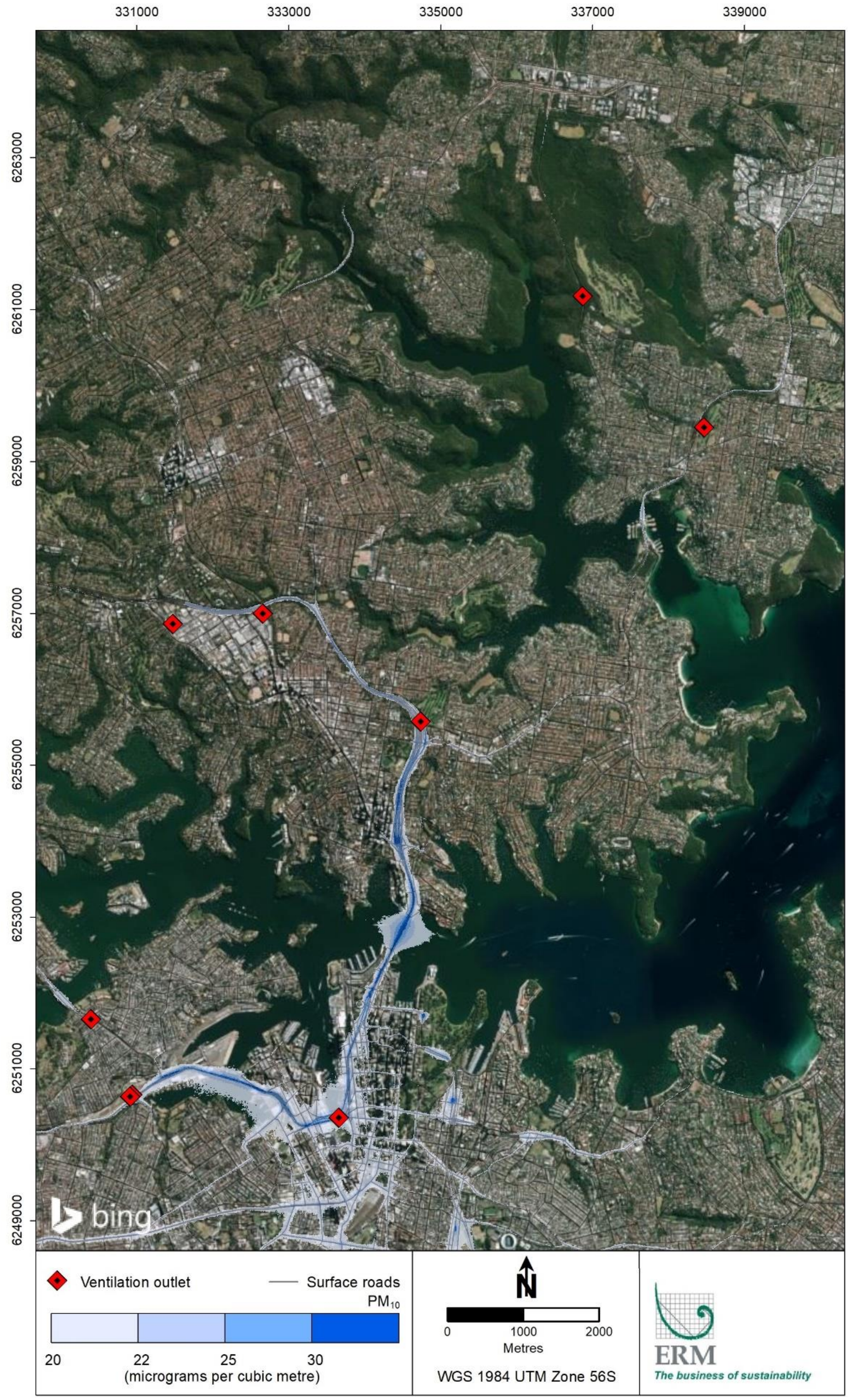


Figure I-22 **Contour plot of annual mean PM_{10} concentration in 2027 Do Something scenario (all sources, 2027-DS(BL))**

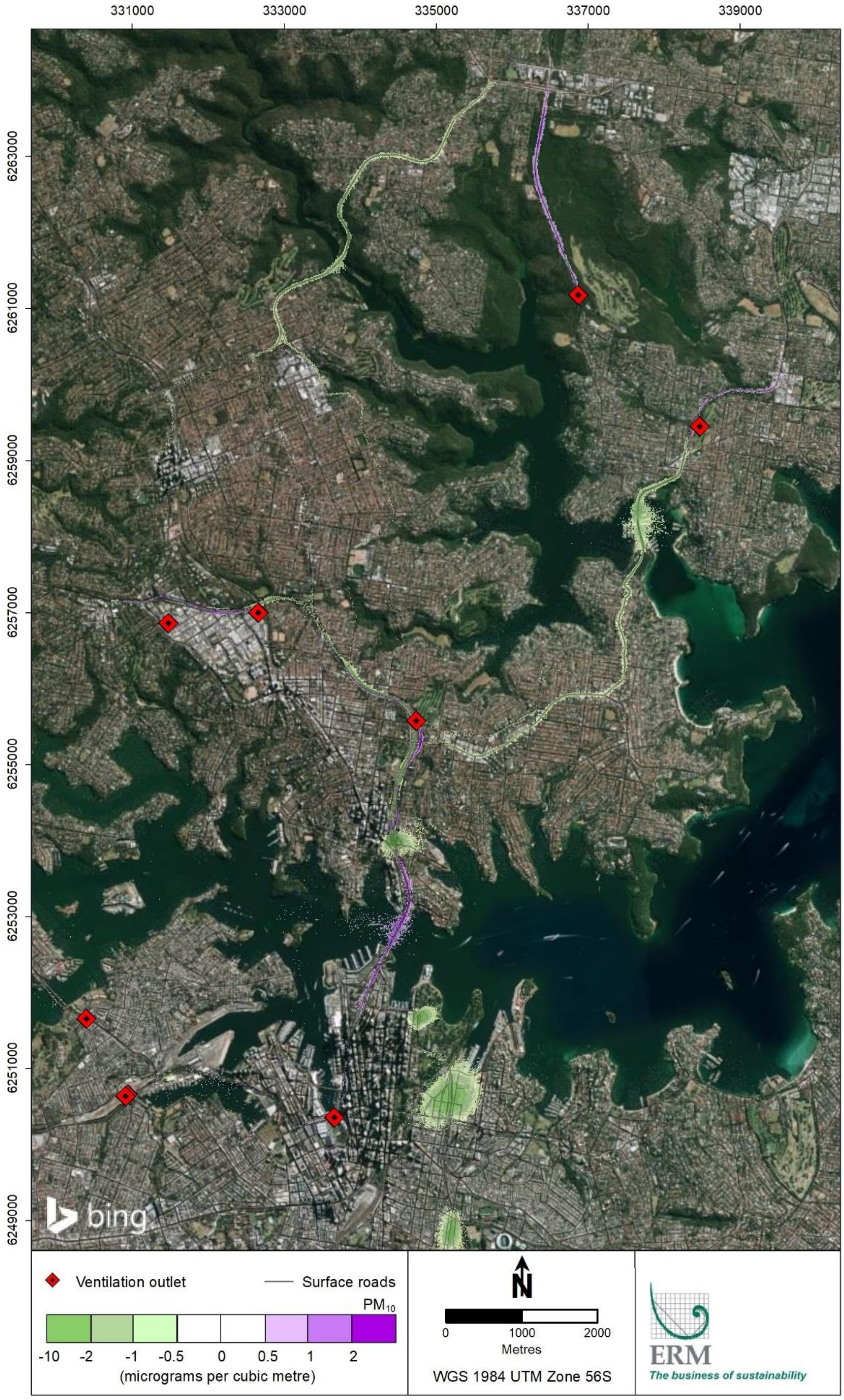


Figure I-23 **Contour plot of change in annual mean PM_{10} concentration in 2027 Do something scenario (all sources, 2027-DS(BL) minus 2027-DM)**

Figure I-24 **Contour plot of annual mean PM_{10} concentration in 2027 cumulative scenario (all sources, 2027-DSC)**

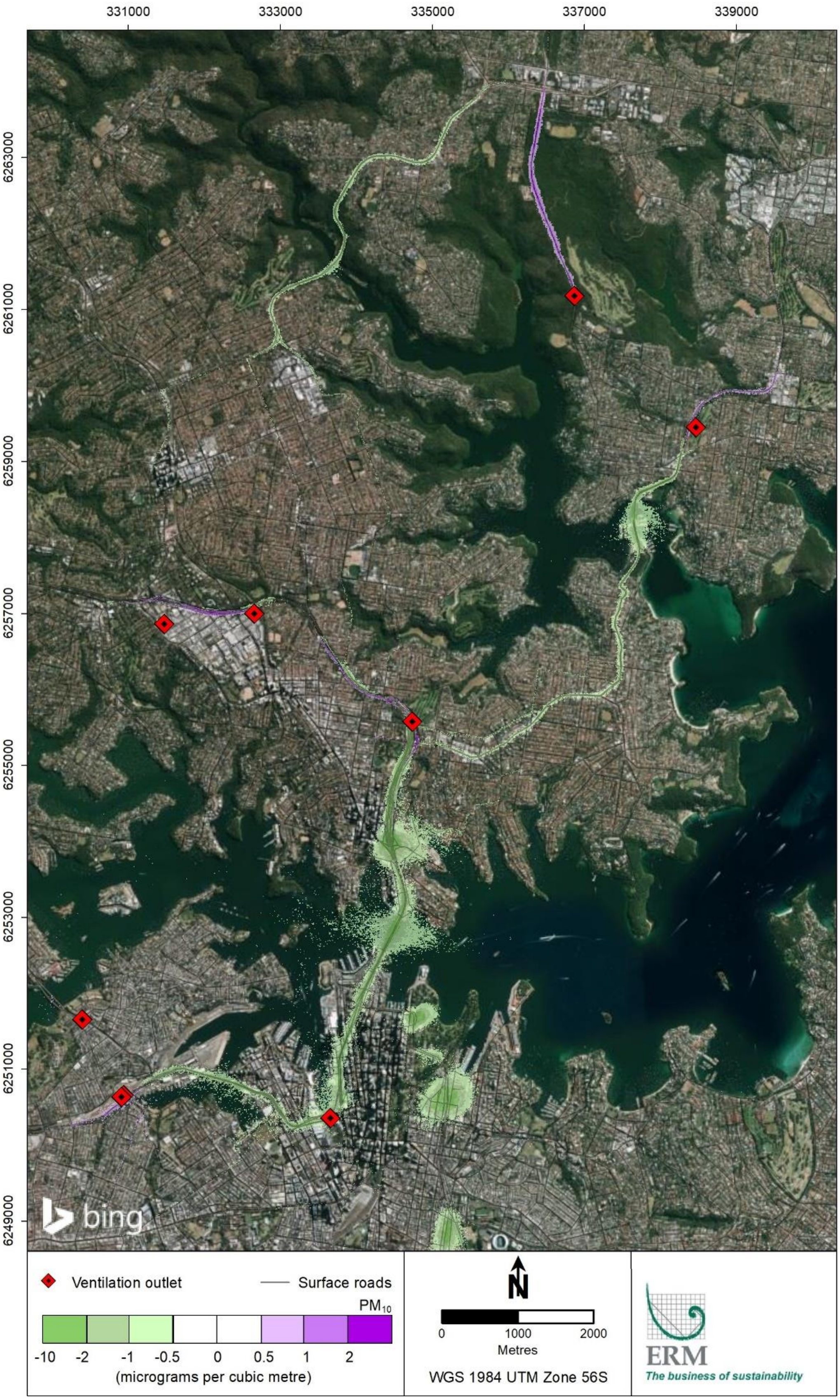


Figure I-25 **Contour plot of change in annual mean PM_{10} concentration in 2027 cumulative scenario (all sources, 2027-DSC minus 2027-DM)**

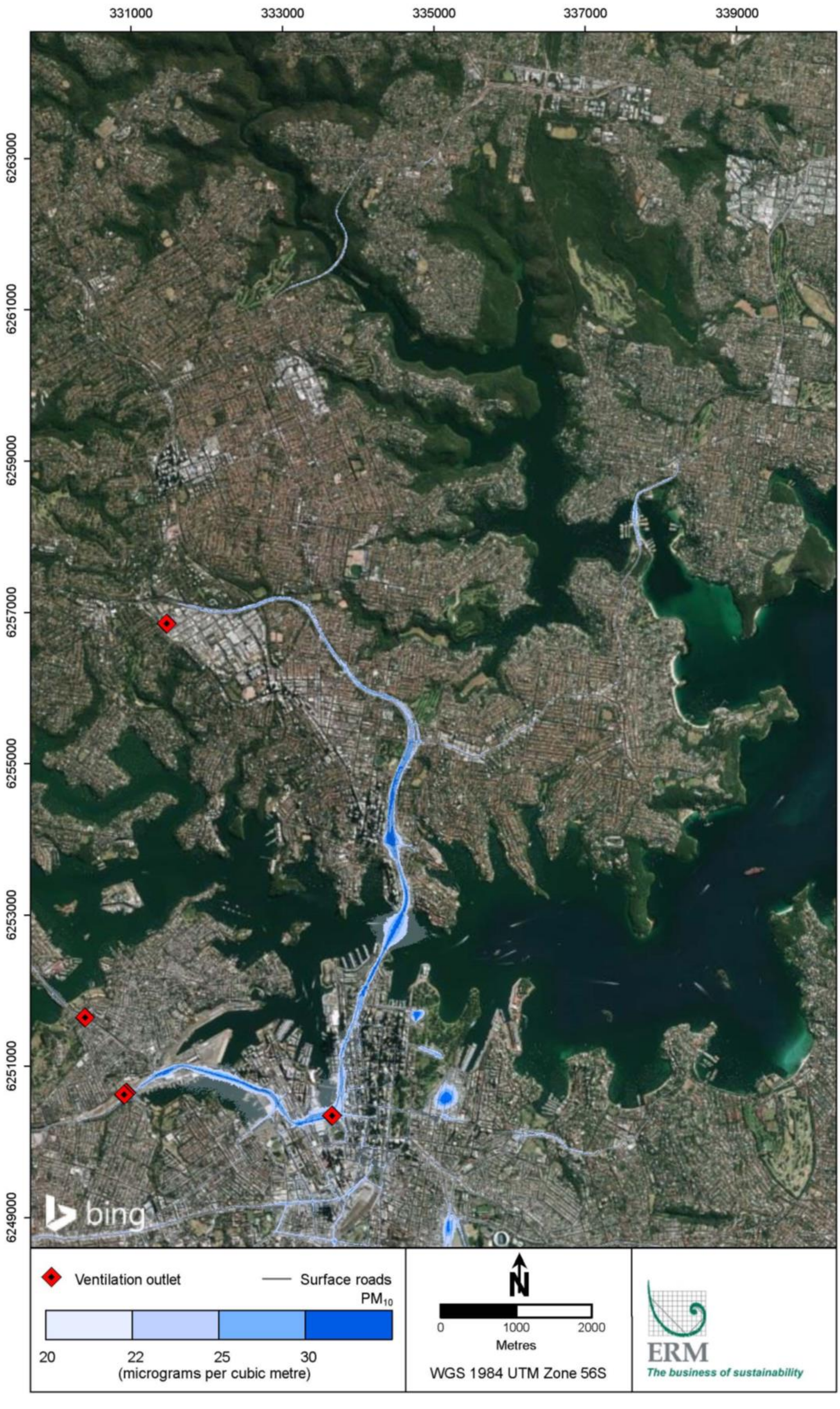


Figure I-26 **Contour plot of annual mean PM_{10} concentration in 2037 Do Minimum scenario (all sources, 2037-DM)**

Figure I-27 Contour plot of annual mean PM_{10} concentration in 2037 Do Something scenario (all sources, 2037-DS(BL))

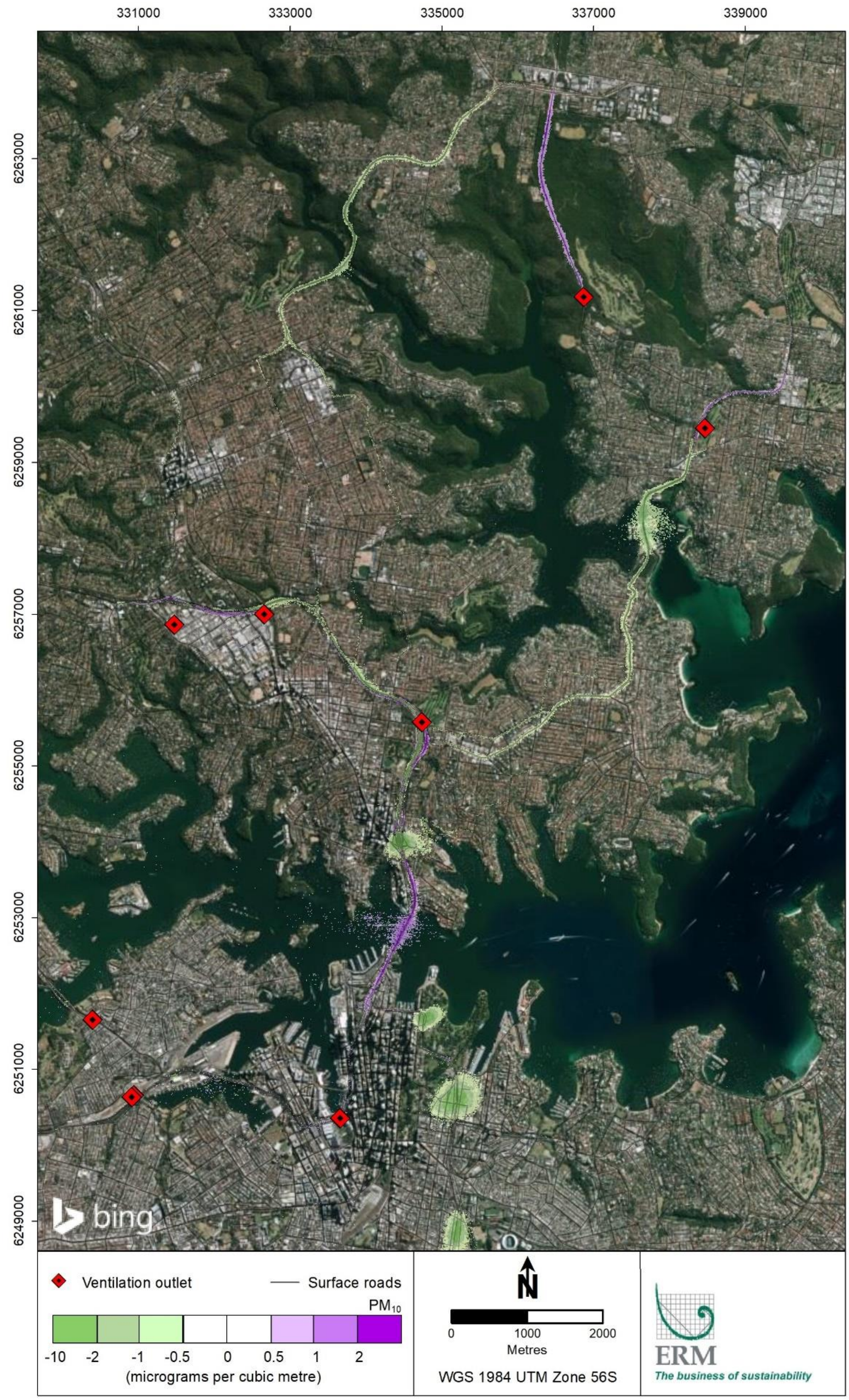


Figure I-28 **Contour plot of change in annual mean PM_{10} concentration in 2037 Do Something scenario (all sources, 2037-DS(BL) minus 2037-DM)**

Figure I-29 **Contour plot of annual mean PM_{10} concentration in 2037 cumulative scenario (all sources, 2037-DSC)**

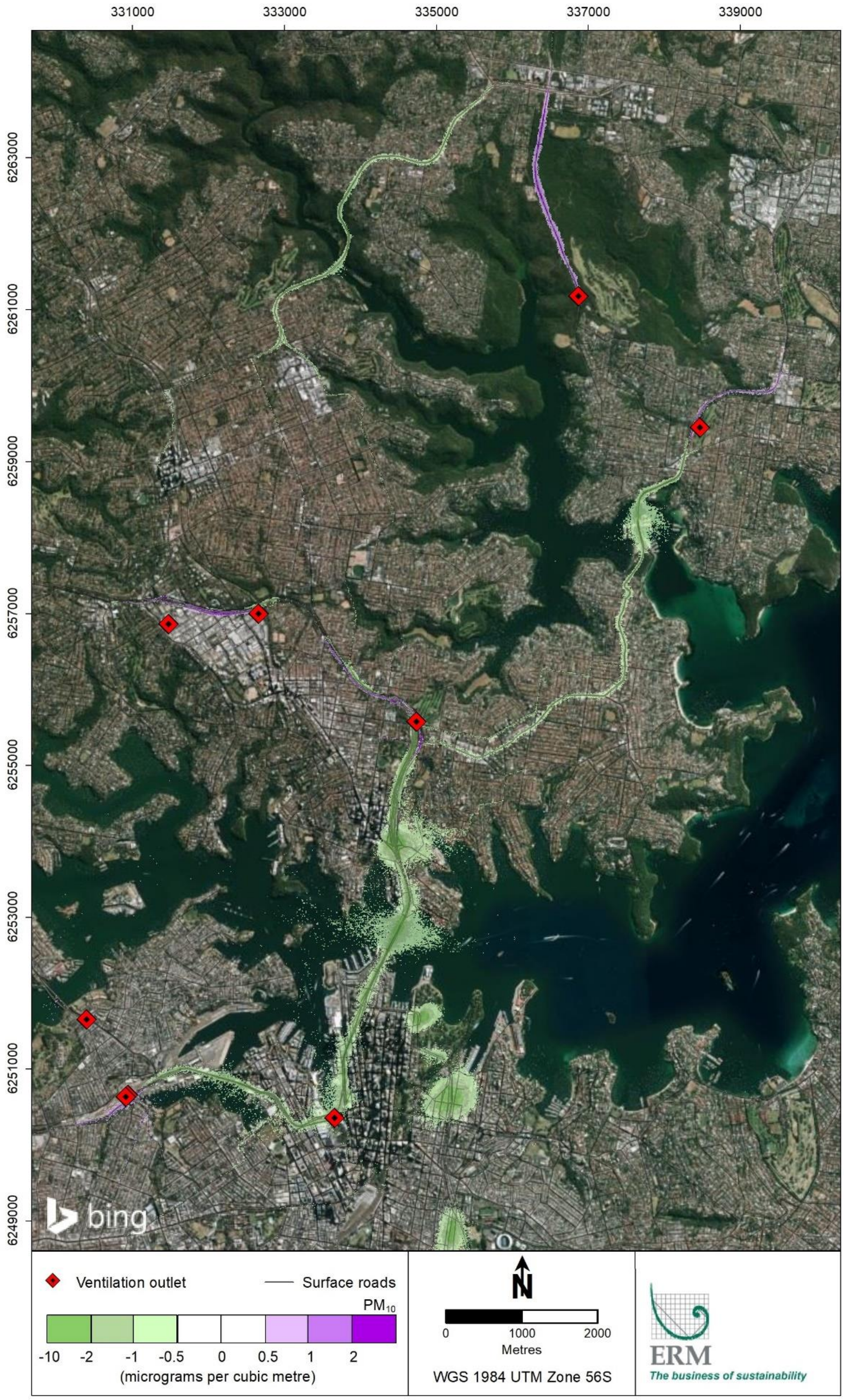


Figure I-30 **Contour plot of change in annual mean PM_{10} concentration in 2037 cumulative scenario (all sources, 2037-DSC minus 2037-DM)**

I.6 PM_{10} (maximum 24-hour mean)

Table I-36 Maximum 24-hour mean PM_{10} concentration at community receptors

Receptor	Maximum 24-hour PM_{10} concentration (µg/m³)							Change relative to Do Minimum (µg/m³)				Change relative to Do Minimum (%)			
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
CR01	-	127.9	127.6	127.4	127.5	127.9	127.6	-0.2	-0.4	0.4	0.1	-0.2%	-0.3%	0.3%	0.1%
CR02	-	126.4	126.3	126.4	126.4	126.4	126.4	-0.1	0.1	0.0	0.0	-0.1%	0.0%	0.0%	0.0%
CR03	-	126.6	126.4	126.4	126.3	126.4	126.4	-0.2	-0.2	0.1	0.1	-0.1%	-0.2%	0.1%	0.1%
CR04	-	126.5	126.4	126.6	126.5	126.6	126.6	0.0	0.1	0.1	0.1	0.0%	0.1%	0.1%	0.1%
CR05	-	127.0	127.1	126.9	127.1	126.9	127.1	0.1	-0.1	-0.2	0.0	0.1%	-0.1%	-0.1%	0.0%
CR06	-	129.7	130.0	129.0	130.2	130.4	129.2	0.2	-0.7	0.2	-1.1	0.2%	-0.6%	0.1%	-0.8%
CR07	-	126.2	126.2	126.3	126.2	126.2	126.2	0.0	0.1	0.1	0.1	0.0%	0.1%	0.0%	0.0%
CR08	-	126.4	126.5	126.5	126.5	126.5	126.6	0.1	0.1	0.0	0.1	0.1%	0.1%	0.0%	0.0%
CR09	-	126.3	126.4	126.4	126.4	126.4	126.4	0.1	0.1	0.0	0.0	0.0%	0.1%	0.0%	0.0%
CR10	-	127.2	127.2	127.0	127.3	127.2	127.2	0.0	-0.2	-0.1	0.0	0.0%	-0.2%	-0.1%	0.0%
CR11	-	129.9	129.5	129.4	129.8	129.5	129.5	-0.4	-0.5	-0.3	-0.3	-0.3%	-0.4%	-0.2%	-0.2%
CR12	-	127.2	127.1	127.1	127.5	127.2	127.0	0.0	-0.1	-0.3	-0.5	0.0%	0.0%	-0.2%	-0.4%
CR13	-	126.8	126.9	126.8	126.7	126.8	126.8	0.1	0.1	0.1	0.1	0.1%	0.1%	0.0%	0.1%
CR14	-	129.6	128.7	128.9	129.3	128.8	129.0	-0.9	-0.7	-0.5	-0.3	-0.7%	-0.5%	-0.4%	-0.2%
CR15	-	126.5	126.5	126.5	126.4	126.5	126.5	0.0	0.0	0.1	0.1	0.0%	0.0%	0.1%	0.1%
CR16	-	126.9	126.8	126.8	126.6	126.7	126.8	-0.1	-0.1	0.1	0.2	-0.1%	-0.1%	0.1%	0.2%
CR17	-	126.9	127.0	127.0	127.0	127.0	127.1	0.0	0.1	0.0	0.1	0.0%	0.1%	0.0%	0.1%
CR18	-	127.1	127.1	127.0	127.2	127.2	127.2	0.0	-0.1	0.0	0.0	0.0%	-0.1%	0.0%	0.0%
CR19	-	126.9	126.8	127.0	127.0	126.9	126.7	-0.1	0.1	-0.2	-0.3	-0.1%	0.1%	-0.1%	-0.3%
CR20	-	127.4	127.4	127.1	127.2	127.6	127.2	0.0	-0.2	0.3	0.0	0.0%	-0.2%	0.3%	0.0%
CR21	-	126.7	126.5	126.4	126.5	126.5	126.5	-0.2	-0.3	0.0	0.0	-0.2%	-0.2%	0.0%	0.0%
CR22	-	126.5	126.6	126.6	126.8	126.6	126.6	0.1	0.2	-0.1	-0.2	0.1%	0.1%	-0.1%	-0.1%
CR23	-	127.2	126.7	126.8	127.3	127.0	127.2	-0.5	-0.4	-0.3	-0.2	-0.4%	-0.3%	-0.3%	-0.1%
CR24	-	126.6	126.7	126.8	126.7	126.7	126.9	0.0	0.2	0.0	0.2	0.0%	0.1%	0.0%	0.2%
CR25	-	126.7	126.8	126.8	126.7	127.0	127.0	0.1	0.1	0.3	0.3	0.1%	0.1%	0.2%	0.2%
CR26	-	126.7	126.9	126.7	127.0	126.8	127.0	0.1	-0.1	-0.2	0.0	0.1%	0.0%	-0.1%	0.0%
CR27	-	126.9	126.7	126.6	126.6	126.6	126.6	-0.2	-0.4	0.0	0.0	-0.2%	-0.3%	0.0%	0.0%
CR28	-	129.2	128.7	128.2	129.1	128.2	128.2	-0.5	-0.9	-1.0	-0.9	-0.3%	-0.7%	-0.7%	-0.7%
CR29	-	127.1	126.9	126.8	126.9	126.7	126.8	-0.2	-0.3	-0.2	0.0	-0.2%	-0.2%	-0.1%	0.0%
CR30	-	126.5	126.6	126.6	126.6	126.6	126.5	0.1	0.1	0.0	-0.1	0.1%	0.1%	0.0%	-0.1%
CR31	-	126.8	127.0	127.1	126.8	127.5	127.1	0.2	0.3	0.7	0.2	0.2%	0.2%	0.5%	0.2%
CR32	-	126.3	126.3	126.3	126.2	126.3	126.3	0.0	0.0	0.1	0.0	0.0%	0.0%	0.1%	0.0%
CR33	-	126.4	126.4	126.3	126.3	126.4	126.4	0.0	0.0	0.1	0.1	0.0%	0.0%	0.1%	0.1%
CR34	-	126.7	126.8	127.0	126.7	126.8	126.8	0.1	0.3	0.1	0.1	0.1%	0.2%	0.1%	0.1%
CR35	-	126.3	126.4	126.4	126.4	126.3	126.4	0.0	0.0	-0.1	0.0	0.0%	0.0%	-0.1%	0.0%
CR36	-	126.5	126.4	126.3	126.4	126.3	126.3	-0.1	-0.1	-0.1	0.0	0.0%	-0.1%	-0.1%	0.0%
CR37	-	127.8	127.9	128.0	128.0	128.1	127.8	0.1	0.3	0.0	-0.3	0.1%	0.2%	0.0%	-0.2%
CR38	-	126.8	126.8	126.8	126.7	126.7	126.8	0.0	0.0	0.0	0.1	0.0%	0.0%	0.0%	0.1%
CR39	-	127.0	126.8	126.8	126.8	127.0	126.9	-0.2	-0.2	0.2	0.1	-0.1%	-0.1%	0.1%	0.1%
CR40	-	126.4	126.4	126.3	126.5	126.3	126.4	0.0	-0.2	-0.2	-0.1	0.0%	-0.1%	-0.2%	-0.1%
CR41	-	126.3	126.2	126.2	126.3	126.2	126.3	0.0	0.0	-0.1	0.0	0.0%	0.0%	-0.1%	0.0%
CR42	-	126.9	126.9	126.9	127.1	126.9	126.9	-0.1	-0.1	-0.2	-0.2	0.0%	-0.1%	-0.1%	-0.1%

Table I-37 Maximum 24-hour mean PM_{10} concentration at community receptors, ranked by concentration

Rank		Ranking by concentration (µg/m³)						
		2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1		-	129.9	130.0	129.4	130.2	130.4	129.5
2		-	129.7	129.5	129.0	129.8	129.5	129.2
3		-	129.6	128.7	128.9	129.3	128.8	129.0
4		-	129.2	128.7	128.2	129.1	128.2	128.2
5		-	127.9	127.9	128.0	128.0	128.1	127.8
6		-	127.8	127.6	127.4	127.5	127.9	127.6
7		-	127.4	127.4	127.1	127.5	127.6	127.2
8		-	127.2	127.2	127.1	127.3	127.5	127.2
9		-	127.2	127.1	127.1	127.3	127.2	127.2
10		-	127.2	127.1	127.0	127.2	127.2	127.2

Table I-38 Maximum 24-hour mean PM_{10} concentration at community receptors, ranked by increase and by decrease in concentration

Rank		Ranking by increase in concentration relative to Do Minimum (µg/m³)					Ranking by decrease in concentration relative to Do Minimum (µg/m³)			
		2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC		2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1		0.23	0.29	0.66	0.29		-0.92	-0.94	-0.97	-1.06
2		0.22	0.28	0.40	0.25		-0.48	-0.73	-0.48	-0.94
3		0.13	0.27	0.34	0.22		-0.45	-0.69	-0.34	-0.52
4		0.12	0.19	0.25	0.21		-0.39	-0.53	-0.32	-0.34
5		0.12	0.15	0.16	0.13		-0.25	-0.43	-0.29	-0.30
6		0.12	0.14	0.15	0.12		-0.24	-0.39	-0.19	-0.26
7		0.11	0.14	0.14	0.12		-0.24	-0.38	-0.18	-0.25
8		0.10	0.12	0.12	0.12		-0.20	-0.31	-0.18	-0.17
9		0.08	0.11	0.11	0.12		-0.19	-0.31	-0.17	-0.16
10		0.08	0.09	0.10	0.11		-0.18	-0.24	-0.17	-0.16

Table I-39 Maximum 24-hour mean PM_{10} concentration at community receptors, ranked by percentage increase and by decrease in concentration

Rank		Ranking by % increase in concentration relative to Do Minimum					Ranking by % decrease in concentration relative to Do Minimum			
		2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC		2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1		0.2%	0.2%	0.5%	0.2%		-0.7%	-0.7%	-0.7%	-0.8%
2		0.2%	0.2%	0.3%	0.2%		-0.4%	-0.6%	-0.4%	-0.7%
3		0.1%	0.2%	0.3%	0.2%		-0.3%	-0.5%	-0.3%	-0.4%
4		0.1%	0.1%	0.2%	0.2%		-0.3%	-0.4%	-0.2%	-0.3%
5		0.1%	0.1%	0.1%	0.1%		-0.2%	-0.3%	-0.2%	-0.2%
6		0.1%	0.1%	0.1%	0.1%		-0.2%	-0.3%	-0.2%	-0.2%
7		0.1%	0.1%	0.1%	0.1%		-0.2%	-0.3%	-0.1%	-0.2%
8		0.1%	0.1%	0.1%	0.1%		-0.2%	-0.2%	-0.1%	-0.1%
9		0.1%	0.1%	0.1%	0.1%		-0.1%	-0.2%	-0.1%	-0.1%
10		0.1%	0.1%	0.1%	0.1%		-0.1%	-0.2%	-0.1%	-0.1%

Table I-40 Maximum 24-hour mean PM_{10} concentration at RWR receptors, ranked by concentration

Rank	Ranking by concentration (µg/m³)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	71.2	71.1	65.9	70.8	70.4	68.8
2	-	70.3	69.2	64.9	68.2	70.3	67.1
3	-	68.7	67.3	64.9	68.1	68.9	66.6
4	-	67.2	66.4	64.6	67.9	68.3	65.4
5	-	66.7	66.3	63.0	67.6	68.1	64.4
6	-	66.3	66.0	62.3	67.2	67.7	64.1
7	-	66.2	65.4	61.6	66.6	66.2	63.7
8	-	65.1	65.1	61.6	66.2	65.6	63.3
9	-	64.9	64.3	61.0	65.4	65.5	62.7
10	-	64.6	64.0	60.8	65.4	64.4	62.0

Table I-41 Maximum 24-hour mean PM_{10} concentration at RWR receptors, ranked by increase and by decrease in concentration

Rank	Ranking by increase in concentration relative to Do Minimum (µg/m³)				Ranking by decrease in concentration relative to Do Minimum (µg/m³)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	6.1	3.1	5.8	3.2	-5.7	-7.9	-6.5	-9.8
2	3.5	3.0	4.0	3.1	-5.2	-6.5	-6.2	-8.0
3	3.2	2.9	4.0	3.1	-5.1	-6.4	-6.1	-7.8
4	3.1	2.9	4.0	3.0	-4.7	-6.1	-5.8	-7.4
5	3.1	2.8	4.0	2.8	-4.7	-5.9	-5.6	-7.2
6	2.9	2.8	3.6	2.7	-4.6	-5.9	-5.4	-7.2
7	2.8	2.8	3.6	2.6	-4.6	-5.9	-5.4	-6.7
8	2.8	2.5	3.6	2.6	-4.6	-5.4	-5.4	-6.7
9	2.7	2.5	3.5	2.5	-4.5	-5.4	-5.3	-6.4
10	2.7	2.5	3.3	2.5	-4.4	-5.4	-4.9	-6.3

Table I-42 Maximum 24-hour mean PM_{10} concentration at RWR receptors, ranked by percentage increase and by decrease in concentration

Rank	Ranking by % increase in concentration relative to Do Minimum				Ranking by % decrease in concentration relative to Do Minimum			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	10.6%	6.2%	10.0%	6.1%	-8.7%	-12.0%	-10.1%	-14.4%
2	6.0%	5.7%	7.2%	5.9%	-8.5%	-10.2%	-9.3%	-12.4%
3	5.7%	5.6%	7.2%	5.5%	-8.1%	-10.0%	-9.2%	-12.1%
4	5.6%	5.6%	7.0%	5.2%	-8.1%	-9.7%	-9.1%	-11.7%
5	5.5%	5.3%	7.0%	5.2%	-7.8%	-9.7%	-9.0%	-11.4%
6	5.5%	5.2%	6.4%	4.9%	-7.5%	-9.6%	-8.8%	-11.1%
7	5.4%	5.0%	6.3%	4.9%	-7.5%	-9.5%	-8.8%	-10.9%
8	5.2%	5.0%	6.1%	4.9%	-7.5%	-9.0%	-8.7%	-10.9%
9	5.2%	4.9%	6.1%	4.8%	-7.4%	-9.0%	-8.6%	-10.4%
10	5.1%	4.7%	6.0%	4.8%	-7.4%	-9.0%	-7.8%	-10.4%

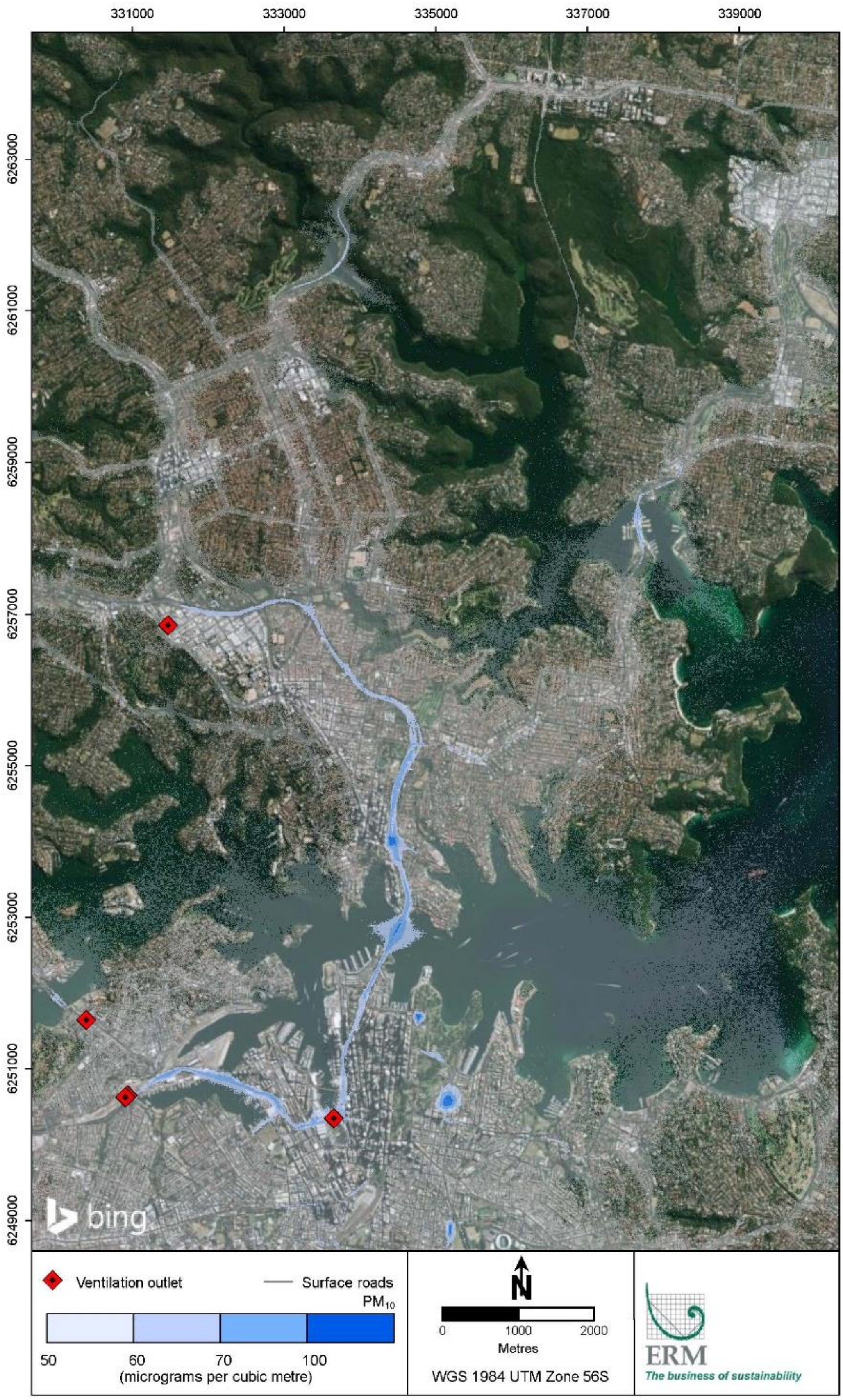


Figure I-31 **Contour plot of maximum 24-hour mean PM_{10} concentration in 2027 Do Minimum scenario (all sources, 2027-DM)**

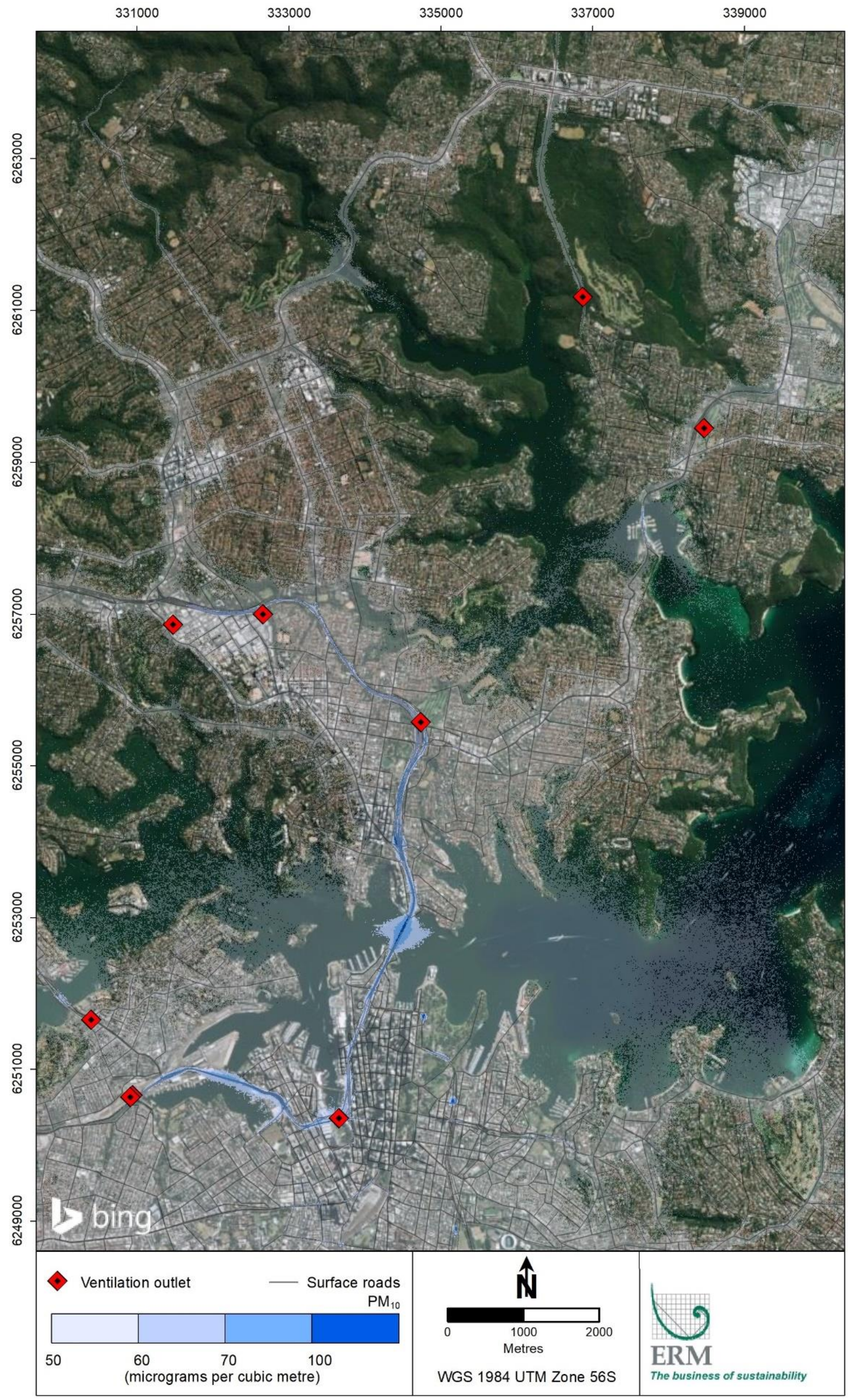


Figure I-32 **Contour plot of maximum 24-hour mean PM_{10} concentration in 2027 Do Something scenario (all sources, 2027-DS(BL))**

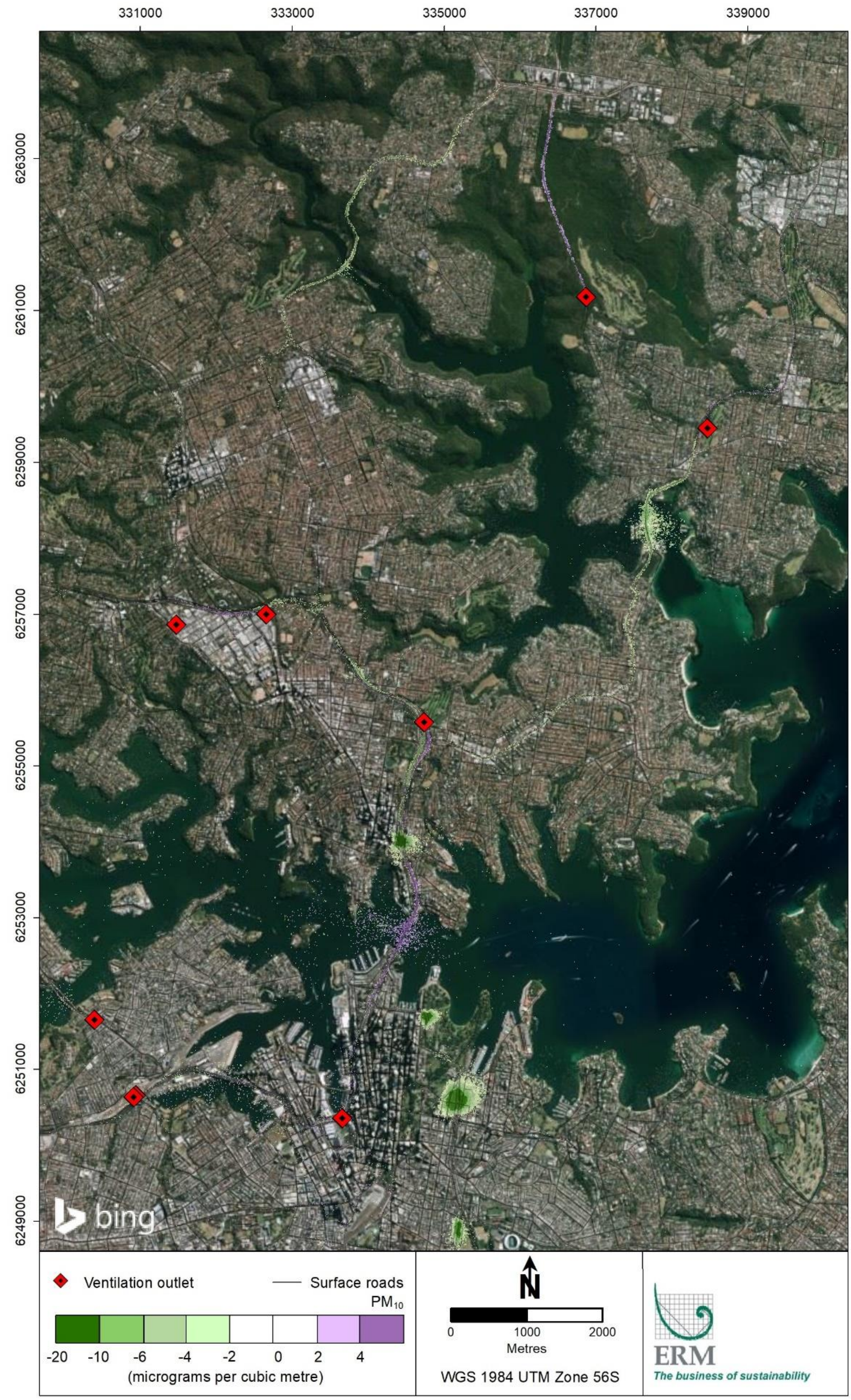


Figure I-33 **Contour plot of change in maximum 24-hour mean PM_{10} concentration in 2027 Do Something scenario (all sources, 2027-DS(BL) minus 2027-DM)**

Figure I-34 **Contour plot of maximum 24-hour mean PM_{10} concentration in 2027 cumulative scenario (all sources, 2027-DSC)**

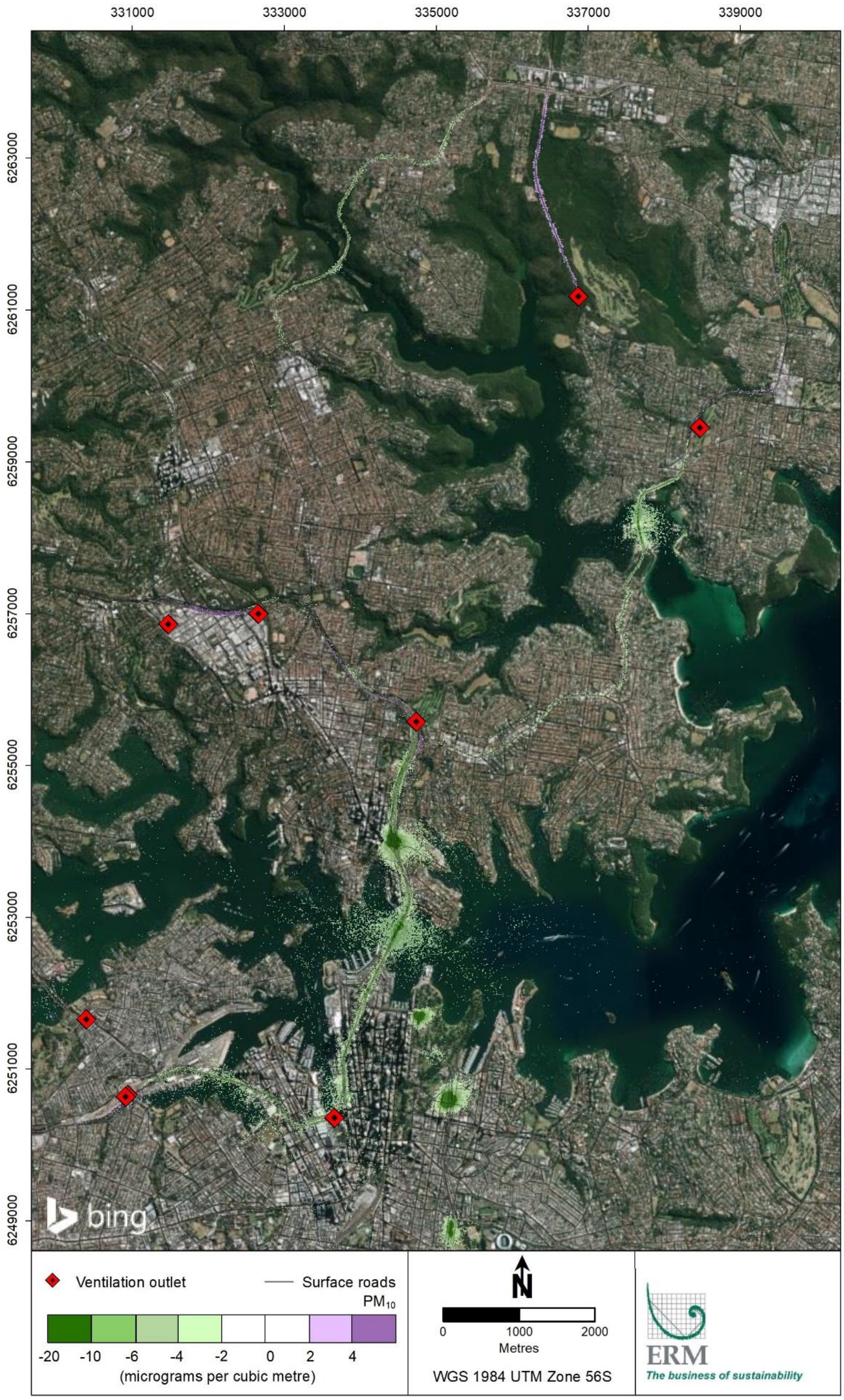


Figure I-35 **Contour plot of change in maximum 24-hour mean PM_{10} concentration in 2027 cumulative scenario (all sources, 2027-DSC minus 2027-DM)**

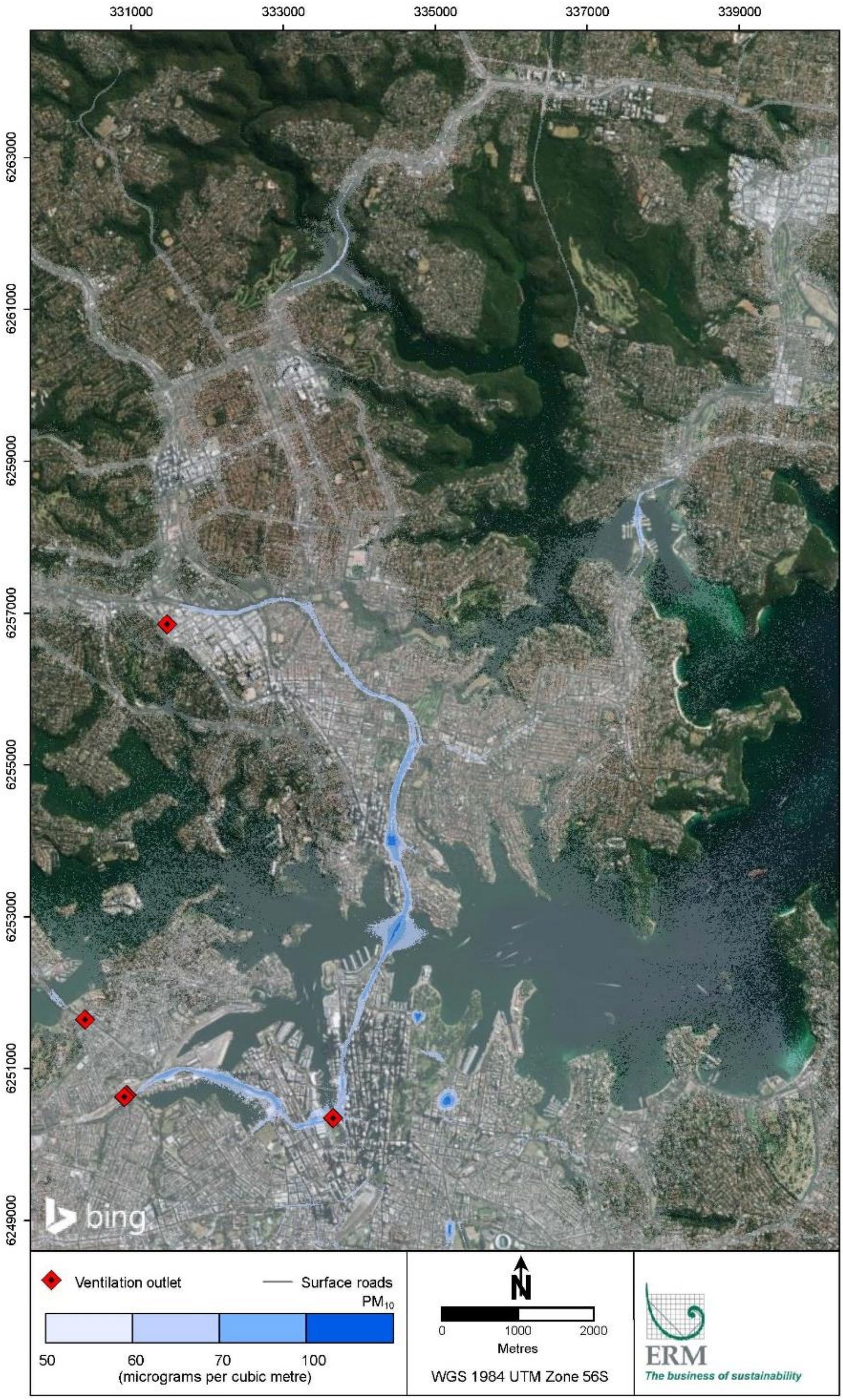


Figure I-36 **Contour plot of maximum 24-hour mean PM_{10} concentration in 2037 Do Minimum scenario (all sources, 2037-DM)**

Figure I-37 **Contour plot of maximum 24-hour mean PM_{10} concentration in 2037 Do Something scenario (all sources, 2037-DS(BL))**

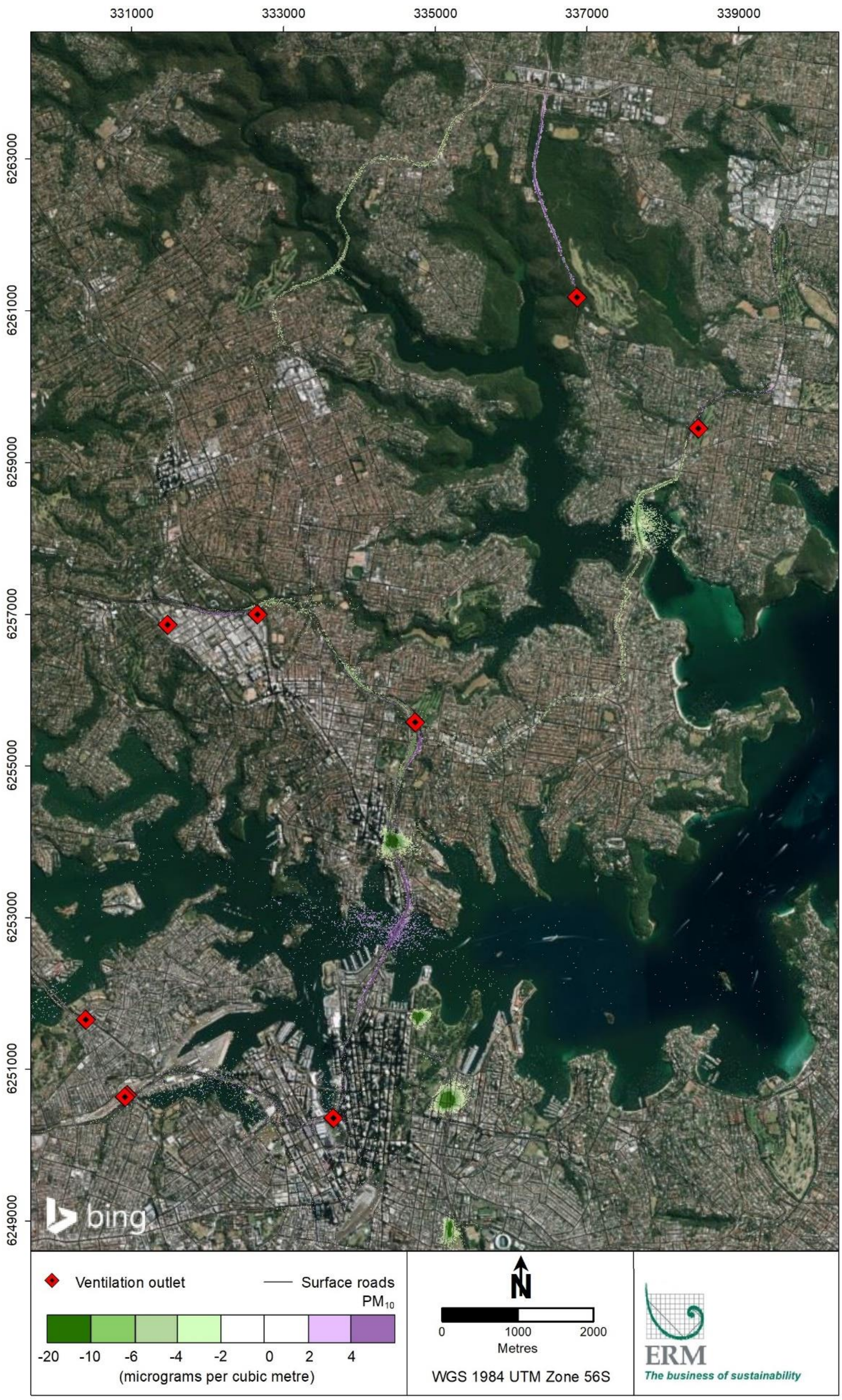


Figure I-38 **Contour plot of change in maximum 24-hour mean PM_{10} concentration in 2037 Do Something scenario (all sources, 2037-DS(BL) minus 2037-DM)**

Figure I-39 **Contour plot of maximum 24-hour mean PM_{10} concentration in 2037 cumulative scenario (all sources, 2037-DSC)**

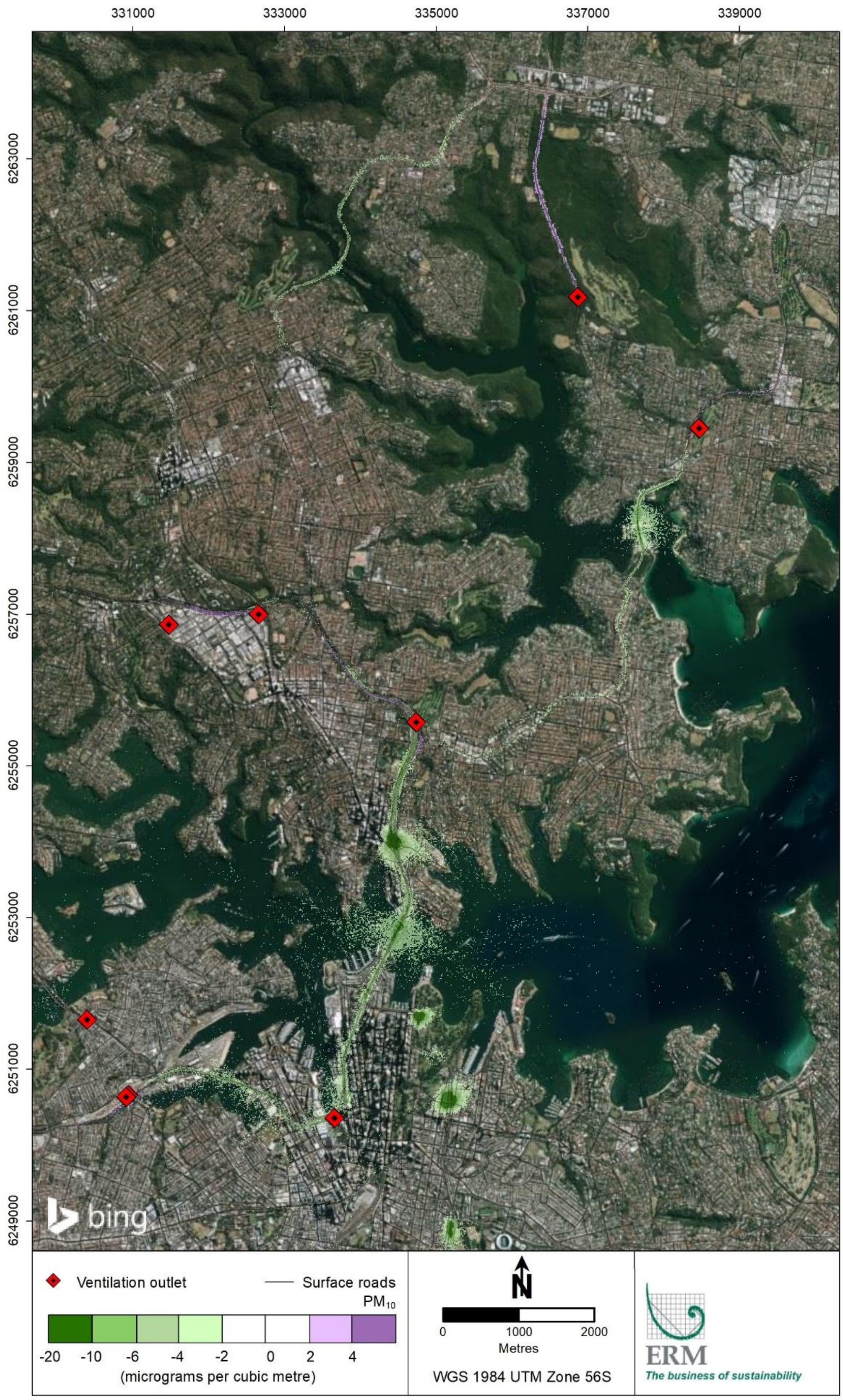


Figure I-40 **Contour plot of change in maximum 24-hour mean PM_{10} concentration in 2037 cumulative scenario (all sources, 2037-DSC minus 2037-DM)**

I.7 $PM_{2.5}$ (annual mean)

Table I-43 Annual mean $PM_{2.5}$ concentration at community receptors

Receptor	Annual mean $PM_{2.5}$ concentration (µg/m³) 2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC	Change relative to Do Minimum (µg/m³) 2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	Change relative to Do Minimum (%) 2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
CR01	-	10.1	10.2	9.9	10.2	10.2	10.1	0.07	-0.18	0.03	-0.08	0.7%	-1.8%	0.3%	-0.8%
CR02	-	8.6	8.5	8.6	8.7	8.6	8.5	-0.09	0.03	-0.18	-0.22	-1.1%	0.4%	-2.1%	-2.5%
CR03	-	8.5	8.5	8.5	8.4	8.5	8.7	-0.08	-0.08	0.07	0.30	-1.0%	-0.9%	0.8%	3.5%
CR04	-	8.1	8.0	8.1	8.2	8.1	8.0	-0.09	0.02	-0.08	-0.14	-1.1%	0.3%	-1.0%	-1.7%
CR05	-	8.0	8.0	8.1	8.1	8.2	8.1	-0.02	0.01	0.02	-0.06	-0.2%	0.2%	0.3%	-0.7%
CR06	-	9.1	9.2	8.8	9.3	9.4	8.9	0.10	-0.26	0.17	-0.37	1.1%	-2.8%	1.8%	-4.0%
CR07	-	8.0	8.0	8.0	8.0	8.1	8.0	-0.04	-0.02	0.02	-0.04	-0.5%	-0.3%	0.3%	-0.5%
CR08	-	8.9	8.9	8.7	8.9	8.9	8.8	-0.02	-0.16	0.01	-0.12	-0.2%	-1.8%	0.1%	-1.4%
CR09	-	8.1	8.1	8.1	8.1	8.1	8.1	-0.04	-0.07	0.00	0.00	-0.5%	-0.9%	0.0%	0.0%
CR10	-	8.7	8.5	8.5	8.6	8.6	8.5	-0.15	-0.11	-0.07	-0.10	-1.7%	-1.3%	-0.8%	-1.2%
CR11	-	9.5	9.2	9.2	9.5	9.3	9.2	-0.26	-0.27	-0.18	-0.26	-2.8%	-2.9%	-1.9%	-2.8%
CR12	-	8.5	8.5	8.5	8.6	8.6	8.5	-0.03	-0.08	0.00	-0.06	-0.3%	-1.0%	0.0%	-0.7%
CR13	-	8.2	8.2	8.2	8.2	8.2	8.2	-0.06	-0.01	-0.05	-0.06	-0.7%	-0.2%	-0.6%	-0.7%
CR14	-	9.6	9.2	9.1	9.6	9.1	9.2	-0.39	-0.50	-0.51	-0.45	-4.0%	-5.2%	-5.3%	-4.7%
CR15	-	8.1	8.1	8.1	8.2	8.1	8.1	-0.04	-0.05	-0.06	-0.03	-0.5%	-0.6%	-0.7%	-0.4%
CR16	-	8.7	8.7	8.7	8.7	8.7	8.7	-0.07	0.02	0.02	0.05	-0.8%	0.2%	0.2%	0.5%
CR17	-	8.4	8.4	8.4	8.4	8.4	8.4	-0.02	-0.04	0.04	-0.01	-0.3%	-0.5%	0.5%	-0.1%
CR18	-	8.2	8.2	8.2	8.3	8.2	8.3	-0.01	-0.02	-0.02	0.05	-0.1%	-0.2%	-0.3%	0.7%
CR19	-	8.5	8.4	8.4	8.5	8.4	8.4	-0.08	-0.09	-0.03	-0.04	-0.9%	-1.1%	-0.3%	-0.4%
CR20	-	8.4	8.5	8.3	8.4	8.4	8.4	0.11	-0.01	0.07	0.05	1.3%	-0.2%	0.9%	0.6%
CR21	-	8.0	8.1	8.1	8.1	8.2	8.1	0.06	0.04	0.05	0.01	0.7%	0.5%	0.6%	0.1%
CR22	-	8.3	8.3	8.3	8.2	8.3	8.3	0.07	0.07	0.09	0.07	0.8%	0.9%	1.0%	0.9%
CR23	-	8.8	8.8	8.8	8.8	8.9	8.8	0.02	0.06	0.10	0.02	0.3%	0.7%	1.1%	0.3%
CR24	-	8.0	8.0	8.0	8.0	8.0	8.0	-0.05	-0.04	0.03	-0.02	-0.7%	-0.5%	0.4%	-0.2%
CR25	-	8.5	8.4	8.4	8.6	8.5	8.6	-0.08	-0.08	-0.09	0.00	-0.9%	-0.9%	-1.1%	0.0%
CR26	-	8.4	8.4	8.3	8.5	8.3	8.4	-0.05	-0.07	-0.16	-0.09	-0.6%	-0.9%	-1.9%	-1.0%
CR27	-	8.0	7.9	7.9	8.0	8.0	8.0	-0.08	-0.09	-0.04	-0.01	-1.1%	-1.1%	-0.5%	-0.1%
CR28	-	10.7	9.8	9.8	10.7	9.9	9.6	-0.85	-0.90	-0.86	-1.09	-8.0%	-8.4%	-8.0%	-10.2%
CR29	-	8.2	8.1	8.1	8.1	8.1	8.2	-0.05	-0.05	0.00	0.05	-0.6%	-0.6%	0.0%	0.6%
CR30	-	8.3	8.2	8.2	8.3	8.2	8.2	-0.04	-0.11	-0.07	-0.07	-0.5%	-1.3%	-0.8%	-0.8%
CR31	-	8.2	8.4	8.3	8.2	8.4	8.3	0.15	0.11	0.13	0.09	1.9%	1.4%	1.6%	1.1%
CR32	-	7.9	7.9	7.9	7.9	7.9	7.9	-0.01	-0.02	-0.03	-0.02	-0.1%	-0.2%	-0.4%	-0.3%
CR33	-	7.9	7.9	8.0	7.9	7.9	7.9	0.01	0.04	-0.02	-0.02	0.1%	0.5%	-0.2%	-0.3%
CR34	-	8.1	8.2	8.2	8.1	8.2	8.2	0.05	0.04	0.08	0.07	0.6%	0.5%	1.0%	0.9%
CR35	-	7.9	7.9	7.9	7.9	7.9	7.9	0.01	0.01	0.01	0.01	0.1%	0.1%	0.2%	0.1%
CR36	-	7.9	8.0	8.0	7.9	7.9	7.9	0.03	0.04	0.01	0.00	0.4%	0.6%	0.2%	0.0%
CR37	-	8.6	8.6	8.6	8.6	8.7	8.7	0.08	0.05	0.09	0.04	0.9%	0.5%	1.1%	0.5%
CR38	-	8.1	8.1	8.0	8.1	8.1	8.0	-0.01	-0.05	-0.02	-0.05	-0.1%	-0.7%	-0.2%	-0.6%
CR39	-	8.1	8.1	8.1	8.2	8.2	8.1	-0.04	-0.03	-0.02	-0.04	-0.5%	-0.3%	-0.3%	-0.5%
CR40	-	8.0	8.0	7.9	8.0	8.0	7.9	-0.05	-0.06	-0.02	-0.04	-0.6%	-0.8%	-0.2%	-0.5%
CR41	-	8.0	8.0	8.0	8.0	8.0	8.0	-0.06	-0.09	-0.07	-0.05	-0.8%	-1.1%	-0.9%	-0.6%
CR42	-	8.1	8.1	8.1	8.1	8.1	8.1	0.01	-0.01	-0.01	-0.01	0.1%	-0.1%	-0.1%	-0.1%

Table I-44 **Annual mean $PM_{2.5}$ concentration at community receptors, ranked by concentration**

Rank	Ranking by concentration (µg/m³)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	10.7	10.2	9.9	10.7	10.2	10.1
2	-	10.1	9.8	9.8	10.2	9.9	9.6
3	-	9.6	9.2	9.2	9.6	9.4	9.2
4	-	9.5	9.2	9.1	9.5	9.3	9.2
5	-	9.1	9.2	8.8	9.3	9.1	8.9
6	-	8.9	8.9	8.8	8.9	8.9	8.8
7	-	8.8	8.8	8.7	8.8	8.9	8.8
8	-	8.7	8.7	8.7	8.7	8.7	8.7
9	-	8.7	8.6	8.6	8.7	8.7	8.7
10	-	8.6	8.5	8.6	8.6	8.6	8.7

Table I-45 **Annual mean $PM_{2.5}$ concentration at community receptors, ranked by increase and by decrease in concentration**

Rank	Ranking by increase in concentration relative to Do Minimum (µg/m³)				Ranking by decrease in concentration relative to Do Minimum (µg/m³)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	0.15	0.11	0.17	0.30	-0.85	-0.90	-0.86	-1.09
2	0.11	0.07	0.13	0.09	-0.39	-0.50	-0.51	-0.45
3	0.10	0.06	0.10	0.07	-0.26	-0.27	-0.18	-0.37
4	0.08	0.05	0.09	0.07	-0.15	-0.26	-0.18	-0.26
5	0.07	0.04	0.09	0.05	-0.09	-0.18	-0.16	-0.22
6	0.07	0.04	0.08	0.05	-0.09	-0.16	-0.09	-0.14
7	0.06	0.04	0.07	0.05	-0.08	-0.11	-0.08	-0.12
8	0.05	0.04	0.07	0.05	-0.08	-0.11	-0.07	-0.10
9	0.03	0.03	0.05	0.04	-0.08	-0.09	-0.07	-0.09
10	0.02	0.02	0.04	0.02	-0.08	-0.09	-0.07	-0.08

Table I-46 **Annual mean $PM_{2.5}$ concentration at community receptors, ranked by percentage increase and by decrease in concentration**

Rank	Ranking by % increase in concentration relative to Do Minimum				Ranking by % decrease in concentration relative to Do Minimum			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	1.9%	1.4%	1.8%	3.5%	-8.0%	-8.4%	-8.0%	-10.2%
2	1.3%	0.9%	1.6%	1.1%	-4.0%	-5.2%	-5.3%	-4.7%
3	1.1%	0.7%	1.1%	0.9%	-2.8%	-2.9%	-2.1%	-4.0%
4	0.9%	0.6%	1.1%	0.9%	-1.7%	-2.8%	-1.9%	-2.8%
5	0.8%	0.5%	1.0%	0.7%	-1.1%	-1.8%	-1.9%	-2.5%
6	0.7%	0.5%	1.0%	0.6%	-1.1%	-1.8%	-1.1%	-1.7%
7	0.7%	0.5%	0.9%	0.6%	-1.1%	-1.3%	-1.0%	-1.4%
8	0.6%	0.5%	0.8%	0.5%	-1.0%	-1.3%	-0.9%	-1.2%
9	0.4%	0.4%	0.6%	0.5%	-0.9%	-1.1%	-0.8%	-1.0%
10	0.3%	0.3%	0.5%	0.3%	-0.9%	-1.1%	-0.8%	-0.8%

Table I-47 Annual mean $PM_{2.5}$ concentration at RWR receptors, ranked by concentration

Rank	Ranking by concentration (µg/m³)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	14.24	14.28	11.79	14.26	14.54	11.69
2	-	12.49	12.67	11.53	12.74	12.64	11.61
3	-	12.24	12.05	11.36	12.32	12.28	11.58
4	-	12.13	11.99	11.25	12.03	12.15	11.30
5	-	12.00	11.81	11.23	11.92	12.06	11.20
6	-	11.92	11.69	10.89	11.91	12.01	11.11
7	-	11.83	11.63	10.86	11.85	11.87	11.06
8	-	11.67	11.56	10.86	11.82	11.79	11.03
9	-	11.67	11.55	10.75	11.70	11.69	10.89
10	-	11.65	11.38	10.74	11.69	11.68	10.88

Table I-48 Annual mean $PM_{2.5}$ concentration at RWR receptors, ranked by increase and by decrease in concentration

Rank	Ranking by increase in concentration relative to Do Minimum (µg/m³)				Ranking by decrease in concentration relative to Do Minimum (µg/m³)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	1.28	0.86	1.65	0.71	-1.64	-2.12	-1.74	-2.28
2	0.82	0.50	0.82	0.62	-1.57	-1.77	-1.41	-1.86
3	0.74	0.48	0.71	0.60	-1.54	-1.67	-1.35	-1.66
4	0.61	0.43	0.56	0.49	-1.23	-1.61	-1.29	-1.65
5	0.51	0.42	0.55	0.47	-1.18	-1.55	-1.25	-1.44
6	0.45	0.41	0.55	0.46	-1.14	-1.51	-1.15	-1.43
7	0.45	0.40	0.53	0.44	-1.13	-1.43	-1.14	-1.43
8	0.43	0.38	0.48	0.42	-1.07	-1.43	-1.10	-1.42
9	0.42	0.36	0.46	0.41	-1.06	-1.43	-1.05	-1.42
10	0.41	0.35	0.44	0.41	-1.06	-1.31	-1.04	-1.39

Table I-49 Annual mean $PM_{2.5}$ concentration at RWR receptors, ranked by percentage increase and by decrease in concentration

Rank	Ranking by % increase in concentration relative to Do Minimum				Ranking by % decrease in concentration relative to Do Minimum			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	12.5%	10.6%	15.8%	8.6%	-15.0%	-17.5%	-14.2%	-18.5%
2	10.1%	5.9%	10.0%	6.7%	-13.2%	-16.3%	-12.1%	-16.0%
3	7.7%	4.8%	7.3%	6.5%	-13.0%	-14.6%	-11.6%	-14.7%
4	6.1%	4.6%	5.6%	5.4%	-12.2%	-13.8%	-11.6%	-14.2%
5	4.9%	4.5%	5.5%	5.3%	-10.5%	-13.8%	-11.4%	-13.4%
6	4.7%	4.5%	5.3%	5.2%	-10.4%	-13.3%	-11.1%	-13.1%
7	4.6%	4.2%	5.3%	4.7%	-9.9%	-13.3%	-10.6%	-13.1%
8	4.6%	4.1%	4.7%	4.7%	-9.9%	-13.3%	-10.2%	-12.9%
9	4.4%	4.0%	4.7%	4.6%	-9.7%	-13.2%	-10.2%	-12.5%
10	4.4%	3.9%	4.3%	4.6%	-9.7%	-12.3%	-9.6%	-12.5%

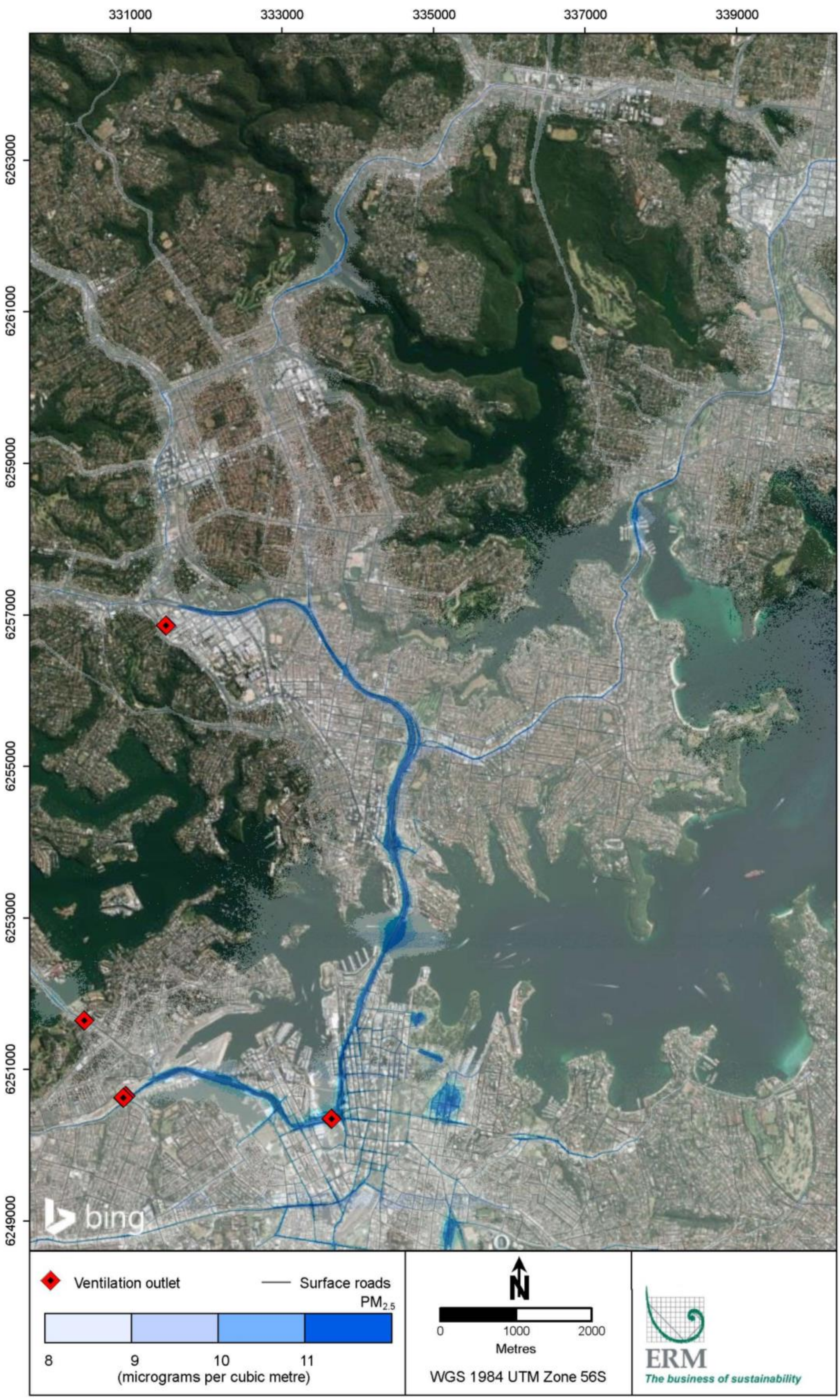


Figure I-41 **Contour plot of annual mean $PM_{2.5}$ concentration in 2027 Do Minimum scenario (all sources, 2027-DM)**

Figure I-42 **Contour plot of annual mean $PM_{2.5}$ concentration in 2027 Do Something scenario (all sources, 2027-DS(BL))**

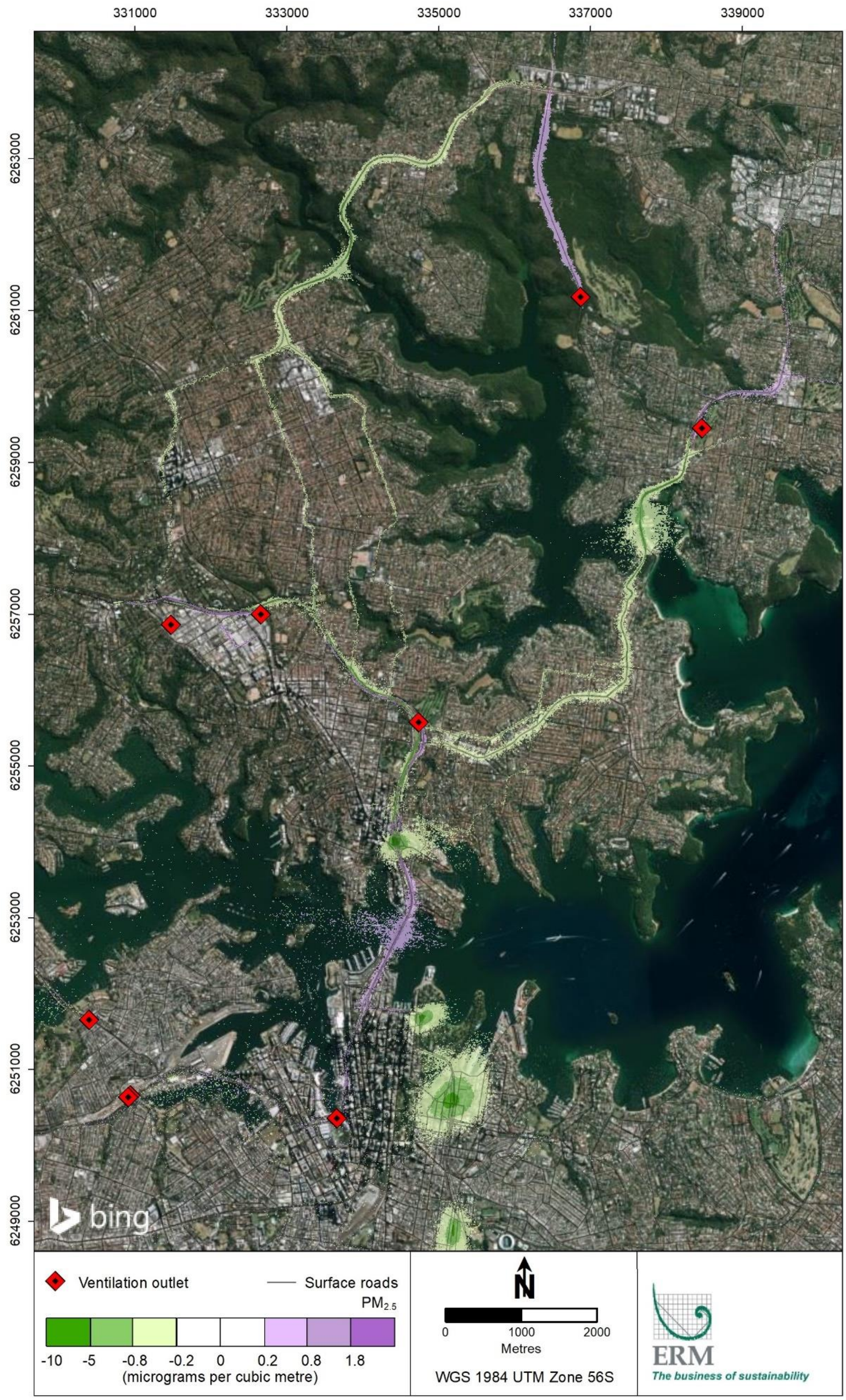


Figure I-43 **Contour plot of change in annual mean $PM_{2.5}$ concentration in 2027 Do Something scenario (all sources, 2027-DS(BL) minus 2027-DM)**

Figure I-44 **Contour plot of annual mean $PM_{2.5}$ concentration in 2027 cumulative scenario (all sources, 2027-DSC)**

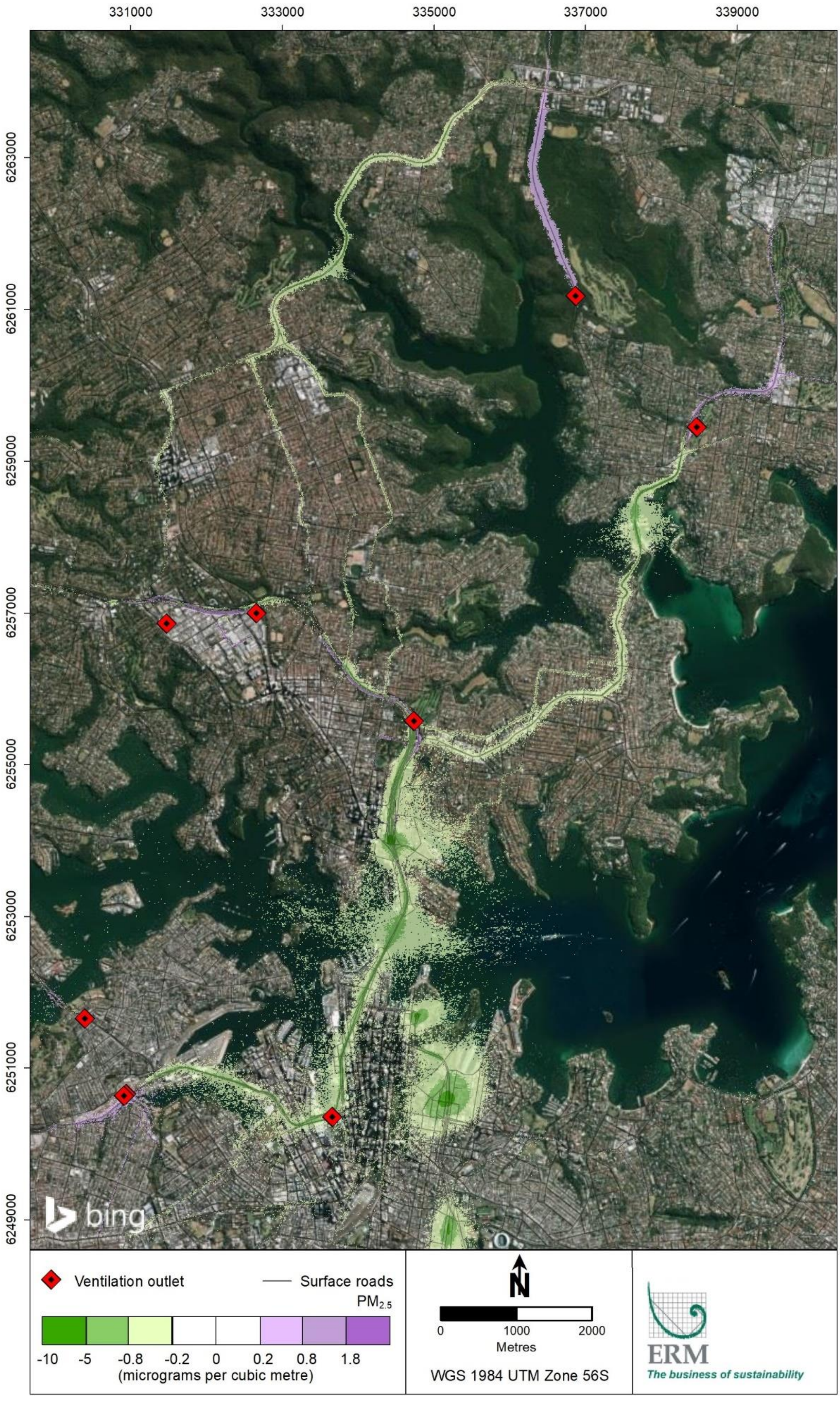


Figure I-45 **Contour plot of change in annual mean $PM_{2.5}$ concentration in 2027 cumulative scenario (all sources, 2027-DSC minus 2027-DM)**

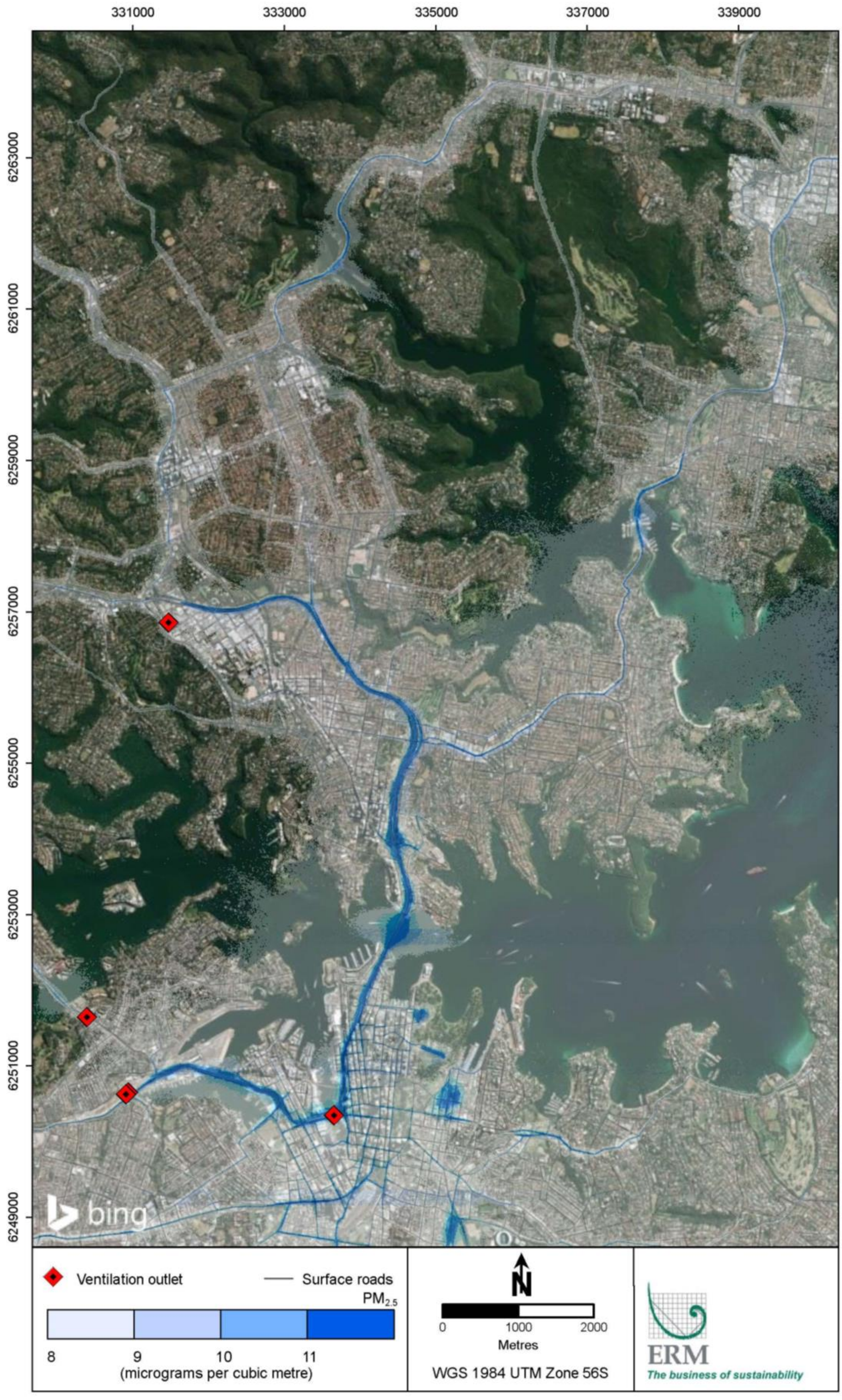


Figure I-46 **Contour plot of annual mean $PM_{2.5}$ concentration in 2037 Do Minimum scenario (all sources, 2037-DM)**

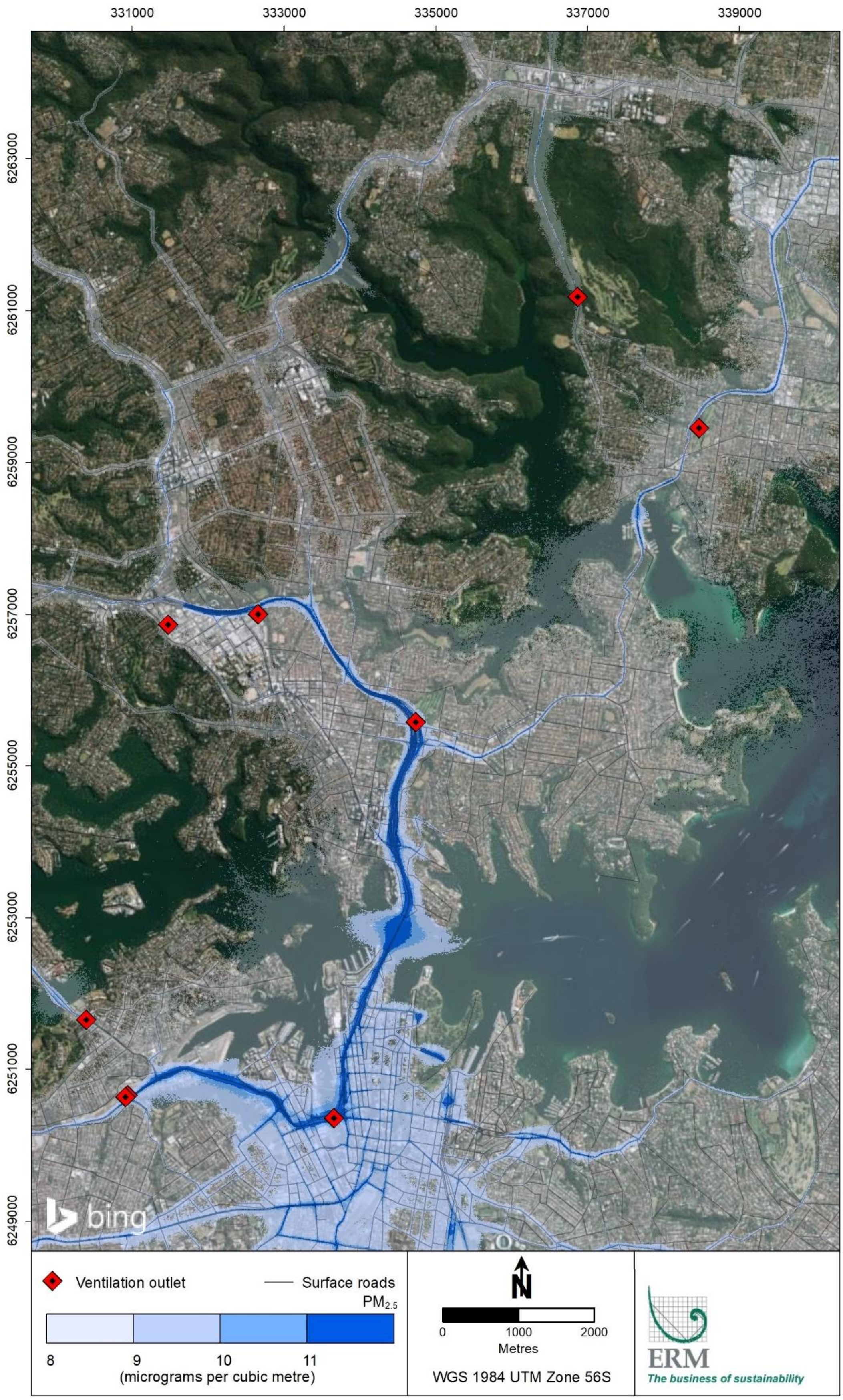


Figure I-47 **Contour plot of annual mean $PM_{2.5}$ concentration in 2037 Do Something scenario (all sources, 2037-DS(BL))**

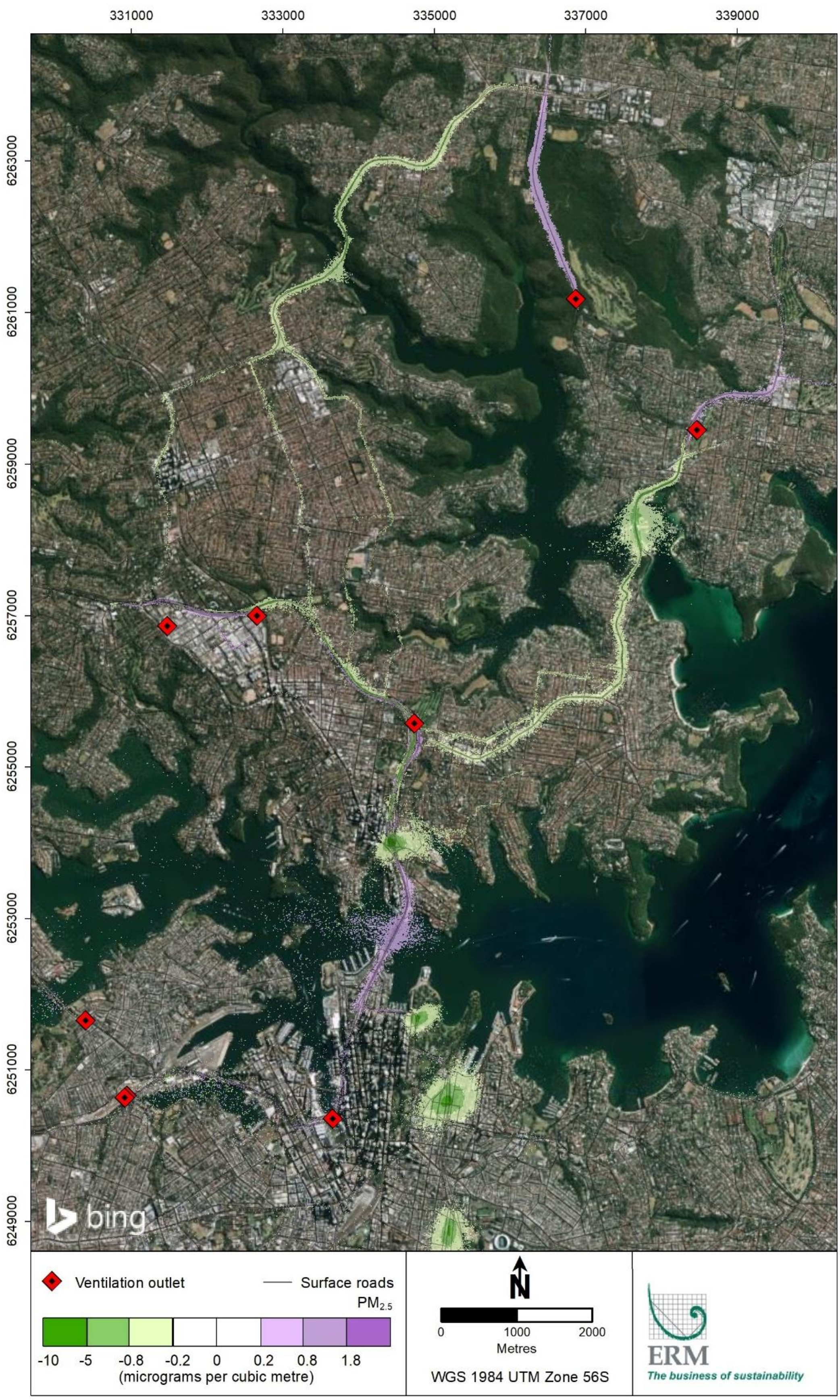


Figure I-48 **Contour plot of change in annual mean $PM_{2.5}$ concentration in 2037 Do Something scenario (all sources, 2037-DS(BL) minus 2037-DM)**

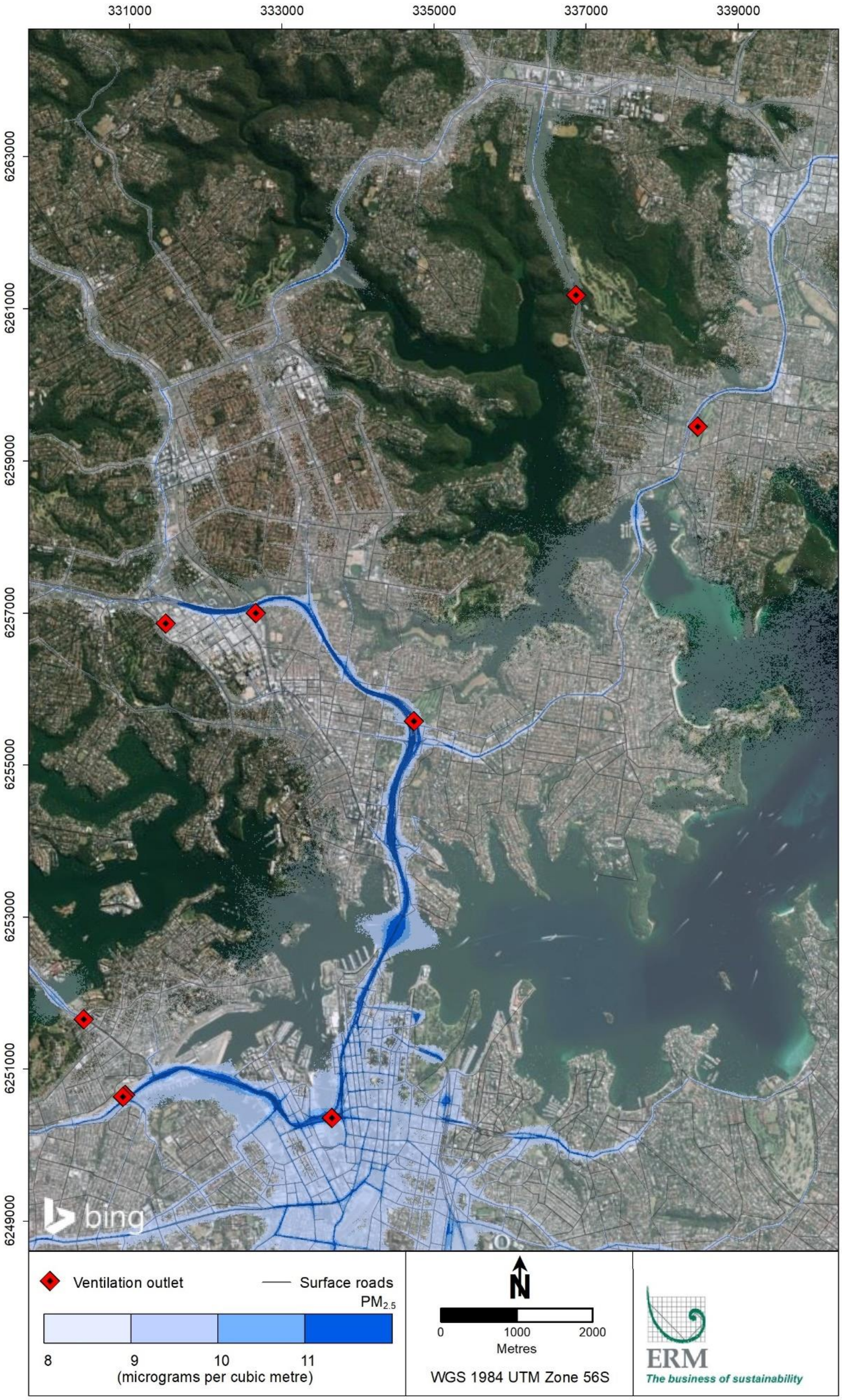


Figure I-49 **Contour plot of annual mean $PM_{2.5}$ concentration in 2037 cumulative scenario (all sources, 2037-DSC)**

Figure I-50 **Contour plot of change in annual mean $PM_{2.5}$ concentration in 2037 cumulative scenario (all sources, 2037-DSC minus 2037-DM)**

I.8 $PM_{2.5}$ (maximum 24-hour mean)

Table I-50 Maximum 24-hour $PM_{2.5}$ concentration at community receptors

Receptor	Maximum 24-hour $PM_{2.5}$ concentration (µg/m³)							Change relative to Do Minimum (µg/m³)				Change relative to Do Minimum (%)			
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
CR01	-	52.4	52.4	52.2	52.6	52.6	52.5	0.0	-0.2	0.026	-0.1	0.0%	-0.3%	0.0%	-0.2%
CR02	-	50.7	50.1	50.6	51.1	50.4	50.2	-0.5	0.0	-0.7	-0.9	-1.1%	-0.1%	-1.4%	-1.7%
CR03	-	50.5	50.2	50.1	50.5	50.4	50.8	-0.3	-0.4	-0.1	0.4	-0.5%	-0.8%	-0.2%	0.7%
CR04	-	50.3	50.3	50.4	50.5	50.2	50.2	-0.1	0.0	-0.3	-0.3	-0.2%	0.0%	-0.5%	-0.7%
CR05	-	50.1	50.0	50.3	50.0	50.3	50.0	-0.2	0.2	0.3	0.0	-0.4%	0.4%	0.6%	0.0%
CR06	-	51.3	50.8	50.9	51.4	51.4	50.5	-0.5	-0.4	0.0	-0.9	-1.0%	-0.8%	0.0%	-1.7%
CR07	-	50.1	49.8	49.9	50.1	49.9	49.8	-0.2	-0.1	-0.2	-0.3	-0.4%	-0.3%	-0.3%	-0.6%
CR08	-	50.8	50.8	51.2	51.1	50.9	50.8	0.0	0.4	-0.3	-0.3	0.0%	0.7%	-0.5%	-0.6%
CR09	-	49.9	50.2	50.1	50.2	50.2	50.0	0.3	0.1	-0.1	-0.2	0.5%	0.2%	-0.1%	-0.4%
CR10	-	50.7	50.4	50.7	50.5	50.6	50.7	-0.2	0.1	0.1	0.2	-0.4%	0.1%	0.2%	0.4%
CR11	-	52.2	51.1	51.4	52.4	51.3	51.3	-1.1	-0.8	-1.1	-1.1	-2.1%	-1.6%	-2.1%	-2.1%
CR12	-	50.6	50.7	50.7	50.6	50.7	50.6	0.1	0.1	0.1	0.0	0.2%	0.2%	0.2%	0.0%
CR13	-	50.0	50.0	49.8	50.1	50.0	50.2	0.0	-0.2	-0.1	0.1	0.0%	-0.4%	-0.3%	0.2%
CR14	-	51.9	51.0	51.3	52.1	50.8	51.4	-0.9	-0.6	-1.3	-0.7	-1.8%	-1.2%	-2.5%	-1.4%
CR15	-	50.1	49.8	50.0	50.2	50.1	50.1	-0.4	-0.2	-0.1	-0.1	-0.8%	-0.3%	-0.1%	-0.1%
CR16	-	51.1	51.1	51.0	50.9	50.6	50.8	0.0	-0.1	-0.3	-0.1	0.0%	-0.2%	-0.5%	-0.2%
CR17	-	50.9	50.7	50.6	50.3	50.7	50.6	-0.3	-0.4	0.4	0.3	-0.6%	-0.7%	0.8%	0.6%
CR18	-	50.3	50.2	50.1	50.7	50.1	50.0	0.0	-0.2	-0.6	-0.7	-0.1%	-0.4%	-1.1%	-1.3%
CR19	-	50.6	50.4	50.2	50.7	50.9	50.6	-0.2	-0.5	0.2	-0.1	-0.4%	-0.9%	0.4%	-0.2%
CR20	-	50.5	50.5	50.4	50.5	51.1	50.4	0.0	-0.1	0.5	-0.2	0.1%	-0.3%	1.0%	-0.3%
CR21	-	50.3	50.6	50.2	50.4	50.2	50.4	0.3	-0.1	-0.3	-0.1	0.5%	-0.1%	-0.5%	-0.1%
CR22	-	50.4	50.6	50.7	50.3	50.4	50.8	0.2	0.3	0.2	0.5	0.4%	0.5%	0.3%	1.0%
CR23	-	52.1	51.4	51.1	52.0	52.0	51.4	-0.7	-1.0	0.0	-0.6	-1.3%	-1.9%	0.0%	-1.2%
CR24	-	50.1	49.7	49.9	50.0	50.2	49.8	-0.3	-0.1	0.2	-0.2	-0.7%	-0.3%	0.4%	-0.3%
CR25	-	50.6	50.5	50.4	50.5	50.6	51.0	-0.1	-0.1	0.2	0.5	-0.2%	-0.3%	0.4%	1.1%
CR26	-	50.9	50.6	50.6	50.6	50.6	50.3	-0.3	-0.3	0.1	-0.2	-0.5%	-0.6%	0.1%	-0.4%
CR27	-	50.0	49.6	49.6	50.3	49.7	49.8	-0.4	-0.3	-0.5	-0.4	-0.8%	-0.6%	-1.0%	-0.8%
CR28	-	54.4	53.1	53.7	53.5	53.2	52.1	-1.4	-0.8	-0.3	-1.4	-2.6%	-1.5%	-0.6%	-2.6%
CR29	-	50.1	50.0	50.0	49.9	50.1	49.9	-0.1	-0.1	0.2	0.1	-0.1%	-0.2%	0.5%	0.1%
CR30	-	50.6	50.2	50.3	50.5	50.1	50.1	-0.4	-0.3	-0.4	-0.4	-0.7%	-0.5%	-0.7%	-0.7%
CR31	-	50.0	50.1	50.3	50.0	50.2	50.4	0.1	0.2	0.2	0.4	0.1%	0.4%	0.3%	0.8%
CR32	-	49.7	49.7	49.5	49.5	49.7	49.6	0.1	-0.1	0.2	0.1	0.2%	-0.2%	0.5%	0.2%
CR33	-	49.6	49.8	49.6	49.7	49.5	49.9	0.2	0.0	-0.1	0.2	0.5%	0.0%	-0.3%	0.4%
CR34	-	50.1	49.9	50.0	50.0	49.8	50.0	-0.2	0.0	-0.2	0.0	-0.3%	-0.1%	-0.4%	0.0%
CR35	-	49.7	49.6	49.6	49.7	49.7	49.5	-0.1	-0.1	0.0	-0.1	-0.2%	-0.3%	0.0%	-0.2%
CR36	-	49.6	49.7	49.8	49.7	49.7	49.5	0.2	0.2	0.0	-0.1	0.3%	0.4%	0.1%	-0.2%
CR37	-	50.7	50.4	50.5	50.5	50.4	50.3	-0.3	-0.3	-0.1	-0.2	-0.6%	-0.5%	-0.1%	-0.3%
CR38	-	50.2	50.7	49.9	50.2	50.1	50.0	0.5	-0.2	-0.1	-0.2	1.0%	-0.5%	-0.2%	-0.4%
CR39	-	50.1	50.0	50.2	50.1	50.1	50.1	-0.1	0.1	0.0	0.0	-0.2%	0.2%	0.0%	-0.1%
CR40	-	49.6	49.8	49.7	49.6	49.8	49.7	0.1	0.1	0.2	0.0	0.3%	0.2%	0.4%	0.0%
CR41	-	49.8	50.0	49.8	49.8	49.9	49.7	0.2	0.0	0.1	-0.1	0.4%	0.1%	0.2%	-0.2%
CR42	-	49.6	49.6	49.6	49.8	49.7	49.8	0.0	0.0	-0.1	0.0	0.0%	-0.1%	-0.1%	0.1%

Table I-51 Maximum 24-hour $PM_{2.5}$ concentration at community receptors, ranked by concentration

Rank	Ranking by concentration ($\mu g/m^3$)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	54.4	53.1	53.7	53.5	53.2	52.5
2	-	52.4	52.4	52.2	52.6	52.6	52.1
3	-	52.2	51.4	51.4	52.4	52.0	51.4
4	-	52.1	51.1	51.3	52.1	51.4	51.4
5	-	51.9	51.1	51.2	52.0	51.3	51.3
6	-	51.3	51.0	51.1	51.4	51.1	51.0
7	-	51.1	50.8	51.0	51.1	50.9	50.8
8	-	50.9	50.8	50.9	51.1	50.9	50.8
9	-	50.9	50.7	50.7	50.9	50.8	50.8
10	-	50.8	50.7	50.7	50.7	50.7	50.8

Table I-52 Maximum 24-hour $PM_{2.5}$ concentration at community receptors, ranked by increase and by decrease in concentration

Rank	Ranking by increase in concentration relative to Do Minimum ($\mu g/m^3$)				Ranking by decrease in concentration relative to Do Minimum ($\mu g/m^3$)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	0.50	0.35	0.52	0.54	-1.39	-0.99	-1.28	-1.37
2	0.27	0.26	0.43	0.52	-1.10	-0.82	-1.08	-1.12
3	0.26	0.21	0.31	0.40	-0.93	-0.79	-0.70	-0.88
4	0.24	0.21	0.24	0.35	-0.70	-0.60	-0.58	-0.88
5	0.22	0.20	0.23	0.31	-0.54	-0.47	-0.52	-0.74
6	0.18	0.12	0.22	0.21	-0.51	-0.43	-0.35	-0.68
7	0.15	0.11	0.20	0.20	-0.40	-0.39	-0.33	-0.64
8	0.13	0.10	0.19	0.10	-0.38	-0.36	-0.27	-0.42
9	0.11	0.08	0.19	0.08	-0.37	-0.31	-0.27	-0.38
10	0.09	0.06	0.17	0.06	-0.34	-0.30	-0.27	-0.34

Table I-53 Maximum 24-hour $PM_{2.5}$ concentration at community receptors, ranked by percentage increase and by decrease in concentration

Rank	Ranking by % increase in concentration relative to Do Minimum				Ranking by % decrease in concentration relative to Do Minimum			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	1.0%	0.7%	1.0%	1.1%	-2.6%	-1.9%	-2.5%	-2.6%
2	0.5%	0.5%	0.8%	1.0%	-2.1%	-1.6%	-2.1%	-2.1%
3	0.5%	0.4%	0.6%	0.8%	-1.8%	-1.5%	-1.4%	-1.7%
4	0.5%	0.4%	0.5%	0.7%	-1.3%	-1.2%	-1.1%	-1.7%
5	0.4%	0.4%	0.5%	0.6%	-1.1%	-0.9%	-1.0%	-1.4%
6	0.4%	0.2%	0.4%	0.4%	-1.0%	-0.8%	-0.7%	-1.3%
7	0.3%	0.2%	0.4%	0.4%	-0.8%	-0.8%	-0.6%	-1.2%
8	0.3%	0.2%	0.4%	0.2%	-0.8%	-0.7%	-0.5%	-0.8%
9	0.2%	0.2%	0.4%	0.2%	-0.7%	-0.6%	-0.5%	-0.7%
10	0.2%	0.1%	0.3%	0.1%	-0.7%	-0.6%	-0.5%	-0.7%

Table I-54 Maximum 24-hour $PM_{2.5}$ concentration at RWR receptors, ranked by concentration

Rank	Ranking by concentration (µg/m³)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	37.2	35.9	33.9	36.3	36.5	33.4
2	-	36.5	35.1	33.3	36.1	35.1	33.4
3	-	35.0	34.8	33.0	35.1	34.3	33.3
4	-	34.0	33.9	32.6	34.4	34.3	32.0
5	-	34.0	33.5	31.0	34.2	34.3	31.6
6	-	33.8	33.3	30.6	34.0	34.1	30.8
7	-	33.8	33.2	30.4	33.9	33.3	30.6
8	-	33.5	33.1	30.1	33.9	32.9	30.6
9	-	33.0	32.4	30.0	33.1	32.8	30.5
10	-	32.8	31.8	30.0	33.0	32.7	30.5

Table I-55 Maximum 24-hour $PM_{2.5}$ concentration at RWR receptors, ranked by increase and by decrease in concentration

Rank	Ranking by increase in concentration relative to Do Minimum (µg/m³)				Ranking by decrease in concentration relative to Do Minimum (µg/m³)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	3.1	2.0	4.2	2.4	-4.4	-5.3	-5.1	-6.3
2	2.3	1.9	2.3	2.0	-3.4	-4.6	-4.2	-4.9
3	2.2	1.9	2.1	1.9	-3.3	-4.5	-3.8	-4.7
4	2.0	1.9	1.8	1.8	-3.2	-4.1	-3.6	-4.5
5	1.6	1.7	1.7	1.7	-3.2	-3.7	-3.3	-3.9
6	1.5	1.7	1.7	1.7	-2.8	-3.7	-3.2	-3.9
7	1.5	1.6	1.7	1.7	-2.8	-3.7	-3.1	-3.7
8	1.5	1.5	1.7	1.6	-2.8	-3.7	-3.0	-3.6
9	1.4	1.5	1.6	1.5	-2.7	-3.6	-2.9	-3.6
10	1.4	1.5	1.6	1.5	-2.7	-3.6	-2.9	-3.6

Table I-56 Maximum 24-hour $PM_{2.5}$ concentration at RWR receptors, ranked by percentage increase and by decrease in concentration

Rank	Ranking by % increase in concentration relative to Do Minimum				Ranking by % decrease in concentration relative to Do Minimum			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	11.2%	8.0%	14.8%	10.1%	-13.7%	-15.7%	-15.0%	-18.4%
2	8.6%	7.8%	9.9%	8.4%	-10.6%	-14.5%	-12.2%	-14.8%
3	8.6%	7.8%	8.5%	7.3%	-10.6%	-14.3%	-12.0%	-14.6%
4	8.4%	6.9%	7.3%	7.1%	-10.3%	-13.2%	-12.0%	-14.3%
5	6.6%	6.8%	6.8%	7.0%	-10.3%	-13.0%	-11.2%	-12.4%
6	6.0%	6.7%	6.8%	6.3%	-9.9%	-12.6%	-10.9%	-12.2%
7	6.0%	6.7%	6.7%	6.3%	-9.9%	-12.1%	-10.5%	-11.9%
8	6.0%	6.5%	6.6%	6.3%	-9.5%	-12.1%	-9.9%	-11.9%
9	5.9%	6.1%	6.5%	6.2%	-9.1%	-11.9%	-9.9%	-11.9%
10	5.8%	6.0%	6.3%	6.1%	-9.1%	-11.4%	-9.6%	-11.9%

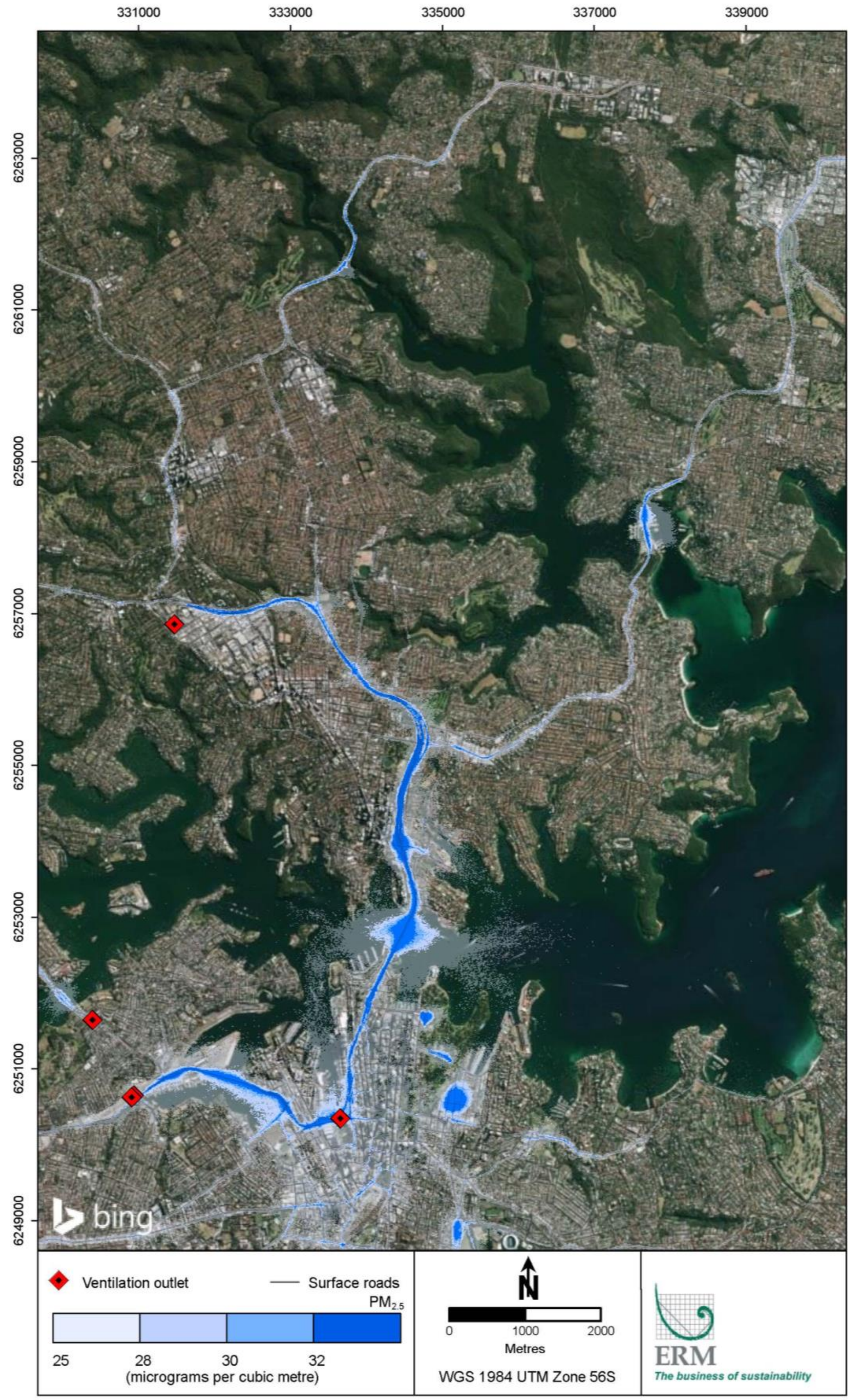


Figure I-51 **Contour plot of maximum 24-hour mean $PM_{2.5}$ concentration in 2027 Do Minimum scenario (all sources, 2027-DM)**

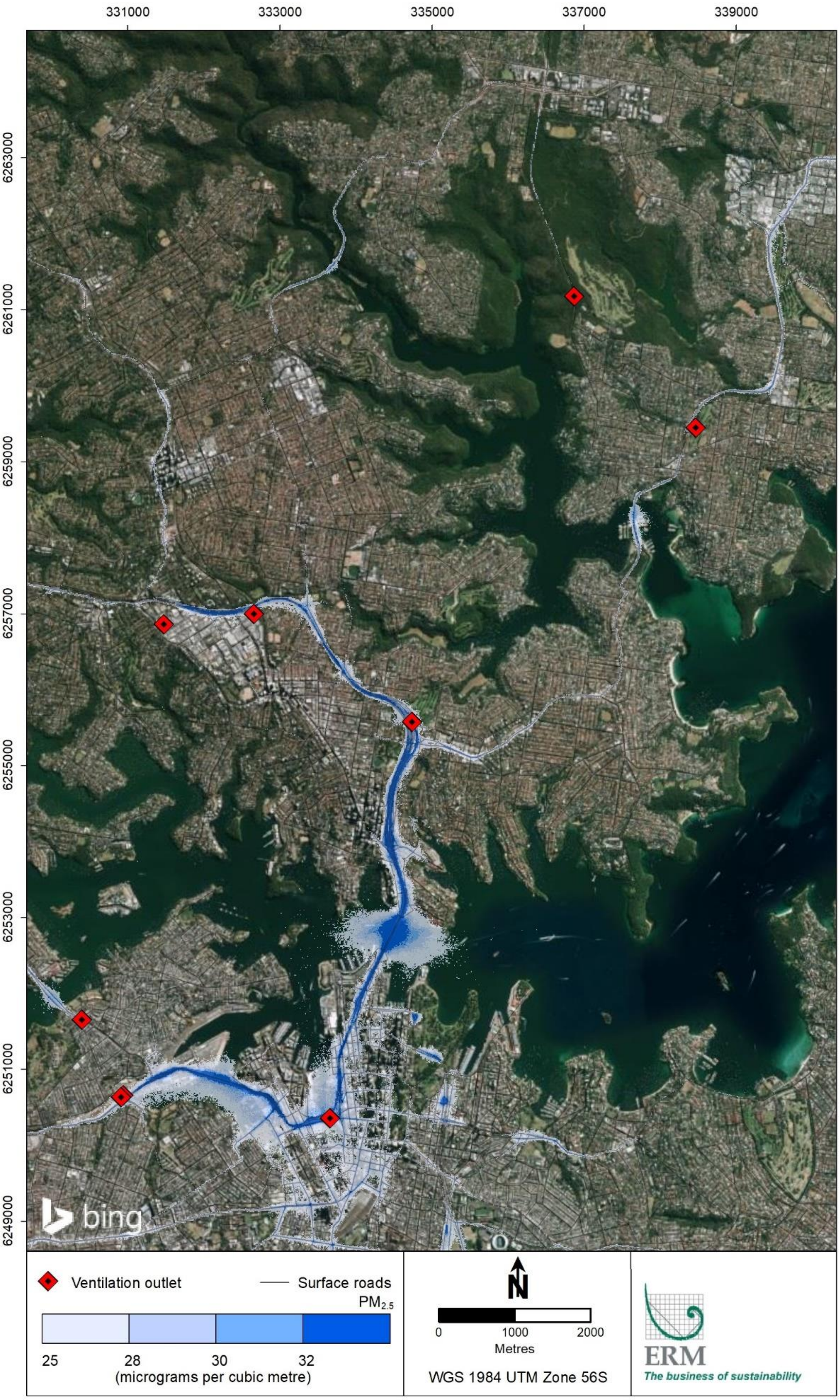


Figure I-52 **Contour plot of maximum 24-hour mean $PM_{2.5}$ concentration in 2027 Do Something scenario (all sources, 2027-DS(BL))**

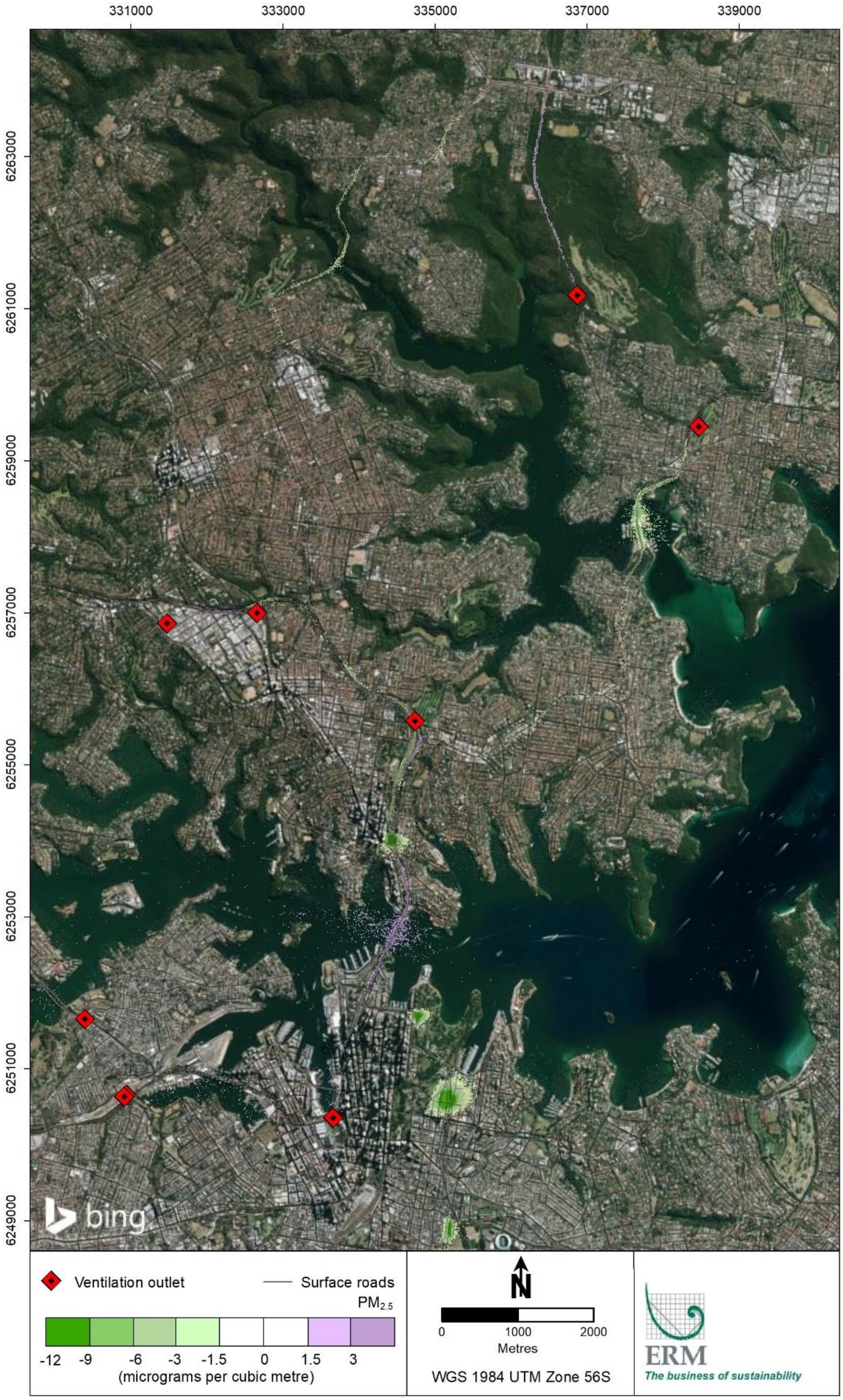


Figure I-53 **Contour plot of change in maximum 24-hour mean $PM_{2.5}$ concentration in 2027 Do Something scenario (all sources, 2027-DS(BL) minus 2027-DM)**

Figure I-54 **Contour plot of maximum 24-hour mean $PM_{2.5}$ concentration in 2027 cumulative scenario (all sources, 2027-DSC)**

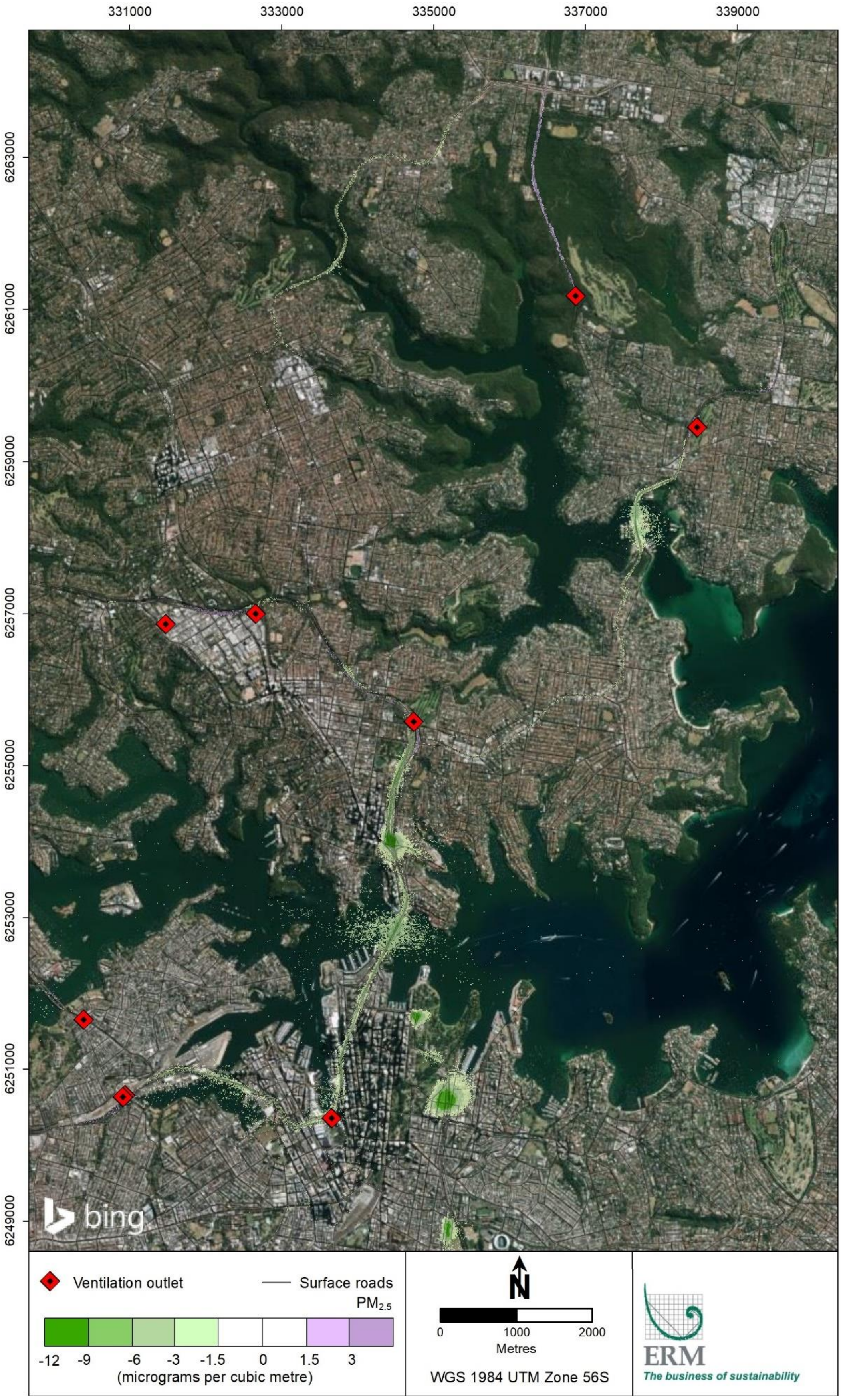


Figure I-55 **Contour plot of change in maximum 24-hour mean $PM_{2.5}$ concentration in 2027 cumulative scenario (all sources, 2027-DSC minus 2027-DM)**

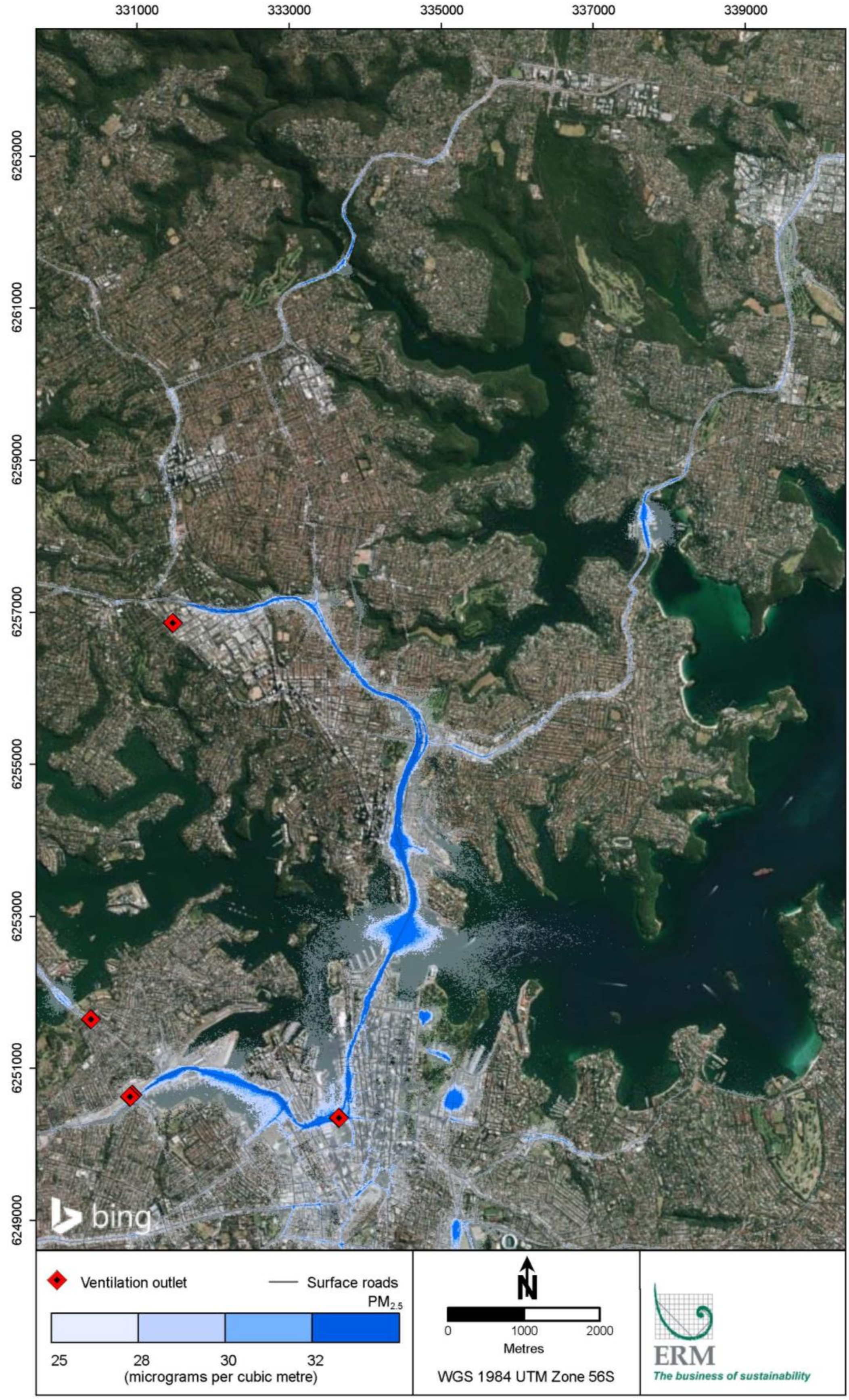


Figure I-56 **Contour plot of maximum 24-hour mean $PM_{2.5}$ concentration in 2037 Do Minimum scenario (all sources, 2037-DM)**

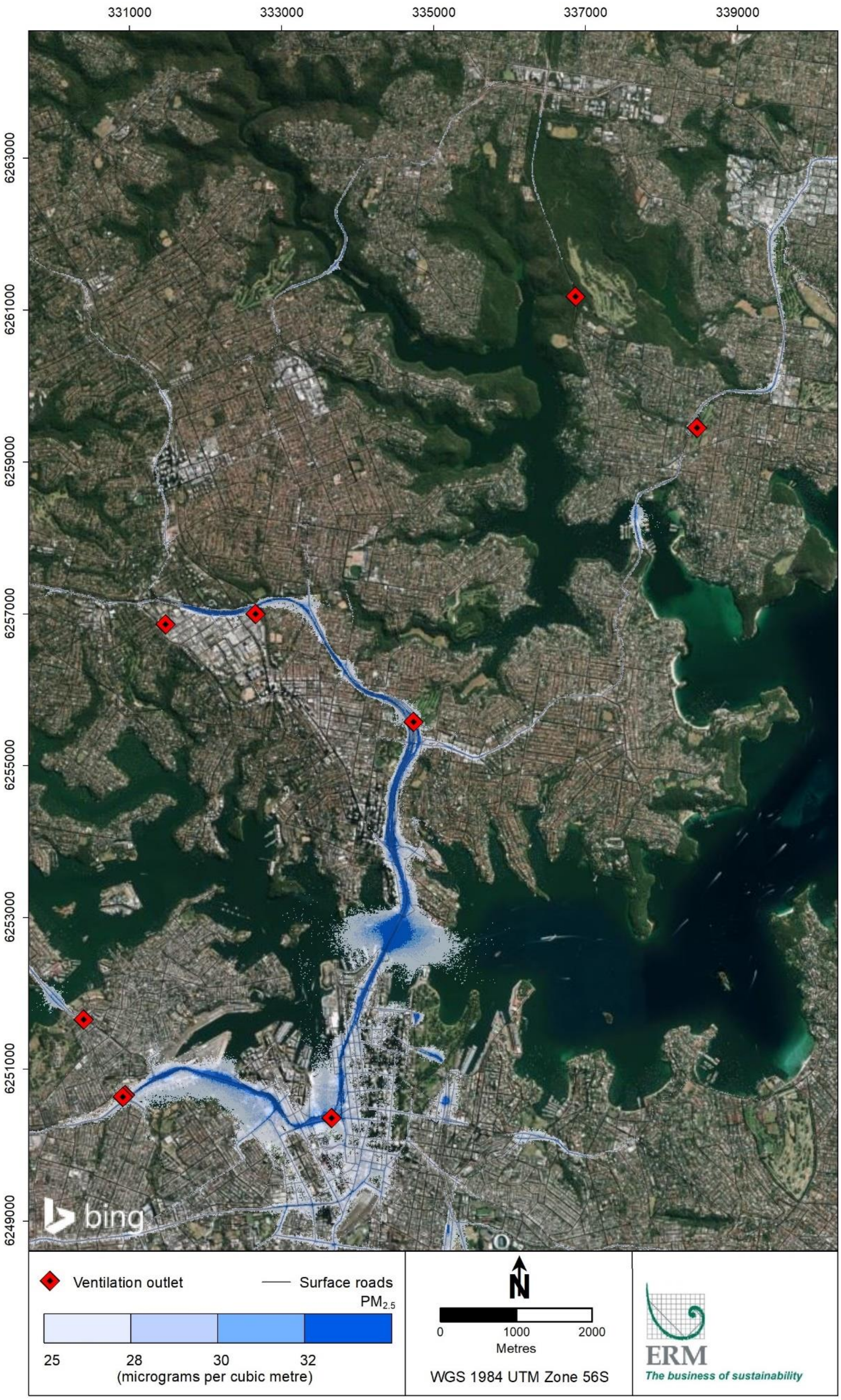


Figure I-57 **Contour plot of maximum 24-hour mean $PM_{2.5}$ concentration in 2037 Do Something scenario (all sources, 2037-DS(BL))**

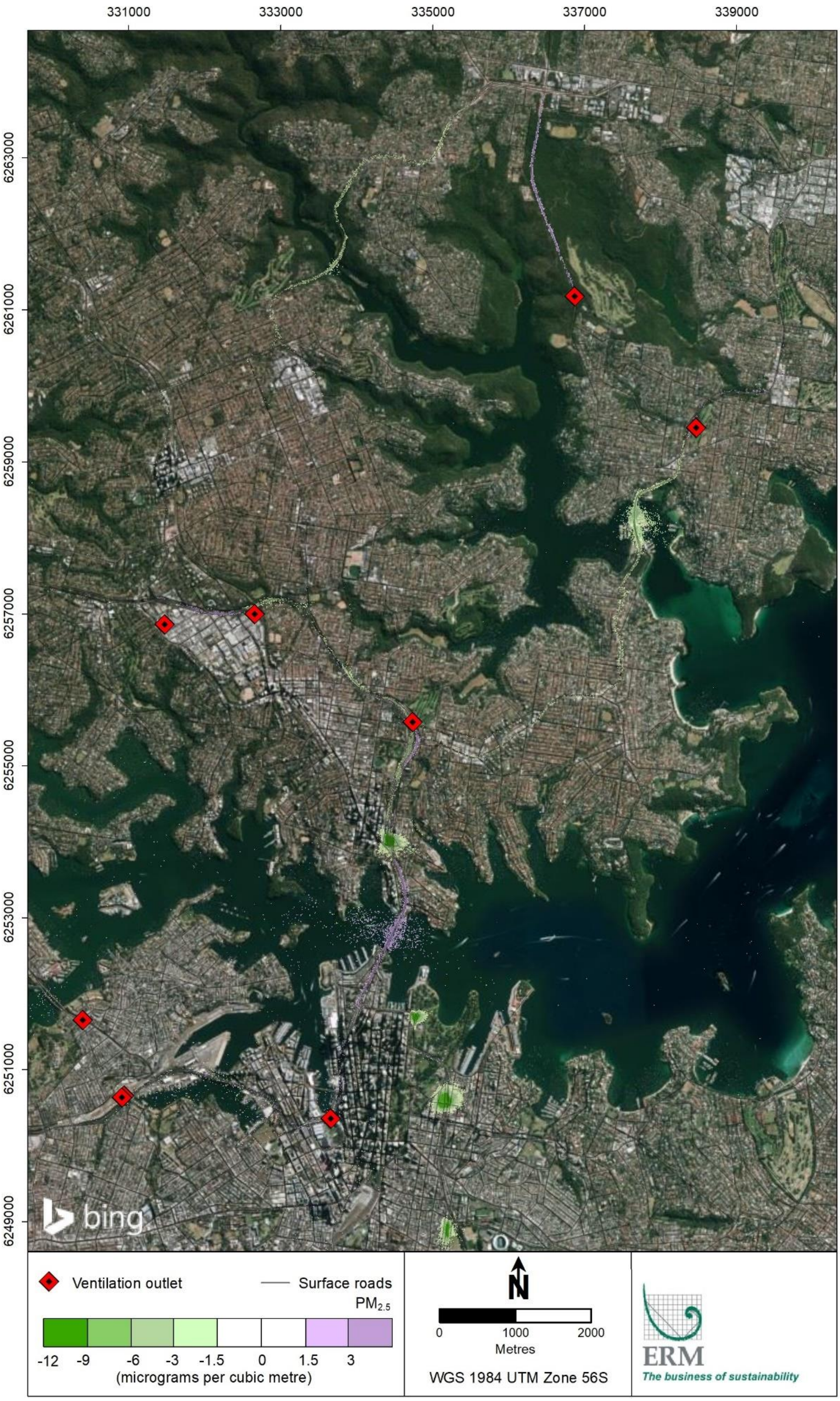


Figure I-58 Contour plot of change in maximum 24-hour mean $PM_{2.5}$ concentration in 2037 Do Something scenario (all sources, 2037-DS(BL) minus 2037-DM)

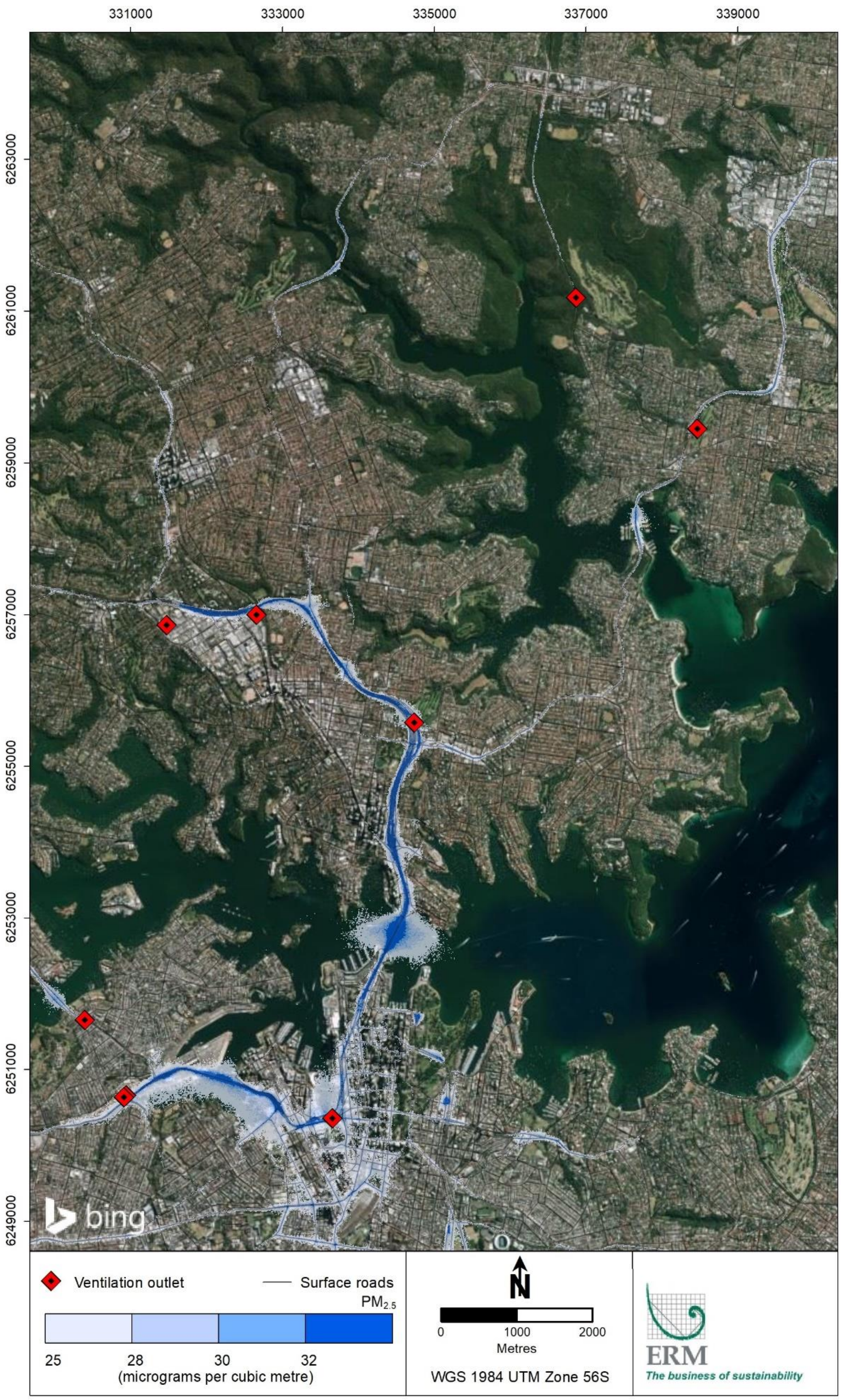


Figure I-59 **Contour plot of maximum 24-hour mean $PM_{2.5}$ concentration in 2037 cumulative scenario (all sources, 2037-DSC)**

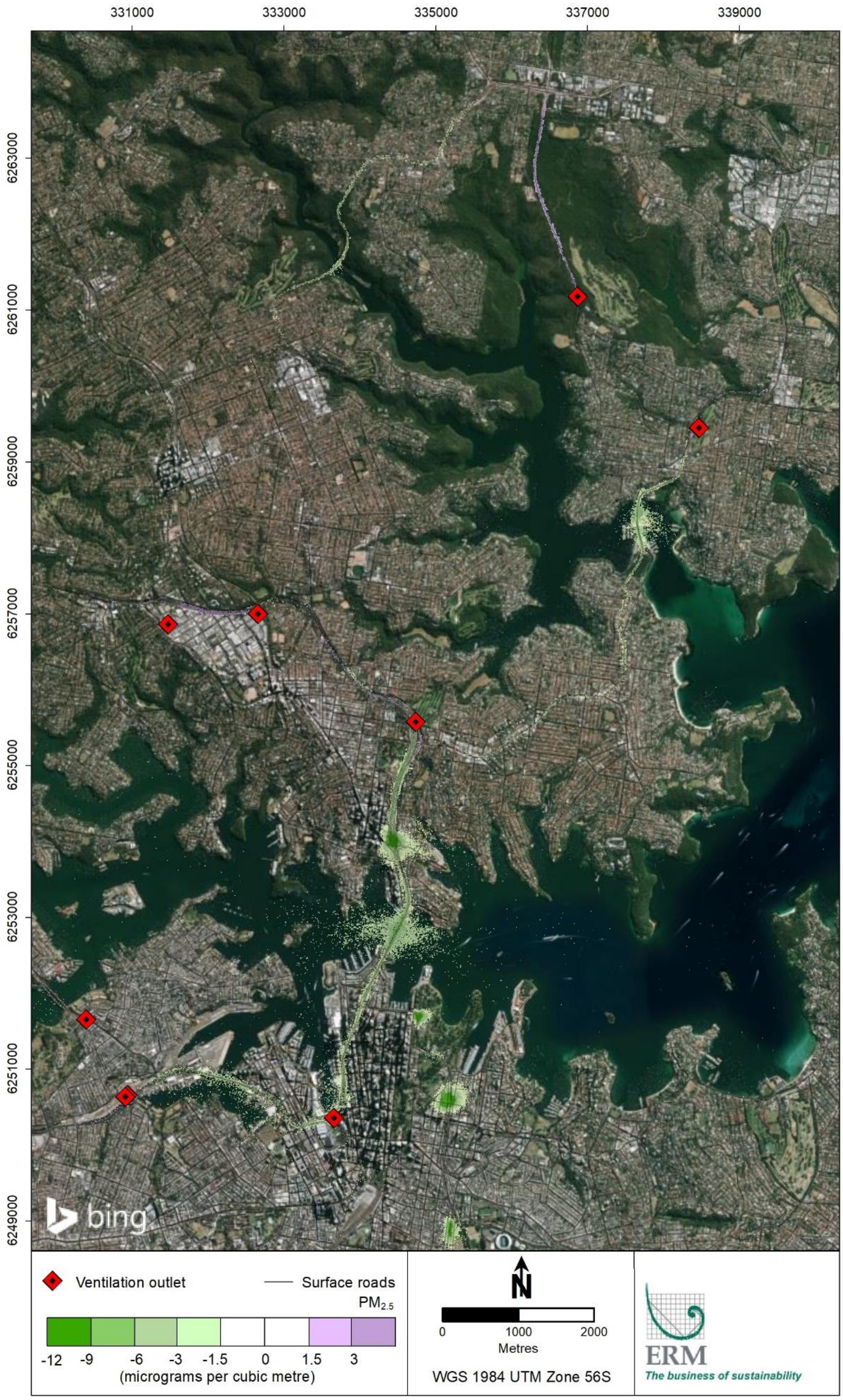


Figure I-60 **Contour plot of change in maximum 24-hour mean $PM_{2.5}$ concentration in 2037 cumulative scenario (all sources, 2037-DSC minus 2037-DM)**

I.9 Air toxics: benzene (maximum 1-hour mean)

Table I-57 Maximum 1-hour mean benzene concentration (excluding background) at community receptors

Receptor	Maximum 1-hour benzene concentration (µg/m³)							Change relative to Do Minimum (µg/m³)			
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
CR01	-	5.2	6.0	4.1	3.8	4.0	3.8	0.8	-1.1	0.2	0.0
CR02	-	2.1	2.1	2.2	1.5	1.3	1.2	0.0	0.1	-0.2	-0.3
CR03	-	2.4	2.9	2.1	1.4	1.7	1.7	0.5	-0.3	0.3	0.3
CR04	-	2.9	2.4	3.3	1.9	2.3	1.7	-0.6	0.3	0.4	-0.1
CR05	-	2.7	2.0	1.9	0.9	1.3	1.1	-0.8	-0.8	0.4	0.2
CR06	-	2.3	2.2	1.2	1.5	1.9	1.4	-0.2	-1.1	0.4	-0.1
CR07	-	1.0	1.2	0.7	1.0	0.6	0.6	0.2	-0.3	-0.4	-0.5
CR08	-	1.4	1.7	2.4	1.2	1.9	1.2	0.3	1.0	0.6	0.0
CR09	-	1.6	1.4	1.2	0.8	1.1	0.8	-0.2	-0.4	0.3	0.0
CR10	-	3.3	3.2	2.2	1.7	1.9	1.6	0.0	-1.1	0.2	-0.1
CR11	-	4.5	6.4	4.4	3.2	2.5	2.8	2.0	0.0	-0.7	-0.4
CR12	-	2.5	2.2	2.1	1.8	1.6	1.4	-0.3	-0.4	-0.2	-0.4
CR13	-	1.7	1.5	1.3	1.1	1.4	0.9	-0.3	-0.5	0.3	-0.1
CR14	-	4.0	2.3	2.7	2.1	1.4	1.3	-1.7	-1.2	-0.8	-0.8
CR15	-	1.1	1.3	1.5	1.4	1.1	1.1	0.2	0.4	-0.3	-0.3
CR16	-	3.4	2.5	3.1	2.4	2.6	1.7	-0.9	-0.3	0.2	-0.7
CR17	-	2.7	2.0	2.6	1.9	1.6	1.6	-0.7	-0.1	-0.2	-0.2
CR18	-	1.4	1.7	1.8	1.1	0.8	1.2	0.3	0.4	-0.3	0.1
CR19	-	1.9	2.9	3.2	1.6	1.4	2.0	1.0	1.3	-0.2	0.4
CR20	-	2.3	2.2	2.2	1.5	1.5	1.2	-0.1	-0.1	0.0	-0.3
CR21	-	1.9	2.1	1.9	1.1	1.2	1.2	0.2	0.0	0.0	0.1
CR22	-	1.8	1.5	1.7	1.7	1.2	0.9	-0.3	-0.1	-0.5	-0.8
CR23	-	1.6	2.4	2.2	1.3	1.1	1.7	0.9	0.6	-0.1	0.4
CR24	-	1.0	1.5	1.3	1.0	1.2	1.1	0.4	0.2	0.2	0.0
CR25	-	2.5	2.3	2.9	1.6	2.3	1.5	-0.2	0.3	0.8	-0.1
CR26	-	1.8	1.6	1.9	1.1	1.3	1.3	-0.2	0.0	0.2	0.2
CR27	-	1.4	1.5	1.0	0.8	0.6	1.1	0.1	-0.4	-0.2	0.3
CR28	-	1.2	1.4	1.3	0.8	0.9	1.3	0.1	0.1	0.1	0.5
CR29	-	1.0	1.2	1.5	0.6	1.1	0.9	0.2	0.5	0.5	0.3
CR30	-	1.7	2.1	1.5	1.0	1.1	1.4	0.4	-0.2	0.1	0.3
CR31	-	2.6	1.5	1.8	1.8	1.1	1.2	-1.1	-0.8	-0.6	-0.5
CR32	-	0.9	0.9	0.8	0.9	1.0	0.7	0.0	-0.1	0.0	-0.2
CR33	-	0.7	0.8	0.9	0.5	0.6	0.6	0.1	0.3	0.1	0.1
CR34	-	1.4	2.0	1.4	0.8	1.0	0.9	0.6	0.0	0.2	0.1
CR35	-	0.6	0.9	0.9	0.5	0.5	0.8	0.3	0.3	0.0	0.3
CR36	-	0.9	1.0	1.2	0.6	0.5	0.5	0.1	0.3	-0.1	-0.1
CR37	-	3.3	2.7	3.4	2.5	1.9	1.8	-0.6	0.1	-0.6	-0.7
CR38	-	2.1	1.8	1.9	1.6	1.7	1.2	-0.3	-0.2	0.0	-0.5
CR39	-	1.8	2.1	1.9	1.1	0.9	1.2	0.4	0.1	-0.2	0.1
CR40	-	1.4	0.7	0.7	0.9	0.8	0.9	-0.7	-0.7	-0.1	0.0
CR41	-	1.4	1.0	1.3	1.2	1.0	0.9	-0.4	-0.1	-0.3	-0.3
CR42	-	1.4	1.5	1.3	0.6	0.8	0.7	0.1	-0.1	0.1	0.1

Table I-58 Maximum 1-hour mean benzene concentration (excluding background) at community receptors, ranked by concentration

Rank	Ranking by concentration (µg/m³)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	5.2	6.4	4.4	3.8	4.0	3.8
2	-	4.5	6.0	4.1	3.2	2.6	2.8
3	-	4.0	3.2	3.4	2.5	2.5	2.0
4	-	3.4	2.9	3.3	2.4	2.3	1.8
5	-	3.3	2.9	3.2	2.1	2.3	1.7
6	-	3.3	2.7	3.1	1.9	1.9	1.7
7	-	2.9	2.5	2.9	1.9	1.9	1.7
8	-	2.7	2.4	2.7	1.8	1.9	1.7
9	-	2.7	2.4	2.6	1.8	1.9	1.6
10	-	2.6	2.3	2.4	1.7	1.7	1.6

Table I-59 Maximum 1-hour mean benzene concentration (excluding background) at community receptors, ranked by increase and by decrease in concentration

Rank	Ranking by increase in concentration relative to Do Minimum (µg/m³)				Ranking by decrease in concentration relative to Do Minimum (µg/m³)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	1.99	1.26	0.75	0.51	-1.71	-1.21	-0.75	-0.82
2	1.03	1.03	0.64	0.42	-1.07	-1.14	-0.71	-0.82
3	0.85	0.59	0.45	0.41	-0.89	-1.10	-0.61	-0.72
4	0.80	0.49	0.44	0.35	-0.76	-1.08	-0.56	-0.65
5	0.58	0.40	0.41	0.33	-0.71	-0.81	-0.54	-0.51
6	0.51	0.37	0.41	0.30	-0.66	-0.80	-0.44	-0.47
7	0.44	0.34	0.33	0.28	-0.63	-0.70	-0.29	-0.45
8	0.42	0.32	0.32	0.25	-0.55	-0.49	-0.28	-0.44
9	0.37	0.30	0.30	0.21	-0.44	-0.43	-0.25	-0.38
10	0.33	0.28	0.24	0.19	-0.32	-0.43	-0.24	-0.33

Table I-60 Maximum 1-hour mean benzene concentration (excluding background) at RWR receptors, ranked by concentration

Rank	Ranking by concentration (µg/m³)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	8.7	7.8	8.4	5.8	5.8	5.5
2	-	8.0	7.8	7.5	5.6	5.5	5.3
3	-	7.4	7.6	7.0	5.4	5.3	5.2
4	-	7.2	7.5	6.9	4.9	5.0	5.1
5	-	7.2	7.5	6.9	4.9	4.9	4.9
6	-	7.1	7.5	6.7	4.9	4.6	4.9
7	-	6.9	7.2	6.7	4.7	4.5	4.8
8	-	6.9	7.1	6.5	4.7	4.5	4.7
9	-	6.8	6.9	6.5	4.6	4.5	4.6
10	-	6.8	6.8	6.5	4.6	4.5	4.6

Table I-61 Maximum 1-hour mean benzene concentration (excluding background) at RWR receptors, ranked by increase and by decrease in concentration

Rank	Ranking by increase in concentration relative to Do Minimum (µg/m³)				Ranking by decrease in concentration relative to Do Minimum (µg/m³)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	3.71	3.23	2.23	1.99	-4.50	-3.91	-2.00	-2.01
2	3.64	2.90	2.01	1.80	-3.14	-3.15	-2.00	-1.95
3	3.05	2.66	1.88	1.80	-3.14	-3.15	-1.98	-1.94
4	3.03	2.54	1.70	1.80	-2.96	-2.74	-1.97	-1.84
5	2.60	2.48	1.66	1.79	-2.85	-2.69	-1.96	-1.83
6	2.60	2.46	1.64	1.75	-2.66	-2.65	-1.93	-1.82
7	2.60	2.32	1.61	1.75	-2.66	-2.65	-1.90	-1.79
8	2.56	2.32	1.59	1.71	-2.58	-2.62	-1.87	-1.79
9	2.44	2.27	1.57	1.70	-2.58	-2.60	-1.76	-1.79
10	2.44	2.27	1.56	1.69	-2.54	-2.46	-1.76	-1.77

I.10 Air toxics: benzo(a)pyrene (maximum 1-hour mean)

Table I-62 Maximum 1-hour mean benzo(a)pyrene concentration (excluding background) at community receptors

Receptor	Maximum 1-hour b(a)p concentration (µg/m^3)							Change relative to Do Minimum (µg/m^3)			
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
CR01	-	5.2	6.0	4.1	3.8	4.0	3.8	0.8	-1.1	0.2	0.0
CR02	-	2.1	2.1	2.2	1.5	1.3	1.2	0.0	0.1	-0.2	-0.3
CR03	-	2.4	2.9	2.1	1.4	1.7	1.7	0.5	-0.3	0.3	0.3
CR04	-	2.9	2.4	3.3	1.9	2.3	1.7	-0.6	0.3	0.4	-0.1
CR05	-	2.7	2.0	1.9	0.9	1.3	1.1	-0.8	-0.8	0.4	0.2
CR06	-	2.3	2.2	1.2	1.5	1.9	1.4	-0.2	-1.1	0.4	-0.1
CR07	-	1.0	1.2	0.7	1.0	0.6	0.6	0.2	-0.3	-0.4	-0.5
CR08	-	1.4	1.7	2.4	1.2	1.9	1.2	0.3	1.0	0.6	0.0
CR09	-	1.6	1.4	1.2	0.8	1.1	0.8	-0.2	-0.4	0.3	0.0
CR10	-	3.3	3.2	2.2	1.7	1.9	1.6	0.0	-1.1	0.2	-0.1
CR11	-	4.5	6.4	4.4	3.2	2.5	2.8	2.0	0.0	-0.7	-0.4
CR12	-	2.5	2.2	2.1	1.8	1.6	1.4	-0.3	-0.4	-0.2	-0.4
CR13	-	1.7	1.5	1.3	1.1	1.4	0.9	-0.3	-0.5	0.3	-0.1
CR14	-	4.0	2.3	2.7	2.1	1.4	1.3	-1.7	-1.2	-0.8	-0.8
CR15	-	1.1	1.3	1.5	1.4	1.1	1.1	0.2	0.4	-0.3	-0.3
CR16	-	3.4	2.5	3.1	2.4	2.6	1.7	-0.9	-0.3	0.2	-0.7
CR17	-	2.7	2.0	2.6	1.9	1.6	1.6	-0.7	-0.1	-0.2	-0.2
CR18	-	1.4	1.7	1.8	1.1	0.8	1.2	0.3	0.4	-0.3	0.1
CR19	-	1.9	2.9	3.2	1.6	1.4	2.0	1.0	1.3	-0.2	0.4
CR20	-	2.3	2.2	2.2	1.5	1.5	1.2	-0.1	-0.1	0.0	-0.3
CR21	-	1.9	2.1	1.9	1.1	1.2	1.2	0.2	0.0	0.0	0.1
CR22	-	1.8	1.5	1.7	1.7	1.2	0.9	-0.3	-0.1	-0.5	-0.8
CR23	-	1.6	2.4	2.2	1.3	1.1	1.7	0.9	0.6	-0.1	0.4
CR24	-	1.0	1.5	1.3	1.0	1.2	1.1	0.4	0.2	0.2	0.0
CR25	-	2.5	2.3	2.9	1.6	2.3	1.5	-0.2	0.3	0.8	-0.1
CR26	-	1.8	1.6	1.9	1.1	1.3	1.3	-0.2	0.0	0.2	0.2
CR27	-	1.4	1.5	1.0	0.8	0.6	1.1	0.1	-0.4	-0.2	0.3
CR28	-	1.2	1.4	1.3	0.8	0.9	1.3	0.1	0.1	0.1	0.5
CR29	-	1.0	1.2	1.5	0.6	1.1	0.9	0.2	0.5	0.5	0.3
CR30	-	1.7	2.1	1.5	1.0	1.1	1.4	0.4	-0.2	0.1	0.3
CR31	-	2.6	1.5	1.8	1.8	1.1	1.2	-1.1	-0.8	-0.6	-0.5
CR32	-	0.9	0.9	0.8	0.9	1.0	0.7	0.0	-0.1	0.0	-0.2
CR33	-	0.7	0.8	0.9	0.5	0.6	0.6	0.1	0.3	0.1	0.1
CR34	-	1.4	2.0	1.4	0.8	1.0	0.9	0.6	0.0	0.2	0.1
CR35	-	0.6	0.9	0.9	0.5	0.5	0.8	0.3	0.3	0.0	0.3
CR36	-	0.9	1.0	1.2	0.6	0.5	0.5	0.1	0.3	-0.1	-0.1
CR37	-	3.3	2.7	3.4	2.5	1.9	1.8	-0.6	0.1	-0.6	-0.7
CR38	-	2.1	1.8	1.9	1.6	1.7	1.2	-0.3	-0.2	0.0	-0.5
CR39	-	1.8	2.1	1.9	1.1	0.9	1.2	0.4	0.1	-0.2	0.1
CR40	-	1.4	0.7	0.7	0.9	0.8	0.9	-0.7	-0.7	-0.1	0.0
CR41	-	1.4	1.0	1.3	1.2	1.0	0.9	-0.4	-0.1	-0.3	-0.3
CR42	-	1.4	1.5	1.3	0.6	0.8	0.7	0.1	-0.1	0.1	0.1

Table I-63 **Maximum 1-hour mean benzo(a)pyrene concentration (excluding background) at community receptors, ranked by concentration**

Rank	Ranking by concentration (µg/m^3)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	5.2	6.4	4.4	3.8	4.0	3.8
2	-	4.5	6.0	4.1	3.2	2.6	2.8
3	-	4.0	3.2	3.4	2.5	2.5	2.0
4	-	3.4	2.9	3.3	2.4	2.3	1.8
5	-	3.3	2.9	3.2	2.1	2.3	1.7
6	-	3.3	2.7	3.1	1.9	1.9	1.7
7	-	2.9	2.5	2.9	1.9	1.9	1.7
8	-	2.7	2.4	2.7	1.8	1.9	1.7
9	-	2.7	2.4	2.6	1.8	1.9	1.6
10	-	2.6	2.3	2.4	1.7	1.7	1.6

Table I-64 **Maximum 1-hour mean benzo(a)pyrene concentration (excluding background) at community receptors, ranked by increase and by decrease in concentration**

Rank	Ranking by increase in concentration relative to Do Minimum (µg/m^3)				Ranking by decrease in concentration relative to Do Minimum (µg/m^3)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	1.99	1.26	0.75	0.51	-1.71	-1.21	-0.75	-0.82
2	1.03	1.03	0.64	0.42	-1.07	-1.14	-0.71	-0.82
3	0.85	0.59	0.45	0.41	-0.89	-1.10	-0.61	-0.72
4	0.80	0.49	0.44	0.35	-0.76	-1.08	-0.56	-0.65
5	0.58	0.40	0.41	0.33	-0.71	-0.81	-0.54	-0.51
6	0.51	0.37	0.41	0.30	-0.66	-0.80	-0.44	-0.47
7	0.44	0.34	0.33	0.28	-0.63	-0.70	-0.29	-0.45
8	0.42	0.32	0.32	0.25	-0.55	-0.49	-0.28	-0.44
9	0.37	0.30	0.30	0.21	-0.44	-0.43	-0.25	-0.38
10	0.33	0.28	0.24	0.19	-0.32	-0.43	-0.24	-0.33

Table I-65 **Maximum 1-hour mean benzo(a)pyrene concentration (excluding background) at RWR receptors, ranked by concentration**

Rank	Ranking by concentration (µg/m^3)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	0.080	0.072	0.078	0.075	0.075	0.070
2	-	0.074	0.072	0.069	0.072	0.071	0.069
3	-	0.068	0.070	0.065	0.069	0.068	0.067
4	-	0.067	0.070	0.064	0.064	0.064	0.065
5	-	0.067	0.069	0.063	0.064	0.064	0.064
6	-	0.066	0.069	0.062	0.063	0.060	0.063
7	-	0.064	0.066	0.062	0.061	0.058	0.061
8	-	0.064	0.066	0.060	0.060	0.058	0.061
9	-	0.063	0.064	0.060	0.060	0.058	0.060
10	-	0.063	0.063	0.060	0.059	0.058	0.060

Table I-66 **Maximum 1-hour mean benzo(a)pyrene concentration (excluding background) at RWR receptors, ranked by increase and by decrease in concentration**

Rank	Ranking by increase in concentration relative to Do Minimum (µg/m³)				Ranking by decrease in concentration relative to Do Minimum (µg/m³)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	0.034	0.030	0.029	0.026	-0.042	-0.036	-0.026	-0.026
2	0.034	0.027	0.026	0.023	-0.029	-0.029	-0.026	-0.025
3	0.028	0.025	0.024	0.023	-0.029	-0.029	-0.025	-0.025
4	0.028	0.024	0.022	0.023	-0.027	-0.025	-0.025	-0.024
5	0.024	0.023	0.021	0.023	-0.026	-0.025	-0.025	-0.024
6	0.024	0.023	0.021	0.023	-0.025	-0.025	-0.025	-0.023
7	0.024	0.021	0.021	0.023	-0.025	-0.025	-0.025	-0.023
8	0.024	0.021	0.020	0.022	-0.024	-0.024	-0.024	-0.023
9	0.023	0.021	0.020	0.022	-0.024	-0.024	-0.023	-0.023
10	0.023	0.021	0.020	0.022	-0.023	-0.023	-0.023	-0.023

I.11 Air toxics: formaldehyde (maximum 1-hour mean)

Table I-67 Maximum 1-hour mean formaldehyde concentration (excluding background) at community receptors

Receptor	Maximum 1-hour formaldehyde concentration (µg/m³)							Change relative to Do Minimum (µg/m³)			
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
CR01	-	4.5	5.2	3.6	5.2	5.4	5.1	0.7	-1.0	0.2	0.0
CR02	-	1.8	1.8	1.9	2.0	1.7	1.6	0.0	0.1	-0.3	-0.4
CR03	-	2.1	2.5	1.8	1.9	2.3	2.3	0.4	-0.2	0.5	0.5
CR04	-	2.5	2.1	2.8	2.5	3.1	2.3	-0.5	0.3	0.6	-0.2
CR05	-	2.4	1.7	1.7	1.2	1.8	1.5	-0.7	-0.7	0.6	0.3
CR06	-	2.0	1.9	1.0	2.0	2.6	1.9	-0.2	-1.0	0.6	-0.2
CR07	-	0.9	1.1	0.6	1.4	0.8	0.8	0.2	-0.3	-0.6	-0.6
CR08	-	1.2	1.5	2.1	1.7	2.5	1.6	0.3	0.9	0.9	0.0
CR09	-	1.4	1.2	1.0	1.1	1.5	1.1	-0.2	-0.4	0.4	0.0
CR10	-	2.9	2.8	1.9	2.4	2.6	2.2	0.0	-0.9	0.3	-0.1
CR11	-	3.9	5.6	3.8	4.3	3.4	3.8	1.7	0.0	-1.0	-0.5
CR12	-	2.2	1.9	1.8	2.5	2.2	1.9	-0.3	-0.4	-0.3	-0.6
CR13	-	1.5	1.3	1.1	1.4	1.9	1.2	-0.2	-0.4	0.4	-0.2
CR14	-	3.4	2.0	2.4	2.9	1.9	1.8	-1.5	-1.1	-1.0	-1.1
CR15	-	1.0	1.1	1.3	1.9	1.5	1.5	0.1	0.3	-0.4	-0.4
CR16	-	2.9	2.2	2.7	3.3	3.5	2.4	-0.8	-0.3	0.2	-0.9
CR17	-	2.3	1.7	2.3	2.5	2.2	2.2	-0.6	-0.1	-0.3	-0.3
CR18	-	1.2	1.5	1.6	1.5	1.2	1.7	0.2	0.3	-0.4	0.2
CR19	-	1.7	2.5	2.7	2.2	1.9	2.7	0.9	1.1	-0.3	0.6
CR20	-	2.0	1.9	1.9	2.1	2.1	1.6	-0.1	-0.1	0.0	-0.4
CR21	-	1.6	1.8	1.6	1.5	1.6	1.7	0.2	0.0	0.1	0.1
CR22	-	1.6	1.3	1.5	2.4	1.6	1.3	-0.3	-0.1	-0.7	-1.1
CR23	-	1.4	2.1	1.9	1.7	1.5	2.3	0.7	0.5	-0.2	0.6
CR24	-	0.9	1.3	1.1	1.4	1.7	1.4	0.4	0.2	0.3	0.1
CR25	-	2.2	2.0	2.5	2.1	3.2	2.0	-0.2	0.3	1.0	-0.1
CR26	-	1.6	1.4	1.6	1.5	1.8	1.8	-0.2	0.0	0.3	0.3
CR27	-	1.2	1.3	0.9	1.1	0.8	1.5	0.1	-0.3	-0.3	0.4
CR28	-	1.1	1.2	1.1	1.1	1.2	1.8	0.1	0.1	0.1	0.7
CR29	-	0.9	1.1	1.3	0.9	1.5	1.2	0.2	0.4	0.6	0.3
CR30	-	1.5	1.8	1.3	1.4	1.4	1.8	0.4	-0.2	0.1	0.5
CR31	-	2.3	1.3	1.6	2.4	1.6	1.7	-0.9	-0.7	-0.8	-0.7
CR32	-	0.7	0.7	0.7	1.3	1.3	1.0	0.0	0.0	0.0	-0.3
CR33	-	0.6	0.7	0.8	0.7	0.8	0.9	0.1	0.2	0.1	0.2
CR34	-	1.2	1.7	1.2	1.1	1.4	1.3	0.5	0.0	0.3	0.2
CR35	-	0.5	0.8	0.8	0.6	0.7	1.1	0.3	0.2	0.1	0.4
CR36	-	0.8	0.9	1.1	0.9	0.7	0.7	0.1	0.3	-0.2	-0.2
CR37	-	2.9	2.3	3.0	3.4	2.6	2.4	-0.5	0.1	-0.8	-1.0
CR38	-	1.8	1.5	1.6	2.2	2.2	1.6	-0.2	-0.1	0.0	-0.6
CR39	-	1.5	1.8	1.6	1.5	1.3	1.7	0.3	0.1	-0.3	0.1
CR40	-	1.2	0.6	0.6	1.2	1.1	1.3	-0.6	-0.6	-0.1	0.1
CR41	-	1.2	0.9	1.1	1.7	1.3	1.3	-0.4	-0.1	-0.3	-0.4
CR42	-	1.2	1.3	1.1	0.9	1.1	1.0	0.1	0.0	0.2	0.1

Table I-68 Maximum 1-hour mean formaldehyde concentration (excluding background) at community receptors, ranked by concentration

Rank	Ranking by concentration (µg/m³)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	4.5	5.6	3.8	5.2	5.4	5.1
2	-	3.9	5.2	3.6	4.3	3.5	3.8
3	-	3.4	2.8	3.0	3.4	3.4	2.7
4	-	2.9	2.5	2.8	3.3	3.2	2.4
5	-	2.9	2.5	2.7	2.9	3.1	2.4
6	-	2.9	2.3	2.7	2.5	2.6	2.3
7	-	2.5	2.2	2.5	2.5	2.6	2.3
8	-	2.4	2.1	2.4	2.5	2.6	2.3
9	-	2.3	2.1	2.3	2.4	2.5	2.2
10	-	2.3	2.0	2.1	2.4	2.3	2.2

Table I-69 Maximum 1-hour mean formaldehyde concentration (excluding background) at community receptors, ranked by increase and by decrease in concentration

Rank	Ranking by increase in concentration relative to Do Minimum (µg/m³)				Ranking by decrease in concentration relative to Do Minimum (µg/m³)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	1.72	1.09	1.02	0.70	-1.48	-1.05	-1.02	-1.12
2	0.89	0.89	0.86	0.56	-0.93	-0.99	-0.96	-1.12
3	0.74	0.51	0.61	0.55	-0.77	-0.96	-0.83	-0.98
4	0.69	0.42	0.60	0.47	-0.66	-0.94	-0.76	-0.88
5	0.50	0.34	0.56	0.45	-0.62	-0.70	-0.73	-0.69
6	0.44	0.32	0.56	0.41	-0.57	-0.69	-0.60	-0.63
7	0.38	0.30	0.45	0.39	-0.55	-0.61	-0.40	-0.61
8	0.36	0.28	0.44	0.34	-0.48	-0.42	-0.37	-0.60
9	0.32	0.26	0.40	0.29	-0.38	-0.37	-0.34	-0.52
10	0.29	0.24	0.33	0.26	-0.28	-0.37	-0.32	-0.45

Table I-70 Maximum 1-hour mean formaldehyde concentration (excluding background) at RWR receptors, ranked by concentration

Rank	Ranking by concentration (µg/m³)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	7.5	6.8	7.3	7.9	7.9	7.4
2	-	6.9	6.8	6.5	7.5	7.4	7.2
3	-	6.4	6.5	6.0	7.3	7.2	7.1
4	-	6.3	6.5	6.0	6.7	6.7	6.9
5	-	6.3	6.5	5.9	6.7	6.7	6.7
6	-	6.2	6.5	5.8	6.7	6.3	6.6
7	-	6.0	6.2	5.8	6.4	6.2	6.5
8	-	6.0	6.2	5.6	6.4	6.2	6.4
9	-	5.9	6.0	5.6	6.3	6.1	6.3
10	-	5.9	5.9	5.6	6.2	6.1	6.3

Table I-71 **Maximum 1-hour mean formaldehyde concentration (excluding background) at RWR receptors, ranked by increase and by decrease in concentration**

Rank		Ranking by increase in concentration relative to Do Minimum (µg/m³)					Ranking by decrease in concentration relative to Do Minimum (µg/m³)			
		2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC		2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1		3.21	2.80	3.03	2.70		-3.90	-3.39	-2.71	-2.72
2		3.15	2.52	2.72	2.44		-2.72	-2.73	-2.71	-2.65
3		2.64	2.31	2.54	2.44		-2.72	-2.73	-2.68	-2.64
4		2.63	2.20	2.31	2.44		-2.57	-2.38	-2.67	-2.50
5		2.25	2.15	2.25	2.43		-2.47	-2.33	-2.66	-2.48
6		2.25	2.13	2.23	2.38		-2.30	-2.30	-2.62	-2.46
7		2.25	2.01	2.18	2.37		-2.30	-2.30	-2.58	-2.43
8		2.22	2.01	2.16	2.32		-2.24	-2.27	-2.53	-2.43
9		2.11	1.97	2.13	2.31		-2.24	-2.26	-2.39	-2.43
10		2.11	1.96	2.12	2.29		-2.20	-2.13	-2.39	-2.40

I.12 Air toxics: 1,3-butadiene (maximum 1-hour mean)

Table I-72 Maximum 1-hour mean 1,3-butadiene concentration (excluding background) at community receptors

Receptor	Maximum 1-hour 1,3-butadiene concentration (µg/m^3)							Change relative to Do Minimum (µg/m^3)			
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
CR01	-	1.4	1.6	1.1	1.0	1.1	1.0	0.2	-0.3	0.0	0.0
CR02	-	0.6	0.6	0.6	0.4	0.3	0.3	0.0	0.0	-0.1	-0.1
CR03	-	0.6	0.8	0.6	0.4	0.5	0.5	0.1	-0.1	0.1	0.1
CR04	-	0.8	0.6	0.9	0.5	0.6	0.5	-0.1	0.1	0.1	0.0
CR05	-	0.7	0.5	0.5	0.2	0.4	0.3	-0.2	-0.2	0.1	0.1
CR06	-	0.6	0.6	0.3	0.4	0.5	0.4	0.0	-0.3	0.1	0.0
CR07	-	0.3	0.3	0.2	0.3	0.2	0.2	0.0	-0.1	-0.1	-0.1
CR08	-	0.4	0.5	0.6	0.3	0.5	0.3	0.1	0.3	0.2	0.0
CR09	-	0.4	0.4	0.3	0.2	0.3	0.2	-0.1	-0.1	0.1	0.0
CR10	-	0.9	0.9	0.6	0.5	0.5	0.4	0.0	-0.3	0.1	0.0
CR11	-	1.2	1.7	1.2	0.9	0.7	0.8	0.5	0.0	-0.2	-0.1
CR12	-	0.7	0.6	0.6	0.5	0.4	0.4	-0.1	-0.1	-0.1	-0.1
CR13	-	0.5	0.4	0.3	0.3	0.4	0.3	-0.1	-0.1	0.1	0.0
CR14	-	1.1	0.6	0.7	0.6	0.4	0.4	-0.5	-0.3	-0.2	-0.2
CR15	-	0.3	0.3	0.4	0.4	0.3	0.3	0.0	0.1	-0.1	-0.1
CR16	-	0.9	0.7	0.8	0.7	0.7	0.5	-0.2	-0.1	0.0	-0.2
CR17	-	0.7	0.5	0.7	0.5	0.4	0.4	-0.2	0.0	-0.1	-0.1
CR18	-	0.4	0.5	0.5	0.3	0.2	0.3	0.1	0.1	-0.1	0.0
CR19	-	0.5	0.8	0.8	0.4	0.4	0.5	0.3	0.3	-0.1	0.1
CR20	-	0.6	0.6	0.6	0.4	0.4	0.3	0.0	0.0	0.0	-0.1
CR21	-	0.5	0.6	0.5	0.3	0.3	0.3	0.1	0.0	0.0	0.0
CR22	-	0.5	0.4	0.4	0.5	0.3	0.3	-0.1	0.0	-0.1	-0.2
CR23	-	0.4	0.6	0.6	0.3	0.3	0.5	0.2	0.2	0.0	0.1
CR24	-	0.3	0.4	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.0
CR25	-	0.7	0.6	0.8	0.4	0.6	0.4	-0.1	0.1	0.2	0.0
CR26	-	0.5	0.4	0.5	0.3	0.4	0.4	-0.1	0.0	0.1	0.1
CR27	-	0.4	0.4	0.3	0.2	0.2	0.3	0.0	-0.1	-0.1	0.1
CR28	-	0.3	0.4	0.3	0.2	0.3	0.4	0.0	0.0	0.0	0.1
CR29	-	0.3	0.3	0.4	0.2	0.3	0.2	0.1	0.1	0.1	0.1
CR30	-	0.5	0.6	0.4	0.3	0.3	0.4	0.1	-0.1	0.0	0.1
CR31	-	0.7	0.4	0.5	0.5	0.3	0.3	-0.3	-0.2	-0.2	-0.1
CR32	-	0.2	0.2	0.2	0.3	0.3	0.2	0.0	0.0	0.0	-0.1
CR33	-	0.2	0.2	0.2	0.1	0.2	0.2	0.0	0.1	0.0	0.0
CR34	-	0.4	0.5	0.4	0.2	0.3	0.3	0.2	0.0	0.1	0.0
CR35	-	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.0	0.1
CR36	-	0.2	0.3	0.3	0.2	0.1	0.1	0.0	0.1	0.0	0.0
CR37	-	0.9	0.7	0.9	0.7	0.5	0.5	-0.2	0.0	-0.2	-0.2
CR38	-	0.5	0.5	0.5	0.4	0.5	0.3	-0.1	0.0	0.0	-0.1
CR39	-	0.5	0.6	0.5	0.3	0.3	0.3	0.1	0.0	-0.1	0.0
CR40	-	0.4	0.2	0.2	0.2	0.2	0.3	-0.2	-0.2	0.0	0.0
CR41	-	0.4	0.3	0.3	0.3	0.3	0.3	-0.1	0.0	-0.1	-0.1
CR42	-	0.4	0.4	0.4	0.2	0.2	0.2	0.0	0.0	0.0	0.0

Table I-73 Maximum 1-hour mean 1,3-butadiene concentration (excluding background) at community receptors, ranked by concentration

Rank	Ranking by concentration (µg/m^3)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	1.4	1.7	1.2	1.0	1.1	1.0
2	-	1.2	1.6	1.1	0.9	0.7	0.8
3	-	1.1	0.9	0.9	0.7	0.7	0.5
4	-	0.9	0.8	0.9	0.7	0.6	0.5
5	-	0.9	0.8	0.8	0.6	0.6	0.5
6	-	0.9	0.7	0.8	0.5	0.5	0.5
7	-	0.8	0.7	0.8	0.5	0.5	0.5
8	-	0.7	0.6	0.7	0.5	0.5	0.5
9	-	0.7	0.6	0.7	0.5	0.5	0.4
10	-	0.7	0.6	0.6	0.5	0.5	0.4

Table I-74 Maximum 1-hour mean 1,3-butadiene concentration (excluding background) at community receptors, ranked by increase and by decrease in concentration

Rank	Ranking by increase in concentration relative to Do Minimum (µg/m^3)				Ranking by decrease in concentration relative to Do Minimum (µg/m^3)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	0.53	0.34	0.21	0.14	-0.46	-0.32	-0.21	-0.23
2	0.28	0.27	0.17	0.11	-0.29	-0.31	-0.19	-0.23
3	0.23	0.16	0.12	0.11	-0.24	-0.30	-0.17	-0.20
4	0.21	0.13	0.12	0.10	-0.20	-0.29	-0.15	-0.18
5	0.16	0.11	0.11	0.09	-0.19	-0.22	-0.15	-0.14
6	0.14	0.10	0.11	0.08	-0.18	-0.21	-0.12	-0.13
7	0.12	0.09	0.09	0.08	-0.17	-0.19	-0.08	-0.12
8	0.11	0.09	0.09	0.07	-0.15	-0.13	-0.08	-0.12
9	0.10	0.08	0.08	0.06	-0.12	-0.12	-0.07	-0.10
10	0.09	0.08	0.07	0.05	-0.09	-0.11	-0.07	-0.09

Table I-75 Maximum 1-hour mean 1,3-butadiene concentration (excluding background) at RWR receptors, ranked by concentration

Rank	Ranking by concentration (µg/m^3)						
	2016-BY	2027-DM	2023-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	2.3	2.1	2.3	1.6	1.6	1.5
2	-	2.1	2.1	2.0	1.5	1.5	1.5
3	-	2.0	2.0	1.9	1.5	1.4	1.4
4	-	1.9	2.0	1.8	1.4	1.4	1.4
5	-	1.9	2.0	1.8	1.4	1.4	1.4
6	-	1.9	2.0	1.8	1.3	1.3	1.3
7	-	1.8	1.9	1.8	1.3	1.2	1.3
8	-	1.8	1.9	1.7	1.3	1.2	1.3
9	-	1.8	1.9	1.7	1.3	1.2	1.3
10	-	1.8	1.8	1.7	1.3	1.2	1.3

Table I-76 Maximum 1-hour mean 1,3-butadiene concentration (excluding background) at RWR receptors, ranked by increase and by decrease in concentration

Rank		Ranking by increase in concentration relative to Do Minimum (µg/m³)					Ranking by decrease in concentration relative to Do Minimum (µg/m³)			
		2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC		2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1		0.99	0.87	0.61	0.55		-1.20	-1.05	-0.55	-0.55
2		0.97	0.78	0.55	0.49		-0.84	-0.84	-0.55	-0.53
3		0.82	0.71	0.51	0.49		-0.84	-0.84	-0.54	-0.53
4		0.81	0.68	0.47	0.49		-0.79	-0.73	-0.54	-0.50
5		0.70	0.66	0.46	0.49		-0.76	-0.72	-0.54	-0.50
6		0.70	0.66	0.45	0.48		-0.71	-0.71	-0.53	-0.50
7		0.70	0.62	0.44	0.48		-0.71	-0.71	-0.52	-0.49
8		0.68	0.62	0.44	0.47		-0.69	-0.70	-0.51	-0.49
9		0.65	0.61	0.43	0.47		-0.69	-0.70	-0.48	-0.49
10		0.65	0.61	0.43	0.46		-0.68	-0.66	-0.48	-0.49

I.13 Air toxics: ethylbenzene (maximum 1-hour mean)

Table I-77 Maximum 1-hour mean ethylbenzene (excluding background) at community receptors

Receptor		Maximum 1-hour 1,3-butadiene concentration (µg/m³)								Change relative to Do Minimum (µg/m³)			
		2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC		2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
CR01		-	2.0	2.0	1.4	1.2	1.3	1.2		0.0	-0.6	0.1	0.0
CR02		-	0.8	0.7	0.7	0.5	0.4	0.4		-0.1	-0.1	-0.1	-0.1
CR03		-	0.9	1.0	0.7	0.4	0.6	0.6		0.0	-0.2	0.1	0.1
CR04		-	1.1	0.8	1.1	0.6	0.7	0.6		-0.3	0.0	0.1	0.0
CR05		-	1.0	0.6	0.6	0.3	0.4	0.4		-0.4	-0.4	0.1	0.1
CR06		-	0.9	0.7	0.4	0.5	0.6	0.4		-0.2	-0.5	0.1	0.0
CR07		-	0.4	0.4	0.2	0.3	0.2	0.2		0.0	-0.2	-0.1	-0.1
CR08		-	0.5	0.6	0.8	0.4	0.6	0.4		0.0	0.3	0.2	0.0
CR09		-	0.6	0.5	0.4	0.3	0.4	0.3		-0.2	-0.2	0.1	0.0
CR10		-	1.3	1.1	0.7	0.6	0.6	0.5		-0.2	-0.5	0.1	0.0
CR11		-	1.7	2.1	1.5	1.0	0.8	0.9		0.4	-0.2	-0.2	-0.1
CR12		-	1.0	0.7	0.7	0.6	0.5	0.4		-0.2	-0.3	-0.1	-0.1
CR13		-	0.7	0.5	0.4	0.3	0.4	0.3		-0.2	-0.3	0.1	0.0
CR14		-	1.5	0.7	0.9	0.7	0.5	0.4		-0.8	-0.6	-0.2	-0.3
CR15		-	0.4	0.4	0.5	0.4	0.4	0.4		0.0	0.1	-0.1	-0.1
CR16		-	1.3	0.8	1.0	0.8	0.8	0.6		-0.5	-0.3	0.1	-0.2
CR17		-	1.0	0.6	0.9	0.6	0.5	0.5		-0.4	-0.2	-0.1	-0.1
CR18		-	0.5	0.6	0.6	0.4	0.3	0.4		0.0	0.1	-0.1	0.0
CR19		-	0.7	1.0	1.0	0.5	0.4	0.6		0.2	0.3	-0.1	0.1
CR20		-	0.9	0.7	0.7	0.5	0.5	0.4		-0.2	-0.1	0.0	-0.1
CR21		-	0.7	0.7	0.6	0.4	0.4	0.4		0.0	-0.1	0.0	0.0
CR22		-	0.7	0.5	0.6	0.6	0.4	0.3		-0.2	-0.1	-0.2	-0.3
CR23		-	0.6	0.8	0.7	0.4	0.4	0.5		0.2	0.1	0.0	0.1
CR24		-	0.4	0.5	0.4	0.3	0.4	0.3		0.1	0.0	0.1	0.0
CR25		-	1.0	0.8	0.9	0.5	0.8	0.5		-0.2	0.0	0.2	0.0
CR26		-	0.7	0.5	0.6	0.4	0.4	0.4		-0.2	-0.1	0.1	0.1
CR27		-	0.5	0.5	0.3	0.3	0.2	0.4		0.0	-0.2	-0.1	0.1
CR28		-	0.5	0.5	0.4	0.3	0.3	0.4		0.0	0.0	0.0	0.2
CR29		-	0.4	0.4	0.5	0.2	0.4	0.3		0.0	0.1	0.1	0.1
CR30		-	0.7	0.7	0.5	0.3	0.3	0.4		0.1	-0.2	0.0	0.1
CR31		-	1.0	0.5	0.6	0.6	0.4	0.4		-0.5	-0.4	-0.2	-0.2
CR32		-	0.3	0.3	0.3	0.3	0.3	0.2		0.0	-0.1	0.0	-0.1
CR33		-	0.3	0.3	0.3	0.2	0.2	0.2		0.0	0.1	0.0	0.0
CR34		-	0.5	0.7	0.5	0.3	0.3	0.3		0.1	-0.1	0.1	0.0
CR35		-	0.2	0.3	0.3	0.2	0.2	0.3		0.1	0.1	0.0	0.1
CR36		-	0.4	0.3	0.4	0.2	0.2	0.2		0.0	0.1	0.0	0.0
CR37		-	1.3	0.9	1.1	0.8	0.6	0.6		-0.4	-0.1	-0.2	-0.2
CR38		-	0.8	0.6	0.6	0.5	0.5	0.4		-0.2	-0.2	0.0	-0.2
CR39		-	0.7	0.7	0.6	0.4	0.3	0.4		0.0	0.0	-0.1	0.0
CR40		-	0.5	0.2	0.2	0.3	0.3	0.3		-0.3	-0.3	0.0	0.0
CR41		-	0.5	0.3	0.4	0.4	0.3	0.3		-0.2	-0.1	-0.1	-0.1
CR42		-	0.5	0.5	0.4	0.2	0.3	0.2		0.0	-0.1	0.0	0.0

Table I-78 Maximum 1-hour mean ethylbenzene concentration (excluding background) at community receptors, ranked by concentration

Rank	Ranking by concentration (µg/m^3)						
	2016-BY	2027-DM	2027-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	2.0	2.1	1.5	1.2	1.3	1.2
2	-	1.7	2.0	1.4	1.0	0.8	0.9
3	-	1.5	1.1	1.1	0.8	0.8	0.6
4	-	1.3	1.0	1.1	0.8	0.8	0.6
5	-	1.3	1.0	1.0	0.7	0.7	0.6
6	-	1.3	0.9	1.0	0.6	0.6	0.6
7	-	1.1	0.8	0.9	0.6	0.6	0.6
8	-	1.0	0.8	0.9	0.6	0.6	0.5
9	-	1.0	0.8	0.9	0.6	0.6	0.5
10	-	1.0	0.8	0.8	0.6	0.6	0.5

Table I-79 Maximum 1-hour mean ethylbenzene concentration (excluding background) at community receptors, ranked by increase and by decrease in concentration

Rank	Ranking by increase in concentration relative to Do Minimum (µg/m^3)				Ranking by decrease in concentration relative to Do Minimum (µg/m^3)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	0.43	0.32	0.24	0.17	-0.77	-0.63	-0.24	-0.27
2	0.24	0.27	0.21	0.13	-0.49	-0.60	-0.23	-0.27
3	0.20	0.12	0.15	0.13	-0.47	-0.52	-0.20	-0.23
4	0.12	0.11	0.14	0.11	-0.39	-0.50	-0.18	-0.21
5	0.09	0.07	0.13	0.11	-0.38	-0.40	-0.17	-0.17
6	0.07	0.06	0.13	0.10	-0.37	-0.40	-0.14	-0.15
7	0.05	0.06	0.11	0.09	-0.33	-0.30	-0.09	-0.15
8	0.05	0.06	0.10	0.08	-0.29	-0.28	-0.09	-0.14
9	0.04	0.05	0.10	0.07	-0.22	-0.27	-0.08	-0.12
10	0.03	0.02	0.08	0.06	-0.22	-0.25	-0.08	-0.11

Table I-80 Maximum 1-hour mean ethylbenzene concentration (excluding background) at RWR receptors, ranked by concentration

Rank	Ranking by concentration (µg/m^3)						
	2016-BY	2027-DM	2023-DS(BL)	2027-DSC	2037-DM	2037-DS(BL)	2037-DSC
1	-	2.9	2.6	2.8	1.9	1.9	1.8
2	-	2.6	2.6	2.5	1.8	1.8	1.7
3	-	2.4	2.5	2.3	1.7	1.7	1.7
4	-	2.4	2.5	2.3	1.6	1.6	1.6
5	-	2.4	2.5	2.3	1.6	1.6	1.6
6	-	2.4	2.5	2.2	1.6	1.5	1.6
7	-	2.3	2.4	2.2	1.5	1.5	1.5
8	-	2.3	2.4	2.2	1.5	1.5	1.5
9	-	2.3	2.3	2.2	1.5	1.5	1.5
10	-	2.2	2.3	2.1	1.5	1.5	1.5

Table I-81 Maximum 1-hour mean ethylbenzene concentration (excluding background) at RWR receptors, ranked by increase and by decrease in concentration

Rank	Ranking by increase in concentration relative to Do Minimum (µg/m^3)				Ranking by decrease in concentration relative to Do Minimum (µg/m^3)			
	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC	2027-DS(BL)	2027-DSC	2037-DS(BL)	2037-DSC
1	1.23	1.07	0.72	0.65	-1.49	-1.29	-0.65	-0.65
2	1.20	0.96	0.65	0.58	-1.04	-1.04	-0.65	-0.63
3	1.01	0.88	0.61	0.58	-1.04	-1.04	-0.64	-0.63
4	1.00	0.84	0.55	0.58	-0.98	-0.91	-0.64	-0.60
5	0.86	0.82	0.54	0.58	-0.94	-0.89	-0.63	-0.59
6	0.86	0.81	0.53	0.57	-0.88	-0.88	-0.62	-0.59
7	0.86	0.77	0.52	0.57	-0.88	-0.88	-0.62	-0.58
8	0.85	0.77	0.51	0.55	-0.85	-0.87	-0.60	-0.58
9	0.81	0.75	0.51	0.55	-0.85	-0.86	-0.57	-0.58
10	0.81	0.75	0.51	0.55	-0.84	-0.81	-0.57	-0.57

Annexure J Dispersion modelling results - ventilation outlets only

J.1 Overview

Given the increase in emphasis on tunnel ventilation outlets, it was considered important to provide a separate summary of the dispersion modelling results for these. This Annexure therefore brings together the various different outcomes for tunnel ventilation outlets for ease of access.

J.2 Approach

The general assessment and modelling approaches were described in section 5 and section 8. The tunnel ventilation outlet parameters are given in Annexure G.

The results presented here are for the ventilation outlet contribution only. The contributions of other sources (background, tunnel portals and surface roads) were not considered and are not presented. The exception to this is NO_2, as the ventilation outlet contribution to NO_2 is dependent on the amount of NO_X present from other sources. The other sources were therefore considered in the NO_2 calculation for ventilation outlets.

It should also be noted that the results presented here relate to all 11 tunnel ventilation outlets combined. That is to say, the tunnel outlet concentration at a given location included contributions from all tunnel outlets in the GRAL domain.

J.3 Results for community receptors

Tunnel ventilation outlet contributions were determined for both annual mean and short-term air quality metrics, and the results for criteria pollutants are given in Table J-1 and Table J-2 respectively. The corresponding air quality criteria are also shown. For the short term criteria two different results are presented:

- The ventilation outlet contribution when the maximum total concentration (including all sources) during the year occurred.
- The largest contribution from tunnel ventilation outlets at any time during the year.

The results are discussed by pollutant and metric below. The largest ventilation outlet contributions relate to any scenario.

For CO, there is no annual mean air quality metric. The contribution of tunnel ventilation outlets to the maximum 1-hour and 8-hour CO concentration was zero or negligible for all community receptors.

For NO_2 the contribution of tunnel ventilation outlets to the annual mean was less than 0.7 per cent of the criterion (62 µg/m^3) in all scenarios. The tunnel ventilation outlet contribution to the maximum total NO_2 concentration was either zero or negligible at all community receptors. Larger 1-hour contributions from ventilation outlets (up to 53.5 µg/m^3) occurred during other hours of the year, but the total concentration was lower of course. In fact, the largest NO_2 contributions were equal to the largest NO_X contributions. This 1:1 relationship only occurred at relatively low total NO_X concentrations.

For annual mean PM_{10} there was generally a small contribution from tunnel ventilation outlets; the largest contribution was 0.154 µg/m^3, or 0.6 per cent of the criterion (25 µg/m^3). For the maximum total 24-hour PM_{10} concentration the largest contribution from ventilation outlets was 0.25 µg/m^3, or 0.5 per cent of the criterion. The largest ventilation outlet contribution to 24-hour PM_{10} at any time was 1.48 µg/m^3 (or 3 per cent of the criterion), but again this would have coincided with relatively low contributions from other sources.

Table J-1 Contribution of ventilation outlets to annual average concentrations of criteria pollutants[(a)]

Scenario	Statistic for outlet contribution	NO_X (µg/m³)	NO_2 (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)
2027-DM	Average contribution	0.011 to 0.499	0.005 to 0.143	0.001 to 0.073	0.001 to 0.051
2027-DS(BL)	Average contribution	0.11 to 0.782	0.034 to 0.3	0.008 to 0.075	0.005 to 0.053
2027-DSC	Average contribution	0.101 to 1.211	0.037 to 0.414	0.011 to 0.101	0.006 to 0.068
2037-DM	Average contribution	0.011 to 0.425	0.005 to 0.128	0.001 to 0.078	0.001 to 0.051
2037-DS(BL)	Average contribution	0.097 to 0.803	0.033 to 0.247	0.009 to 0.086	0.005 to 0.054
2037-DSC	Average contribution	0.141 to 1.173	0.06 to 0.413	0.01 to 0.154	0.006 to 0.098
Air quality criterion		N/A	62	25	8

(a) Ranges reflect values across all community receptors.

Table J-2 Contribution of ventilation outlets to maximum short-term concentrations of criteria pollutants[(a)]

Scenario	Statistic for outlet contribution	CO Max. 1-hour (mg/m³)	CO Max. 8-hour (mg/m³)	NO_x Max. 1-hour (µg/m³)	NO_2 Max. 1-hour (µg/m³)	PM_{10} Max. 24-hour (µg/m³)	$PM_{2.5}$ Max. 24-hour (µg/m³)
2027-DM	Contribution when max. total occurs	-	0 to 0.001	0 to 0.184	0 to 0.01	0 to 0.071	0 to 0.026
	Largest contribution at any time	0.003 to 0.019	0 to 0.012	1.28 to 9.44	0 to 9.44	0.011 to 0.620	0.007 to 0.408
2027-DS(BL)	Contribution when max. total occurs	0 to 0.002	0 to 0.001	0 to 0.539	-	0 to 0.247	0 to 0.057
	Largest contribution at any time	0.006 to 0.037	0.002 to 0.026	3.27 to 28.53	0 to 28.53	0 to 0.526	0.035 to 0.539
2027-DSC	Contribution when max. total occurs	-	0 to 0.002	0 to 0.608	-	0 to 0.274	0 to 0.143
	Largest contribution at any time	0.008 to 0.047	0.002 to 0.030	5.6 to 36.7	0 to 36.7	0.059 to 1.440	0.044 to 0.981
2037-DM	Contribution when max. total occurs	-	-	0 to 0.139	0 to 0.007	0 to 0.055	0 to 0.031
	Largest contribution at any time	0.002 to 0.018	0 to 0.010	0.91 to 8.37	0 to 8.37	0.014 to 0.695	0.010 to 0.459
2037-DS(BL)	Contribution when max. total occurs	0 to 0.001	0 to 0.001	0 to 0.235	0 to 0.014	0 to 0.24	0.001 to 0.068
	Largest contribution at any time	0.005 to 0.040	0.002 to 0.024	3.49 to 30.13	0 to 30.13	0.071 to 0.907	0.035 to 0.589
2037-DSC	Contribution when max. total occurs	-	0 to 0.001	-	-	0 to 0.249	0 to 0.099
	Largest contribution at any time	0.009 to 0.051	0.002 to 0.027	4.29 to 53.51	0 to 53.51	0.070 to 1.480	0.050 to 1.073
Air quality criterion		30	10	N/A	246	50	25

(a) Ranges reflect values across all community receptors.

(b) '-' = zero contribution from outlets at all community receptors

For annual mean $PM_{2.5}$ there was again a small contribution from tunnel ventilation outlets; the largest contribution was 0.14 µg/m^3, or 1.7 per cent of the criterion (8 µg/m^3). For the maximum total 24-hour $PM_{2.5}$ concentration the largest contribution from ventilation outlets was around 0.5 µg/m^3, or 1.9 per cent of the criterion. The largest ventilation outlet contribution to 24-hour PM_{10} at any time was 1.5 µg/m^3 (or around 6 per cent of the criterion), but again this would have coincided with relatively low contributions from other sources.

For total hydrocarbons and air toxics, only the largest outlet contributions are shown in Table J-3.

Table J-3 Largest contribution of ventilation outlets to concentrations of air toxics[(a)]

Statistic	Scenario	THC (µg/m^3)	Benzene (µg/m^3)	Toluene (µg/m^3)	Xylenes (µg/m3)	PAH (µg/m^3)	Formaldehyde (µg/m^3)	1,3-butadiene (µg/m^3)
Annual average	2027-DM	0.030	0.0012	0.00	0.0018	0.00001	-	-
	2027-DS(BL)	0.055	0.0022	0.00	0.0032	0.00002	-	-
	2027-DSC	0.079	0.0031	0.01	0.0046	0.00003	-	-
	2037-DM	0.017	0.0006	0.00	0.0008	0.00001	-	-
	2037-DS(BL)	0.051	0.0017	0.00	0.0025	0.00002	-	-
	2037-DSC	0.089	0.0030	0.01	0.0043	0.00004	-	-
Maximum 24-hour	2027-DM	0.243	-	0.02	0.0143	-	0.008	-
	2027-DS(BL)	0.351	-	0.03	0.0207	-	0.012	-
	2027-DSC	0.659	-	0.05	0.0388	-	0.022	-
	2037-DM	0.128	-	0.01	0.0062	-	0.006	-
	2037-DS(BL)	0.331	-	0.02	0.0161	-	0.015	-
	2037-DSC	0.757	-	0.04	0.0368	-	0.035	-
Maximum 1-hour	2027-DM	0.578	0.0227	-	-	0.00021	0.020	0.006
	2027-DS(BL)	1.587	0.0624	-	-	0.00058	0.054	0.017
	2027-DSC	0.077	0.0030	-	-	0.00003	0.003	0.001
	2037-DM	0.334	0.0114	-	-	0.00015	0.015	0.003
	2037-DS(BL)	1.387	0.0472	-	-	0.00061	0.064	0.013
	2037-DSC	3.437	0.1169	-	-	0.00151	0.158	0.032

(a) Ranges reflect values across all community receptors.

J.4 Results for RWR receptors

Figure J-1 presents the ranked results for the ventilation outlet contributions at all RWR receptors, and statistics for these receptors are given in **Error! Reference source not found.**.

The largest contributions of tunnel ventilation outlets at any RWR receptor in any scenario were as follows:

- Max. 1-hour CO: 0.07 mg/m^3, or 0.2 per cent of the criterion (30 mg/m^3) [2027-DSC]
- Annual NO_2: 0.67 µg/m^3, or 1.1 per cent of the criterion (62 µg/m^3) [2027-DSC]
- Annual PM_{10}: 0.29 µg/m^3, or 1.2 per cent of the criterion (25 µg/m^3) [2037-DSC]
- Max. 24-hour PM_{10}: 1.80 µg/m^3, or 3.6 per cent of the criterion (50 µg/m^3) [2037-DSC]
- Annual $PM_{2.5}$: 0.18 µg/m^3, or 2.3 per cent of the criterion (8 µg/m^3) [2037-DSC]
- Max. 24-hour $PM_{2.5}$: 1.10 µg/m^3, or 4.4 per cent of the criterion (25 µg/m^3) [2037-DSC]

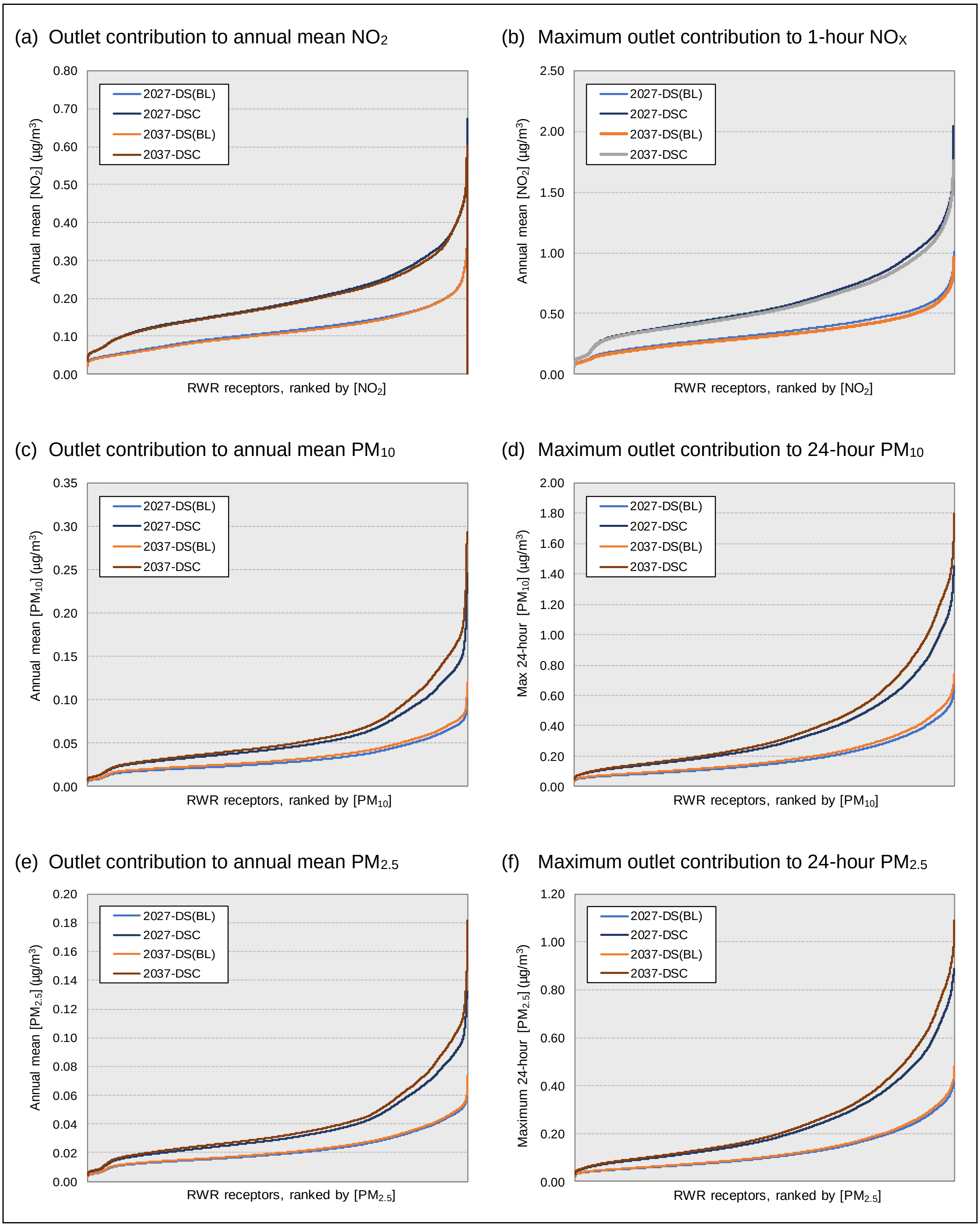


Figure J-1 Ventilation outlet contributions to NO_2, NO_X, PM_{10} and $PM_{2.5}$ at RWR receptors

Table J-4 Maximum contributions of ventilation outlets at RWR receptors

Scenario	Statistic	CO 1-hour (mg/m³)	NO_X Annual (µg/m³)	NO_X 1-hour (µg/m³)	NO_2 Annual (µg/m³)	NO_2 1-hour (µg/m³)	PM_{10} Annual (µg/m³)	PM_{10} 24-hour (µg/m³)	$PM_{2.5}$ Annual (µg/m³)	$PM_{2.5}$ 24-hour (µg/m³)
2027-DM	Average	0.006	N/A	3.217	0.034	N/A	0.014	0.101	0.010	0.071
	Maximum	0.028	N/A	14.374	0.179	N/A	0.101	0.641	0.098	0.428
	98th percentile	0.019	N/A	10.052	0.131	N/A	0.067	0.484	0.046	0.331
2027-DS(BL)	Average	0.009	N/A	7.637	0.116	N/A	0.031	0.181	0.022	0.125
	Maximum	0.031	N/A	33.154	0.376	N/A	0.110	0.677	0.074	0.489
	98th percentile	0.020	N/A	17.988	0.234	N/A	0.072	0.502	0.049	0.343
2027-DSC	Average	0.017	N/A	15.068	0.197	N/A	0.054	0.350	0.036	0.235
	Maximum	0.065	N/A	60.231	0.673	N/A	0.246	1.450	0.169	0.967
	98th percentile	0.044	N/A	34.484	0.417	N/A	0.143	1.094	0.095	0.725
2037-DM	Average	0.005	N/A	2.791	0.030	N/A	0.015	0.111	0.011	0.075
	Maximum	0.025	N/A	13.394	0.147	N/A	0.108	0.705	0.100	0.455
	98th percentile	0.016	N/A	8.781	0.110	N/A	0.072	0.534	0.047	0.350
2037-DS(BL)	Average	0.008	N/A	7.212	0.113	N/A	0.034	0.198	0.023	0.131
	Maximum	0.029	N/A	30.864	0.371	N/A	0.119	0.737	0.073	0.479
	98th percentile	0.018	N/A	16.893	0.233	N/A	0.078	0.550	0.051	0.362
2037-DSC	Average	0.015	N/A	14.323	0.193	N/A	0.060	0.395	0.039	0.257
	Maximum	0.062	N/A	58.719	0.602	N/A	0.293	1.798	0.182	1.090
	98th percentile	0.041	N/A	32.996	0.418	N/A	0.171	1.296	0.108	0.829

J.5 Contour plots – ventilation outlets only

J.5.1 Annual mean NO_X

J.5.1.1 2027-DS(BL) scenario

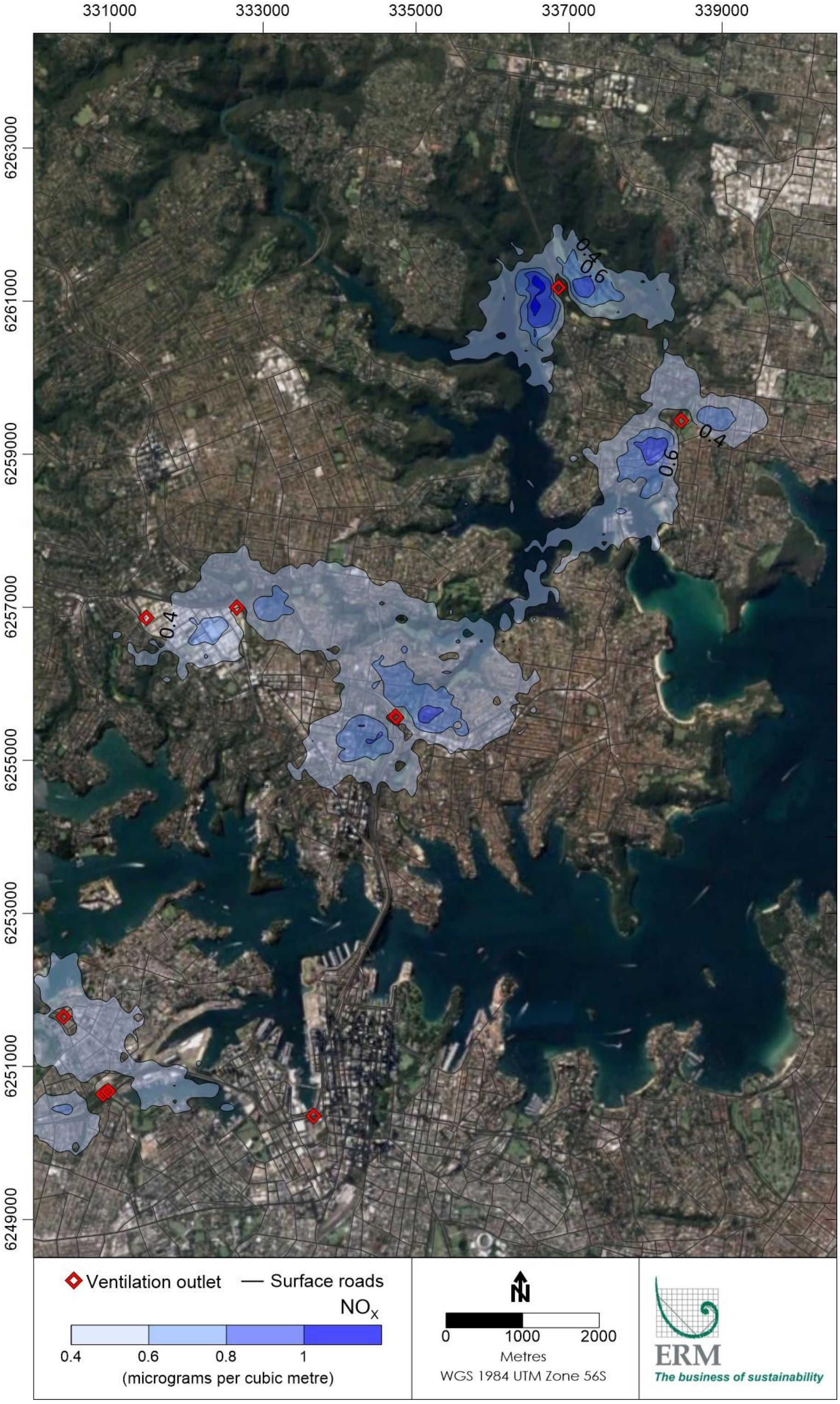


Figure J-2 Contour plot of annual mean NO_X for all ventilation outlets in 2027-DS(BL) scenario

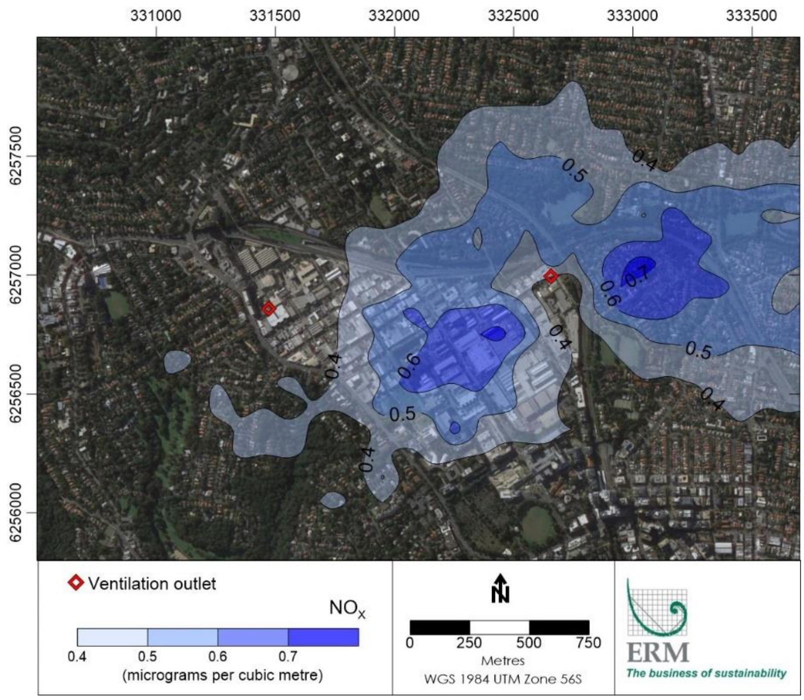


Figure J-3 Local contour plot of annual mean NO_X for Gore Hill Freeway in 2027-DS(BL) scenario

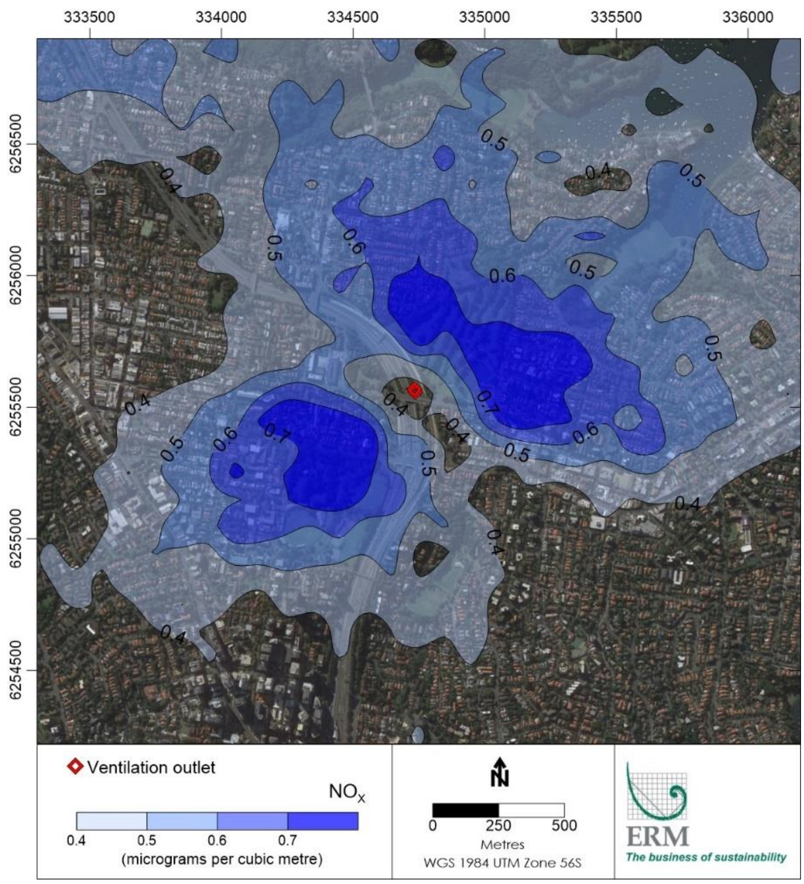


Figure J-4 Local contour plot of annual mean NO_X for Warringah Freeway in 2027-DS(BL) scenario

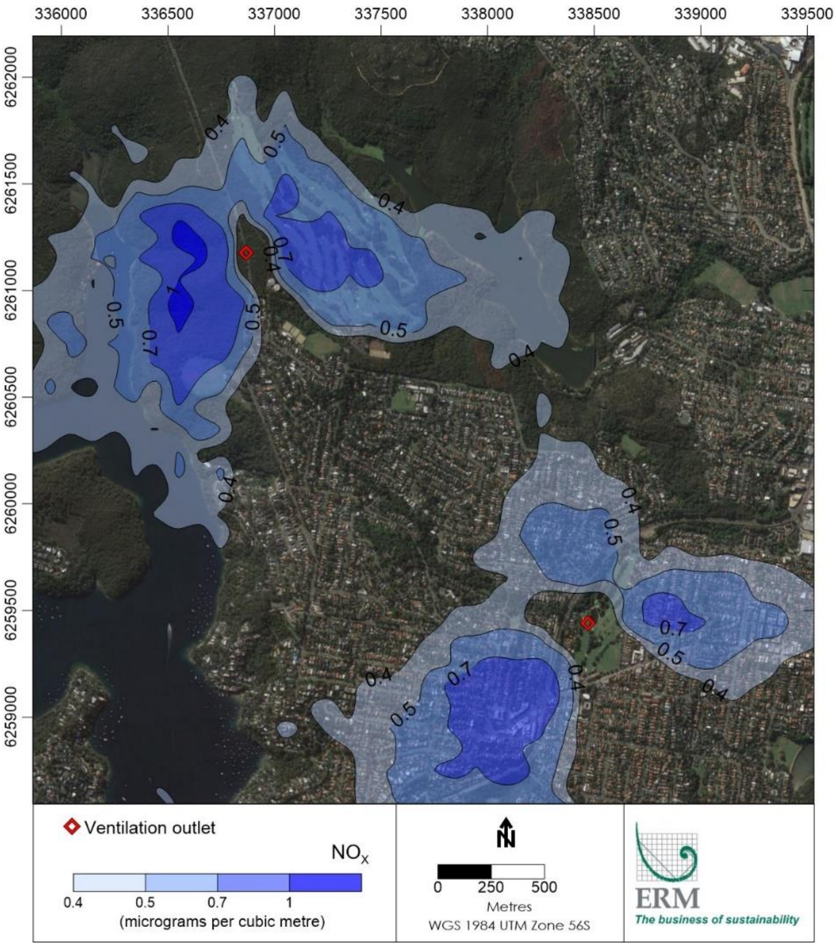


Figure J-5 **Local contour plot of annual mean NO_X for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2027-DS(BL) scenario**

J.5.1.2 2027-DSC scenario

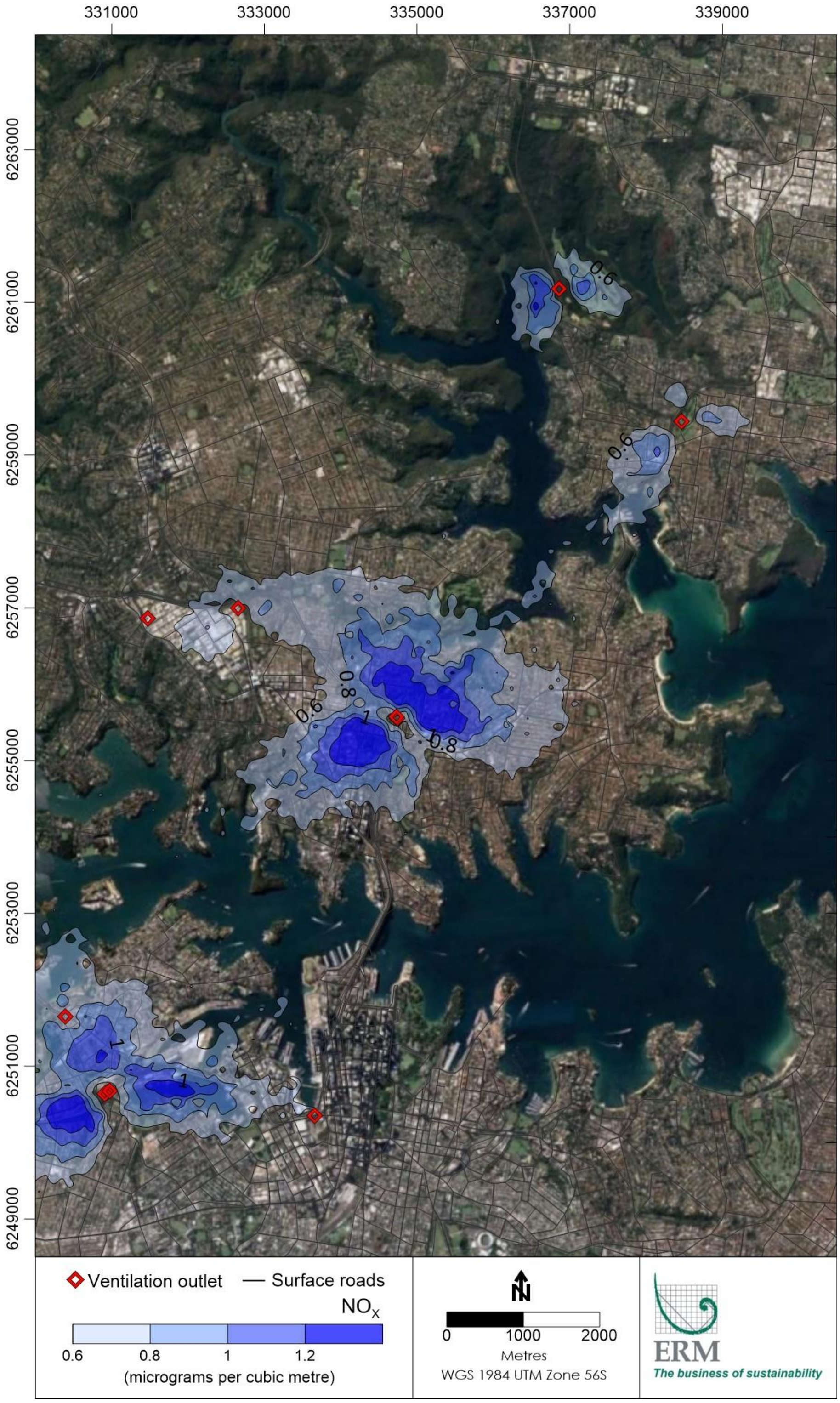


Figure J-6 Contour plot of annual mean NO_X for all ventilation outlets in 2027-DSC scenario

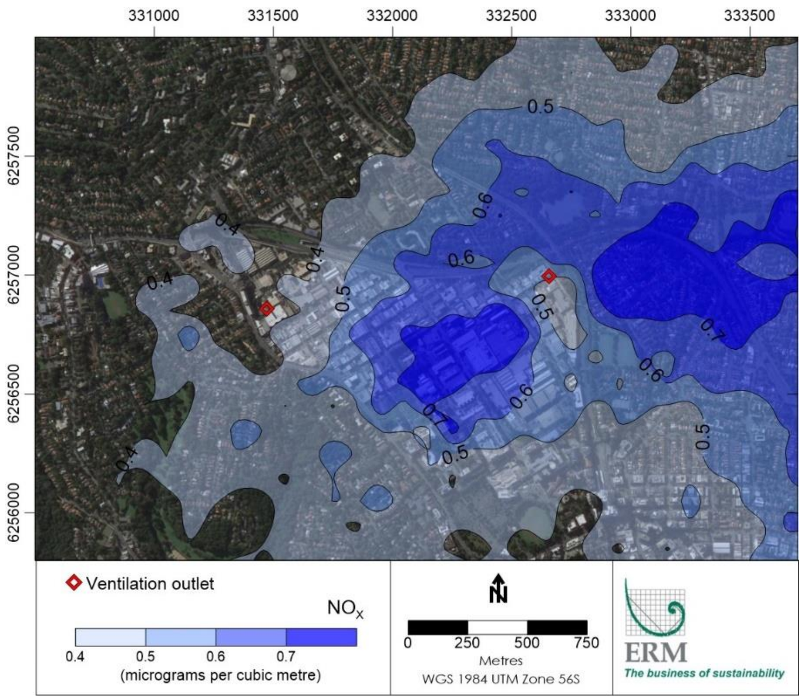


Figure J-7 Local contour plot of annual mean NO_X for Gore Hill Freeway in 2027-DSC scenario

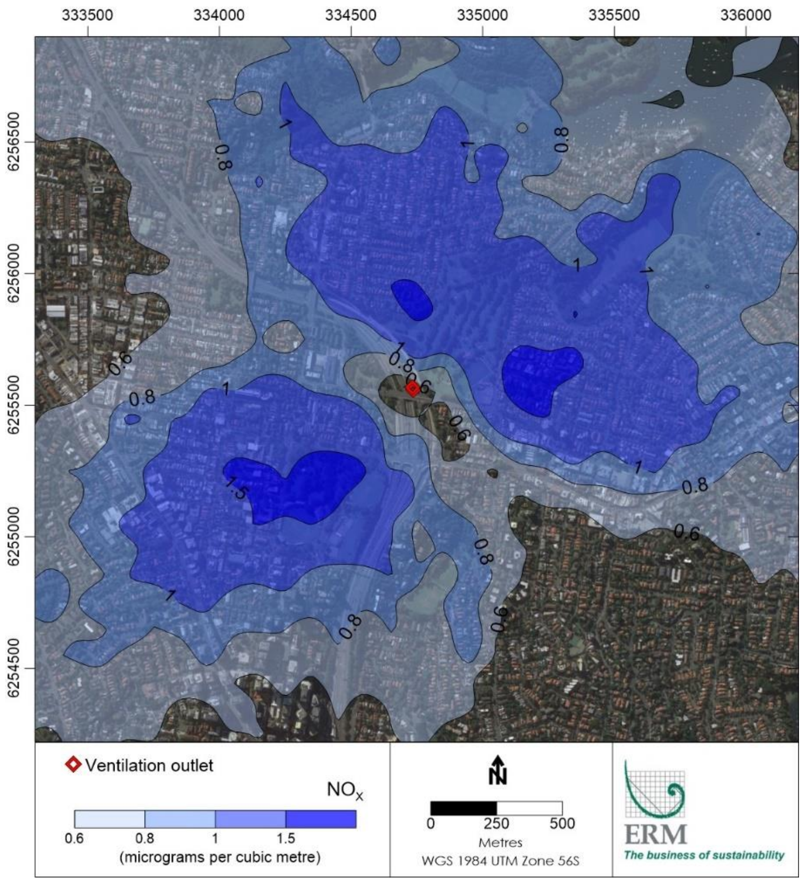


Figure J-8 Local contour plot of annual mean NO_X for Warringah Freeway in 2027-DSC scenario

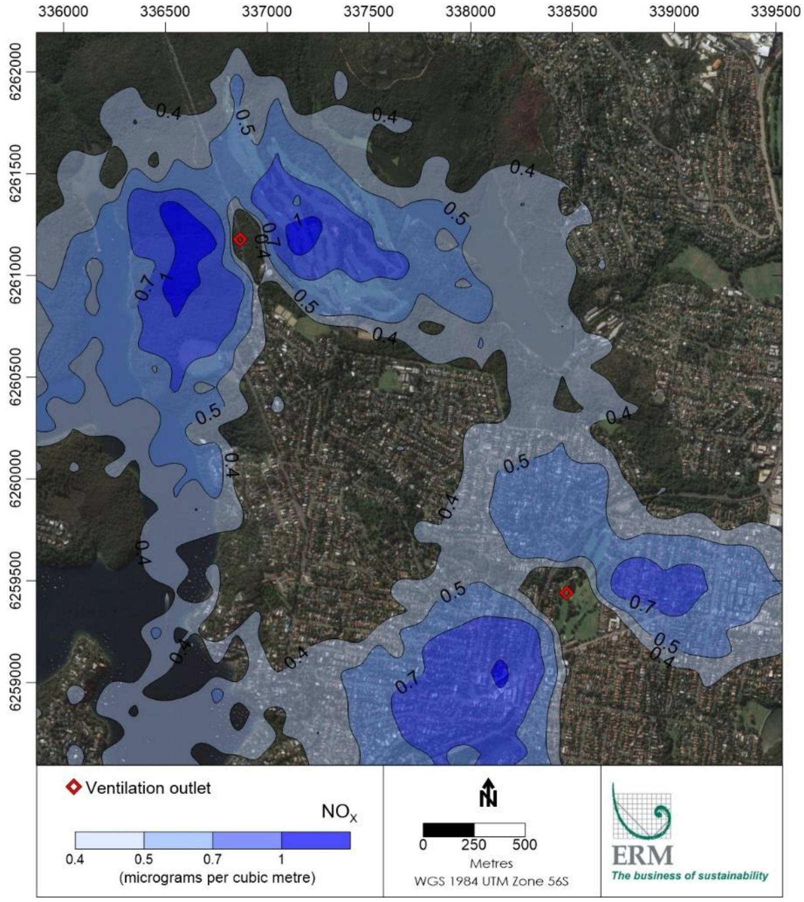


Figure J-9 **Local contour plot of annual mean NO_X for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2027-DSC scenario**

J.5.1.3 2037-DS(BL) scenario

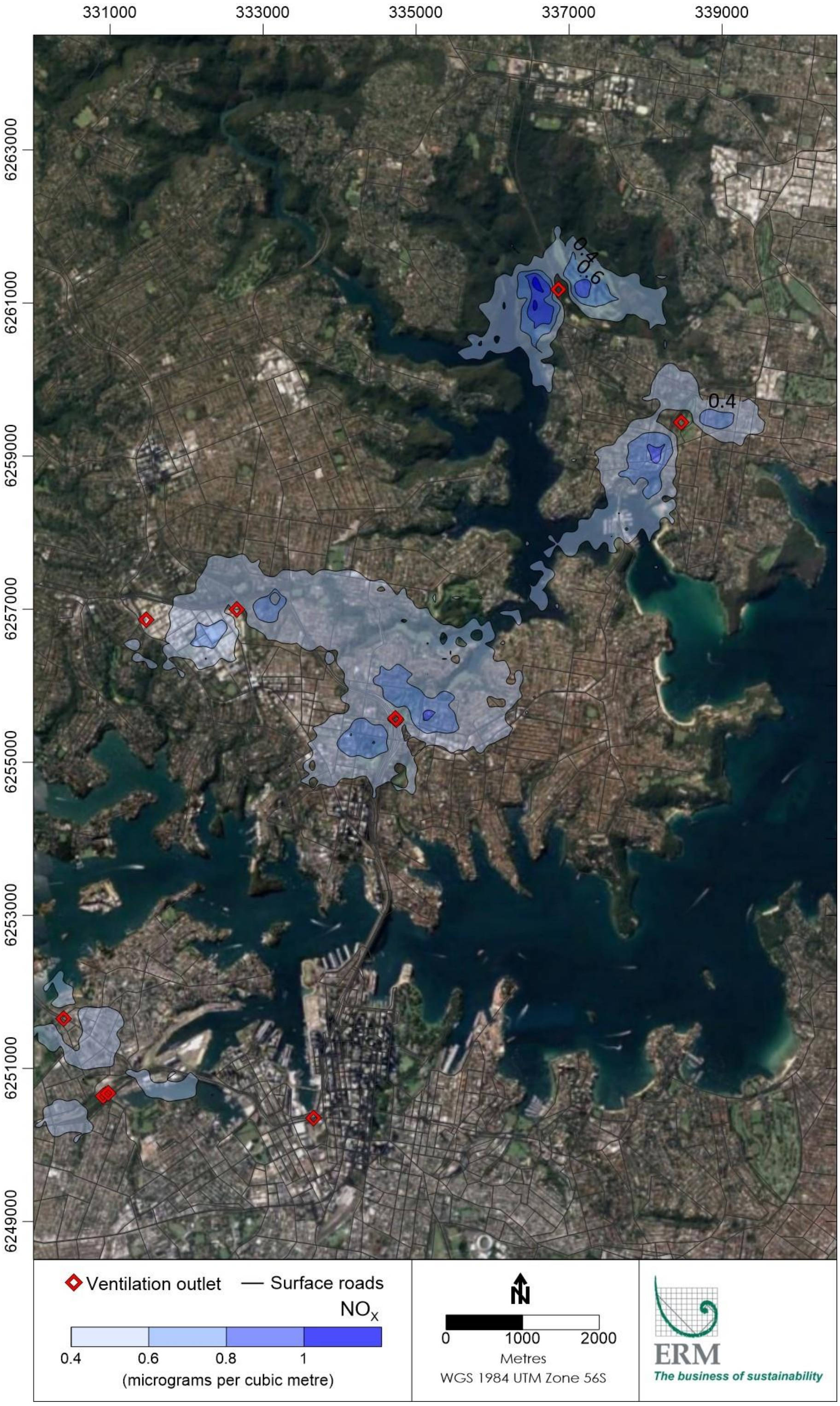


Figure J-10 Contour plot of annual mean NO_X for all ventilation outlets in 2037-DS(BL) scenario

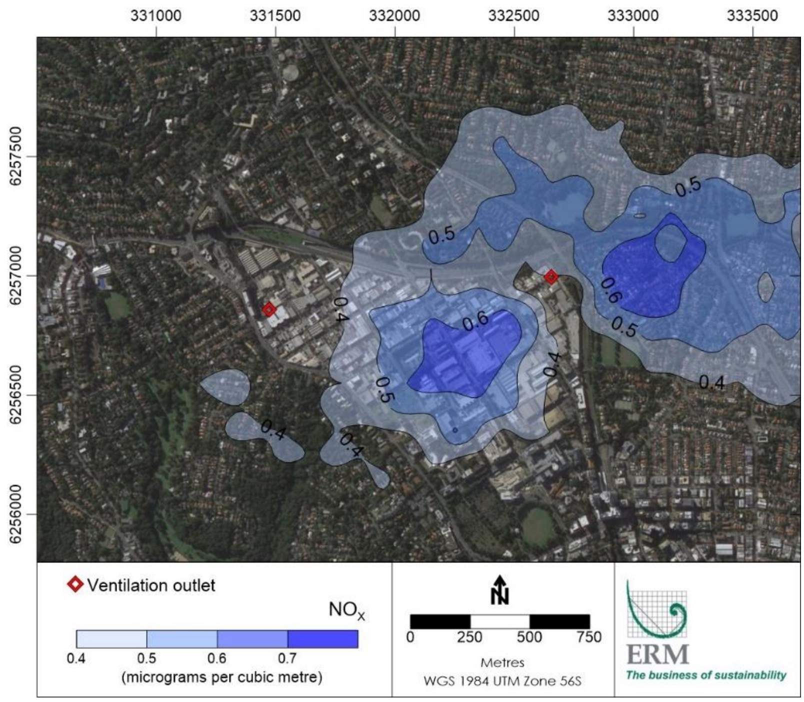


Figure J-11 Local contour plot of annual mean NO_X for Gore Hill Freeway in 2037-DS(BL) scenario

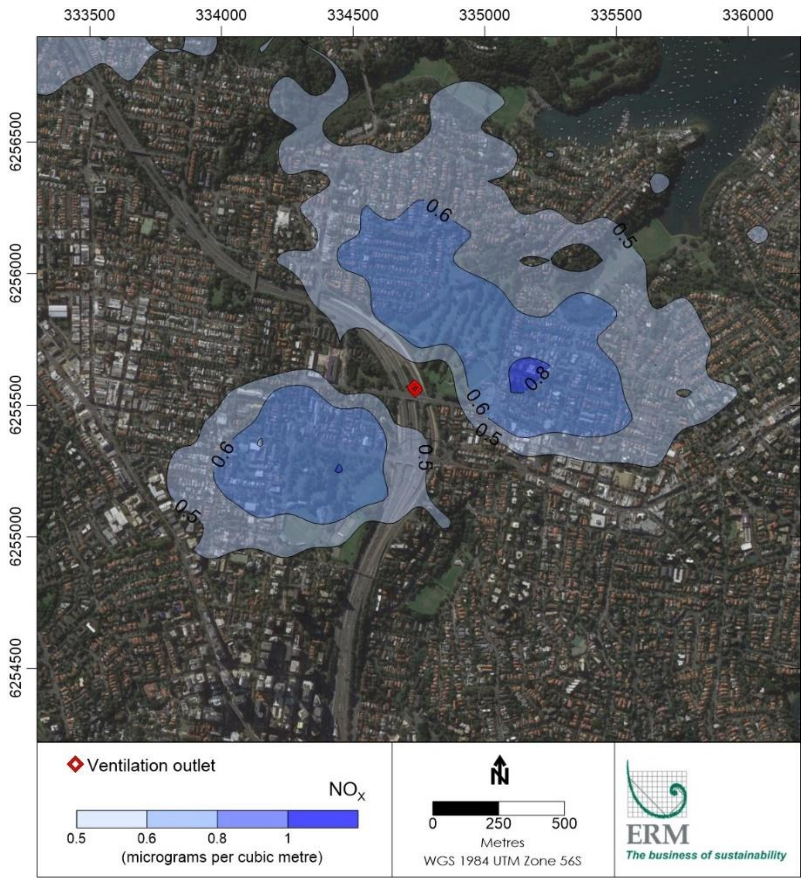


Figure J-12 Local contour plot of annual mean NO_X for Warringah Freeway in 2037-DS(BL) scenario

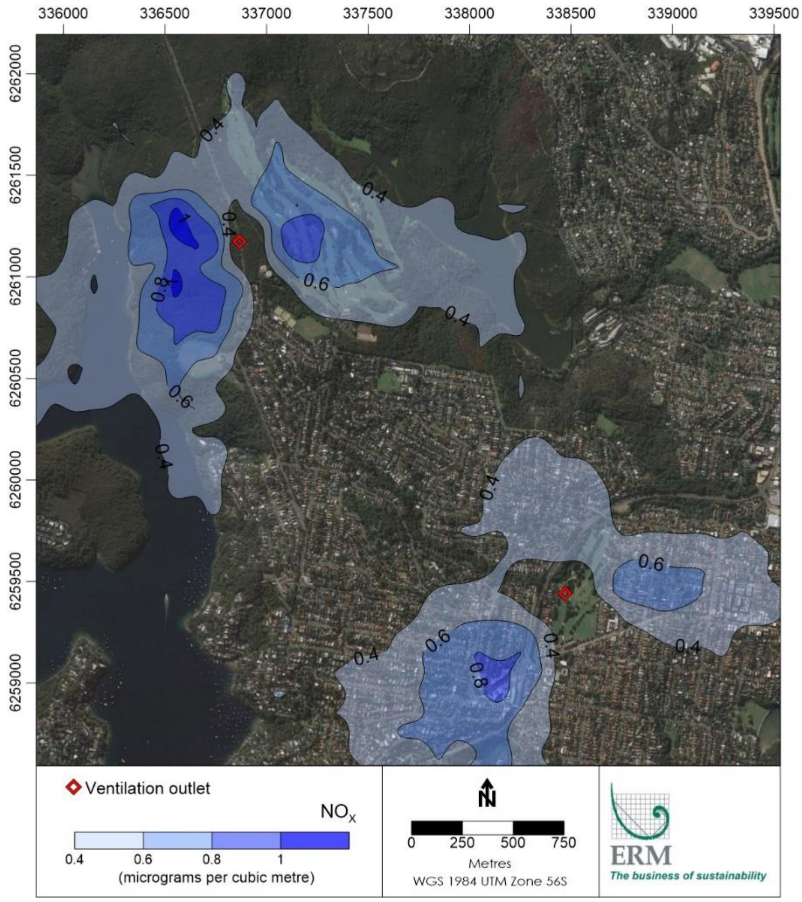


Figure J-13 **Local contour plot of annual mean NO_X for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2027(BL) scenario**

J.5.1.4 2037-DSC scenario

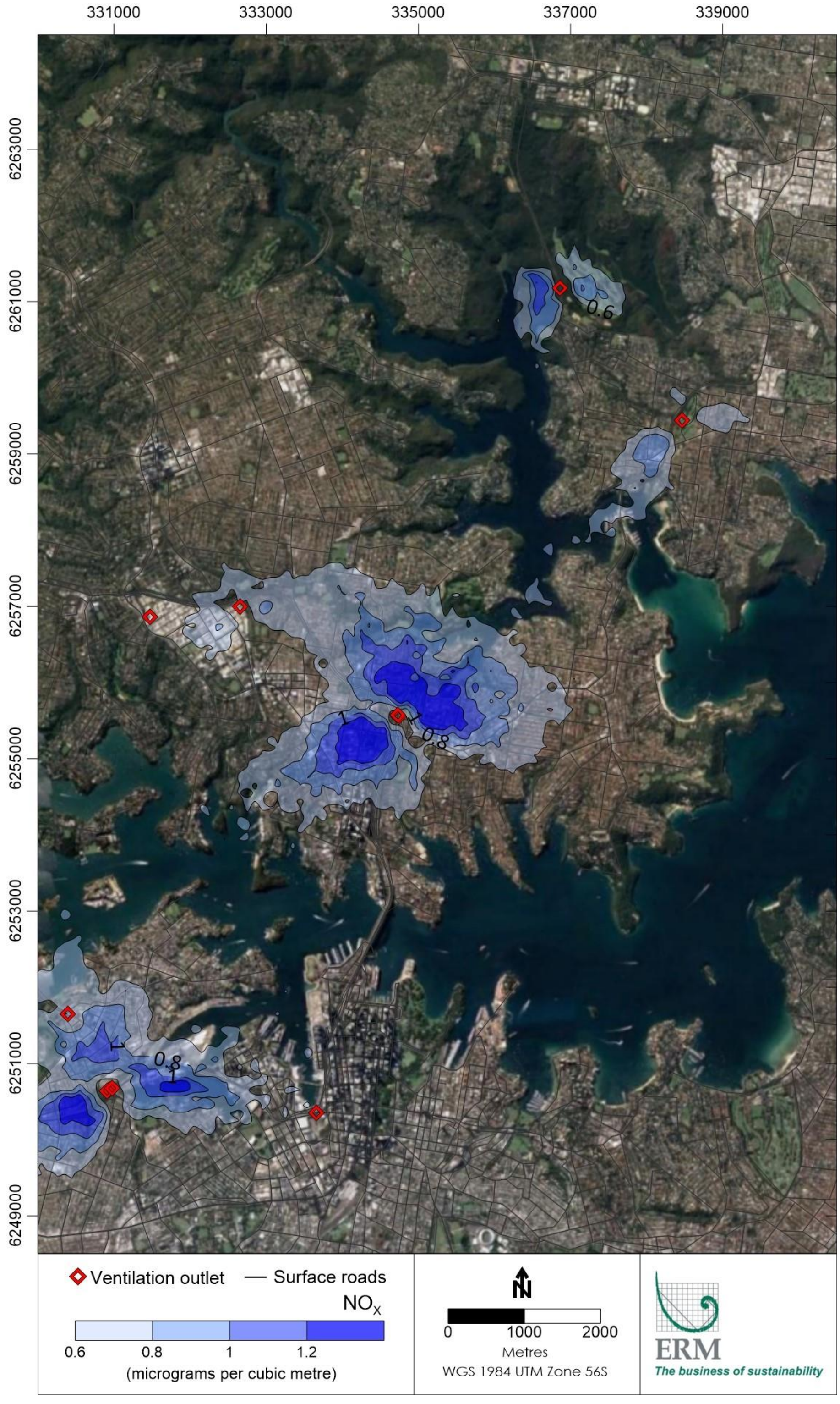


Figure J-14 Contour plot of annual mean NO_X for all ventilation outlets in 2037-DSC scenario

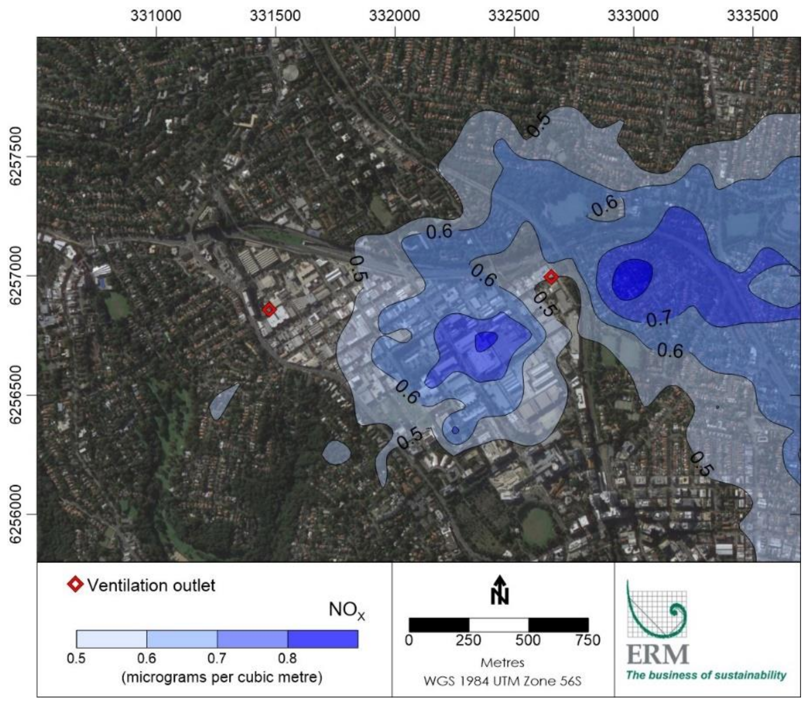


Figure J-15 **Local contour plot of annual mean NO_X for Gore Hill Freeway in 2037-DSC scenario**

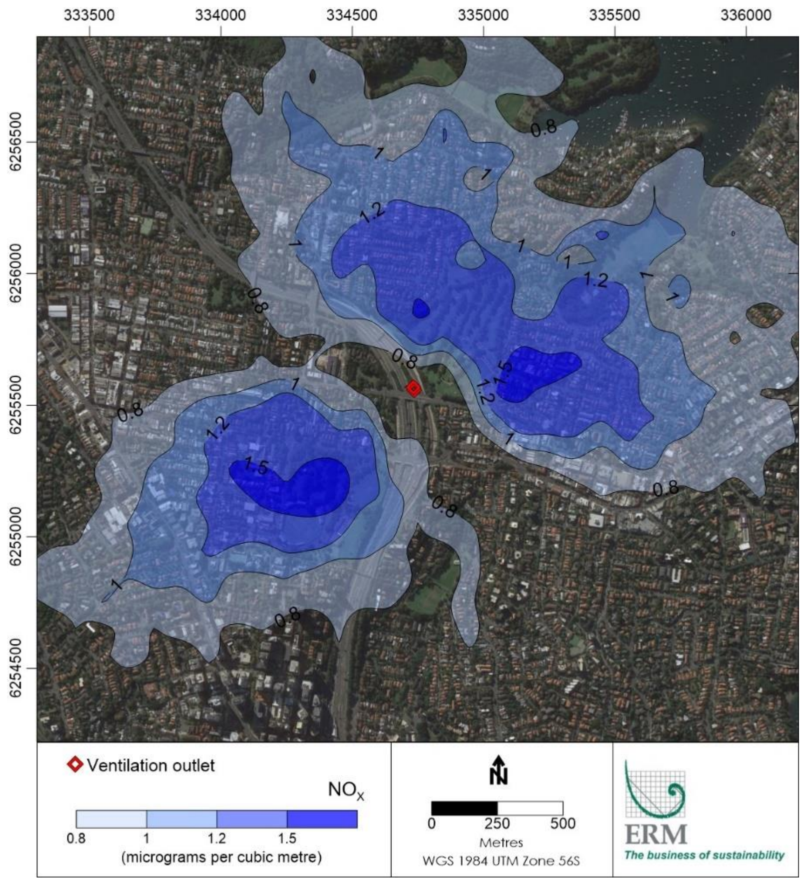


Figure J-16 **Local contour plot of annual mean NO_X for Warringah Freeway in 2037-DSC scenario**

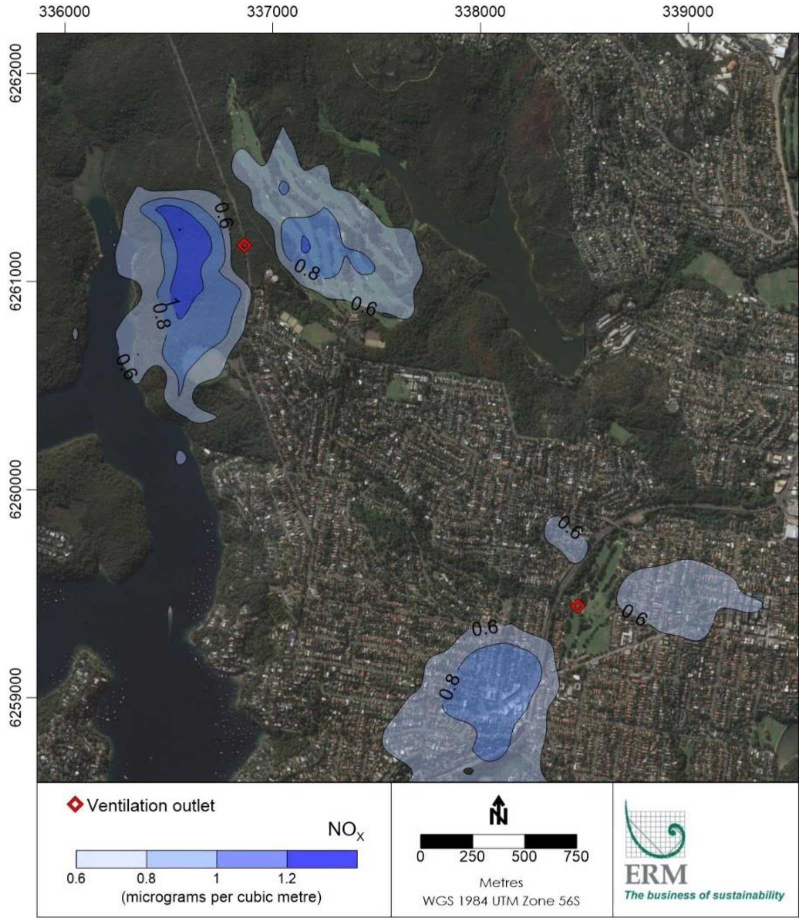


Figure J-17 **Local contour plot of annual mean NO_X for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2037 DSC scenario**

J.5.2 Maximum 1-hour NO_X

J.5.2.1 2027-DS(BL) scenario

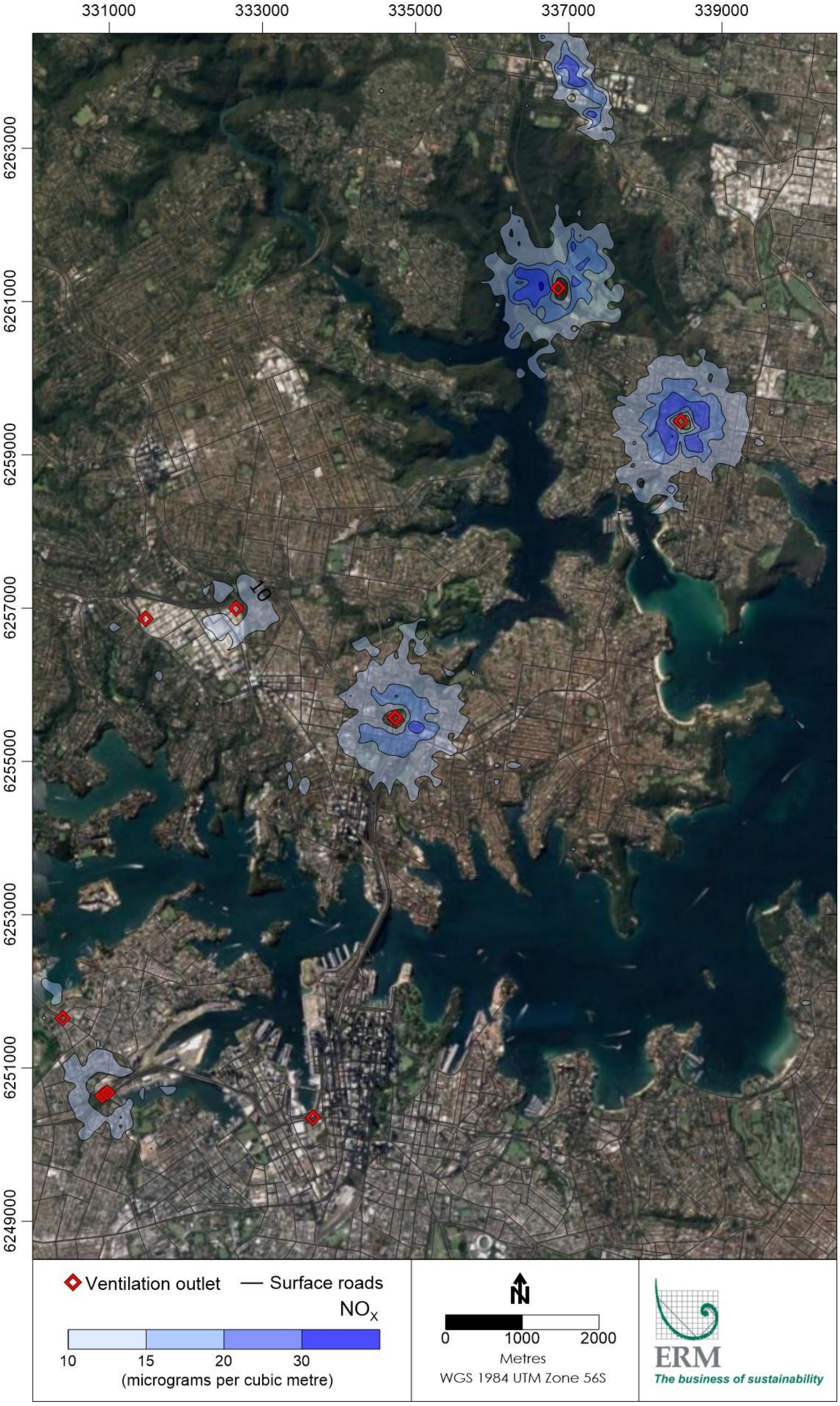


Figure J-18 Contour plot of maximum 1-hour NO_X for all ventilation outlets in 2027-DS(BL) scenario

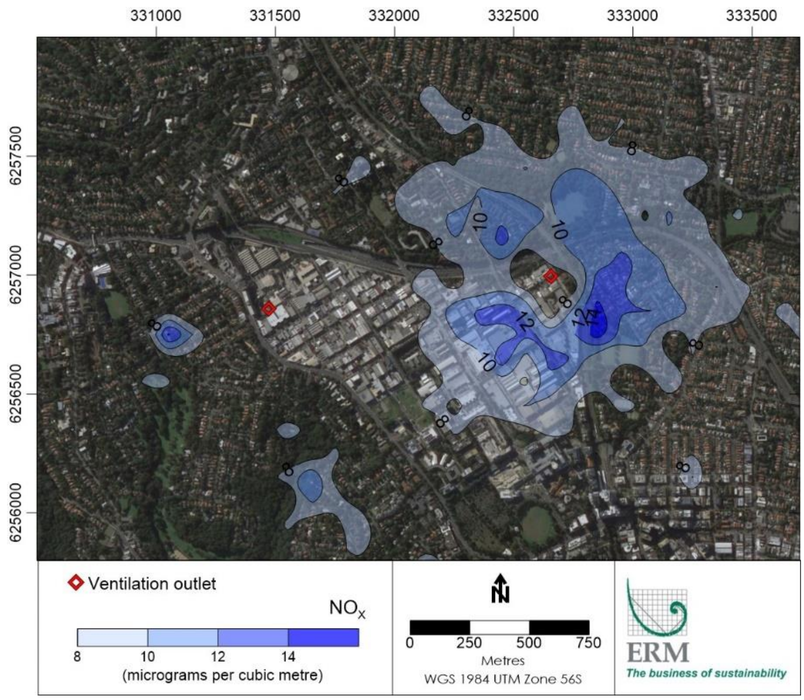


Figure J-19 **Local contour plot of maximum 1-hour NO_X for Gore Hill Freeway in 2027-DS(BL) scenario**

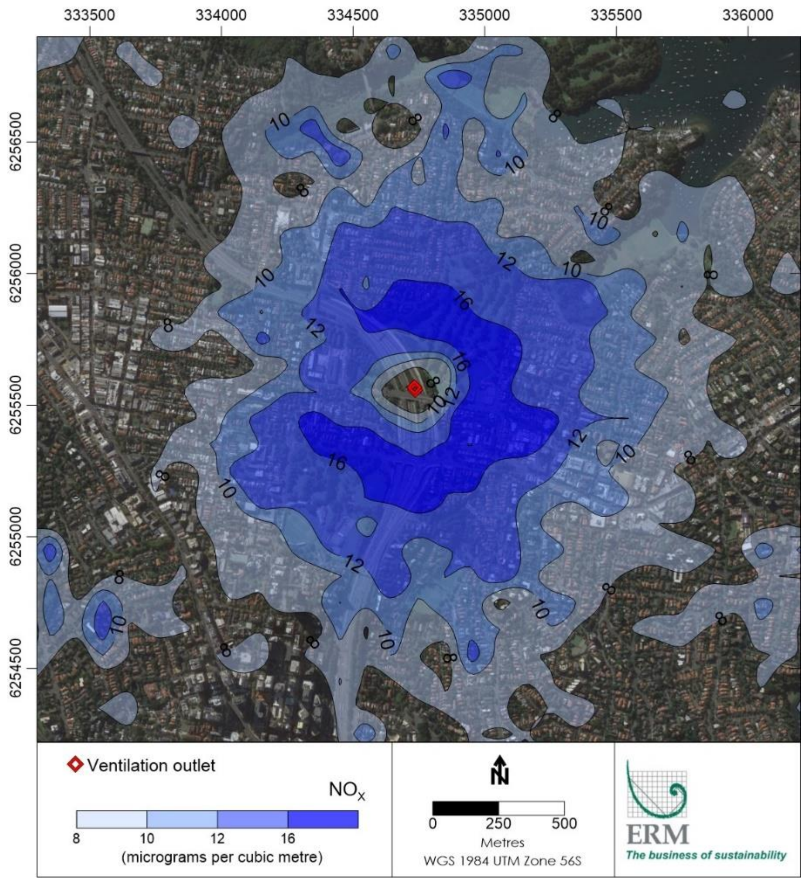


Figure J-20 **Local contour plot of maximum 1-hour NO_X for Warringah Freeway in 2027-DS(BL) scenario**

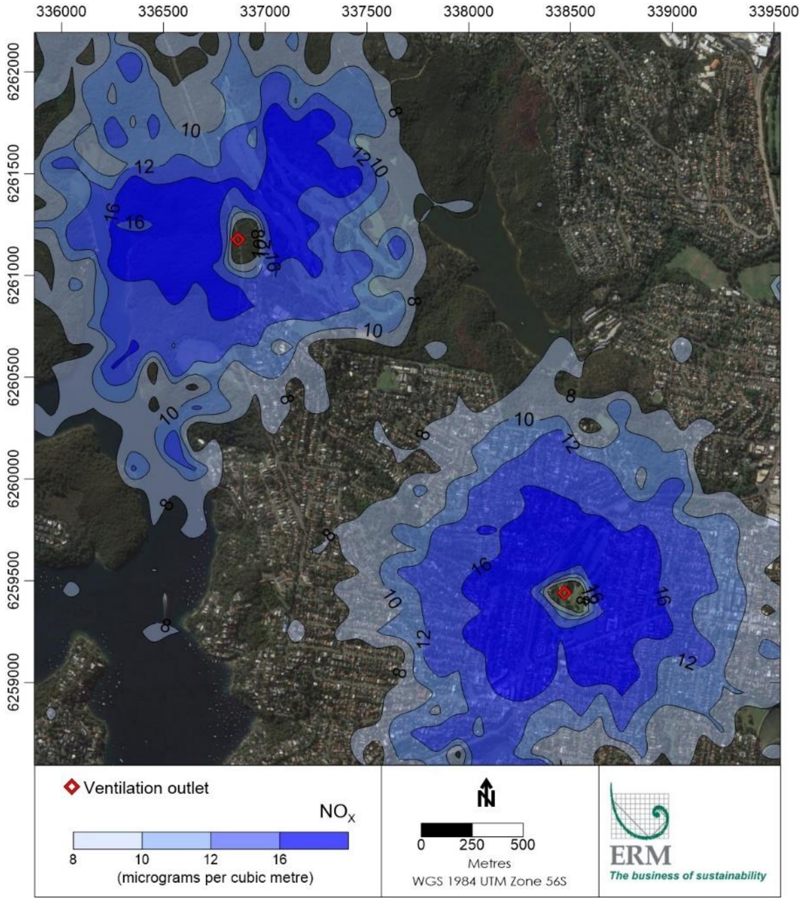


Figure J-21 **Local contour plot of maximum 1-hour NO_X for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2027(BL) scenario**

J.5.2.2 2027-DSC scenario

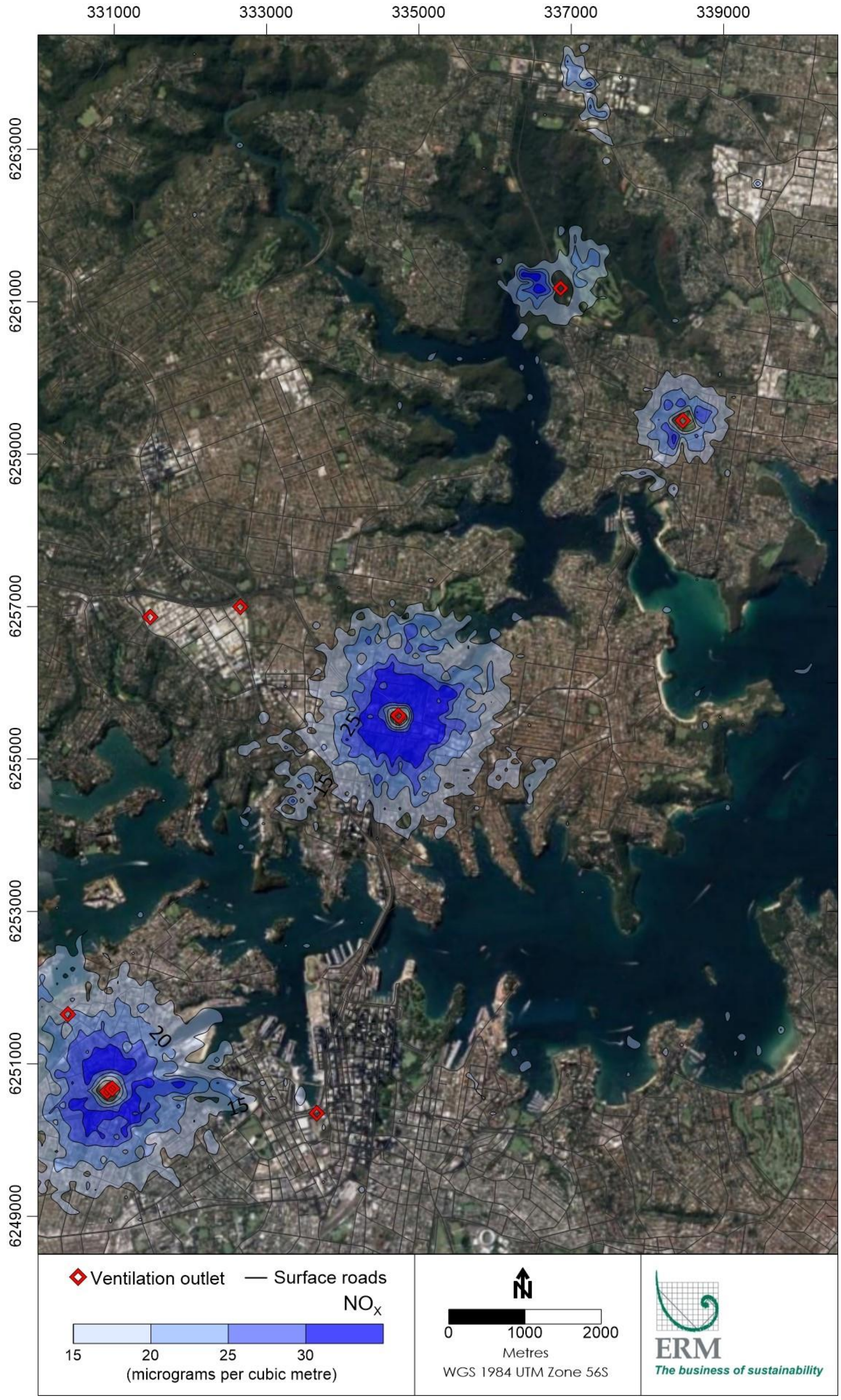


Figure J-22 Contour plot of maximum 1-hour NO_X for all ventilation outlets in 2027-DSC scenario

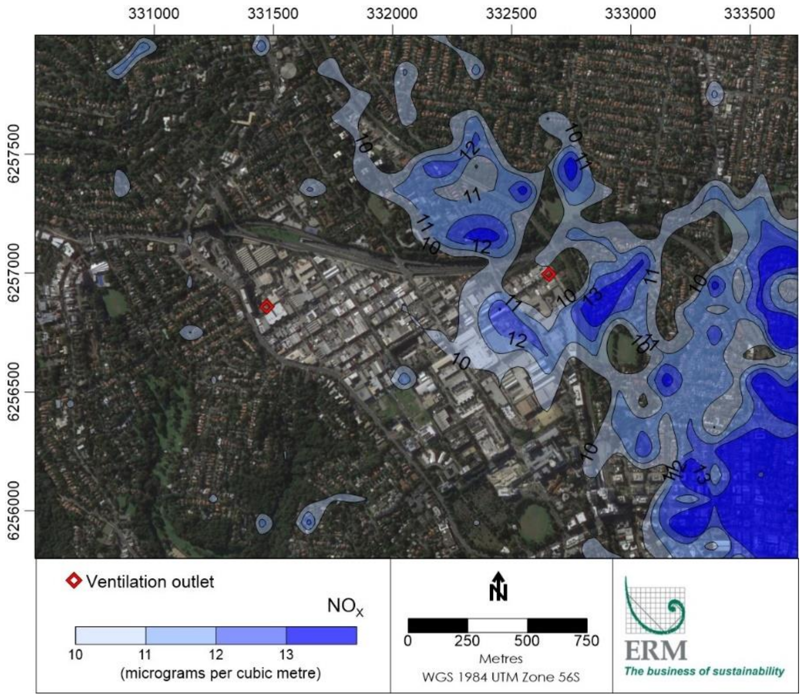


Figure J-23 Local contour plot of maximum 1-hour NO_X for Gore Hill Freeway in 2027-DSC scenario

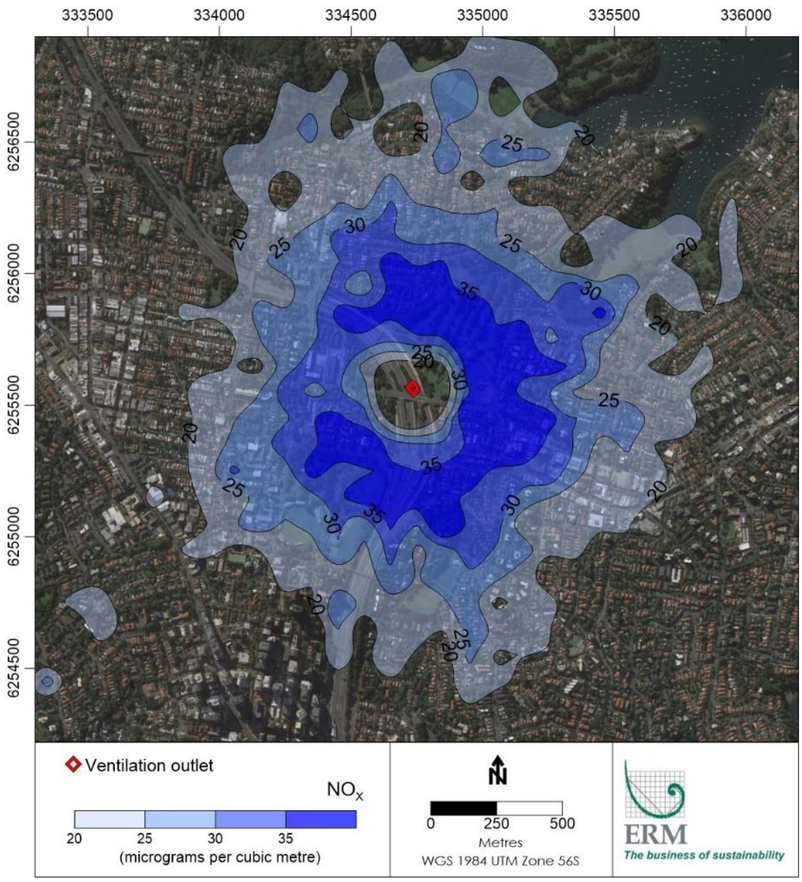


Figure J-24 Local contour plot of maximum 1-hour NO_X for Warringah Freeway in 2027-DSC scenario

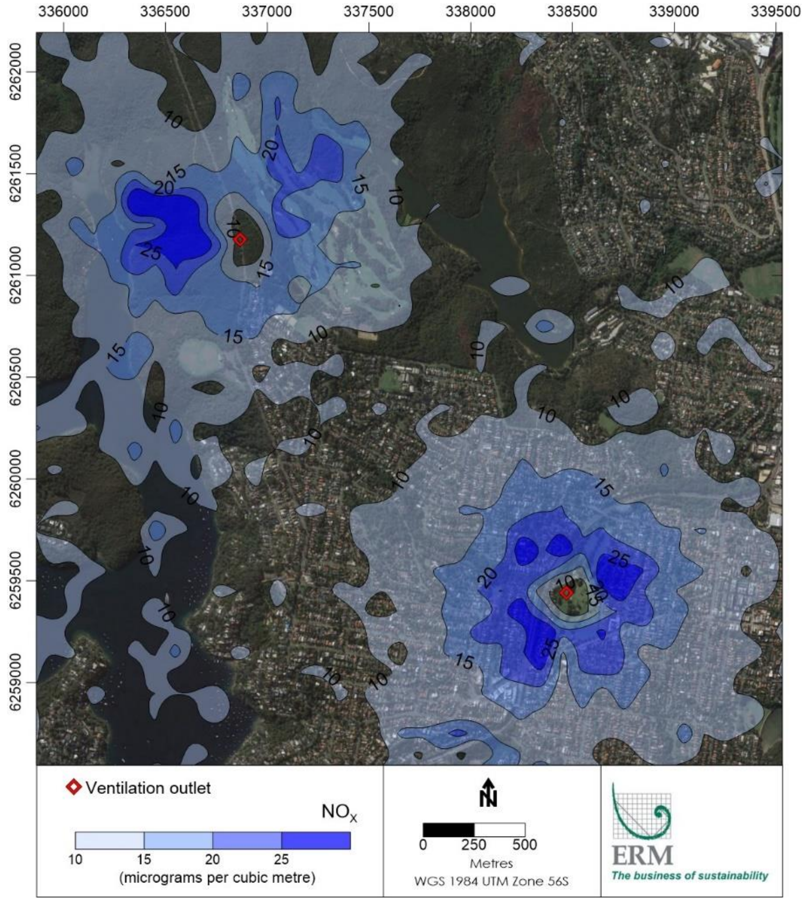


Figure J-25 **Local contour plot of maximum 1-hour NO_X for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2027 DSC scenario**

J.5.2.3 2037-DS(BL) scenario

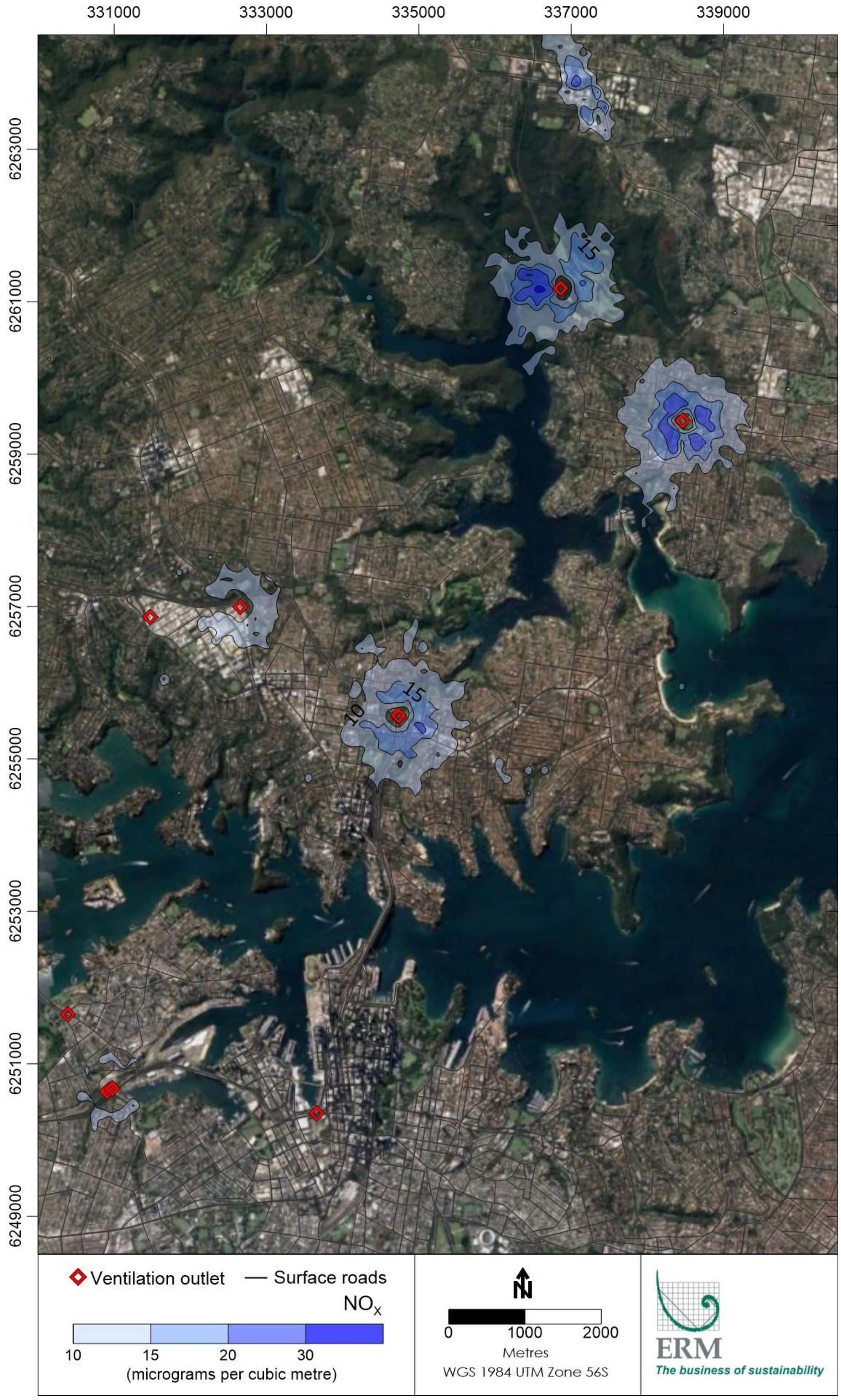


Figure J-26 Contour plot of maximum 1-hour NO_X for all ventilation outlets in 2037-DS(BL) scenario

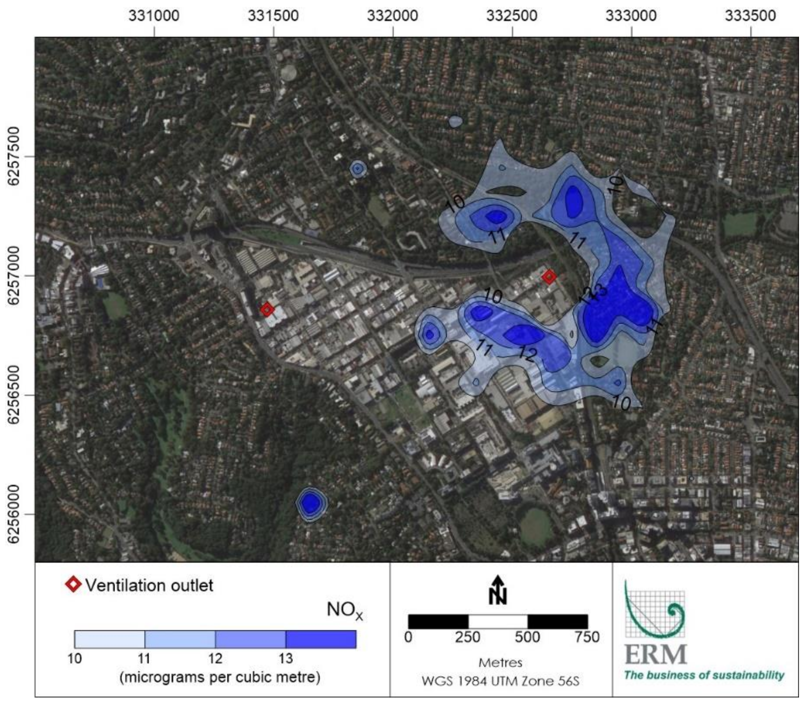


Figure J-27 **Local contour plot of maximum 1-hour NOx for Gore Hill Freeway in 2037-DS(BL) scenario**

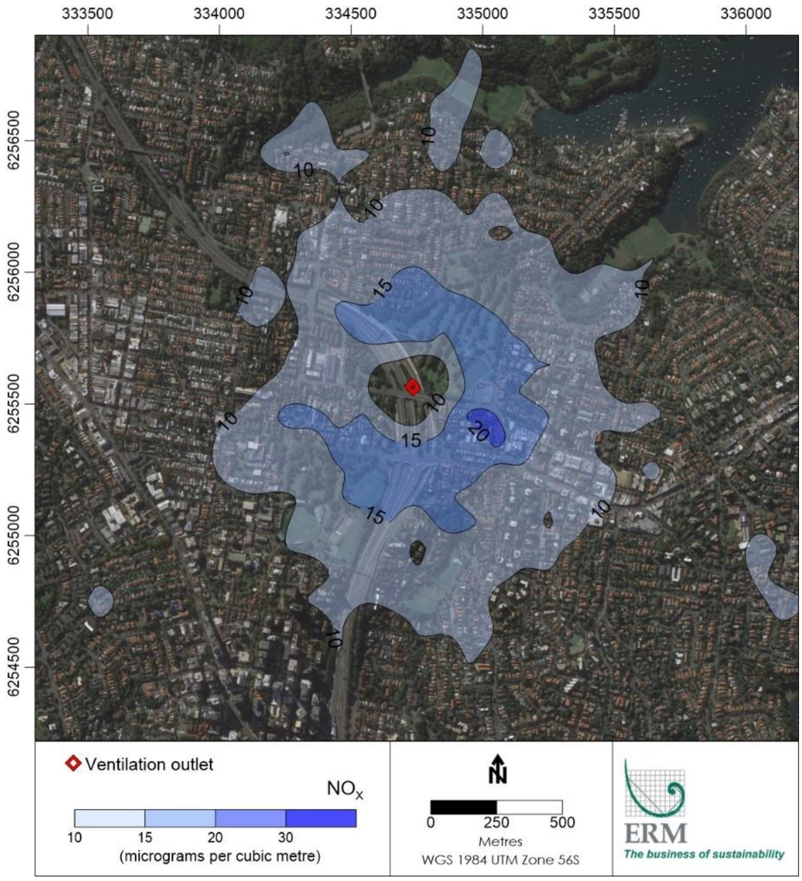


Figure J-28 **Local contour plot of maximum 1-hour NOx for Warringah Freeway in 2037-DS(BL) scenario**

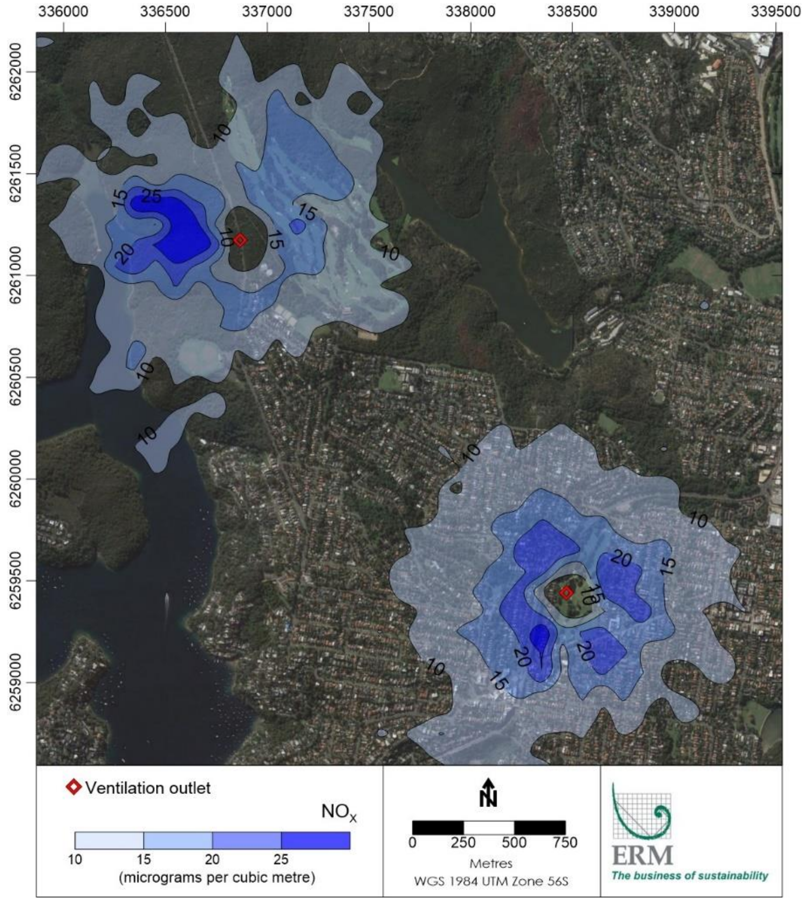


Figure J-29 Local contour plot of maximum 1-hour NO_X for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2037-DS(BL) scenario

J.5.2.4 2037-DSC scenario

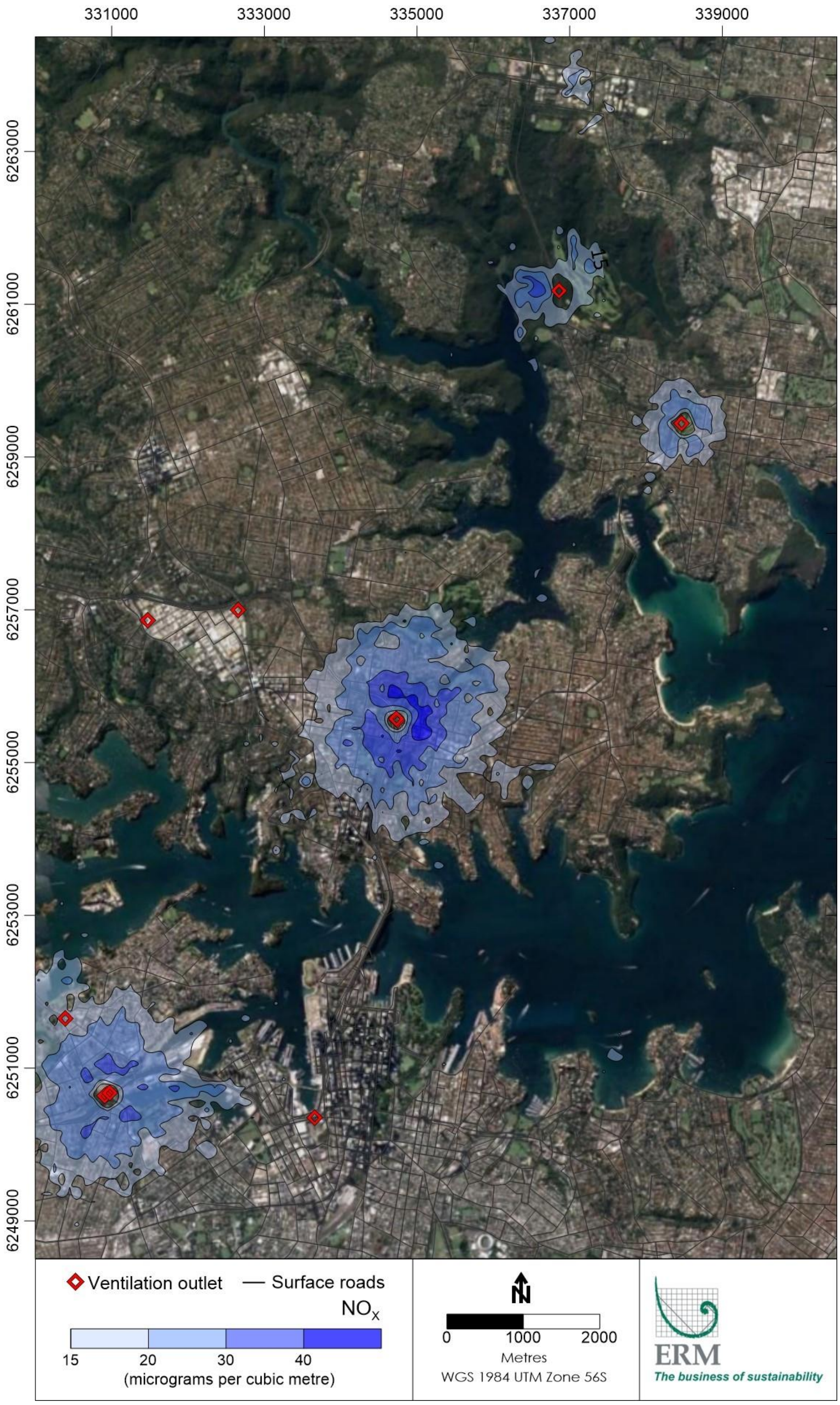


Figure J-30 Contour plot of maximum 1-hour NO_X for all ventilation outlets in 2037-DSC scenario

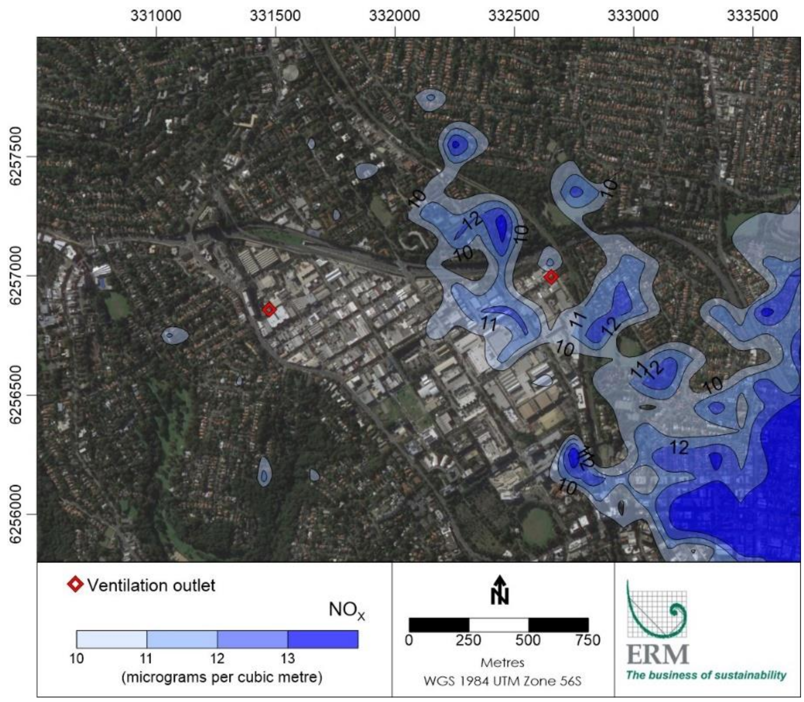


Figure J-31 Local contour plot of maximum 1-hour NO_X for Gore Hill Freeway in 2037-DSC scenario

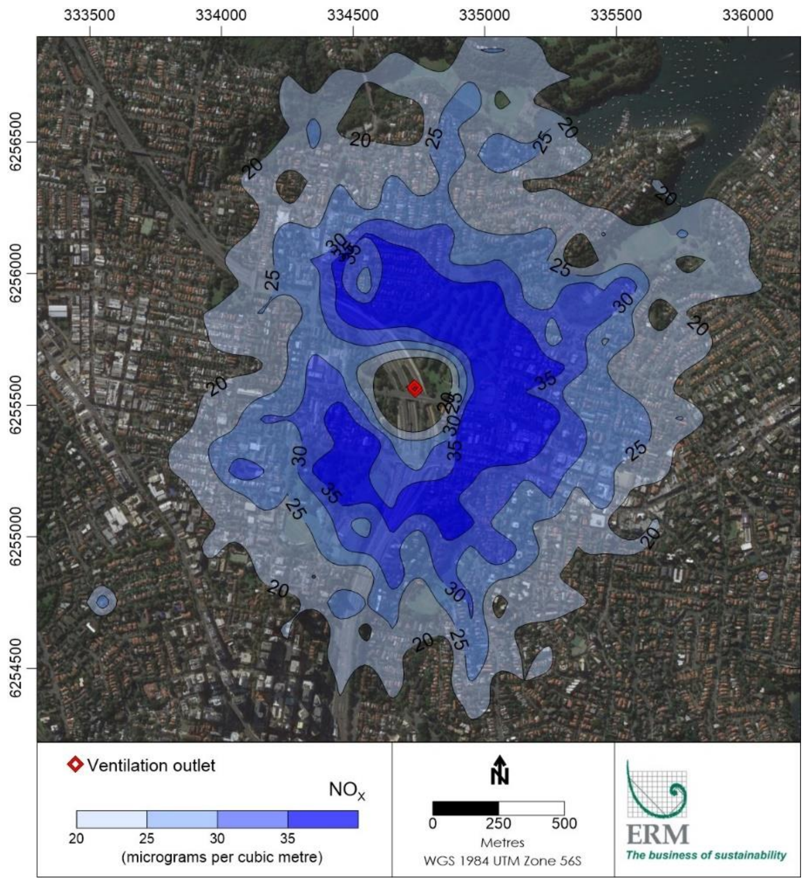


Figure J-32 Local contour plot of maximum 1-hour NO_X for Warringah Freeway in 2037-DSC scenario

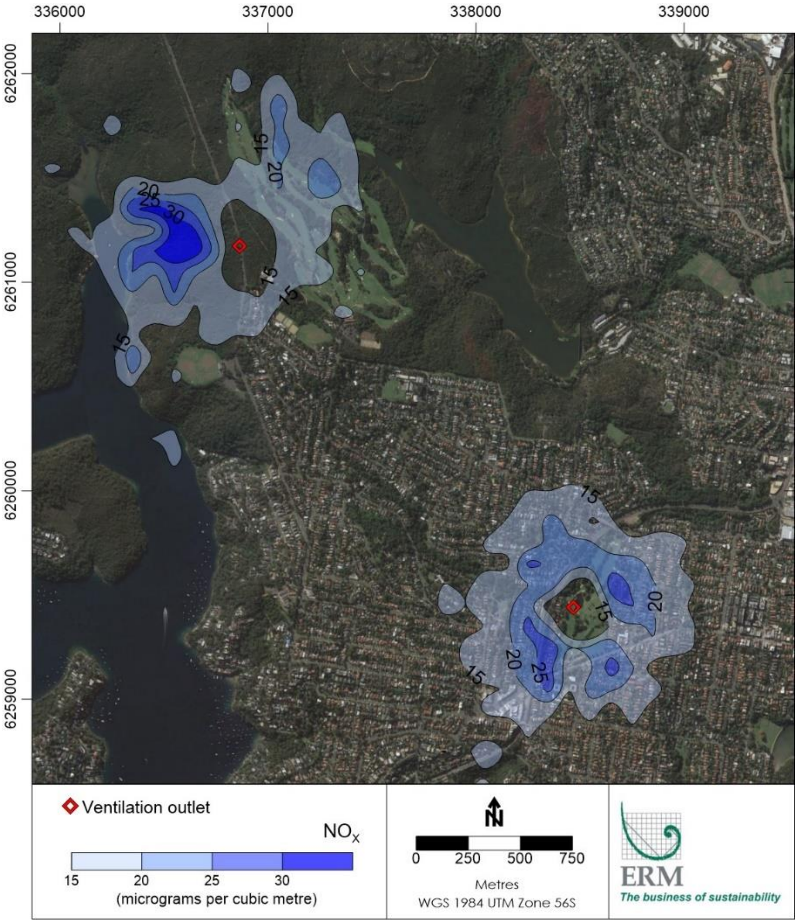


Figure J-33 Local contour plot of maximum 1-hour NO_X for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2037-DSC scenario

J.5.3 Annual PM_{10}

J.5.3.1 2027-DS(BL) scenario

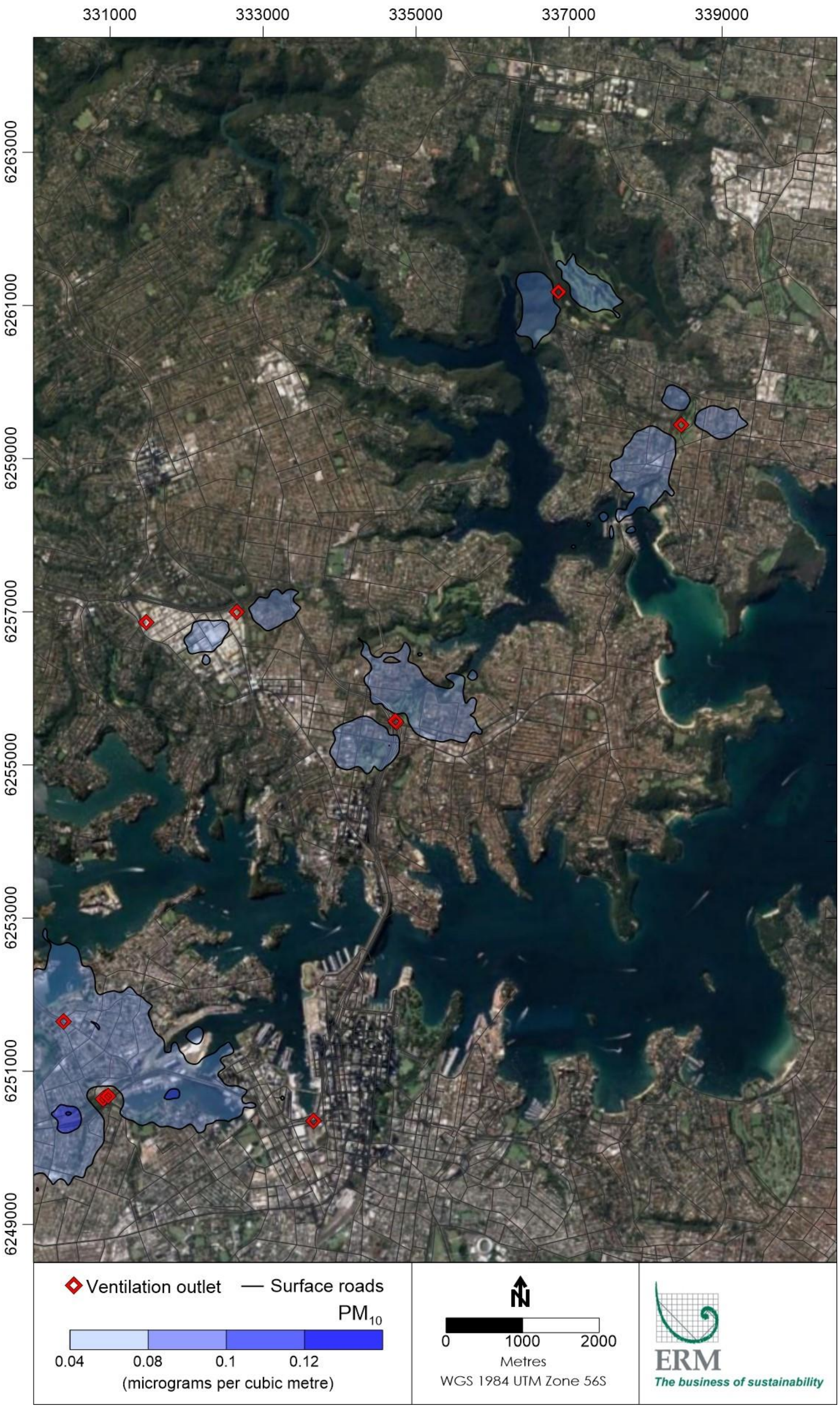


Figure J-34 Contour plot of annual mean PM_{10} for all ventilation outlets in 2027-DS(BL) scenario

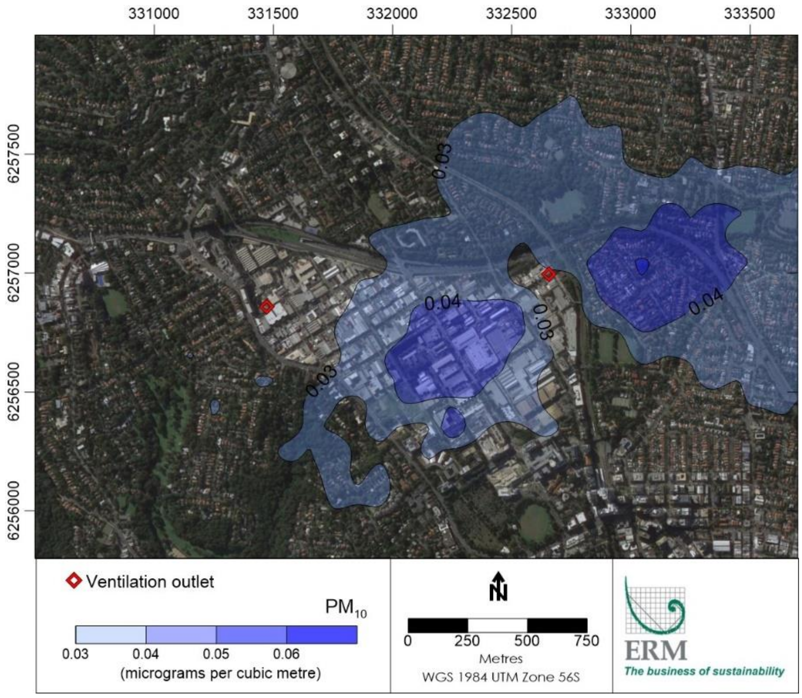


Figure J-35 Local contour plot of annual mean PM_{10} for Gore Hill Freeway in 2027-DS(BL) scenario

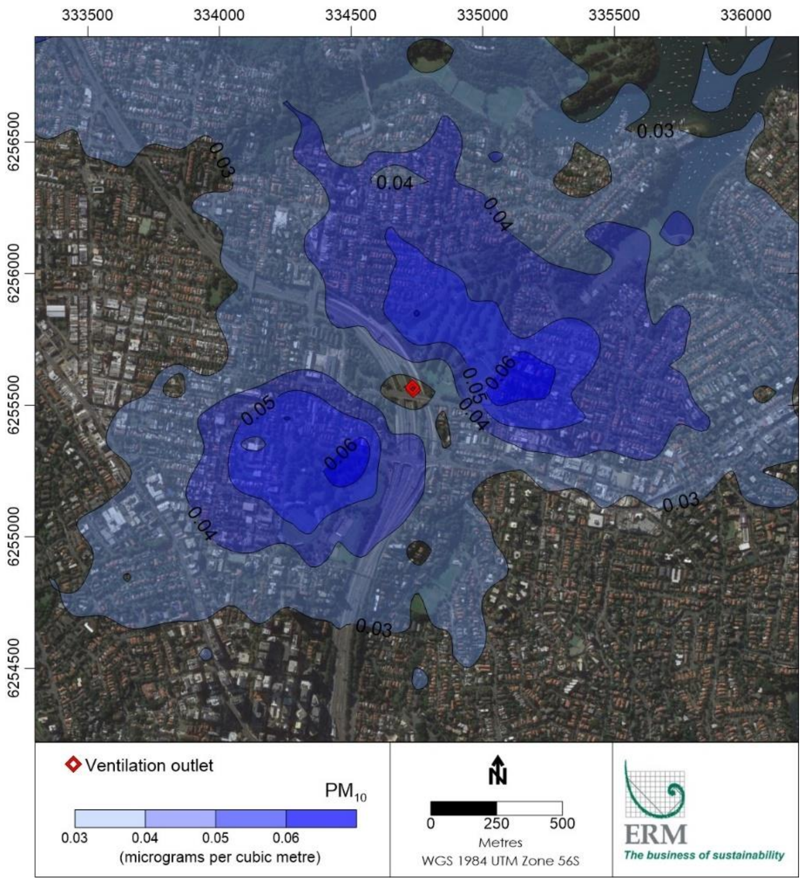


Figure J-36 Local contour plot of annual mean PM_{10} for Warringah Freeway in 2027-DS(BL) scenario

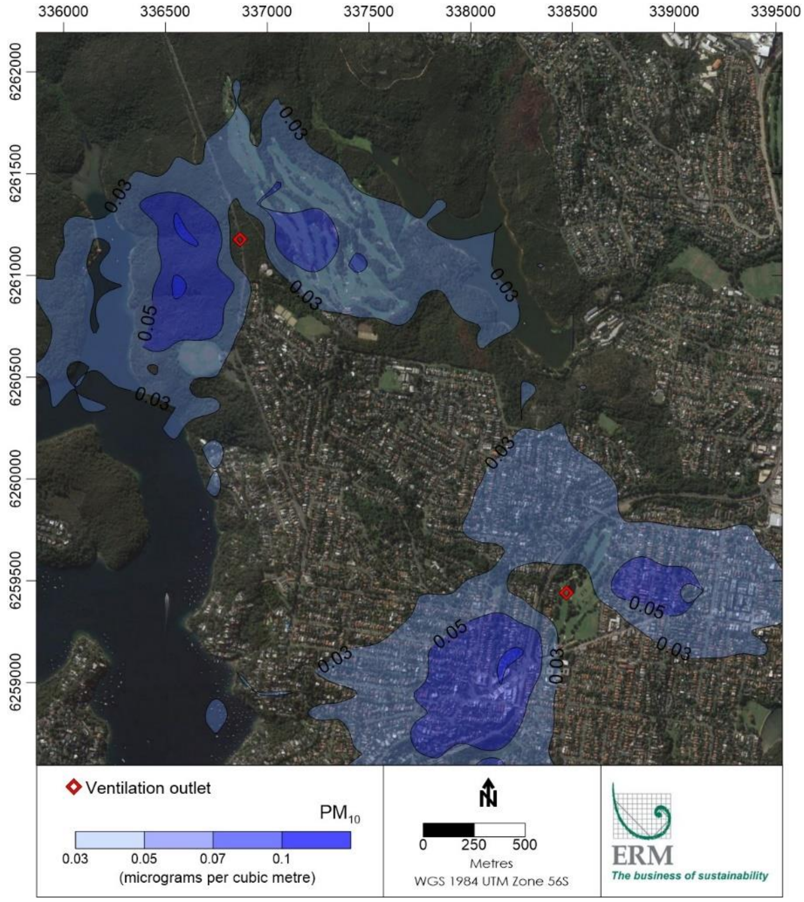


Figure J-37 **Local contour plot of maximum 1-hour NO_X for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2037-DSC scenario**

J.5.3.2 2027-DSC scenario

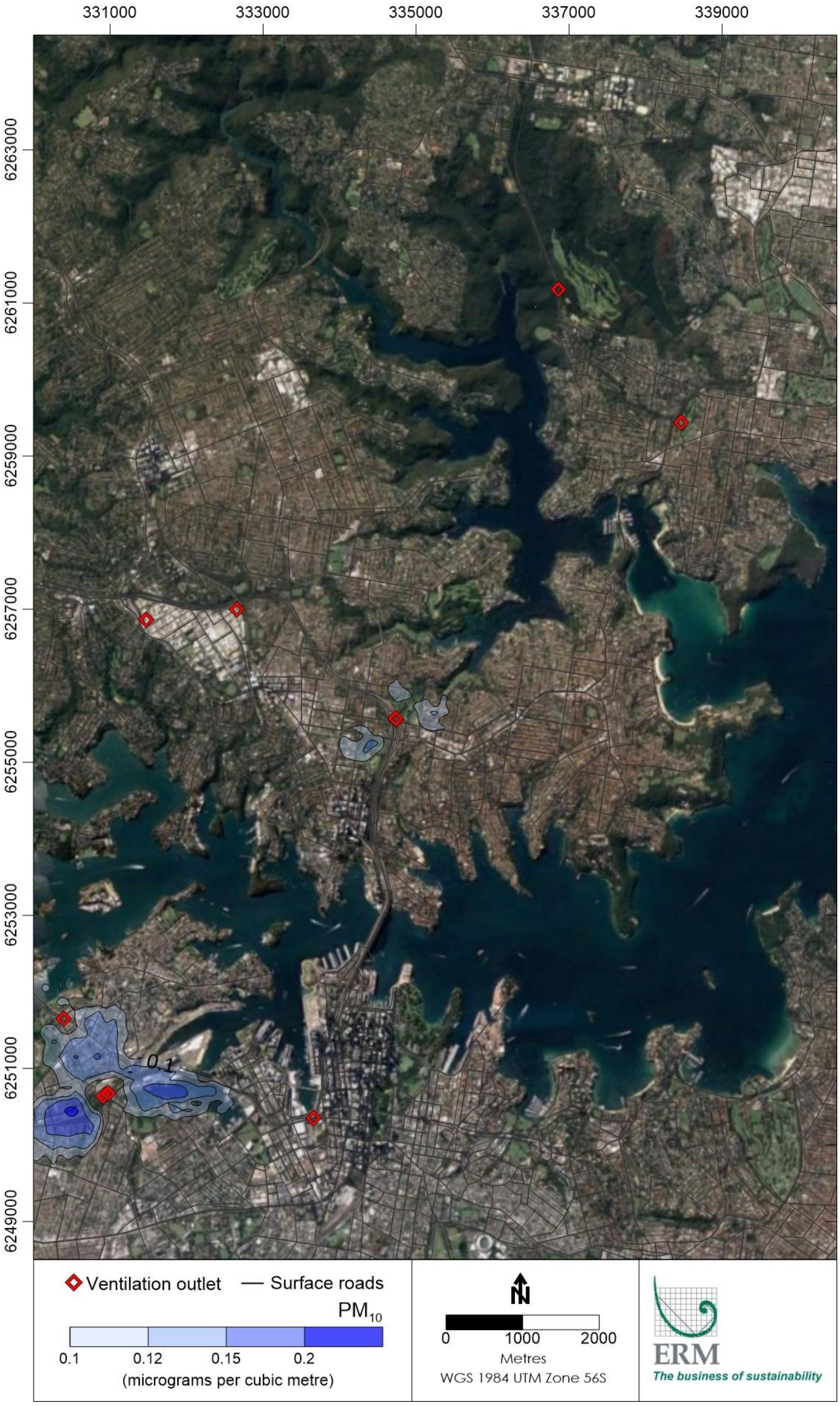


Figure J-38 Contour plot of annual mean PM_{10} for all ventilation outlets in 2027-DSC scenario

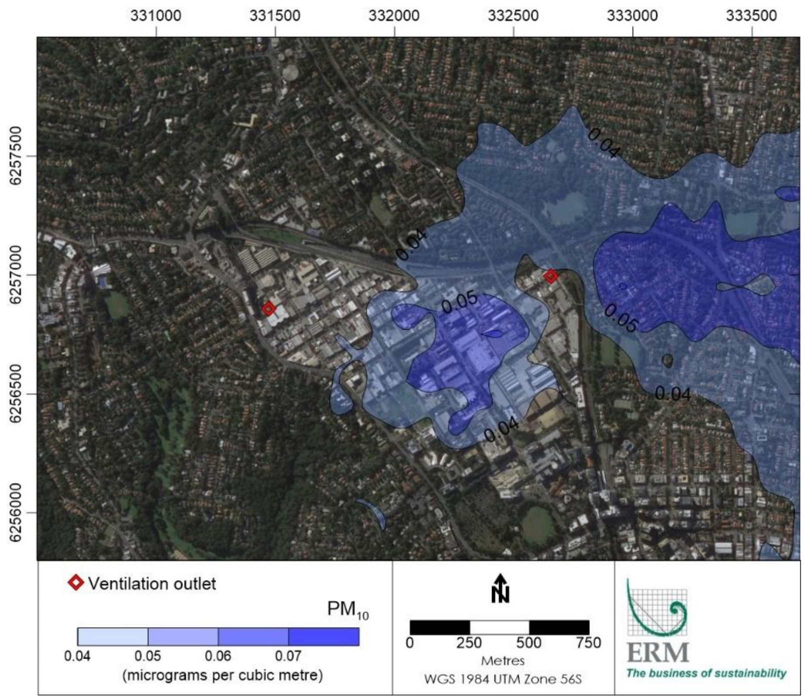


Figure J-39 **Local contour plot of annual mean PM_{10} for Gore Hill Freeway in 2027-DSC scenario**

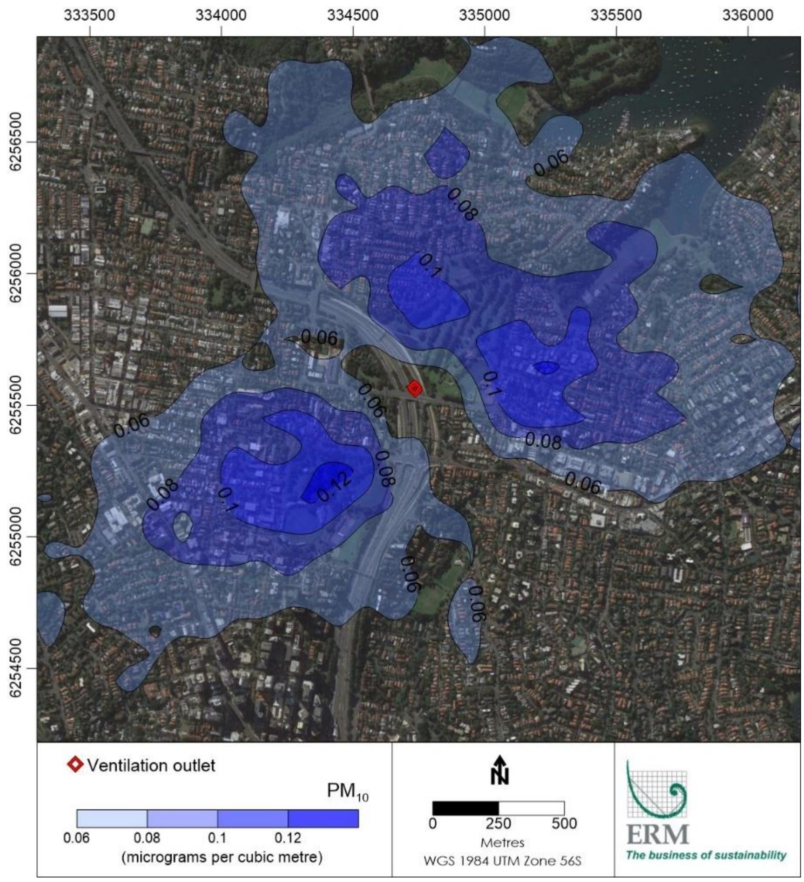


Figure J-40 **Local contour plot of annual mean PM_{10} for Warringah Freeway in 2027-DSC scenario**

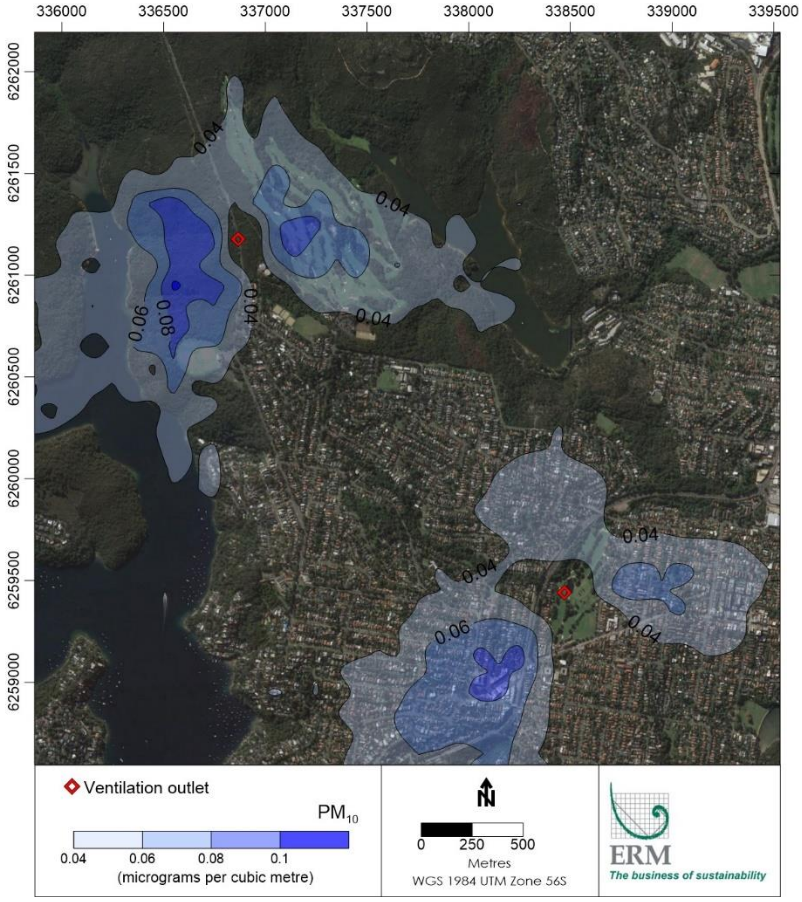


Figure J-41 Local contour plot of annual mean PM_{10} for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2027-DSC scenario

J.5.3.3 2037-DS(BL) scenario

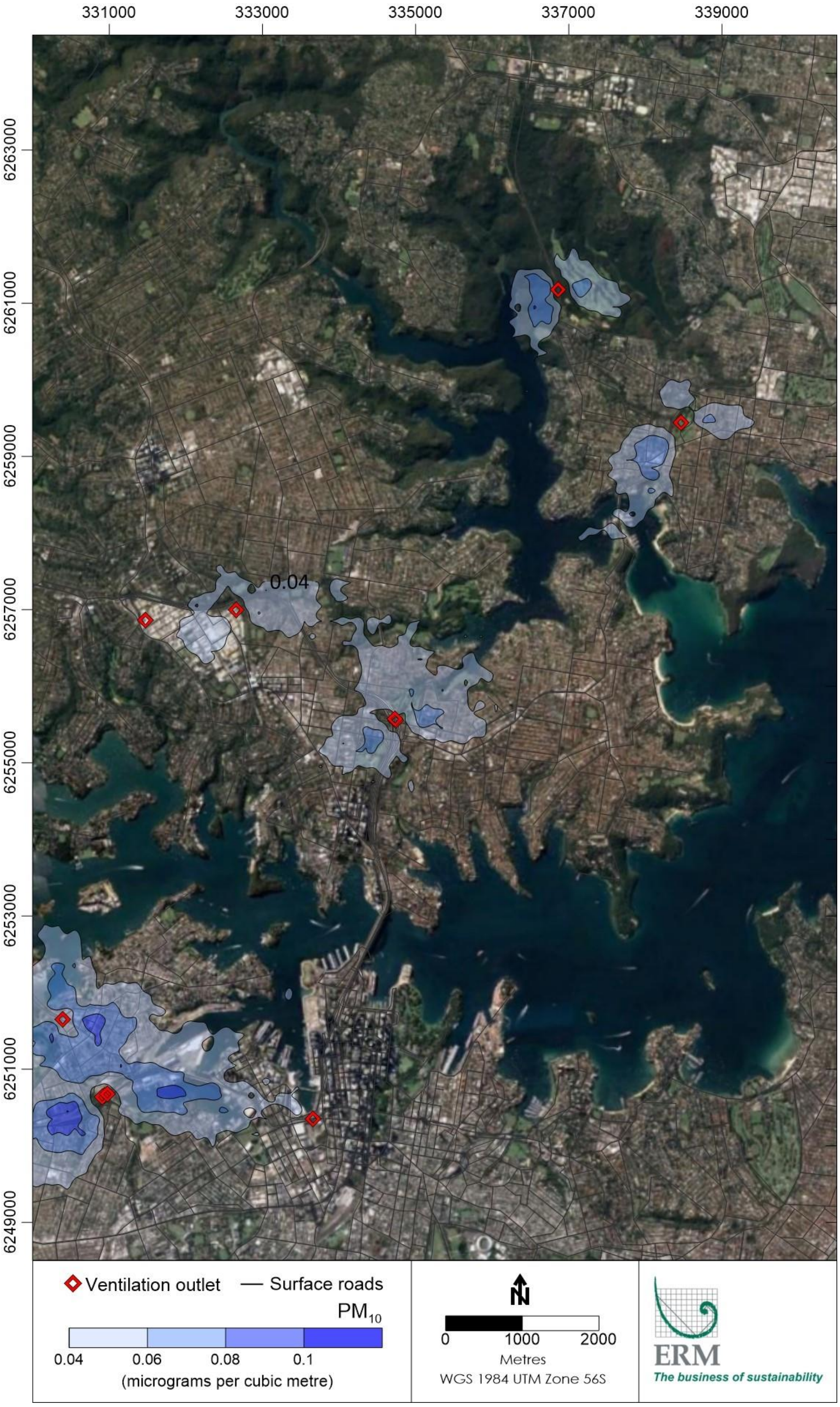


Figure J-42 Contour plot of annual mean PM_{10} for all ventilation outlets in 2037-DS(BL) scenario

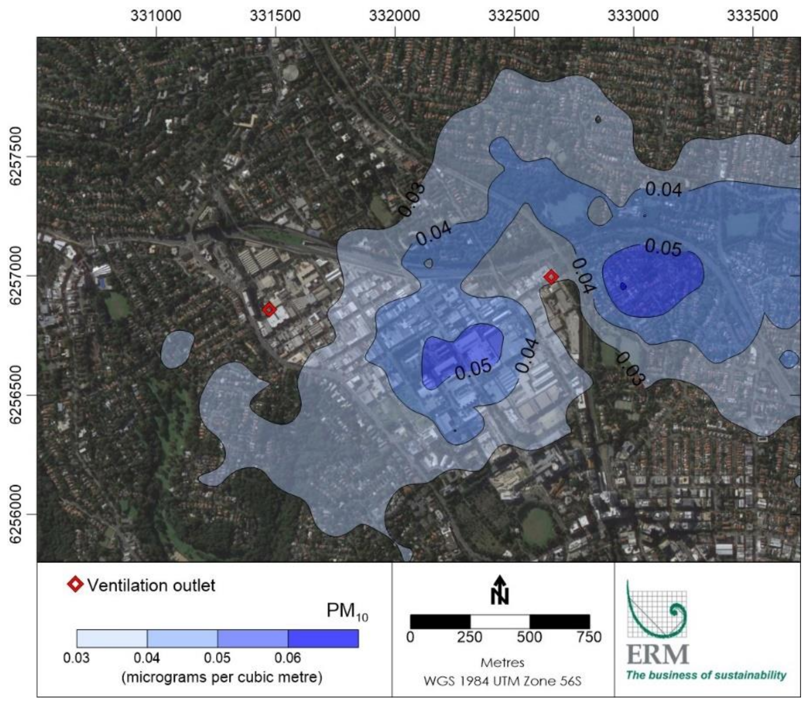


Figure J-43 **Local contour plot of annual mean PM_{10} for Gore Hill Freeway in 2037-DS(BL) scenario**

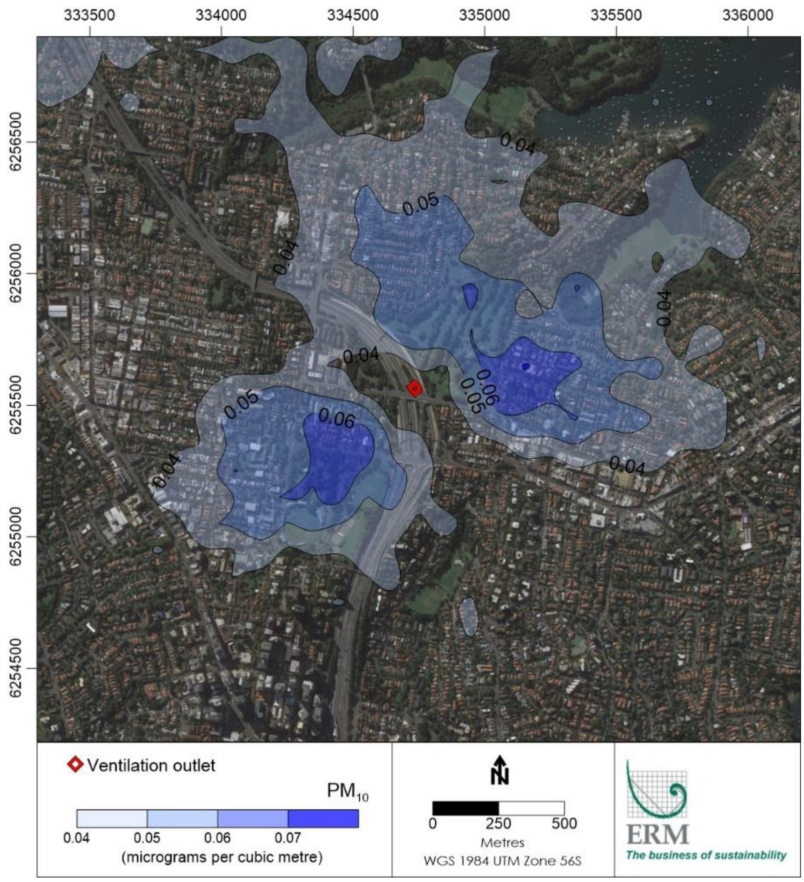


Figure J-44 **Local contour plot of annual mean PM_{10} for Warringah Freeway in 2037-DS(BL) scenario**

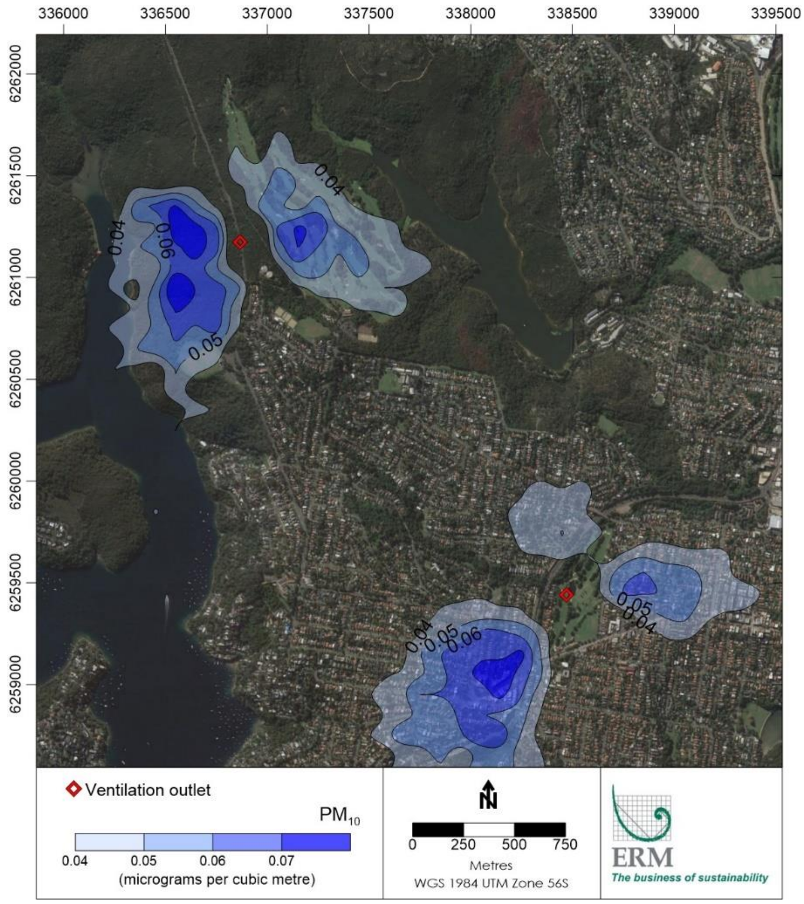


Figure J-45 **Local contour plot of annual mean PM_{10} for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2037-DS(BL) scenario**

J.5.3.4 2037-DSC scenario

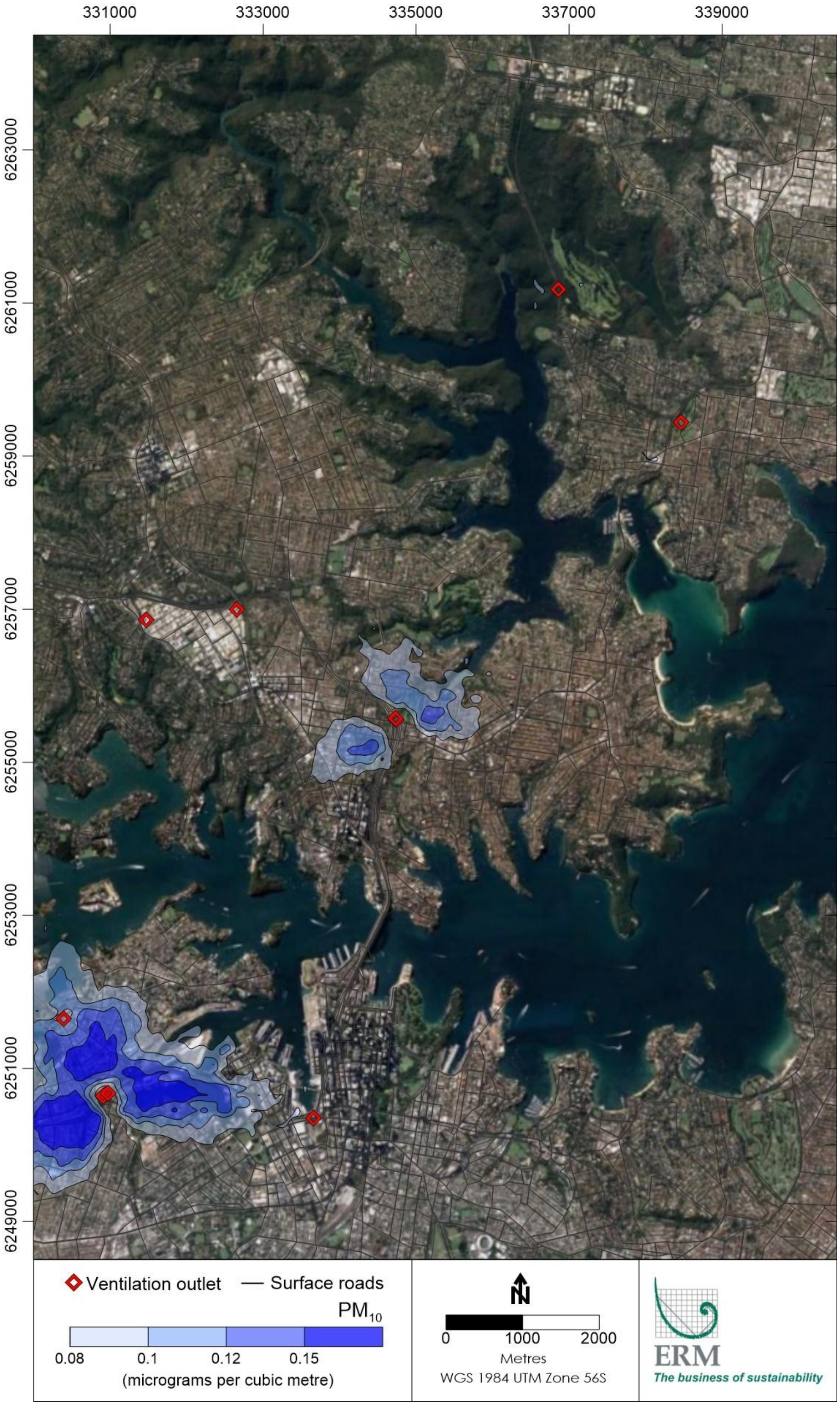


Figure J-46 Contour plot of annual mean PM_{10} for all ventilation outlets in 2037-DSC scenario

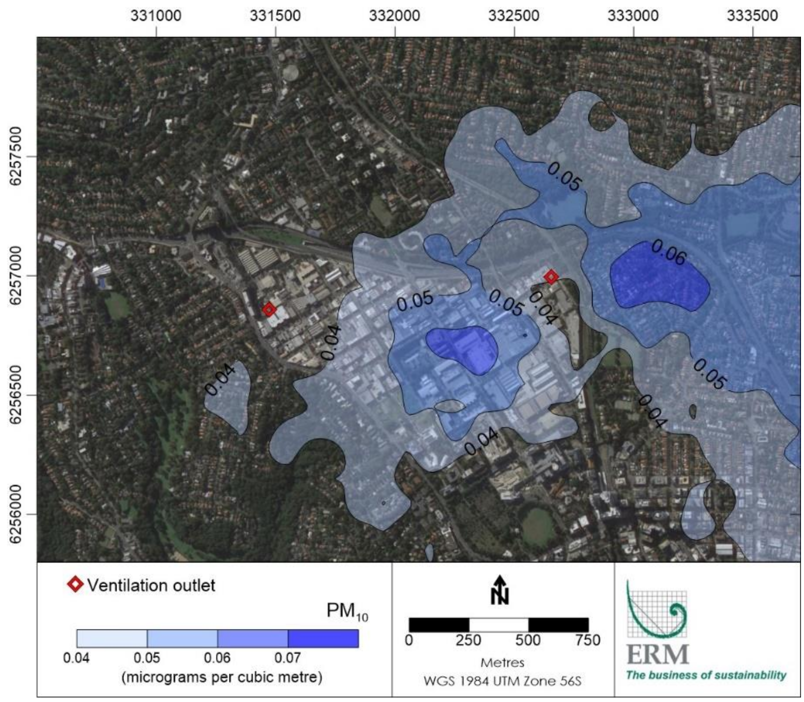


Figure J-47 **Local contour plot of annual mean PM10 for Gore Hill Freeway in 2037-DSC scenario**

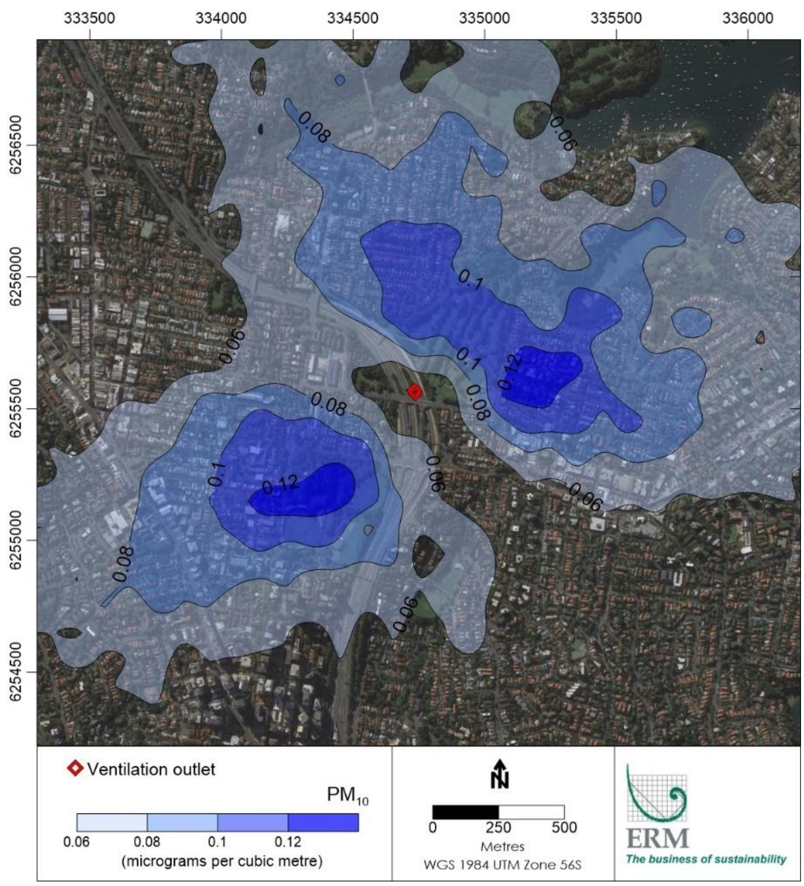


Figure J-48 **Local contour plot of annual mean PM10 for Warringah Freeway in 2037-DSC scenario**

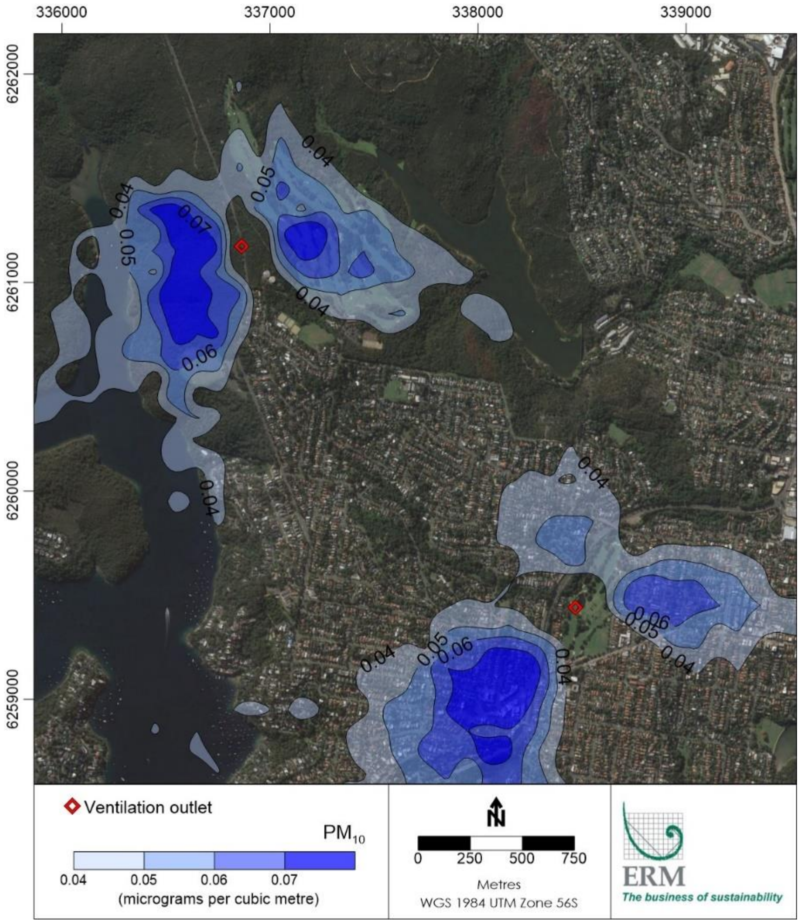


Figure J-49 Local contour plot of annual mean PM_{10} for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2037-DSC scenario

J.5.4 Maximum 24-hour PM_{10}

J.5.4.1 2027-DS(BL) scenario

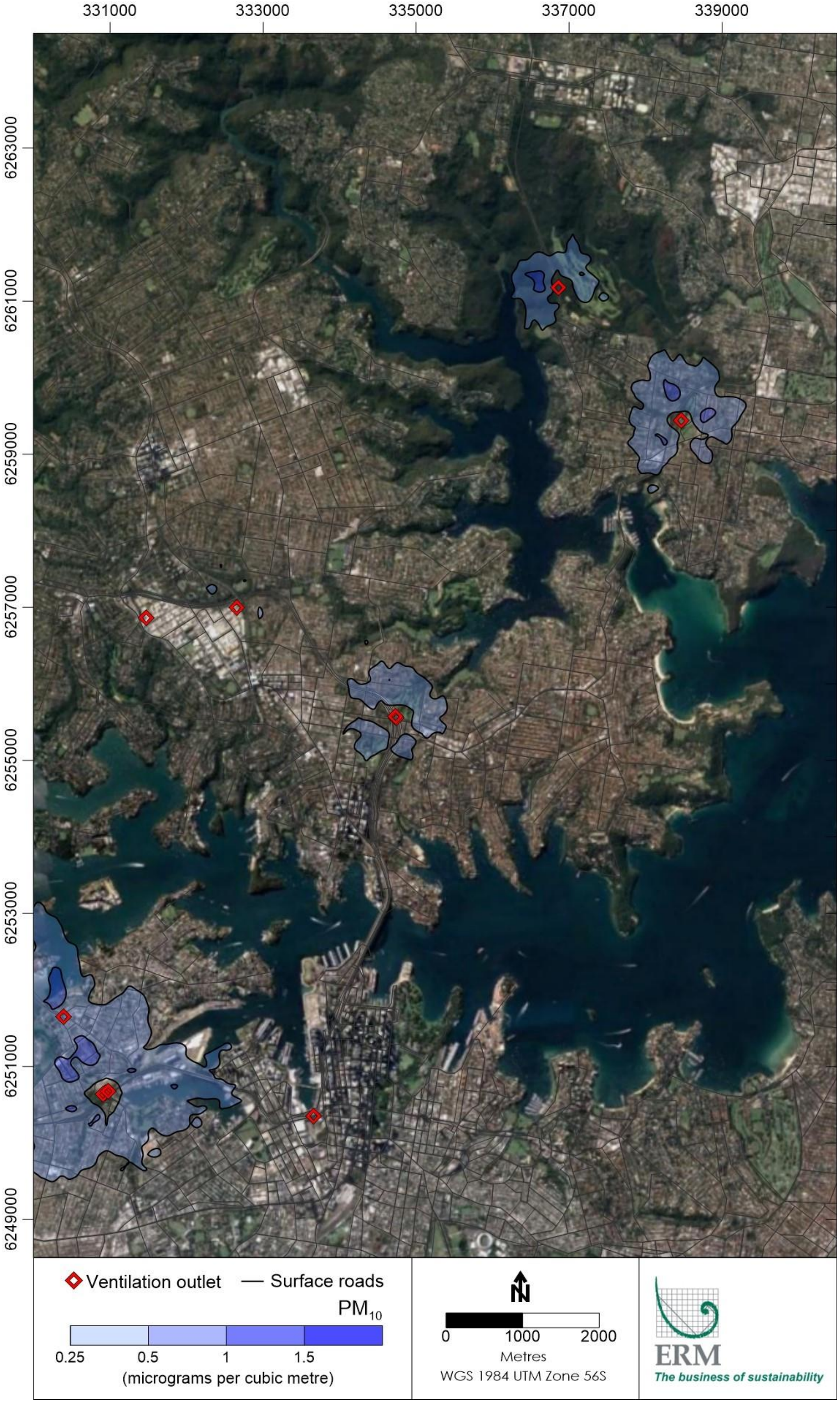


Figure J-50 Contour plot of maximum 24-hour PM_{10} for all ventilation outlets in 2027-DS(BL) scenario

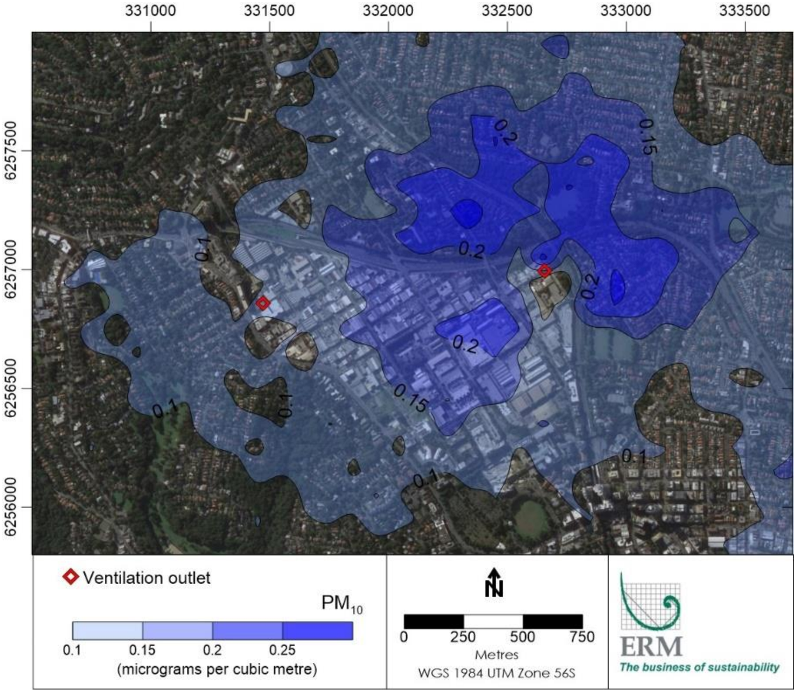


Figure J-51 Local contour plot of maximum 24-hour PM_{10} for Gore Hill Freeway in 2027-DS(BL) scenario

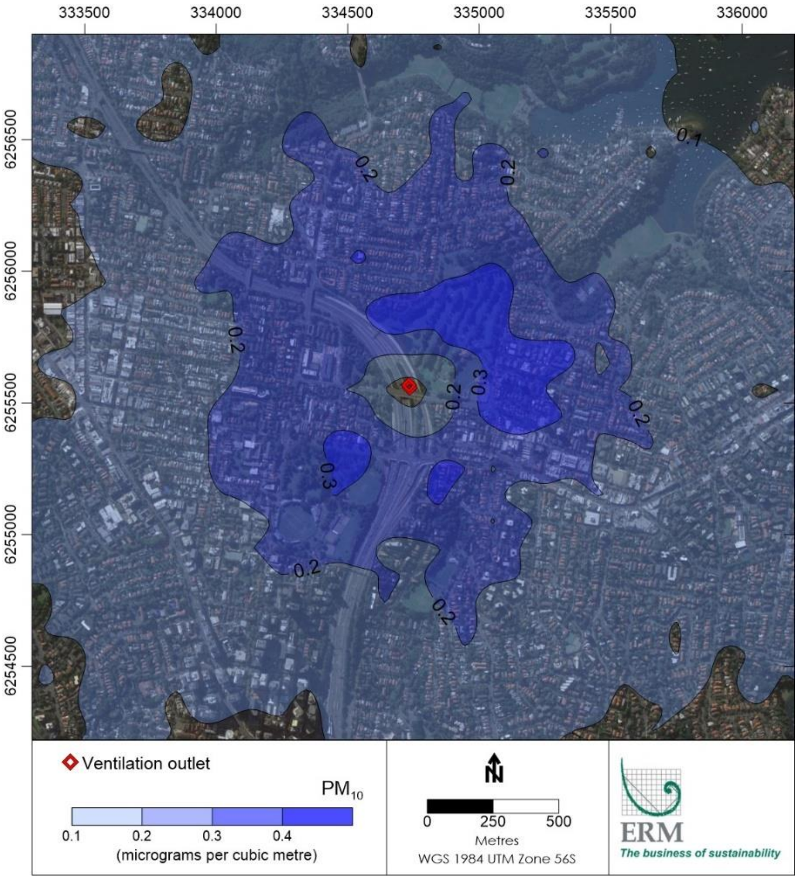


Figure J-52 Local contour plot of maximum 24-hour PM_{10} for Warringah Freeway in 2027-DS(BL) scenario

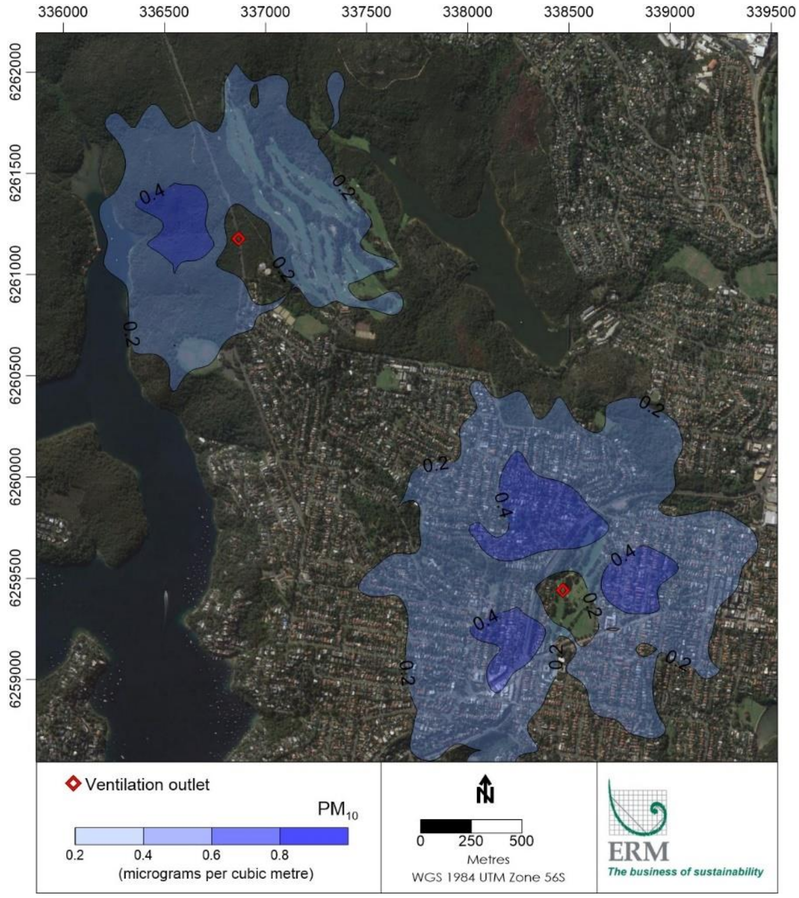


Figure J-53 **Local contour plot of maximum 24-hour PM_{10} for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2027-DS(BL) scenario**

J.5.4.2 2027-DSC scenario

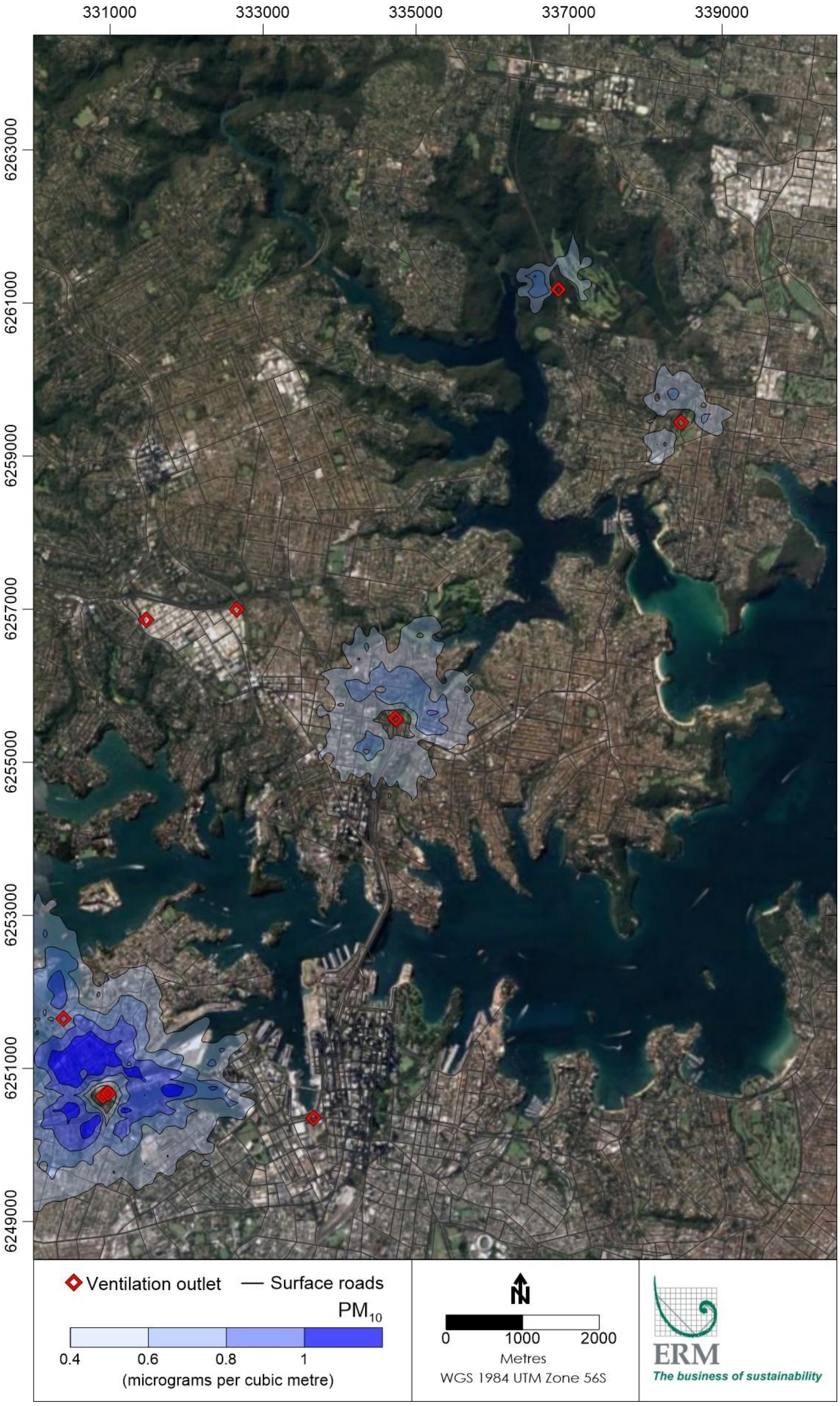


Figure J-54 Contour plot of maximum 24-hour PM_{10} for all ventilation outlets in 2027-DSC scenario

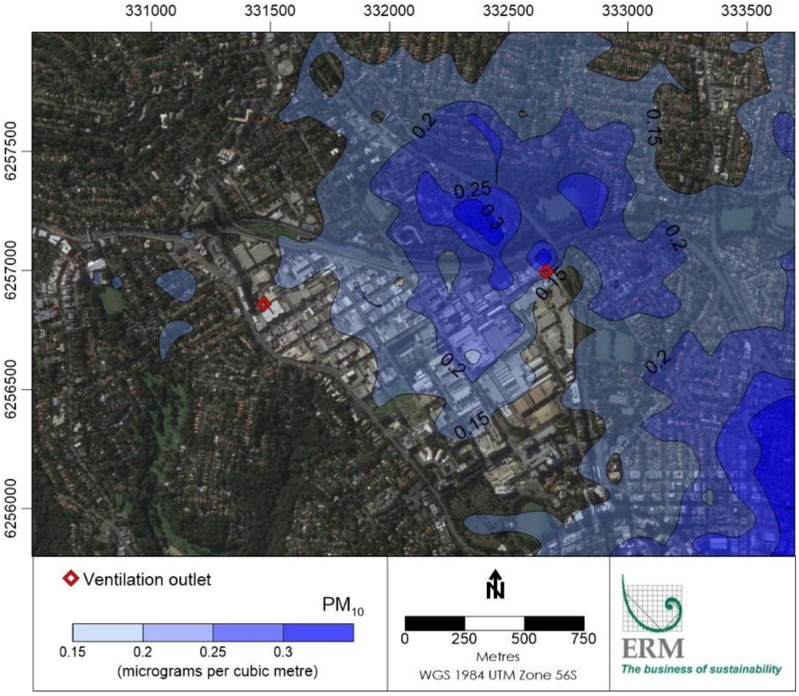


Figure J-55 Local contour plot of maximum 24-hour PM_{10} for Gore Hill Freeway in 2027-DSC scenario

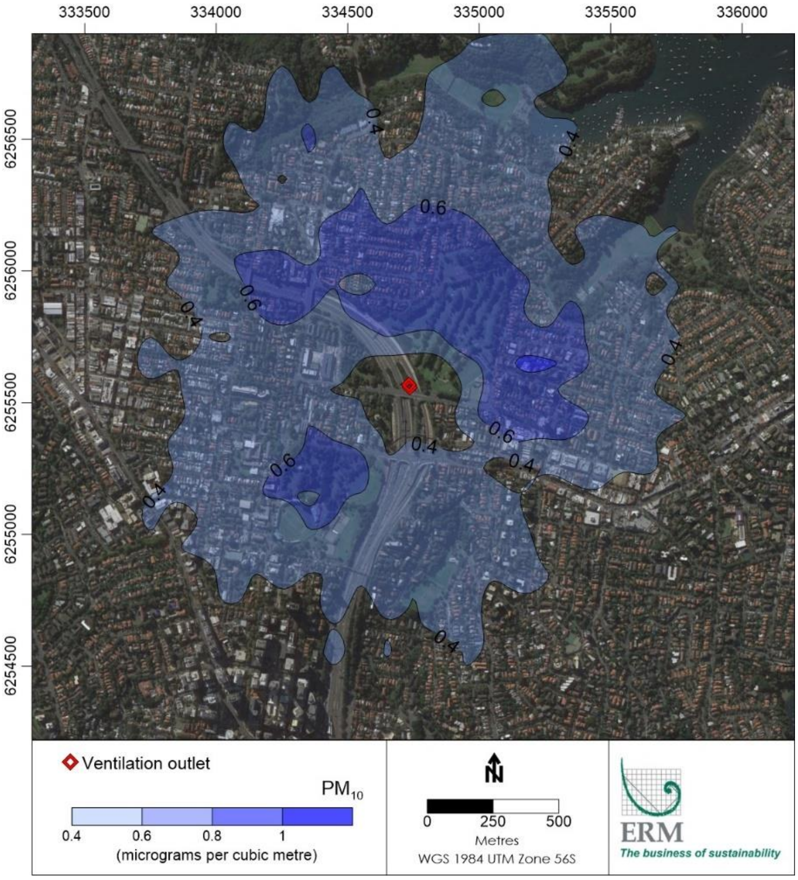


Figure J-56 Local contour plot of maximum 24-hour PM_{10} for Warringah Freeway in 2027-DSC scenario

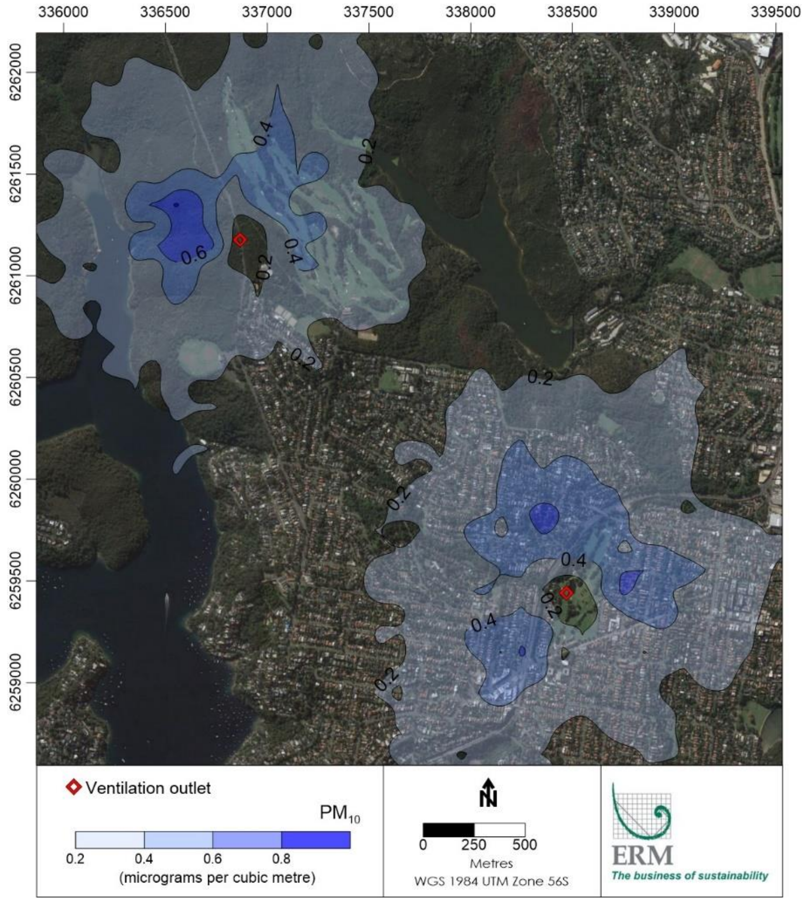


Figure J-57 Local contour plot of maximum 24-hour PM_{10} for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2027-DSC scenario

J.5.4.3 2037-DS(BL) scenario

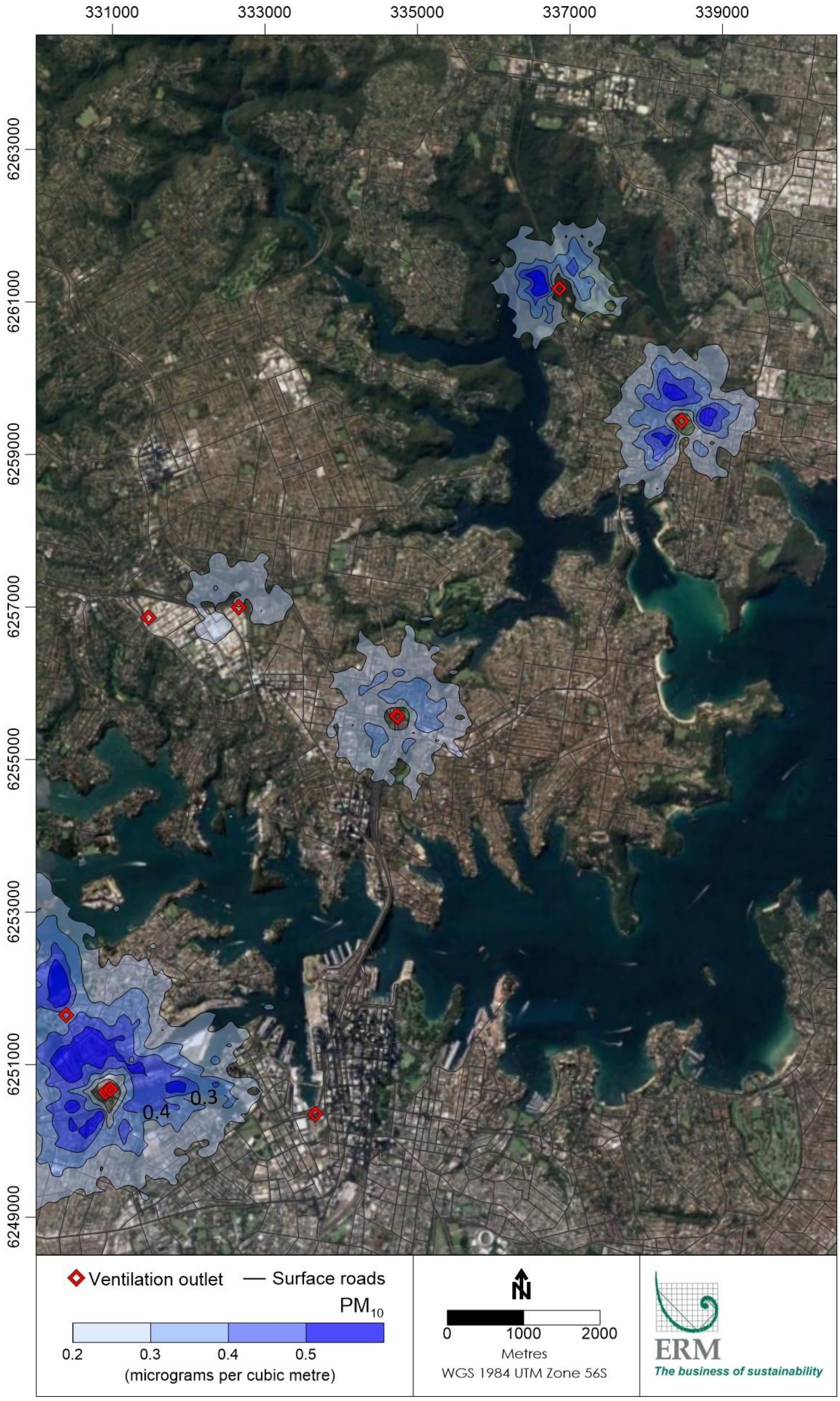


Figure J-58 Contour plot of maximum 24-hour PM_{10} for all ventilation outlets in 2037-DS(BL) scenario

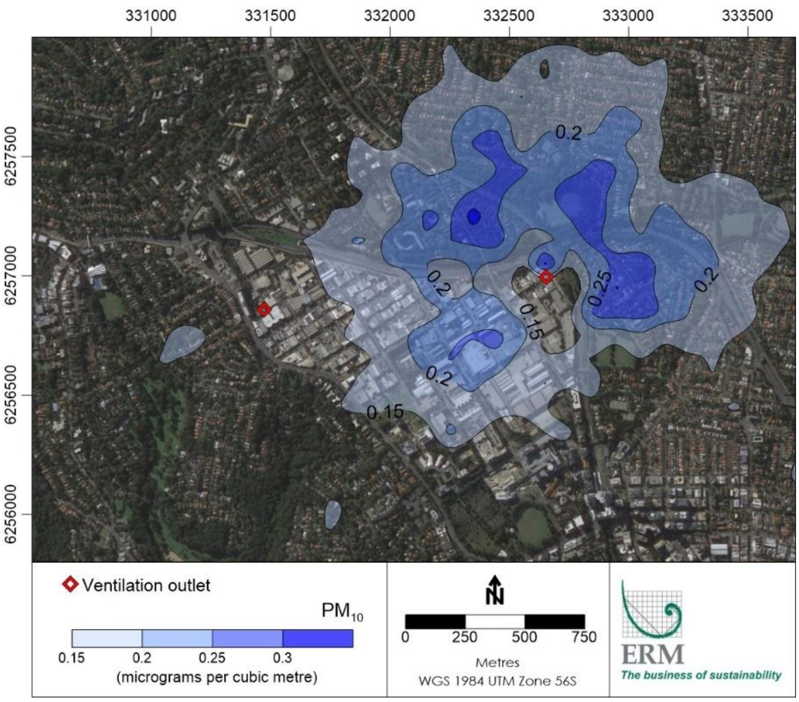


Figure J-59 Local contour plot of maximum 24-hour PM_{10} for Gore Hill Freeway in 2037-DS(BL) scenario

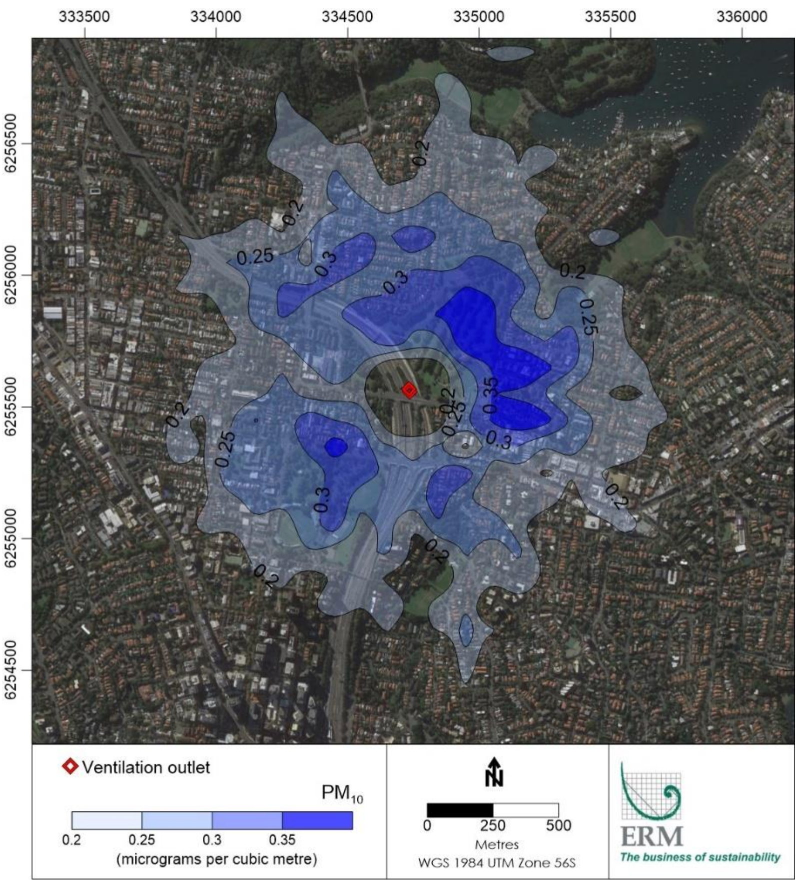


Figure J-60 Local contour plot of maximum 24-hour PM_{10} for Warringah Freeway in 2037-DS(BL) scenario

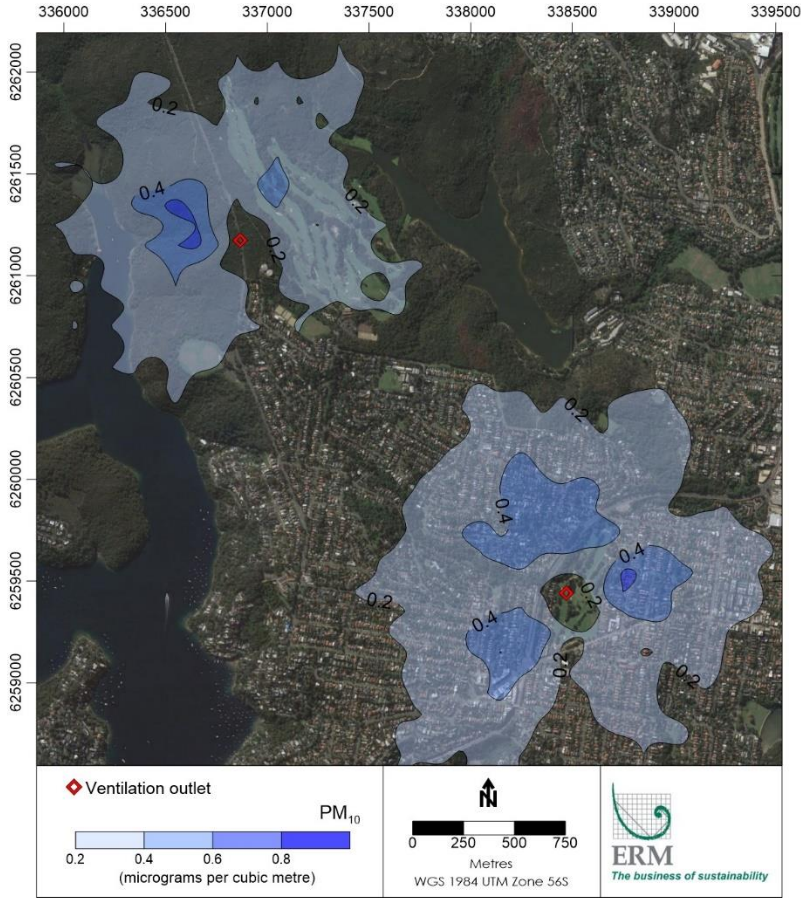


Figure J-61 **Local contour plot of annual mean PM_{10} for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2037-DS(BL) scenario**

J.5.4.4 2037-DSC scenario

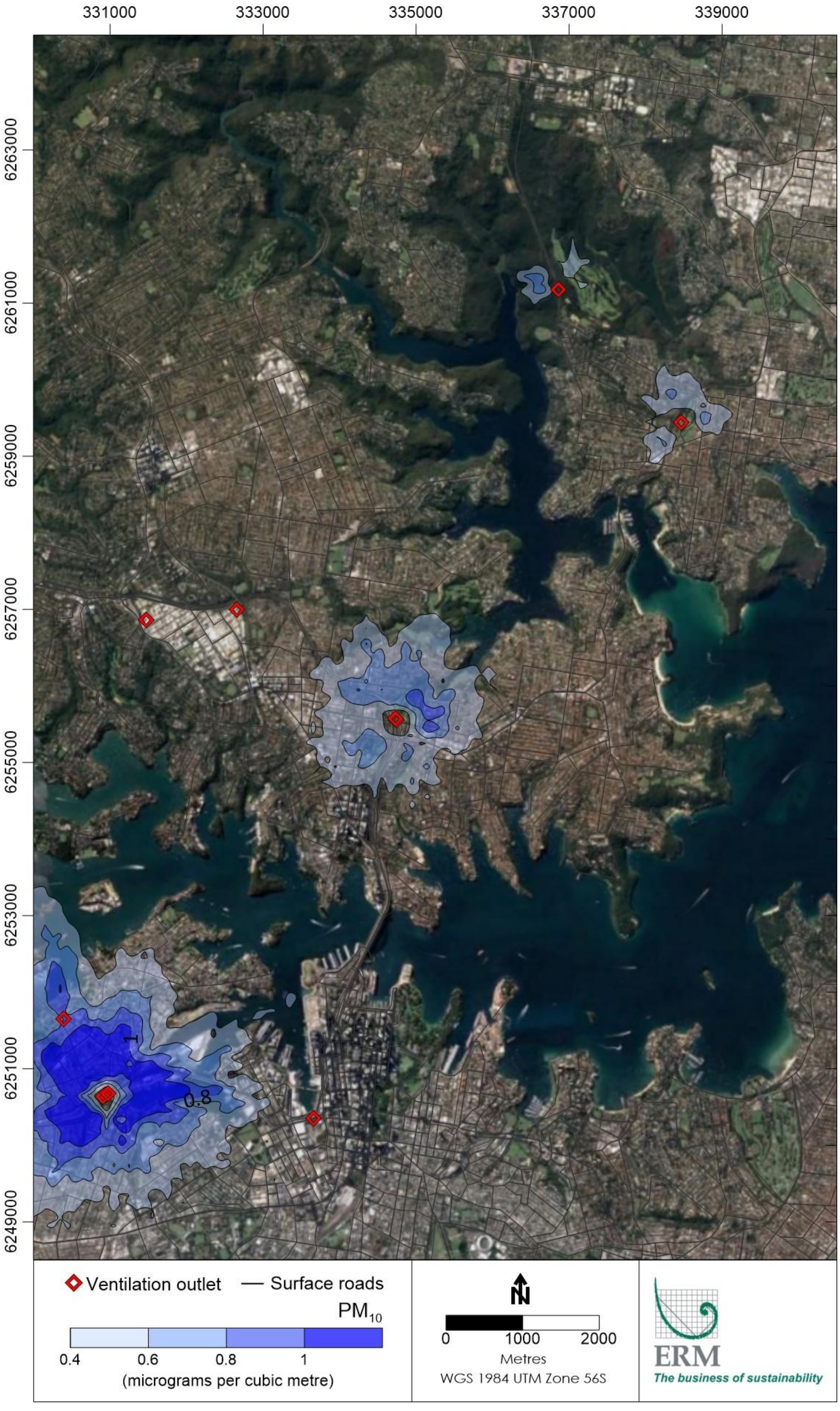


Figure J-62 Contour plot of maximum 24-hour PM_{10} for all ventilation outlets in 2037-DSC scenario

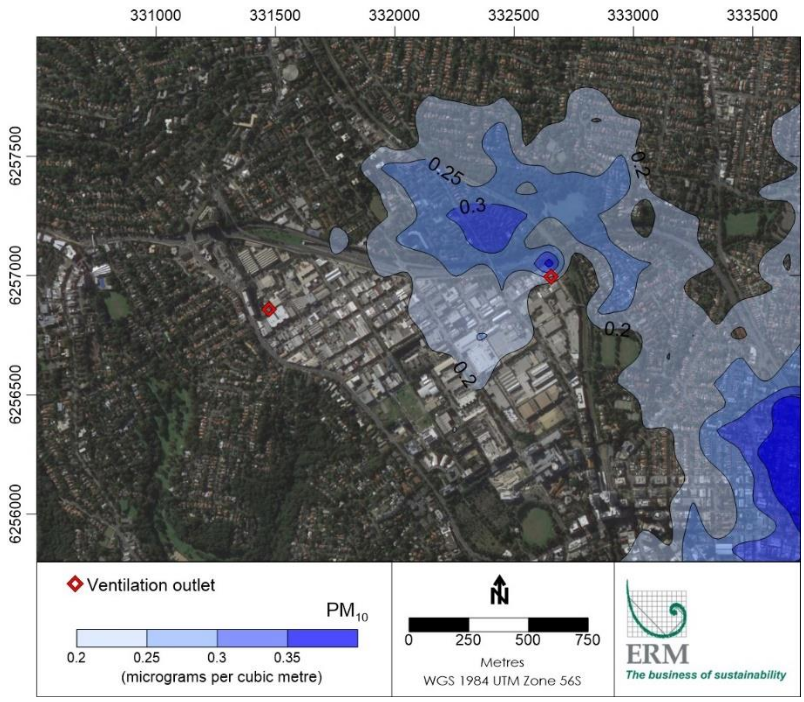


Figure J-63 Local contour plot of maximum 24-hour PM_{10} for Gore Hill Freeway in 2037-DSC scenario

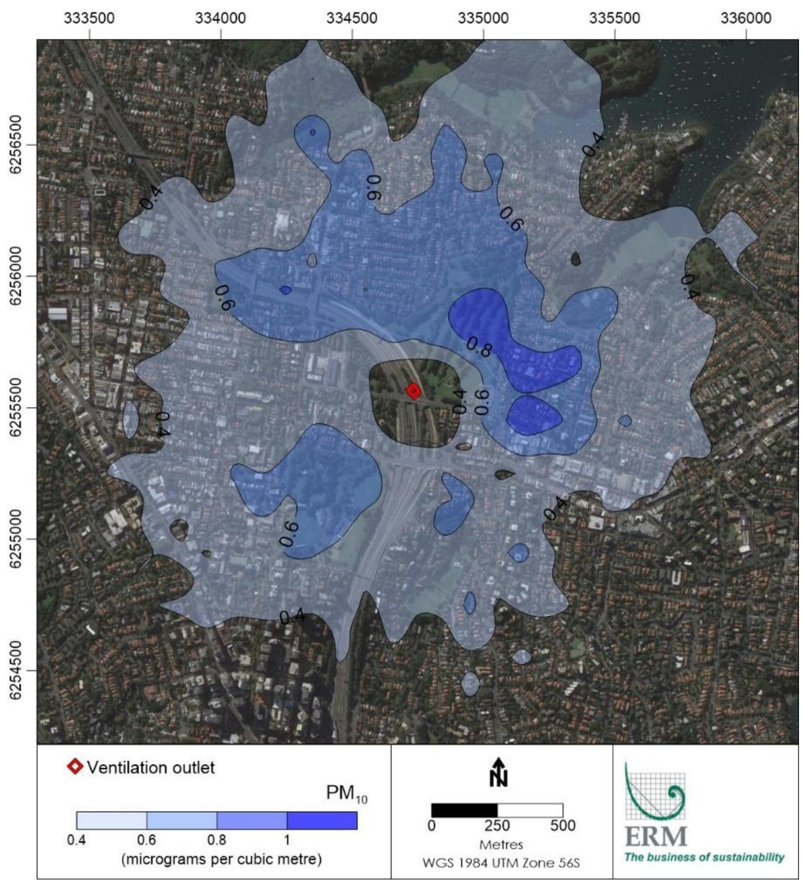


Figure J-64 Local contour plot of maximum 24-hour PM_{10} for Warringah Freeway in 2037-DSC scenario

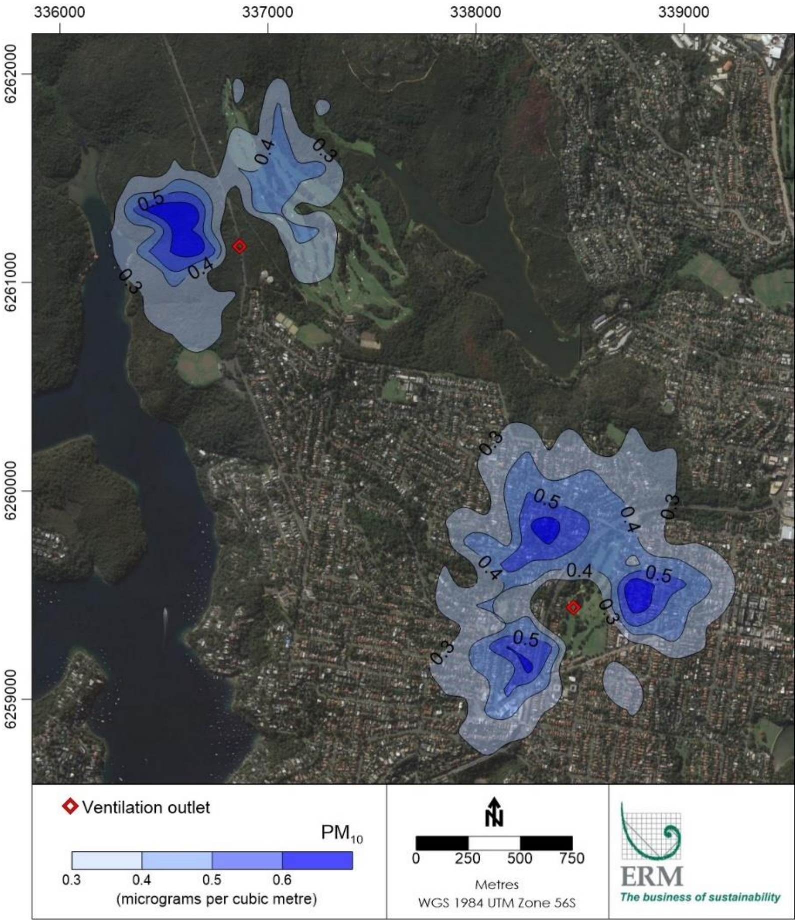


Figure J-65 Local contour plot of annual mean PM_{10} for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2037-DSC scenario

J.5.5 Annual $PM_{2.5}$

J.5.5.1 2027-DS(BL) scenario

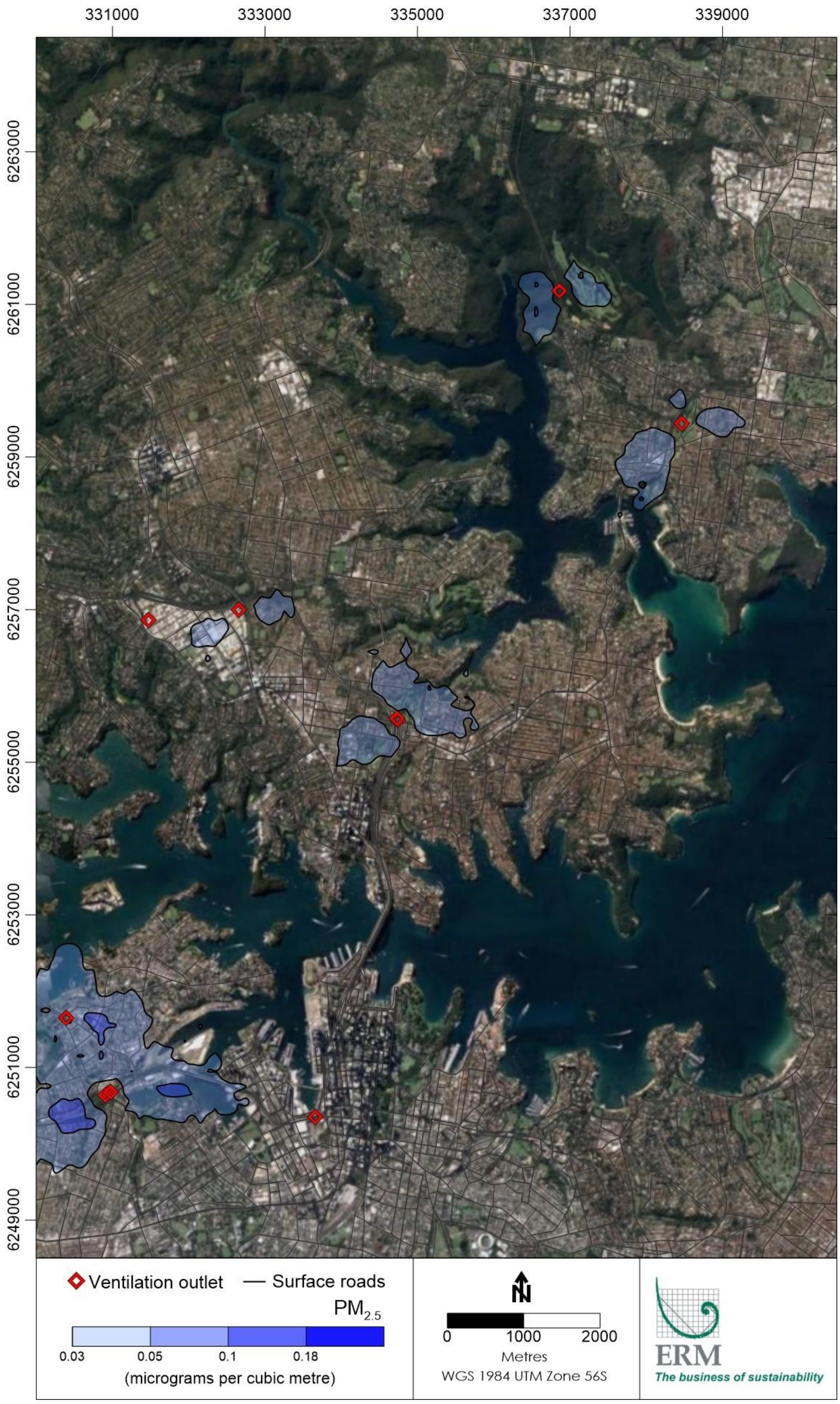


Figure J-66 Contour plot of annual mean $PM_{2.5}$ for all ventilation outlets in 2027-DS(BL) scenario

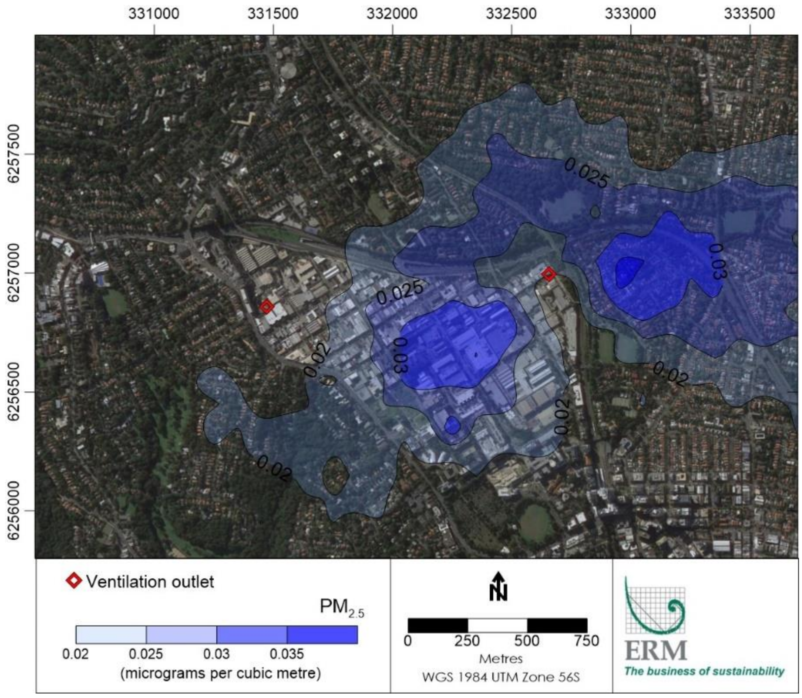


Figure J-67 **Local contour plot of annual mean $PM_{2.5}$ for Gore Hill Freeway in 2027-DS(BL) scenario**

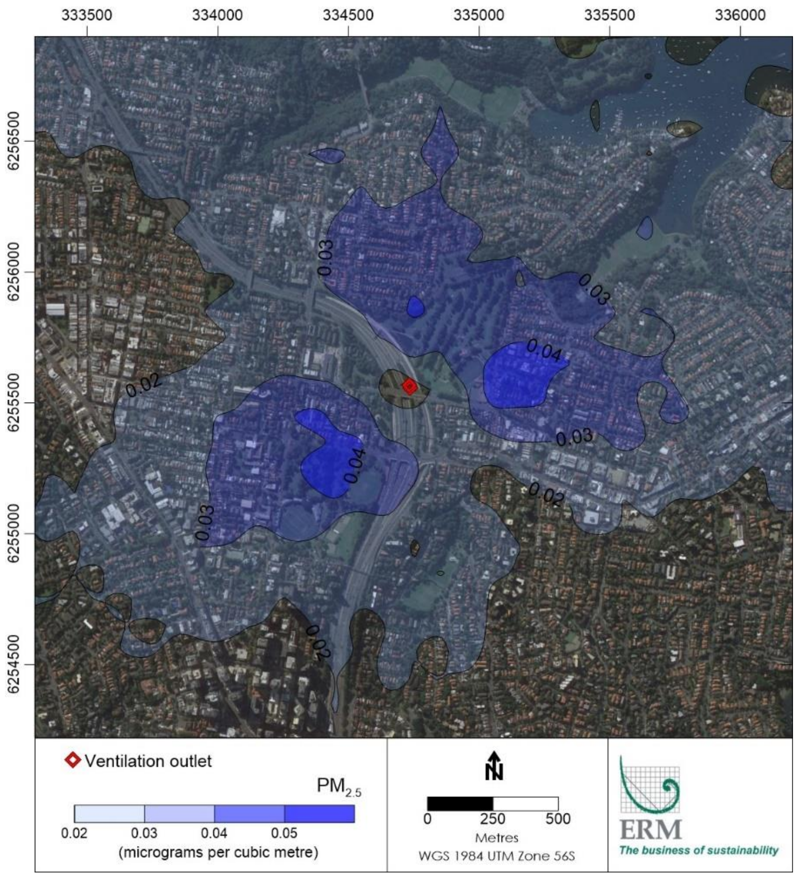


Figure J-68 **Local contour plot of annual mean $PM_{2.5}$ for Warringah Freeway in 2027-DS(BL) scenario**

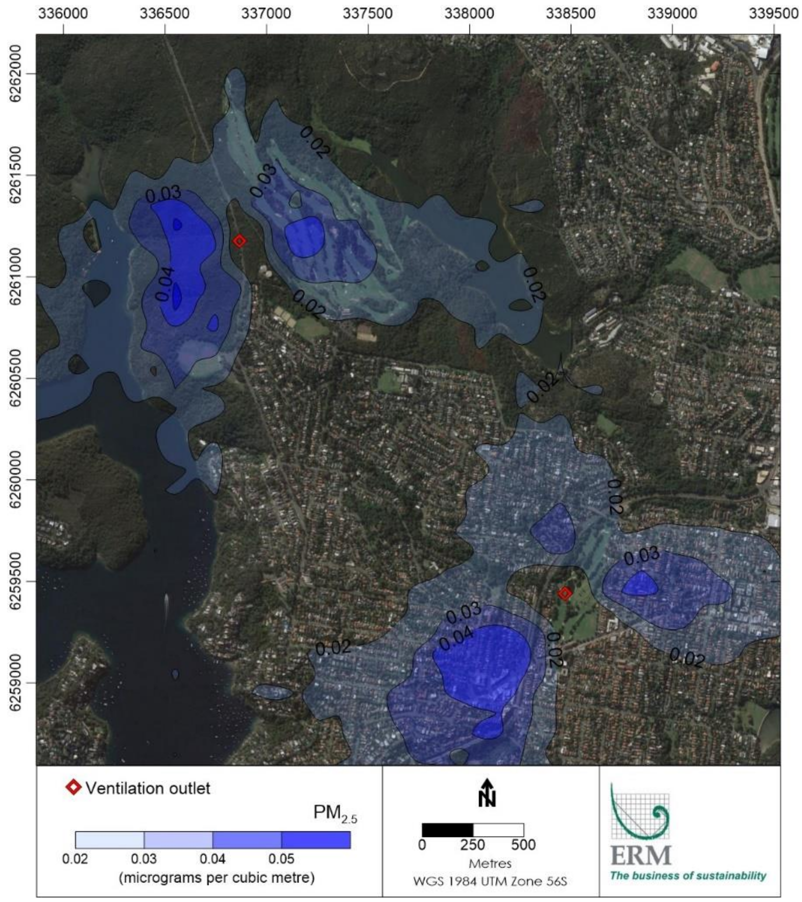


Figure J-69 **Local contour plot of annual mean $PM_{2.5}$ for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2027-DS(BL) scenario**

J.5.5.2 2027-DSC scenario

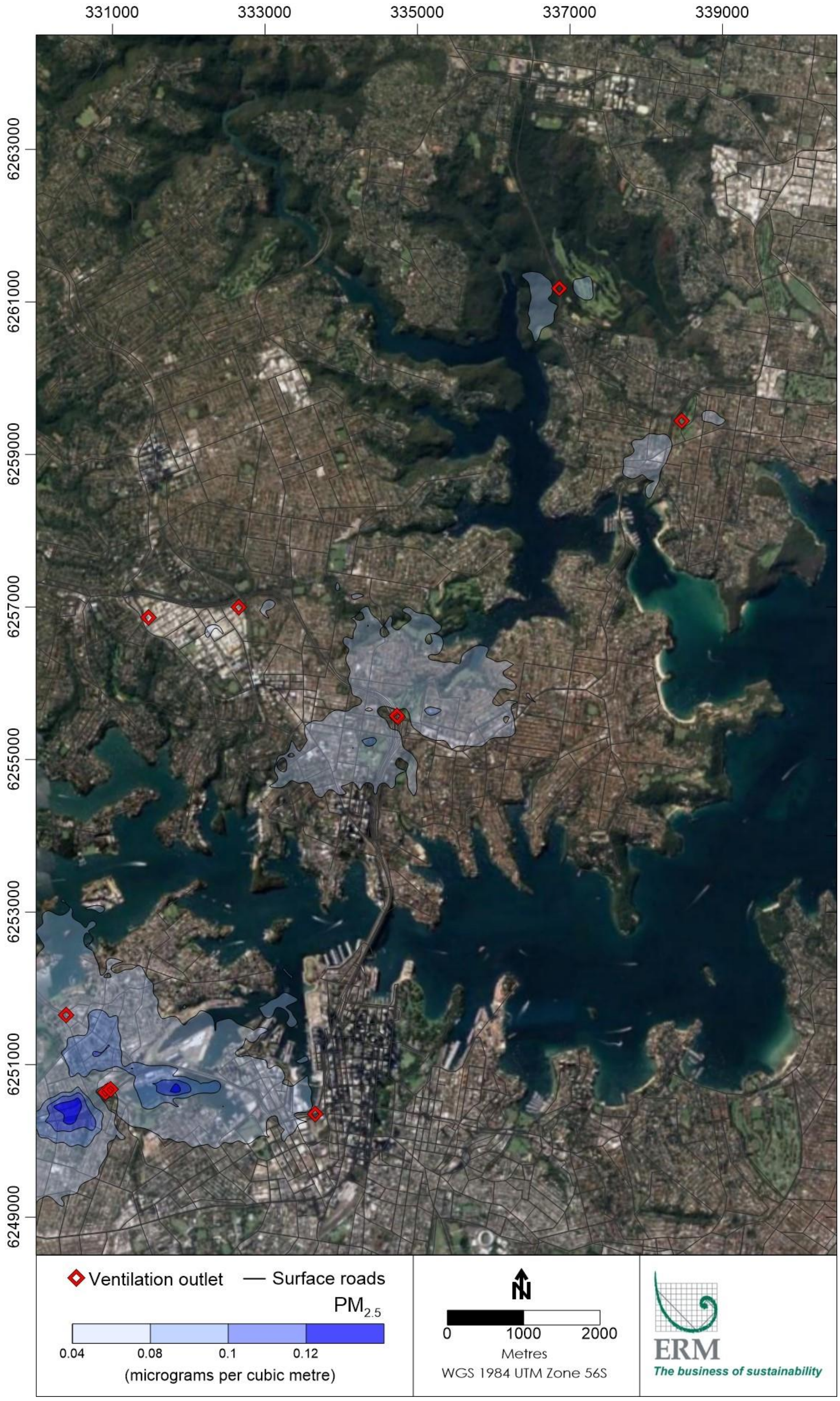


Figure J-70 Contour plot of annual mean $PM_{2.5}$ for all ventilation outlets in 2027-DSC scenario

Figure J-71 **Local contour plot of annual mean $PM_{2.5}$ for Gore Hill Freeway in 2027-DSC scenario**

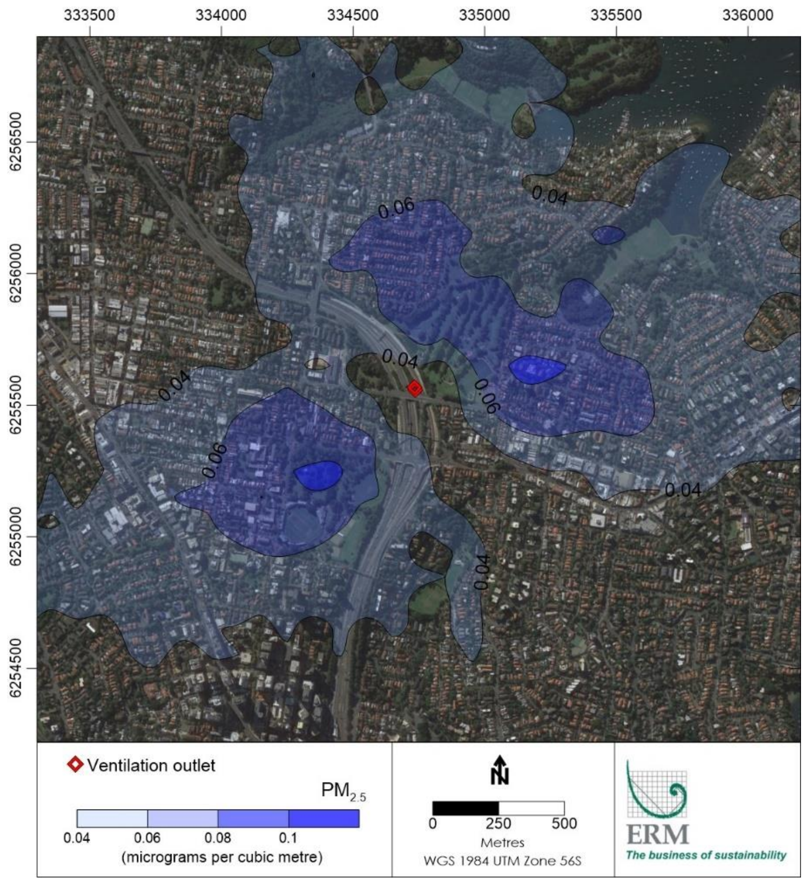


Figure J-72 **Local contour plot of annual mean $PM_{2.5}$ for Warringah Freeway in 2027-DSC scenario**

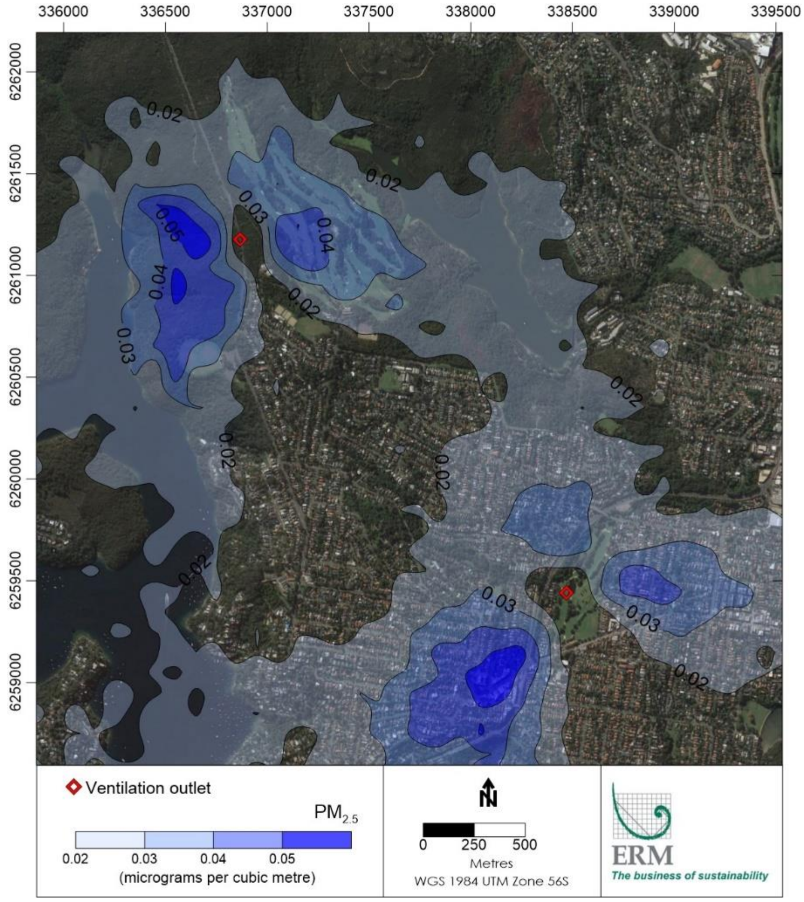


Figure J-73 **Local contour plot of annual mean $PM_{2.5}$ for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2027-DSC scenario**

J.5.5.3 2037-DS(BL) scenario

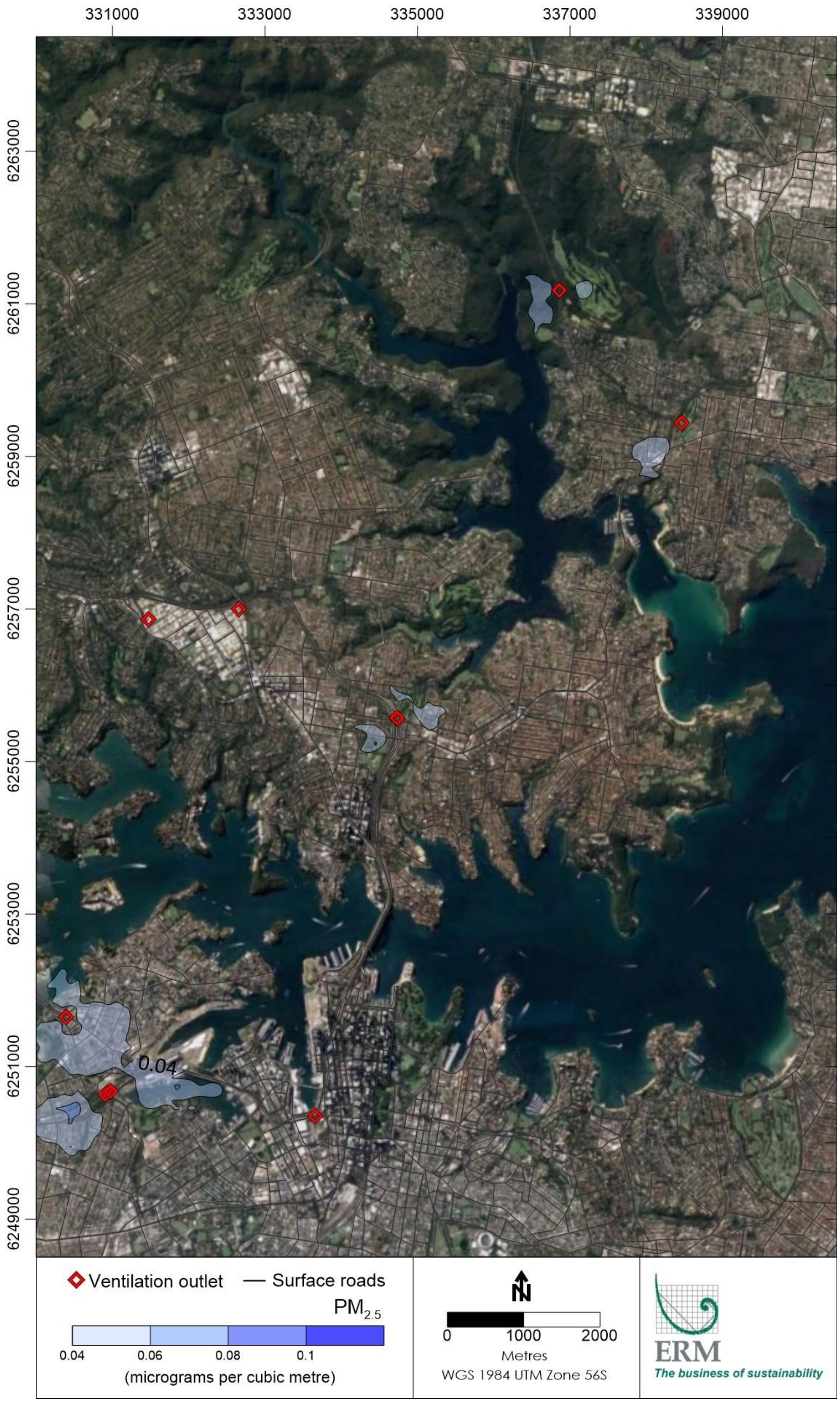


Figure J-74 Contour plot of annual mean $PM_{2.5}$ for all ventilation outlets in 2037-DS(BL) scenario

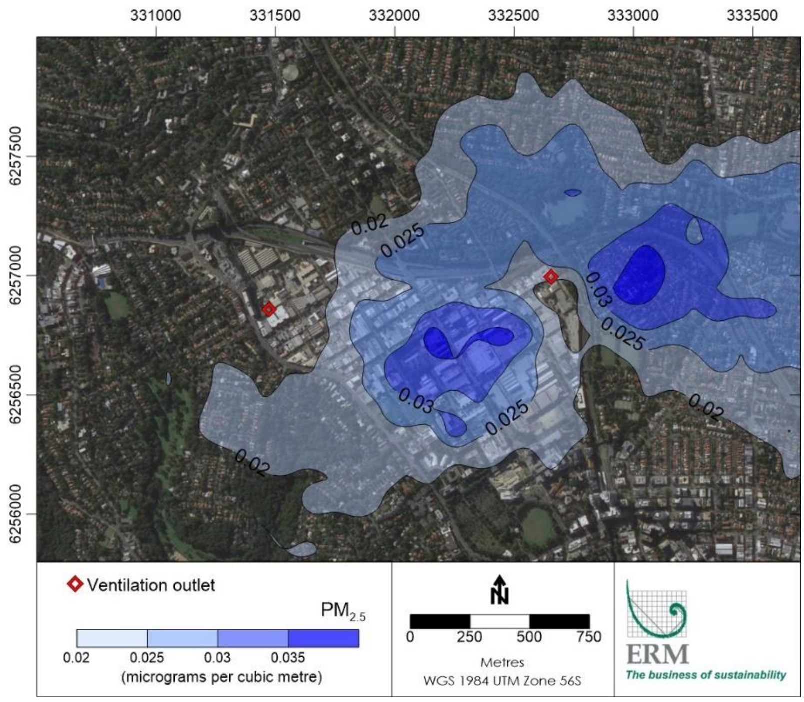


Figure J-75 **Local contour plot of annual mean $PM_{2.5}$ for Gore Hill Freeway in 2037-DS(BL) scenario**

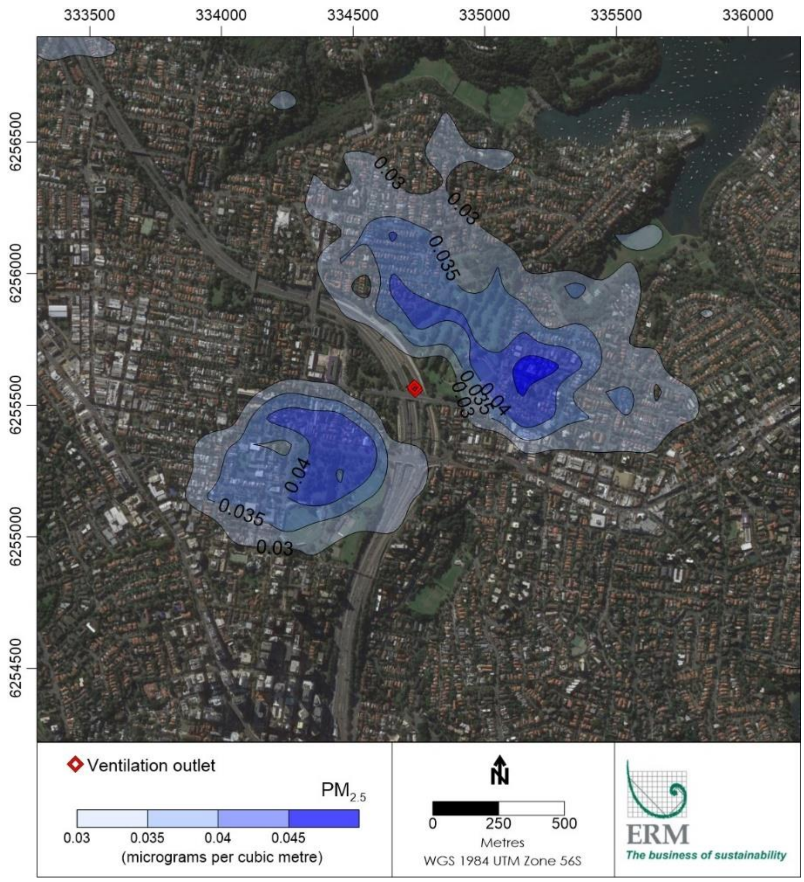


Figure J-76 **Local contour plot of annual mean $PM_{2.5}$ for Warringah Freeway in 2037-DS(BL) scenario**

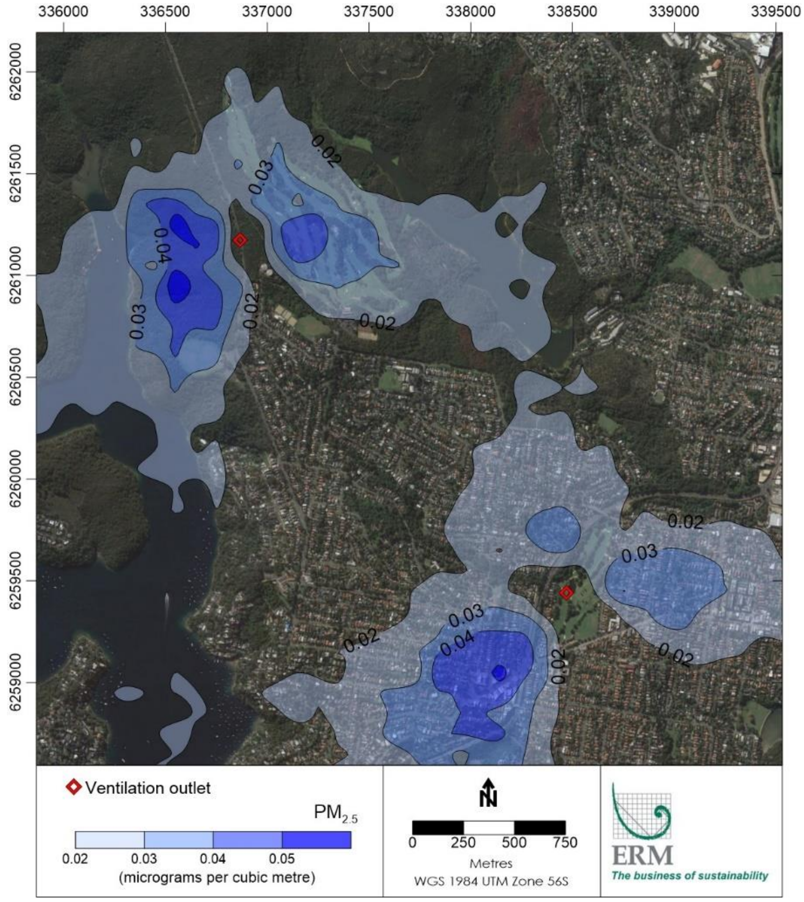


Figure J-77 Local contour plot of annual mean $PM_{2.5}$ for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2037-DS(BL) scenario

J.5.5.4 2037-DSC scenario

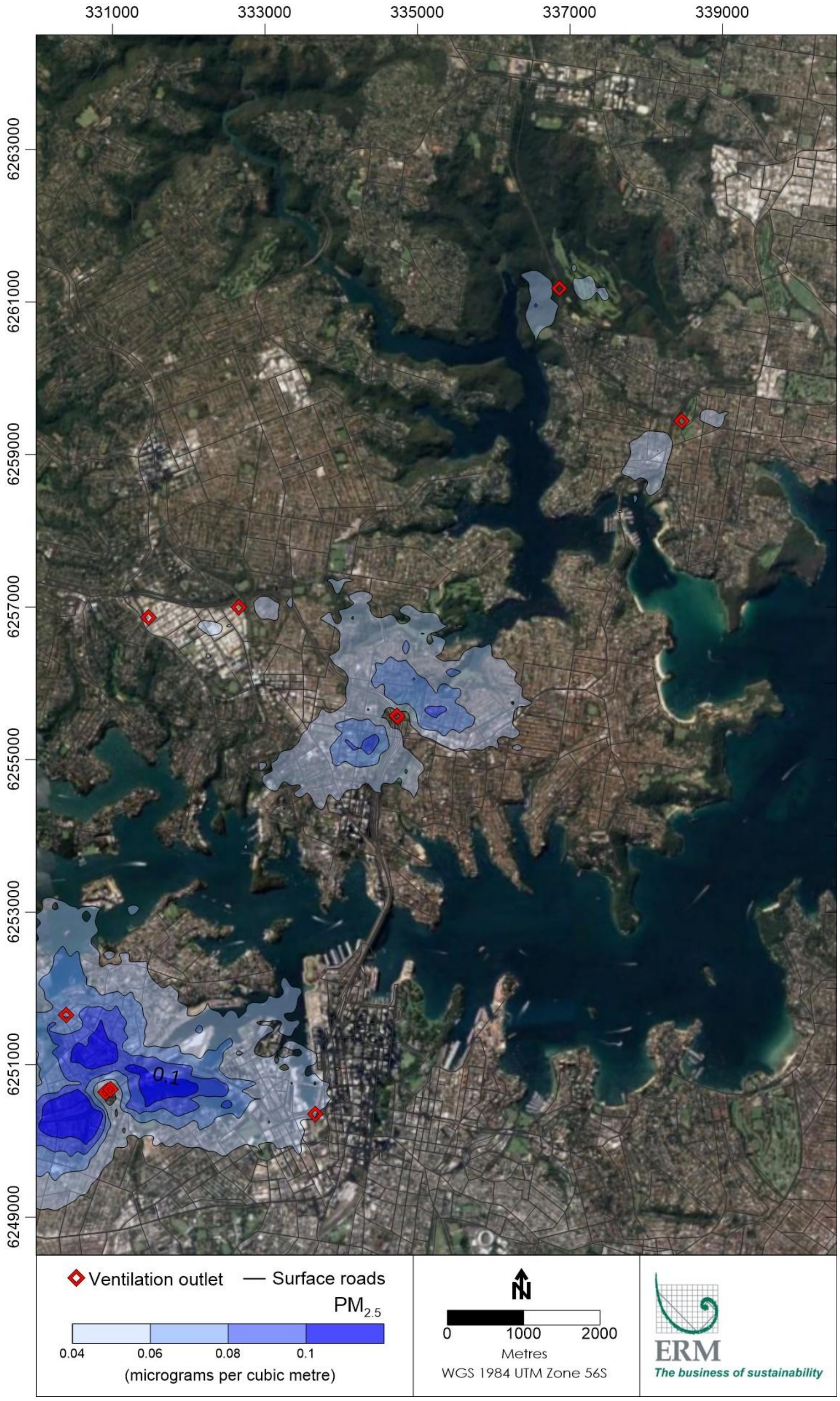


Figure J-78 Contour plot of annual mean $PM_{2.5}$ for all ventilation outlets in 2037-DSC scenario

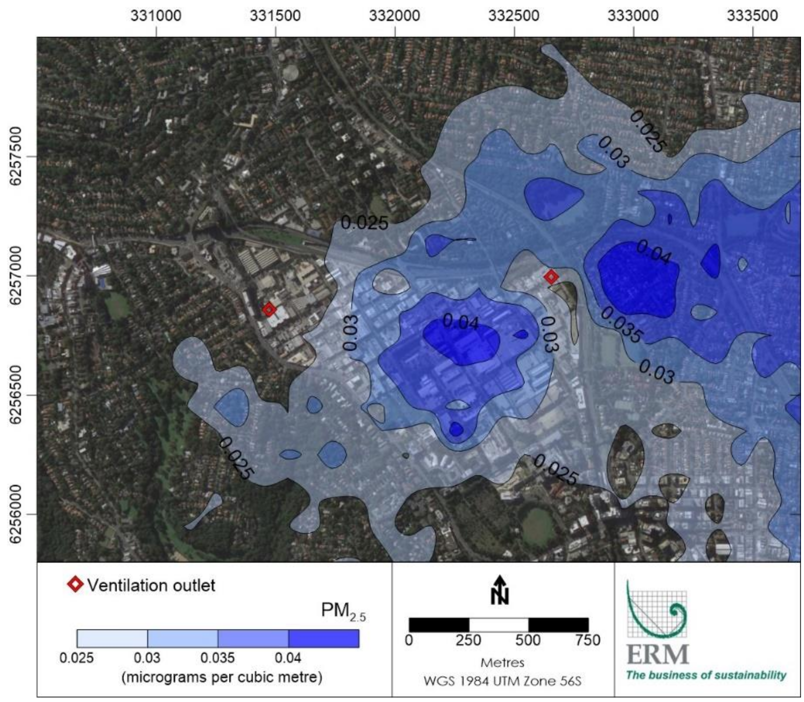


Figure J-79 Local contour plot of annual mean $PM_{2.5}$ for Artarmon in 2037-DSC scenario

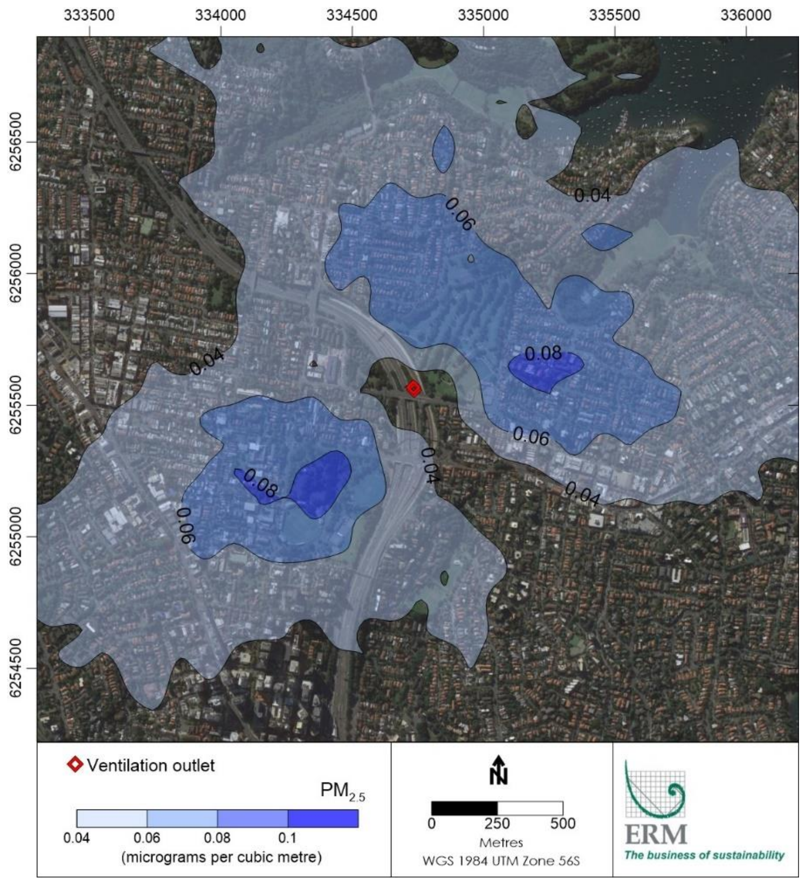


Figure J-80 Local contour plot of annual mean $PM_{2.5}$ for Warringah Freeway in 2037-DSC scenario

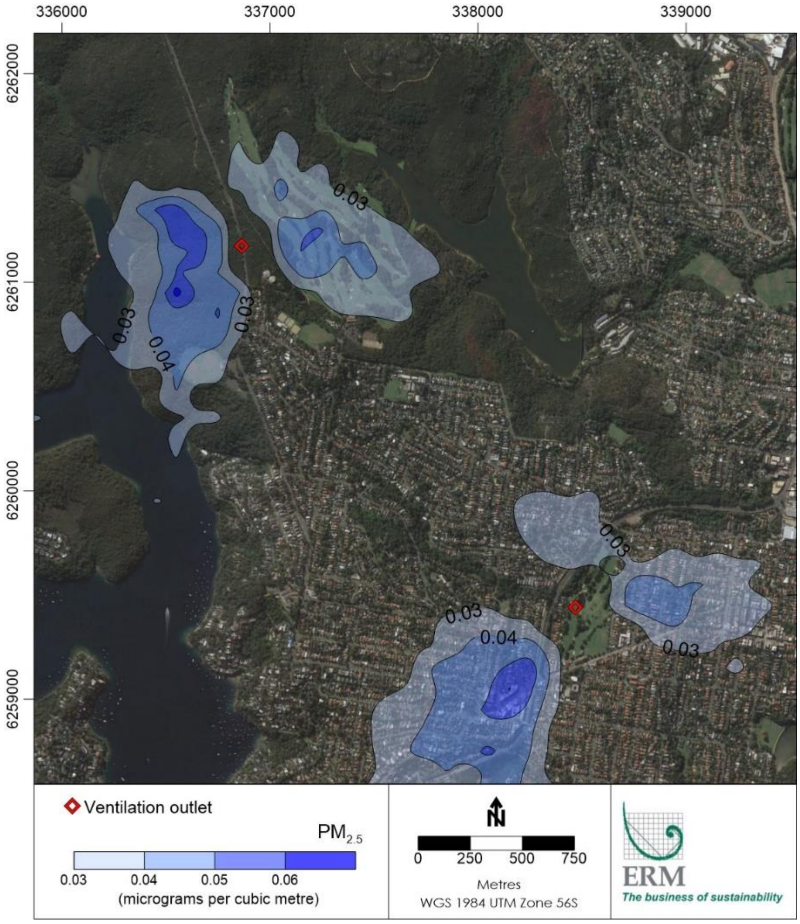


Figure J-81 **Local contour plot of annual mean $PM_{2.5}$ for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2037-DSC scenario**

J.5.6 Maximum 24-hour $PM_{2.5}$

J.5.6.1 2027-DS(BL) scenario

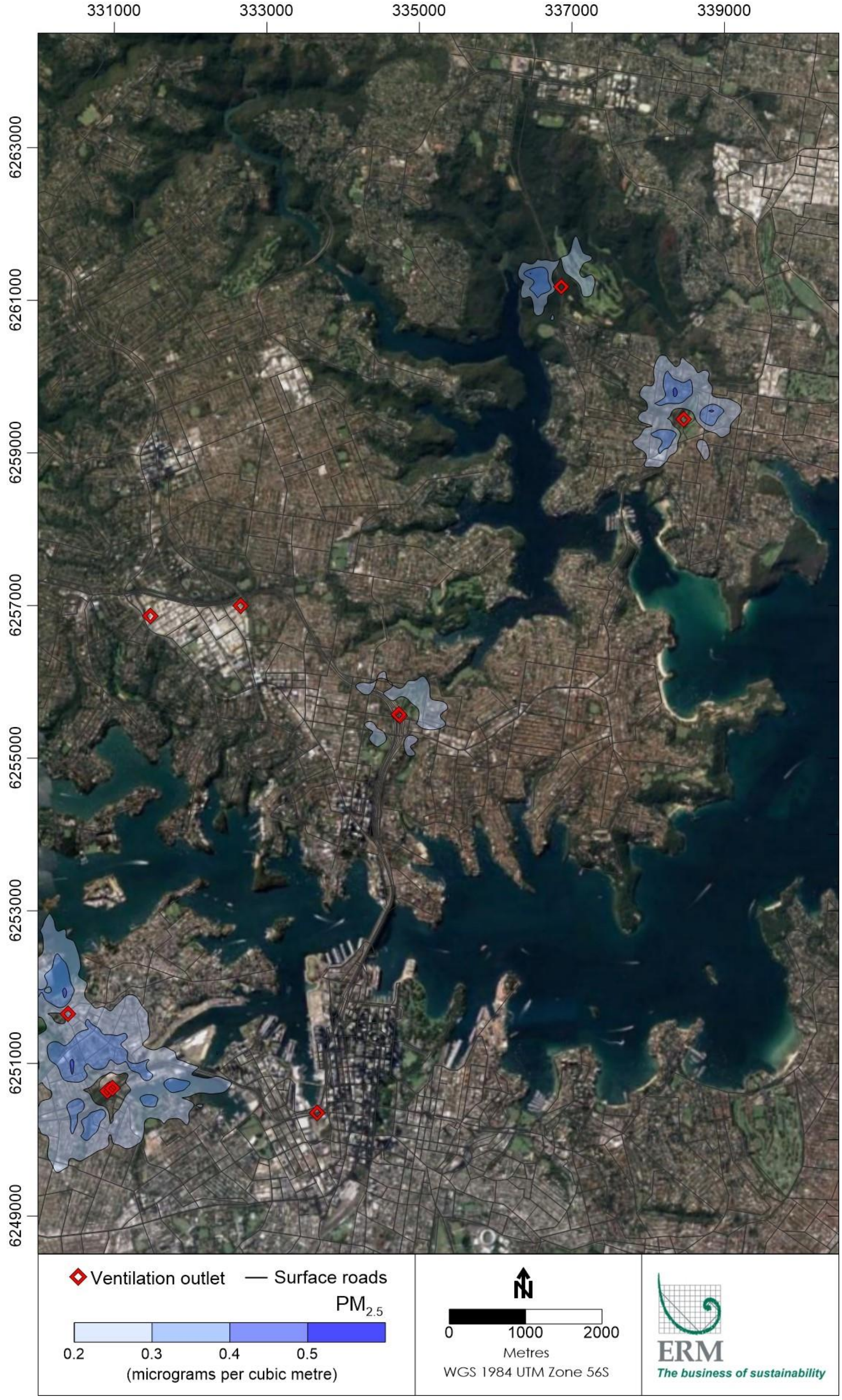


Figure J-82 Contour plot of maximum 24-hour $PM_{2.5}$ for all ventilation outlets in 2027-DS(BL) scenario

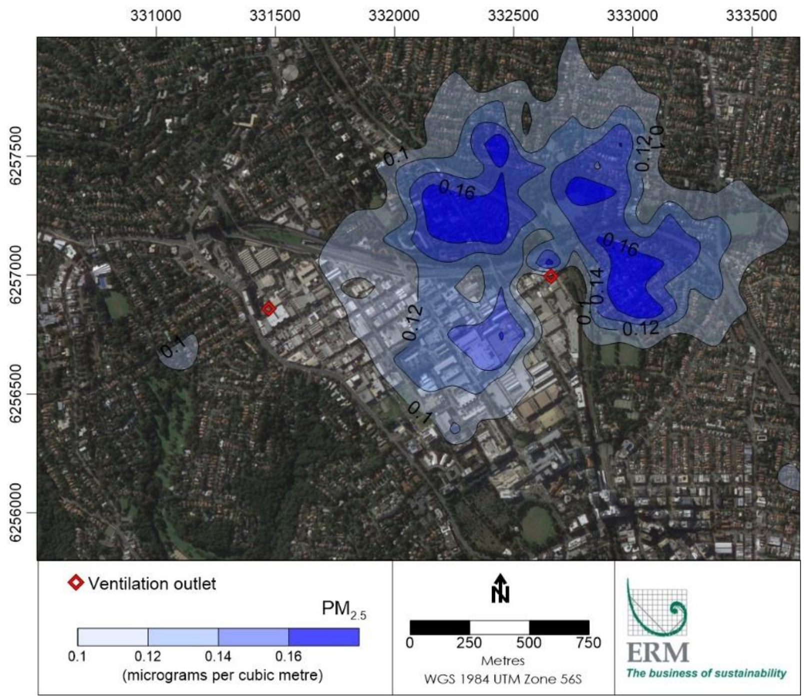


Figure J-83 **Local contour plot of maximum 24-hour $PM_{2.5}$ for Gore Hill Freeway in 2027-DS(BL) scenario**

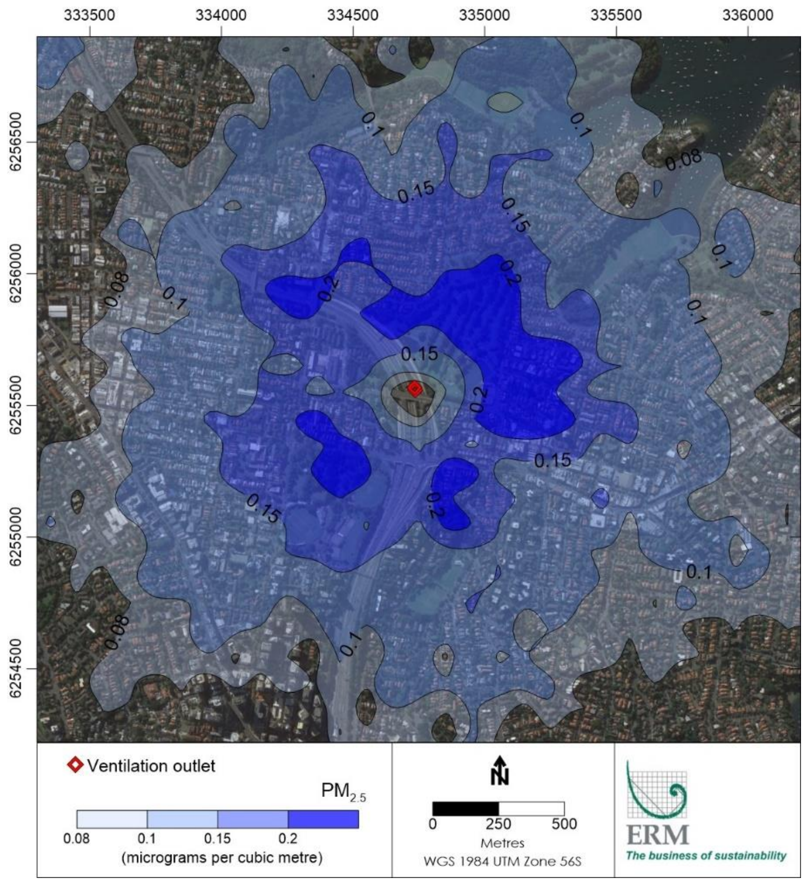


Figure J-84 **Local contour plot of maximum 24-hour $PM_{2.5}$ for Warringah Freeway in 2027-DS(BL) scenario**

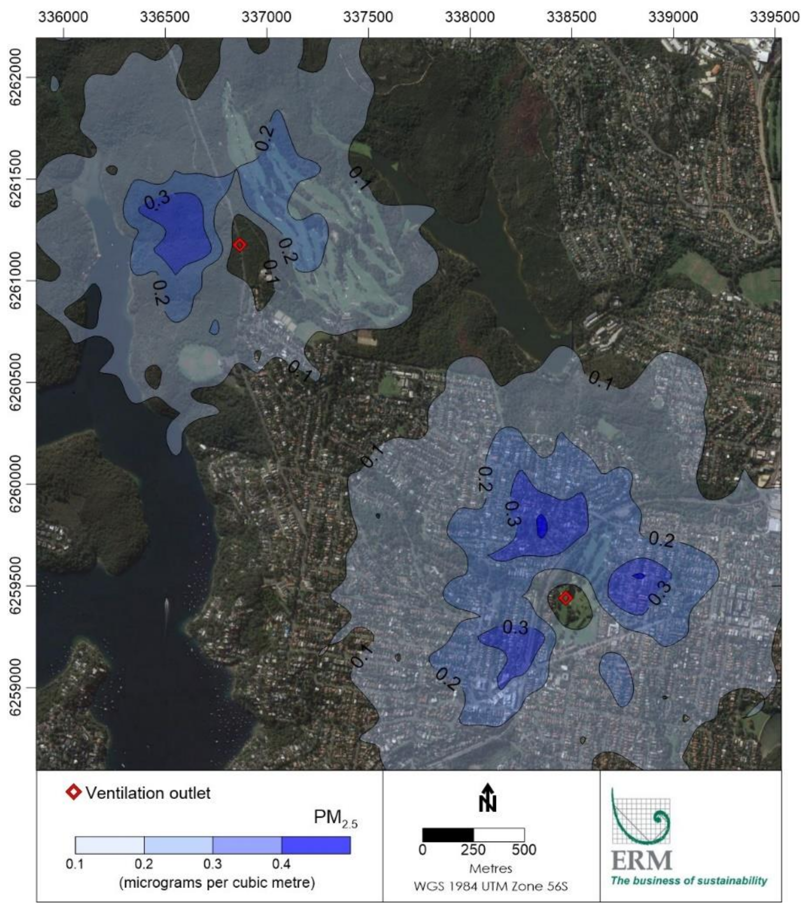


Figure J-85 **Local contour plot of annual mean $PM_{2.5}$ for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2027-DS(BL) scenario**

J.5.6.2 2027-DSC scenario

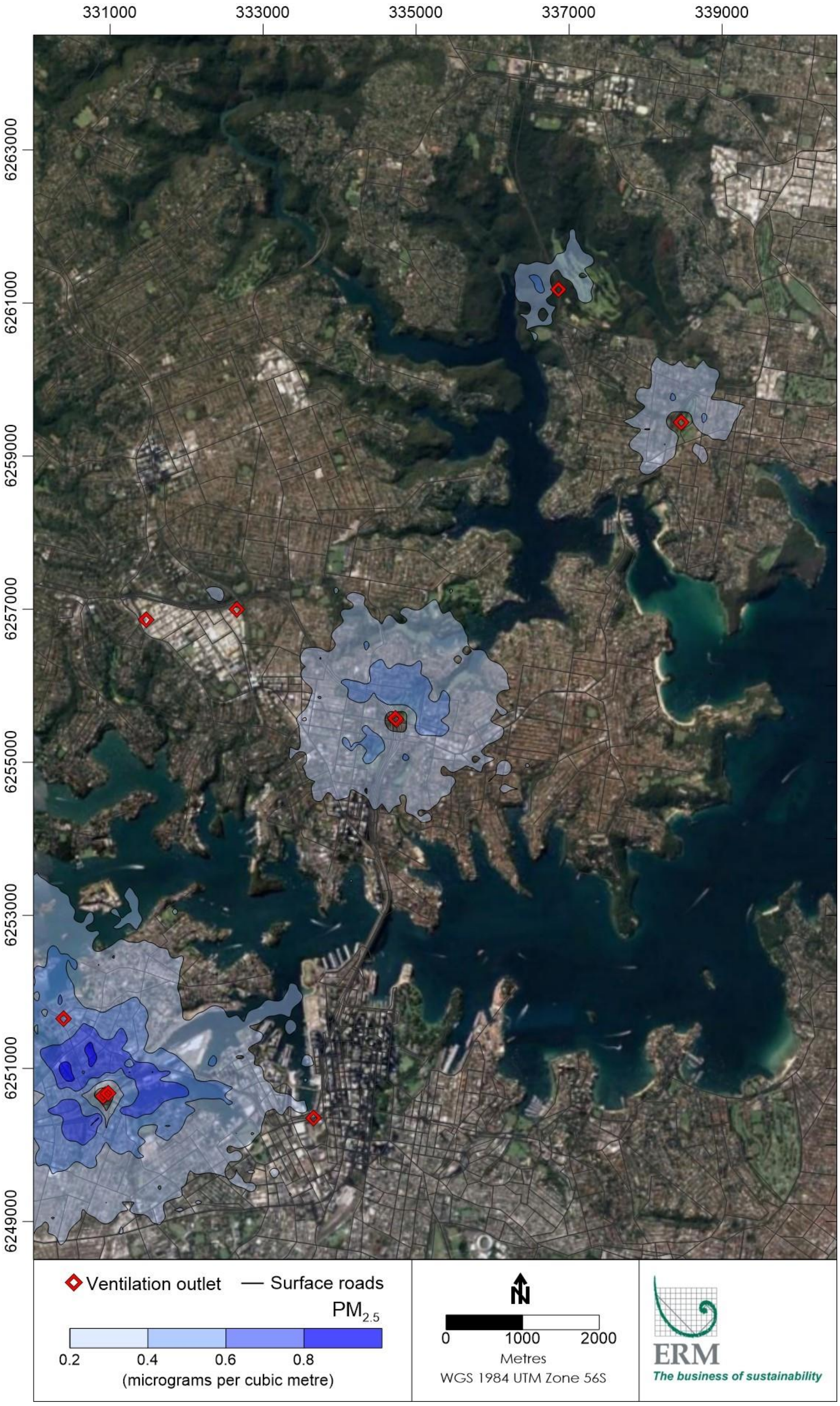


Figure J-86 Contour plot of maximum 24-hour $PM_{2.5}$ for all ventilation outlets in 2027-DSC scenario

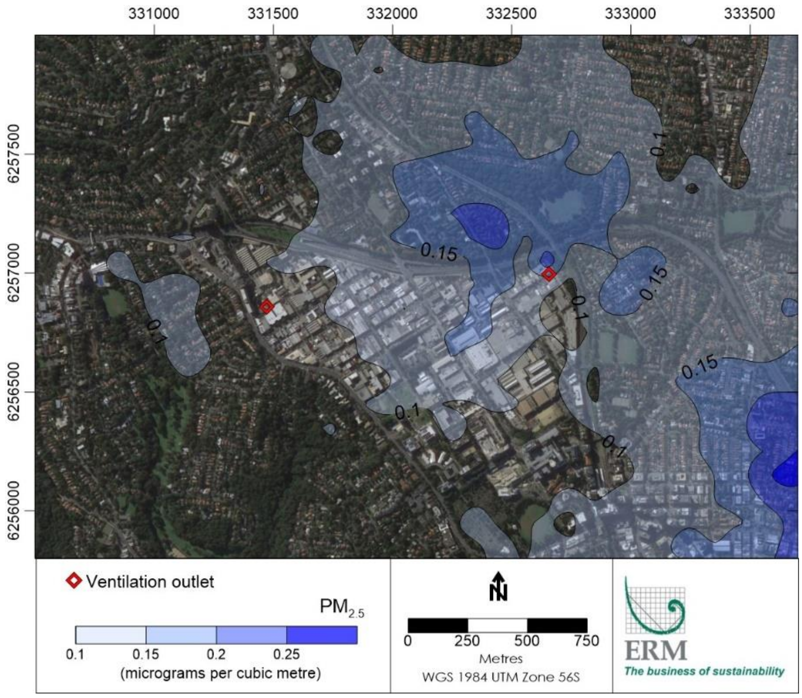


Figure J-87 **Local contour plot of maximum 24-hour $PM_{2.5}$ for Gore Hill Freeway in 2027-DSC scenario**

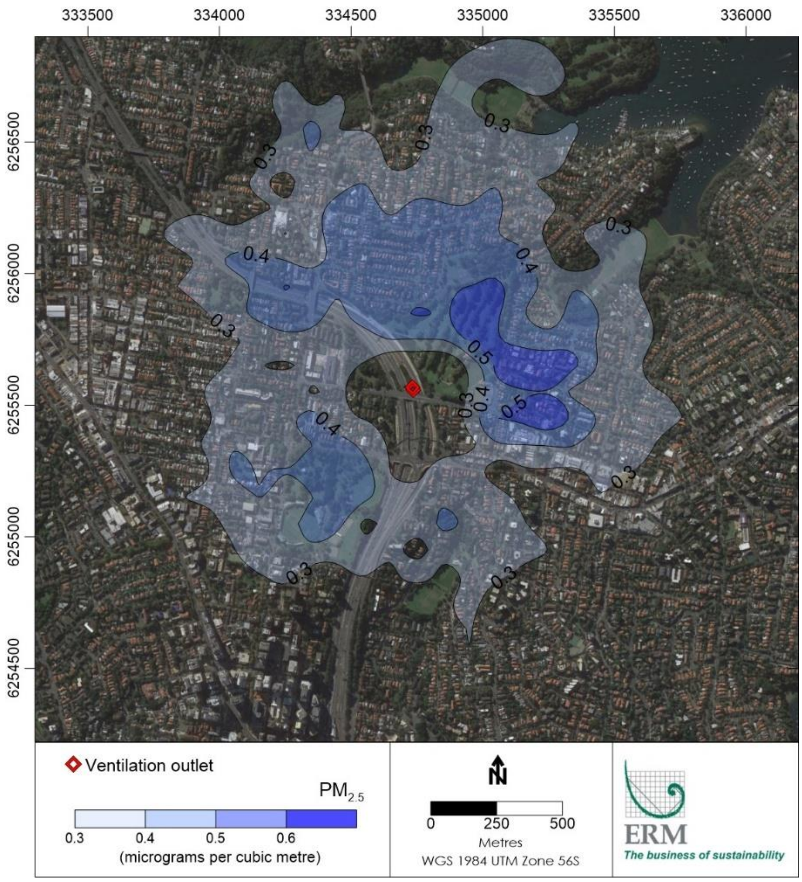


Figure J-88 **Local contour plot of maximum 24-hour $PM_{2.5}$ for Warringah Freeway in 2027-DSC scenario**

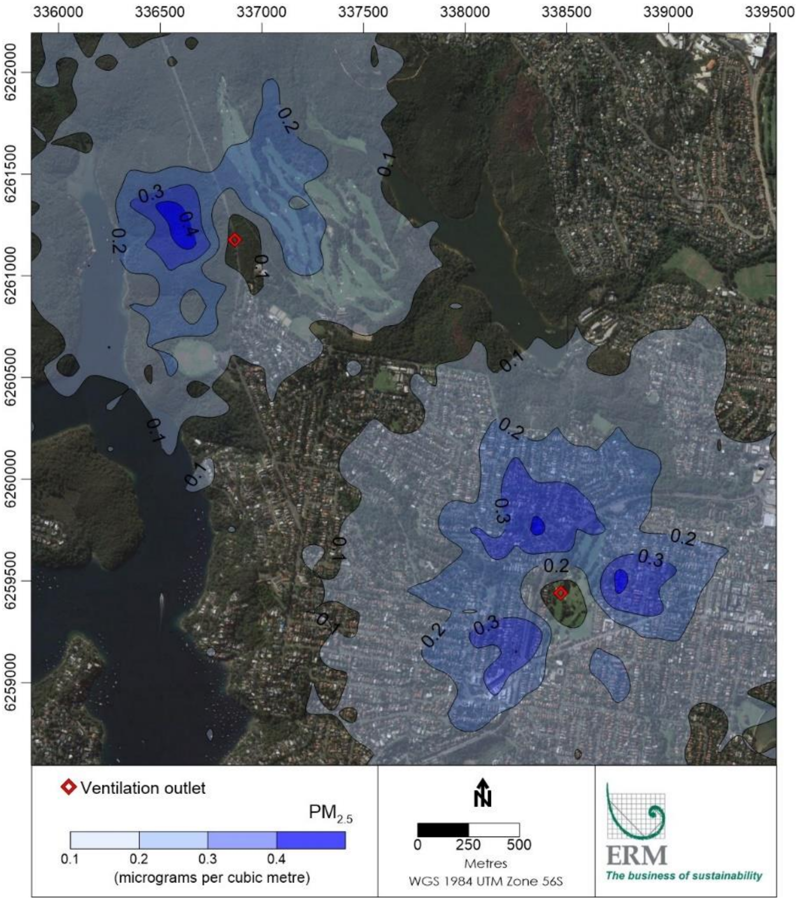


Figure J-89 **Local contour plot of maximum 24-hour $PM_{2.5}$ for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2027-DSC scenario**

J.5.6.3 2037-DS(BL) scenario

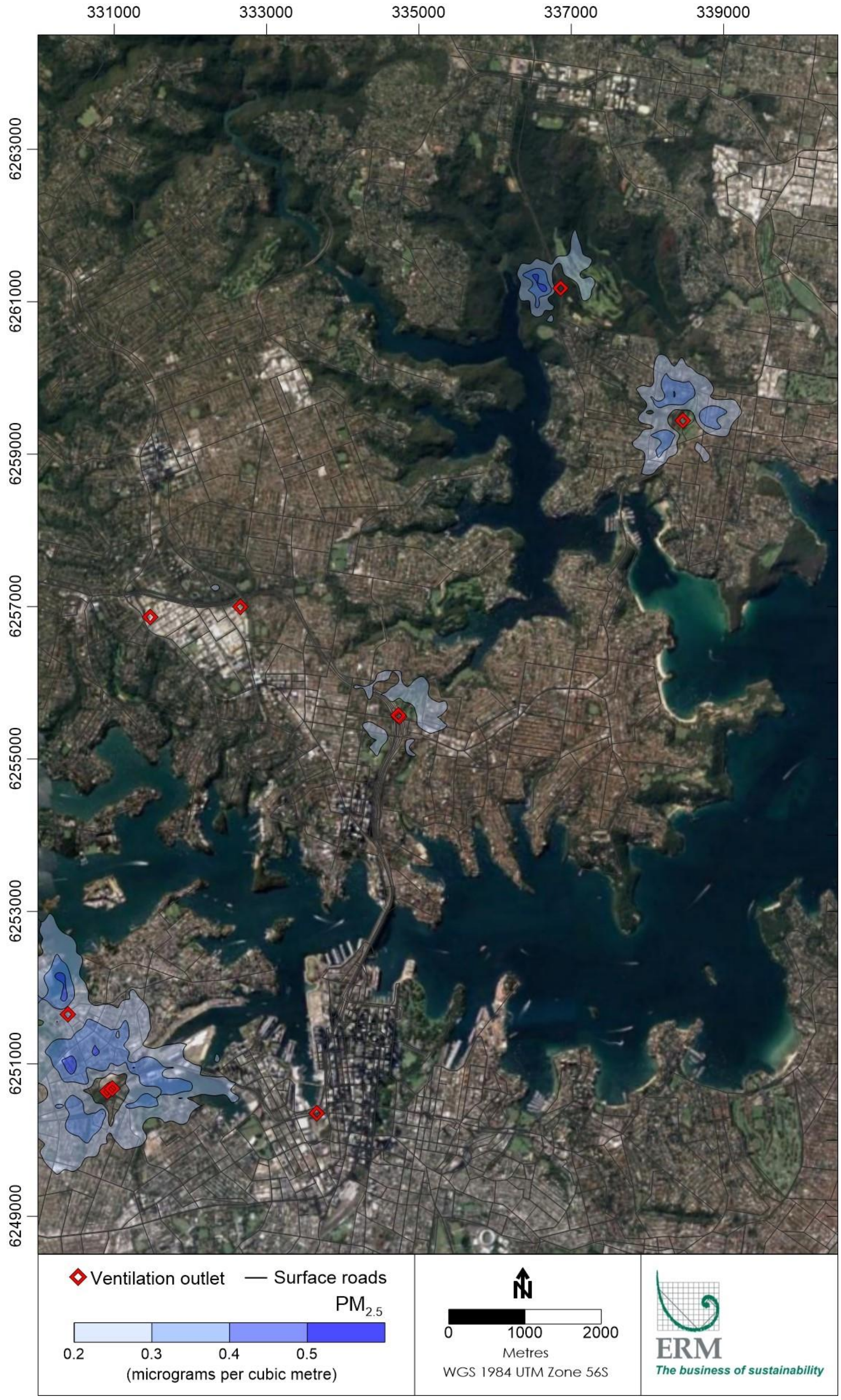


Figure J-90 **Contour plot of maximum 24-hour $PM_{2.5}$ for all ventilation outlets in 2037-DS(BL) scenario**

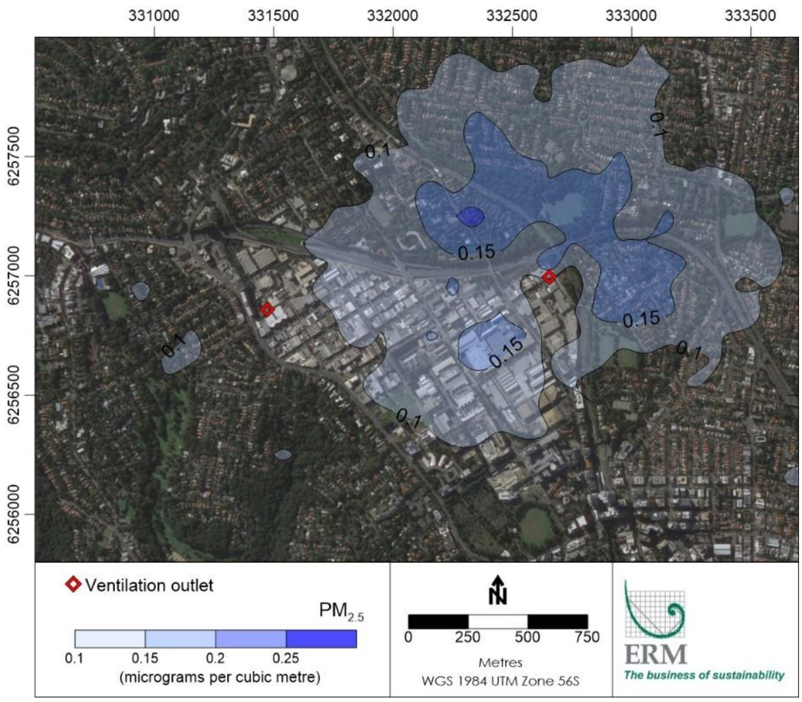


Figure J-91 **Local contour plot of maximum 24-hour $PM_{2.5}$ for Gore Hill Freeway in 2037-DS(BL) scenario**

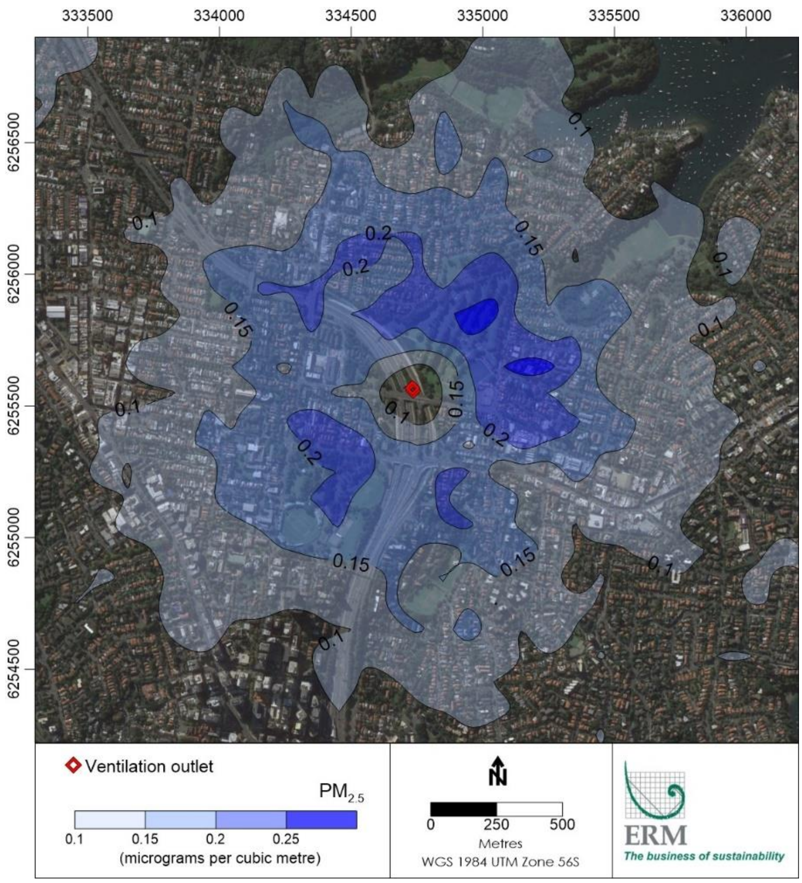


Figure J-92 **Local contour plot of maximum 24-hour $PM_{2.5}$ for Warringah Freeway in 2037-DS(BL) scenario**

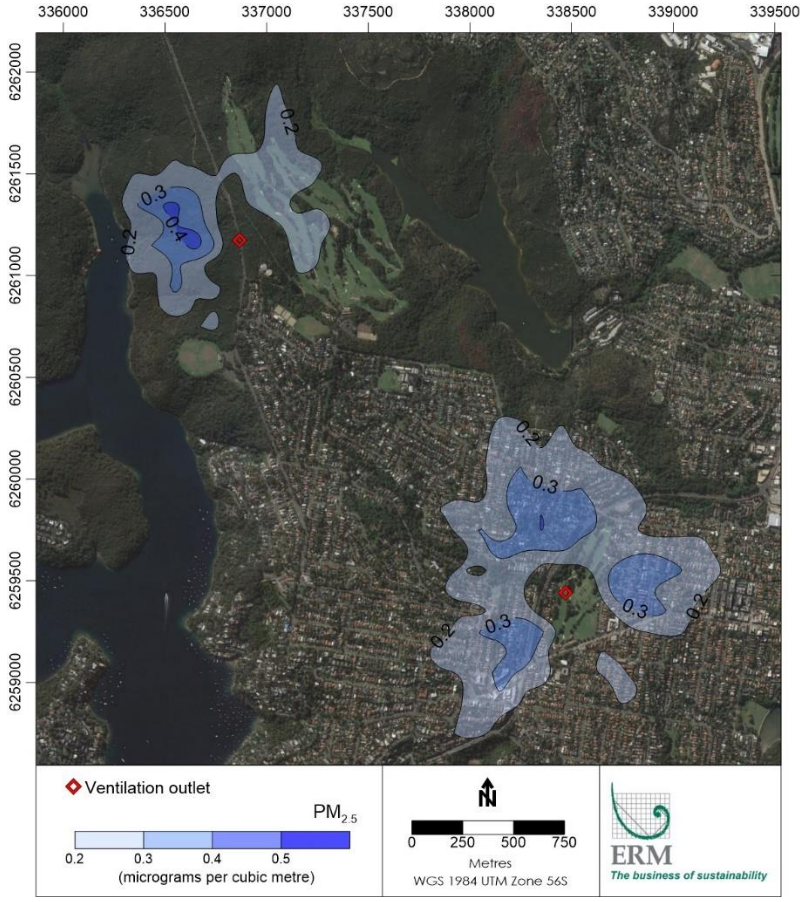


Figure J-93 **Local contour plot of maximum 24-hour $PM_{2.5}$ for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2037-DS(BL) scenario**

J.5.6.4 2037-DSC scenario

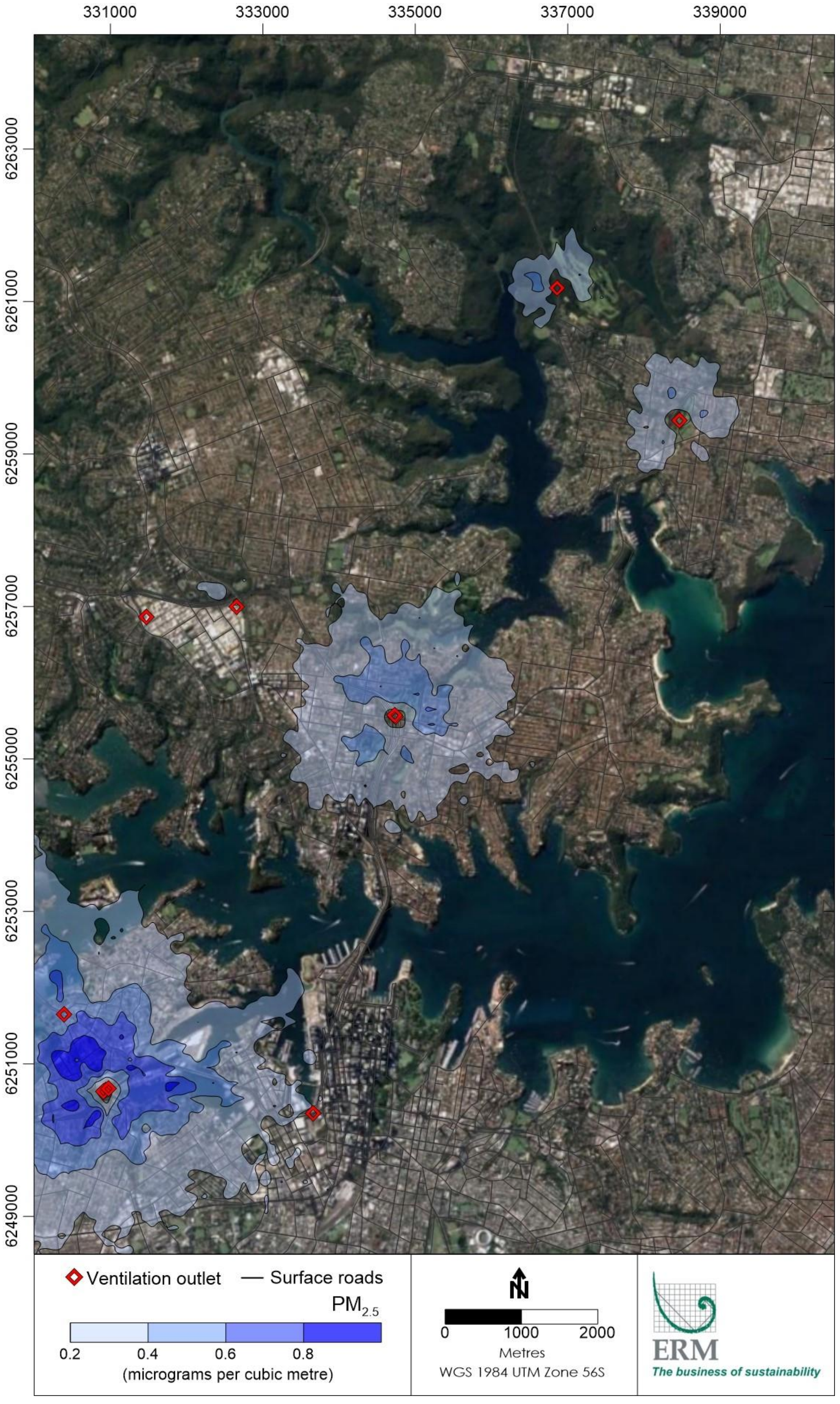


Figure J-94 Contour plot of maximum 24-hour $PM_{2.5}$ for all ventilation outlets in 2037-DSC scenario

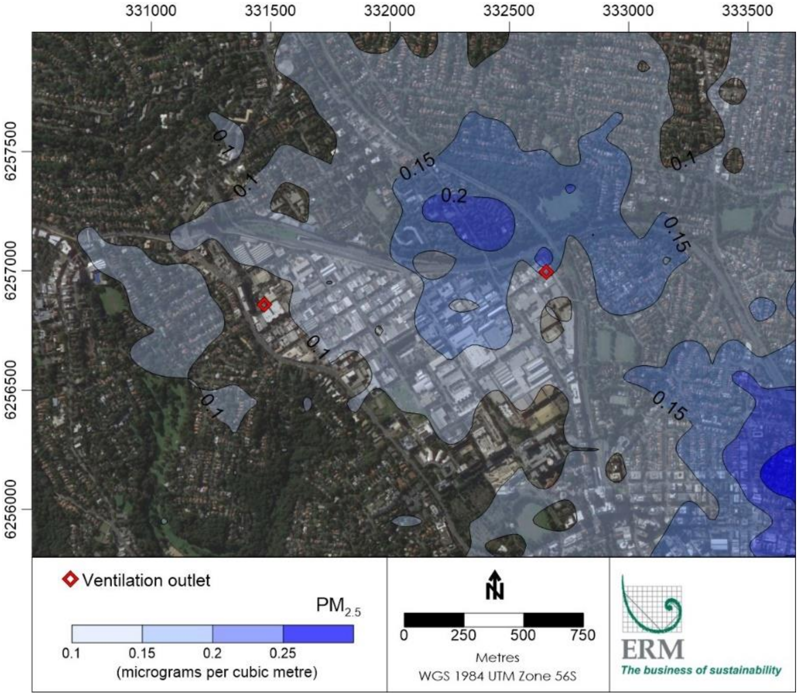


Figure J-95 **Local contour plot of maximum 24-hour $PM_{2.5}$ for Artarmon in 2037-DSC scenario**

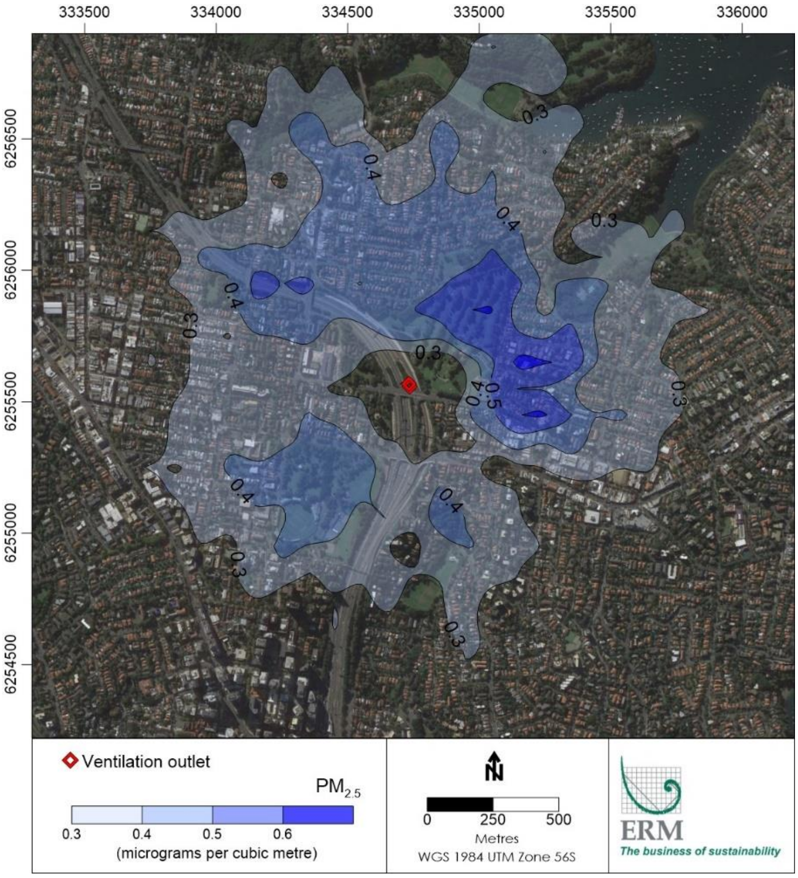


Figure J-96 **Local contour plot of maximum 24-hour $PM_{2.5}$ for Warringah Freeway in 2037-DSC scenario**

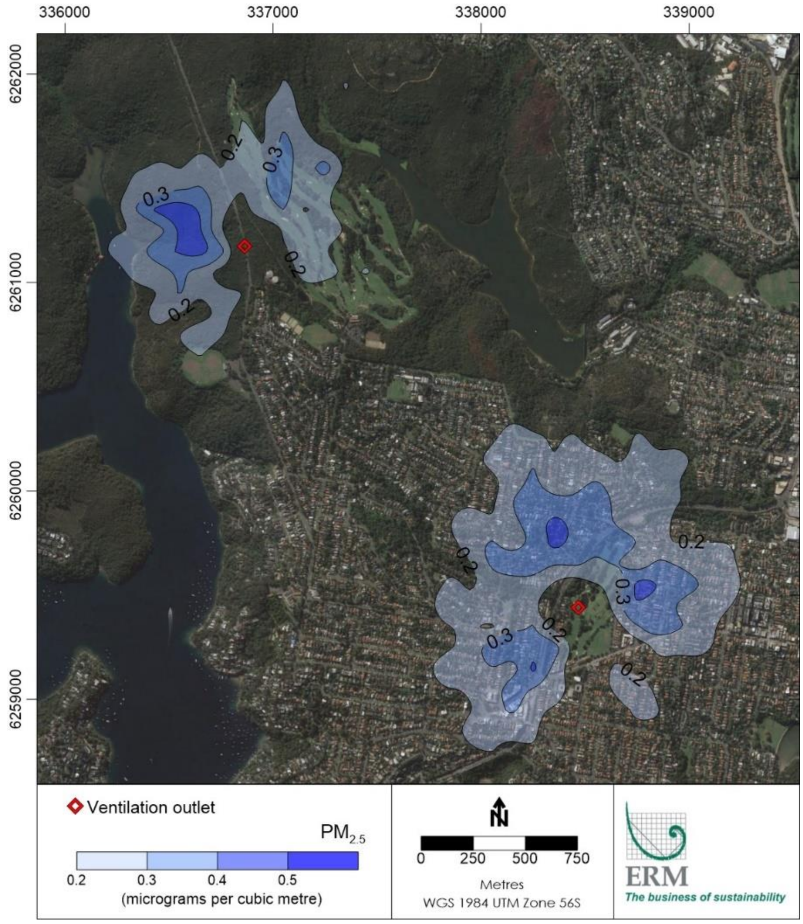


Figure J-97 Local contour plot of maximum 24-hour $PM_{2.5}$ for Wakehurst Parkway and Burnt Bridge Creek Deviation in 2037-DSC scenario

Annexure K - Ventilation report

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Appendix H Annexure K: Ventilation Report

December 2020

Prepared for

Transport for NSW

Prepared by

WSP and ARUP

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Glossary

Term	Explanation
ACTAQ	Advisory Committee on Tunnel Air Quality. A committee chaired by the Chief Scientist and Engineer of NSW.
BL	Beaches Link
BOM	(Australian) Bureau of Meteorology. The source of climate and weather data.
Do something	A model or analysis scenario with Beaches Link and Gore Hill Freeway Connection
CASA	Civil Aviation Safety Authority.
CO	Carbon Monoxide.
Cumulative (or also called Do something cumulative)	An analysis scenario for the tunnel system with M4 East, New M5, M4-M5 Link, Western Harbour Tunnel, and Beaches Link. For model year 2037, future M6 Stage 1 is also included.
EIS	Environmental Impact Statement
Expected (traffic)	The 24 hr traffic profiles based on demand predicted by SMPM (Strategic Motorway Planning Model)
M6 Stage 1	A proposed motorway link between the New M5 at Arncliffe and the existing M1 Princes Highway at Loftus, generally along the alignment known as the M6 corridor.
HGV	Heavy Goods Vehicle, generally aligned with PIARC HGV vehicle category.
Hour	Hour of the day, with the value representing the start time for the hour. That is, Hour 0 is the period midnight to 1 am, Hour 1 is the period 1 am to 2 am, etc.
IDA Tunnel	IDA Tunnel, version 1.2, by EQUA AB in Sweden
Jet fan	A fan installed on the tunnel ceiling or walls to add momentum to the tunnel air via a high-speed outlet air jet, and hence promote longitudinal airflow.
LDV	Light Duty Vehicle, generally aligned with PIARC LDV vehicle category.
NSW	New South Wales
NO	Nitrogen Oxide
NO_2	Nitrogen Dioxide
NO_X	Oxides of Nitrogen. Within this report, is assumed as NO + NO_2 only.
O&M	Operations and Maintenance
PC	Passenger Car, generally aligned with PIARC PC vehicle category.

Term	Explanation
PCU	Passenger Car Unit. A unit used to represent an equivalent number of passenger cars for each real vehicle.
PCU/ln/hr	Number of passenger car unit per lane per hour.
PIARC	World Road Association (formerly known as the Permanent International Association of Road Congresses) and which has retained the acronym. It is the global body which develops, collects and disseminates information about all aspects of road design and operation. Refer http://www.piarc.org/en/.
PIARC detailed method	The method for estimating vehicle emissions using the base emission tables in PIARC document 2019R02EN noted above.
Piston effect	Common term used to describe the effect of the vehicle aerodynamic drag force acting on the tunnel air that promotes longitudinal airflow.
PM	Particulate Matter. Within this report means either vehicle exhaust or roadway based (non-exhaust).
ppm	Parts per million
Project (or the project)	Beaches Link and Gore Hill Freeway Connection
Roads and Maritime	NSW Roads and Maritime Services.
SEARs	Secretary's environmental assessment requirements
SMPM	Strategic Motorway Planning Model (Traffic model, the sources of the traffic forecast used in this work.)
Tunnel segment	A tunnel segment is considered to be a length of carriageway between any two of the following adjacent elements: a) entry portal b) merge c) diverge d) ventilation tunnel e) exit portal.
Worst-case (traffic)	The traffic case(s) which result in the most onerous requirements for the tunnel ventilation system.
WFU	Warringah Freeway Upgrade
WHT	Western Harbour Tunnel.
WHTBL	Western Harbour Tunnel and Beaches Link.

Executive summary

This report outlines the assessment of the tunnel ventilation system reference design and performance for the Beaches Link tunnel in conjunction with the Gore Hill Freeway Connection (the project) to support the associated environmental impact statement for the project.

The report provides a project overview, tunnel ventilation system description, the basis of design and design criteria, and outlines the methodology of the tunnel ventilation system assessment. The report presents the results of the analysis from expected traffic volumes, together with the worst-case scenarios of congestion and breakdown.

The report also assesses the overall long journey impacts based on assumptions for interfaces with other adjacent tunnels such as Western Harbour Tunnel, WestConnex, and the M6 Stage 1.

The ventilation system design for the Beaches Link tunnel is a longitudinal ventilation system. The operation of the ventilation system will be continuously monitored and controlled. Ventilation air would be drawn into the tunnel with the traffic via the “piston effect”, and would be extracted from the tunnel through the ventilation outlets using axial fans. There would be no portal emissions. Where Beaches Link and the Western Harbour Tunnel join, the ventilation system has been designed to limit the carry-over of polluted air from one tunnel to another. The polluted air would be extracted via the ventilation outlets, while fresh air would be supplied into the tunnel.

This assessment demonstrates that the tunnel ventilation system meets the New South Wales in-tunnel air quality criteria for tunnels for expected traffic conditions, worst-case (variable speed) scenarios, and the worst-case (breakdown) scenario. To calculate the in-tunnel air quality, World Road Association (formally known as the Permanent International Association of Road Congresses (PIARC)) 2019 emission estimation methodologies were used and the analysis was carried out on tunnel-ventilation specific software, IDA Tunnel 1.2, developed by EQUA AB in Sweden.

Jet fans would be installed in the tunnel primarily for smoke control in fire or emergency. Under expected traffic scenarios, jet fans would not be needed to maintain in-tunnel air quality as the ‘piston effect’ alone provide sufficient airflow to dilute emissions. Under worst-case scenarios of lower traffic speeds at maximum theoretical capacity and breakdown, jet fans would be required to supplement the airflow generated by the traffic to maintain in-tunnel air quality.

Nitrogen dioxide (NO_2) was the most onerous pollutant in all simulation cases and is a driver for jet fan capacities.

The wider tunnel network was assessed in terms of maintaining acceptable in-tunnel air quality over extended journeys through adjacent tunnels. Each project would be responsible for maintaining NO_2 concentrations below an average of 0.5 parts per million over the length of the tunnel, consistent with existing recent approvals for NorthConnex, M4 East, New M5 and M4-M5 link. Provided that each project satisfies the air quality criteria, the average through the entire network would remain at, or below, 0.5 parts per million under all traffic conditions.

1 Introduction

This section provides an overview of the Beaches Link and Gore Hill Freeway Connection (the project), including its key features and location. It also outlines the Secretary's environmental assessment requirements addressed in this technical working paper.

1.1 Overview

The Greater Sydney Commission's Greater Sydney Region Plan – A Metropolis of Three Cities (Greater Sydney Commission, 2018) proposes a vision of three cities where most residents have convenient and easy access to jobs, education and health facilities and services. In addition to this plan, and to accommodate for Sydney's future growth the NSW Government is implementing the Future Transport Strategy 2056 (Transport for NSW, 2018), that sets the 40 year vision, directions and outcomes framework for customer mobility in NSW. The Western Harbour Tunnel and Beaches Link program of works is proposed to provide additional road network capacity across Sydney Harbour and Middle Harbour and to improve transport connectivity with Sydney's Northern Beaches. The Western Harbour Tunnel and Beaches Link program of works include:

- The Western Harbour Tunnel and Warringah Freeway Upgrade project which comprises a new tolled motorway tunnel connection across Sydney Harbour, and an upgrade of the Warringah Freeway to integrate the new motorway infrastructure with the existing road network and to connect to the Beaches Link and Gore Hill Freeway Connection project
- The Beaches Link and Gore Hill Freeway Connection project which comprises a new tolled motorway tunnel connection across Middle Harbour from the Warringah Freeway and the Gore Hill Freeway to Balgowlah and Killarney Heights and including the surface upgrade of the Wakehurst Parkway from Seaforth to Frenchs Forest and upgrade and integration works to connect to the Gore Hill Freeway at Artarmon.

A combined delivery of the Western Harbour Tunnel and Beaches Link program of works would unlock a range of benefits for freight, public transport and private vehicle users. It would support faster travel times for journeys between the Northern Beaches and areas south, west and north-west of Sydney Harbour. Delivering the program of works would also improve the resilience of the motorway network, given that each project provides an alternative to heavily congested existing harbour crossings.

1.2 The project

Transport for NSW is seeking approval under Part 5, Division 5.2 of the Environmental Planning and Assessment Act 1979 to construct and operate the Beaches Link and Gore Hill Freeway Connection project, which would comprise two components:

- Twin tolled motorway tunnels connecting the Warringah Freeway at Cammeray and the Gore Hill Freeway at Artarmon to the Burnt Bridge Creek Deviation at Balgowlah and the Wakehurst Parkway at Killarney Heights, and an upgrade of the Wakehurst Parkway (the Beaches Link)
- Connection and integration works along the existing Gore Hill Freeway and surrounding roads at Artarmon (the Gore Hill Freeway Connection).

A detailed description of these two components is provided in Section 1.4.

1.3 Project location

The project would be located within the North Sydney, Willoughby, Mosman and Northern Beaches local government areas, connecting Cammeray in the south with Killarney Heights, Frenchs Forest and Balgowlah in the north. The project would also connect to both the Gore Hill Freeway and Reserve Road in Artarmon in the west.

Commencing at the Warringah Freeway at Cammeray, the mainline tunnels would pass under Naremburn and Northbridge, then cross Middle Harbour between Northbridge and Seaforth. The mainline tunnels would then split under Seaforth into two ramp tunnels and continue north to the Wakehurst Parkway at Killarney Heights and north-east to Balgowlah, linking directly to the Burnt Bridge Creek Deviation to the south of the existing Kitchener Street bridge.

The mainline tunnels would also have on and off ramps from under Northbridge connecting to the Gore Hill Freeway and Reserve Road east of the existing Lane Cove Tunnel. Surface works would also be carried out at the Gore Hill Freeway in Artarmon, Burnt Bridge Creek Deviation at Balgowlah and along the Wakehurst Parkway between Seaforth and Frenchs Forest to connect the project to the existing arterial and local road networks.

1.4 Key features of the project

Key features of the Beaches Link component of the project are shown in Figure 1-1 and would include:

- Twin mainline tunnels about 5.6 kilometres long and each accommodating three lanes of traffic in each direction, together with entry and exit ramp tunnels to connections at the surface. The crossing of Middle Harbour between Northbridge and Seaforth would involve three lane, twin immersed tube tunnels
- Connection to the stub tunnels constructed at Cammeray as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project
- Twin two lane ramp tunnels:
  - Eastbound and westbound connections between the mainline tunnel under Seaforth and the surface at the Burnt Bridge Creek Deviation, Balgowlah (about 1.2 kilometres in length)
  - Northbound and southbound connections between the mainline tunnel under Seaforth and the surface at the Wakehurst Parkway, Killarney Heights (about 2.8 kilometres in length)
- Eastbound and westbound connections between the mainline tunnel under Northbridge and the surface at the Gore Hill Freeway and Reserve Road, Artarmon (about 2.1 kilometres in length). An access road connection at Balgowlah between the Burnt Bridge Creek Deviation and Sydney Road including the modification of the intersection at Maretimo Street and Sydney Road, Balgowlah
- Upgrade and integration works along the Wakehurst Parkway, at Seaforth, Killarney Heights and Frenchs Forest, through to Frenchs Forest Road East
- New open space and recreation facilities at Balgowlah
- New and upgraded pedestrian and cyclist infrastructure
- Ventilation outlets and motorway facilities at the Warringah Freeway in Cammeray, the Gore Hill Freeway in Artarmon, the Burnt Bridge Creek Deviation in Balgowlah and the Wakehurst Parkway in Killarney Heights
- Operational facilities, including a motorway control centre at the Gore Hill Freeway in Artarmon, and tunnel support facilities at the Gore Hill Freeway in Artarmon and the Wakehurst Parkway in Frenchs Forest
- Other operational infrastructure including groundwater and tunnel drainage management and treatment systems, surface drainage, signage, tolling infrastructure, fire and life safety systems, roadside furniture, lighting, emergency evacuation and emergency smoke extraction infrastructure, Closed Circuit Television (CCTV) and other traffic management systems.

Key features of the Gore Hill Freeway Connection component of the project are shown in Figure 1-2 and would include:

- Upgrade and reconfiguration of the Gore Hill Freeway between the T1 North Shore & Western Line and T9 Northern Line and the Pacific Highway

- Modifications to the Reserve Road and Hampden Road bridges
- Widening of Reserve Road between the Gore Hill Freeway and Dickson Avenue
- Modification of the Dickson Avenue and Reserve Road intersection to allow for the Beaches Link off ramp
- Upgrades to existing roads around the Gore Hill Freeway to integrate the project with the surrounding road network
- Upgrade of the Dickson Avenue and Pacific Highway intersection
- New and upgraded pedestrian and cyclist infrastructure
- Other operational infrastructure, including surface drainage and utility infrastructure, signage and lighting, CCTV and other traffic management systems.

A detailed description of the project is provided in Chapter 5 (Project description) of the environmental impact statement.

Subject to obtaining planning approval, construction of the project is anticipated to commence in 2023 and is expected to take around five to six years to complete.

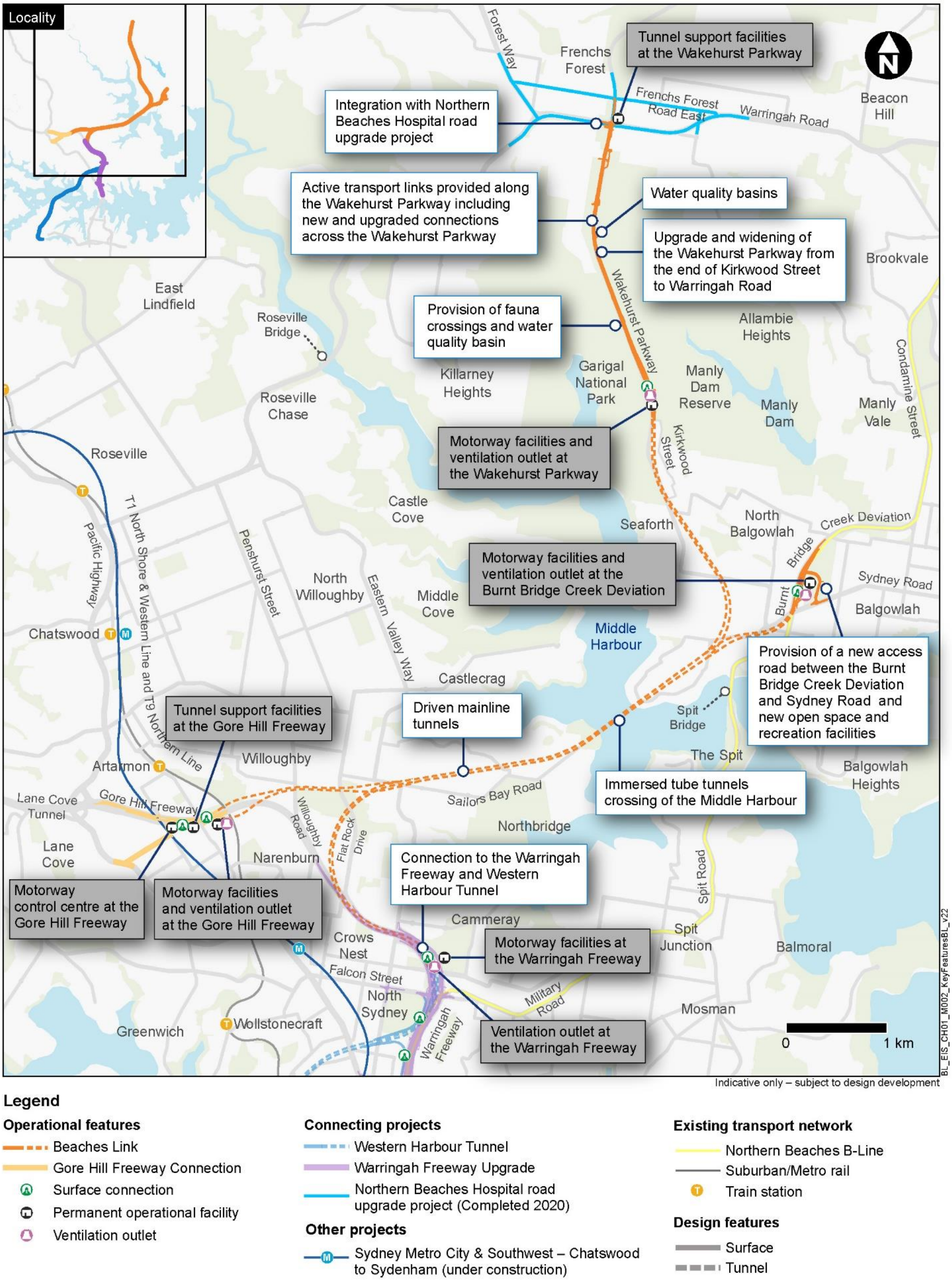
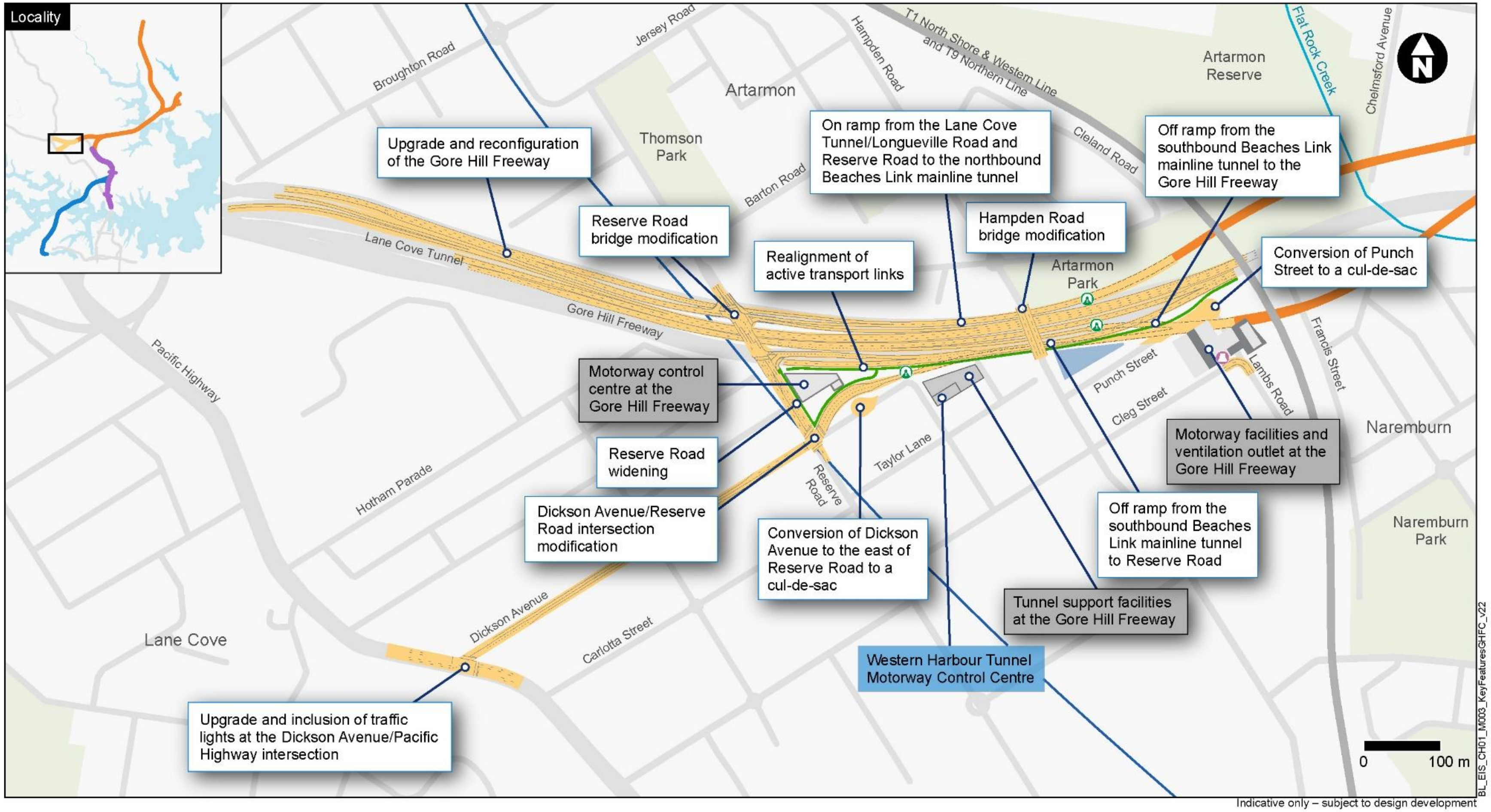


Figure 1-1 Key features of the Beaches Link component of the project



Legend

Operational features
- Gore Hill Freeway Connection
- Beaches Link
- Permanent operational facility
- Surface connection
- Ventilation outlet
- Pedestrian / active transport links
- Permanent water quality basin

Existing rail network
- Suburban/Metro rail

Other projects
- Sydney Metro City & Southwest – Chatswood to Sydenham (under construction)

Figure 1-2 Key features of the Gore Hill Freeway component of the project

1.5 Key construction activities

The area required to construct the project is referred to as the construction footprint. The majority of the construction footprint would be located underground within the mainline and ramp tunnels. However, surface areas would also be required to support tunnelling activities and to construct the tunnel connections, tunnel portals, surface road upgrades and operational facilities.

Key construction activities would include:

- Early works and site establishment, with typical activities being property acquisition and condition surveys, utilities installation, protection, adjustments and relocations, installation of site fencing, environmental controls (including noise attenuation and erosion and sediment control), traffic management controls, vegetation clearing, earthworks, demolition of structures, building construction support sites including acoustic sheds and associated access decline acoustic enclosures (where required), construction of minor access roads and the provision of property access, temporary relocation of pedestrian and cycle paths and bus stops, temporary relocation of swing moorings and/or provision of alternative facilities (mooring or marina berth) within Middle Harbour
- Construction of the Beaches Link, with typical activities being excavation of tunnel construction access declines, construction of driven tunnels, cut and cover and trough structures, construction of surface upgrade works, construction of cofferdams, dredging and immersed tube tunnel piled support activities in preparation for the installation of immersed tube tunnels, casting and installation of immersed tube tunnels and civil finishing and tunnel fitout
- Construction of operational facilities comprising:
  - A motorway control centre at the Gore Hill Freeway in Artarmon
  - Tunnel support facilities at the Gore Hill Freeway in Artarmon and at the Wakehurst Parkway in Frenchs Forest
  - Motorway facilities and ventilation outlets at the Warringah Freeway in Cammeray (fitout only of the Beaches Link ventilation outlet at the Warringah Freeway (being constructed by the Western Harbour Tunnel and Warringah Freeway Upgrade project), the Gore Hill Freeway in Artarmon, the Burnt Bridge Creek Deviation in Balgowlah and the Wakehurst Parkway in Killarney Heights
  - A wastewater treatment plant at the Gore Hill Freeway in Artarmon
  - Installation of motorway tolling infrastructure
- Staged construction of the Gore Hill Freeway Connection at Artarmon and upgrade and integration works at Balgowlah and along the Wakehurst Parkway with typical activities being earthworks, bridgeworks, construction of retaining walls, stormwater drainage, pavement works and linemarking and the installation of roadside furniture, lighting, signage and noise barriers
- Testing of plant and equipment and commissioning of the project, backfill of access declines, removal of construction support sites, landscaping and rehabilitation of disturbed areas and removal of environmental and traffic controls.

Temporary construction support sites would be required as part of the project (refer to Figure 1-3), and would include tunnelling and tunnel support sites, civil surface sites, cofferdams, mooring sites, wharf and berthing facilities, laydown areas, parking and workforce amenities. Construction support sites would include:

- Cammeray Golf Course (BL1)
- Flat Rock Drive (BL2)
- Punch Street (BL3)
- Dickson Avenue (BL4)
- Barton Road (BL5)
- Gore Hill Freeway median (BL6)
- Middle Harbour south cofferdam (BL7)

- Middle Harbour north cofferdam (BL8)
- Spit West Reserve (BL9)
- Balgowlah Golf Course (BL10)
- Kitchener Street (BL11)
- Wakehurst Parkway south (BL12)
- Wakehurst Parkway east (BL13)
- Wakehurst Parkway north (BL14).

A detailed description of construction works for the project is provided in Chapter 6 (Construction work) of the environmental impact statement.

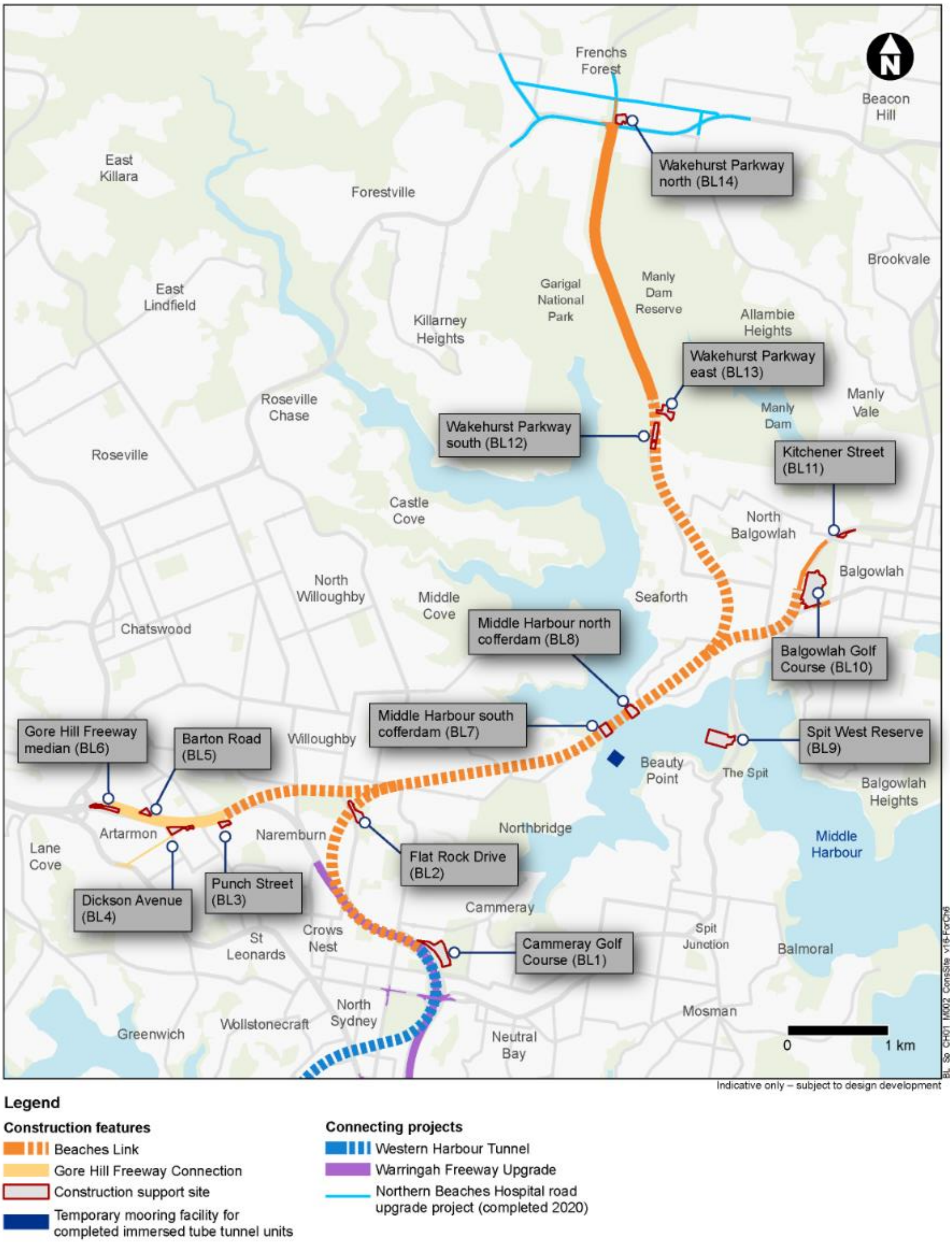


Figure 1-3 Overview of the construction support sites

1.6 Purpose of this report

This report has been prepared to support the environmental impact statement for the project and to address the environmental assessment requirements of the Secretary of the NSW Department of Planning, Industry and Environment.

This report provides the details of the tunnel ventilation assessment to support the air quality study carried out to address the Secretary's environmental assessment requirements. One of the main outputs of the tunnel ventilation modelling is the estimated airflow and emissions rates from ventilation outlets, which form an input to the ambient air quality assessment.

1.7 Secretary's environmental assessment requirements

The Secretary's environmental assessment requirements relating to Air Quality, and where these requirements are addressed in this report are outlined in Table 1.1.

Table 1.1 Secretary's environmental assessment requirements – Air Quality

Secretary's environmental assessment requirements	Where addressed
1. The Proponent must undertake an Air Quality Impact Assessment (AQIA) for construction and operation of the project in accordance with the current guidelines.	Appendix H (Technical working paper: Air quality)
2. The Proponent must ensure the AQIA also includes the following:	
a) demonstrated ability to comply with the relevant regulatory framework, specifically the Protection of the Environment Operations Act 1997 and the Protection of the Environment Operations (Clean Air) Regulation 2010;	Appendix H (Technical working paper: Air quality)
b) the identification of all potential sources of air pollution including details of the location, configuration and design of all potential emission sources including ventilation systems and tunnel portals;	The potential sources of air pollution, in the context of tunnel ventilation, are the vehicle emissions and particulate matter generated from vehicle movement. These pollutants include volatile organic compounds (VOCs) and sulphur dioxide. However, the leading indicators in terms of pollutants for human health are carbon monoxide (CO), oxides of nitrogen (NO_X), with Nitrogen Dioxide (NO_2) being the primary pollutant of interest and particulate matter (PM – as visibility). The tunnel ventilation report concentrates on, and assesses, the in-tunnel air pollutant concentrations of CO, NO_2, and PM in Section 7 for expected traffic scenarios. The design criteria to be met is listed in Section 4. The in-tunnel pollutant concentrations of CO, NO_X, and PM are also converted to provide the emission concentrations from the ventilation outlets. These provide input for the ambient air quality assessment. These results are provided in Section 7.1 and Section 7.2.
c) a review of vehicle emission trends and an assessment that uses or sources best available information on vehicle emission factors;	The vehicle emission trends are based on a forecast study carried out by Transport for NSW, and the vehicle emission factors are based on data from World Road Association (formerly known as the Permanent International Association of Road Congresses (PIARC)). Both have been outlined in Section 6.2.4.

Secretary's environmental assessment requirements		Where addressed
d)	an assessment of impacts (including human health impacts) from potential emissions of PM_{10}, $PM_{2.5}$, CO, NO_2 and other nitrogen oxides and volatile organic compounds (e.g. BTEX) including consideration of short and long-term exposure periods;	The concentration of emissions of $PM_{2.5}$ and PM_{10} (in terms of visibility), CO, and NO_2 have been assessed for 'Do something', 'Do something cumulative', and extended journey cases in Section 7.1, Section 7.2, and Section 5.2.7.
e)	consider the impacts from the dispersal of these air pollutants on the ambient air quality along the proposal route, proposed ventilation outlets and portals, surface roads, ramps and interchanges and the alternative surface road network;	Appendix H (Technical working paper: Air quality) The emission of airborne pollutants from the tunnel is managed via the use of the use of motorway facilities containing axial fans to exhaust tunnel air via ventilation outlets to allow dispersion of pollutants and portal emission control. The results of ventilation outlet emissions are provided in Section 7.1 and Section 7.2.
f)	a qualitative assessment of the redistribution of ambient air quality impacts compared with existing conditions, due to the predicted changes in traffic volumes;	Section 7.1 and Section 7.2 provide the ventilation outlet emissions due to the predicted changes in traffic volumes. The values provided are an input to the ambient air quality assessment in Appendix H (Technical Working Paper: Air Quality).
g)	assessment of worst-case scenarios for in-tunnel and ambient air quality, including a range of potential ventilation scenarios and range of traffic scenarios, including worst-case design maximum traffic flow scenario (variable speed) and worst-case breakdown scenario, and discussion of the likely occurrence of each;	The worst-case design maximum traffic flow scenario (variable speed) has been assessed in Section 8. Section 6.1.3.4 discusses the possible breakdown scenarios and determines the scenarios that may be the most onerous in terms of the generation of pollutants in the tunnel, and the most onerous for the ventilation system. The assessment of the worst-case breakdown scenario has been outlined in Section 9.
h)	details of the proposed tunnel design and mitigation measures to address in-tunnel air quality and the air quality in the vicinity of portals and any mechanical ventilation systems (i.e. ventilation outlets and air inlets) including details of proposed air quality monitoring (including frequency and criteria);	The overall tunnel ventilation overview has been provided in Section 3. Section 3.4 discusses the ventilation strategy specific to the project.
i)	a demonstration of how the project and ventilation design ensures that concentrations of air emissions meet NSW, national and international best practice for in-tunnel and ambient air quality, and taking into consideration the approved criteria for the M4 East project, New M5 project and the In-Tunnel Air Quality (Nitrogen Dioxide) Policy;	Section 7 outlines all the assessment results and how the ventilation design meets both the in-tunnel air quality and the approved design criteria based on other Sydney projects and the In-Tunnel Air Quality (Nitrogen Dioxide) Policy.
j)	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;	Section 4.3 provides the criteria to be met in emergency events, and Section 3.6 describes the tunnel ventilation operation in those situations.
k)	details of in-tunnel air quality control measures considered, including air filtration, and justification of the proposed measures or for the exclusion of other measures;	Alternative ventilation system options have been assessed in Section 3.4.2

Secretary's environmental assessment requirements		Where addressed
l)	a description and assessment of the impacts of potential emissions sources relating to construction, including details of the proposed mitigation measures to prevent the generation and emission of dust (particulate matter and TSP) and air pollutants (including odours) during the construction of the proposal, particularly in relation to ancillary facilities (such as concrete batching plants), dredge and tunnel spoil handling and storage, the use of mobile plant, stockpiles and the processing and movement of spoil; and	Appendix H (Technical working paper: Air quality)
m)	a cumulative assessment of the in-tunnel, local and regional air quality impacts from the operation of the project and due to the operation of and potential continuous travel through motorway tunnels and surface roads.	A long journey exposure has been provided in Section 5.2.7, assessing the worst potential extended continuous travel through motorway tunnels.

2 Scope

This report documents the ventilation analysis carried out as part of the environmental impact statement to provide the relevant Government departments and authorities an opportunity to review and understand the analysis carried out, the nature of the impact of the tunnel ventilation system on the environment and to be able to provide comment on the viability of the methodology adopted and applicability of the resulting solutions proposed. Further, the information presented is intended to inform the preparation of related assessments (by others) as part of the wider application for the approval of the project.

The report describes the tunnel ventilation system configuration, outlines the input data and assumptions used in the analysis and defines the minimum exhaust emission rates at the ventilation outlets to maintain acceptable in-tunnel air quality for a range of traffic scenarios.

For completeness, an outline of the emergency ventilation system and the associated operational response are also included for the critical fire locations.

3 Tunnel ventilation overview

3.1 Objectives

The tunnel ventilation system is intended to provide a safe and comfortable environment for motorists, in a reliable and efficient manner. To achieve this, the ventilation systems for the project needs to meet the following three main objectives:

1. Maintain air quality within the tunnel under all traffic conditions
2. Avoid portal emissions
3. Manage smoke during fire incidents.

The main tunnel ventilation system elements for the Western Harbour Tunnel and Beaches Link are provided in Figure 3-1.

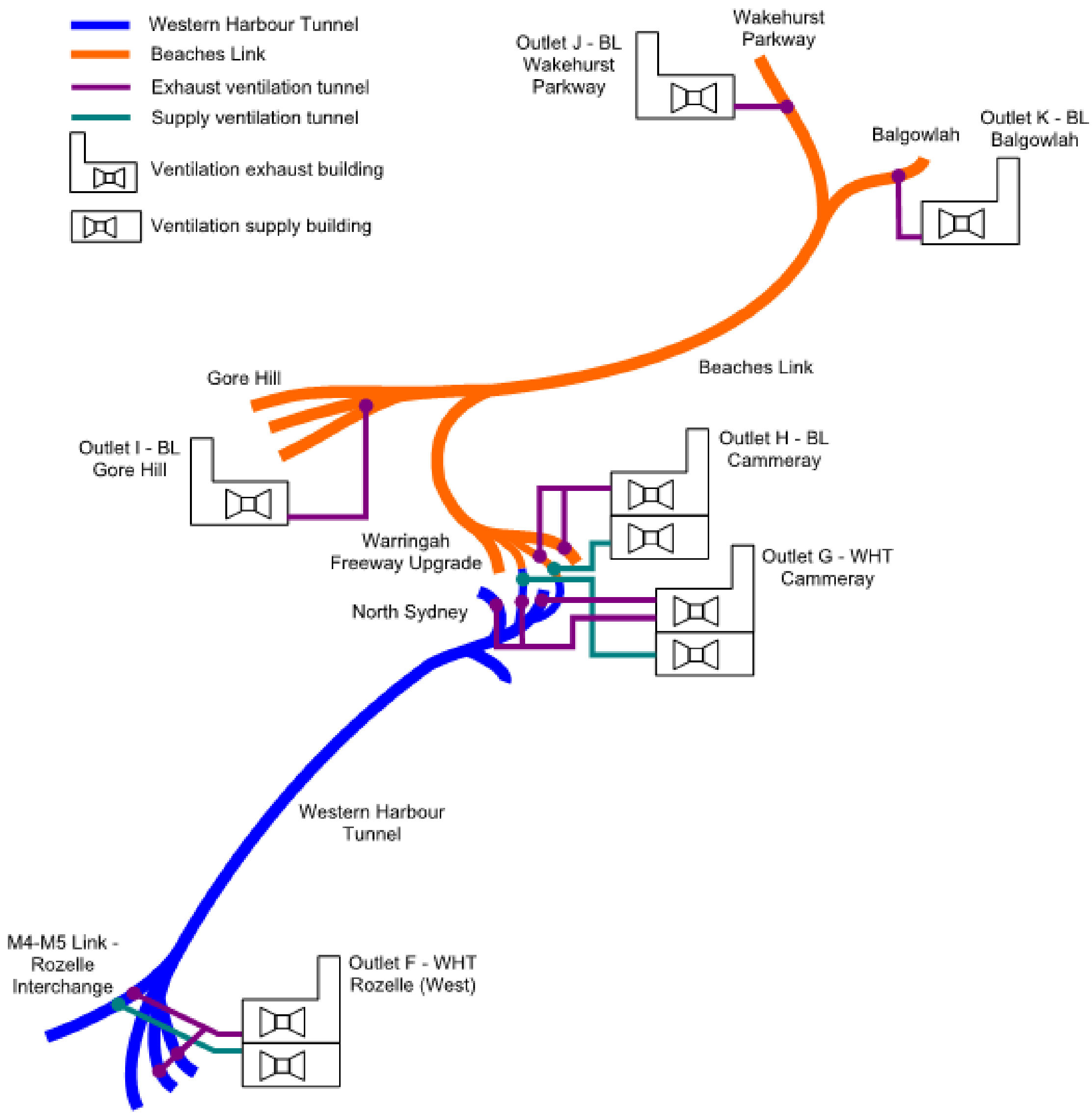


Figure 3-1 Tunnel ventilation system overview of Western Harbour Tunnel and Beaches Link

The tunnel ventilation system would reduce pollution levels in the tunnel during normal and congested operation and provide smoke management in a fire event to enhance life safety by providing a suitable and safe environment for motorists.

Emissions will be discharged vertically through the ventilation outlets, with no portal emissions.

3.2 Project tunnel ventilation system

The tunnel ventilation method adopted for the Beaches Link tunnel is based on a longitudinal ventilation system, where fresh air is introduced into the tunnels via the entry portals, extracted prior to the exit portals and discharged to atmosphere via the ventilation outlets. The primary motive force for airflow through the tunnel is the vehicle piston effect, which can be supplemented by jet fan operation, typically at lower average traffic speeds, if required.

Jet fans would be distributed throughout the tunnel segments to supplement the airflow when in-tunnel air quality approaches the allowable limit, and for smoke management during a fire event.

The tunnel ventilation system for the Beaches Link and Gore Hill Freeway Connection is shown in Figure 3-2 and Figure 3-3. The tunnel ventilation system for Beaches Link, Western Harbour Tunnel and Warringah Freeway Upgrade is shown in Figure 3-4 and Figure 3-5.

Motorway facilities housing axial fans are typically located as close as practical to exit portals and interfaces with adjacent road tunnels. Note that the final locations are subject to confirmation at subsequent design phases. It is also noted that the final air flowrates are subject to confirmation at subsequent design phases.

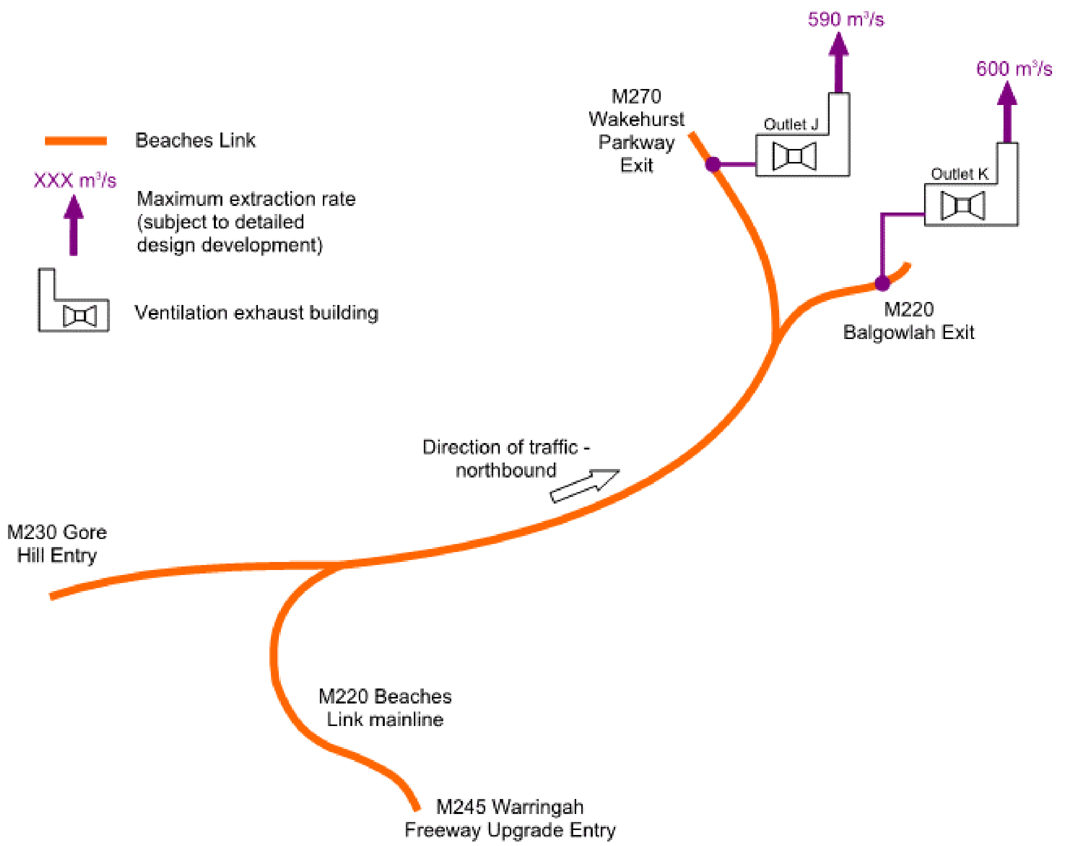


Figure 3-2 'Do something' – northbound tunnel ventilation system

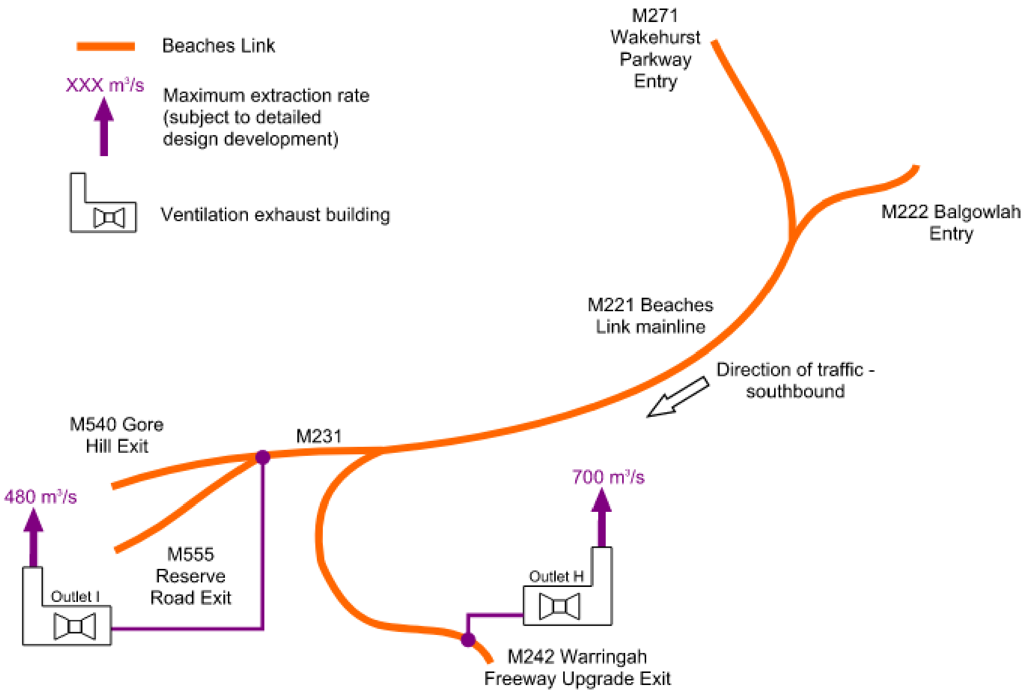


Figure 3-3 'Do something' – southbound tunnel ventilation system

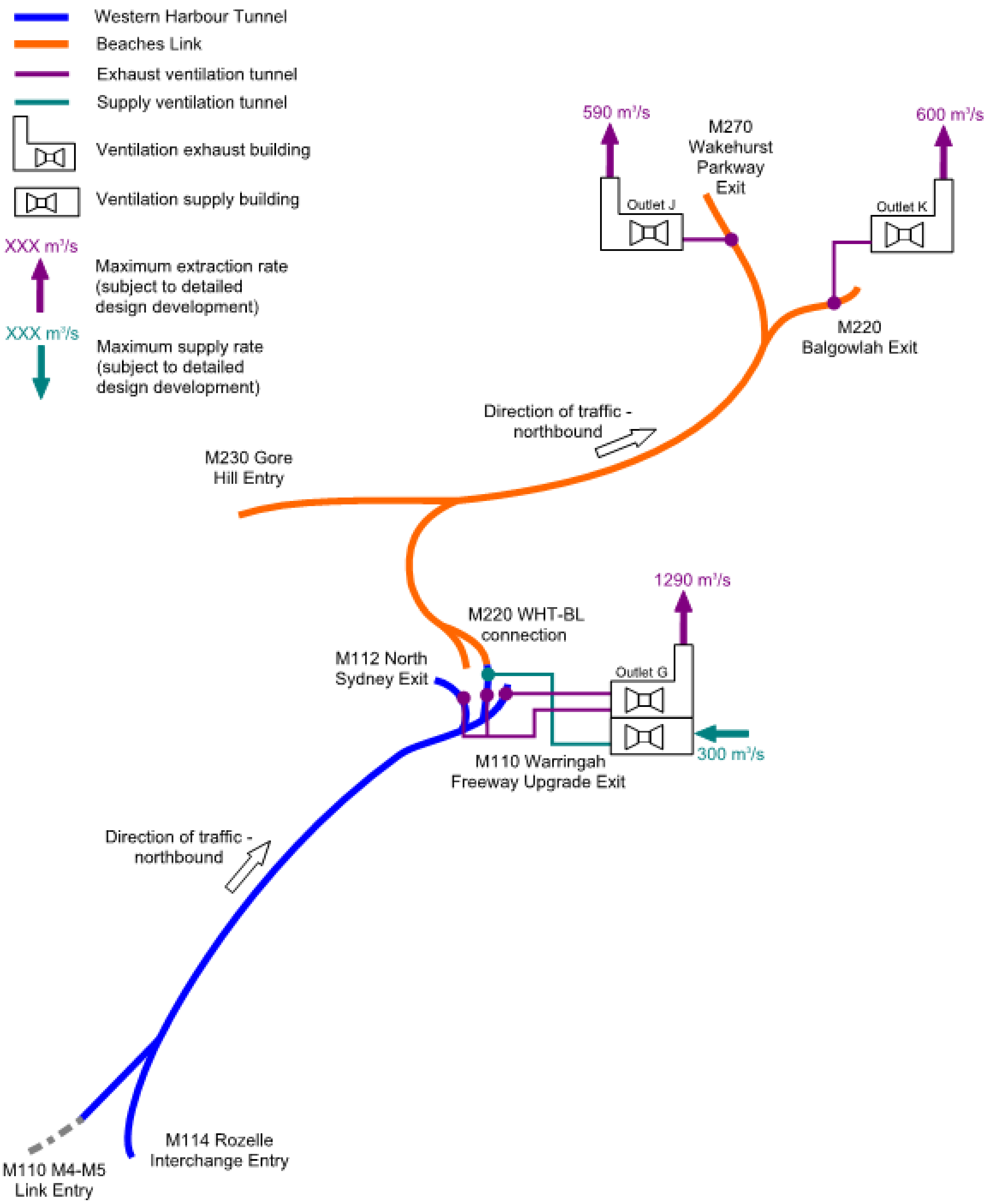


Figure 3-4 ‘Do something cumulative’ – northbound tunnel ventilation system

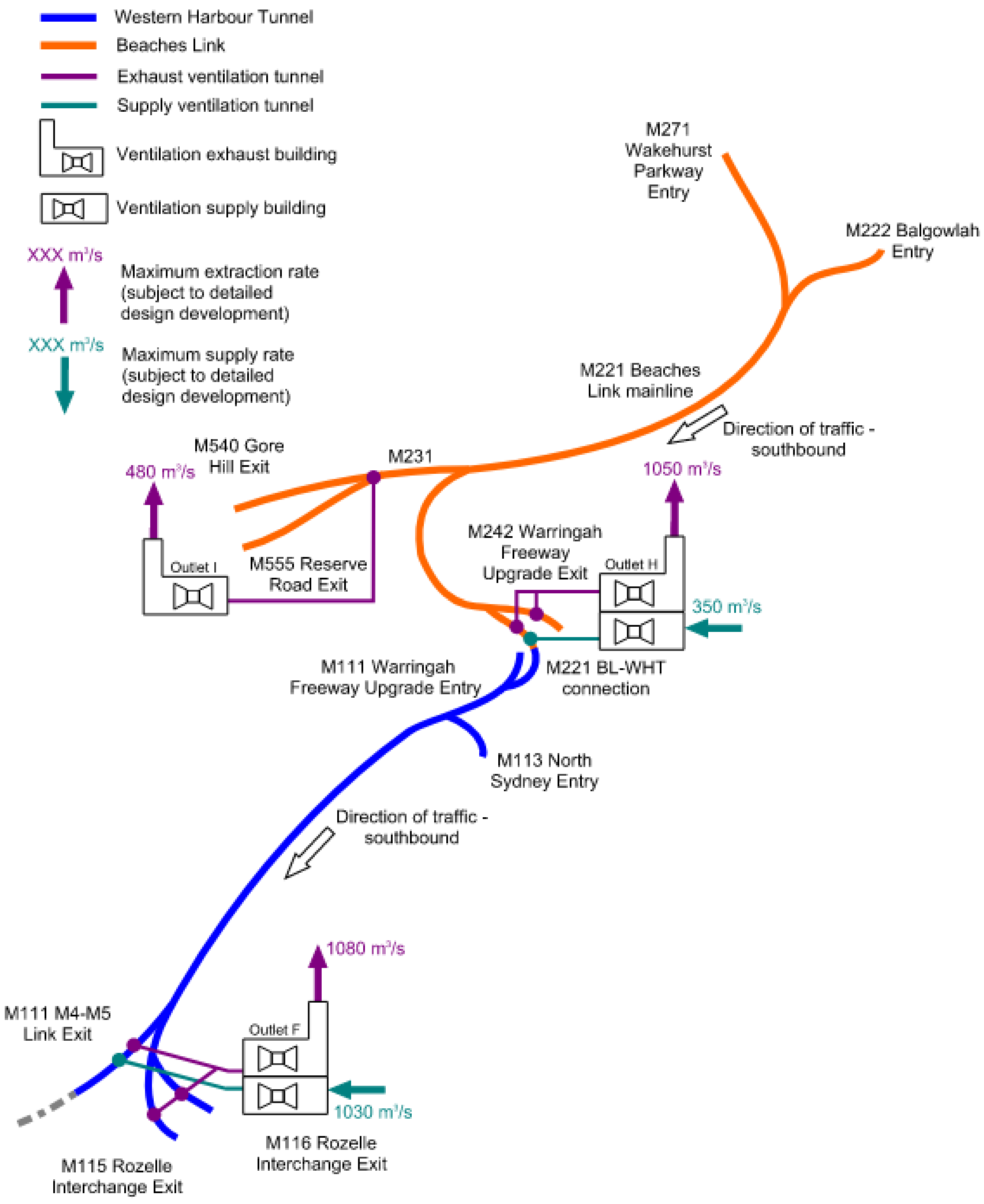


Figure 3-5 'Do something cumulative' – southbound tunnel ventilation system

3.3 Interfaces with adjacent tunnels

The project design for the Beaches Link proposes a direct underground connection to the Western Harbour Tunnel, which results in an aerodynamic connection between the tunnels. The operation of each tunnel would need to be coordinated with the adjacent tunnel to ensure safe and effective ventilation is maintained under all credible circumstances.

The ventilation system design in this area must also provide a demarcation between each asset (project interface) and maximise the independence of the construction, operation and maintenance of the ventilation systems.

An aerodynamic decoupling in the form of an air exchange prior to the project interface, as shown in the generic example in Figure 3-6, is proposed to segregate the two tunnels. At each interface, air from the upstream tunnel carriageway would be extracted and replenished with a suitable volume of fresh air for the downstream tunnel.

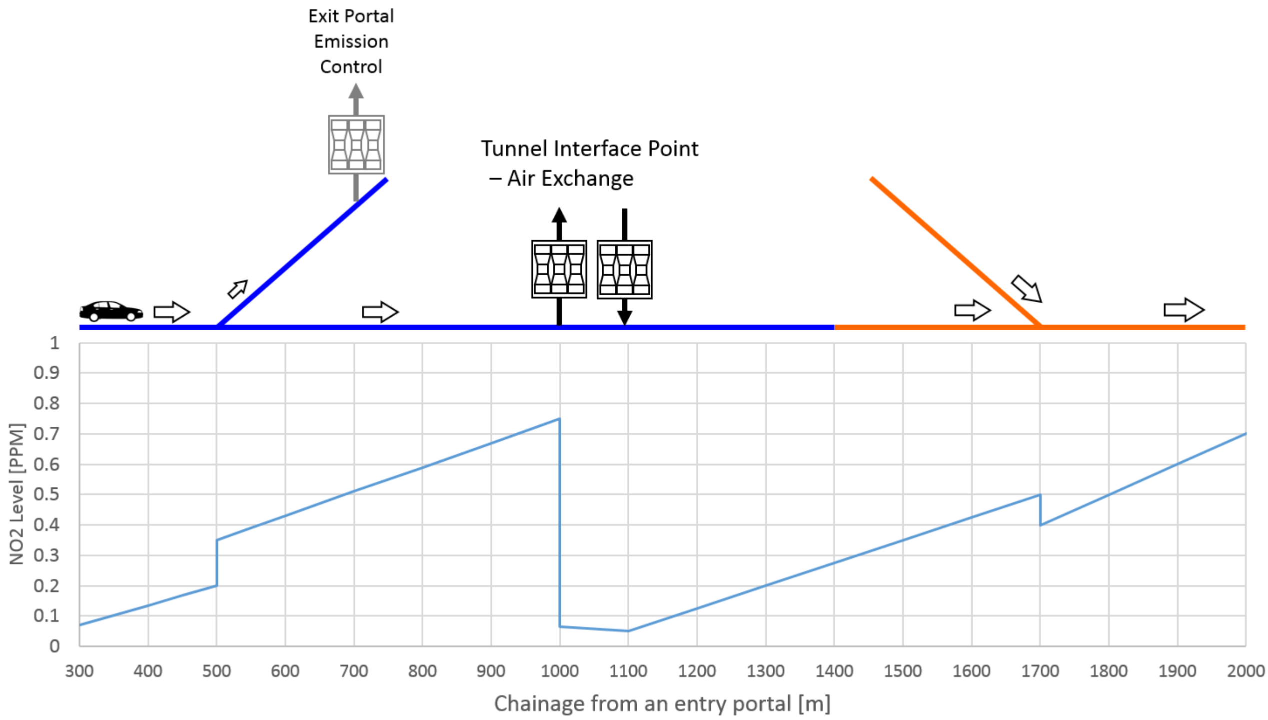


Figure 3-6 Concept of air exchange at tunnel interface points

3.3.1 Warringah Freeway motorway facility

A motorway facility is proposed within the Cammeray Golf Course, adjacent to the proposed Western Harbour Tunnel motorway facility. This facility would:

- Capture and disperse tunnel air from the Beaches Link southbound carriageway
- Provide clean air into the proposed Western Harbour Tunnel southbound carriageway.

Figure 3-7 provides an overview of the motorway facilities and ventilation tunnel connections at the Cammeray interchange, between the Western Harbour Tunnel and Beaches Link tunnels.

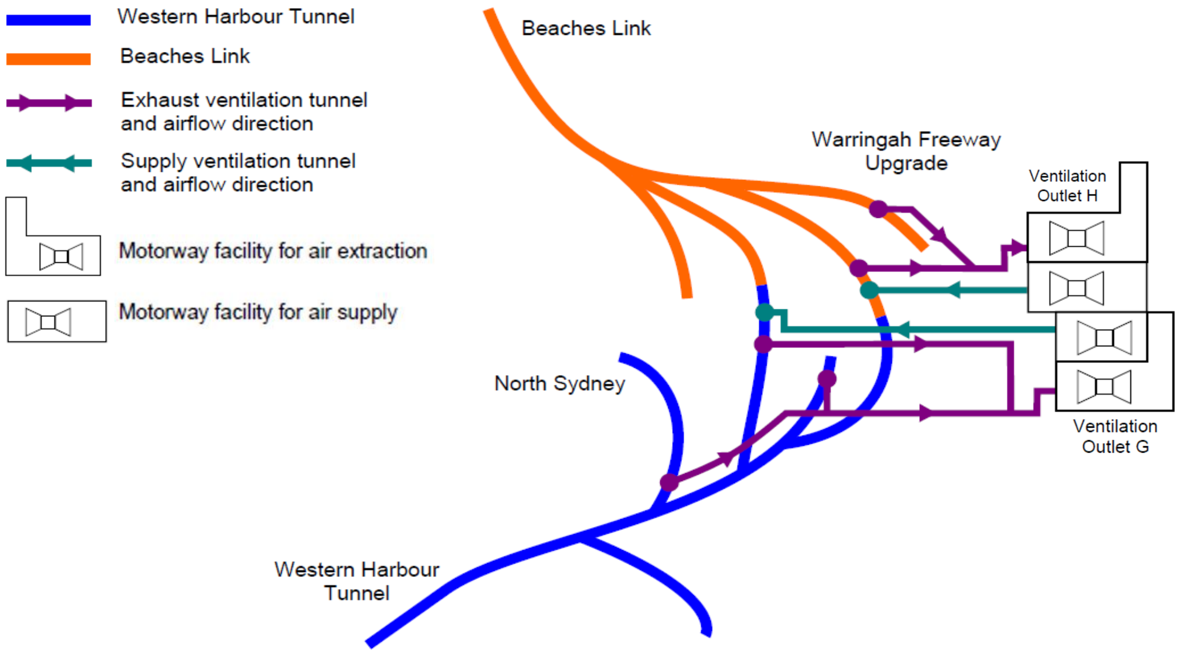


Figure 3-7 Localised schematic of motorway facility and ventilation tunnel connections showing airflow directions – Warringah Freeway motorway facility

3.4 Tunnel ventilation strategy

3.4.1 Overall concept

The Beaches Link tunnel is proposed to be longitudinally ventilated with point extraction near the exit portals for portal emission control. In a longitudinally ventilated system, air would be drawn into and along each carriageway with the flow of traffic to dilute the concentration of vehicle emissions generated within the tunnel. A typical longitudinal ventilation system concept is shown in Figure 3-8.

Longitudinal ventilation is considered to be more energy efficient as traffic flows passively ventilate the tunnel with minimal use of jet fans, thereby minimising energy consumption. Often the air pushed through the tunnel by the vehicle piston effect can be greater than the minimum volume required to dilute emissions to the allowable air quality limits. In these cases, the tunnel can be self-ventilating.

Jet fans would be distributed throughout the tunnel segments to supplement the airflow through the tunnel when in-tunnel air quality approaches the allowable limit. They would also be used for smoke management during emergency operation.

To avoid portal emissions, motorway facilities located adjacent to exit portals capture and exhaust the tunnel air from ventilation outlets at elevated heights. This allows the development of a suitable plume rise and the dispersion of pollutants.

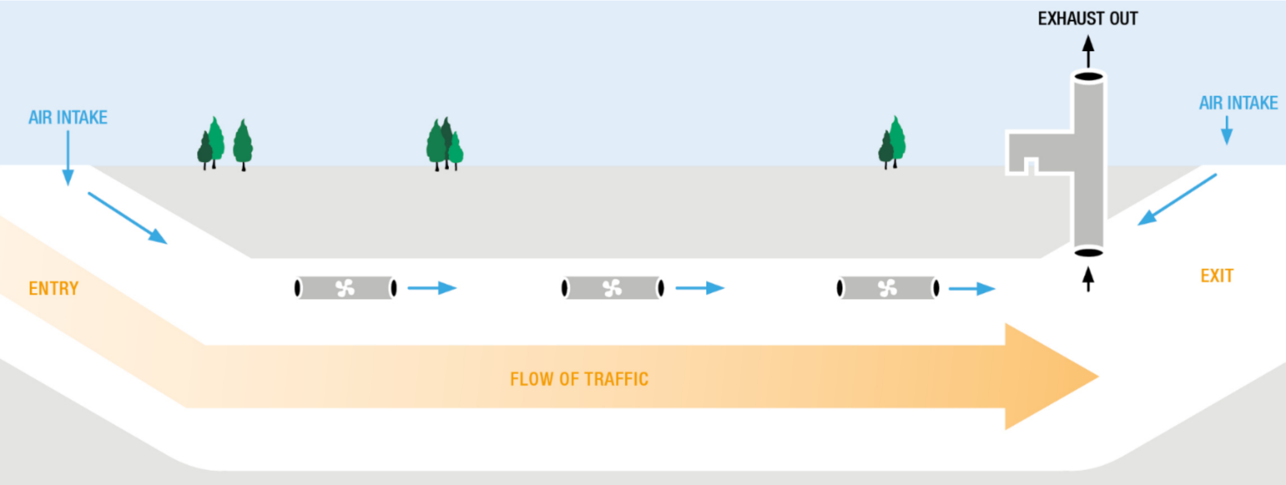


Figure 3-8 Longitudinal system with portal emission control in normal operating mode

3.4.2 Alternative tunnel ventilation system schemes

Any type of ventilation system relies on providing sufficient airflow to dilute emissions. Ventilation strategies vary by the way air is brought into and removed from a tunnel. Road tunnels are typically longitudinally ventilated as proposed, transversely ventilated or semi-transversely ventilated. Alternative tunnel ventilation strategies considered are outlined below.

3.4.2.1 Transverse ventilation

Transverse ventilation systems use two separate ducts for introduction of fresh air into the tunnel and to extract the polluted in-tunnel air or smoke during normal or emergency operations respectively. Although transverse systems may have advantages in maintaining acceptable in-tunnel air quality in some instances, they can also have negative impacts which include capital and operational cost, and spatial implications.

The high capital costs coupled with a high level of operating complexity means the applicability of transverse ventilation systems for the project is limited, especially when modelling results suggest that tunnels can be self-ventilating during free-flowing traffic. This free flow effect negates many of the benefits of a transverse ventilation system.

A schematic of a typical transverse system is shown in Figure 3-9.

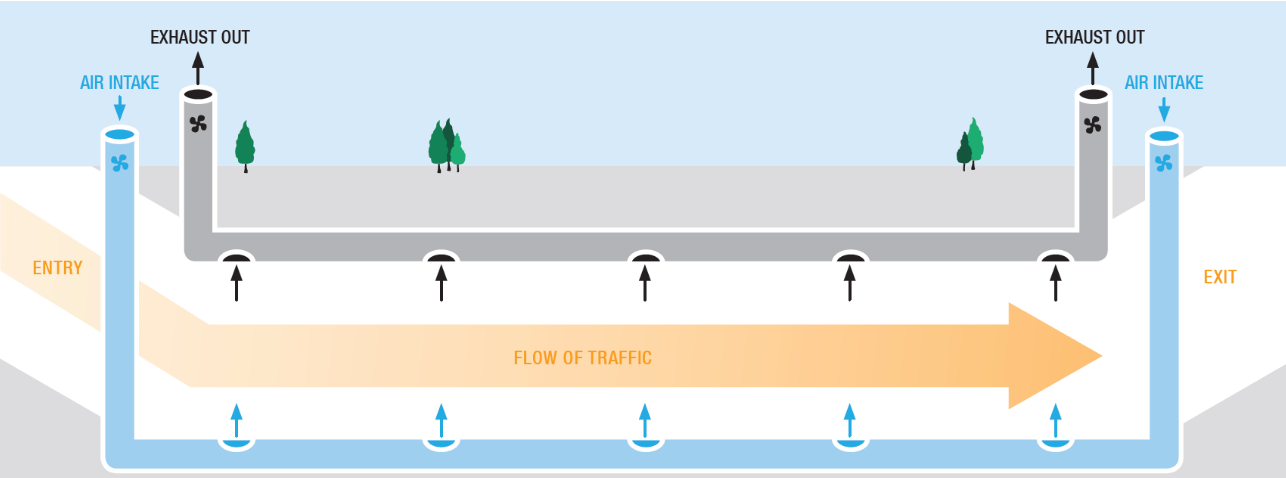


Figure 3-9 Typical transverse system in normal operating mode

3.4.2.2 Semi-transverse ventilation

Semi-transverse ventilation systems utilise ductwork to either supply, or exhaust, air from the tunnel, with traffic movement relied upon to assist the airflow where possible. These systems are termed as either semi-transverse supply, or semi-transverse exhaust depending on the airflow direction through the duct.

The advantage of a semi-transverse exhaust system is evident during emergency operation where smoke extraction can be achieved via a high-level duct, however, the same may not be true for normal and congested operation. The applicability of this system would need to be assessed on a case by case basis. Similarly, the semi-transverse supply system shows no advantage over a longitudinal ventilation system during emergency operation as the tunnel is used as the medium for transporting the smoke in both cases.

Typically, ducted systems are limited in tunnel length, with multiple in-tunnel facilities containing axial fans required with increasing length to overcome the losses in a duct of limited cross-sectional area. The length of the Beaches Link tunnel would mean that in-tunnel facilities may be required.

A schematic of a typical semi-transverse exhaust system is shown in Figure 3-10.

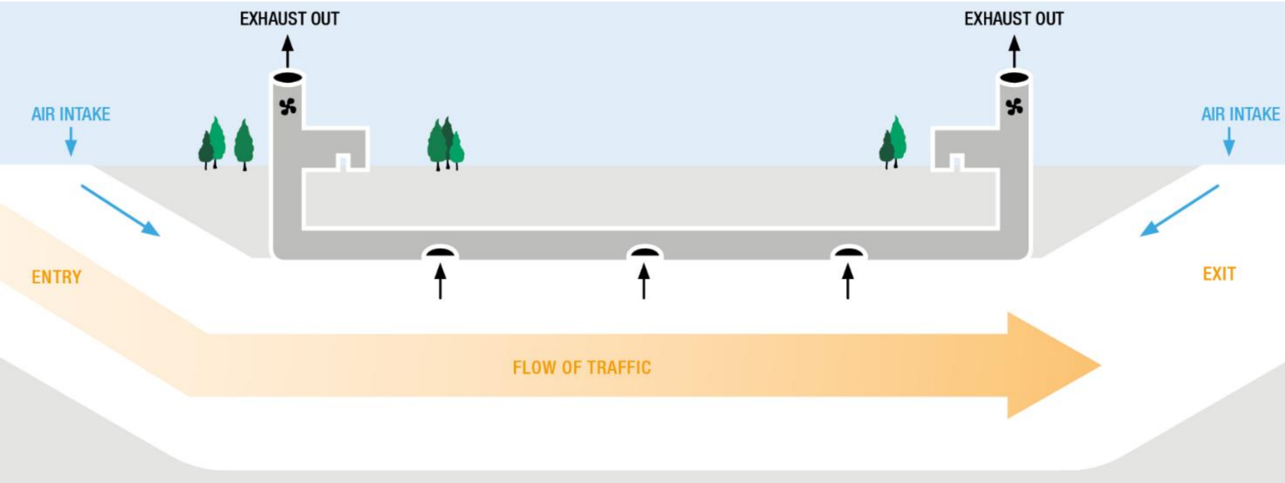


Figure 3-10 Typical semi-transverse system in normal operating mode

3.4.2.3 Rationale for adoption of longitudinal ventilation system

Although both semi and fully transverse ventilation systems can be designed to meet the in-tunnel air quality criteria, a longitudinal system has been selected as the preferred option for the Beaches Link tunnel, for the following reasons:

- Longitudinal ventilation systems allow the construction of longer sections of tunnel, without the need for major intermediate motorway facilities, relying on the traffic piston effect and jet fans to maintain acceptable in-tunnel air quality
- The longitudinal ventilation system is less complex to operate, especially for capturing emissions prior to exit portals, with minimal impact on ambient air quality at the portals
- A longitudinal ventilation system is considered to be a more cost-effective solution for tunnel ventilation when compared to other systems.

In addition, the adoption of a longitudinal ventilation strategy aligns positively with the adjacent, and wider tunnel network.

3.5 In-tunnel air quality monitoring strategy

The continuous monitoring of in-tunnel air quality, visibility and velocity (airflow) is a key factor in maintaining the in-tunnel environment and road safety. The concentration of the oxides of nitrogen (particularly nitrogen dioxide), which are primarily produced by an increasing number of diesel vehicles, as well as particulate matter in the form of particles of dust and soot (including abrasion from tyres and brakes) need to be accurately monitored.

Air quality within the Beaches Link tunnel would be monitored by a network of air quality sensors positioned in key locations along the length of the tunnel. These locations, and number of devices required within each tunnel carriageway, would be determined during detailed design and are expected to comply with the minimum requirements of *Specification R165* (NSW Roads and Maritime, 2017).

Air velocity sensors would be used to control the tunnel ventilation system in response to changes in the tunnel air quality, and during emergency operation to achieve critical velocity too. These sensors, located within each tunnel segment, are critical to maintaining effective and efficient operation of the fans and associated equipment.

The following pollutants would be monitored within the tunnel:

- Carbon monoxide (CO)
- Nitrogen oxide (NO)
- Nitrogen dioxide (NO_2)
- Visibility.

A generic description of the main pollutants to be monitored within the tunnel is provided below:

1. CO – is an odourless, colourless gas produced by incomplete oxidation (burning). Although any combustion process would contribute CO, in cities, petrol engine motor vehicles add greatly to the overall CO emissions. Other sources include fires and natural processes such as the oxidation, in the oceans and air, of methane produced from organic decomposition.

   CO enters the bloodstream through the lungs and inhibits transport of oxygen by blood, thereby reducing oxygen reaching the body's organs and tissues, especially the heart. Long exposure to high levels of CO causes headaches followed by unconsciousness. People suffering from heart disease are most at risk and may experience chest pain from CO exposure particularly while exercising.
2. NO and NO_2 – are pollutants resulting from the combustion of fossil fuels, especially in diesel engines. Most of the emitted oxides of nitrogen (NO_X) consist of NO, which is oxidised into NO_2 in the presence of oxygen (especially ozone (O_3)) and sunlight outside of the tunnel. NO by itself is not considered a harmful pollutant at commonly encountered levels. On the other hand, NO_2 is highly noxious, even at low concentrations, and can irritate the lungs and lower the resistance to respiratory infections such as influenza.
3. Visibility – the presence of particulate matter (PM) in the air leads to reduced visibility inside the tunnel. The consideration of visibility criteria in the design of the tunnel ventilation system is required due to the need for visibility levels that exceed the minimum vehicle stopping distance at the design speed. There are two primary sources of PM in a tunnel, exhaust emissions and non-exhaust emissions. Exhaust emissions consist of PM emanating from the tailpipe mainly as a result of the diesel combustion process. Non-exhaust PM consists of tyre and brake wear, road surface abrasion and re-suspended dust.

The location of air quality monitors is also critical in obtaining relevant data that is representative of the air quality within the tunnel. Typical locations for air quality monitors include:

- Within 100 metres from entry portals
- Within 100 metres from exit portals
- At the start and end of each tunnel segment
- At interface points with adjacent tunnels
- Within ventilation tunnels

- Other critical locations required for the effective operation of the ventilation system.

3.6 Emergency operation

In the event of an emergency, particularly a fire event, it is expected that vehicles upstream of the fire location would have stopped while those downstream of the fire location are able to continue driving out of the tunnel. Jet fans would be in operation to prevent back layering of smoke, directing the smoke away from the stopped vehicles, in the direction of travel. In the event of an emergency, motorists would be expected to evacuate the tunnel against the airflow, into the fresh air, as depicted in Figure 3-11.

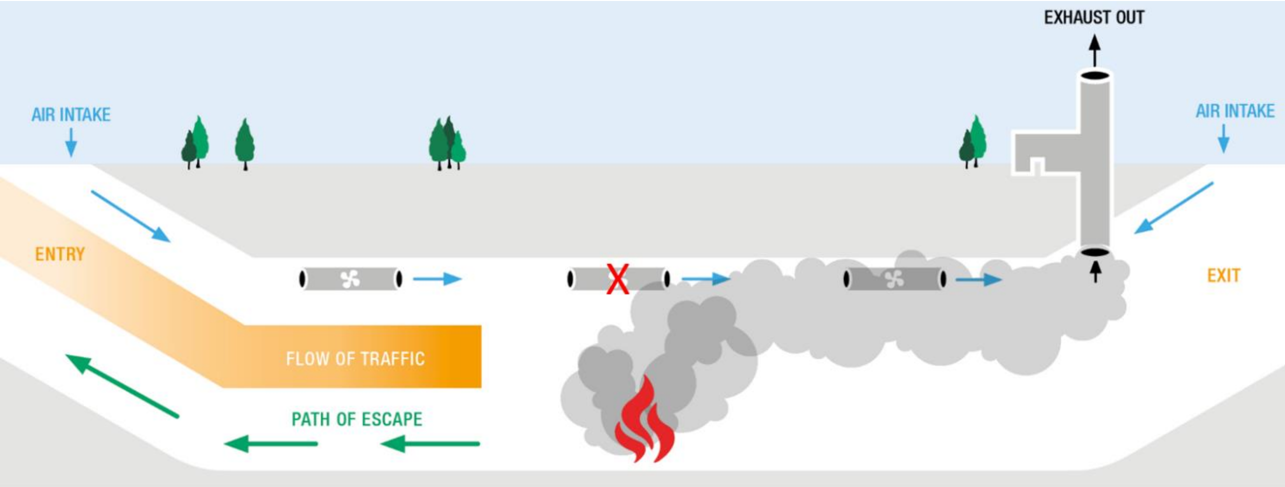


Figure 3-11 Longitudinal smoke management system in emergency operating mode

4 Design criteria

4.1 Basis of assessment

The design criteria are based on the following documents and reference guides:

- *In-Tunnel Air Quality (Nitrogen Dioxide) Policy* (NSW Government, Advisory Committee on Tunnel Air Quality, 2016)

  This technical paper notes the requirement of in-tunnel NO_2 design criteria
- *Road tunnels: vehicle emissions and air demand for ventilation, 2019R02EN* (PIARC Technical Committee D.5 Road Tunnels, 2019)

  This reference document from PIARC notes the design criteria as well as the emission values of different vehicle and fuel types. The document also provides guidance on the numerical relationship between turbidity, extinction coefficient and $PM_{2.5}$ emissions
- *Technical Paper 4: Road Tunnel Ventilation Systems* (NSW Government, Transport for NSW (then NSW Roads and Maritime) 2019)

  This technical paper provides information about the basis of design of road tunnel ventilation systems in NSW
- *Guide to Road Tunnels Part 2: Planning, Design and Commissioning* (Austroads, 2019)

  The Guide to Road Tunnels Part 2 provides guidance on design of new road tunnels in Australia and New Zealand as well as planning and commissioning. The expectation regarding appropriate design for road tunnels are outlined in the Guide.

4.2 In-tunnel air quality limits

Best practice in-tunnel air quality limits have been established by the NSW Advisory Committee on Tunnel Air Quality and applied on recent motorway projects in NSW including for this assessment. Accordingly, air quality within the Beaches Link tunnel must be maintained at or below the allowable limits shown in Table 4.1, independent of the adjacent Western Harbour Tunnel. The limits in Table 4.1 are derived from relevant limits detailed in *Technical Paper TP07: Criteria for In-tunnel and Ambient Air Quality* (Advisory Committee on Tunnel Air Quality, 2018). The average concentration along the tunnel refers to the average concentration of NO_2 and CO along all reasonable travel routes through the tunnel in a single direction.

Table 4.1 In-tunnel air quality limits for ventilation design

Pollutant/parameter	Concentration limit	Units of measurement	Type of measurement	Averaging period
CO	87	ppm	Average along tunnel	Rolling 15 min
CO	50	ppm	Average along tunnel	Rolling 30 min
CO	200	ppm	Maximum in tunnel	Rolling 3 min
NO_2	0.5	ppm	Average along tunnel	Rolling 15 min
Visibility	0.005	m^{-1}	Maximum in tunnel	Rolling 15 min

Source: *Transport for NSW design criteria (derived from relevant limits detailed in Table 4, 5 and 6 of Technical Paper TP07: Criteria for In-tunnel and Ambient Air Quality (Advisory Committee on Tunnel Air Quality, 2018)*

The air quality limits listed have been converted to the respective in-tunnel emission levels provided in Table 4.2, for steady-state modelling purposes. Since the modelling approach considers steady state spatial distribution of pollutants in the tunnel environment, the onerous CO concentration limit of 50 parts per million has been adopted for conservatism.

Table 4.2 Converted in-tunnel emission criteria for ventilation design

Pollutant/parameter	Concentration limit	Converted concentration limit	Type of measurement
CO	50ppm	57mg/m^3	Average along tunnel
NO_2	0.5ppm	940µg/m^3	Average along tunnel
Visibility	0.005m^{-1}	0.005m^{-1}	Maximum in tunnel

Steady-state modelling has been assumed throughout, regardless of the averaging period, with the stabilised pollutant concentration levels studied further. Steady-state modelling assumes an unchanged traffic flow and ventilation operation such that the parameters do not vary over time. Due to the stable variations in vehicle flow rate and average speeds, a steady-state modelling approach is appropriate. The steady-state emission concentration figures provided for in-tunnel air quality can be considered as for rolling average periods of 30 minutes, 15 minutes and 15 minutes for CO, NO_2 and visibility, respectively.

Due to improvements in vehicle engine operation in recent years, the dominant criterion for the development of the tunnel ventilation system is NO_2 (as opposed to CO).

4.2.1 Tunnel air speed criteria

The maximum allowable in-tunnel air velocity is assumed to be 10 metres per second to facilitate acceptable evacuation during emergency operation.

An air velocity greater than 10 metres per second is assumed to be permissible as an exception during normal operations, when the air speed is generated from the piston effect induced by free-flowing traffic.

4.2.2 Portal emission control

Portal emission control would be implemented via air inflow at all exit portals, at a nominal velocity of one metre per second as a rolling average over a 15 minute period, except:

- Where required to safely manage incidents
- During maintenance periods.

4.3 Emergency control

The tunnel ventilation system would be designed to not only provide adequate air quality within the tunnel but also manage smoke in case of a fire in the tunnel. The performance of the tunnel ventilation system for smoke management would be assessed for fire cases at critical locations.

4.3.1 Critical velocity requirement

Critical velocity is the minimum steady-state air velocity required to prevent back layering of smoke. To enhance life safety, during a fire event in the tunnel, the required minimum air velocity upstream of the fire is the critical velocity at the incident location. Critical velocity depends on the open cross-sectional area of the tunnel that is aerodynamically available for airflow, the tunnel height, the gradient, and the convective portion of the fire.

The critical velocity is determined in accordance with *NFPA 502 Standard for Road Tunnels, Bridges and Other Limited Access Highways* (National Fire Protection Association (NFPA)).

4.3.2 Fire locations

Individual fire cases have been modelled for each tunnel at the following critical locations:

- Mainline entry portal, where sufficient thrust needs to be applied to overcome the pressure drop from the length of the tunnel up to the exhaust point
- Prior to the low point in the main tunnel section, where fresh air needs to be provided against smoke stratification
- Prior to bifurcations to understand the split of smoke flow between the various legs of the tunnel
- Before exit portals on the mainline tunnel, to understand the required thrust to overcome the effects of vehicle blockage in a congested tunnel
- Before the air exchange point between the Beaches Link tunnel and Western Harbour Tunnel.

The locations selected are believed to be the most onerous from a ventilation perspective. If fires at these locations can be managed, fires at other locations in the tunnel are expected to be well within the capacity of the ventilation system, and also more easily managed, with some safety margin.

In addition to limiting smoke back layering upstream of the fire, the tunnel ventilation system can be used to limit smoke spread to adjacent tunnels (i.e. the Western Harbour Tunnel).

The resulting required critical velocities at the nominated locations are summarised in Table 4.3.

Table 4.3 Critical velocity at fire locations

Fire location	Control line – chainage	Critical velocity (metres per second
Traffic direction – northbound		
Warringah Freeway Upgrade Entry	M245 - 2250	2.84
Gore Hill Entry	M230 - 1400	3.02
Beaches Link Mainline before Low Point	M220 - 6125	2.6
Beaches Link Mainline before Bifurcation	M220 - 7075	2.6
Wakehurst Parkway Exit Ramp	M270 - 200	2.75
Balgowlah Exit	M220 - 8800	2.6
Traffic direction – southbound		
Balgowlah Entry	M222 - 500	2.6
M555 Reserve Road Exit	M555 - 425	3.39
M540 Gore Hill Exit	M522 - 300	3.26
Wakehurst Parkway Entry	M271 - 1000	2.75
Middle of Beaches Link Mainline before Low Point	M221 - 6150	2.6
Beaches Link Mainline before Gore Hill Exit	M221 - 4500	2.7
Warringah Freeway Upgrade Exit from Beaches Link	M242 - 630	3.23
Prior to Beaches Link-Western Harbour Tunnel Air Exchange	M221 - 2038	3.12

5 Tunnel ventilation assessment methodology

The performance of the tunnel ventilation system has been analysed for a variety of expected traffic conditions, as well as for worst-case variable speed scenarios and breakdowns. The scenarios analysed in this report are anticipated to encapsulate all feasible traffic scenarios for the Beaches Link tunnel and demonstrate that the ventilation system would be able to achieve the three key objectives outlined in Section 3.

Table 5.1 summarises the traffic and ventilation scenarios that have been assessed.

Table 5.1 Summary of traffic and ventilation scenarios

	Scenario	Fuel composition year	Traffic description	Speed	Analysis results
Expected traffic scenarios	'Do something'	2027	Beaches Link plus Warringah Freeway Upgrade No Western Harbour Tunnel Full WestConnex (including revised The Crescent Design), no Sydney Gateway	80 km/h mainline 60 km/h ramps	Section 7.1.1
	'Do something'	2037	Beaches Link plus Warringah Freeway Upgrade No Western Harbour Tunnel Full WestConnex (including revised The Crescent Design) plus Sydney Gateway	80 km/h mainline 60 km/h ramps	Section 7.1.2
	'Do something cumulative'	2027	With Beaches Link, Western Harbour Tunnel, and Warringah Freeway Upgrade Full WestConnex (including revised The Crescent Design) plus Sydney Gateway M6 Stage 1	80 km/h mainline 60 km/h ramps	Section 7.2.1
	'Do something cumulative'	2037	With Beaches Link, Western Harbour Tunnel, and Warringah Freeway Upgrade Full WestConnex (including revised The Crescent Design), plus Sydney Gateway M6 Stage 1	80 km/h mainline 60 km/h ramps	Section 7.2.2
	Extended journey	2037	With Beaches Link, Western Harbour Tunnel, and Warringah Freeway Upgrade Full WestConnex (including revised The Crescent Design), plus Sydney Gateway M6 Stage 1	80 km/h mainline 60 km/h ramps	Section 5.2.7
Worst case (variable speed)	20 km/h	2027	Beaches Link plus Warringah Freeway Upgrade No Western Harbour Tunnel Full WestConnex (including revised The Crescent Design), no Sydney Gateway	20 km/h	Section 8

	Scenario	Fuel composition year	Traffic description	Speed	Analysis results
	40 km/h	2027	Beaches Link plus Warringah Freeway Upgrade No Western Harbour Tunnel Full WestConnex (including revised The Crescent Design), no Sydney Gateway	40 km/h	Section 8
	60 km/h	2027	Beaches Link plus Warringah Freeway Upgrade No Western Harbour Tunnel Full WestConnex (including revised The Crescent Design), no Sydney Gateway	60 km/h	Section 8
	80 km/h	2027	Beaches Link plus Warringah Freeway Upgrade No Western Harbour Tunnel Full WestConnex (including revised The Crescent Design), no Sydney Gateway	80 km/h mainline 60 km/h ramps	Section 8
Worst case (Breakdown)	'Do something'	2027	Beaches Link plus Warringah Freeway Upgrade No Western Harbour Tunnel Full WestConnex (including revised The Crescent Design), no Sydney Gateway	20 km/h mainline	Section 9
	'Do something cumulative'	2027	With Beaches Link, Western Harbour Tunnel, and Warringah Freeway Upgrade Full WestConnex (including revised The Crescent Design) plus Sydney Gateway M6 Stage 1	20 km/h mainline	Section 9

5.1 Simulation software

The evaluation of airflow and air quality has been carried out on a one-dimensional (1D) aerodynamic and fire analysis software package called IDA Tunnel, version 1.2, by EQUA AB in Sweden (IDA Tunnel). IDA Tunnel was used for the design development of the tunnel ventilation system of the Western Harbour Tunnel and Beaches Link. It was also used for the New M5 and M4-M5 Link environmental impact statements, as well as for the design development of those projects.

IDA Tunnel is a verified, reputable software, developed especially for road tunnel ventilation system analysis due to its capability to model traffic flow, which determines the vehicle emissions, and the pollutant levels, in the tunnel.

It was selected due to the complexity of the tunnel network and associated operating scenarios with multiple assumptions and inputs such as traffic density, fleet composition, traffic average speeds and traffic splits being part of the assessment.

In addition, the aerodynamics of a tunnel system such as WHT-BL with converging/diverging tunnels and air extracted prior to the exit portals and discharge to atmosphere via the ventilation outlets is much more complicated than a straight tunnel.

The proposed 1D simulations provide a robust understanding of the airflow characteristics throughout the tunnel network. The tunnel network is divided into finite tunnel segments, with different geometrical and physical properties. Each of the small segments is then assumed to have the same average flow characteristics (e.g. velocity, temperature and emission rates) within it. The small segments together provide a bigger picture of the aerodynamic characteristics in the entire tunnel.

5.2 Simulation approach

The 1D simulations carried out provide a robust understanding of the air flow characteristics throughout the tunnel network. For the simulations, the tunnel network has been divided into finite tunnel segments, each having different geometrical and physical properties. Each of these segments are then assumed to have the same average flow characteristics (e.g. velocity, temperature, emission rates, etc) within it. The aggregation of the segments provides a complete picture of the aerodynamic characteristics through the entire tunnel.

5.2.1 Models

The simulation model concentrates on the Beaches Link Tunnel. There are two geometry models for the calculation:

1. Beaches Link – Project Only
2. Beaches Link and Western Harbour Tunnel – Cumulative Model.

The overall underground road tunnel network consists of the following major tunnels:

- M6 Stage 1
- WestConnex (M4 East, New M5 and M4-M4 Link)
- Western Harbour Tunnel
- Beaches Link.

Whilst these tunnels are physically connected, the use of the air exchange points at the tunnel interfaces allow the tunnels to be monitored, controlled and analysed separately. These fixed boundary conditions are independent of traffic and applied at the tunnel connection from/to the Western Harbour Tunnel to/from the Beaches Link tunnel.

When the tunnel is operational and the change in traffic is not significant, the airflow and in-tunnel air quality would reach a steady state condition, which forms the basis of the simulations.

5.2.2 Emission calculation

Concentrations of three pollutants have been studied for the in-tunnel air quality assessment:

1. Average CO concentrations (parts per million) along all possible routes
2. Average NO_2 concentrations (parts per million) along all possible route
3. Maximum visibility (m^{-1}) along the tunnel (which is affected by exhaust $PM_{2.5}$ emissions).

Over the years, the advancement of vehicle emission standards and the accompanying vehicle technology developed has resulted in an overall reduction in CO emissions, comparatively well below that of NO_X (NO_2) and PM. The dominant pollutant determining the ventilation system operation is NO_2. The following section provides an overview of the route average NO_2 concentration modelling methodology.

5.2.2.1 Route average NO_2 concentration calculation

The key criterion for in-tunnel air quality assessment is the average NO_2 concentration along every possible route through the tunnel network. This is calculated assessing the NO_2 level in each finite tunnel segment (or grid cells) over the length of each cell. The assessment method calculates the NO_2 generated in the cell by vehicle emissions and includes the ambient background level of NO_2. The final average NO_2 level calculated can be expressed by the following equation:

$$Average\ NO2\ level\ along\ a\ route\ = \frac{\sum((NO_2)_{cell} \times Length_{cell})}{Total\ Route\ Length}$$

The grid length varies along the length of the tunnel network depending on the length of each underground ramp, and any changes in tunnel features. Where there are rapid geometry changes, the grid lengths would generally be shorter to capture the aerodynamic details.

Figure 5-1 depicts an example of NO_2 levels along the first 2000 metres of a mainline tunnel and an on-ramp joining at 1000 metres.

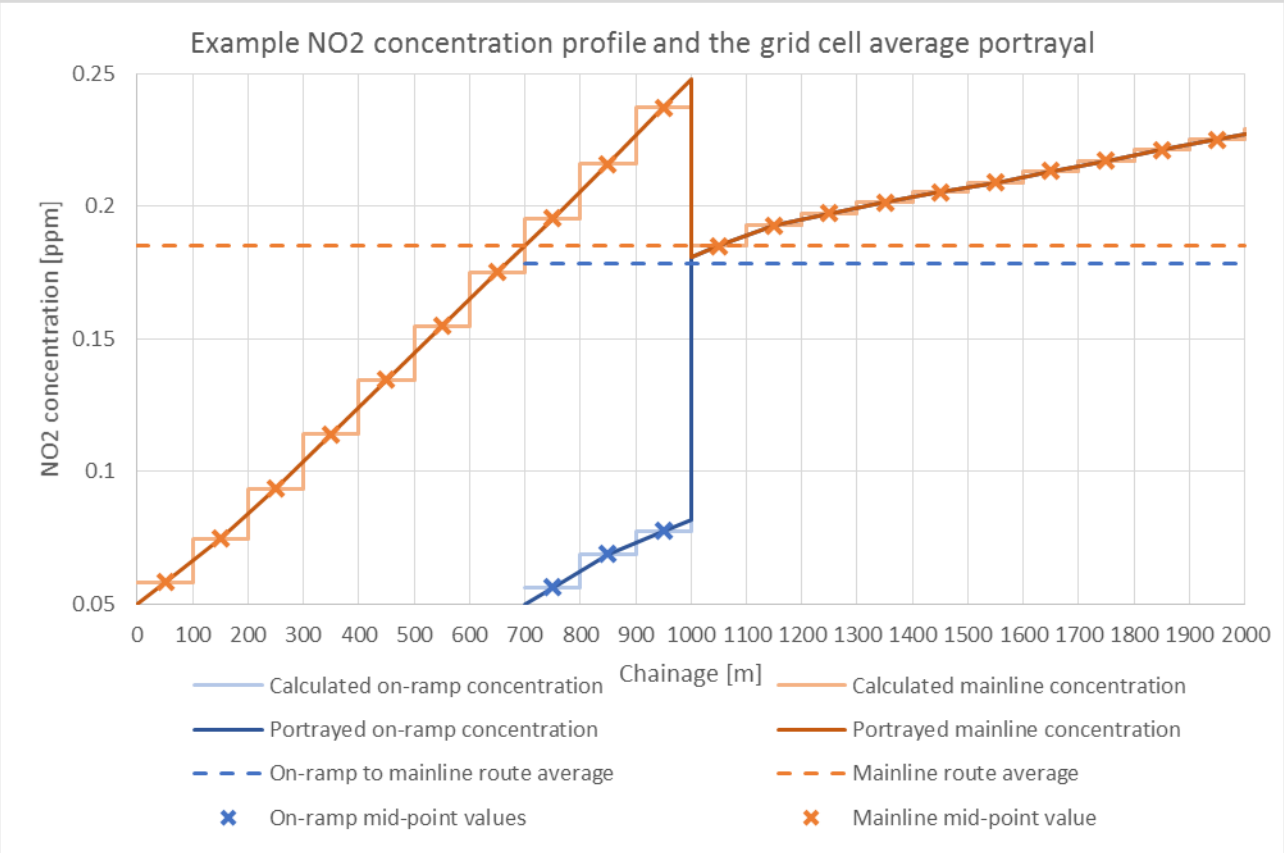


Figure 5-1 Example NO_2 concentration profiles in the first 2000 metres of a tunnel

The NO_2 concentration levels have been calculated for the routes using the methodology outlined above. For routes continuing from, and onto, adjacent tunnels of the Western Harbour Tunnel, boundary conditions are applied as background NO_2 levels, which is ambient NO_2 level plus vehicle emissions from the air exchange to the tunnel interface point. For the 'cumulative' case assessment with the Western Harbour Tunnel, both tunnels were modelled together.

Each tunnel is capable of being operated independently, and each tunnel is assessed separately for air quality levels. Provided that each tunnel along the underground journey from the M6 Stage 1 via WestConnex and the Western Harbour Tunnel to the Beaches Link meets the same air quality criteria, the average along the entire route is expected to meet the air quality criteria for NO_2 and CO.

5.2.2.2 Assessed routes

All possible routes within the Beaches Link have been assessed to meet the in-tunnel air quality criteria. Each route starts either at an entry portal or a tunnel interface point with an adjacent tunnel and ends at an exit portal or at a tunnel interface point with the next tunnel.

Figure 5-2 and Figure 5-3 portray the tunnel layouts and show the tunnel entries and exits for the 'Do something' and 'Do something cumulative' scenarios.

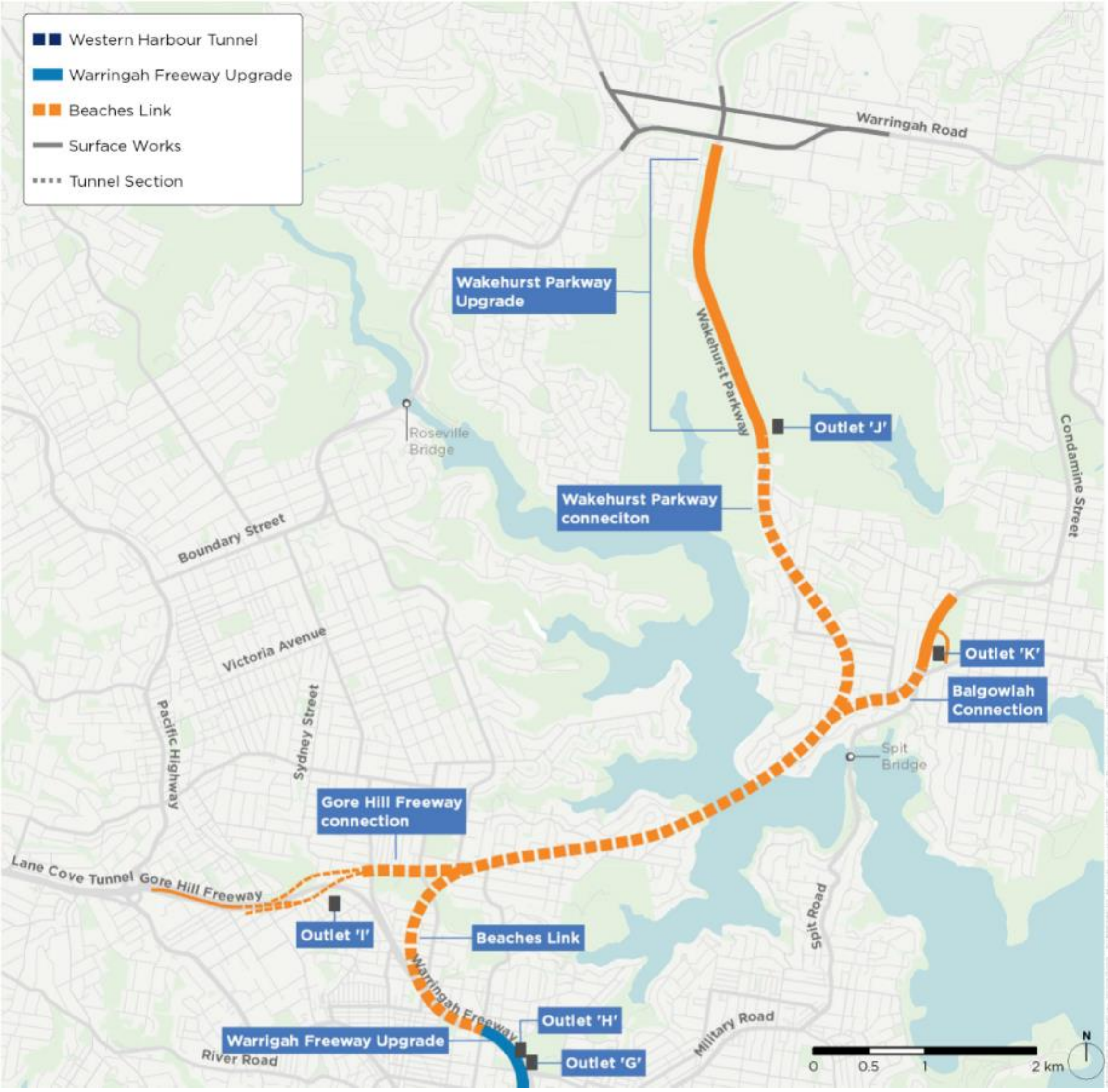


Figure 5-2 Beaches Link tunnel overview (to be read with Table 5.2 for various possible routes)

The routes in Table 5.2 are assessed for in-tunnel air quality for the 'Do something' scenario.

Table 5.2 'Do something' scenario travel routes

Route ID	Entry portal	Exit portal	Lengths
Northbound			
DS-NB-A	Warringah Freeway Upgrade Entry	Balgowlah (Beaches Link) Exit	7.2 km
DS-NB-B	Warringah Freeway Upgrade Entry	Wakehurst Parkway (Beaches Link) Exit	8.8 km
DS-NB-C	Gore Hill (Beaches Link) Entry	Balgowlah (Beaches Link) Exit	6.6 km
DS-NB-D	Gore Hill (Beaches Link) Entry	Wakehurst Parkway (Beaches Link) Exit	8.1 km
Southbound			
DS-SB-A	Wakehurst Parkway (Beaches Link) Entry	M540 Gore Hill (Beaches Link) Exit	8.2 km
DS-SB-B	Wakehurst Parkway (Beaches Link) Entry	M555 Reserve Road (Beaches Link) Exit	8.4 km
DS-SB-C	Balgowlah (Beaches Link) Entry	M540 Gore Hill (Beaches Link) Exit	6.6 km
DS-SB-D	Balgowlah (Beaches Link) Entry	M555 Reserve Road (Beaches Link) Exit	6.8 km
DS-SB-E	Balgowlah (Beaches Link) Entry	Warringah Freeway Upgrade Exit	7.3 km
DS-SB-F	Wakehurst Parkway (Beaches Link) Entry	Warringah Freeway Upgrade Exit	8.9 km

For the 'Do something cumulative' scenario, in-tunnel air quality has been assessed for all possible routes within the Beaches Link and ending at the Beaches Link to Western Harbour Tunnel connection and all the possible routes all the way from/to Beaches Link to Balgowlah and Wakehurst Parkway to the M4-M5 Link Mainline Tunnel Connection and the Rozelle Interchange exit.

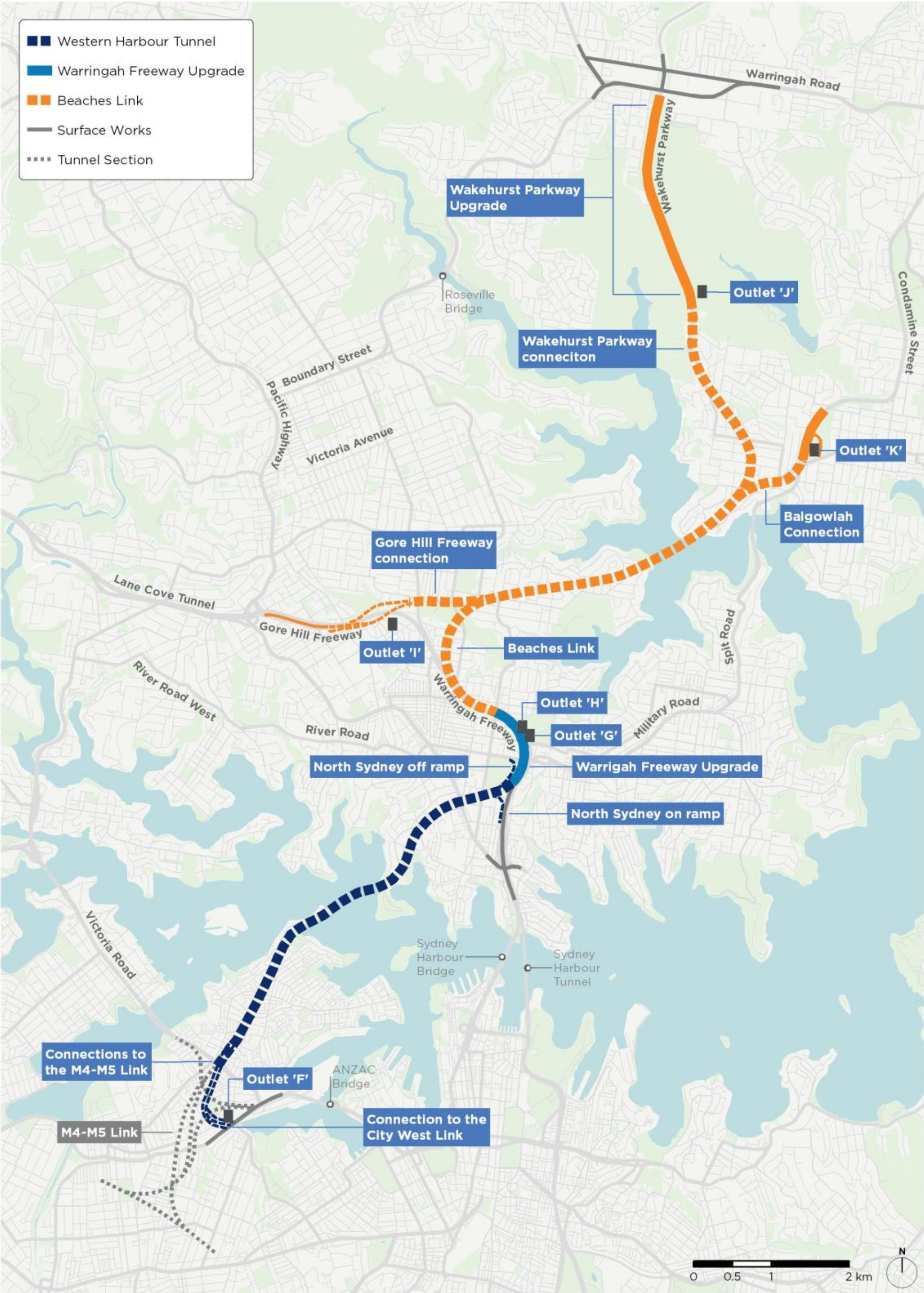


Figure 5-3 Cumulative tunnel overview (to be read with for various possible routes)

Table 5.3 Cumulative case travel routes

Route ID	Entry portal	Exit portal	Length
Northbound			
DSC-NB-A	Warringah Freeway Upgrade Entry	Balgowlah (Beaches Link) Exit	7.2 km
DSC-NB-B	Warringah Freeway Upgrade Entry	Wakehurst Parkway (Beaches Link) Exit	8.8 km
DSC-NB-C	Gore Hill (Beaches Link) Entry	Balgowlah (Beaches Link) Exit	6.6 km
DSC-NB-D	Gore Hill (Beaches Link) Entry	Wakehurst Parkway (Beaches Link) Exit	8.1 km
DSC-NB-E	Western Harbour Tunnel-Beaches Link Connection	Balgowlah (Beaches Link) Exit	8.9 km
DSC-NB-F	Western Harbour Tunnel-Beaches Link Connection	Wakehurst Parkway (Beaches Link) Exit	10.5 km
DSC-NB-G	Rozelle Interchange (Western Harbour Tunnel) Entry	Balgowlah (Beaches Link) Exit	14.3 km
DSC-NB-H	Rozelle Interchange (Western Harbour Tunnel) Entry	Wakehurst Parkway (Beaches Link) Exit	15.9 km
DSC-NB-I	M4-M5 Link (Western Harbour Tunnel) Entry	Balgowlah (Beaches Link) Exit	13.5 km
DSC-NB-J	M4-M5 Link (Western Harbour Tunnel) Entry	Wakehurst Parkway (Beaches Link) Exit	15.1 km
Southbound			
DSC-SB-A	Wakehurst Parkway (Beaches Link) Entry	M540 Gore Hill (Beaches Link) Exit	8.2 km
DSC-SB-B	Wakehurst Parkway (Beaches Link) Entry	M555 Reserve Road (Beaches Link) Exit	8.4 km
DSC-SB-C	Balgowlah (Beaches Link) Entry	M540 Gore Hill (Beaches Link) Exit	6.6 km
DSC-SB-D	Balgowlah (Beaches Link) Entry	M555 Reserve Road (Beaches Link) Exit	6.8 km
DSC-SB-E	Balgowlah (Beaches Link) Entry	Beaches Link-Western Harbour Tunnel Connection	7.7 km
DSC-SB-F	Balgowlah (Beaches Link) Entry	Warringah Freeway Upgrade Entry	7.3 km
DSC-SB-G	Wakehurst Parkway (Beaches Link) Entry	Beaches Link-Western Harbour Tunnel Connection	9.3 km
DSC-SB-H	Wakehurst Parkway (Beaches Link) Entry	Warringah Freeway Upgrade Entry	8.9 km
DSC-SB-I	Balgowlah (Beaches Link) Entry	M116 Rozelle (Western Harbour Tunnel) Exit	14.2 km
DSC-SB-J	Balgowlah (Beaches Link) Entry	M115 Rozelle (Western Harbour Tunnel) Exit	14.3 km
DSC-SB-K	Balgowlah (Beaches Link) Entry	M4-M5 Link (Western Harbour Tunnel) Exit	13.6 km
DSC-SB-L	Wakehurst Parkway (Beaches Link) Entry	M116 Rozelle (Western Harbour Tunnel) Exit	15.9 km
DSC-SB-M	Wakehurst Parkway (Beaches Link) Entry	M115 Rozelle (Western Harbour Tunnel) Exit	15.9 km
DSC-SB-N	Wakehurst Parkway (Beaches Link) Entry	M4-M5 Link (Western Harbour Tunnel) Exit	15.2 km

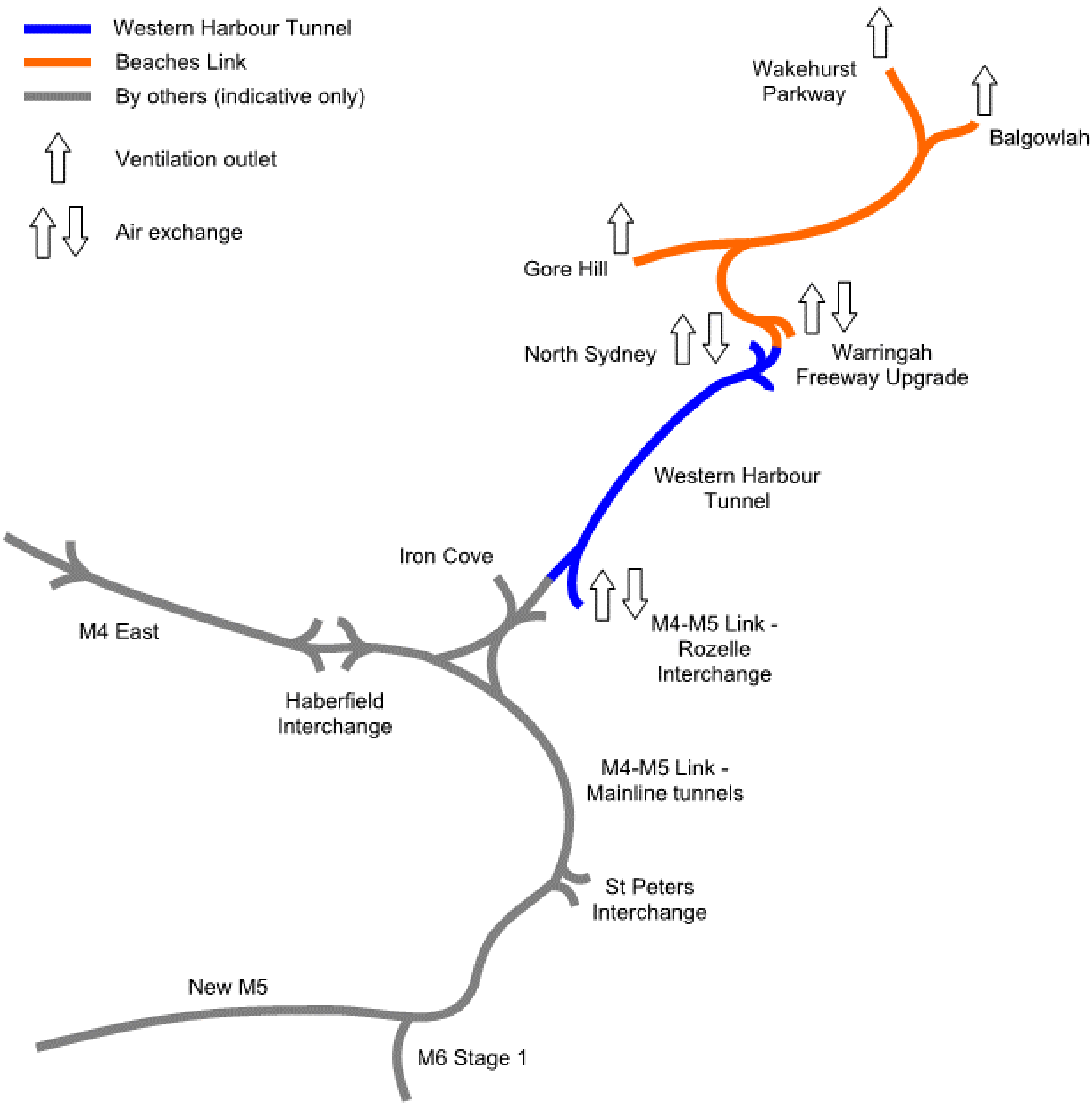


Figure 5-4 Schematic of extended underground journeys (to be read with Table 5.4 for various possible routes)

Table 5.4 Extended journey travel routes

Route ID	Entry portal	Exit portal	Length
Northbound			
EJ-NB-A	New M5 Kingsgrove Entry	Wakehurst Parkway (Beaches Link) Exit	30.6 km
EJ-NB-B	M4 East Entry Portal (Homebush) Entry	Wakehurst Parkway (Beaches Link) Exit	25.3 km
EJ-NB-C	M6 Stage 1 (Rockdale) Entry	Wakehurst Parkway (Beaches Link) Exit	28.5 km
Southbound			
EJ-SB-A	Balgowlah (Beaches Link) Entry	New M5 Kingsgrove Exit	28.9 km
EJ-SB-B	Balgowlah (Beaches Link) Entry	M4 East Entry Portal (Homebush) Exit	23.6 km
EJ-SB-C	Balgowlah (Beaches Link) Entry	M6 Stage 1 (Rockdale) Exit	26.8 km

5.2.3 Expected traffic operations (24 hours)

The Strategic Motorway Planning Model (SMPM) provides a strategic traffic forecast in the vicinity of the Beaches Link and Western Harbour Tunnel for the AM Peak, Inter-peak, PM Peak, and Evening periods for year 2027 and 2037. The time periods represent:

- AM peak – 7.00am to 9.00am
- Inter-peak period – 9.00am to 3.00pm
- PM peak – 3.00pm to 6.00pm
- Evening – 6.00pm to 7.00am

The SMPM results are provided in the form of traffic flow rate and average vehicle speed for a tunnel section, such as the entry ramps, mainline, and the exit ramps. In addition, the operational traffic model predicts the distribution of traffic at the Rozelle Interchange exit from the Western Harbour Tunnel in the southbound direction, and the bus traffic in the Beaches Link tunnel. The results from the operational traffic model have been applied for the years 2027 and 2037.

The combination of traffic demand predictions and trends provide an input to the calculation of the expected configuration of tunnel ventilation operations over a 24-hour profile.

As the predicted traffic density is below the theoretical maximum vehicle lane capacity for the given average vehicle speed, the models have been run at free-flowing traffic conditions. This means that under normal operations, congestion should not be encountered.

With the given traffic flow rate and traffic speed, the conclusion was that the tunnel would be self-ventilating, and that the exit portal tunnel inflow air velocity criteria could be managed purely using the axial extraction fans.

5.2.4 Worst-case (variable speed) traffic operation

The worst-case (variable speed) traffic operation is the scenario where mainline reaches the theoretical maximum lane capacity in terms of traffic flow rate. In addition, the highest predicted bus numbers have been introduced to the Beaches Link tunnel simulation model that connects to the Western Harbour Tunnel.

Four different average speeds for the lane capacity traffic operations were considered:

1. 20 km/h
2. 40 km/h
3. 60 km/h, with M555 Reserve Road Exit ramp at 50 km/h
4. 80 km/h, with the relevant ramps of Beaches Link tunnel at 60km/h and M555 Reserve Road Exit ramp at 50 km/h.

These are intended to represent an upper bound on daily operations for the ventilation system, regardless of year of operation.

5.2.5 Worst-case (breakdown or major incident) operation

The tunnel ventilation system is designed to cater for various traffic scenarios, including a case where there is a breakdown at a point along the tunnel, resulting in congestion and the need for traffic management to be implemented.

One scenario studied was to assess the most onerous case, from a traffic perspective, where the resulting congestion due to a breakdown affects the longest length within the tunnel. It was assumed that a breakdown would cause a complete blockage of a specific ramp, or exit, causing traffic to take other routes. It was assumed that downstream of the breakdown, the tunnel would be free of vehicles, including a reasonable allowance for surface road congestion or congestion due to traffic signals. It was assumed that upstream of the breakdown there would be a queue of vehicles that had stopped. However, as these vehicles would be instructed to switch off their engines, the simulation is not expected to be affected other than for increased drag due to the blockage from the vehicles.

The following traffic incident scenarios have been studied, including the potential for surface traffic congestions in the immediate vicinity of the tunnel, to arrive at the worst-case scenario:

Table 5.5 Possible traffic breakdown locations

Arrangement	Traffic direction	Breakdown location
'Do something'	Northbound	Wakehurst Parkway Exit
'Do something'	Northbound	Balgowlah Exit
'Do something'	Southbound	Gore Hill Exit
'Do something'	Southbound	North Sydney Exit
'Do something cumulative'	Northbound	Wakehurst Parkway Exit
'Do something cumulative'	Northbound	Balgowlah Exit
'Do something cumulative'	Southbound	Gore Hill Exit
'Do something cumulative'	Southbound	North Sydney Exit
'Do something cumulative'	Southbound	Beaches Link-Western Harbour Tunnel Connection

The most onerous case from the traffic perspective was determined to be the case where there is a breakdown southbound on the Warringah Freeway exit ramp. Further details of this scenario can be found in Section 6.1.3.4.

5.2.6 Temperature estimates

The air quality, at a given airflow rate and temperature, at each ventilation outlet supports the plume rise assessment. The temperature differential between the ventilation outlet temperature and ambient temperature is a key variable in dispersion modelling to be able to understand the buoyancy effects of the exhaust air.

During normal operation, ambient air enters the tunnels from on-ramps and moves in the travel direction due to the piston effect created by the moving vehicles. Heat transfer between the vehicle engines and the air is assumed to occur, thereby theoretically increasing the air temperature. However, in a similar way heat is also transferred from the air to the cooler tunnel walls, which effectively behave as a heat sink and cool the air. The extent of heat transferred to the tunnel walls is a function of thermal properties of the material surrounding the tunnel and the ambient conditions of the area.

Operational temperature data obtained from the Lane Cove Tunnel has been considered as representative of the temperature differential between the tunnel air and ambient temperatures, as the traffic, ambient conditions and geology are similar to that of the Beaches Link Tunnel. The recorded data was used to derive the maximum and average differences between the ventilation outlet temperature and the ambient air temperature. When calculating the average temperature difference, conservatively, any negative values were disregarded.

Heat transfer, and therefore the air temperature within the tunnels, has not been assessed using IDA Tunnel as PIARC does not provide emission factors for different ambient temperatures.

Table 5.6 summarises the maximum and average temperature difference, in any given month, in the year 2016 for the Lane Cove Tunnel.

Table 5.6 Site data of maximum and average temperature difference at Lane Cove Tunnel

Month	Predicted maximum temperature difference (ºC)	Predicted average temperature difference (ºC)
January	12	4
February	11	5
March	12	6
April	11	6
May	13	7
June	13	7
July	13	7
August	12	7
September	11	6
October	13	6
November	12	6
December	11	5

5.2.7 2037 Extended journey air quality

The average concentration of NO_2 has been estimated for longest potential journeys through Western Harbour Tunnel and Beaches Link and the adjacent connected tunnels. Accordingly, the Western Harbour Tunnel and Beaches Link, WestConnex network and the M6 Stage 1 tunnel network was identified as the longest potential tunnel journey that could be taken by motorists and was considered from a cumulative in-tunnel air quality impact perspective.

It is accepted that in-tunnel air-quality would vary depending on fleet mix, density, average traffic speed and the performance of each of the individual tunnel ventilation systems. However, regardless of this, it is also expected that each project would be responsible for maintaining NO_2 concentrations below an average of 0.5 parts per million over the length of the tunnel, consistent with existing recent approvals for NorthConnex, M4 East and New M5. Provided that each project satisfies the air quality criteria, the average through the entire network would remain at, or below, 0.5 parts per million under all traffic conditions.

The extension of the journey from the WestConnex network-M6 Stage 1 into the Western Harbour Tunnel and Beaches Link tunnels (or vice versa), does not require the re-modelling of NO_2 concentrations along the full length of this network, instead, it provides an opportunity to combine the results into a single estimate of averaged NO_2.

The estimated average NO_2 concentrations along the extended journeys, carried out as part of the M4-M5 Link environmental impact statement assessment, have been combined with those modelled as part of the Western Harbour Tunnel and Beaches Link and summarised in Table 5.7 and Table 5.8. The tunnel network is portrayed in Figure 5-4.

Table 5.7 Extended journey 2037 northbound in-tunnel air quality results

Period	Route ID	DSC-NB-J	EJ-NB-A	EJ-NB-B	EJ-NB-C
	Entry portal	M4-M5 Link	New M5 Kingsgrove	M4 East Entry Portal (Homebush)	M6 Stage 1 (Rockdale)
	Exit portal	Wakehurst Parkway	Wakehurst Parkway	Wakehurst Parkway	Wakehurst Parkway
	Lengths	15.1 km	30.6 km	25.3 km	28.5 km
7.00 to 9.00	Avg NO_2 [ppm][1]	0.20	0.35	0.32	0.34
9.00 to 10.00	Avg NO_2 [ppm]	0.20	0.35	0.32	0.34
10.00 to 15.00	Avg NO_2 [ppm]	0.20	0.35	0.32	0.34
15.00 to 16.00	Avg NO_2 [ppm]	0.20	0.35	0.32	0.34
16.00 to 17.00	Avg NO_2 [ppm]	0.20	0.35	0.32	0.34
17.00 to 18.00	Avg NO_2 [ppm]	0.20	0.35	0.32	0.34
18.00 to 19.00	Avg NO_2 [ppm]	0.11	0.31	0.27	0.29
19.00 to 7.00	Avg NO_2 [ppm]	0.11	0.31	0.27	0.29

Notes:
(1) NO_2 Average 0.5 ppm

Table 5.8 Extended journey 2037 southbound in-tunnel air quality results

Period	Route ID	DSC-SB-K	EJ-SB-A	EJ-SB-B	EJ-SB-C
	Entry portal	Balgowlah	Balgowlah	Balgowlah	Balgowlah
	Exit portal	M4-M5 Link	New M5 Kingsgrove	M4 East Entry Portal (Homebush)	M6 Stage 1 (Rockdale)
	Lengths	13.6 km	28.9 km	23.6 km	26.8 km
7.00 to 8.00	Avg NO_2 [ppm][1]	0.19	0.35	0.32	0.34
8.00 to 9.00	Avg NO_2 [ppm]	0.19	0.35	0.32	0.34
9.00 to 10.00	Avg NO_2 [ppm]	0.16	0.34	0.30	0.33
10.00 to 15.00	Avg NO_2 [ppm]	0.16	0.34	0.30	0.33
15.00 to 16.00	Avg NO_2 [ppm]	0.15	0.34	0.30	0.32
16.00 to 17.00	Avg NO_2 [ppm]	0.15	0.34	0.30	0.32
17.00 to 18.00	Avg NO_2 [ppm]	0.15	0.34	0.30	0.32
18.00 to 19.00	Avg NO_2 [ppm]	0.09	0.31	0.26	0.29
19.00 to 6.00	Avg NO_2 [ppm]	0.09	0.31	0.26	0.29
6.00 to 7.00	Avg NO_2 [ppm]	0.09	0.30	0.25	0.28

Notes:
(1) NO_2 Average 0.5 ppm

These figures include the case average NO_2 concentrations throughout the WestConnex network-M6 Stage 1 side of the tunnel network provided within M4-M5 Link Ventilation Report for environmental impact statement, 26 July 2017, Section 9 [1]. The results of the analysis carried out as part of that work, suggest that an assumption of average 0.5 parts per million NO_2 concentration throughout the WestConnex network-M6 Stage 1 tunnel network, would be conservative.

The aerodynamic decoupling of adjacent projects mentioned earlier in this report provides a break in emission concentrations, back down to much lower levels, at the project interfaces, via the use of air exchange points.

Ideally, air exchange points would facilitate the full exchange of tunnel air via the use of exhaust and supply points, just upstream of the adopted project interface boundaries. They enable vitiated air to be exhausted from the tunnel and replaced with fresh air from outside. To conserve energy, the operation air exchanges would vary from time to time provided that each tunnel within the network continues to maintain in-tunnel air quality compliance, as set out in Section 3 of this report.

It is recognised that the failure of one tunnel to meet its air quality obligations may jeopardise the air quality compliance of the adjacent tunnel (e.g. the inadequate operation of the air exchange for whatever reason), however, the environmental impact statement ventilation analysis does not assess scenarios where an adjacent tunnel does not meet its air quality criteria.

Although traffic management systems are expected to be implemented at various times (e.g. during peak or incident operation), sustained travel at average 20 km/h over the considered extended journey is viewed as unlikely, with motorists advised of alternative exit routes and surface detours.

6 Input data and design assumptions

6.1 Input data

6.1.1 Assessment years

The assessment years are 2027 and 2037. The basis for the assessment years is the strategic traffic forecast in the vicinity of the Beaches Link and Western Harbour Tunnel provided by SMPM.

6.1.2 Tunnel geometry

6.1.2.1 Tunnel wall friction factors

The wall friction factors for the tunnel ventilation design are shown in Table 6.1. These are based on Australian tunnels with similar construction. The friction factor accounts for losses due to traffic signs, lighting, deluge pipes, and other equipment/devices creating an obstruction within the tunnel.

Table 6.1 Tunnel wall friction factor

Traffic scenario	Tunnel friction factor
Free flowing traffic	0.035
Slow moving traffic speeds	0.035
Stopped traffic	0.035

6.1.2.2 Typical cross-sections

Table 6.2 summarises the tunnel cross section geometry inputs.

Table 6.2 Tunnel cross sectional geometry

Tunnel type	3-lane undrained tunnel	3-lane tunnel umbrella	2-lane undrained tunnel	2-lane tunnel umbrella	Immersed Tube
Number of Lanes	3	3	2	2	3
Cross Sectional Area (m^2)	106	106	80	80	82
Perimeter (m)	42	42	36	36	41
Hydraulic Diameter (m)	10.0	10.0	8.9	8.9	8.0
Tunnel Height (m)	7.9	7.9	7.9	7.9	5.9

6.1.2.3 Vertical alignment

Figure 6-1, Figure 6-2, Figure 6-3, and Figure 6-4 show the vertical alignment adopted. It should be noted that different vertical and horizontal scales are used within the graphs and as such tunnel gradients appear exaggerated. Please refer to Figure 3-2 and Figure 3-3 for the codes used for tunnel segments and ramps.

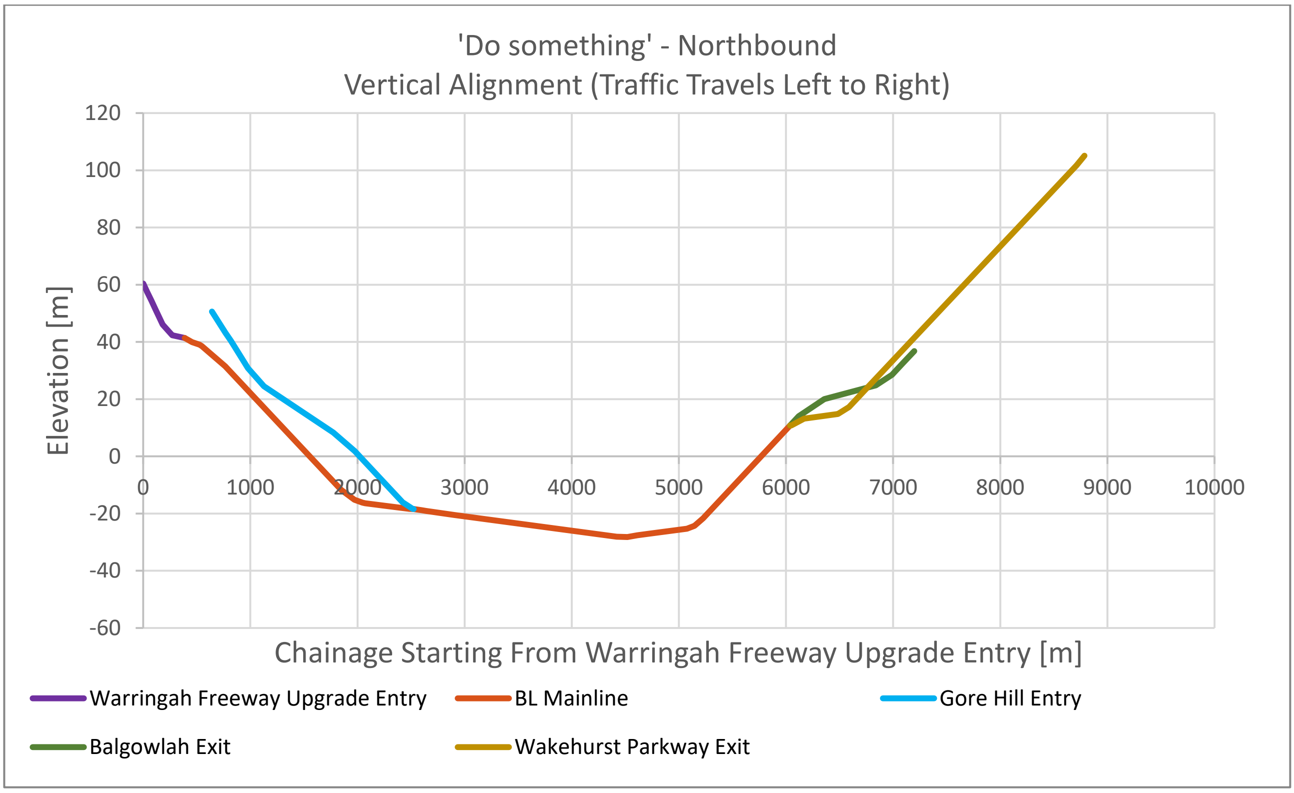


Figure 6-1 Beaches Link 'Do something' (project only) northbound vertical alignment

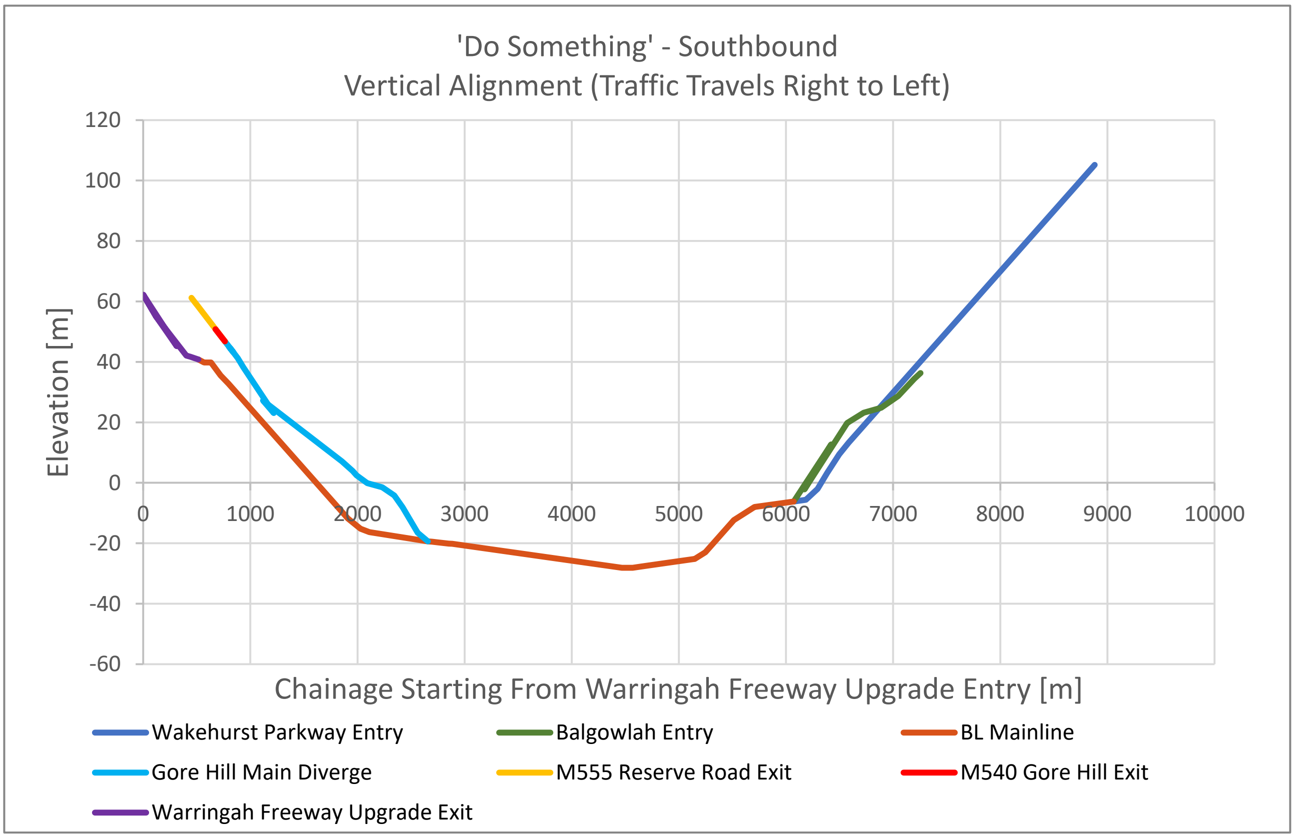


Figure 6-2 Beaches Link 'Do something' (project only) southbound vertical alignment

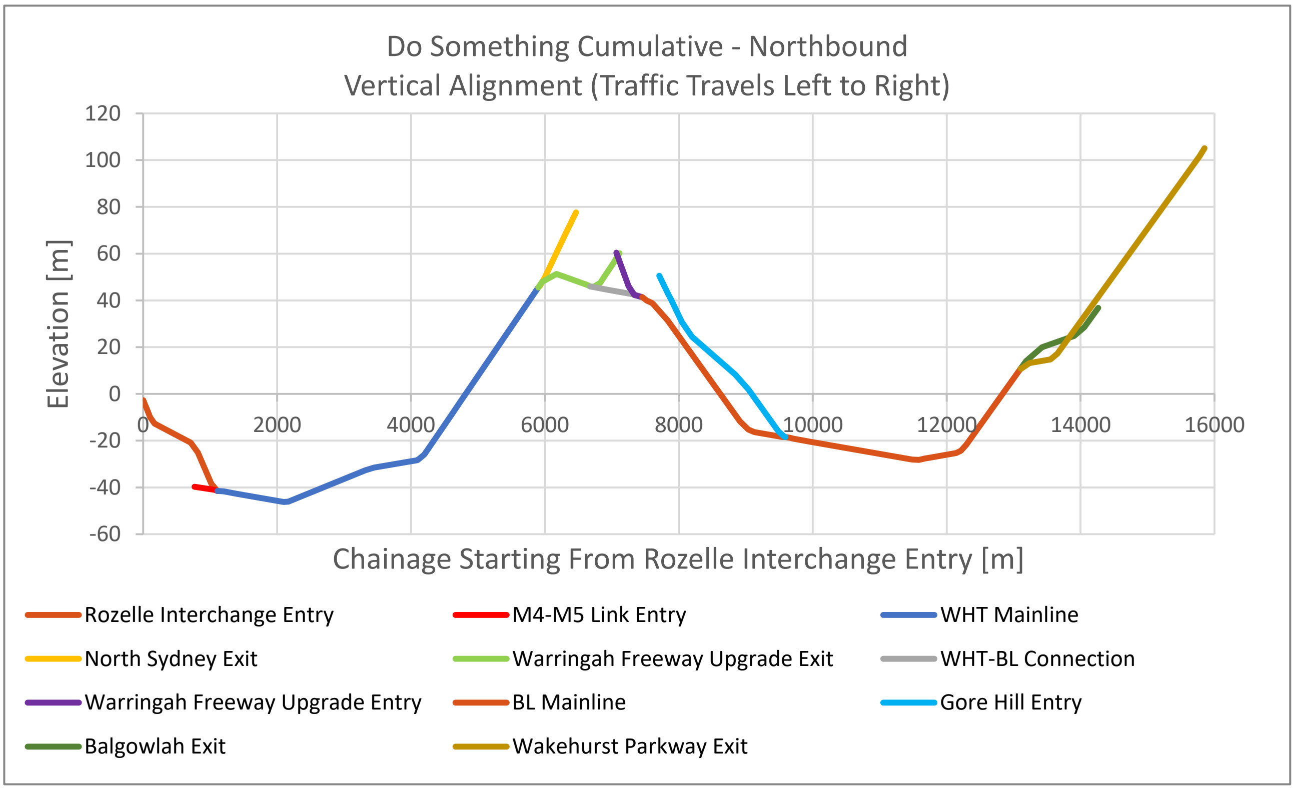


Figure 6-3 Northbound ‘Do something cumulative’ vertical alignment

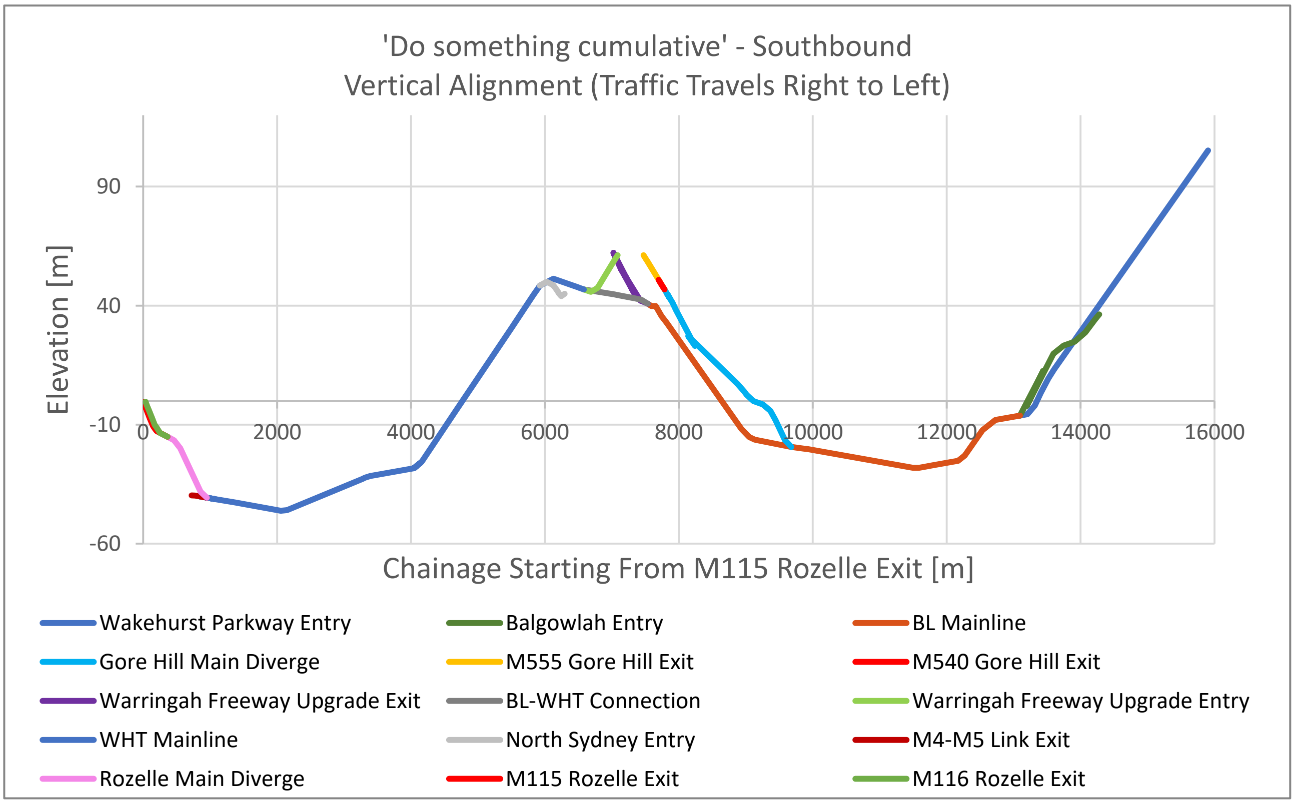


Figure 6-4 Southbound cumulative vertical alignment

6.1.3 Traffic

The analysis is centred around the following key traffic conditions:

- Traffic scenarios outlined in Table 6.3
- Traffic flow at maximum theoretical capacity (variable speed)
- Breakdown scenario
- Emergency operation.

Table 6.3 Expected traffic scenarios and description

Expected traffic scenario	Description
'Do something 2027' (i.e. with project)	Beaches Link No Western Harbour Tunnel plus Warringah Freeway Upgrade
'Do something cumulative 2027' (i.e. with the full Western Harbour Tunnel and Beaches Link)	With Western Harbour Tunnel, Warringah Freeway Upgrade and Beaches Link Full WestConnex M6 Stage 1
'Do something 2037' (i.e. with project)	Beaches Link No Western Harbour Tunnel plus Warringah Freeway Upgrade
'Do something cumulative 2027' (i.e. with the full Western Harbour Tunnel and Beaches Link)	With Western Harbour Tunnel, Warringah Freeway Upgrade and Beaches Link Full WestConnex M6 Stage 1

Table 6.4 provides a description of different traffic cases.

Table 6.4 Description of traffic cases

Term	Explanation
Expected traffic (24 hour)	Tunnel ventilation operations with 24 hourly expected traffic forecasts by SMPM. This is intended to represent the (average) day-to-day operations of the ventilation system subjected to forecast traffic demand. The SMPM forecasts the traffic flow of passenger cars, light-duty vehicles and heavy-duty vehicles.
Worst-case scenario (variable speed)	Tunnel ventilation operations where the traffic is at its theoretical maximum capacity in the tunnel for any given speed.
Worst-case scenario (breakdown mode)	Tunnel ventilation operations for onerous traffic conditions for the ventilation system. These simulations are based on a major incident or a breakdown causing a closure of a tunnel. In the tunnel ramp at the location of the incident, it is assumed that the tunnel is blocked. In other locations, different vehicle speeds are assumed at maximum theoretical traffic capacity.
Emergency operation	The emergency scenario refers to cases with fire.

6.1.3.1 Traffic data for expected scenarios

The posted speed limit in the mainline tunnels and in motorway to motorway connections would be 80 km/h, with entry/exit ramps having a speed limit of 60 km/h. However, for the modelling, the predicted average vehicle speeds from the SMPM were applied. These are typically between 77 and 80 km/h on the mainline and 55 to 63 km/h on the ramps, except on the M555 Reserve Road exit ramp from the Beaches Link mainline, where it is about 50 km/h.

The daily traffic flows for each scenario provided by SMPM were applied for the assessment. The traffic figures used for the assessment have been graphed in Figure 6-5 to Figure 6-12.

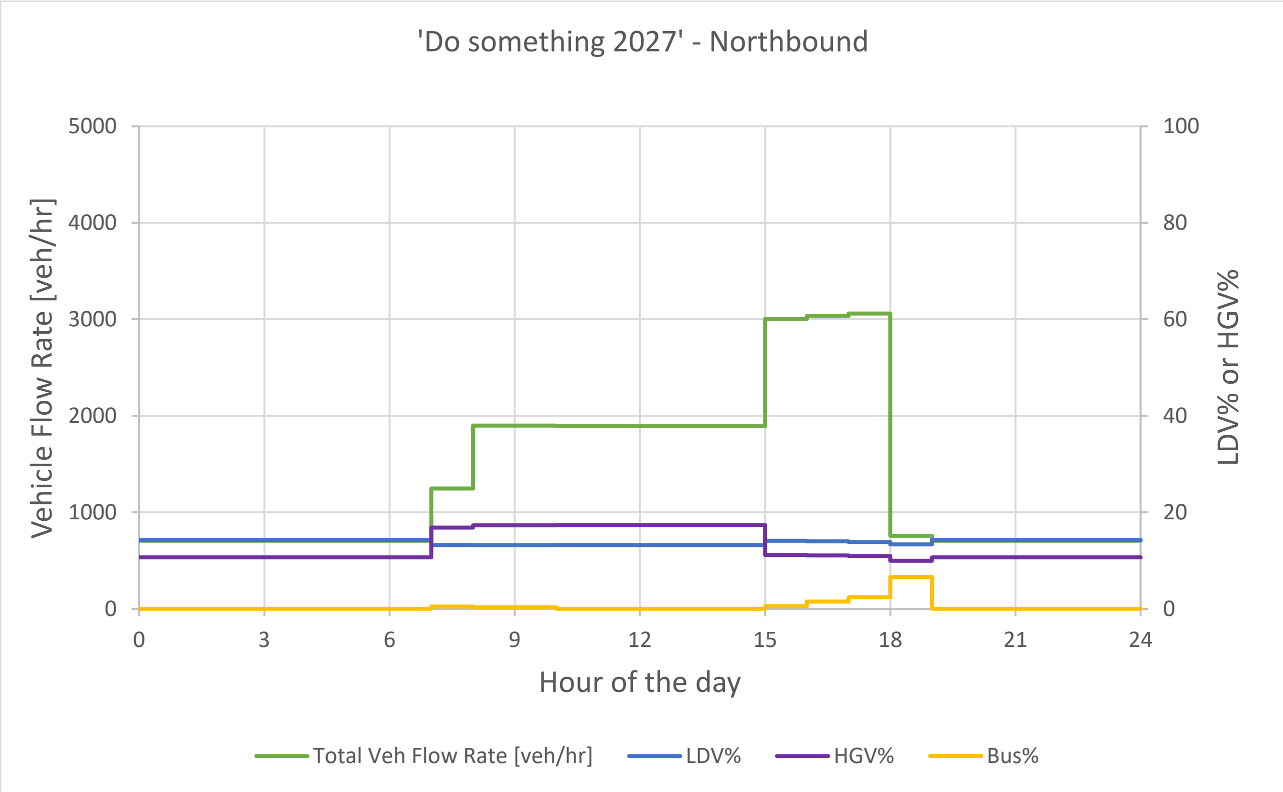


Figure 6-5 'Do something 2027' – northbound

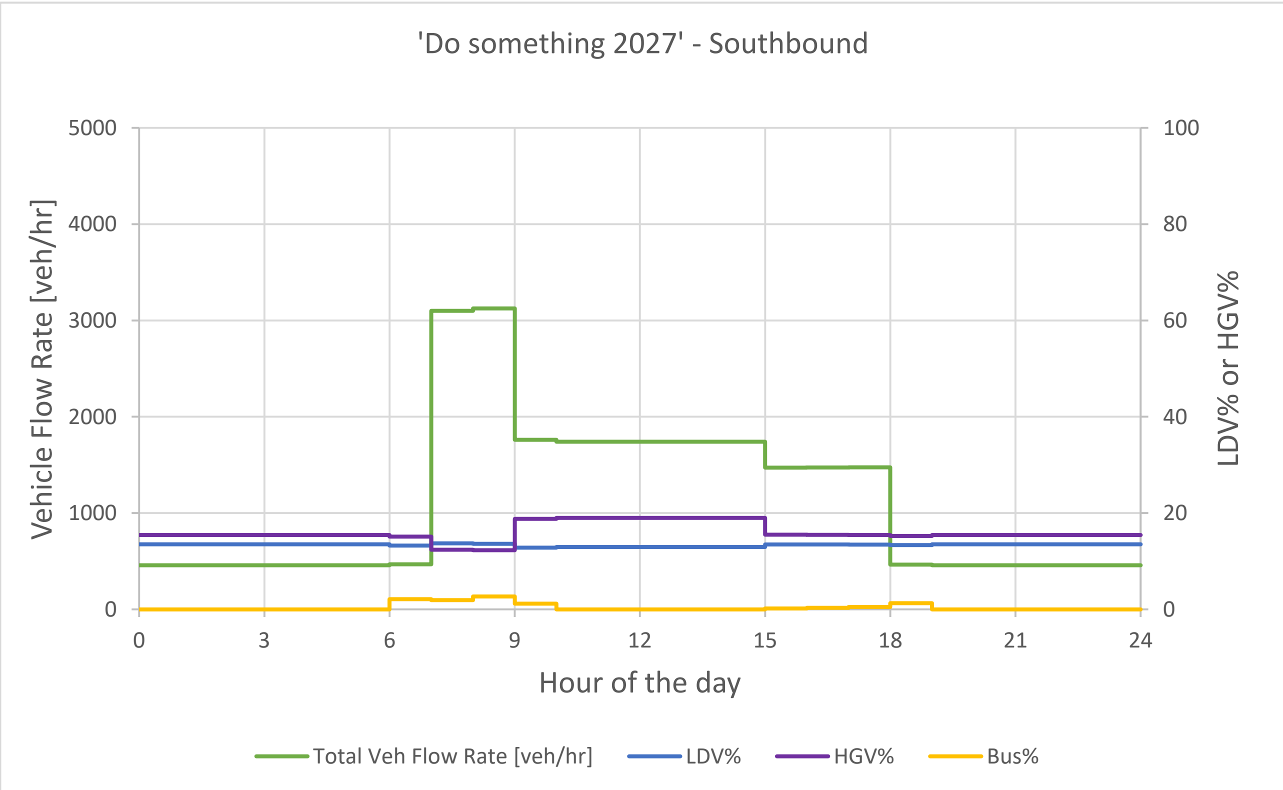


Figure 6-6 'Do something 2027' – southbound

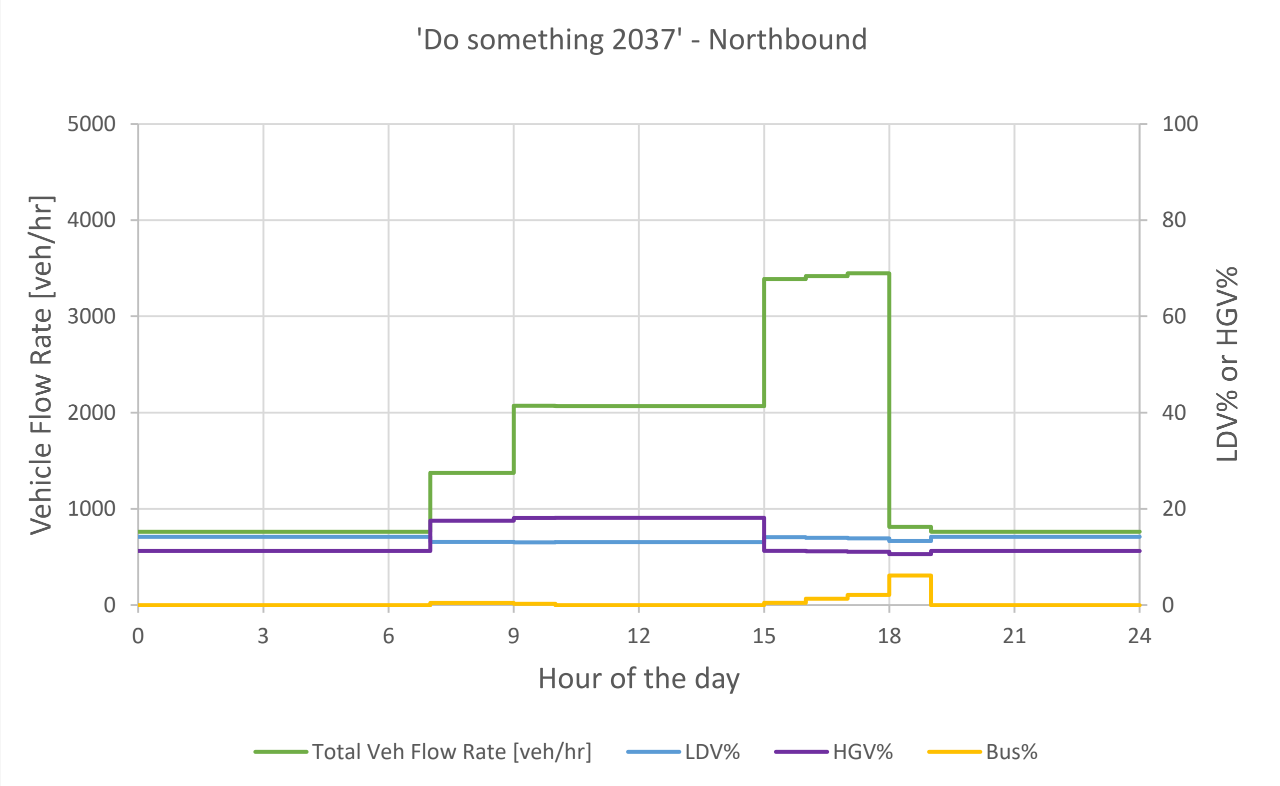


Figure 6-7 'Do something 2037' – northbound

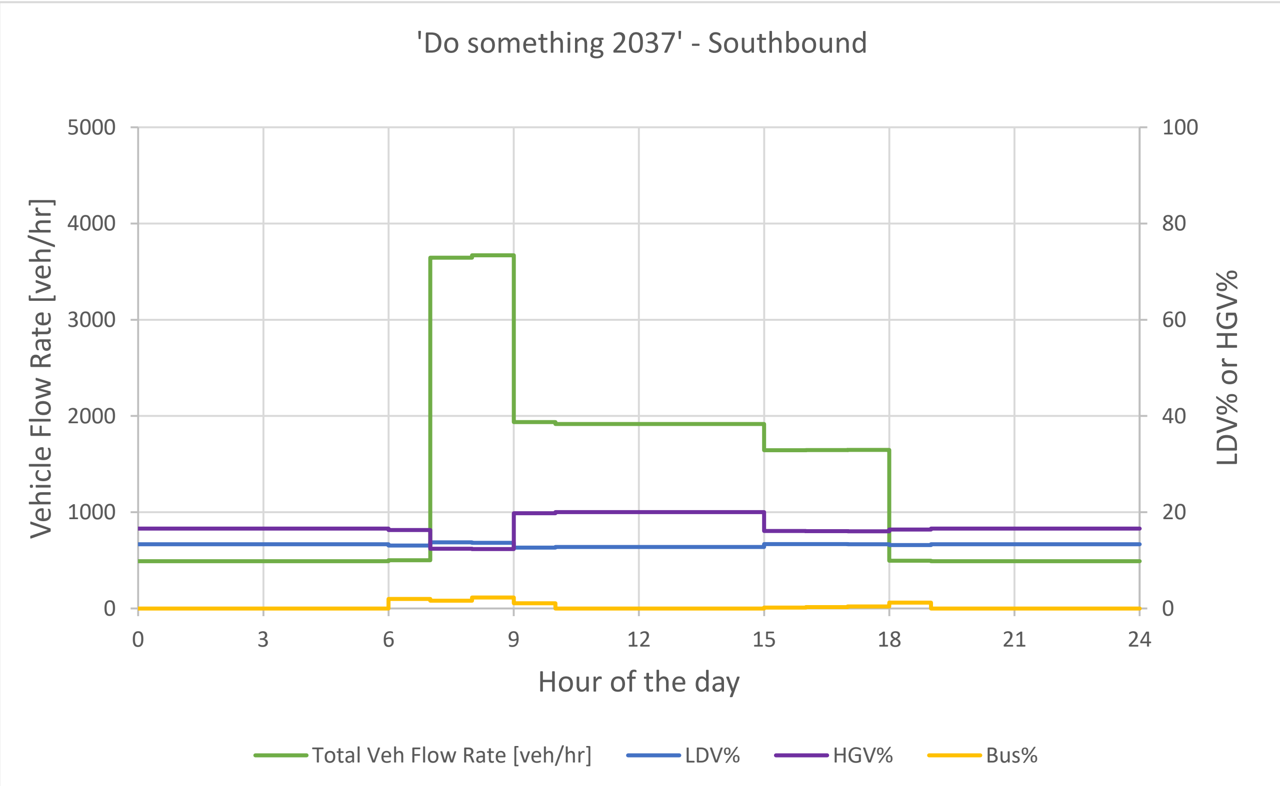


Figure 6-8 'Do something 2037' – southbound

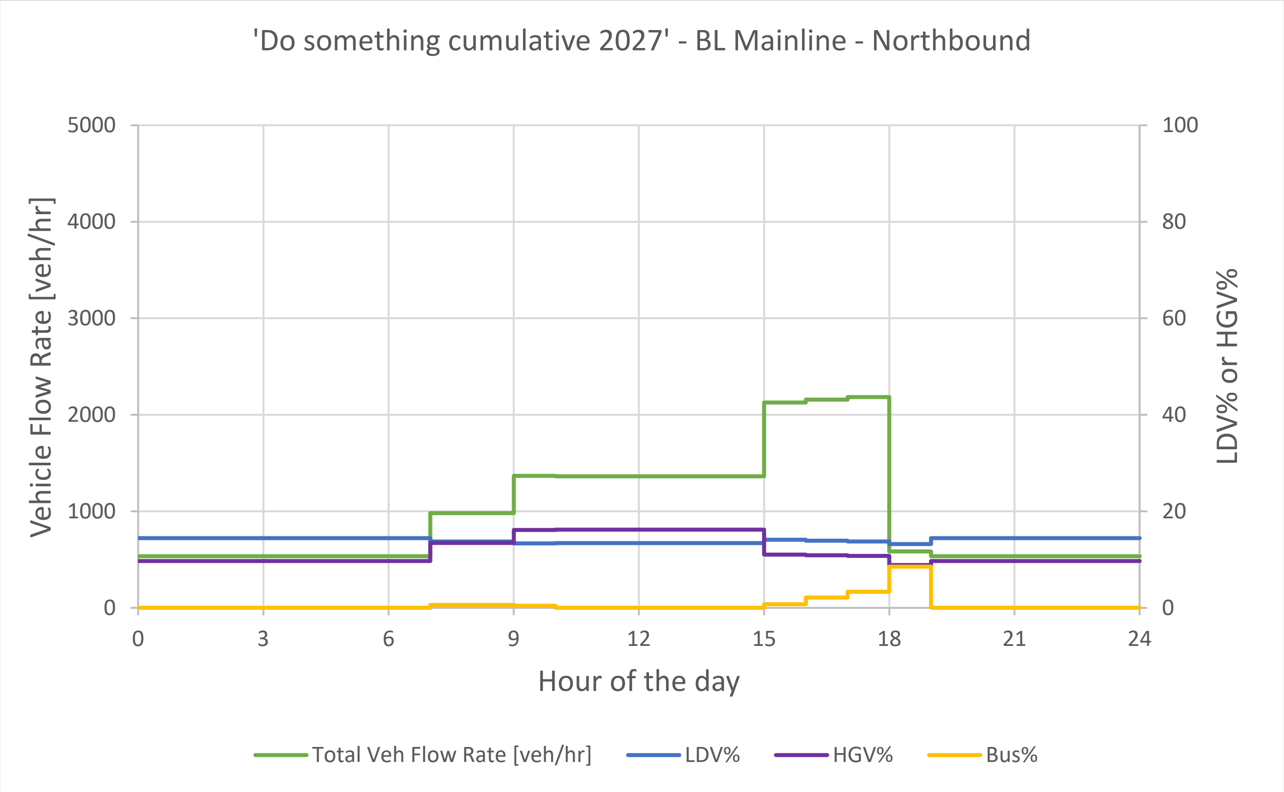


Figure 6-9 'Do something cumulative 2027' – Beaches Link Mainline – northbound

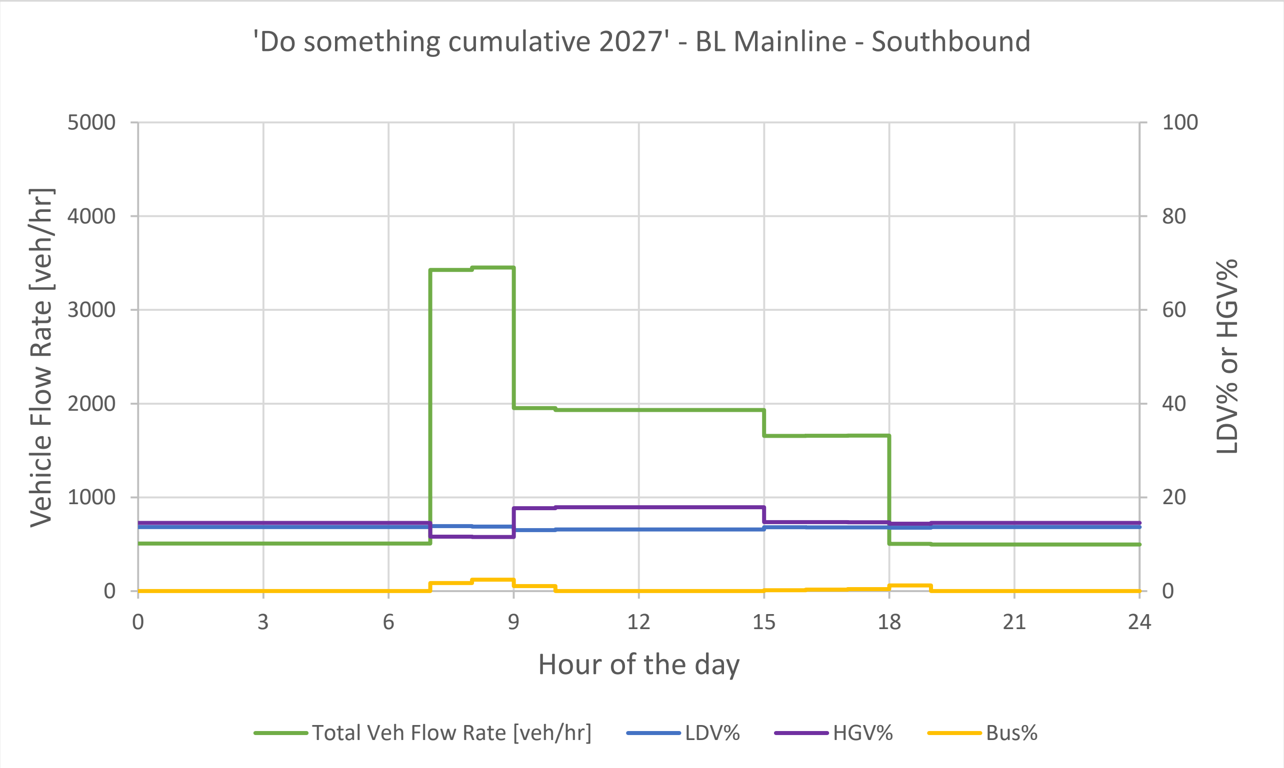


Figure 6-10 'Do something cumulative 2027' – Beaches Link Mainline – southbound

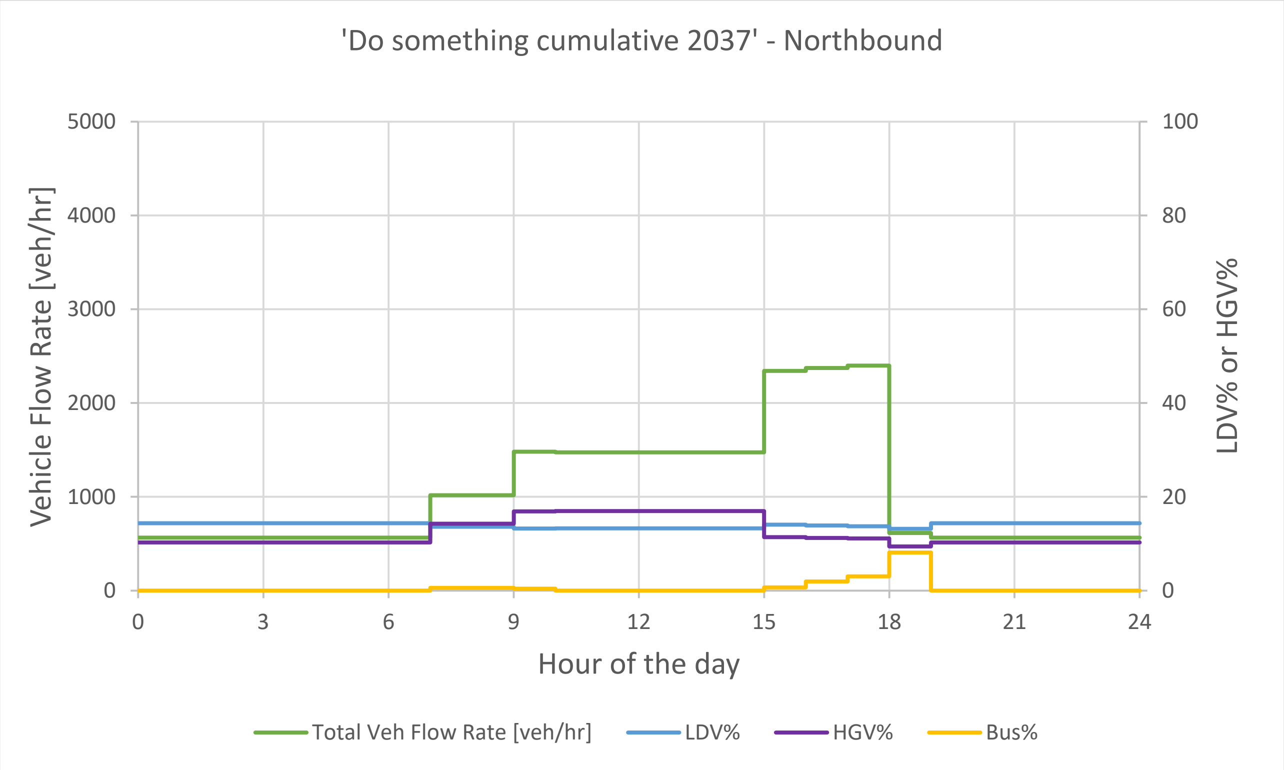


Figure 6-11 ‘Do something cumulative 2037’ – Beaches Link Mainline – northbound

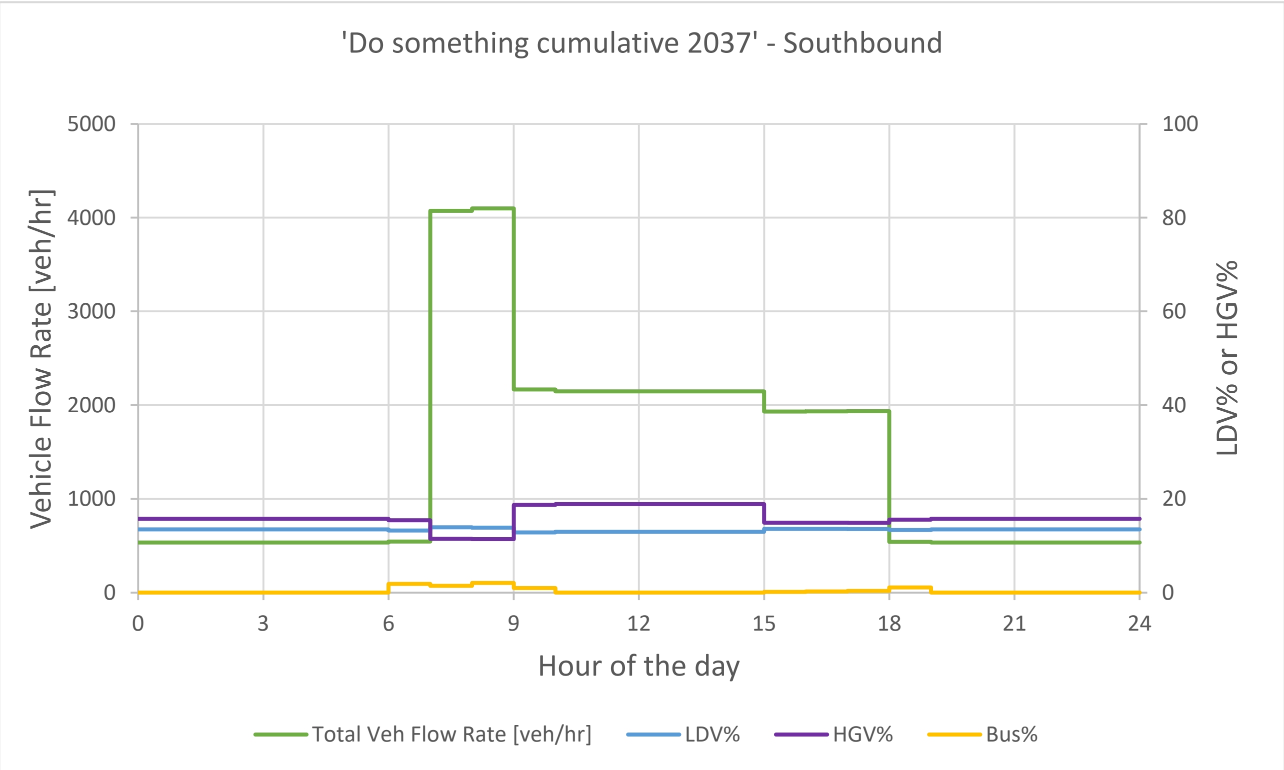


Figure 6-12 ‘Do something cumulative 2037’ – Beaches Link Mainline – southbound

6.1.3.2 Predicted bus numbers

The operational traffic model predicts the bus figures in Beaches Link. These figures were adopted for both year 2027 and 2037 'Do Something cumulative' scenarios where both the Western Harbour Tunnel and Beaches Link tunnel are assessed. The same figures also adopted for both year 2027 and 2037 'Do Something' scenarios.

For the worst-case (variable speed) scenarios, the maximum bus flow rate in each direction was used.

Table 6.5 Predicted bus numbers

AM peak			PM peak		
Time interval	**Outbound[1]**	**City-bound[2]**	**Time interval**	**Outbound[1]**	**City-bound[2]**
06.00-07.00	0	10	**15.00-16.00**	16	3
07.00-08.00	6	59	**16.00-17.00**	46	5
08.00-09.00	6	84	**17.00-18.00**	73	7
09.00-10.00	6	21	**18.00-19.00**	50	6

Notes:
1. Outbound = northbound – entering at Warringah Freeway and exiting at Balgowlah
2. City-bound = southbound – entering at Balgowlah and exiting at Warringah Freeway

6.1.3.3 Worst-case (variable speed) scenarios

The following mainline worst-case (variable speed) scenarios were considered:

- 'Do something' (Beaches Link only) – 20 km/h on the mainline
- 'Do something' (Beaches Link only) – 40 km/h on the mainline
- 'Do something' (Beaches Link only) – 60 km/h on the mainline
- 'Do something' (Beaches Link only) – 80 km/h on the mainline
- 'Do something cumulative' – 20 km/h on the mainline
- 'Do something cumulative' – 40 km/h on the mainline
- 'Do something cumulative' – 60 km/h on the mainline
- 'Do something cumulative' – 80 km/h on the mainline.

The ventilation system must provide acceptable in-tunnel air quality for all traffic conditions considered.

Table 6.6 Indicative ventilation requirements for variable speeds

Traffic speed	Portal capture	Interface	Jet fans
80 km/h	Maximum demand	Maximum demand	No demand
60 km/h	High demand	High demand	No/Low demand
40 km/h	Minimum demand	Low demand	High demand
20 km/h	Moderate demand	Minimum demand	Maximum demand

The laneway flow capacities in the form of passenger car unit per lane per hour (PCU/ln/hr) and average traffic speeds are provided in Table 6.7, up to and including the posted speed limit. These flow capacities have been applied at the three-lane mainline section of the Beaches Link, with entry and exit ramps adjusted for continuity.

Table 6.7 Adopted maximum lane capacity as a function of speed.

Traffic speed (km/h)	PCU/lane/h	HGV:PCU ratio
0	165 PCU/km	3:1
20	1350	3:1
40	1860	2:1
60	2050	2:1
80	1900	2:1

Note: The ratios in the third column are the equivalence between HGVs and PCUs in terms of lane space used at each speed

The end traffic composition has been calculated and provided in Figure 6-13 and Figure 6-14. As the peak periods of the expected traffic scenario resemble the highest traffic flow rates, these periods are used to calculate the traffic distribution at various on-ramps and off-ramps and the LDV and HGV percentages. The average vehicle speed on the on-ramp and off-ramps are assumed to be a maximum of 60 km/h. This is particularly important for the 80 km/h case. The bus flow rates were set at 73 buses per hour for northbound and 84 buses per hour for southbound.

'Do something' northbound scenario traffic is calculated based on 'Do something 2037' AM peak period. LDV percentage and HGV percentage are 16 per cent and 18.2 per cent.

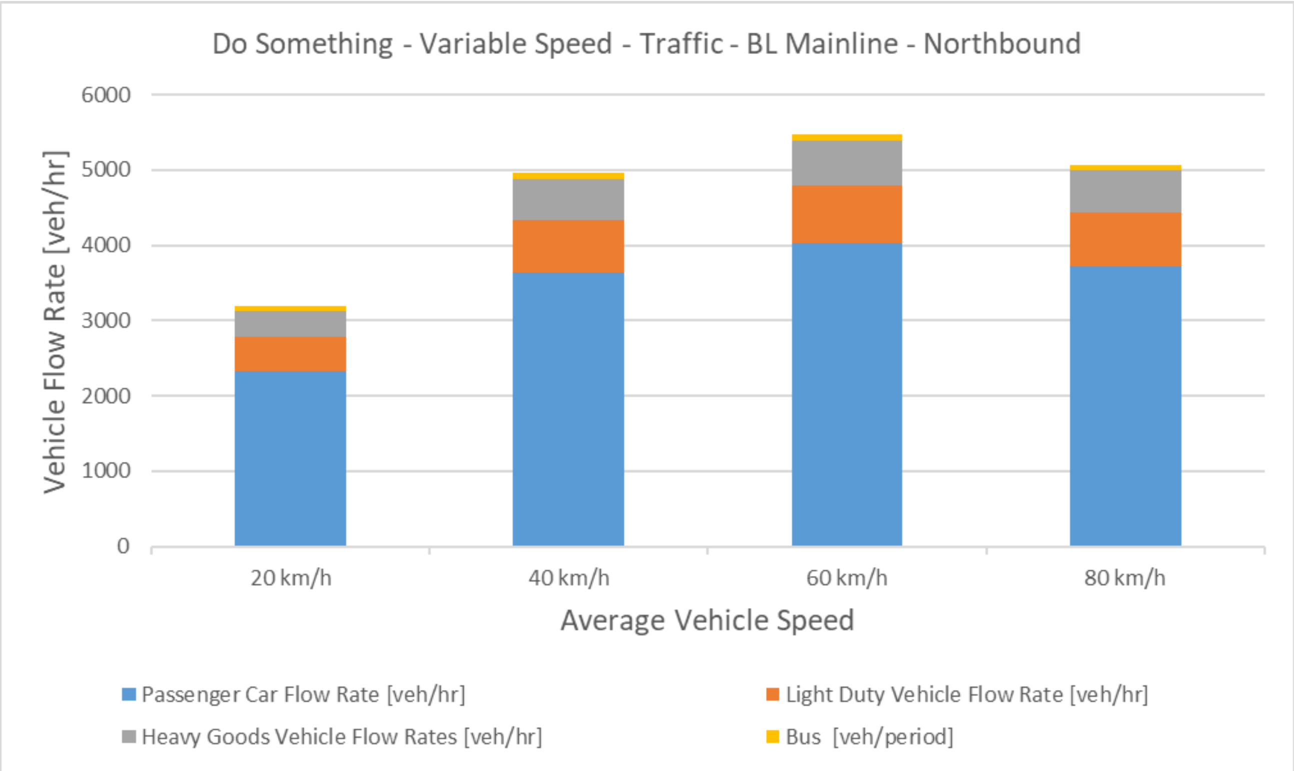


Figure 6-13 'Do something' variable speed northbound traffic

'Do something' southbound scenario traffic is calculated based on 'Do something 2037' AM peak period. LDV percentage and HGV percentage are 16 per cent and 20 per cent.

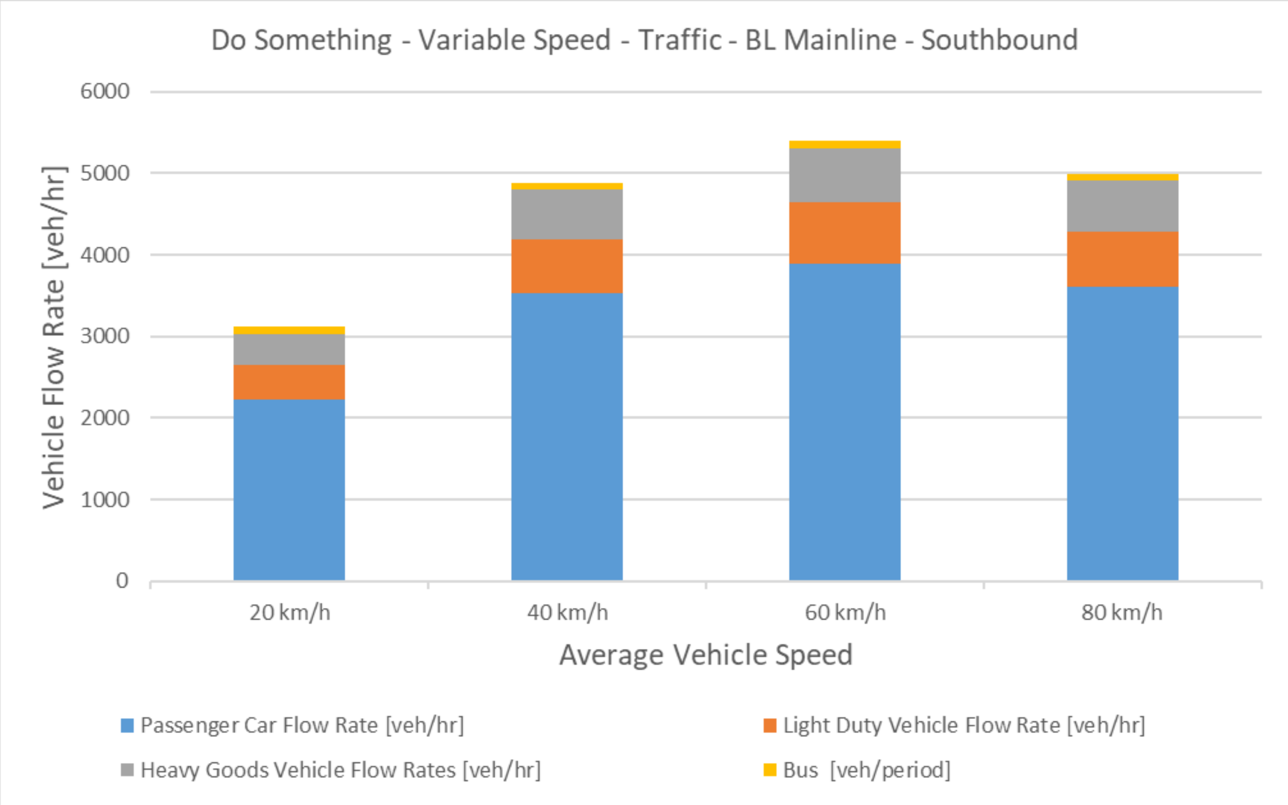


Figure 6-14 'Do something' variable speed southbound traffic

'Do something cumulative' northbound scenario traffic is calculated based on 'Do something 2037' AM peak period. LDV percentage and HGV percentage are 16 per cent and 17.4 per cent.

6.1.3.4 Worst-case scenario (breakdown or major incident)

After a scenario assessment of different possible breakdown locations, the worst-case scenarios for each traffic assessment scenario have been identified as:

- 'Do something' (Beaches Link only) – southbound – Warringah Freeway exit blocked
- 'Do something cumulative' – southbound – Warringah Freeway exit blocked.

In carrying out the analysis, it has been assumed that relevant traffic control measures would be in place to direct the traffic away from a closed exit and to maintain a minimum traffic speed of 20 km/h in the non-closed tunnel section. For the closed section of the tunnel, it has been assumed that drivers on the Warringah Freeway exit would be instructed to switch off their engines, and that the drivers would comply.

Assumptions for the scenarios are listed below:

'Do something' (Beaches Link only) – southbound – Warringah Freeway exit blocked:

- Congestion at Gore Hill off ramps as all traffic must leave at the Gore Hill exits.
- Traffic speed is reduced to 20 km/h at Beaches Link mainline and Gore Hill off ramps.

The case has been portrayed in Figure 6-15Figure 6-16.

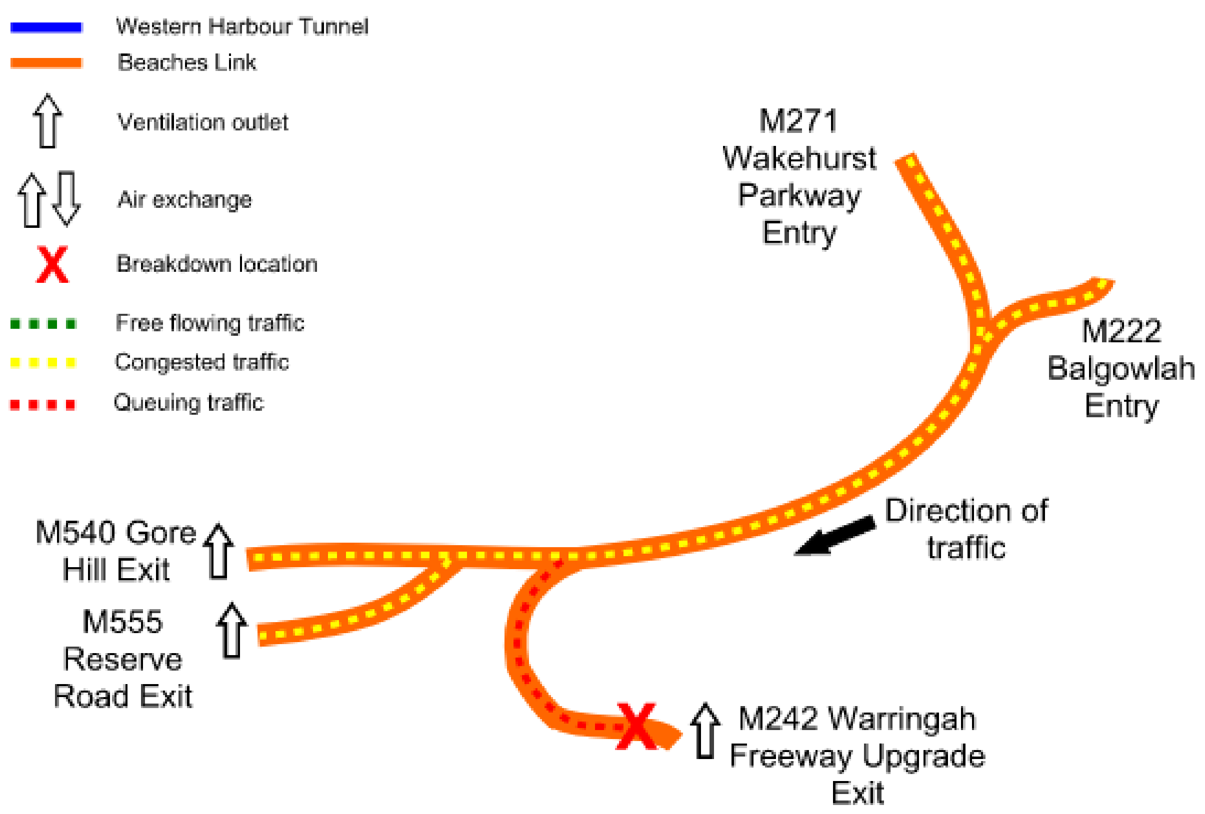


Figure 6-15 Breakdown case for 'Do something' (Beaches Link only)

'Do something cumulative' – southbound – Warringah Freeway exit blocked:

- Congestion at Gore Hill exits and the Beaches Link-Western Harbour Tunnel connection as traffic will be directed to those tunnel sections.
- Traffic speed is reduced to 20 km/h at Beaches Link mainline, Gore Hill off ramps and the Beaches Link-Western Harbour Tunnel connection.

The case has been portrayed in Figure 6-16.

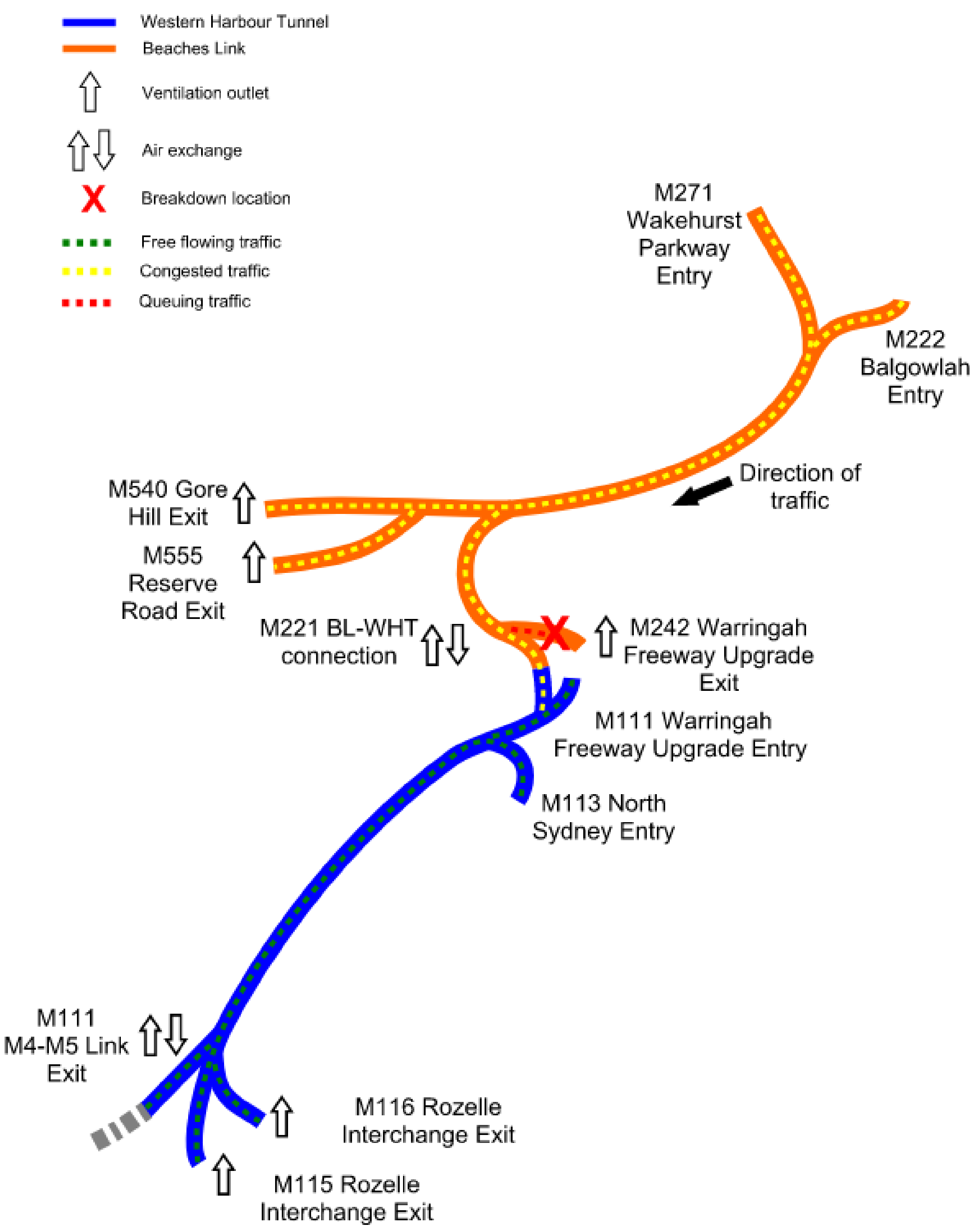


Figure 6-16 Breakdown case for 'Do something cumulative'

6.1.4 Ventilation equipment

6.1.4.1 Jet fans

The jet fan specifications are defined in Table 6.8, based on *QA Specification R164 for Tunnel Jet Fans* (NSW Roads and Maritime, 2017).

Table 6.8 Jet fan characteristics

Transport for NSW jet fan specification	Value	Unit
Nominal thrust	1500	N
Installation efficiency	70%	
Motor power	45	kW
Direction	Fully reversible	

6.2 Design assumptions

6.2.1 Baseline conditions

The simulations are performed under the following assumptions:

- No external portal wind pressures
- Constant ambient conditions (30°C ambient temperature, 50 per cent relative humidity and 30°C ground temperature)
- Heat-neutral conditions (no vehicle heat, no heat flow through tunnel wall) effectively eliminating any buoyancy effects and air-temperature changes along the tunnel.

The impact of ambient air temperature on the tunnel ventilation simulation for normal operation is minimal. This is because the effects of buoyancy are relatively small in comparison to other effects, such as piston effects of the running vehicle.

6.2.2 Background air quality

Table 6.9 shows the assumed background air quality concentrations at all ventilation supply points and portals.

Table 6.9 Assumed background air quality levels

Pollutant/parameter	Background level	Units of measurement
CO	1.3	ppm
NO_2	0.05	ppm
Visibility (extinction co-efficient)	0.0001	m^{-1}

6.2.3 Vehicle drag

The drag coefficient values nominated by Transport for NSW are shown in

Table 6.10.

Table 6.10 Typical vehicle dimensions for Beaches Link from Transport for NSW

Vehicle type	Length (metres)	Frontal area (m^2)	Drag coefficient
Passenger cars	4	2.5	0.4
LDVs	6	5	0.6
HGVs	12.5	7	0.8
Bus	12.5	13.7	0.9

Source: Bus source: Transport State Transit (NSW Government) Bus Infrastructure Guide, July 2011 [2]

6.2.4 Emissions factors

6.2.4.1 Fleet characteristics

The fleet composition is determined based on Table 6.11, which outlines the year's vehicle emission standards were implemented in Australia. Based on trends in vehicle registrations and new car purchases in NSW, Transport for NSW (then NSW Roads and Maritime) has developed a forecast of the NSW fleet in future years. The fleet composition assumed for years 2027 and 2037 are provided

Table 6.12 and Table 6.13 respectively.

Table 6.11 Assumed periods of implementation for vehicle emission standards

<table>
<tr><th>Year</th><th>- 1995</th><th>1996-1998</th><th>1999-2002</th><th>2003</th><th>2004-2005</th><th>2006</th><th>2007</th><th>2008 - 2009</th><th>2010</th><th>2011-2016</th><th>2017-2027</th><th>2028-</th></tr>
<tr><td>Petrol PCs</td><td>Euro 0</td><td colspan="3">Euro 1
(ADR 37/01)</td><td>Euro 2</td><td colspan="3">Euro 3 (ADR79/01)</td><td colspan="2">Euro 4
(ADR79/02)</td><td>Euro 5</td><td>Euro 6</td></tr>
<tr><td>Diesel PCs</td><td>Euro 0</td><td colspan="2">Euro 1*</td><td colspan="4">Euro 2 (ADR 79/00)</td><td colspan="3">Euro 4 (ADR 79/02)</td><td>Euro 5</td><td>Euro 6</td></tr>
<tr><td>Petrol LDVs</td><td>Euro 0</td><td colspan="3">Euro 1
(ADR 37/01)</td><td>Euro 2</td><td colspan="3">Euro 3 (ADR79/01)</td><td colspan="2">Euro 4
(ADR79/02)</td><td>Euro 5</td><td>Euro 6</td></tr>
<tr><td>Diesel LDVs</td><td>Euro 0</td><td colspan="2">Euro 1*</td><td colspan="4">Euro 2 (ADR 79/00)</td><td colspan="3">Euro 4 (ADR 79/02)</td><td>Euro 5</td><td>Euro 6</td></tr>
<tr><td>Diesel HGVs</td><td>Euro 0</td><td colspan="2">Euro I
(ADR 70/00)</td><td colspan="4">Euro III (ADR 80/00)</td><td colspan="2">Euro IV
(ADR 80/02)</td><td colspan="3">Euro V (ADR 80/03)</td></tr>
</table>

Table 6.12 Fleet composition – 2027

	PC petrol	PC diesel	LDV petrol	LDV diesel	HGV diesel
Pre Euro	0.01%	0.00%	0.14%	0.02%	1.25%
Euro 1	0.11%	0.00%	0.47%	0.05%	1.75%
Euro 2	0.16%	0.05%	0.46%	0.42%	0.00%
Euro 3	1.44%	0.00%	1.11%	0.00%	4.64%
Euro 4	14.51%	3.17%	4.13%	12.91%	4.96%
Euro 5	57.14%	23.40%	7.58%	72.71%	87.40%
Euro 6	0.00%	0.00%	0.00%	0.00%	0.00%
Total	100.00%		100.00%		100.00%

Source: NSW Fleet Forecast for Tunnel Ventilation Design: 2016 to 2040. [3]

Table 6.13 Fleet composition – 2037

	PC petrol	PC diesel	LDV petrol	LDV diesel	HGV diesel
Pre Euro	0.00%	0.00%	0.01%	0.00%	0.68%
Euro 1	0.00%	0.00%	0.02%	0.00%	0.85%
Euro 2	0.00%	0.00%	0.02%	0.02%	0.00%
Euro 3	0.01%	0.00%	0.05%	0.00%	1.69%
Euro 4	0.33%	0.07%	0.28%	0.86%	2.27%
Euro 5	16.44%	7.62%	1.73%	20.90%	94.51%
Euro 6	42.87%	32.65%	1.78%	74.33%	0.00%
Total	**100.00%**		**100.00%**		**100.00%**

Source: NSW Fleet Forecast for Tunnel Ventilation Design: 2016 to 2040. [3]

6.2.4.2 Nitrogen dioxide emissions

The overall percentage of NO_2 to NO_X is calculated separately for each scenario as a weighted average based on the overall fleet composition for the assessment year combined with the primary NO_2 ratio of the values from*: Update of the Air Emissions Inventory Guidebook – Road Transport 2016* (European Environment Agency, 2017) [4].

Table 6.14 Primary NO_2:NO_X ratio by emissions standard for ventilation design

	Pre-Euro	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6
PC petrol	4%	4%	4%	3%	3%	3%	3%
PC diesel	15%	13%	13%	51%	46%	33%	30%
LDV petrol	4%	4%	4%	3%	3%	3%	3%
LDV diesel	15%	13%	13%	27%	46%	33%	30%
HGV diesel	11%	11%	11%	14%	10%	12%	8%

Source: *Update of the Air Emissions Inventory Guidebook – Road Transport 2016 (European Energy Agency, 2017) [4]*

6.2.4.3 PIARC emission values for CO, NO_X and PM

PIARC provides the data for CO, NO_X and PM in the reference document of *Road tunnels: vehicle emissions and air demand for ventilation, 2019R02EN* (PIARC Technical Committee C.4 Road Tunnel Operation, 2019) [5].

6.2.4.4 Particulate matter emissions and in-tunnel visibility

There are two primary sources of PM in a tunnel, these are vehicle exhaust emissions and non-exhaust emissions. Non-exhaust emissions include tyre and brake wear, road surface abrasion and re-suspended dust.

Exhaust emissions consist of PM emanating from the tailpipe and, according to PIARC [5], are very small particles mainly in the range of 0.01 to 0.20 micrometres. Particles in this range are very effective in light extinction, which impacts in-tunnel visibility. Diesel combustion contributes significantly to PM emissions and diesel engines without a diesel particle filter (DPF) from earlier EURO engines can lead to higher PM emissions than petrol engines.

Non-exhaust emissions consist of particulates from abrasion of roads, tyres, and brake pads and re-suspension of road dust. According to PIARC [5], these particle emissions are mainly in the size from one micrometre upwards and contribute less to light extinction than smaller particles.

Visibility is impacted by the light extinction from the scattering and absorption of light by PM suspended in the air. The visibility is mainly reduced by particles of diameter of 0.7 micrometres, as this is about the wave length of visible light. According to PIARC [5], $PM_{2.5}$ mainly impacts light extinction, and the equation for calculating the light extinction for a diluted exhaust gas is:

$$Light\ Extinction\ [m^{-1}] = 0.0047\ \times PM_{2.5}[mg/m^3]$$

The non-exhaust PM calculation is carried out using the non-exhaust particulate emission factors from PIARC. Non-exhaust PM emissions are dependent on the vehicle type and speed. The $PM_{2.5}$ emission factors are provided in Table 6.15.

A study was carried out to estimate the percentage split of exhaust and non-exhaust PM emission within the tunnels. Representative scenarios were chosen from normal and worst-case operations and modelled with and without the contribution of non-exhaust PM emission. Normal operation for cumulative northbound and cumulative southbound were chosen to observe the variation of PM split for different routes. Beaches Link southbound worst-case scenarios for three different traffic speeds (20 km/h, 40 km/h and 60 km/h) were selected to observe the effect of different traffic speeds on PM emission.

The results showed that the percentage variation of non-exhaust PM could vary between 55 and 75 per cent of the total PM emissions. The corollary is that 25 to 45 per cent of PM emissions could originate from vehicle exhaust. However, it should be noted that the percentage split of PM emissions depends highly on fleet compositions and traffic speed.

Table 6.15 Factors for $PM_{2.5}$ non-exhaust emissions

Speed (km/h)	PC/LDV [m²/h]	HGV [m²/h]
0	0	0
10	0.7	4.4
20	1.3	8.8
30	2.0	13.3
40	2.6	17.7

Speed (km/h)	PC/LDV [m^2/h]	HGV [m^2/h]
50	3.3	22.1
60	3.9	26.5
70	4.6	30.9
80	5.3	35.3

6.2.4.5 Degradation factor

PIARC [5], considers the use of engine degradation factors to be inappropriate for emissions modelling beyond the year 2018, as the degradation for vehicles complying with the Euro 0 to Euro 4 emission standards are already at their maximum, and no valid statistical data is currently available for newer engines complying with Euro 5 and 6 standards.

6.2.5 Heavy vehicle mass

The average mass of HGVs for the Beaches Link tunnel is estimated to be 21 tonnes. This is based on the historical mean mass of heavy vehicles passing the Weigh in Motion station in Botany in the morning peak period.

PIARC on the other hand provides emission factors referring to an average vehicle mass of 23 tonnes [5].

For this assessment, the emission factors were adopted without applying a reduction factor for adjustment to compensate for the reduced mass. The reduction factor would have minimal impact on the assessment and the application of the base emissions would be more conservative.

6.3 Emergency scenarios

6.3.1 Design fire parameters

The design fire size is the design heat release rate with the consideration of a deluge system.

Table 6.16 Design fire parameters

Parameter	Value	Comments
Design heat release rate (hot)	50 MW	Used where buoyancy of the smoke resists the ventilation effort.
Fire power to air	0.7	The fraction of convective heat to the HRR that goes to heating the tunnel air and smoke – typical value without deluge operation. May be lower with deluge, which provides additional cooling of the smoke.

6.4 Sensitivity of input data and assumptions

There are many parameters which may influence the performance and operation of the ventilation system, with some influencing the ventilation system more than others, these include:

- **Traffic Forecasts** – expected traffic may not eventuate or the tunnel may prove more popular than expected. So, the ventilation system is designed for all feasible traffic scenarios

- **Fleet Composition** – the composition would vary, however, the fleet forecast for ventilation design is considered to be conservative in that it does not account for alternatively fuelled and low (or zero) emission vehicles such as hybrid, hydrogen or electric
- **Emissions Factors including Primary NO_2** – PIARC 2019 base Euro emissions factors applied in this assessment are considered to be representative of real-world driving conditions within tunnels [5].

While the tunnel ventilation assessment provided in the report is considered to be conservative and encapsulates all feasible traffic scenarios, if in the unlikely event that during operation of the tunnel the ventilation system is unable to achieve the objectives set out in Section 3.1, traffic management measures may need to be implemented for short periods of time.

Background pollution levels assumed in this report are considered to be typical figures used in the development of in-tunnel air quality and ventilation system analysis and are adopted for all periods and all scenarios. It should be noted that these values are highly variable, continuously fluctuating with changes in environmental conditions, traffic, fleet, air intake locations and time of day, among others.

Sensitivity modelling, based on increasing the assumed background levels by 50 per cent, resulted in a two to seven per cent overall increase in the pollutant concentrations in the tunnel depending upon the scenario. The results suggest that changes in the pollution levels are relatively unaffected by changes in background levels.

7 Analysis outputs – expected traffic operations

This section of the report presents the analysis results in three ways:

1. 24-hour operating profile for each of the ventilation outlets in terms of the exhaust flow rate, NO_X emission rate, CO emission rate, and total $PM_{2.5}$ emission rate
2. In-tunnel air quality: Average CO concentration along every route, average NO_2 concentration along every route and the minimum visibility emissions along every route
3. For the period of time with the highest NO_2 concentration (highlighted in blue in the table with the in-tunnel air quality results), the NO_2 profile along every route is portrayed.

The ventilation outlet emissions are inputs to the ambient air quality assessment around the Beaches Link and Gore Hill Freeway Connection network.

The assessed routes are described in Section 5.2.2.2.

The results are based on steady-state modelling which assumes unchanged traffic speed and fleet composition for a period.

The figures portraying NO_2 profile along every route is shown in the following manner:

As an example, Figure 7-1 shows the NO_2 profile of all four routes in the 'Do something 2027 (Beaches Link only) southbound PM period. The locations along the routes are marked by the labelled red markers at the top of the figure. However, as significant sections of the routes happen to coincide, such as the Beaches Link mainline tunnel section indicated between "BL Mainline Merge" and "BL Mainline Diverge", the results could be depicted clearer by showing the profiles as superimposed, as seen in Figure 7-2, which is the actual format presented in this report.

Note, it is stressed here that the dashed horizontal grey line at 0.5 parts per million only indicates the maximum allowable limit for the route-average in-tunnel NO_2 concentration, as specified in Table 4.2, The actual route-average in-tunnel NO_2 concentration, as well as other pollutant values (e.g. CO and visibility), can be read directly from the air quality results tables. By virtual of being an average, it is possible that certain parts of the tunnel section may see discrete measurements that are higher than the average concentration limit (i.e. 0.5 parts per million indicated by the grey dashed horizontal line), while the actual route-average is still lower than that limit. This is reflected in Figure 7-2, where the actual concentration measured near the northern end of the tunnel at Wakehurst Parkway Exit exceeds the 0.5 parts per million limit, but the actual route-averages of all four routes are below 0.5 parts per million (refer to Table 7.1 for the actual values).

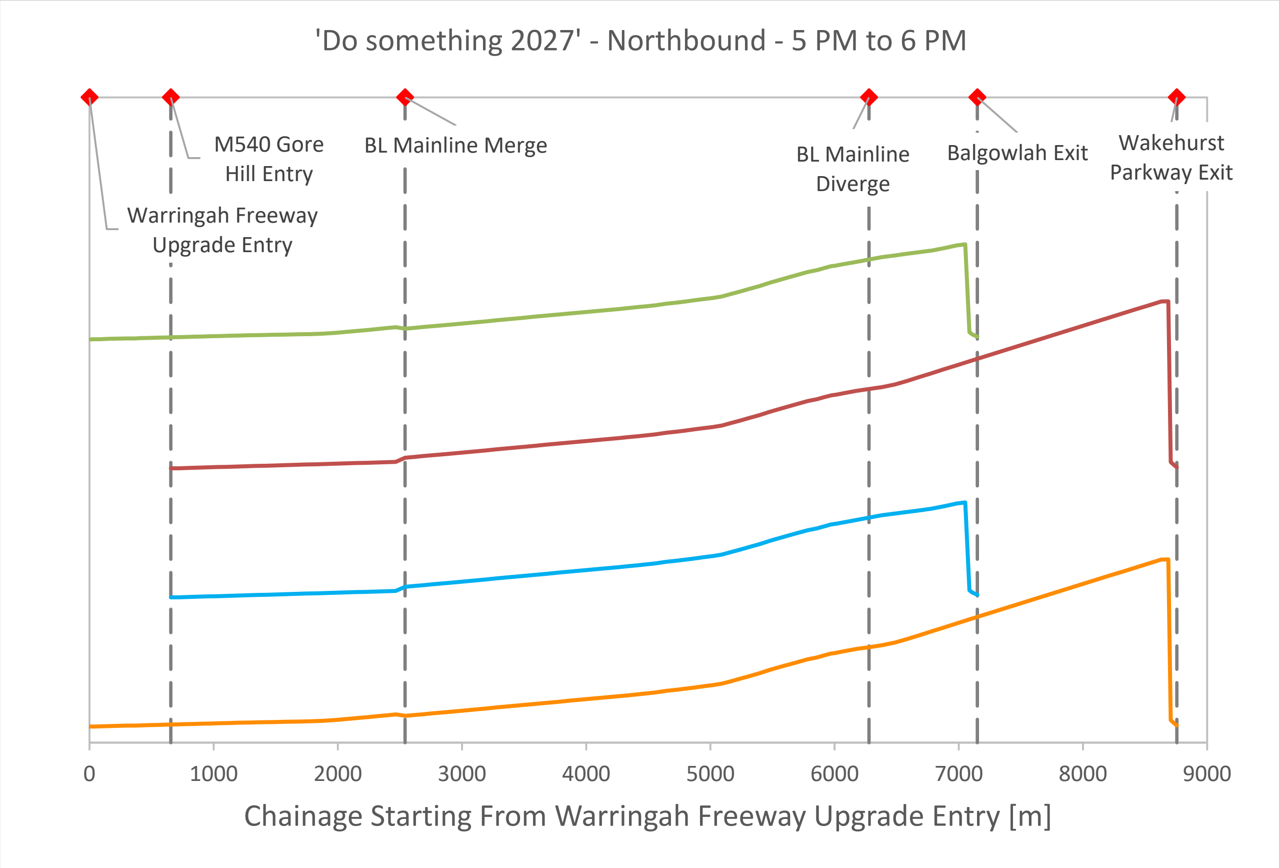


Figure 7-1 NO_2 profile routes separated sample

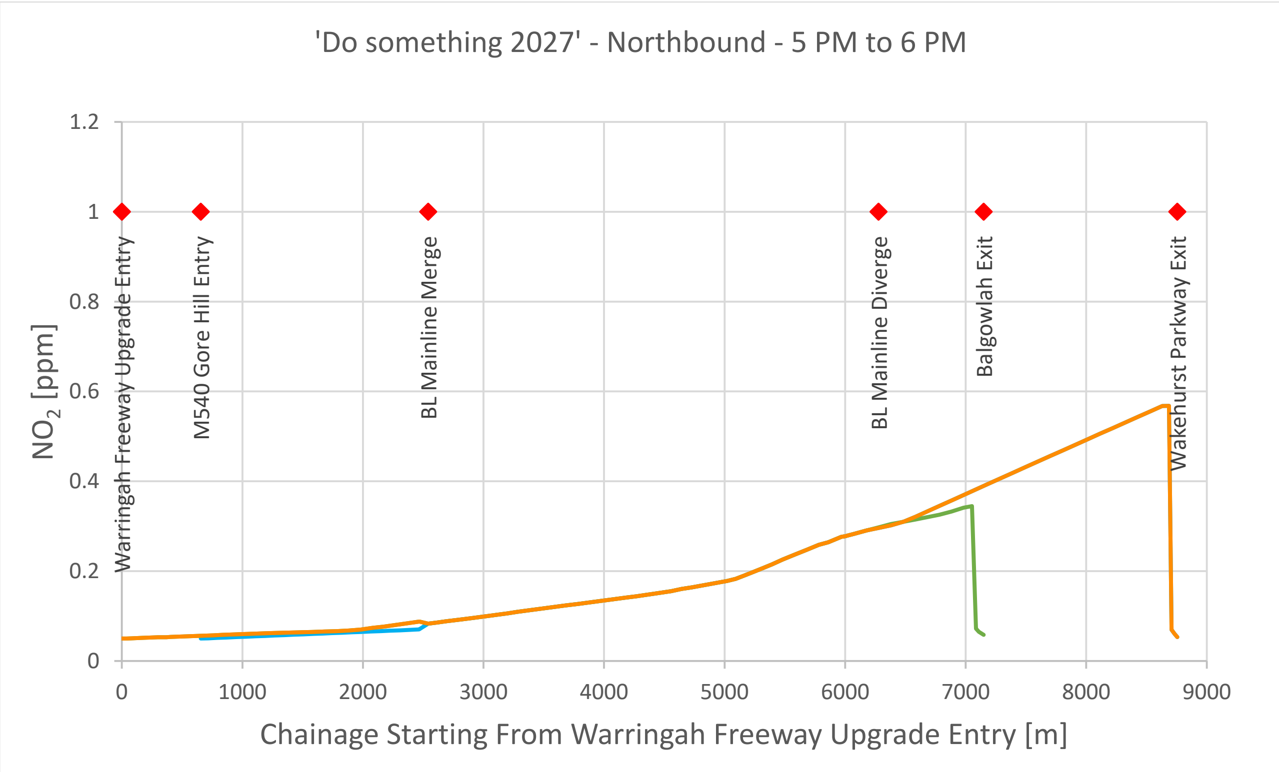


Figure 7-2 NO_2 profile routes superimposed format

7.1 'Do something'

7.1.1 2027 expected traffic operations

7.1.1.1 Ventilation outlet emissions

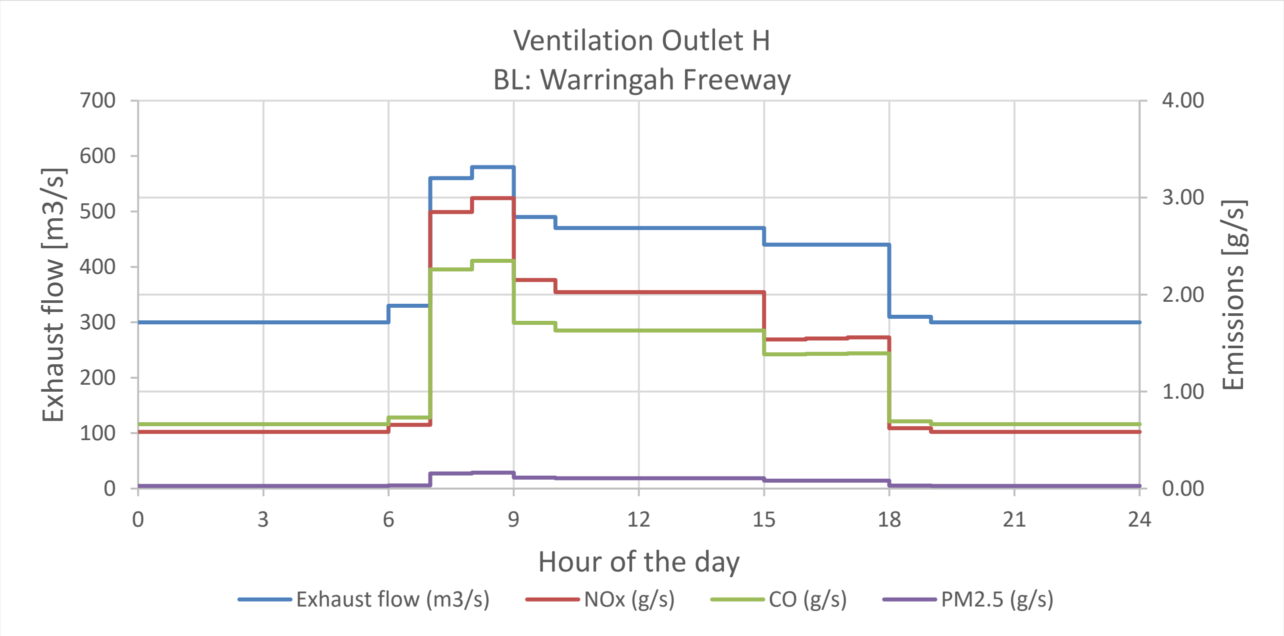


Figure 7-3 Ventilation Outlet H: Warringah Freeway – 'Do something 2027' (Beaches Link only)

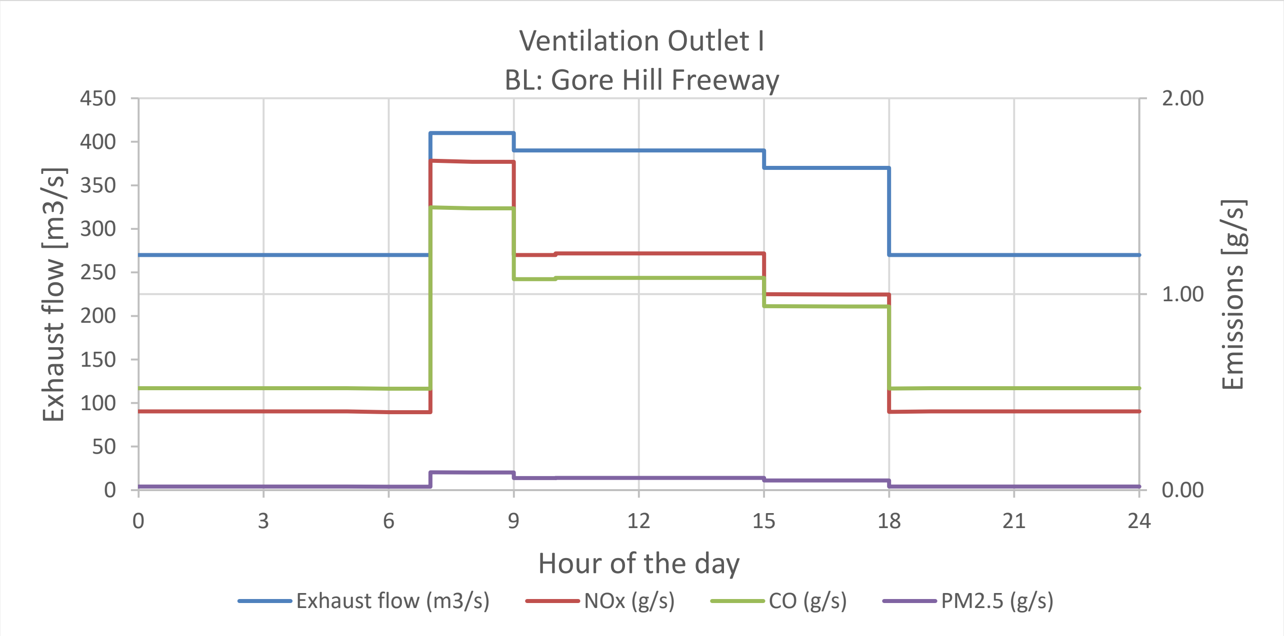


Figure 7-4 Ventilation Outlet I: Gore Hill Freeway – 'Do something 2027' (Beaches Link only)

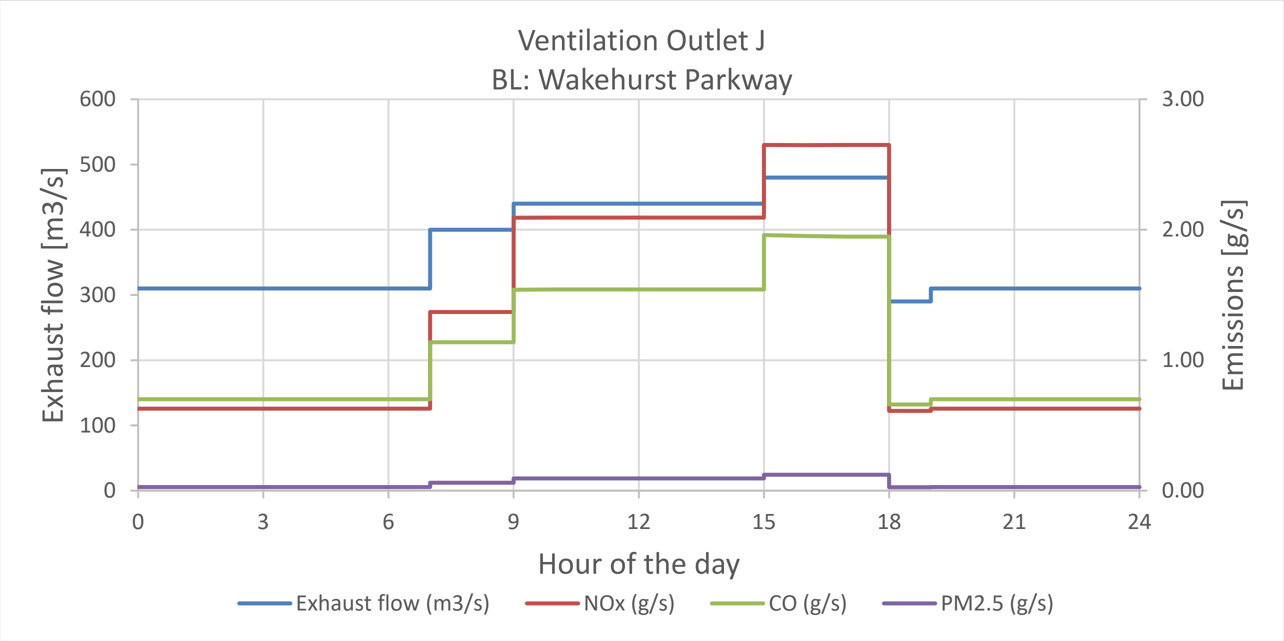


Figure 7-5 Ventilation Outlet J: Wakehurst Parkway – 'Do something 2027' (Beaches Link only)

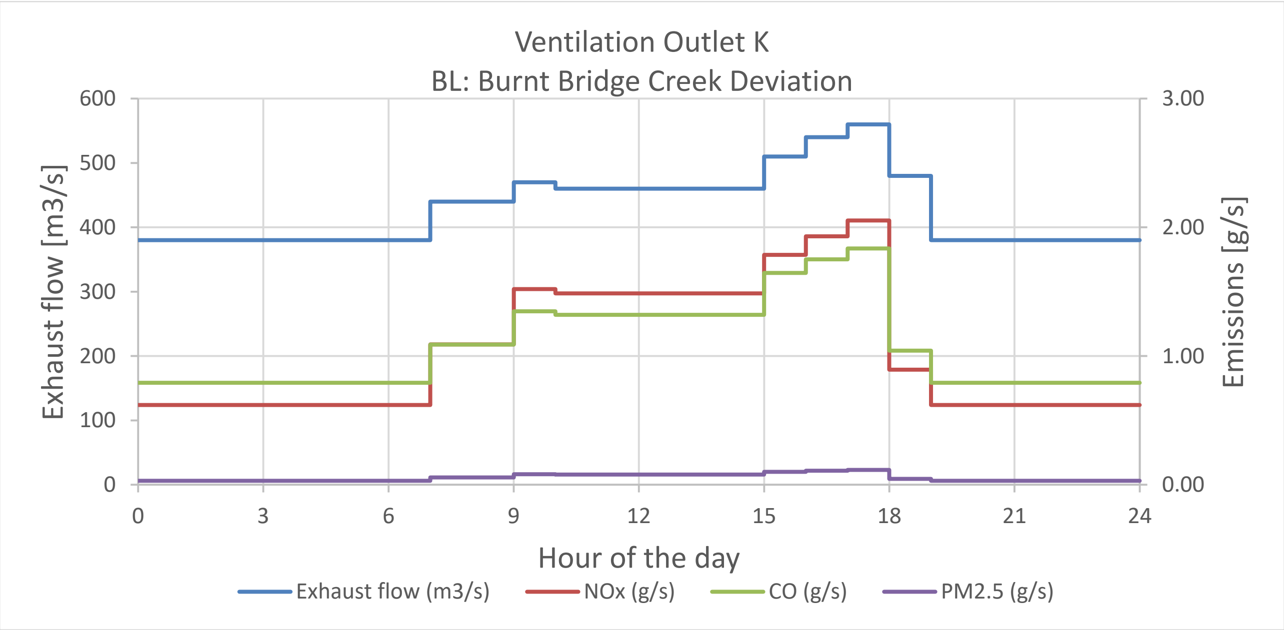


Figure 7-6 Ventilation Outlet K: Burnt Bridge Creek Deviation – 'Do something 2027' (Beaches Link only)

7.1.1.2 In-tunnel air quality

Table 7.1 'Do something 2027' northbound in-tunnel air quality results

Time period	Route ID	DS-NB-A	DS-NB-B	DS-NB-C	DS-NB-D
	Entry portal	Warringah Freeway Upgrade	Warringah Freeway Upgrade	Gore Hill	Gore Hill
	Exit portal	Balgowlah	Wakehurst Parkway	Balgowlah	Wakehurst Parkway
	Length	7.2 km	8.8 km	6.6 km	8.1 km
7.00 to 9.00	Average CO [ppm][(1)]	1.7	2.0	1.8	2.0
	Average NO_2 [ppm][(1)]	0.112	0.152	0.117	0.159
	Min visibility [m^{-1}][(1)]	0.00084	0.00108	0.00084	0.00108
9.00 to 10.00	Average CO [ppm]	1.9	2.2	1.9	2.2
	Average NO_2 [ppm]	0.134	0.186	0.140	0.195
	Min visibility [m^{-1}]	0.00108	0.00140	0.00108	0.00140
10.00 to 15.00	Average CO [ppm]	1.9	2.2	1.9	2.2
	Average NO_2 [ppm]	0.133	0.186	0.139	0.195
	Min visibility [m^{-1}]	0.00108	0.00140	0.00108	0.00140
15.00 to 16.00	Average CO [ppm]	2.0	2.4	2.1	2.4
	Average NO_2 [ppm]	0.143	0.205	0.150	0.216
	Min visibility [m^{-1}]	0.00121	0.00162	0.00121	0.00162
16.00 to 17.00	Average CO [ppm]	2.0	2.4	2.1	2.5
	Average NO_2 [ppm]	0.145	0.207	0.152	0.218
	Min visibility [m^{-1}]	0.00123	0.00164	0.00123	0.00164
17.00 to 18.00	Average CO [ppm]	2.0	2.4	2.1	2.5
	Average NO_2 [ppm]	0.146	0.209	0.153	0.220
	Min visibility [m^{-1}]	0.00124	0.00165	0.00124	0.00165
18.00 to 19.00	Average CO [ppm]	1.6	1.8	1.6	1.8
	Average NO_2 [ppm]	0.091	0.116	0.094	0.121
	Min visibility [m^{-1}]	0.00059	0.00075	0.00059	0.00075
19.00 to 7.00	Average CO [ppm]	1.6	1.8	1.6	1.8
	Average NO_2 [ppm]	0.088	0.111	0.091	0.115
	Min visibility [m^{-1}]	0.00055	0.00069	0.00055	0.00069

Notes:

(1) Air Quality Criteria: CO Average 50 ppm, NO_2 Average 0.5 ppm and Visibility 0.005m^{-1}.
(2) Refer to Figure 7-7 for typical in-tunnel nitrogen dioxide air quality.
(3) The assessment values include background air quality.

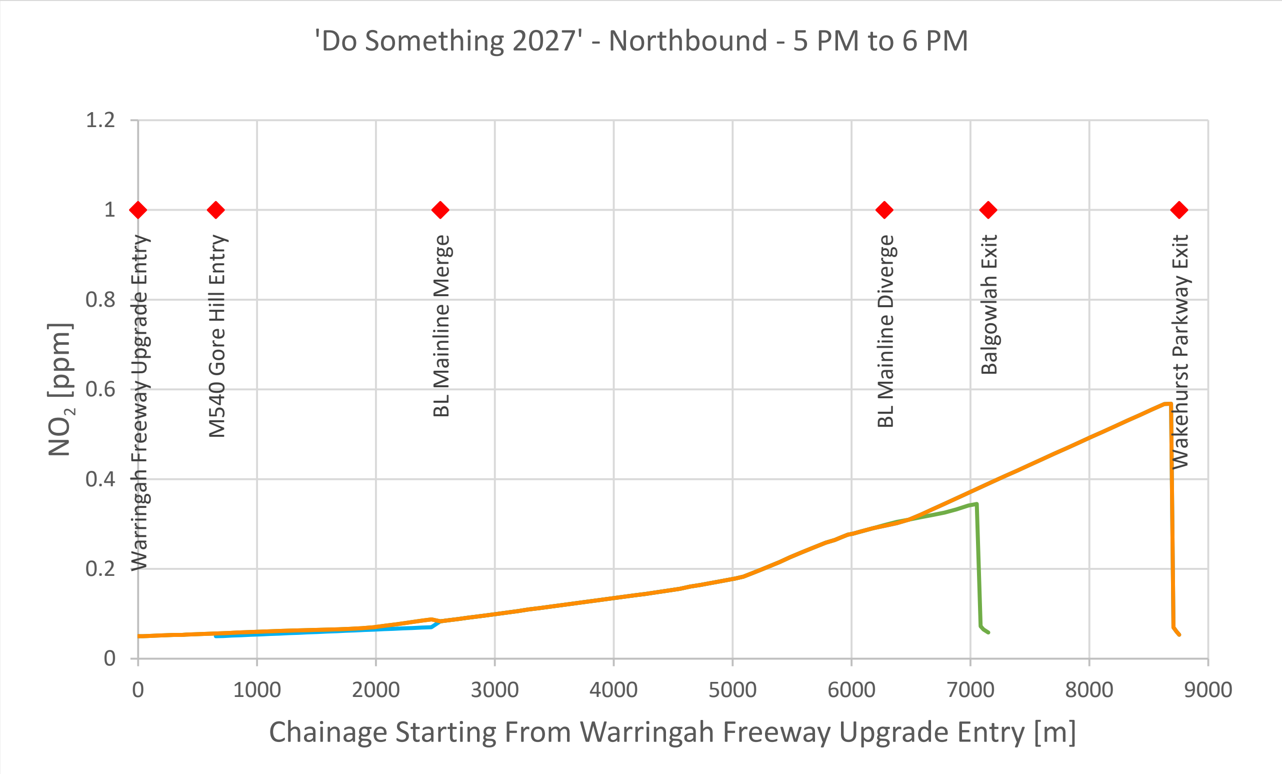


Figure 7-7 NO_2 concentration profile along the routes for 'Do something 2027' northbound, peak period

Table 7.2 'Do something 2027' southbound in-tunnel air quality results

Time period	Route ID	DS-SB-A	DS-SB-B	DS-SB-C	DS-SB-D	DS-SB-E	DS-SB-F
	Entry portal	Wakehurst Parkway	Wakehurst Parkway	Balgowlah	Balgowlah	Balgowlah	Wakehurst Parkway
	Exit portal	M540 Gore Hill	M555 Reserve Road	M540 Gore Hill	M555 Reserve Road	Warringah Freeway Upgrade	Warringah Freeway Upgrade
	Length	8.2 km	8.4 km	6.6 km	6.8 km	7.3 km	8.9 km
7.00 to 8.00	Avg CO [ppm](1)	2.0	2.0	2.2	2.1	2.3	2.1
	Avg NO_2 [ppm](1)	0.146	0.145	0.167	0.164	0.186	0.164
	Min visibility [m^{-1}](1)	0.00145	0.00145	0.00145	0.00145	0.00151	0.00151
8.00 to 9.00	Avg CO [ppm]	2.0	2.0	2.2	2.1	2.3	2.1
	Avg NO_2 [ppm]	0.147	0.145	0.168	0.165	0.188	0.165
	Min visibility [m^{-1}]	0.00147	0.00147	0.00147	0.00147	0.00152	0.00152
9.00 to 10.00	Avg CO [ppm]	1.8	1.8	2.0	1.9	2.1	1.9
	Avg NO_2 [ppm]	0.128	0.126	0.145	0.142	0.162	0.143
	Min visibility [m^{-1}]	0.00118	0.00118	0.00118	0.00118	0.00125	0.00125
10.00 to 15.00	Avg CO [ppm]	1.8	1.8	2.0	1.9	2.1	2.0
	Avg NO_2 [ppm]	0.127	0.125	0.144	0.141	0.162	0.143
	Min visibility [m^{-1}]	0.00117	0.00117	0.00117	0.00117	0.00125	0.00125
16.00 to 16.00	Avg CO [ppm]	1.8	1.8	1.9	1.8	2.0	1.9
	Avg NO_2 [ppm]	0.115	0.114	0.130	0.128	0.141	0.126
	Min visibility [m^{-1}]	0.00100	0.00100	0.00100	0.00100	0.00103	0.00103
16.00 to 17.00	Avg CO [ppm]	1.8	1.8	1.9	1.8	2.0	1.9
	Avg NO_2 [ppm]	0.115	0.114	0.130	0.128	0.141	0.126
	Min visibility [m^{-1}]	0.00100	0.00100	0.00100	0.00100	0.00103	0.00103
17.00 to 18.00	Avg CO [ppm]	1.8	1.8	1.9	1.8	2.0	1.9
	Avg NO_2 [ppm]	0.115	0.114	0.130	0.128	0.141	0.126
	Min visibility [m^{-1}]	0.00100	0.00100	0.00100	0.00100	0.00103	0.00103
18.00 to 19.00	Avg CO [ppm]	1.5	1.5	1.6	1.6	1.6	1.6
	Avg NO_2 [ppm]	0.082	0.081	0.089	0.088	0.096	0.088
	Min visibility [m^{-1}]	0.00053	0.00053	0.00053	0.00053	0.00056	0.00056
19.00 to 06.00	Avg CO [ppm]	1.5	1.5	1.6	1.6	1.6	1.6
	Avg NO_2 [ppm]	0.082	0.081	0.089	0.088	0.096	0.088
	Min visibility [m^{-1}]	0.00053	0.00053	0.00053	0.00053	0.00056	0.00056
06.00 to 07.00	Avg CO [ppm]	1.5	1.5	1.6	1.6	1.6	1.6
	Avg NO_2 [ppm]	0.082	0.082	0.090	0.088	0.096	0.088
	Min visibility [m^{-1}]	0.00054	0.00054	0.00054	0.00054	0.00056	0.00056

Notes:
(1) Air Quality Criteria: CO Average 50 ppm, NO_2 Average 0.5 ppm and Visibility 0.005m^{-1}
(2) Refer to Figure 7-8 for typical in-tunnel nitrogen dioxide air quality.
(3) The assessment values include background air quality.

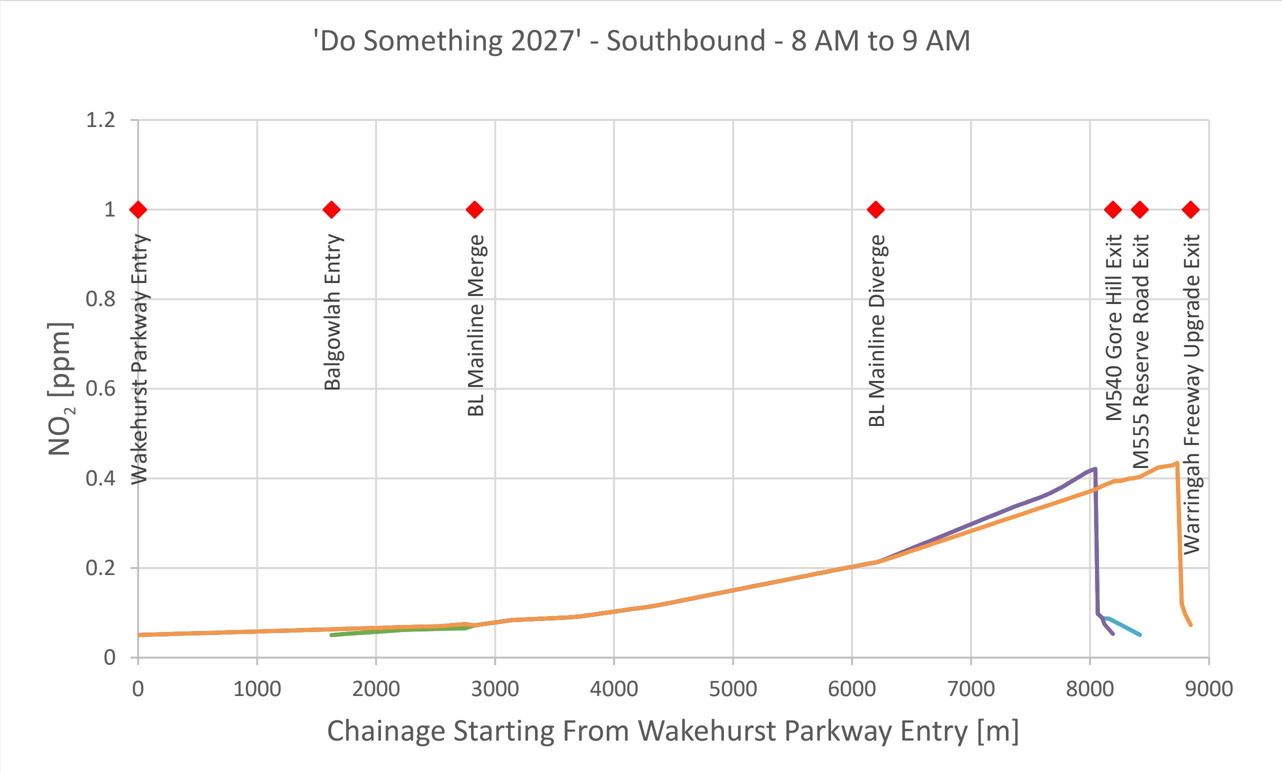


Figure 7-8 NO_2 concentration profile along the routes for 'Do something 2027' southbound, peak period

7.1.2 2037 expected traffic operations

7.1.2.1 Ventilation outlets emissions

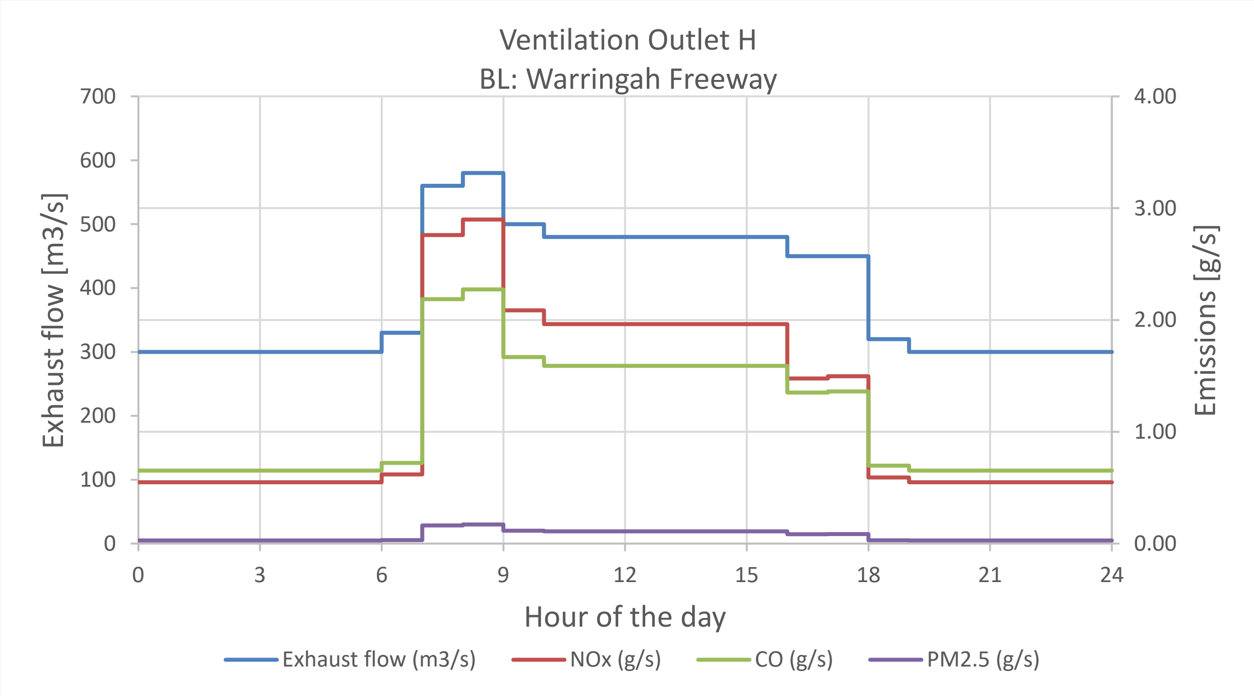


Figure 7-9 Ventilation Outlet H: Warringah Freeway – ‘Do something 2027’ (Beaches Link only)

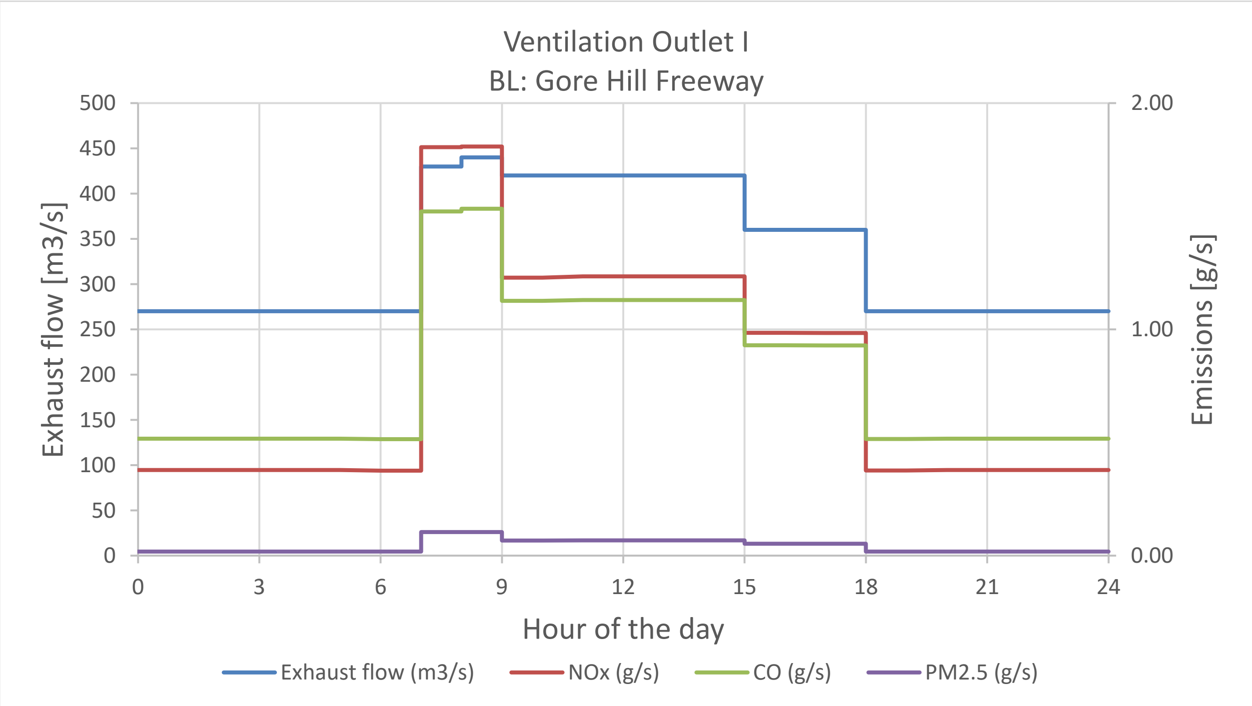


Figure 7-10 Ventilation Outlet I: Gore Hill Freeway - ‘Do something 2027’ (Beaches Link only)

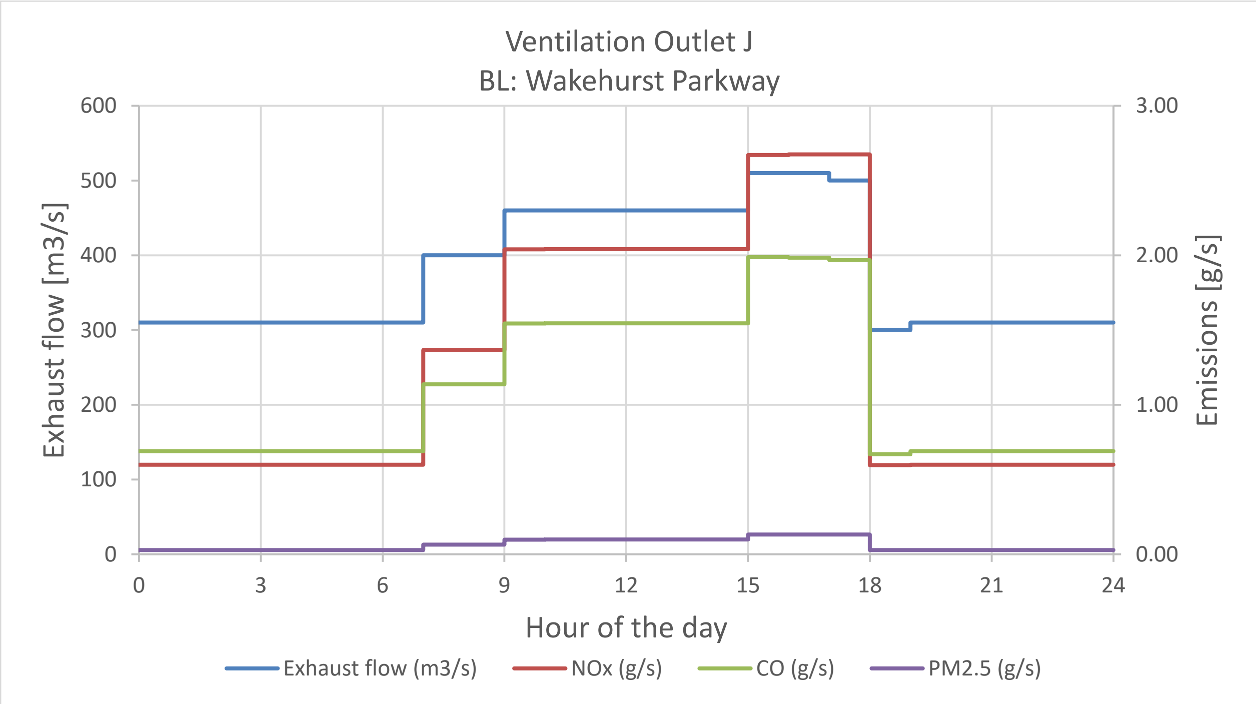


Figure 7-11 Ventilation Outlet J: Wakehurst Parkway - ‘Do something 2027’ (Beaches Link only)

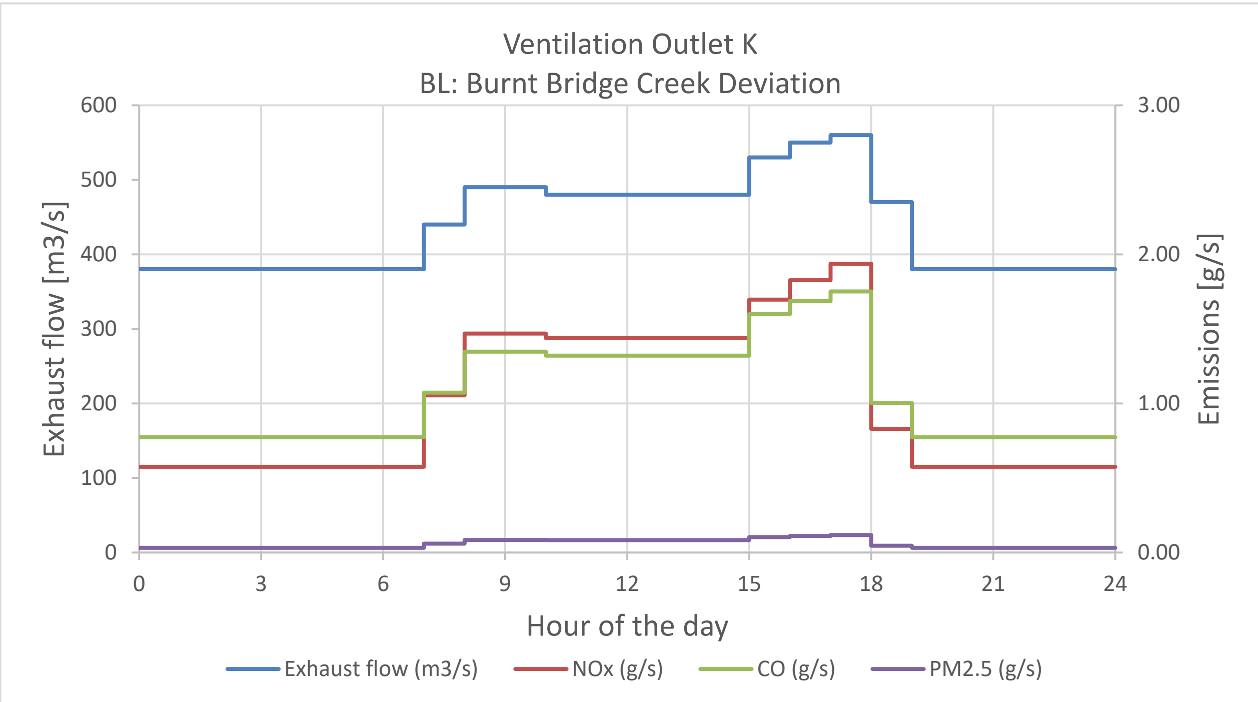


Figure 7-12 Ventilation Outlet K: Burnt Bridge Creek Deviation - ‘Do something 2027’ (Beaches Link only)

7.1.2.2 In-tunnel air quality

Table 7.3 ‘Do something 2037’ northbound in-tunnel air quality results

Time period	Route ID	DS-NB-A	DS-NB-B	DS-NB-C	DS-NB-D
	Entry portal	**Warringah Freeway Upgrade**	**Warringah Freeway Upgrade**	**Gore Hill**	**Gore Hill**
	Exit portal	**Balgowlah**	**Wakehurst Parkway**	**Balgowlah**	**Wakehurst Parkway**
	Length	**7.2 km**	**8.8 km**	**6.6 km**	**8.1 km**
7.00 to 9.00	**Average CO [ppm](1)**	1.7	1.9	1.7	2.0
	Average NO_2 [ppm](1)	0.117	0.160	0.122	0.168
	Min visibility [m^{-1}](1)	0.00085	0.00109	0.00085	0.00109
9.00 to 10.00	**Average CO [ppm]**	1.8	2.1	1.9	2.2
	Average NO_2 [ppm]	0.139	0.194	0.145	0.204
	Min visibility [m^{-1}]	0.00109	0.00140	0.00109	0.00140
10.00 to 15.00	**Average CO [ppm]**	1.8	2.1	1.9	2.2
	Average NO_2 [ppm]	0.139	0.194	0.145	0.203
	Min visibility [m^{-1}]	0.00109	0.00139	0.00109	0.00139
15.00 to 16.00	**Average CO [ppm]**	1.9	2.3	2.0	2.3
	Average NO_2 [ppm]	0.150	0.217	0.157	0.229
	Min visibility [m^{-1}]	0.00122	0.00163	0.00122	0.00163
16.00 to 17.00	**Average CO [ppm]**	1.9	2.3	2.0	2.4
	Average NO_2 [ppm]	0.152	0.220	0.159	0.231
	Min visibility [m^{-1}]	0.00124	0.00165	0.00124	0.00165
17.00 to 18.00	**Average CO [ppm]**	1.9	2.3	2.0	2.4
	Average NO_2 [ppm]	0.153	0.222	0.161	0.234
	Min visibility [m^{-1}]	0.00125	0.00167	0.00125	0.00167
18.00 to 19.00	**Average CO [ppm]**	1.6	1.7	1.6	1.7
	Average NO_2 [ppm]	0.094	0.121	0.098	0.126
	Min visibility [m^{-1}]	0.00059	0.00073	0.00059	0.00073
19.00 to 7.00	**Average CO [ppm]**	1.6	1.7	1.6	1.7
	Average NO_2 [ppm]	0.090	0.114	0.093	0.118
	Min visibility [m^{-1}]	0.00055	0.00068	0.00055	0.00068

Notes:

(1) Air Quality Criteria: CO Average 50 ppm, NO_2 Average 0.5 ppm and Visibility 0.005m^{-1}
(2) Refer to Figure 7-13 for typical in-tunnel nitrogen dioxide air quality.
(3) The assessment values include background air quality.

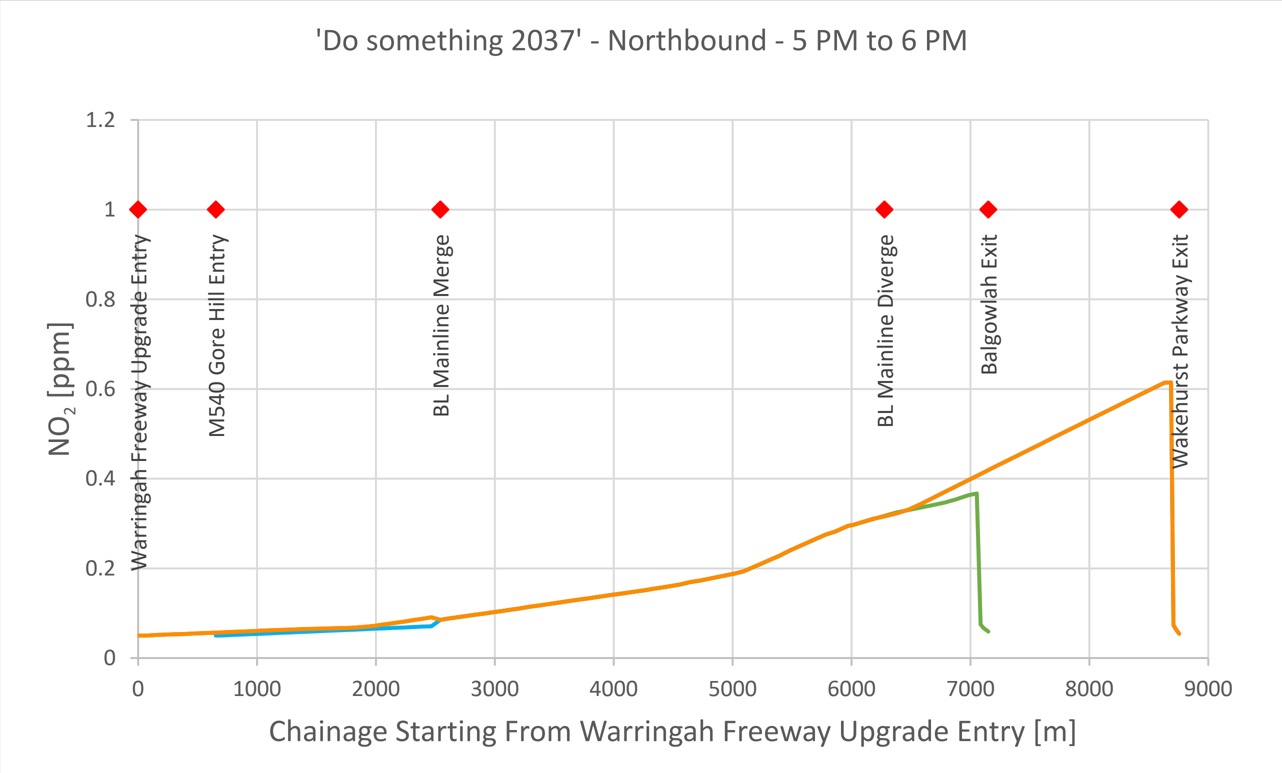


Figure 7-13 NO_2 concentration profile along the routes for 'Do something 2037' – northbound, peak period

Table 7.4 'Do something 2037' southbound in-tunnel air quality results

Time period	Route ID	DS-SB-A	DS-SB-B	DS-SB-C	DS-SB-D	DS-SB-E	DS-SB-F
	Entry portal	Wakehurst Parkway	Wakehurst Parkway	Balgowlah	Balgowlah	Balgowlah	Wakehurst Parkway
	Exit portal	M540 Gore Hill	M555 Reserve Road	M540 Gore Hill	M555 Reserve Road	Warringah Freeway Upgrade	Warringah Freeway Upgrade
	Length	8.2 km	8.4 km	6.6 km	6.8 km	7.3 km	8.9 km
7.00 to 8.00	Avg CO [ppm](1)	2.0	2.0	2.1	2.1	2.2	2.1
	Avg NO_2 [ppm](1)	0.157	0.155	0.180	0.177	0.200	0.175
	Min visibility [m^{-1}](1)	0.00152	0.00152	0.00152	0.00152	0.00156	0.00156
8.00 to 9.00	Avg CO [ppm]	2.0	2.0	2.1	2.1	2.2	2.1
	Avg NO_2 [ppm]	0.158	0.156	0.182	0.179	0.202	0.176
	Min visibility [m^{-1}]	0.00153	0.00153	0.00153	0.00153	0.00157	0.00157
9.00 to 10.00	Avg CO [ppm]	1.8	1.8	1.9	1.9	2.0	1.9
	Avg NO_2 [ppm]	0.134	0.132	0.153	0.149	0.171	0.151
	Min visibility [m^{-1}]	0.00120	0.00120	0.00120	0.00120	0.00127	0.00127
10.00 to 15.00	Avg CO [ppm]	1.8	1.8	1.9	1.9	2.0	1.9
	Avg NO_2 [ppm]	0.133	0.131	0.152	0.148	0.170	0.150
	Min visibility [m^{-1}]	0.00119	0.00119	0.00119	0.00119	0.00126	0.00126
16.00 to 16.00	Avg CO [ppm]	1.7	1.7	1.8	1.8	1.9	1.8
	Avg NO_2 [ppm]	0.120	0.119	0.136	0.134	0.148	0.131
	Min visibility [m^{-1}]	0.00102	0.00102	0.00102	0.00102	0.00104	0.00104
16.00 to 17.00	Avg CO [ppm]	1.7	1.7	1.8	1.8	1.9	1.8
	Avg NO_2 [ppm]	0.120	0.119	0.136	0.134	0.148	0.131
	Min visibility [m^{-1}]	0.00102	0.00102	0.00102	0.00102	0.00104	0.00104
17.00 to 18.00	Avg CO [ppm]	1.7	1.7	1.8	1.8	1.9	1.8
	Avg NO_2 [ppm]	0.121	0.119	0.136	0.134	0.148	0.131
	Min visibility [m^{-1}]	0.00102	0.00102	0.00102	0.00102	0.00104	0.00104
18.00 to 19.00	Avg CO [ppm]	1.5	1.5	1.6	1.6	1.6	1.6
	Avg NO_2 [ppm]	0.084	0.083	0.092	0.091	0.099	0.090
	Min visibility [m^{-1}]	0.00053	0.00053	0.00053	0.00053	0.00056	0.00056
19.00 to 06.00	Avg CO [ppm]	1.5	1.5	1.6	1.6	1.6	1.6
	Avg NO_2 [ppm]	0.084	0.083	0.091	0.090	0.098	0.090
	Min visibility [m^{-1}]	0.00053	0.00053	0.00053	0.00053	0.00056	0.00056
06.00 to 07.00	Avg CO [ppm]	1.5	1.5	1.6	1.6	1.6	1.6
	Avg NO_2 [ppm]	0.084	0.084	0.092	0.091	0.099	0.091
	Min visibility [m^{-1}]	0.00054	0.00054	0.00054	0.00054	0.00056	0.00056

Notes:

(1) Air Quality Criteria: CO Average 50 ppm, NO_2 Average 0.5 ppm and Visibility 0.005m^{-1}
(2) Refer to Figure 7-14 for typical in-tunnel nitrogen dioxide air quality.

(3) The assessment values include background air quality.

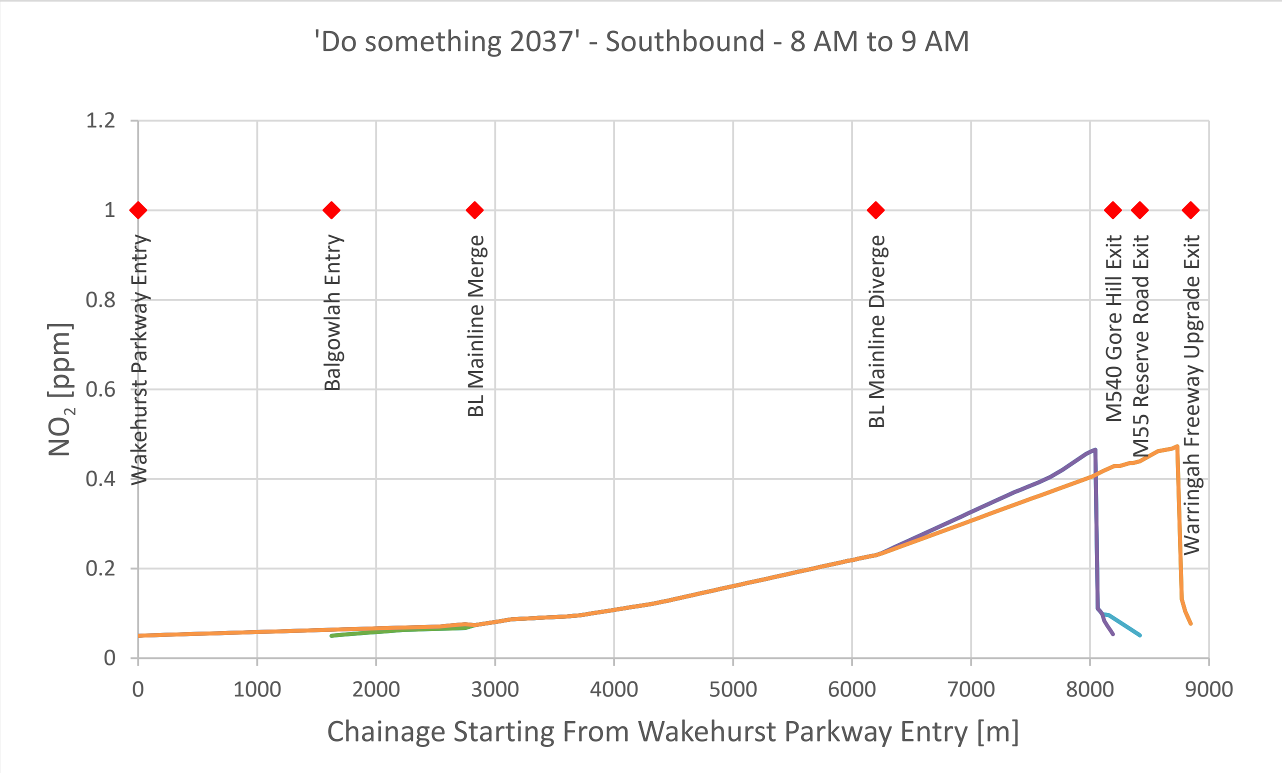


Figure 7-14 NO_2 concentration profile along the routes for 'Do something 2037' – southbound, peak period

7.2 'Do something cumulative'

7.2.1 2027 expected traffic operations

7.2.1.1 Ventilation outlets emissions

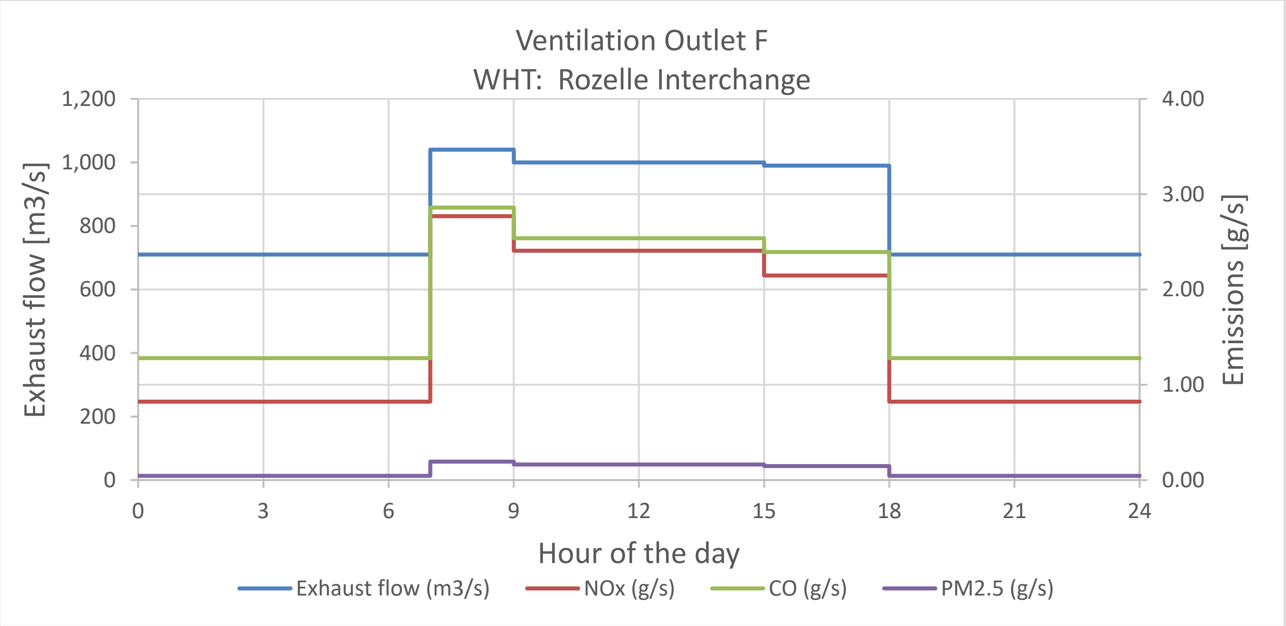


Figure 7-15 Ventilation Outlet F: Rozelle Interchange – 'Do something cumulative 2027'

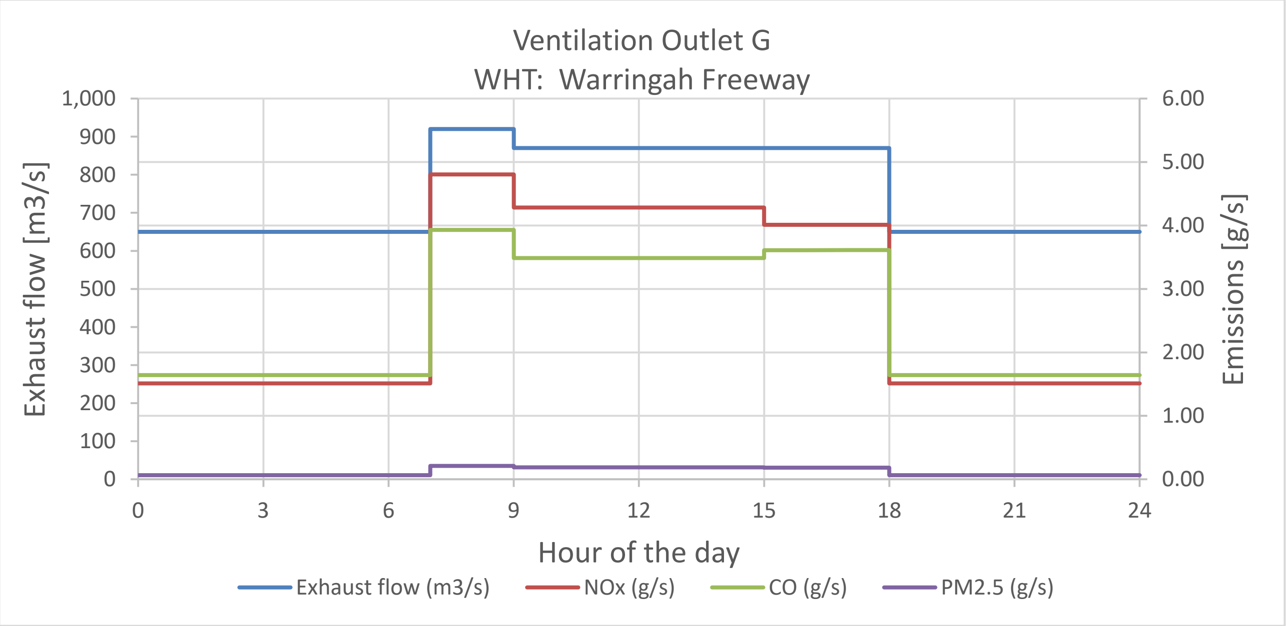


Figure 7-16 Ventilation Outlet G: Warringah Freeway (Western Harbour Tunnel) – 'Do something cumulative 2027'

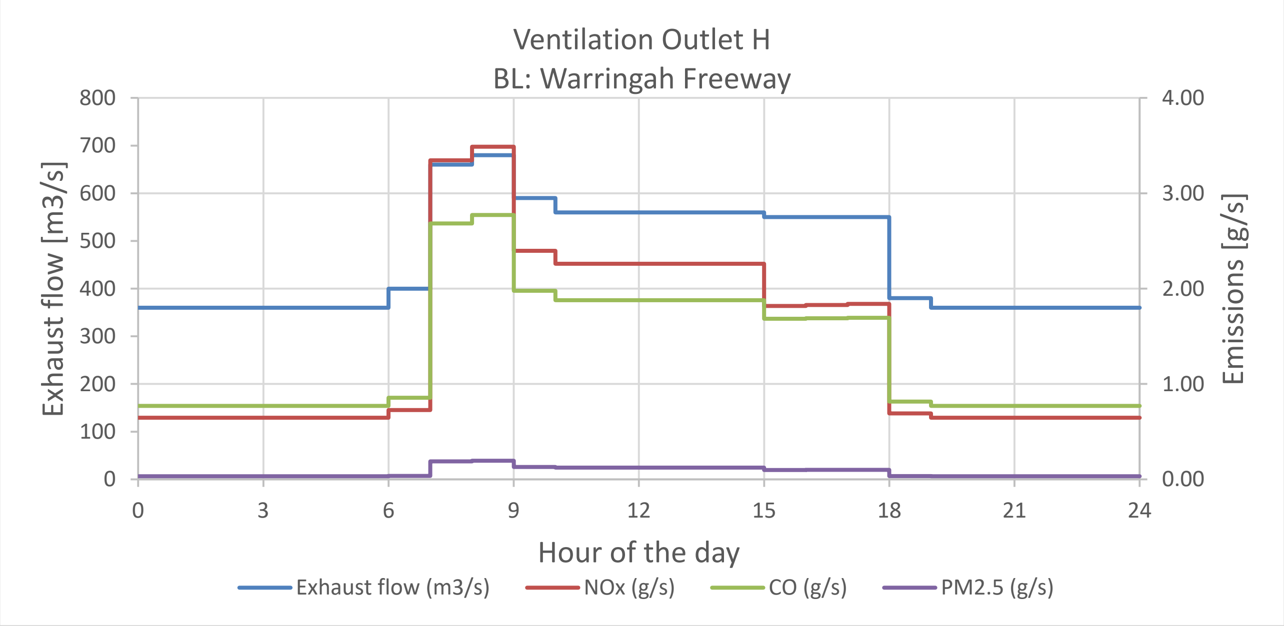


Figure 7-17 Ventilation Outlet H: Warringah Freeway (Beaches Link) - 'Do something cumulative 2027'

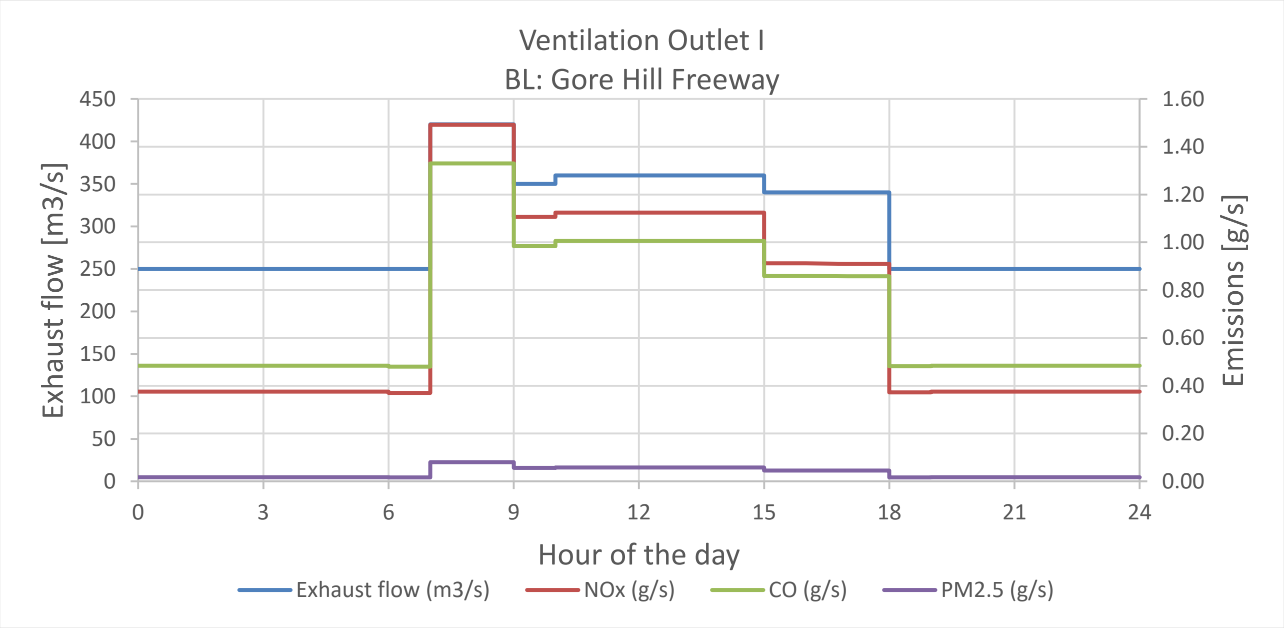


Figure 7-18 Ventilation Outlet I: Gore Hill Freeway - 'Do something cumulative 2027'

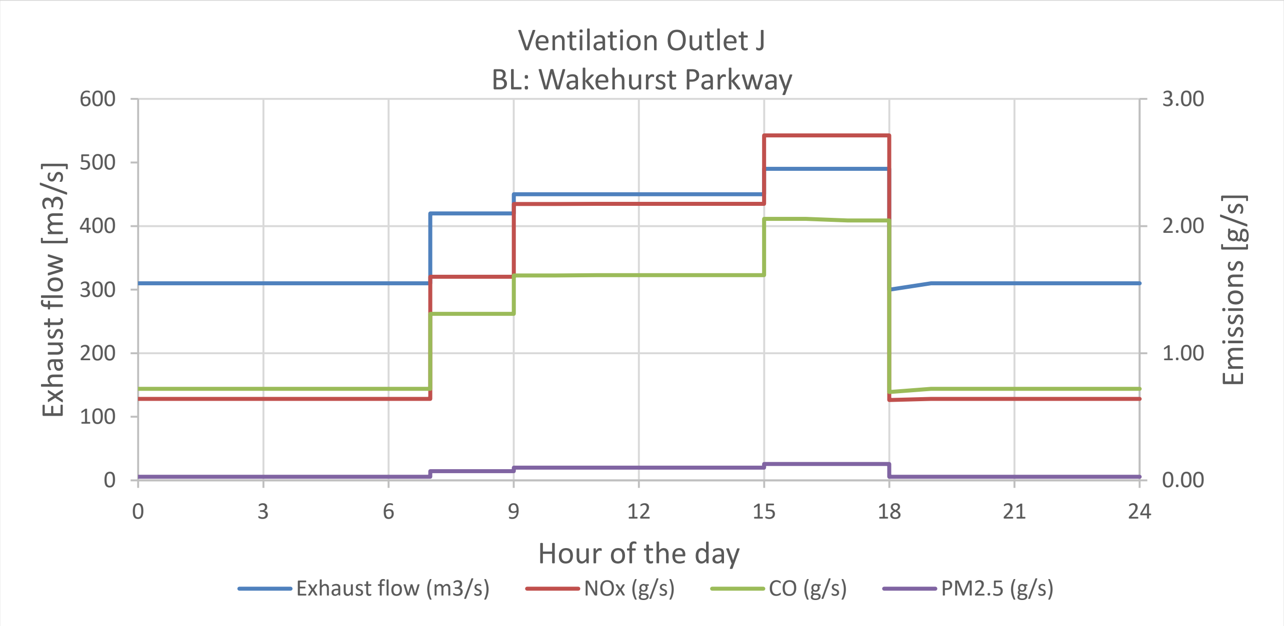


Figure 7-19 Ventilation Outlet J: Wakehurst Parkway- 'Do something cumulative 2027'

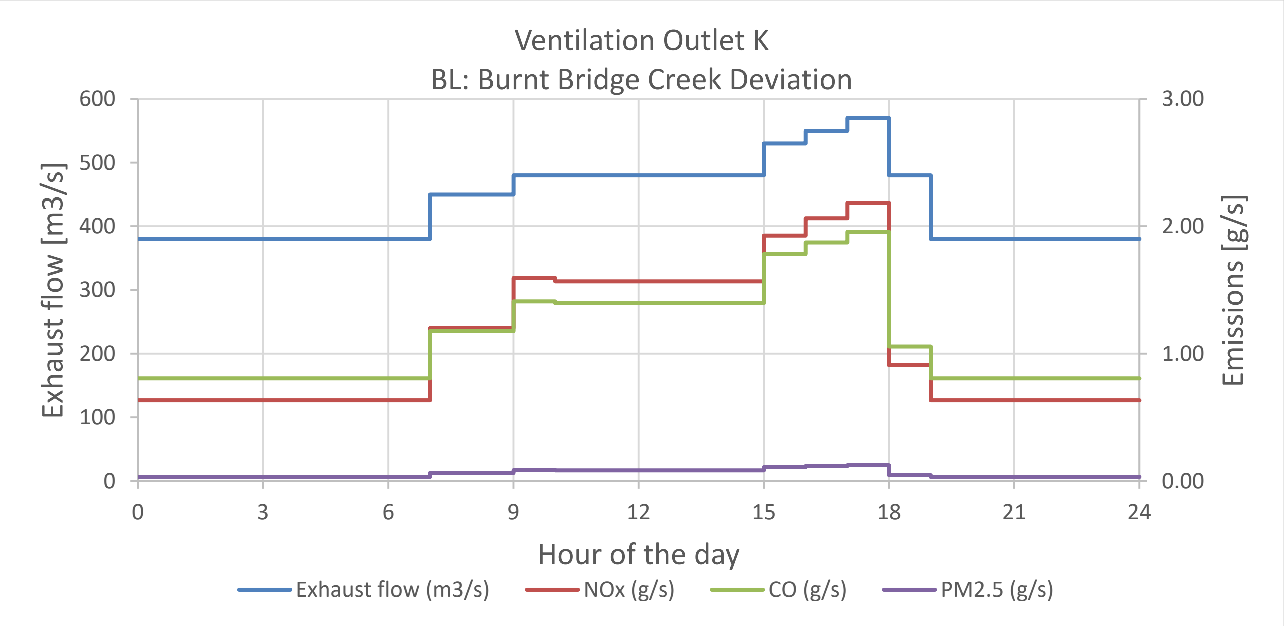


Figure 7-20 Ventilation Outlet K: Burnt Bridge Creek Deviation - 'Do something cumulative 2027'

7.2.1.2 In-tunnel air quality

Table 7.5 'Do something cumulative 2027' – northbound in-tunnel air quality results

Time period	Route ID	DSC-NB-A	DSC-NB-B	DSC-NB-C	DSC-NB-D	DSC-NB-E	DSC-NB-F	DSC-NB-G	DSC-NB-H	DSC-NB-I	DSC-NB-J
	Entry portal	Warringah Freeway Upgrade	Warringah Freeway Upgrade	Gore Hill	Gore Hill	WHT-BL Connection	WHT-BL Connections	Rozelle Interchange	Rozelle Interchange	M4-M5 Link	M4-M5 Link
	Exit portal	Balgowlah	Wakehurst Parkway	Balgowlah	Wakehurst Parkway	Balgowlah	Wakehurst	Balgowlah	Wakehurst Parkway	Balgowlah	Wakehurst Parkway
	Length	7.2 km	8.8 km	6.6 km	8.1 km	8.9 km	10.5 km	14.3 km	15.9 km	13.5 km	15.1 km
7.00 to 9.00	Avg CO [ppm][(1)]	1.8	2.1	1.8	2.1	1.9	2.1	2.2	2.3	2.2	2.3
	Avg NO_2 [ppm][(1)]	0.123	0.166	0.126	0.172	0.130	0.170	0.172	0.191	0.179	0.198
	Min visibility [m^{-1}][(1)]	0.00092	0.00118	0.00092	0.00118	0.00134	0.00134	0.00134	0.00134	0.00134	0.00134
9.00 to 10.00	Avg CO [ppm]	1.9	2.2	2.0	2.3	2.0	2.3	2.2	2.3	2.2	2.4
	Avg NO_2 [ppm]	0.141	0.194	0.145	0.202	0.146	0.196	0.174	0.201	0.182	0.208
	Min visibility [m^{-1}]	0.00112	0.00144	0.00112	0.00144	0.00127	0.00144	0.00127	0.00144	0.00127	0.00144
10.00 to 15.00	Avg CO [ppm]	1.9	2.2	2.0	2.3	2.0	2.3	2.2	2.3	2.2	2.4
	Avg NO_2 [ppm]	0.141	0.194	0.145	0.201	0.146	0.196	0.174	0.200	0.182	0.208
	Min visibility [m^{-1}]	0.00111	0.00144	0.00111	0.00144	0.00127	0.00144	0.00127	0.00144	0.00127	0.00144
15.00 to 16.00	Avg CO [ppm]	2.1	2.5	2.1	2.5	2.1	2.5	2.3	2.5	2.3	2.5
	Avg NO_2 [ppm]	0.152	0.214	0.157	0.223	0.156	0.215	0.175	0.207	0.182	0.215
	Min visibility [m^{-1}]	0.00126	0.00167	0.00126	0.00167	0.00126	0.00167	0.00126	0.00167	0.00126	0.00167
16.00 to 17.00	Avg CO [ppm]	2.1	2.5	2.1	2.5	2.1	2.5	2.3	2.5	2.3	2.5
	Avg NO_2 [ppm]	0.153	0.216	0.158	0.225	0.157	0.217	0.175	0.208	0.182	0.216
	Min visibility [m^{-1}]	0.00128	0.00169	0.00128	0.00169	0.00128	0.00169	0.00128	0.00169	0.00128	0.00169

Time period	Route ID	DSC-NB-A	DSC-NB-B	DSC-NB-C	DSC-NB-D	DSC-NB-E	DSC-NB-F	DSC-NB-G	DSC-NB-H	DSC-NB-I	DSC-NB-J
	Entry portal	Warringah Freeway Upgrade	Warringah Freeway Upgrade	Gore Hill	Gore Hill	WHT-BL Connection	WHT-BL Connections	Rozelle Interchange	Rozelle Interchange	M4-M5 Link	M4-M5 Link
	Exit portal	Balgowlah	Wakehurst Parkway	Balgowlah	Wakehurst Parkway	Balgowlah	Wakehurst	Balgowlah	Wakehurst Parkway	Balgowlah	Wakehurst Parkway
	Length	7.2 km	8.8 km	6.6 km	8.1 km	8.9 km	10.5 km	14.3 km	15.9 km	13.5 km	15.1 km
17.00 to 18.00	Avg CO [ppm]	2.1	2.5	2.1	2.5	2.1	2.5	2.3	2.5	2.3	2.5
	Avg NO_2 [ppm]	0.154	0.218	0.160	0.227	0.158	0.218	0.176	0.209	0.183	0.217
	Min visibility [m^{-1}]	0.00129	0.00171	0.00129	0.00171	0.00129	0.00171	0.00129	0.00171	0.00129	0.00171
18.00 to 19.00	Avg CO [ppm]	1.6	1.8	1.6	1.8	1.6	1.8	1.7	1.8	1.8	1.8
	Avg NO_2 [ppm]	0.093	0.118	0.096	0.122	0.095	0.119	0.107	0.120	0.111	0.123
	Min visibility [m^{-1}]	0.00060	0.00075	0.00060	0.00075	0.00064	0.00075	0.00064	0.00075	0.00064	0.00075
19.00 to 7.00	Avg CO [ppm]	1.6	1.8	1.6	1.8	1.6	1.8	1.7	1.8	1.8	1.8
	Avg NO_2 [ppm]	0.090	0.113	0.092	0.116	0.092	0.113	0.106	0.117	0.109	0.120
	Min visibility [m^{-1}]	0.00056	0.00070	0.00056	0.00070	0.00064	0.00070	0.00064	0.00070	0.00064	0.00070

Notes:

(1) Air Quality Criteria: CO Average 50 ppm, NO_2 Average 0.5 ppm and Visibility $0.005m^{-1}$
(2) Refer to Figure 7-21 for typical in-tunnel nitrogen dioxide air quality.
(3) The assessment values include background air quality.

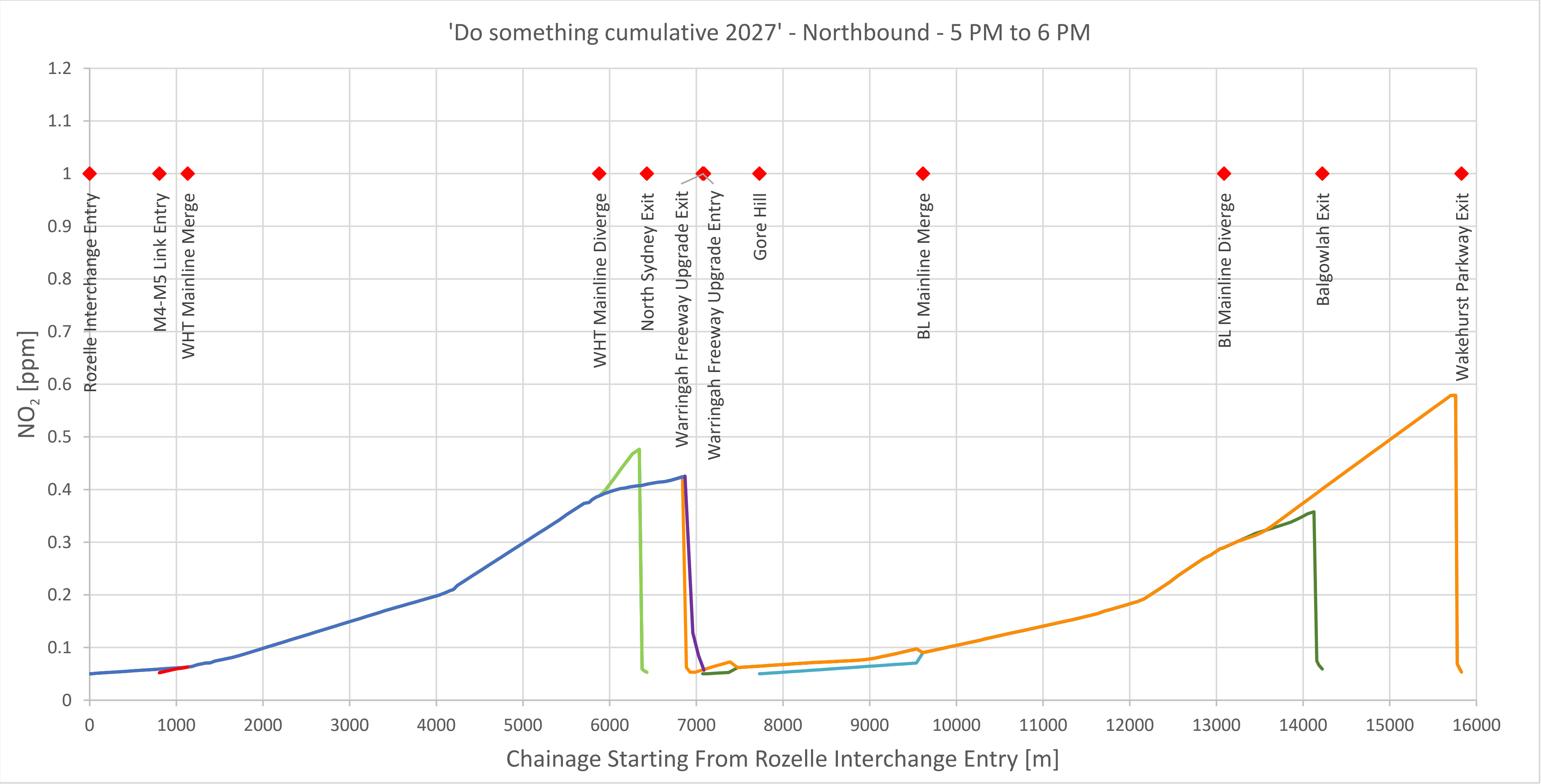


Figure 7-21 NO_2 concentration profile along the routes for ‘Do something cumulative 2027’ – northbound, peak period

Table 7.6 'Do something cumulative 2027' – southbound in-tunnel air quality results

Time period	Route ID	DSC-SB-A	DSC-SB-B	DSC-SB-C	DSC-SB-D	DSC-SB-E	DSC-SB-F	DSC-SB-G	DSC-SB-H	DSC-SB-I	DSC-SB-J	DSC-SB-K	DSC-SB-L	DSC-SB-M	DSC-SB-N
	Entry portal	Wakehurst Parkway	Wakehurst Parkway	Balgowlah	Balgowlah	Balgowlah	Balgowlah	Wakehurst Parkway	Wakehurst Parkway	Balgowlah	Balgowlah	Balgowlah	Wakehurst Parkway	Wakehurst Parkway	Wakehurst Parkway
	Exit portal	M540 Gore Hill	M555 Reserve Road	M540 Gore Hill	M555 Reserve Road	BL-WHT Connection	Warringah Freeway Upgrade	BL-WHT Connection	Warringah Freeway Upgrade	M116 Rozelle	M115 Rozelle	M4-M5 Link	M116 Rozelle	M115 Rozelle	M4-M5 Link
	Length	8.2 km	8.4 km	6.6 km	6.8 km	7.7 km	7.3 km	9.3 km	8.9 km	14.2 km	14.3 km	13.6 km	15.9 km	15.9 km	15.2 km
7.00 to 8.00	Avg CO [ppm][1]	2.0	2.0	2.2	2.2	2.3	2.3	2.1	2.2	2.2	2.2	2.2	2.1	2.1	2.1
	Avg NO_2 [ppm][1]	0.151	0.149	0.172	0.169	0.189	0.194	0.167	0.170	0.174	0.174	0.169	0.162	0.162	0.158
	Min visibility [m^{-1}][1]	0.00150	0.00150	0.00150	0.00150	0.00162	0.00158	0.00162	0.00158	0.00162	0.00162	0.00162	0.00162	0.00162	0.00162
8.00 to 9.00	Avg CO [ppm]	2.0	2.0	2.2	2.2	2.3	2.3	2.2	2.2	2.2	2.2	2.2	2.1	2.1	2.1
	Avg NO_2 [ppm]	0.152	0.150	0.174	0.171	0.190	0.196	0.168	0.171	0.174	0.174	0.170	0.163	0.163	0.158
	Min visibility [m^{-1}]	0.00152	0.00152	0.00152	0.00152	0.00163	0.00159	0.00163	0.00159	0.00163	0.00163	0.00163	0.00163	0.00163	0.00163
9.00 to 10.00	Avg CO [ppm]	1.9	1.9	2.0	2.0	2.1	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	Avg NO_2 [ppm]	0.132	0.130	0.150	0.147	0.163	0.167	0.144	0.147	0.155	0.155	0.151	0.146	0.146	0.141
	Min visibility [m^{-1}]	0.00123	0.00123	0.00123	0.00123	0.00131	0.00129	0.00131	0.00129	0.00131	0.00131	0.00131	0.00131	0.00131	0.00131
10.00 to 15.00	Avg CO [ppm]	1.9	1.9	2.0	2.0	2.1	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	Avg NO_2 [ppm]	0.131	0.129	0.149	0.145	0.162	0.167	0.144	0.147	0.155	0.155	0.151	0.145	0.146	0.141
	Min visibility [m^{-1}]	0.00121	0.00121	0.00121	0.00121	0.00131	0.00129	0.00131	0.00129	0.00131	0.00131	0.00131	0.00131	0.00131	0.00131
15.00 to 16.00	Avg CO [ppm]	1.8	1.8	1.9	1.9	2.0	2.0	1.9	1.9	2.0	2.0	1.9	1.9	1.9	1.9
	Avg NO_2 [ppm]	0.119	0.117	0.134	0.132	0.143	0.147	0.128	0.130	0.139	0.139	0.135	0.131	0.131	0.126
	Min visibility [m^{-1}]	0.00105	0.00105	0.00105	0.00105	0.00110	0.00109	0.00110	0.00109	0.00110	0.00110	0.00110	0.00110	0.00110	0.00110
16.00 to 17.00	Avg CO [ppm]	1.8	1.8	1.9	1.9	2.0	2.0	1.9	1.9	2.0	2.0	1.9	1.9	1.9	1.9
	Avg NO_2 [ppm]	0.119	0.118	0.134	0.132	0.143	0.147	0.128	0.130	0.139	0.139	0.135	0.131	0.131	0.126

Time period	Route ID	DSC-SB-A	DSC-SB-B	DSC-SB-C	DSC-SB-D	DSC-SB-E	DSC-SB-F	DSC-SB-G	DSC-SB-H	DSC-SB-I	DSC-SB-J	DSC-SB-K	DSC-SB-L	DSC-SB-M	DSC-SB-N
	Entry portal	Wakehurst Parkway	Wakehurst Parkway	Balgowlah	Balgowlah	Balgowlah	Balgowlah	Wakehurst Parkway	Wakehurst Parkway	Balgowlah	Balgowlah	Balgowlah	Wakehurst Parkway	Wakehurst Parkway	Wakehurst Parkway
	Exit portal	M540 Gore Hill	M555 Reserve Road	M540 Gore Hill	M555 Reserve Road	BL-WHT Connection	Warringah Freeway Upgrade	BL-WHT Connection	Warringah Freeway Upgrade	M116 Rozelle	M115 Rozelle	M4-M5 Link	M116 Rozelle	M115 Rozelle	M4-M5 Link
	Length	8.2 km	8.4 km	6.6 km	6.8 km	7.7 km	7.3 km	9.3 km	8.9 km	14.2 km	14.3 km	13.6 km	15.9 km	15.9 km	15.2 km
	Min visibility [m^{-1}]	0.00105	0.00105	0.00105	0.00105	0.00110	0.00109	0.00110	0.00109	0.00110	0.00110	0.00110	0.00110	0.00110	0.00110
17.00 to 18.00	Avg CO [ppm]	1.8	1.8	1.9	1.9	2.0	2.0	1.9	1.9	2.0	2.0	1.9	1.9	1.9	1.9
	Avg NO_2 [ppm]	0.119	0.118	0.135	0.132	0.143	0.147	0.128	0.130	0.139	0.139	0.135	0.131	0.131	0.126
	Min visibility [m^{-1}]	0.00105	0.00105	0.00105	0.00105	0.00110	0.00109	0.00110	0.00109	0.00110	0.00110	0.00110	0.00110	0.00110	0.00110
18.00 to 19.00	Avg CO [ppm]	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
	Avg NO_2 [ppm]	0.083	0.082	0.091	0.089	0.095	0.097	0.087	0.089	0.090	0.090	0.089	0.086	0.086	0.085
	Min visibility [m^{-1}]	0.00055	0.00055	0.00055	0.00055	0.00057	0.00057	0.00057	0.00057	0.00057	0.00057	0.00057	0.00057	0.00057	0.00057
19.00 to 6.00	Avg CO [ppm]	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
	Avg NO_2 [ppm]	0.083	0.082	0.090	0.089	0.095	0.097	0.087	0.089	0.090	0.090	0.089	0.086	0.086	0.085
	Min visibility [m^{-1}]	0.00054	0.00054	0.00054	0.00054	0.00057	0.00057	0.00057	0.00057	0.00057	0.00057	0.00057	0.00057	0.00057	0.00057
6.00 to 7.00	Avg CO [ppm]	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
	Avg NO_2 [ppm]	0.084	0.083	0.091	0.090	0.095	0.097	0.087	0.089	0.090	0.090	0.089	0.086	0.086	0.085
	Min visibility [m^{-1}]	0.00055	0.00055	0.00055	0.00055	0.00057	0.00057	0.00057	0.00057	0.00057	0.00057	0.00057	0.00057	0.00057	0.00057

Notes:

(1) Air Quality Criteria: CO Average 50 ppm, NO_2 Average 0.5 ppm and Visibility 0.005m^{-1}
(2) Refer to Figure 7-22 for typical in-tunnel nitrogen dioxide air quality.

(3) The assessment values include background air quality.

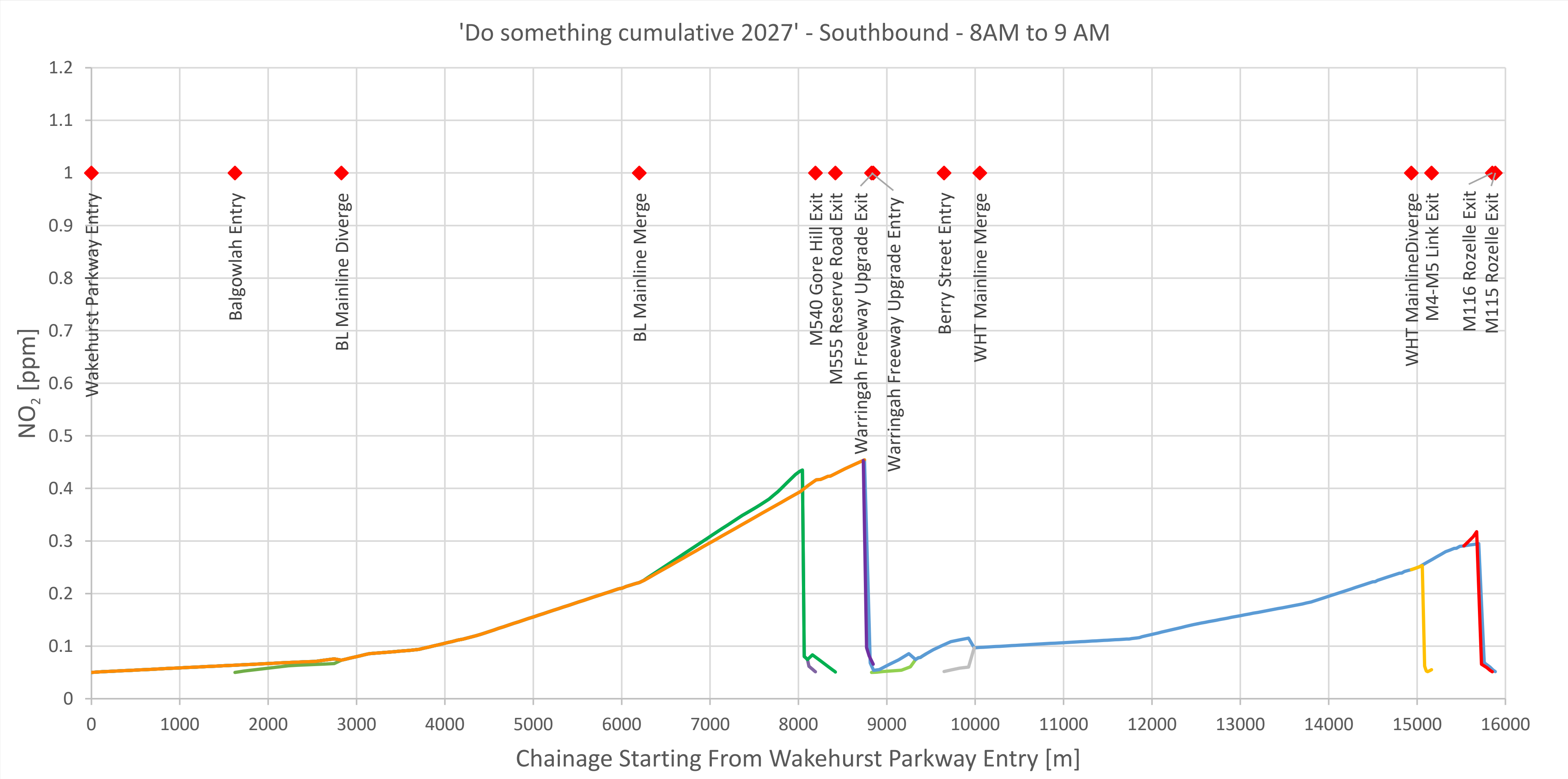


Figure 7-22 NO_2 concentration profile along the routes for 'Do something cumulative 2027' – southbound, peak period

7.2.2 2037 expected traffic operations

7.2.2.1 Ventilation outlet emissions

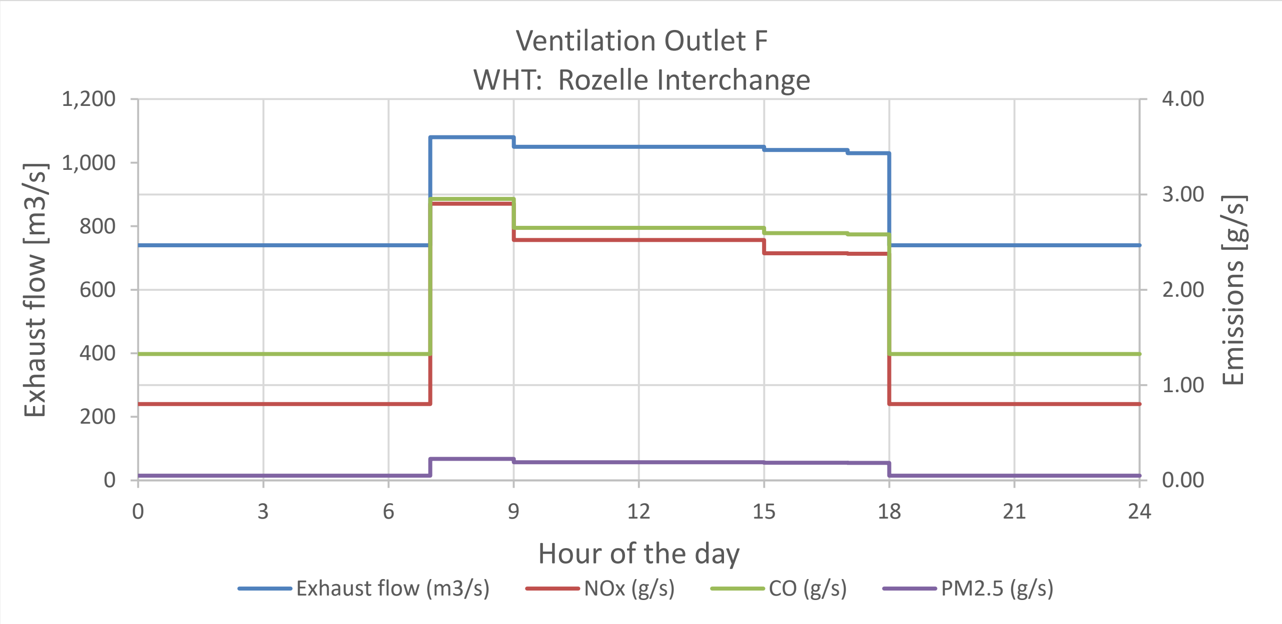


Figure 7-23 Ventilation Outlet F: Rozelle Interchange ‘Do something cumulative 2037’

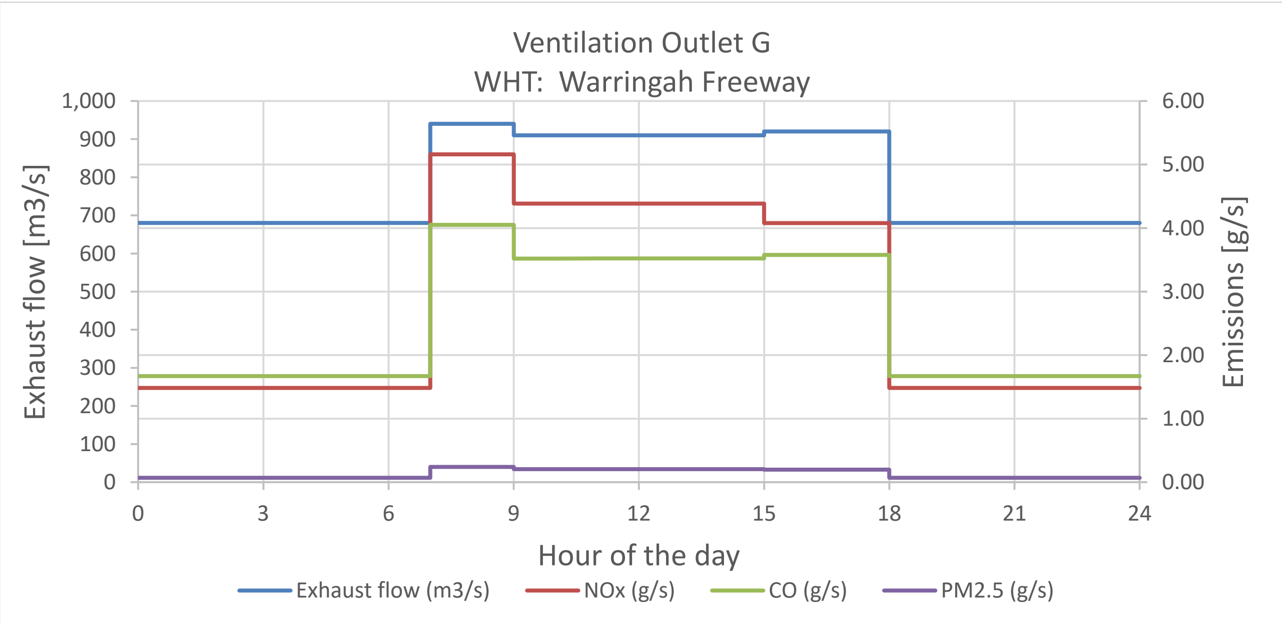


Figure 7-24 Ventilation Outlet G: Warringah Freeway (Western Harbour Tunnel) - ‘Do something cumulative 2037’

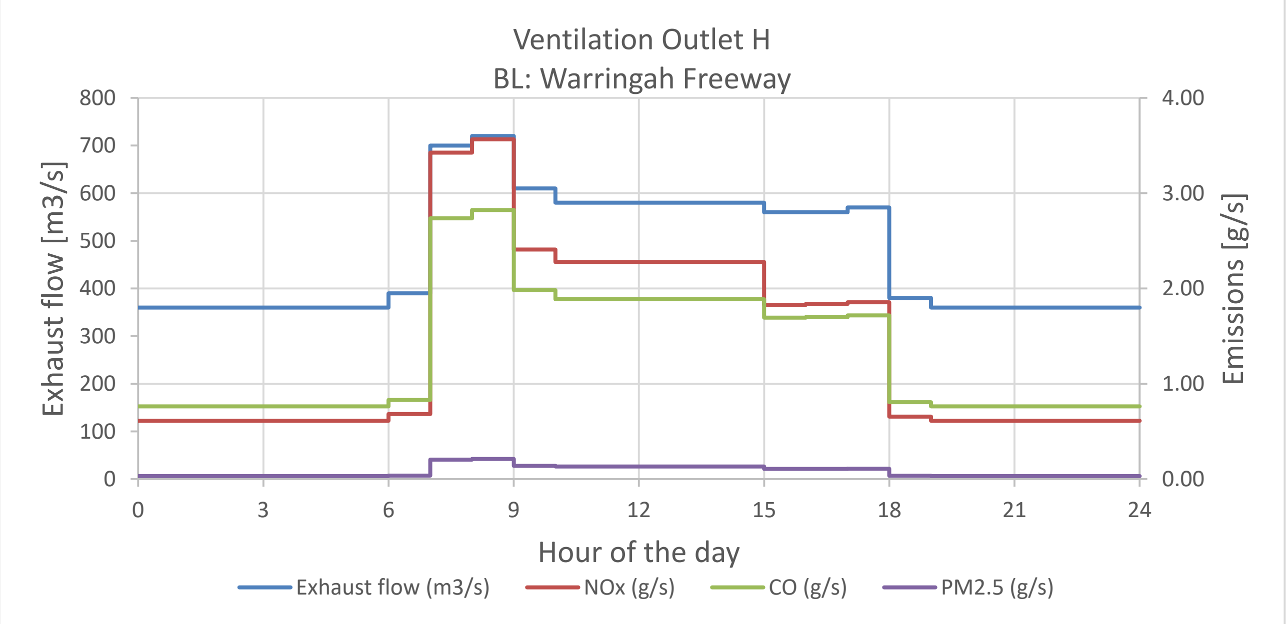


Figure 7-25 Ventilation Outlet H: Warringah Freeway (Beaches Link) - 'Do something cumulative 2037'

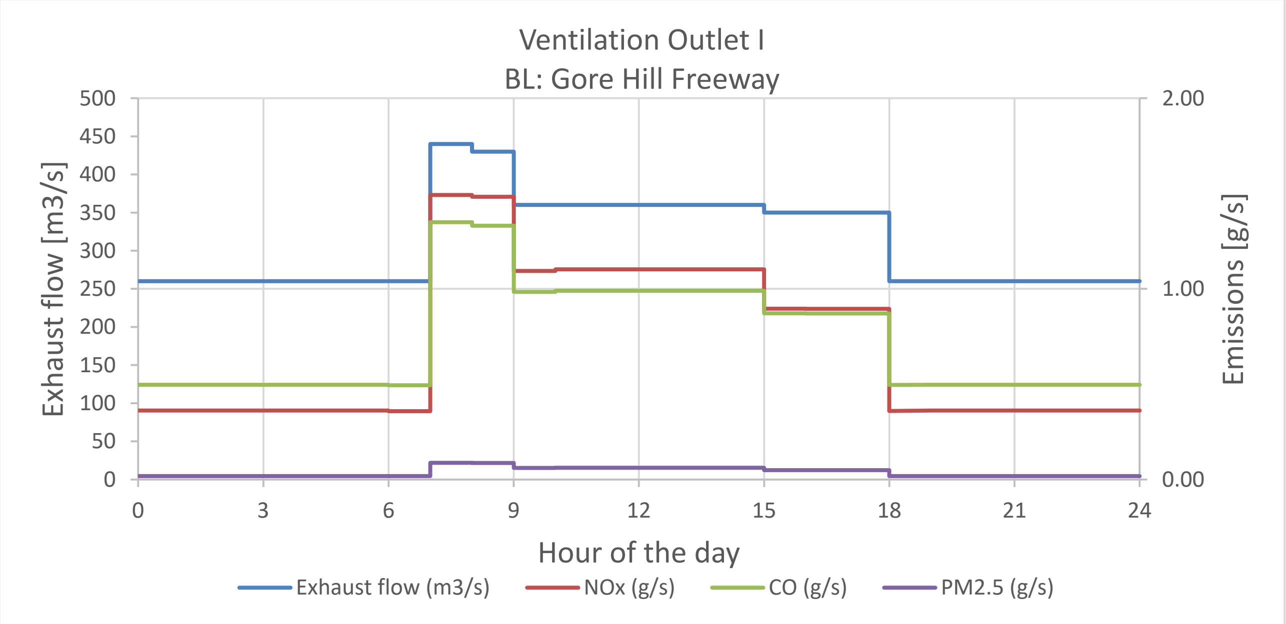


Figure 7-26 Ventilation Outlet I: Gore Hill Freeway - 'Do something cumulative 2037'

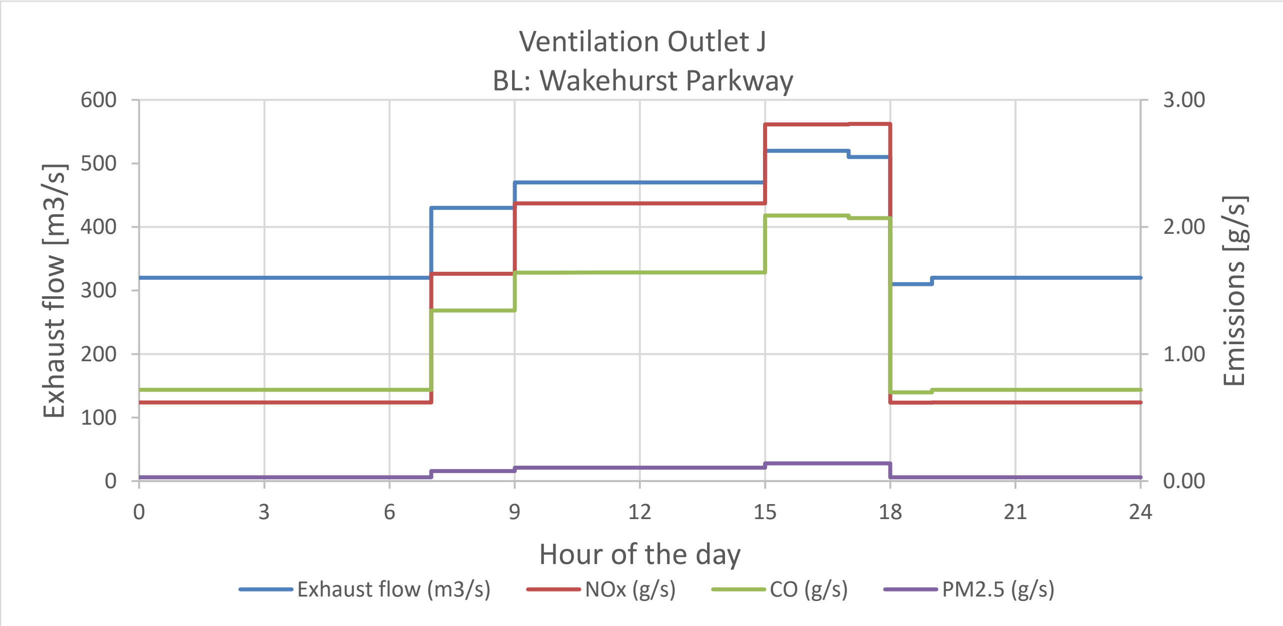


Figure 7-27 Ventilation Outlet J: Wakehurst Parkway - 'Do something cumulative 2037'

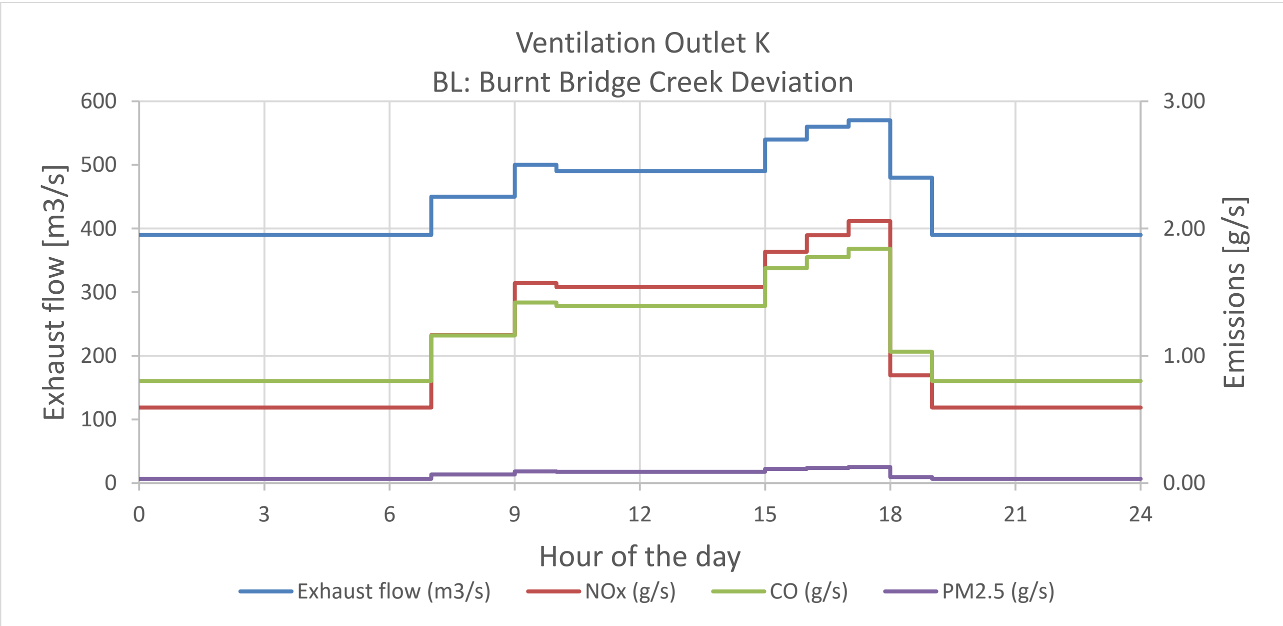


Figure 7-28 Ventilation Outlet K: Burnt Bridge Creek Deviation - 'Do something cumulative 2037'

7.2.2.2 In-tunnel air quality

Table 7.7 'Do something cumulative 2037' – northbound in-tunnel air quality results

Time period	Route ID	DSC-NB-A	DSC-NB-B	DSC-NB-C	DSC-NB-D	DSC-NB-E	DSC-NB-F	DSC-NB-G	DSC-NB-H	DSC-NB-I	DSC-NB-J
	Entry portal	Warringah Freeway Upgrade	Warringah Freeway Upgrade	Gore Hill	Gore Hill	WHT-BL Link	WHT-BL Link	Rozelle Interchange	Rozelle Interchange	M4-M5 Link	M4-M5 Link
	Exit portal	Balgowlah	Wakehurst Parkway	Balgowlah	Wakehurst Parkway	Balgowlah	Wakehurst	Balgowlah	Wakehurst Parkway	Balgowlah	Wakehurst Parkway
	Length	7.2 km	8.8 km	6.6 km	8.1 km	8.9 km	10.5 km	14.3 km	15.9 km	13.5 km	15.1 km
7.00 to 9.00	Avg CO [ppm](1)	1.8	2.0	1.8	2.1	1.8	2.1	2.1	2.2	2.2	2.3
	Avg NO_2 ppm](1)	0.131	0.178	0.134	0.185	0.139	0.183	0.190	0.210	0.198	0.218
	Min visibility [m^{-1}](1)	0.00094	0.00120	0.00094	0.00120	0.00145	0.00145	0.00145	0.00145	0.00145	0.00145
9.00 to 10.00	Avg CO [ppm]	1.9	2.2	1.9	2.2	1.9	2.2	2.1	2.2	2.2	2.3
	Avg NO_2 [ppm]	0.150	0.208	0.154	0.216	0.155	0.210	0.188	0.216	0.196	0.225
	Min visibility [m^{-1}]	0.00114	0.00146	0.00114	0.00146	0.00132	0.00146	0.00132	0.00146	0.00132	0.00146
10.00 to 15.00	Avg CO [ppm]	1.9	2.2	1.9	2.2	1.9	2.2	2.1	2.2	2.2	2.3
	Avg NO_2 [ppm]	0.149	0.207	0.154	0.215	0.155	0.210	0.188	0.216	0.195	0.224
	Min visibility [m^{-1}]	0.00114	0.00146	0.00114	0.00146	0.00132	0.00146	0.00132	0.00146	0.00132	0.00146
15.00 to 16.00	Avg CO [ppm]	2.0	2.4	2.0	2.4	2.0	2.4	2.2	2.3	2.2	2.4
	Avg NO_2 [ppm]	0.163	0.232	0.167	0.241	0.168	0.233	0.189	0.224	0.197	0.233
	Min visibility [m^{-1}]	0.00127	0.00170	0.00127	0.00170	0.00127	0.00170	0.00127	0.00170	0.00127	0.00170
16.00 to 17.00	Avg CO [ppm]	2.0	2.4	2.0	2.4	2.0	2.4	2.2	2.4	2.2	2.4
	Avg NO_2 [ppm]	0.164	0.235	0.169	0.244	0.169	0.236	0.189	0.226	0.197	0.235
	Min visibility [m^{-1}]	0.00129	0.00172	0.00129	0.00172	0.00129	0.00172	0.00129	0.00172	0.00129	0.00172

Time period	Route ID	DSC-NB-A	DSC-NB-B	DSC-NB-C	DSC-NB-D	DSC-NB-E	DSC-NB-F	DSC-NB-G	DSC-NB-H	DSC-NB-I	DSC-NB-J
	Entry portal	Warringah Freeway Upgrade	Warringah Freeway Upgrade	Gore Hill	Gore Hill	WHT-BL Link	WHT-BL Link	Rozelle Interchange	Rozelle Interchange	M4-M5 Link	M4-M5 Link
	Exit portal	Balgowlah	Wakehurst Parkway	Balgowlah	Wakehurst Parkway	Balgowlah	Wakehurst	Balgowlah	Wakehurst Parkway	Balgowlah	Wakehurst Parkway
	Length	7.2 km	8.8 km	6.6 km	8.1 km	8.9 km	10.5 km	14.3 km	15.9 km	13.5 km	15.1 km
17.00 to 18.00	Avg CO [ppm]	2.0	2.4	2.0	2.4	2.0	2.4	2.2	2.4	2.2	2.4
	Avg NO_2 [ppm]	0.166	0.237	0.171	0.246	0.171	0.238	0.190	0.227	0.198	0.236
	Min visibility [m^{-1}]	0.00131	0.00174	0.00131	0.00174	0.00131	0.00174	0.00131	0.00174	0.00131	0.00174
18.00 to 19.00	Avg CO [ppm]	1.6	1.7	1.6	1.8	1.6	1.8	1.7	1.8	1.7	1.8
	Avg NO_2 [ppm]	0.097	0.123	0.099	0.128	0.099	0.124	0.111	0.124	0.114	0.128
	Min visibility [m^{-1}]	0.00060	0.00074	0.00060	0.00074	0.00063	0.00074	0.00063	0.00074	0.00063	0.00074
19.00 to 7.00	Avg CO [ppm]	1.6	1.7	1.6	1.7	1.6	1.7	1.7	1.7	1.7	1.8
	Avg NO_2 [ppm]	0.093	0.117	0.095	0.120	0.095	0.118	0.109	0.121	0.112	0.124
	Min visibility [m^{-1}]	0.00056	0.00069	0.00056	0.00069	0.00063	0.00069	0.00063	0.00069	0.00063	0.00069

Notes:

(1) Air Quality Criteria: CO Average 50 ppm, NO_2 Average 0.5 ppm and Visibility 0.005m^{-1}
(2) Refer to Figure 7-29 for typical in-tunnel nitrogen dioxide air quality.
(3) The assessment values include background air quality.

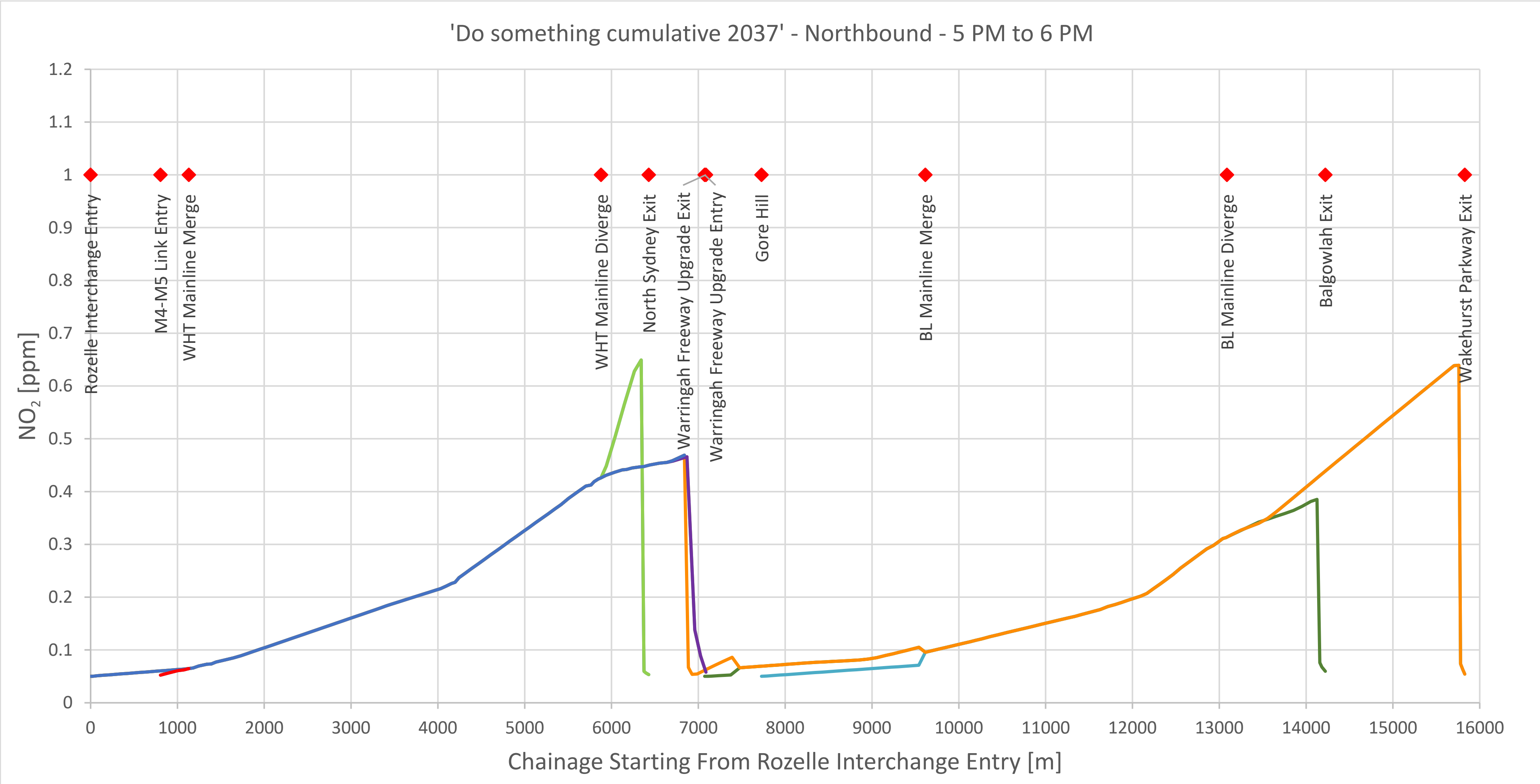


Figure 7-29 NO_2 concentration profile along the routes for 'Do something cumulative 2037' – northbound, peak period

Table 7.8 'Do something cumulative 2037'– southbound in-tunnel air quality results

Time period	Route ID	DSC-SB-A	DSC-SB-B	DSC-SB-C	DSC-SB-D	DSC-SB-E	DSC-SB-F	DSC-SB-G	DSC-SB-H	DSC-SB-I	DSC-SB-J	DSC-SB-K	DSC-SB-L	DSC-SB-M	DSC-SB-N
	Entry portal	Wakehurst Parkway	Wakehurst Parkway	Balgowlah	Balgowlah	Balgowlah	Balgowlah	Wakehurst Parkway	Wakehurst Parkway	Balgowlah	Balgowlah	Balgowlah	Wakehurst Parkway	Wakehurst Parkway	Wakehurst Parkway
	Exit portal	M540 Gore Hill	M555 Reserve Road	M540 Gore Hill	M555 Reserve Road	BL-WHT Connection	Warringah Freeway	BL-WHT Connection	Warringah Freeway	M116 Rozelle	M115 Rozelle	M4-M5 Link	M116 Rozelle	M115 Rozelle	M4-M5 Link
	Length	8.2 km	8.4 km	6.6 km	6.8 km	7.7 km	7.3 km	9.3 km	8.9 km	14.2 km	14.3 km	13.6 km	15.9 km	15.9 km	15.2 km
7:00 to 8:00	Avg CO [ppm](1)	2.0	2.0	2.1	2.1	2.2	2.3	2.1	2.1	2.2	2.2	2.1	2.1	2.1	2.1
	Avg NO_2 [ppm] (1)	0.161	0.159	0.185	0.181	0.207	0.211	0.182	0.184	0.194	0.193	0.187	0.180	0.180	0.174
	Min visibility [m^{-1}] (1)	0.00155	0.00155	0.00155	0.00155	0.00175	0.00164	0.00175	0.00164	0.00203	0.00175	0.00175	0.00203	0.00175	0.00175
8:00 to 9:00	Avg CO [ppm]	2.0	2.0	2.1	2.1	2.2	2.3	2.1	2.1	2.2	2.2	2.1	2.1	2.1	2.1
	Avg NO_2 [ppm]	0.162	0.160	0.187	0.183	0.209	0.213	0.183	0.185	0.194	0.194	0.188	0.180	0.180	0.175
	Min visibility [m^{-1}]	0.00156	0.00156	0.00156	0.00156	0.00177	0.00165	0.00177	0.00165	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177
9:00 to 10:00	Avg CO [ppm]	1.8	1.8	1.9	1.9	2.0	2.1	1.9	1.9	2.0	2.0	2.0	1.9	1.9	1.9
	Avg NO_2 [ppm]	0.140	0.137	0.159	0.156	0.174	0.179	0.154	0.157	0.168	0.168	0.163	0.157	0.157	0.152
	Min visibility [m^{-1}]	0.00126	0.00126	0.00126	0.00126	0.00135	0.00132	0.00135	0.00132	0.00135	0.00135	0.00135	0.00135	0.00135	0.00135

Time period	Route ID	DSC-SB-A	DSC-SB-B	DSC-SB-C	DSC-SB-D	DSC-SB-E	DSC-SB-F	DSC-SB-G	DSC-SB-H	DSC-SB-I	DSC-SB-J	DSC-SB-K	DSC-SB-L	DSC-SB-M	DSC-SB-N
	Entry portal	Wakehurst Parkway	Wakehurst Parkway	Balgowlah	Balgowlah	Balgowlah	Balgowlah	Wakehurst Parkway	Wakehurst Parkway	Balgowlah	Balgowlah	Balgowlah	Wakehurst Parkway	Wakehurst Parkway	Wakehurst Parkway
	Exit portal	M540 Gore Hill	M555 Reserve Road	M540 Gore Hill	M555 Reserve Road	BL-WHT Connection	Warringah Freeway	BL-WHT Connection	Warringah Freeway	M116 Rozelle	M115 Rozelle	M4-M5 Link	M116 Rozelle	M115 Rozelle	M4-M5 Link
	Length	8.2 km	8.4 km	6.6 km	6.8 km	7.7 km	7.3 km	9.3 km	8.9 km	14.2 km	14.3 km	13.6 km	15.9 km	15.9 km	15.2 km
10:00 to 15:00	Avg CO [ppm]	1.8	1.8	1.9	1.9	2.0	2.1	1.9	1.9	2.0	2.0	2.0	1.9	1.9	1.9
	Avg NO_2 [ppm]	0.138	0.136	0.158	0.155	0.174	0.178	0.154	0.156	0.168	0.168	0.162	0.157	0.157	0.151
	Min visibility [m^{-1}]	0.00124	0.00124	0.00124	0.00124	0.00135	0.00132	0.00135	0.00132	0.00135	0.00135	0.00135	0.00135	0.00135	0.00135
15:00 to 16:00	Avg CO [ppm]	1.8	1.8	1.9	1.8	1.9	2.0	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9
	Avg NO_2 [ppm]	0.126	0.124	0.143	0.140	0.152	0.156	0.136	0.138	0.153	0.153	0.147	0.143	0.143	0.137
	Min visibility [m^{-1}]	0.00108	0.00108	0.00108	0.00108	0.00115	0.00112	0.00115	0.00112	0.00126	0.00125	0.00118	0.00126	0.00125	0.00118
16:00 to 17:00	Avg CO [ppm]	1.8	1.8	1.9	1.8	1.9	2.0	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9
	Avg NO_2 [ppm]	0.126	0.124	0.143	0.140	0.152	0.156	0.136	0.138	0.153	0.153	0.147	0.143	0.143	0.138
	Min visibility [m^{-1}]	0.00109	0.00109	0.00109	0.00109	0.00115	0.00112	0.00115	0.00112	0.00126	0.00125	0.00118	0.00126	0.00125	0.00118
17:00 to 18:00	Avg CO [ppm]	1.8	1.8	1.9	1.8	1.9	2.0	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9
	Avg NO_2 [ppm]	0.126	0.124	0.143	0.140	0.153	0.157	0.136	0.138	0.153	0.153	0.147	0.143	0.143	0.138
	Min visibility [m^{-1}]	0.00109	0.00109	0.00109	0.00109	0.00115	0.00112	0.00115	0.00112	0.00126	0.00125	0.00118	0.00126	0.00125	0.00118

Time period	Route ID	DSC-SB-A	DSC-SB-B	DSC-SB-C	DSC-SB-D	DSC-SB-E	DSC-SB-F	DSC-SB-G	DSC-SB-H	DSC-SB-I	DSC-SB-J	DSC-SB-K	DSC-SB-L	DSC-SB-M	DSC-SB-N
	Entry portal	Wakehurst Parkway	Wakehurst Parkway	Balgowlah	Balgowlah	Balgowlah	Balgowlah	Wakehurst Parkway	Wakehurst Parkway	Balgowlah	Balgowlah	Balgowlah	Wakehurst Parkway	Wakehurst Parkway	Wakehurst Parkway
	Exit portal	M540 Gore Hill	M555 Reserve Road	M540 Gore Hill	M555 Reserve Road	BL-WHT Connection	Warringah Freeway	BL-WHT Connection	Warringah Freeway	M116 Rozelle	M115 Rozelle	M4-M5 Link	M116 Rozelle	M115 Rozelle	M4-M5 Link
	Length	8.2 km	8.4 km	6.6 km	6.8 km	7.7 km	7.3 km	9.3 km	8.9 km	14.2 km	14.3 km	13.6 km	15.9 km	15.9 km	15.2 km
18:00 to 19:00	Avg CO [ppm]	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
	Avg NO_2 [ppm]	0.086	0.085	0.094	0.092	0.098	0.100	0.090	0.092	0.094	0.094	0.092	0.089	0.089	0.088
	Min visibility [m^{-1}]	0.00055	0.00055	0.00055	0.00055	0.00058	0.00057	0.00058	0.00057	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058
19:00 to 6:00	Avg CO [ppm]	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
	Avg NO_2 [ppm]	0.085	0.084	0.093	0.092	0.098	0.100	0.090	0.091	0.093	0.093	0.092	0.089	0.089	0.088
	Min visibility [m^{-1}]	0.00055	0.00055	0.00055	0.00055	0.00058	0.00057	0.00058	0.00057	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058
6:00 to 7:00	Avg CO [ppm]	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
	Avg NO_2 [ppm]	0.086	0.085	0.094	0.093	0.099	0.101	0.091	0.092	0.094	0.094	0.092	0.089	0.090	0.088
	Min visibility [m^{-1}]	0.00055	0.00055	0.00055	0.00055	0.00058	0.00057	0.00058	0.00057	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058

Notes:

Notes:
(1) Air Quality Criteria: CO Average 50 ppm, NO_2 Average 0.5 ppm and Visibility 0.005m^{-1}
(2) Refer to Figure 7-30 for typical in-tunnel nitrogen dioxide air quality.
(3) The assessment values include background air quality.

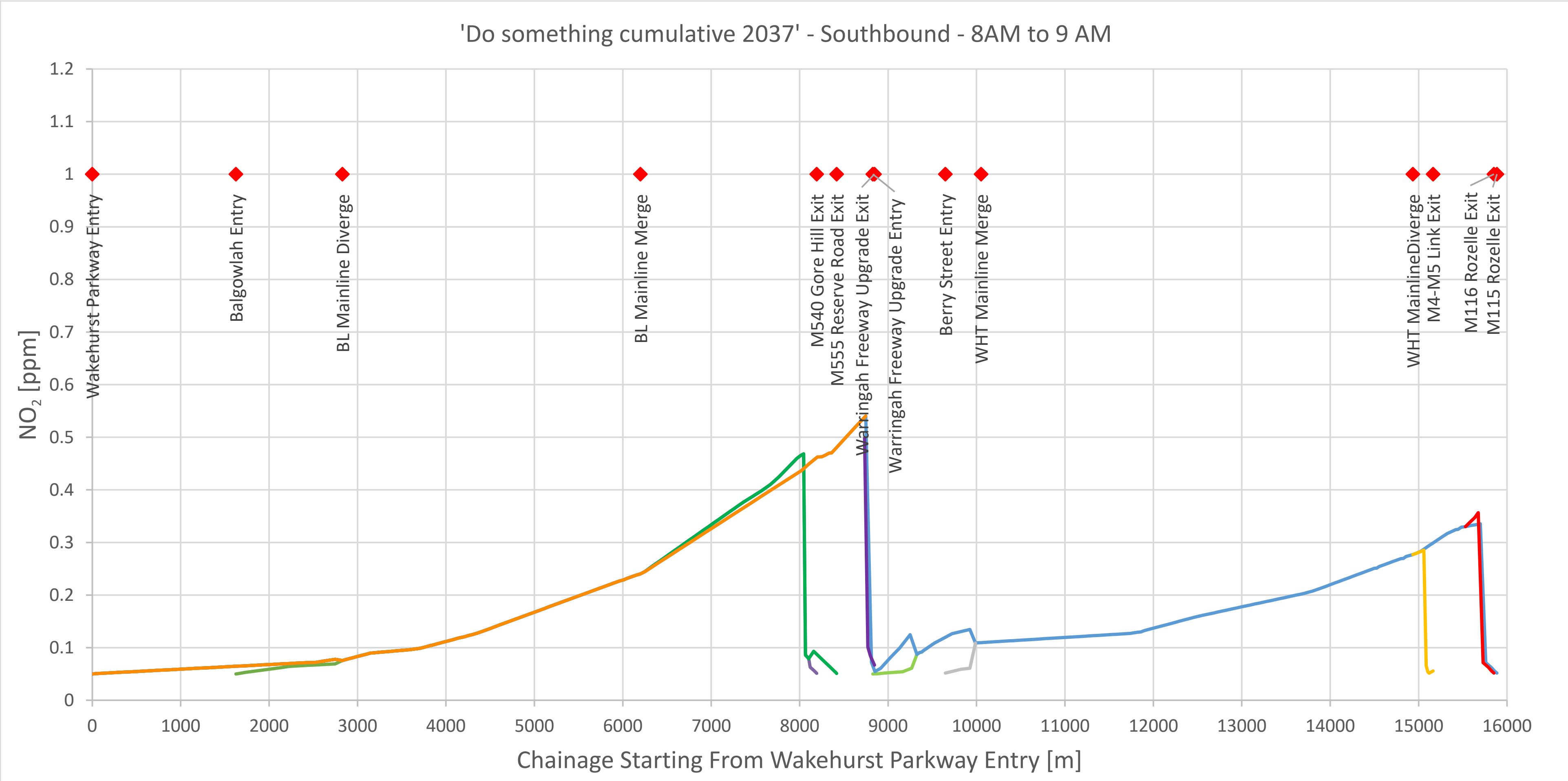


Figure 7-30 NO_2 concentration profile along the routes for ‘Do something cumulative 2037’ – southbound, peak period

8 Analysis outputs – worst-case design maximum traffic flow scenario (variable speed) traffic operations

This section of the report presents the analysis results in two ways:

1. In-tunnel air quality for 20 km/h, 40 km/h, 60 km/h, and 80 km/h: Average CO concentration along every route; average NO_2 concentration along every route; and the minimum visibility along every route
2. NO_2 concentration profiles for every vehicle speed for the route with the highest NO_2 concentration (highlighted in blue in Table 8.3).

The assessed routes are described in Section 5.2.2.2.

'Do something' scenario is the worst-case scenario as similar traffic flow is leaving the tunnel through a lower number of exits than in the 'Do something cumulative' scenario.

8.1 'Do something' – northbound

The ventilation outlet emissions are presented in Table 8.1 and Table 8.2.

Table 8.1 Ventilation outlet emissions for the worst-case (variable speed) scenario

Ventilation outlet identifier:	J			
Name	Beaches Link: Wakehurst Parkway			
Speed	Exhaust flow (m^3/s)	NO_x (g/s)	CO (g/s)	Total $PM_{2.5}$ (g/s)
20 km/h	500	4.89	2.99	0.15
40 km/h	450	4.44	2.72	0.21
60 km/h	490	4.12	2.52	0.21
80 km/h	570	4.37	3.01	0.20

Table 8.2 Ventilation outlet emissions for the worst-case (variable speed) scenario

Ventilation outlet identifier:	K			
Name	Beaches Link: Burnt Bridge Creek Deviation			
Speed	Exhaust flow (m3/s)	NO_x (g/s)	CO (g/s)	Total $PM_{2.5}$ (g/s)
20 km/h	530	4.00	2.58	0.13
40 km/h	420	3.09	1.94	0.16
60 km/h	530	3.02	2.10	0.18
80 km/h	600	2.97	2.48	0.17

Table 8.3 'Do something 2027' northbound in-tunnel air quality results

Average vehicle speed on the mainline	Route ID	DS-NB-A	DS-NB-B	DS-NB-C	DS-NB-D
	Entry portal	Warringah Freeway Upgrade	Warringah Freeway Upgrade	Gore Hill	Gore Hill
	Exit portal	Balgowlah	Wakehurst Parkway	Balgowlah	Wakehurst Parkway
	Lengths	7.2 km	8.8 km	6.6 km	8.1 km
20 km/h	Average CO [ppm](1)	2.9	3.5	2.9	3.5
	Average NO_2 [ppm](1)	0.365	0.468	0.355	0.468
	Min visibility [m^{-1}](1)	0.00154	0.00197	0.00154	0.00197
40 km/h	Average CO [ppm]	2.8	3.4	2.9	3.6
	Average NO_2 [ppm]	0.350	0.465	0.367	0.487
	Min visibility [m^{-1}]	0.00256	0.00320	0.00256	0.00320
60 km/h	Average CO [ppm]	2.3	2.9	2.4	3.0
	Average NO_2 [ppm]	0.231	0.329	0.243	0.346
	Min visibility [m^{-1}]	0.00209	0.00279	0.00209	0.00279
80 km/h	Average CO [ppm]	2.3	2.8	2.4	2.9
	Average NO_2 [ppm]	0.180	0.267	0.190	0.281
	Min visibility [m^{-1}]	0.00167	0.00220	0.00167	0.00220

Notes:

(1) Air Quality Criteria: CO Average 50 ppm, NO_2 Average 0.5 ppm and Visibility 0.005m^{-1}

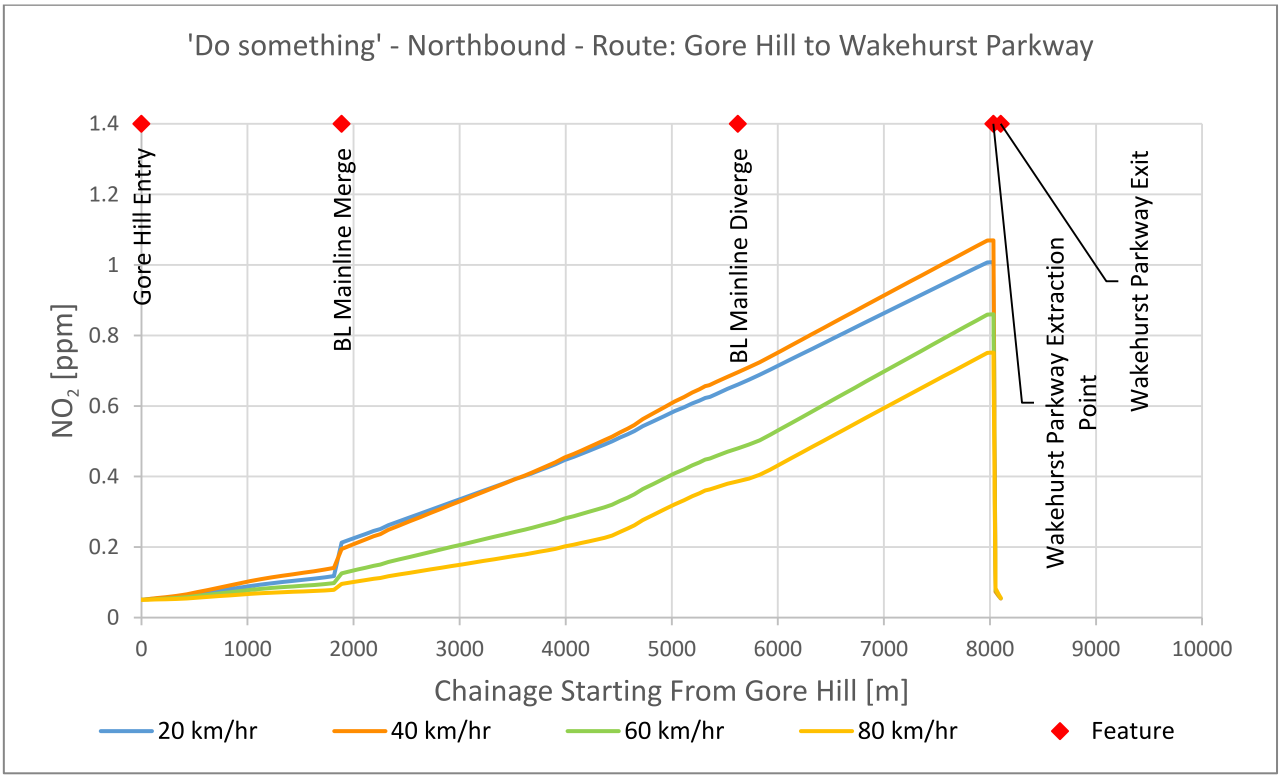


Figure 8-1 'Do something' – northbound – Route: Gore Hill to Wakehurst Parkway

8.2 'Do something' – southbound

The ventilation outlet emissions are presented in Table 8.4 and Table 8.5.

Table 8.4 Ventilation outlet emissions for the worst-case (variable speed) scenario

Ventilation Outlet identifier:	H			
Name	Beaches Link: Warringah Freeway			
Speed	Exhaust flow (m^3/s)	NO_x (g/s)	CO (g/s)	Total $PM_{2.5}$ (g/s)
20 km/h	470	5.30	3.07	0.17
40 km/h	420	4.73	2.71	0.24
60 km/h	540	4.34	2.70	0.26
80 km/h	620	4.48	3.22	0.25

Table 8.5 Ventilation outlet emissions for the worst-case (variable speed) scenario

Ventilation outlet identifier:	I			
Name	Beaches Link: Gore Hill Freeway			
Speed	Exhaust flow (m^3/s)	NO_x (g/s)	CO (g/s)	Non-exhaust $PM_{2.5}$ (g/s)
20 km/h	460	3.73	2.34	0.12

Ventilation outlet identifier:	I			
Name	**Beaches Link: Gore Hill Freeway**			
Speed	**Exhaust flow (m^3/s)**	**NO_X (g/s)**	**CO (g/s)**	**Non-exhaust $PM_{2.5}$ (g/s)**
40 km/h	340	2.85	1.76	0.14
60 km/h	420	2.66	1.76	0.15
80 km/h	450	2.66	2.04	0.14

Table 8.6 'Do something 2027' southbound in-tunnel air quality results

Average vehicle speed on the mainline	Route ID	DS-SB-A	DS-SB-B	DS-SB-C	DS-SB-D	DS-SB-E	DS-SB-F
	Entry portal	Wakehurst Parkway	Wakehurst Parkway	Balgowlah	Balgowlah	Balgowlah	Wakehurst Parkway
	Exit portal	M540 Gore Hill	M555 Reserve Road	M540 Gore Hill	M555 Reserve Road	Warringah Freeway Upgrade	Warringah Freeway Upgrade
	Lengths	8.2 km	8.4 km	6.6 km	6.8 km	7.3 km	8.9 km
20 km/h	Average CO [ppm](1)	2.9	2.8	3.2	3.1	3.5	3.2
	Average NO_2 [ppm](1)	0.366	0.359	0.420	0.409	0.484	0.422
	Min visibility [m^{-1}](1)	0.00172	0.00172	0.00172	0.00172	0.00202	0.00202
40 km/h	Average CO [ppm]	2.9	2.9	3.2	3.1	3.4	3.1
	Average NO_2 [ppm](2)	0.377	0.369	0.435	0.423	0.483	0.420
	Min visibility [m^{-1}]	0.00311	0.00311	0.00311	0.00311	0.00326	0.00326
60 km/h	Average CO [ppm]	2.3	2.3	2.5	2.5	2.7	2.5
	Average NO_2 [ppm]	0.233	0.229	0.269	0.264	0.301	0.261
	Min visibility [m^{-1}]	0.00243	0.00243	0.00243	0.00243	0.00254	0.00254
80 km/h	Average CO [ppm]	2.3	2.3	2.5	2.5	2.6	2.4
	Average NO_2 [ppm]	0.197	0.194	0.226	0.221	0.252	0.221
	Min visibility [m^{-1}]	0.00202	0.00202	0.00202	0.00202	0.00209	0.00209

Notes:

(1) Air Quality Criteria: CO Average 50 ppm, NO_2 Average 0.5 ppm and Visibility 0.005m^{-1}

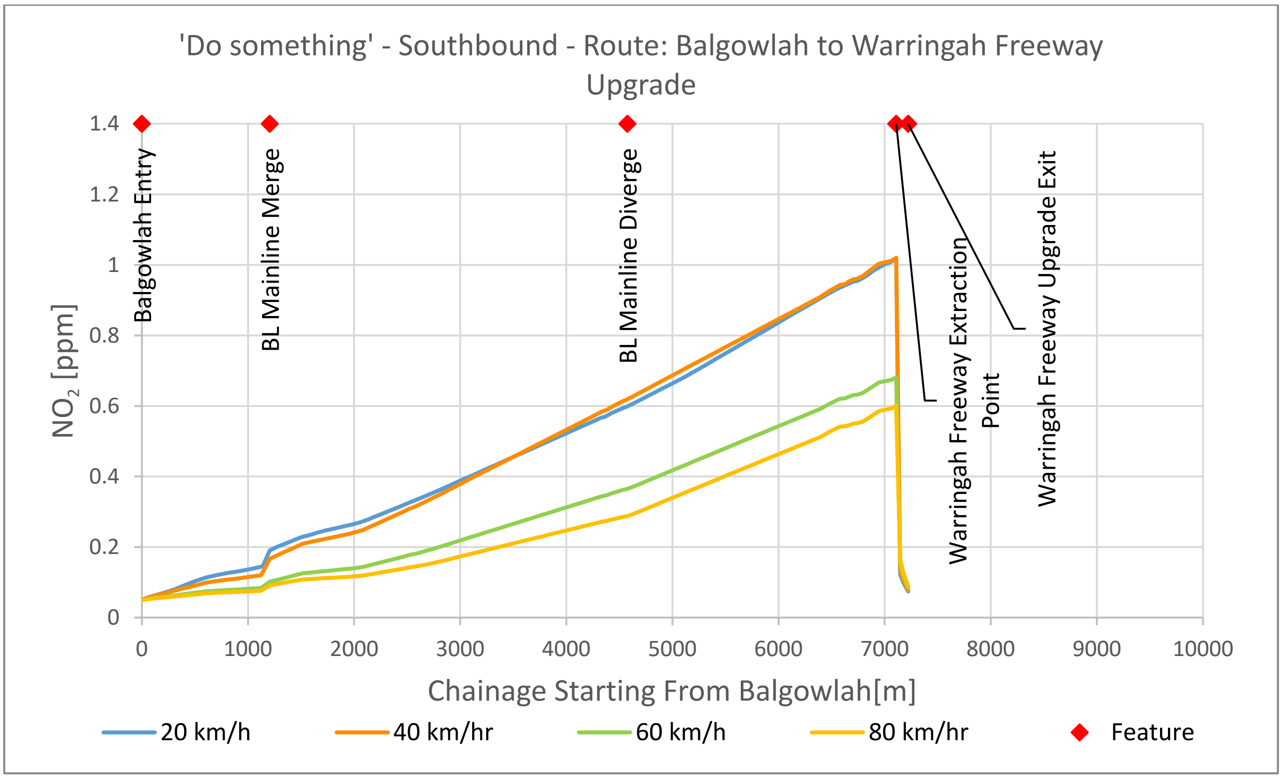


Figure 8-2 ‘Do something’ – southbound – Route: Balgowlah to Warringah Freeway Upgrade exit

9 Analysis outputs – worst-case scenario (breakdown) traffic operations

This section of the report presents the analysis results in two ways:

1. In-tunnel air quality for all possible routes: Average CO concentration along every route; average NO_2 concentration along every route; and the minimum visibility emission along every route
2. NO_2 concentration profile along the most affected route, in terms of air quality.

As the ventilation outlet emissions are inputs to the ambient air quality assessment, for the worst-case (breakdown) scenario, these have not been presented.

The assessed routes are described in Section 6.1.3.4.

The in-tunnel air quality of worst-case scenario (breakdown) scenario is comparable to the worst-case scenario (lane capacity) with an average traffic speed of 20 km/h. It is assumed that a breakdown in the tunnel would cause congestion in the tunnel, as if the traffic is running at a low speed of 20 km/h and is at the theoretical maximum lane capacity in the tunnel upstream of the breakdown. For the tunnel section downstream of the breakdown, it is assumed there would be a standstill of traffic with engines switched off.

9.1 Southbound – 'Do something' (Beaches Link only) – Warringah Freeway exit

Figure 9-1 portrays the assessed breakdown scenario.

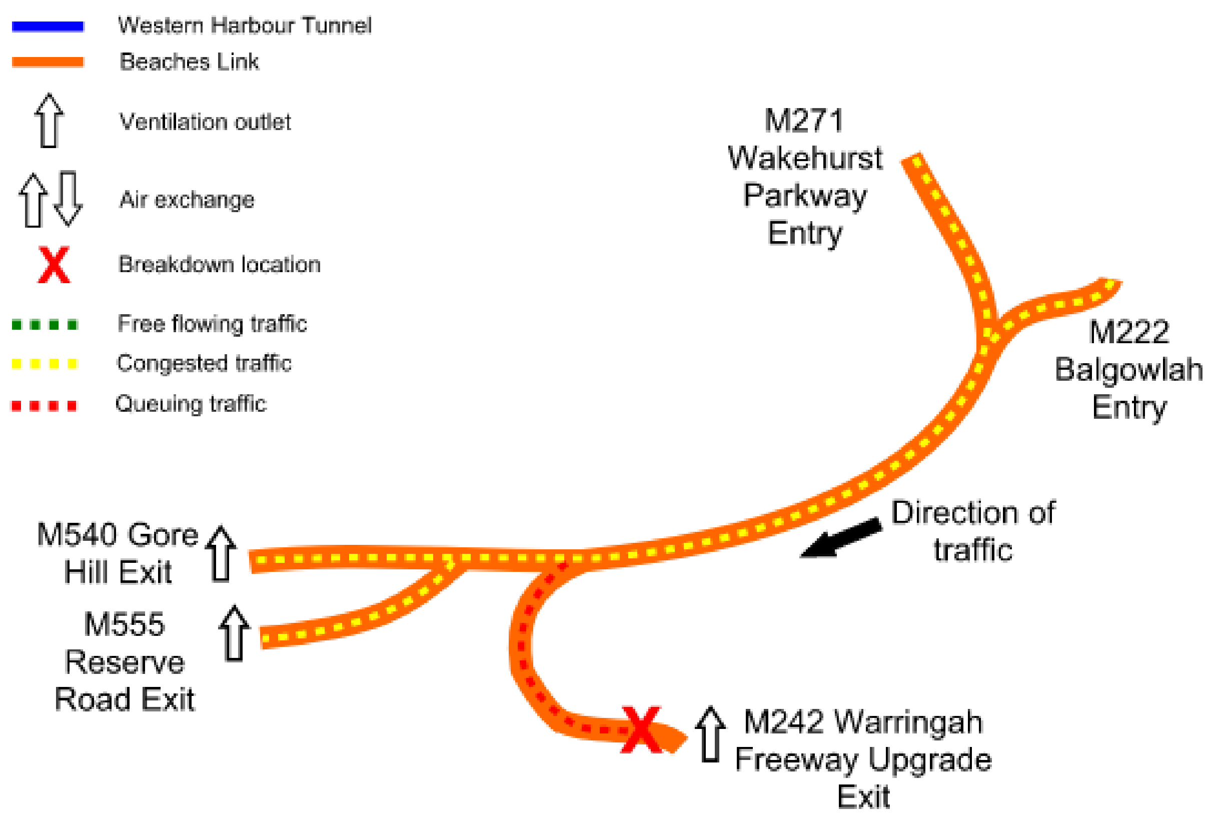


Figure 9-1 'Do something' – breakdown – schematic

Table 9.1 Worst-case (breakdown) scenario – in-tunnel air quality

	Route ID	DS-SB-A	DS-SB-B	DS-SB-C	DS-SB-D	DS-SB-E	DS-SB-F
	Entry portal	Wakehurst Parkway	Wakehurst Parkway	Balgowlah	Balgowlah	Balgowlah	Wakehurst Parkway
	Exit portal	M540 Gore Hill	M555 Reserve Road	M540 Gore Hill	M555 Reserve Road	Warringah Freeway Upgrade	Warringah Freeway Upgrade
	Length	8.2 km	8.4 km	6.6 km	6.8 km	7.3 km	8.9 km
Breakdown in Warringah Freeway Exit	Average CO [ppm](1)	2.2	2.1	2.3	2.3	2.5	2.3
	Average NO_2 [ppm](1)	0.213	0.210	0.248	0.242	0.290	0.251
	Min visibility [m^{-1}](1)	0.00162	0.00162	0.00162	0.00162	0.00186	0.00186

Notes:

(1) Air Quality Criteria: CO Average 50 ppm, NO_2 Average 0.5 ppm and Visibility 0.005 m^{-1}

Figure 9-2 portrays the level of NO_2 concentrations along every possible route in the tunnel.

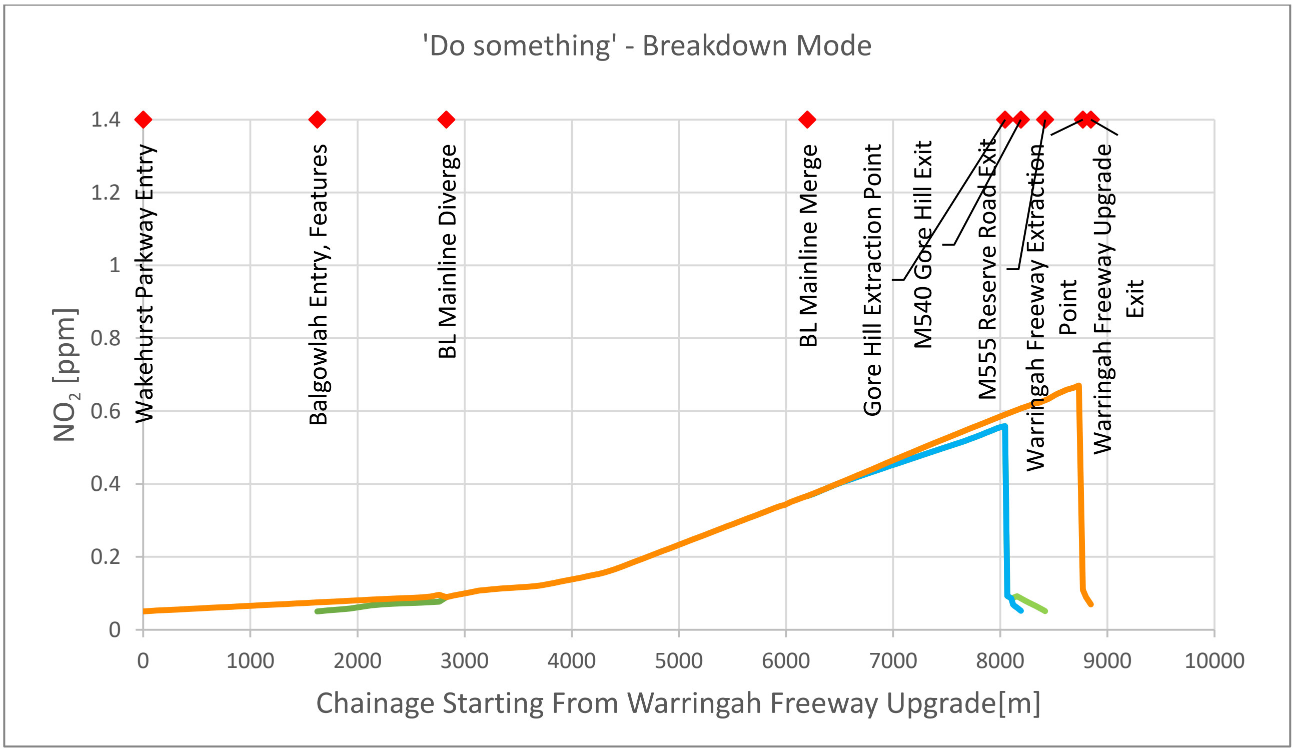


Figure 9-2 'Do something' – breakdown – NO_2 profile

9.2 Southbound – 'Do something cumulative' – Warringah Freeway exit

Figure 9-3 portrays the assessed breakdown scenario.

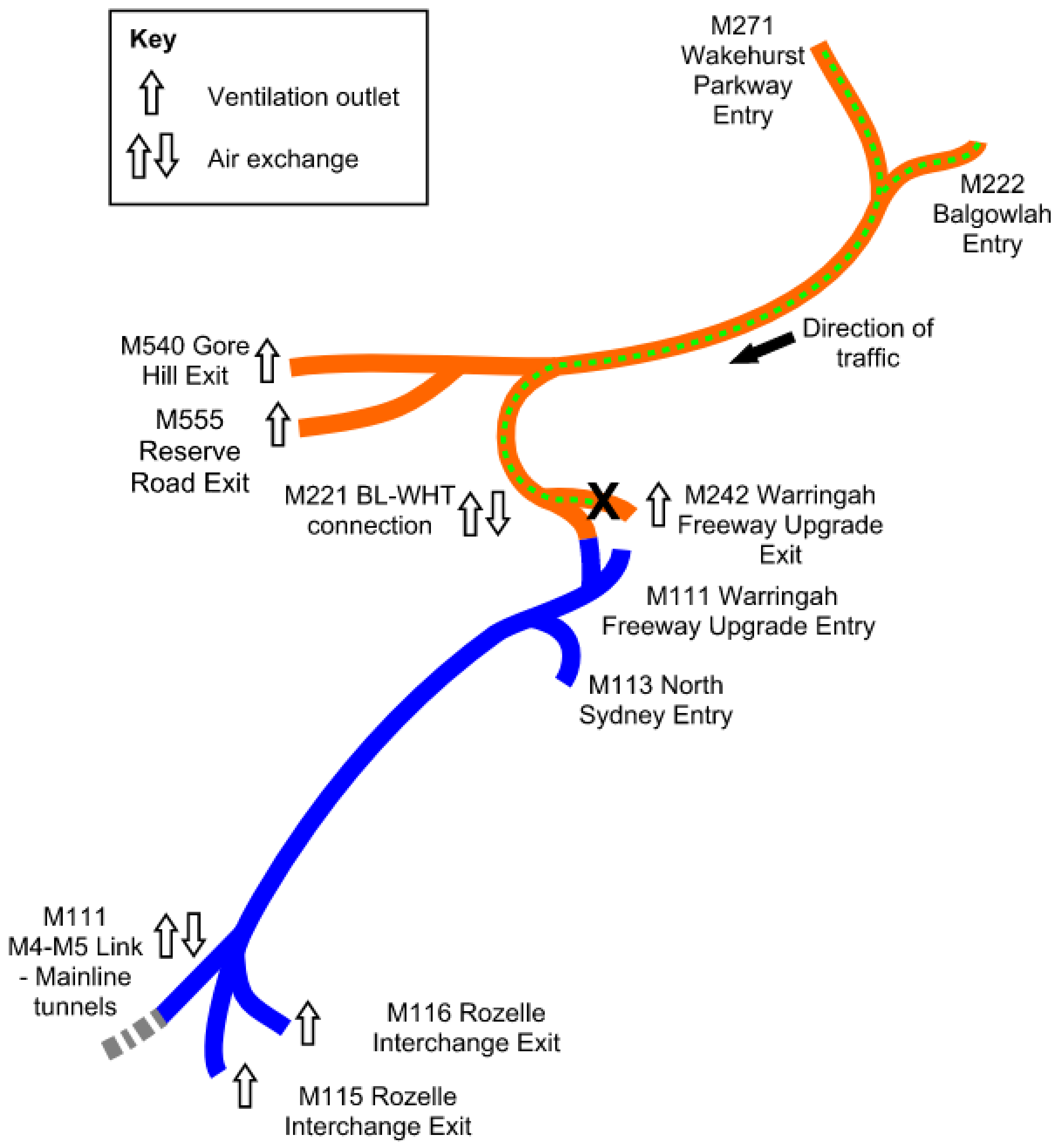


Figure 9-3 'Do something cumulative' – breakdown – schematic

Table 9.2 Worst-case (breakdown) scenario – in-tunnel air quality

	Route ID	DSC-SB-A	DSC-SB-B	DSC-SB-C	DSC-SB-D
	Entry portal	Wakehurst Parkway	Wakehurst Parkway	Balgowlah	Balgowlah
	Exit portal	M540 Gore Hill	M555 Reserve Road	M540 Gore Hill	M555 Reserve Road
	Lengths	8.2 km	8.4 km	6.6 km	6.8 km
Breakdown in Warringah Freeway Exit	Avg CO [ppm][(1)]	2.5	2.5	2.8	2.7
	Avg NO_2 [ppm][(1)]	0.285	0.279	0.335	0.326
	Min Visibility [m^{-1}][(1)]	0.00228	0.00228	0.00228	0.00228
	Route ID	DSC-SB-E	DSC-SB-F	DSC-SB-G	DSC-SB-H
	Entry portal	Balgowlah	Balgowlah	Wakehurst Parkway	Wakehurst Parkway
	Exit portal	BL-WHT Connection	Warringah Freeway Upgrade	BL-WHT Connection	Warringah Freeway Upgrade
	Lengths	7.7 km	7.3 km	9.3 km	8.9 km
Breakdown in Warringah Freeway Exit	Avg CO [ppm][(1)]	3.1	3.2	2.8	2.9
	Avg NO_2 [ppm][(1)]	0.391	0.403	0.337	0.344
	Min Visibility [m^{-1}][(1)]	0.00277	0.00269	0.00277	0.00269

Notes:

(1) Air Quality Criteria: CO Average 50 ppm, NO_2 Average 0.5 ppm and Visibility 0.005 m^{-1}

Figure 9-4 portrays the level of NO_2 concentrations along every possible route in the tunnel.

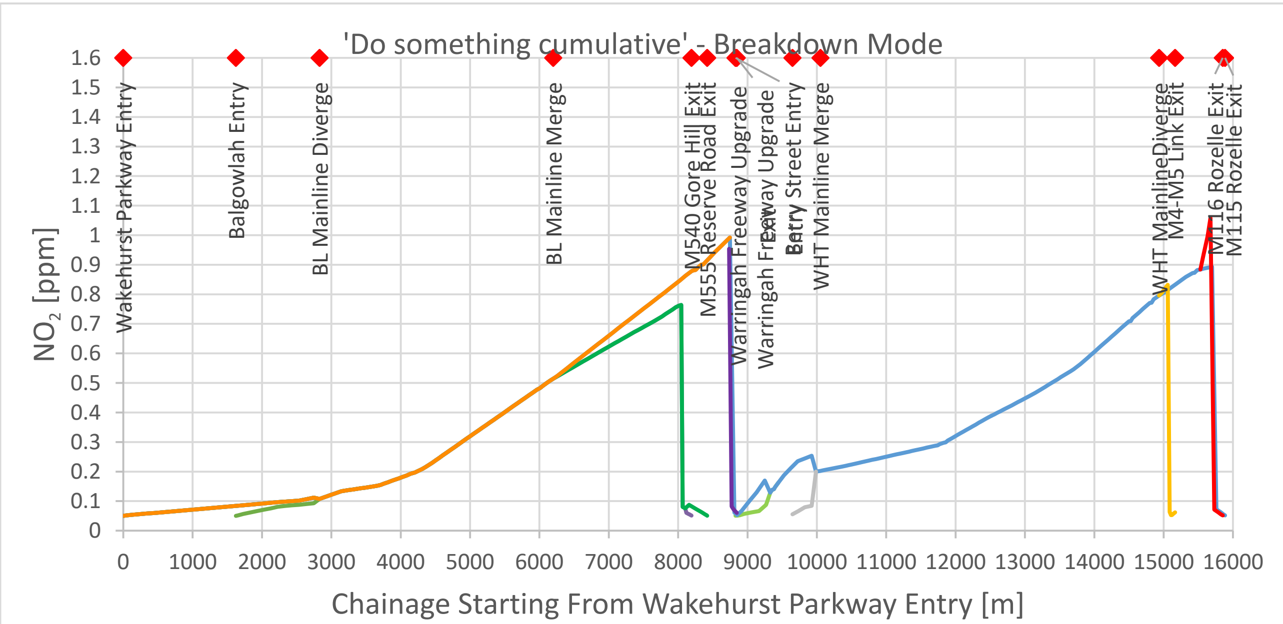


Figure 9-4 'Do something cumulative' – breakdown – NO_2 profile

10 References

[1] Stacey Agnew Pty. Ltd., M4-M5 Link Ventilation Report for Environmental Impact Statement, 26 July 2017, NSW Government, 2017.

[2] State Transit, Bus Infrastructure Guide (PROC 48.14) - Issue 2, NSW Government, 2011.

[3] Roads and Maritime Services, NSW Fleet Forecast for Tunnel Ventilation Design: 2016 to 2040, Transport for NSW, NSW Government, 2016.

[4] European Environment Agency, EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016 - Update, Publications Office of the European Union, 2017.

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[6] Advisory Committee on Tunnel Air Quality, In-Tunnel Air Quality (Nitrogen Dioxide) Policy, NSW Government, 2016.

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[8] Austroads, Guide to Road Tunnels Part 2: Planning, Design and Commissioning, Austroads Ltd, 2015.

[9] QA Specification R165 In-Tunnel Air Quality Monitors, NSW Roads and Maritime, 2017

[10] QA Specification R164 for Tunnel Jet Fans, NSW Roads and Maritime, 2017

Annexure L Additional results for traffic and emissions sensitivity test

Receptor plots

Figure L-1 Location of the ten most impacted RWR receptors for annual mean and maximum 24-hour $PM_{2.5}$ around the Western Harbour Tunnel and Beaches Link Warringah Freeway ventilation outlet (H)

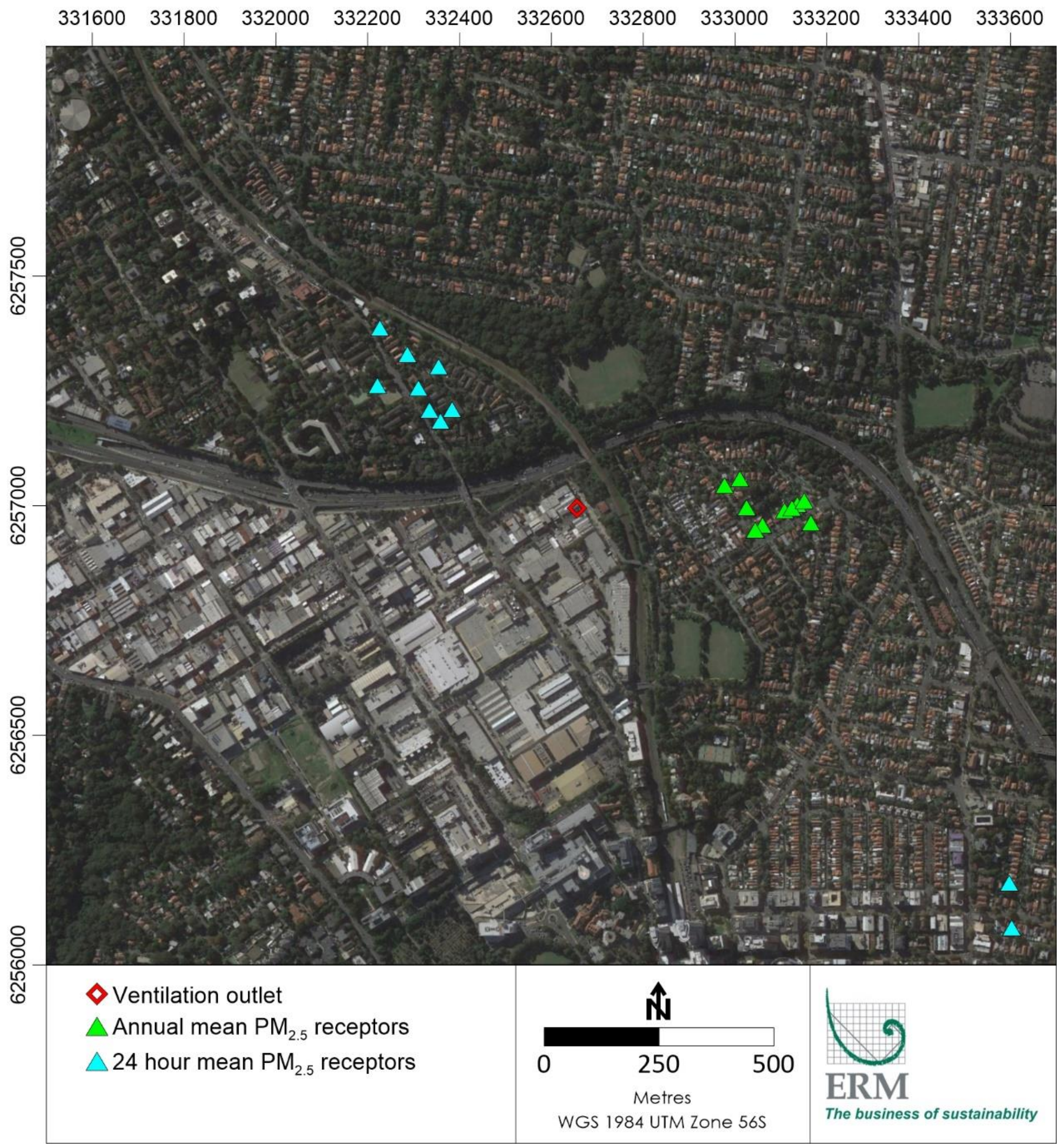

Figure L-2 Location of the ten most impacted RWR receptors for annual mean and maximum 24-hour $PM_{2.5}$ around the Beaches Link Gore Hill Freeway ventilation outlet (I)

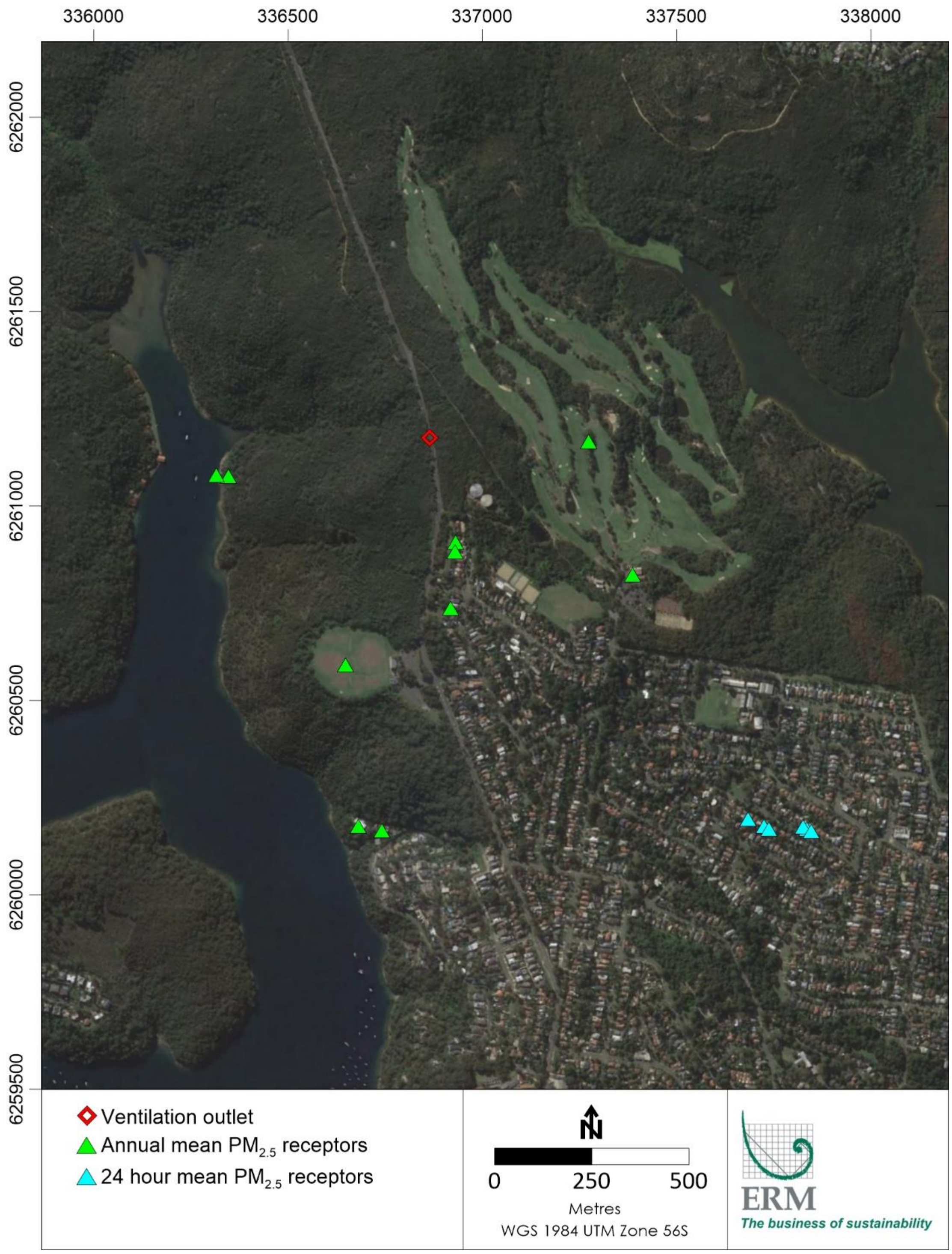

Figure L-3 **Location of the ten most impacted RWR receptors for annual mean and maximum 24-hour $PM_{2.5}$ around the Beaches Link Wakehurst Parkway ventilation outlet (J)**

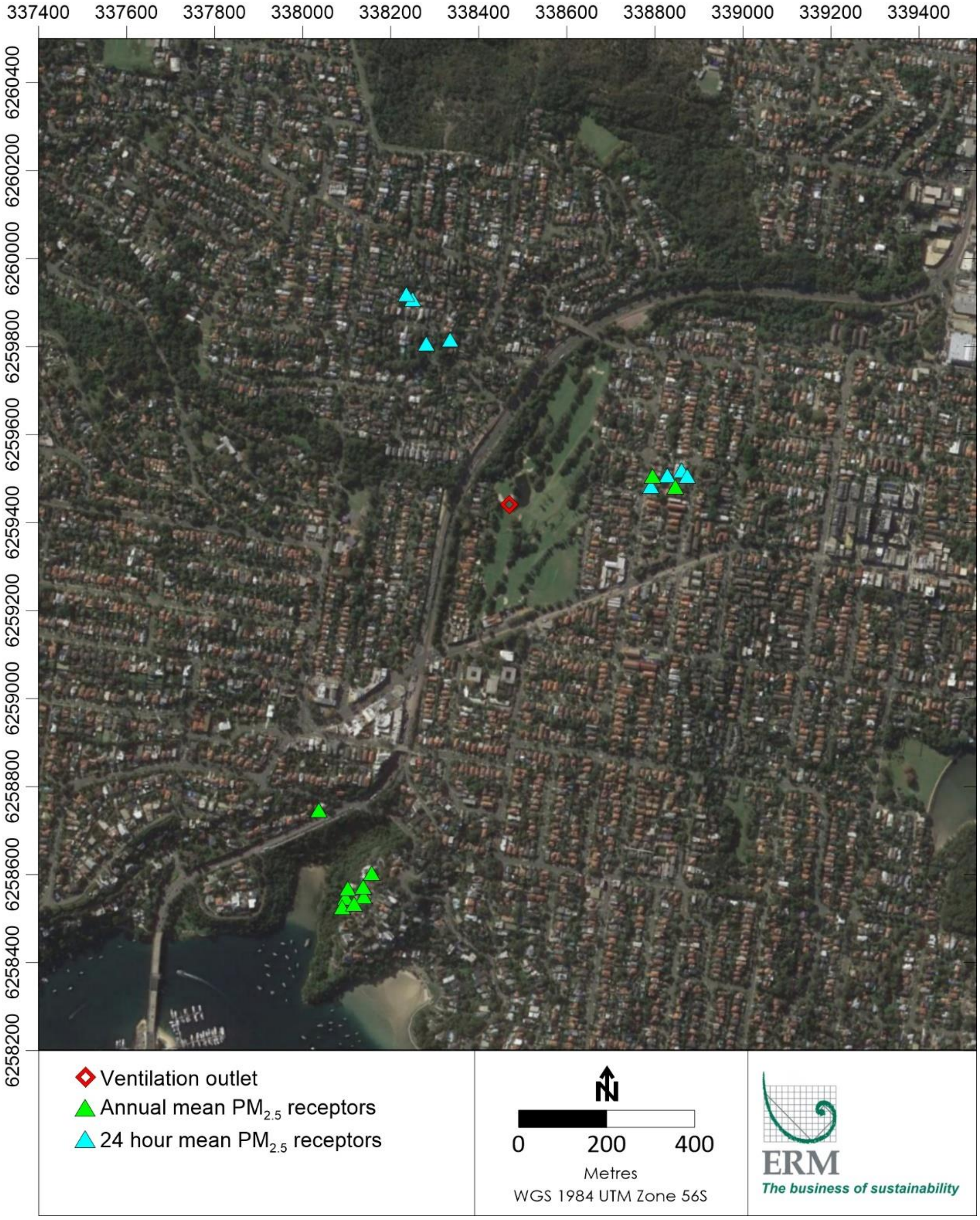

Figure L-4 **Location of the ten most impacted RWR receptors for annual mean and maximum 24-hour $PM_{2.5}$ around the Beaches Link Burnt Bridge Creek Deviation ventilation outlet (K)**

Annual mean $PM_{2.5}$ results

The results for all scenarios (Expected Traffic, Sensitivity and RWC) are to a significant number of decimal places and for ease of reporting, have been rounded to two decimal places in the following tables. The Sensitivity as a percentage of RWC has been calculated using the original results and presented to the nearest whole number.

Table L-1 Annual mean $PM_{2.5}$ results of sensitivity emissions test compared with RWC and ET for the ten most impacted RWR receptors surrounding the Beaches Link Warringah Freeway ventilation outlet (H)

ID	x	y	Expected Traffic (µg/m^3)	Sensitivity (µg/m^3)	RWC (µg/m^3)	Sensitivity as % of RWC
RWR-14793	334829	6256195	0.07	0.27	0.66	42
RWR-13132	335249	6255691	0.08	0.31	0.65	48
RWR-13133	335255	6255690	0.09	0.34	0.65	53
RWR-13039	335245	6255657	0.09	0.33	0.64	52
RWR-13335	335266	6255745	0.08	0.30	0.63	47
RWR-13143	335231	6255681	0.09	0.33	0.63	53
RWR-14430	334744	6256110	0.09	0.32	0.63	51
RWR-13126	335261	6255668	0.09	0.33	0.62	53
RWR-14385	334718	6256097	0.09	0.32	0.62	52
RWR-15570	334897	6256390	0.07	0.27	0.62	44

Table L-2 Annual mean $PM_{2.5}$ results of sensitivity emissions test compared with RWC and ET for the ten most impacted RWR receptors surrounding the Beaches Link Gore Hill Freeway ventilation outlet (I)

ID	x	y	Expected Traffic (µg/m^3)	Sensitivity (µg/m^3)	RWC (µg/m^3)	Sensitivity as % of RWC
RWR-17650	333025	6256996	0.05	0.17	0.43	40
RWR-17851	333011	6257059	0.04	0.16	0.42	38
RWR-17533	333165	6256962	0.04	0.15	0.41	37
RWR-17641	333108	6256989	0.04	0.16	0.41	38
RWR-17782	332977	6257044	0.04	0.16	0.41	38
RWR-17536	333060	6256957	0.05	0.18	0.41	43
RWR-17676	333136	6257002	0.04	0.16	0.41	38
RWR-17654	333124	6256995	0.04	0.16	0.41	39
RWR-17709	333150	6257010	0.04	0.16	0.41	38
RWR-17469	333044	6256946	0.04	0.15	0.41	37

Table L-3 **Annual mean $PM_{2.5}$ results of sensitivity emissions test compared with RWC and ET for the ten most impacted RWR receptors surrounding the Beaches Link Wakehurst Parkway ventilation outlet (J)**

ID	x	y	Expected Traffic (µg/m^3)	Sensitivity (µg/m^3)	RWC (µg/m^3)	Sensitivity as % of RWC
RWR-33167	337273	6261165	0.04	0.16	0.36	45
RWR-33359	337386	6260823	0.03	0.11	0.29	39
RWR-33256	336648	6260591	0.04	0.13	0.25	52
RWR-03056	336680	6260177	0.03	0.11	0.24	46
RWR-33300	336346	6261077	0.03	0.13	0.24	53
RWR-03004	336741	6260165	0.03	0.11	0.23	48
RWR-33259	336316	6261079	0.03	0.12	0.23	53
RWR-03624	336931	6260907	0.03	0.10	0.22	48
RWR-03622	336929	6260882	0.03	0.10	0.20	50
RWR-03598	336918	6260737	0.02	0.09	0.20	45

Table L-4 **Annual mean $PM_{2.5}$ results of sensitivity emissions test compared with RWC and ET for the ten most impacted RWR receptors surrounding the Beaches Link Burnt Bridge Creek Deviation ventilation outlet (K)**

ID	x	y	Expected Traffic (µg/m^3)	Sensitivity (µg/m^3)	RWC (µg/m^3)	Sensitivity as % of RWC
RWR-05855	338097	6258547	0.05	0.19	0.47	41
RWR-05813	338089	6258526	0.04	0.16	0.45	36
RWR-05856	338139	6258550	0.05	0.19	0.44	42
RWR-33593	338036	6258747	0.04	0.16	0.44	37
RWR-05890	338102	6258568	0.04	0.16	0.43	37
RWR-05903	338137	6258572	0.04	0.16	0.43	37
RWR-01254	338846	6259481	0.05	0.19	0.42	44
RWR-05828	338117	6258533	0.04	0.17	0.42	39
RWR-05968	338157	6258603	0.05	0.19	0.42	45
RWR-01302	338795	6259506	0.05	0.18	0.41	43

Maximum 24-hour average $PM_{2.5}$ results

The results for all scenarios (Expected Traffic, Sensitivity and RWC) are to a significant number of decimal places and for ease of reporting, have been rounded to two decimal places in the following tables. The Sensitivity as a percentage of RWC has been calculated using the original results and presented to the nearest whole number.

Table L-5 Maximum 24-hour $PM_{2.5}$ results of sensitivity emissions test compared with RWC and ET for the ten most impacted RWR receptors surrounding the Beaches Link Warringah Freeway ventilation outlet (H)

ID	x	y	Expected Traffic (µg/m³)	Sensitivity (µg/m³)	RWC (µg/m³)	Sensitivity as % of RWC
RWR-14430	334744	6256110	0.65	2.42	5.44	44
RWR-14385	334718	6256097	0.60	2.22	5.12	43
RWR-14414	334705	6256101	0.60	2.21	5.11	43
RWR-14424	334692	6256104	0.61	2.25	4.98	45
RWR-14714	334719	6256185	0.51	1.90	4.77	40
RWR-14432	334678	6256105	0.50	1.84	4.57	40
RWR-14382	334743	6256097	0.52	1.91	4.54	42
RWR-13099	335334	6255673	0.54	2.01	4.39	46
RWR-13128	335310	6255687	0.61	2.26	4.39	52
RWR-13132	335249	6255691	0.65	2.40	4.37	55

Table L-6 Maximum 24-hour $PM_{2.5}$ results of sensitivity emissions test compared with RWC and ET for ten most impacted RWR receptors surrounding the Beaches Link Gore Hill Freeway ventilation outlet (I)

ID	x	y	Expected Traffic (µg/m³)	Sensitivity (µg/m³)	RWC (µg/m³)	Sensitivity as % of RWC
RWR-18390	332384	6257209	0.25	0.93	2.42	38
RWR-33423	332221	6257262	0.22	0.82	2.35	35
RWR-18833	332287	6257330	0.21	0.78	2.31	34
RWR-19066	332226	6257387	0.19	0.69	2.26	31
RWR-18575	332311	6257256	0.22	0.82	2.26	36
RWR-18305	332359	6257184	0.28	1.04	2.23	47
RWR-14688	333597	6256178	0.28	1.02	2.22	46
RWR-14329	333603	6256081	0.22	0.80	2.20	37
RWR-18726	332354	6257303	0.20	0.75	2.20	34
RWR-18335	332334	6257208	0.29	1.07	2.15	50

Table L-7 Maximum 24-hour $PM_{2.5}$ results of sensitivity emissions test compared with RWC and ET for the ten most impacted RWR receptors surrounding the Beaches Link Wakehurst Parkway ventilation outlet (J)

ID	x	y	Expected Traffic (µg/m³)	Sensitivity (µg/m³)	RWC (µg/m³)	Sensitivity as % of RWC
RWR-33300	336346	6261077	0.25	0.92	1.81	51
RWR-33259	336316	6261079	0.22	0.80	1.47	55
RWR-33167	337273	6261165	0.20	0.73	1.45	51
RWR-03040	337725	6260176	0.12	0.44	1.41	31
RWR-03021	337737	6260169	0.11	0.42	1.36	30
RWR-03037	337835	6260170	0.12	0.45	1.27	36
RWR-03036	337825	6260175	0.14	0.51	1.25	41
RWR-33256	336648	6260591	0.18	0.68	1.24	55
RWR-03090	337684	6260195	0.13	0.48	1.22	39
RWR-03003	337847	6260164	0.12	0.45	1.20	38

Table L-8 Maximum 24-hour $PM_{2.5}$ results of sensitivity emissions test compared with RWC and ET for ten most impacted RWR receptors surrounding the Beaches Link Burnt Bridge Creek Deviation ventilation outlet (K)

ID	x	y	Expected Traffic (µg/m³)	Sensitivity (µg/m³)	RWC (µg/m³)	Sensitivity as % of RWC
RWR-02278	338249	6259907	0.43	1.59	4.02	40
RWR-02065	338335	6259816	0.48	1.78	4.01	44
RWR-01254	338846	6259481	0.45	1.67	4.01	42
RWR-01303	338828	6259507	0.47	1.75	4.00	44
RWR-01332	338860	6259519	0.44	1.65	3.96	42
RWR-01324	338873	6259506	0.43	1.59	3.95	40
RWR-01253	338791	6259483	0.48	1.77	3.93	45
RWR-01302	338795	6259506	0.47	1.74	3.93	44
RWR-02048	338280	6259807	0.43	1.60	3.85	42
RWR-02295	338236	6259919	0.40	1.46	3.83	38

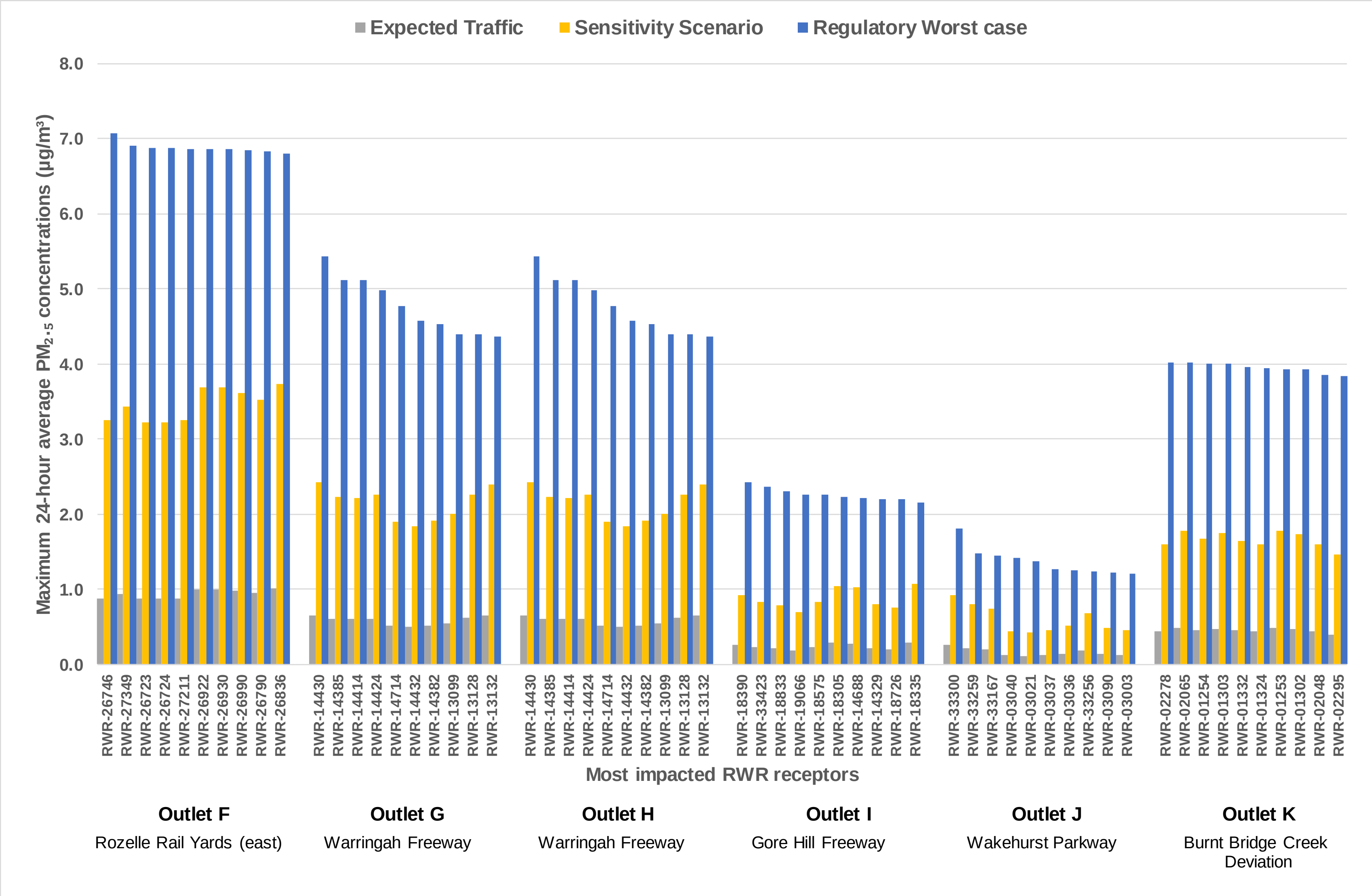

Figure L-5 **Maximum 24-hour average $PM_{2.5}$ concentrations for the Sensitivity scenario compared against ET and RWC for the ten most impacted receptors surrounding each of the ventilation outlets**

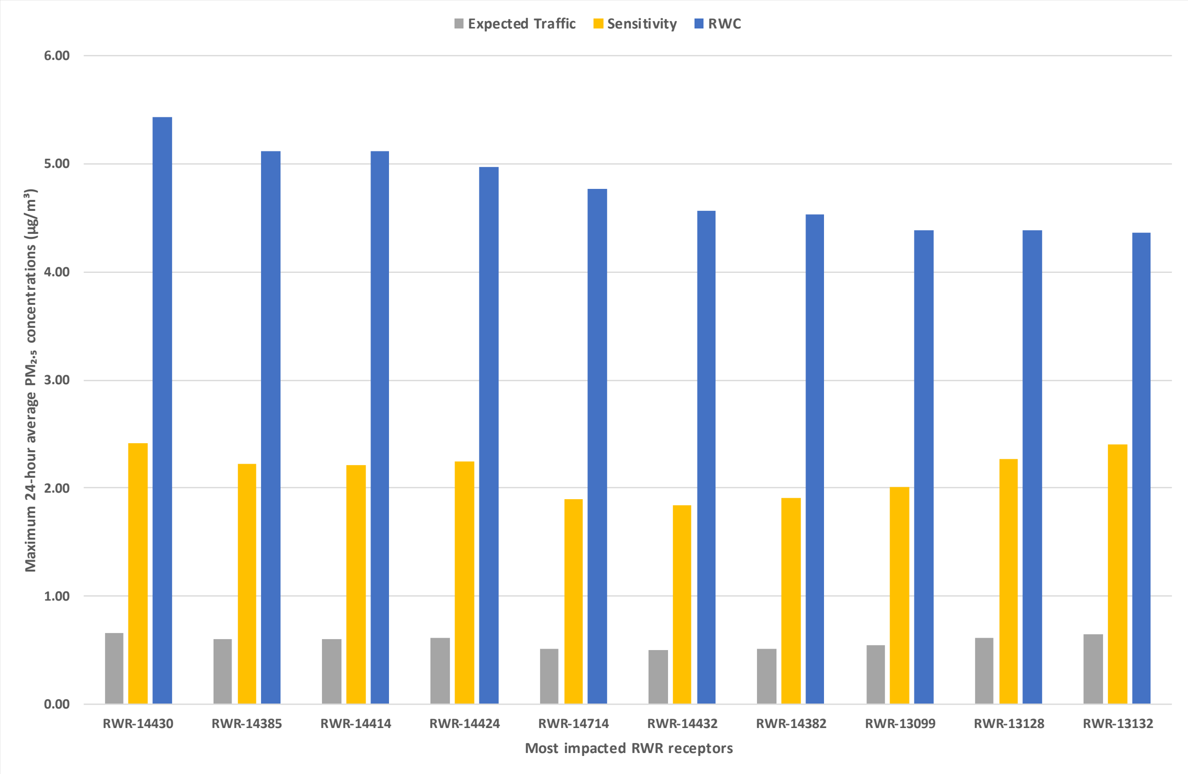

Figure L-6 **Maximum 24-hour average $PM_{2.5}$ concentrations for the Sensitivity scenario compared against ET and RWC for the ten most impacted receptors surrounding the Beaches Link Warringah Freeway ventilation outlet (H)**

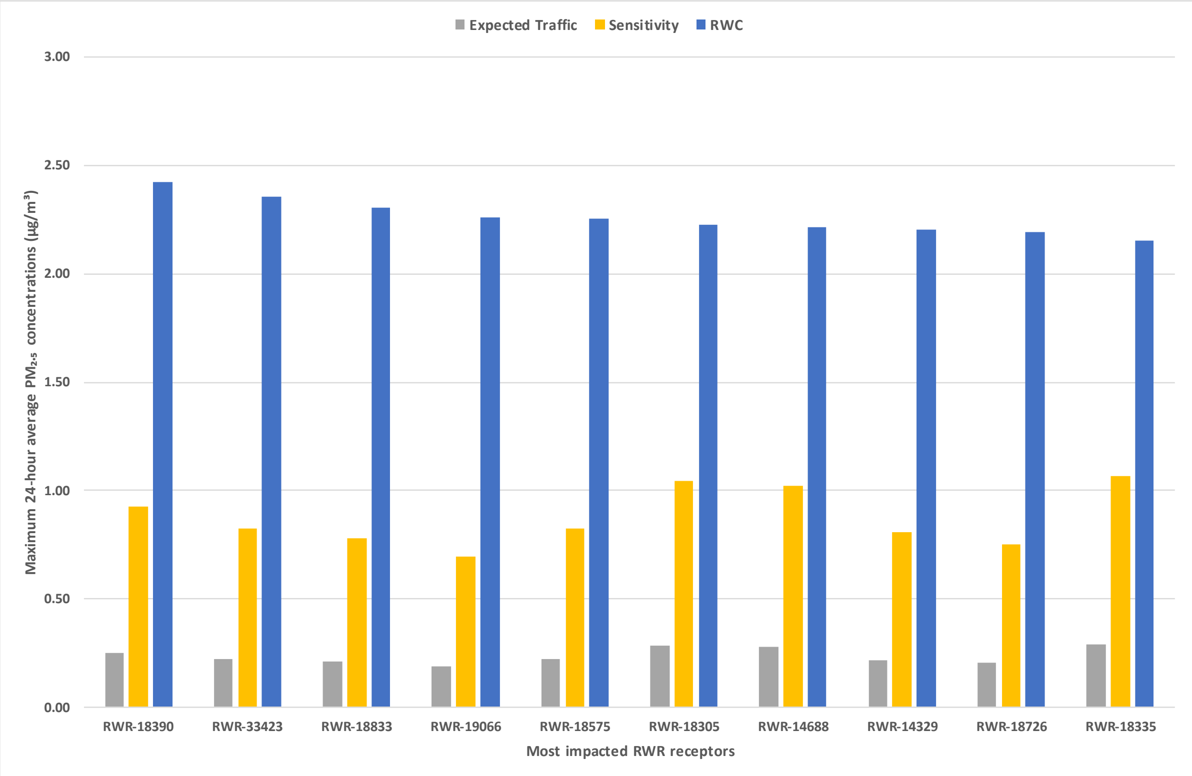

Figure L-7 **Maximum 24-hour average $PM_{2.5}$ concentrations for the Sensitivity scenario compared against ET and RWC for the ten most impacted receptors surrounding the Beaches Link Gore Hill Freeway ventilation outlet (I)**

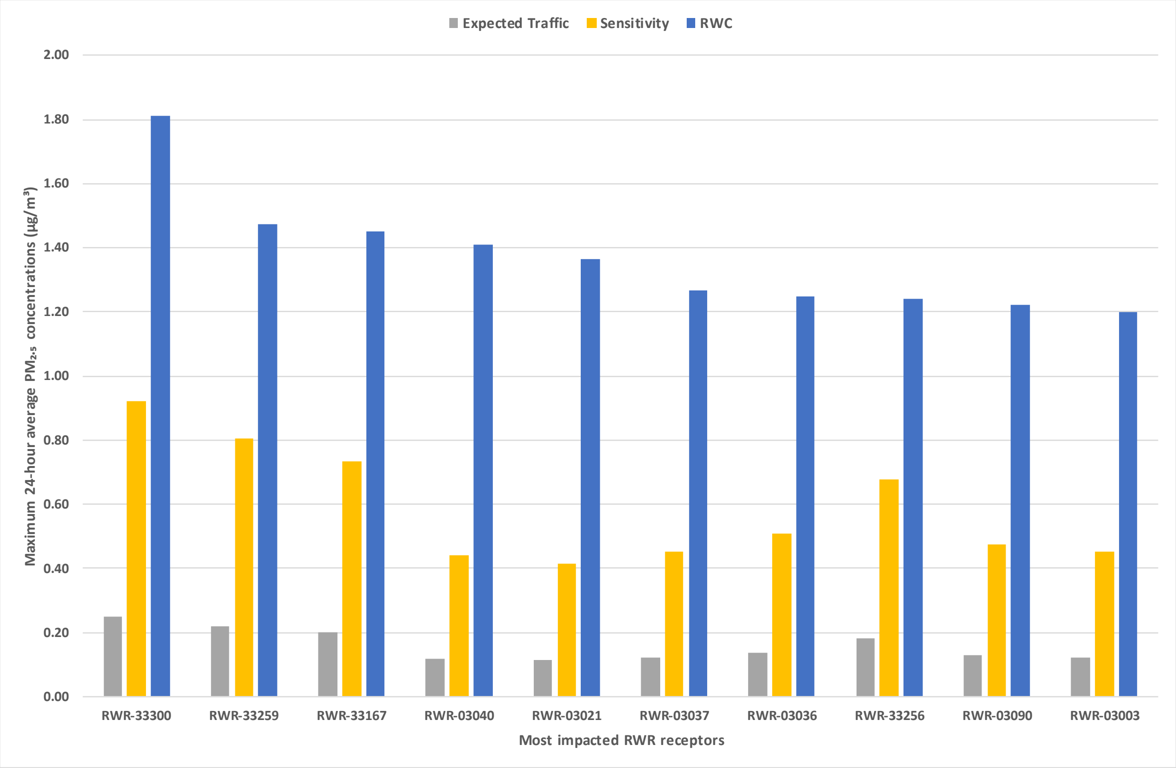

Figure L-8 **Maximum 24-hour average $PM_{2.5}$ concentrations for the Sensitivity scenario compared against ET and RWC for the ten most impacted receptors surrounding the Beaches Link Wakehurst Parkway ventilation outlet (J)**

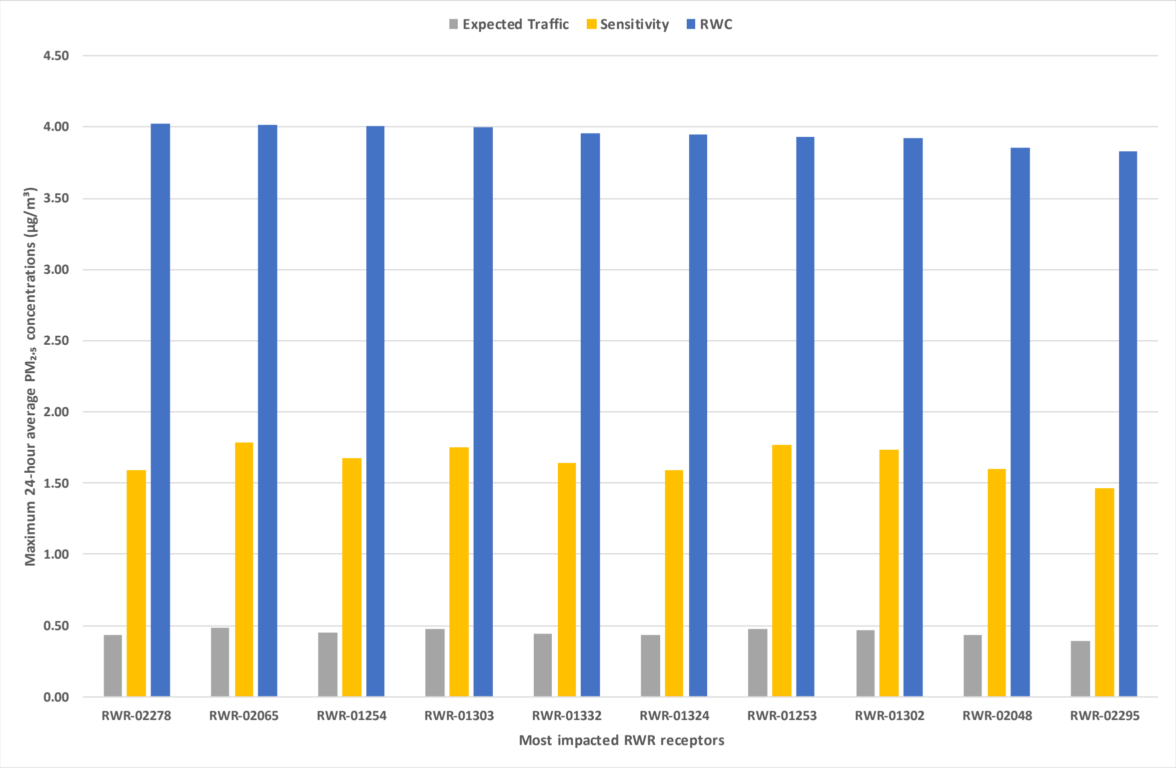

Figure L-9 **Maximum 24-hour average $PM_{2.5}$ concentrations for the Sensitivity scenario compared against ET and RWC for the ten most impacted receptors surrounding the Beaches Link Burnt Bridge Creek Deviation ventilation outlet (K)**