WestConnex

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Environmental Impact Statement

August 2017

Appendix I

Volume 2C (Part B)

Since finalisation of the Environmental Impact Statement, the project has been declared by Ministerial Order to be State significant infrastructure and critical State significant infrastructure under sections 115U (4) and 115V of the *Environmental Planning and Assessment Act 1979*. The Ministerial Order also amended Schedule 5 of *State Environmental Planning Policy (State and Regional Development) 2011*. The project remains subject to assessment under Part 5.1 of the *Environmental Planning and Assessment Act 1979* and requires the approval of the Minister for Planning.

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Volume 2C (Part B)

Appendix

WestConnex

Annexure A - Traffic pollutants and their effects

A.1 Overview

This Annexure summarises the health and non-health effects of the traffic-related pollutants that were included in the assessment.

Road vehicles emit a complex mixture of pollutants. These are generated though combustion processes (CO, NO_X, PM and many different hydrocarbon compounds), evaporation processes (VOCs) and abrasion processes (PM from tyre wear, brake wear, etc.). The resuspension of material on the road surface also contributes to ambient PM concentrations, but this is not always considered in models because of its site-specific nature and a lack of suitable emission factors.

Various studies have linked road traffic emissions to health outcomes, and this Annexure has considered reviews of these studies by the following organisations:

- The World Health Organization (WHO).
- The United States Environmental Protection Agency (USEPA).
- The Committee on the Medical Effects of Air Pollutants (COMEAP) in the UK.
- The Health Effects Institute (HEI).

In the following sections a traditional approach is used to explain the health effects of traffic pollutants, whereby each pollutant is treated separately. The traffic pollutants causing most concern at present are NO_2 and PM. For example, $PM_{2.5}$ from vehicle exhaust is increasingly cited as a key health-related metric. It has been noted by WHO that there is an elevated health risk associated with living close to roads, but also that this is unlikely to be explained by $PM_{2.5}$ alone (WHO Regional Office for Europe, 2013). Although it has not been reviewed here, a review of particulate matter in NSW was written by Hime et al. (2015), and this contains updated information of health impacts.

A.2 Carbon monoxide

A.2.1 Health effects

Carbon monoxide (CO) is a colourless, odourless gas. It can be harmful to humans because, when inhaled, it is taken up by haemoglobin in the blood (forming carboxyhaemoglobin) in preference to oxygen, thus reducing the capacity of the blood to transport oxygen. The affinity of CO for haemoglobin is more than 200 times greater than that of oxygen.

At low concentrations the symptoms of CO intoxication include lethargy in healthy adults, and chest pain in people with heart disease. At higher concentrations CO leads to impaired vision and coordination, headaches, dizziness, confusion and nausea. CO is fatal at very high concentrations[1]. Symptoms are not generally reported until the carboxyhaemoglobin level in the blood exceeds 10%. This is approximately the equilibrium value achieved with an ambient concentration of 70 mg/m^3 for a person engaged in light activity. There is evidence that there is a risk for individuals with cardiovascular disease at lower carboxyhaemoglobin levels. A carboxyhaemoglobin level in the blood of 40-50% usually leads to death. However, in most Australian towns and cities the levels of CO in ambient air are well below those that are hazardous to human health. Only in larger cities do CO levels have the potential to have harmful effects[2].

A.2.2 Other effects

CO plays a role in the formation of ground-level ozone. It also has an indirect radiative forcing effect on climate by elevating concentrations of methane and tropospheric ozone through chemical reactions

[1] http://www.epa.gov/iaq/co.html#Health_Effects
[2] http://www.environment.gov.au/protection/publications/factsheet-carbon-monoxide-co

with other atmospheric constituents (e.g. the hydroxyl radical, OH) that would otherwise destroy them.

A.3 Nitrogen dioxide

A.3.1 Health effects

Nitrogen dioxide (NO_2) is one of the most important road traffic pollutants. It is an irritant and oxidant which has been linked to a range of adverse health effects including deterioration in lung function, respiratory symptoms, asthma prevalence and incidence, cancer incidence, and birth outcomes (e.g. birth weight). The most consistent associations, however, have been found with respiratory outcomes (COMEAP, 2009).

For short-term exposure, the extensive review by the WHO Regional Office Europe (2013) noted that many studies have documented associations between variations in NO_2 concentration and respiratory symptoms, hospital admissions and mortality, even after adjustment for PM and other pollutants for some health outcomes.

For long-term exposure, there is likely to be a causal relationship between NO_2 and respiratory effects, although NO_2 may act as a marker for other traffic pollutants. The evidence for cardiovascular effects and total mortality is suggestive, but not sufficient to infer a causal relationship (WHO Regional Office for Europe, 2013; USEPA, 2015).

A recent review conducted by Jalaludin (2015) concluded that NO_2 exposure is associated with adverse health effects, with the strongest evidence for respiratory effects with exposure times of one hour or more. Evidence is limited, but chamber studies consistently find no adverse health effects for exposures of less than 0.2 ppm over 20 to 30 minutes, but some health effects in people with mild asthma at levels between 0.2 ppm and 0.5 ppm over 20 to 30 minutes.

A.3.2 Other effects

Emissions of nitrogen oxides (NO_x) are implicated in regional phenomena such as acidification, eutrophication and loss of biodiversity, as well as the formation of secondary PM and ozone in the atmosphere. NO_2 absorbs visible solar radiation and therefore contributes to reduced atmospheric visibility.

A.4 Particulate matter

A.4.1 Health effects

The road traffic pollutant generally accepted as having the greatest public health impact is particulate matter (Harrison, 2010). The biological effects of inhaled particles are determined by their physical and chemical properties, by their sites of deposition, and by their mechanisms of action. The extent to which particles can penetrate the respiratory tract, and their potential for causing health effects, is directly related to their size (Harrison et al., 2010). Notably, particles with a diameter of less than 2.5 µm ($PM_{2.5}$) can penetrate deep into the human respiratory system, and it is these which are of most concern.

In recent years evidence has accumulated indicating that airborne particles have a range of adverse effects on health. These effects – which are diverse in scope, severity and duration - include:

- Premature mortality.
- Aggravation of cardiovascular disease such as atherosclerosis.
- Aggravation of existing respiratory disease such as asthma.
- Changes to lung tissue, structure and function.
- Cancer[3]. Importantly, the International Agency for Research on Cancer has recently classified outdoor air pollution as carcinogenic to humans, with a specific emphasis on PM and diesel engine exhaust (PIARC, 2012; 2013).

[3] Particles may contain carcinogenic substances such as polycyclic aromatic hydrocarbons (PAHs) or heavy metals.

- Reproductive and developmental effects.
- Changes in the function of the nervous system.

There is evidence that short-term and long-term exposure to $PM_{2.5}$ causes illness and death from cardiovascular conditions, and is likely to cause respiratory conditions (USEPA 2009; WHO Regional Office for Europe, 2013). The effects observed in relation to $PM_{2.5}$ from a large study conducted in Australia and New Zealand (EPHC, 2010) are consistent with the effects reported in the international literature.

There is extensive evidence that short-term exposure to particles with a diameter of less than 10 µm (PM_{10}) is associated with health effects, and that these effects are independent of the effects of $PM_{2.5}$ (USEPA, 2009; WHO Regional Office for Europe, 2013). There is substantially less evidence that long-term exposure to PM_{10} has health effects that are independent of those caused by long-term exposure to $PM_{2.5}$. As with $PM_{2.5}$, the effects observed in the Australian and New Zealand NEPC multi-city study (EPHC, 2010) in relation to PM_{10} exposure are consistent with those observed internationally.

Studies have also investigated the relationship between specific PM components - for example, black carbon, secondary organic aerosol (SOA) and secondary inorganic aerosol (SIA) - and health effects (WHO Regional Office for Europe, 2013). In the future, the use of these metrics may provide a better indication of exposure to PM from particular sources, such as vehicle exhaust, and may improve the understanding of the associated health risks.

No safe threshold has been identified for the human health effects of particles (DECCW, 2010); for $PM_{2.5}$ there is substantial evidence of health associations down to very low levels. In Canada, Crouse *et al.* (2012) investigated the long-term exposure to ambient $PM_{2.5}$ and observed associations with cardiovascular mortality at concentrations as low as only a few micrograms per cubic meter. This last study is particularly relevant, because it investigated the effects of $PM_{2.5}$ at the levels commonly experienced in Australia.

A.4.2 Other effects

Particulate matter has the capacity to influence climate locally, regionally and globally. Black carbon from combustion sources has much the same effect as a greenhouse gas, although the mechanisms are different. White particles such as ammonium sulfate are reflective and have a net cooling effect by reflecting incoming solar radiation back to space. Water-soluble particles can act as cloud condensation nuclei, thus affecting the reflectivity of clouds and leading to a reduction in land surface warming (Harrison, 2010).

Airborne particles also reduce atmospheric visibility by the scattering and absorption of visible light. Visibility is an important safety concern for tunnel design. The amount of scattering or absorption is dependent upon particle size, composition and density. Vehicle exhaust contains a large number of very small particles (0.01 to 0.20 µm diameter) (see Annexure B), and particles in this size range are very effective at light extinction (PIARC, 2012).

A.5 Air toxics

Road vehicles produce a wide range of organic compounds through combustion and evaporation. These compounds are involved in the formation of photochemical smog, which is associated with irritation of the eyes and respiratory tract, amongst other things. Many of the organic compounds emitted by road vehicles also have impacts on health and the environment in their own right.

It is uncommon for air quality assessments to address a large number of organic pollutants. It is more usual for a small number of the most important components to be assessed, with inferences being made in relation to others. The compounds included in the assessment were benzene, benzo(a)pyrene (as a marker for polycyclic aromatic hydrocarbons), formaldehyde, and 1,3-butadiene. With respect to road traffic these pollutants are generally less of a concern now than in the past, as improvements in fuel quality (through fuel standards) in recent years have reduced the amounts being emitted from vehicles.

A.5.1 Benzene

Benzene is a constituent of automotive petrol, but since 2006 the benzene content in Australia has been limited to 1% by volume (compared with 5% previously). This reduction had an immediate and sustained impact on ambient benzene levels.

Short-term inhalation exposure to benzene can cause drowsiness, dizziness, headaches, as well as eye, skin, and respiratory tract irritation, and, at high levels, unconsciousness. Long-term inhalation exposure has caused blood disorders including reduced numbers of red blood cells and anaemia. Reproductive effects have been reported for women. The USEPA has classified benzene as known human carcinogen[4], and an increased incidence of leukaemia has been observed in humans occupationally exposed to benzene.

A.5.2 Polycyclic aromatic hydrocarbons

The term polycyclic aromatic hydrocarbons (PAH) covers a large group of organic compounds with two or more fused aromatic rings. Around 500 PAHs and related compounds have been detected in the air (WHO, 2000). PAHs are formed by incomplete combustion of fuels, including transport fuels, and can be present in both the gas and (more commonly) particle phases. The USEPA has designated 32 PAH compounds as priority pollutants. A short list of compounds is often targeted for measurement in environmental samples. Of these, the most measurements have been made for benzo(a)pyrene, and this compound is used as a marker for PAHs in the Air Toxics NEPM (NEPC, 2011).

PAHs are a concern because they are persistent in the environment for long periods of time, but there is little information on the health effects of exposure to individual PAHs at specific concentrations. Short-term exposure to mixtures of PAHs is known to cause skin irritation and inflammation. Anthracene, benzo(a)pyrene and naphthalene are direct skin irritants, whereas anthracene and benzo(a)pyrene are reported to cause an allergic skin response. The health effects of long-term exposure to PAHs may include cataracts, kidney and liver damage and jaundice. Naphthalene, a specific PAH, can cause the breakdown of red blood cells if inhaled or ingested in large amounts. Long-term studies of workers exposed to mixtures of PAHs and other workplace chemicals have shown an increased risk of skin, lung, bladder and gastrointestinal cancers (USEPA, 2008; SA Health, 2009).

A.5.3 Formaldehyde

Formaldehyde is a colourless gas with a pungent odour. Major sources include power plants, manufacturing facilities, incinerators, and automobile exhaust. Short-term and long-term inhalation of formaldehyde can result in respiratory symptoms and eye, nose, and throat irritation. Limited human studies have reported an association between formaldehyde exposure and lung and nasopharyngeal cancer. The USEPA considers formaldehyde to be a probable human carcinogen[5].

A.5.4 1,3-butadiene

Motor vehicle exhaust is a source of 1,3-butadiene. Although it breaks down quickly in the atmosphere it is usually found at low ambient levels in urban and suburban areas. Short-term exposure to 1,3-butadiene by inhalation results in irritation of the eyes, nasal passages, throat, and lungs. Epidemiological studies have reported a possible association between 1,3-butadiene exposure and cardiovascular diseases. The USEPA has classified 1,3-butadiene as carcinogenic to humans by inhalation[6].

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[4] http://www.epa.gov/ttn/atw/hlthef/benzene.html

[5] http://www.epa.gov/ttn/atw/hlthef/formalde.html

[6] http://www.epa.gov/ttnatw01/hlthef/butadien.html

Annexure B - Pollutant formation, dispersion and transformation

B.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 pollutants included in the assessment.

B.2 Formation of primary pollutants

B.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 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 in the following sections.

B.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 the emission legislation effectively mandating the fitting of a three-way catalyst (TWC)[1]. Diesel engines produce relatively little CO as they burn the fuel with excess air in the combustion chamber, even at high engine loads.

B.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, and hydrocarbon emissions from diesel engines are low for the reason mentioned above for CO.

B.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 B.3.3.1). Any NO_2 that is emitted directly from vehicles is referred to as ‘primary NO_2’.

[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.

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 in recent years (Jenkin, 2004; 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 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 Boulter and Bennett (2015). 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 E), weighted for the default traffic mix in each year, and the associated values of *f*-NO_2, are shown in Figure B-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 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 12-15 per cent (no Euro VI case) between 2020 and 2030.

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, and so it is not possible to determine the extent to which this is a contributing factor.

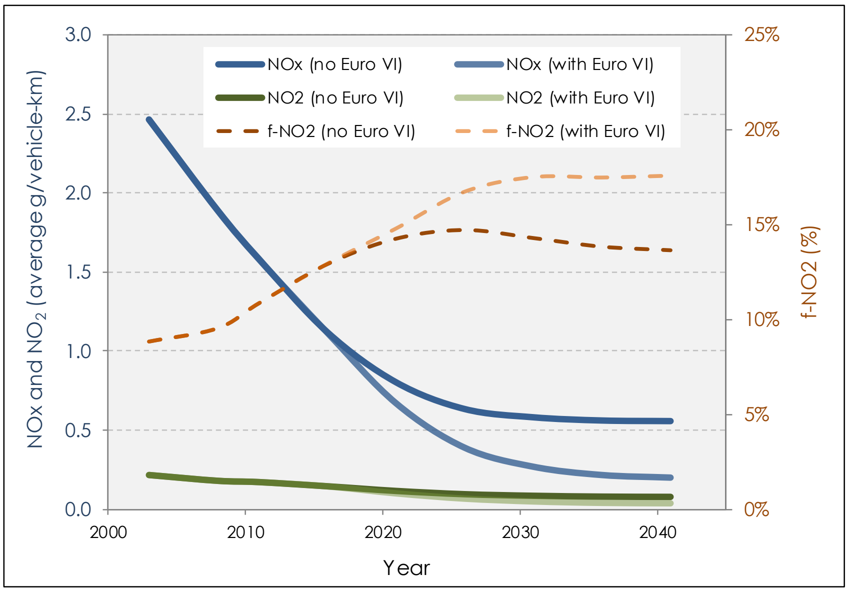

Figure B-1 **Emission factors for NO_x, NO_2 and f-NO_2 from the NSW EPA model for highways/freeways (80 km/h), weighted for default traffic mix (Boulter and Bennett, 2015)**

B.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 B-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 (nm), but other size cut-offs have been used. Accumulation mode particles range in size from around 50 nm to around 1 µm, with particles smaller than 0.1 µm being referred to as ultrafine particles. The coarse mode consists of particles larger than around 1 µm.

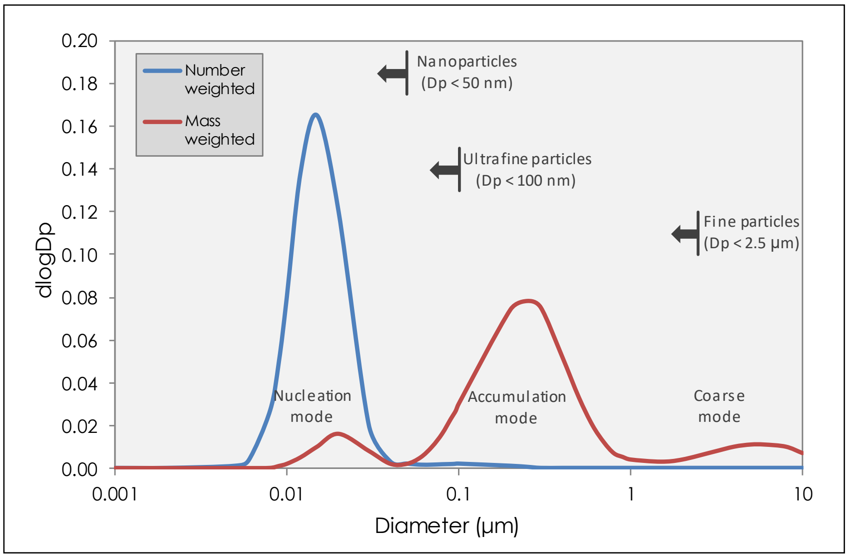

Figure B-2 **Typical particle size distributions in vehicle exhaust; the y-axis is a normalised log scale (adapted from Kittelson, 1998)**

The processes of particle formation during diesel combustion have been described in detail (*e.g.* Heywood, 1988). Carbonaceous spherules (soot) are initially created in the cylinder. A phase of particle growth then follows, involving the adsorption of gas-phase components, as well as coagulation and agglomeration. Almost all the particle mass found in the exhaust prior to dilution is present as these carbonaceous agglomerates. Most nucleation mode particles are thought to originate from the condensation of volatile material (hydrocarbons, hydrated sulphuric acid and salts) in the exhaust gas during dilution, rather than during combustion itself, and their formation is a function of measurement parameters such as temperature, dilution ratio, residence time, and humidity (Kittelson, 1998; Abdul-Khalek *et al*., 1999; Mathis, 2002), as well as fuel sulphur content (Maricq *et al*., 1999; Ntziachristos *et al.*, 2000). Particles in the coarse mode are formed by re-entrainment of material previously deposited on engine cylinder and exhaust system surfaces.

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 (DPF) which physically captures particles in the exhaust stream. However, DPFs can have limited effectiveness in controlling non-solid PM components, and some increases in particle number have also been reported due to hydrocarbon and sulphate nucleation occurring downstream of after-treatment devices.

B.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 of 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).

B.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 μm (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 than on surface roads (e.g. fewer intersections), and less cornering (i.e. tyre wear). 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.

B.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.

B.3 Pollutant dispersion and transformation

B.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 B.3.3), result in a very uneven distribution of pollution across an urban area.

Figure B-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).

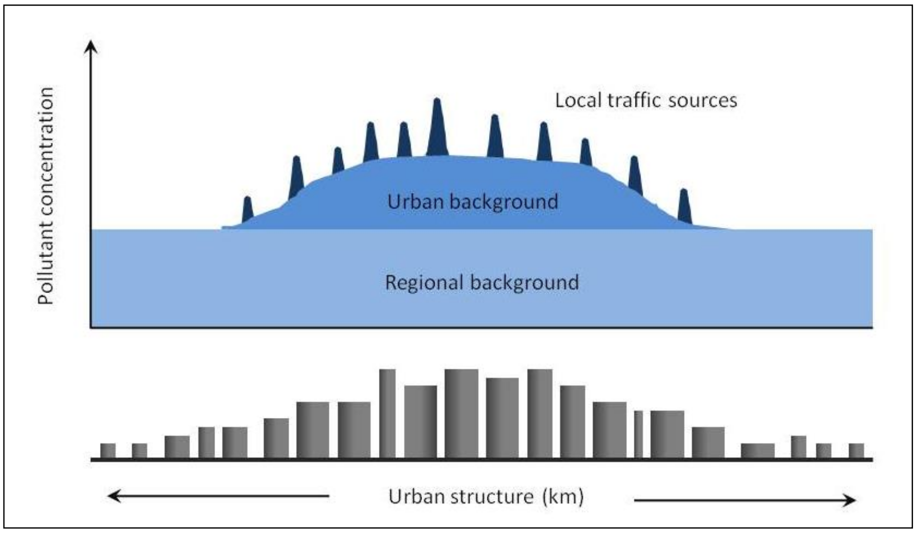

Figure B-3 **Simplified representation of urban structure and pollution levels (adapted from Keuken *et al*., 2005)**

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 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.

B.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 B-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. 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.

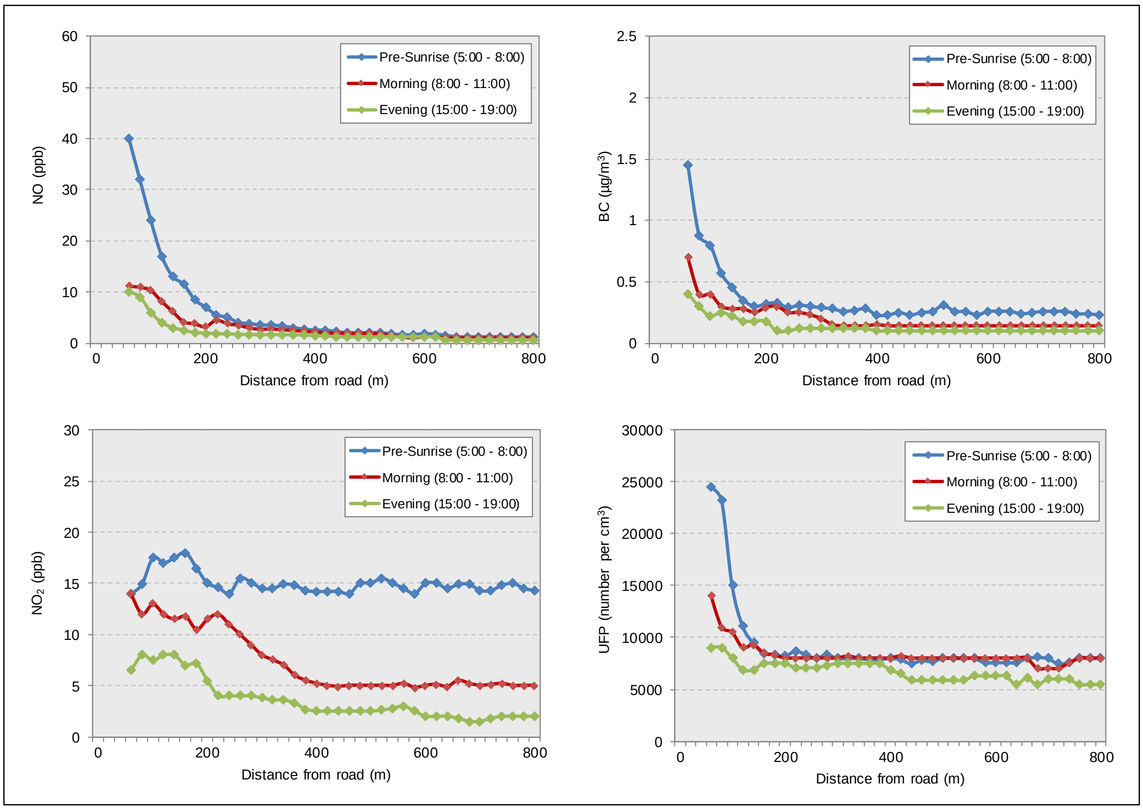

Figure B-4 **Median concentrations of pollutants in the vicinity of a major highway (adapted from Gordon et al., 2012)**

B.3.3 Pollutant transformation

B.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 B1

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

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 ozone 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 ozone, as shown in Equation B2 and Equation B3:

Equation B2

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

Equation B3

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

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

Dilution process decreases 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 B-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 ozone - is removed relatively quickly. Once the ozone is removed, NO_2 formation via Equation B1 will stop (Barrefors, 1996). As there is little natural sunlight inside a road tunnel, the destruction of NO_2 via Equation B2 is also limited. Consequently, much of the NO_2 in tunnel air is likely to be primary in origin.

B.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 to 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 7–30 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 nitrogen oxides (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 1 per cent per hour and 5 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 C - Review of legislation and criteria relating to emissions and air quality

C.1 Overview

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

C.2 National emission standards for new vehicles

C.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 3,500 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 legislation also distinguishes between petrol and diesel vehicles.
- Heavy-duty vehicles, with a GVM of more than 3,500 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, reflecting that the same engine model could be used in many different vehicles.

The Australian Design Rules (ADRs) set limits on the exhaust emissions of CO, HC, NO_X and PM. Some of the pollutants in vehicle exhaust are not regulated, including specific 'air toxics' and the greenhouse gases CO_2, CH_4 and 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 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 the limit on NO_X emissions by 77 per cent relative to Euro V, and by 89 per cent relative to Euro IV,

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[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.).

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 SCR 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 EU. For heavy-duty vehicles the Euro V standards have not achieved 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).

C.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 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.

C.3 In-tunnel limits – international practice

Guidelines for the calculation of the fresh air requirements of tunnel ventilation systems are presented by PIARC (2012). 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 sensor limit level (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.

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, including a safety margin.

Table C-1 provides a summary of the PIARC in-tunnel CO and visibility limits for ventilation design, tunnel operation, and tunnel closure. The 100 ppm value for CO corresponds to a 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 C-2. The national limits for CO in each country are broadly similar to the values recommended by PIARC.

Table C-1 CO and visibility limit values (PIARC, 2012)

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	100	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 C-2 In-tunnel CO and visibility limits for ventilation design and tunnel closure

<table>
<tr><th rowspan="2">Country</th><th rowspan="2">Condition for ventilation design</th><th colspan="2">Limit values for ventilation design</th><th colspan="2">Limit values for tunnel closure</th></tr>
<tr><th>CO (ppm)</th><th>Visibility (/m)</th><th>CO (ppm)</th><th>Visibility (/m)</th></tr>
<tr><td rowspan="2">Austria</td><td rowspan="2">Regular congestion</td><td rowspan="2">100</td><td rowspan="2">0.007</td><td>150[(a)]</td><td>0.012[(a)]</td></tr>
<tr><td>100[(b)]</td><td>-</td></tr>
<tr><td>France</td><td>Free-flow and congested</td><td>50</td><td>0.005</td><td>-</td><td>-</td></tr>
<tr><td rowspan="2">Germany</td><td>Regular congestion</td><td>70</td><td>0.005</td><td>200</td><td>0.012</td></tr>
<tr><td>Occasional congestion</td><td>100</td><td>0.007</td><td>-</td><td>-</td></tr>
<tr><td>Hong Kong</td><td>5-min average</td><td>100</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="2">Japan</td><td>60 km/h</td><td>50-100</td><td><0.009</td><td rowspan="2">150</td><td rowspan="2">0.012</td></tr>
<tr><td>80 km/h</td><td>50-100</td><td><0.007</td></tr>
<tr><td>Norway[(c)]</td><td>Mid-tunnel</td><td>75</td><td>-</td><td>100[(d)]</td><td>-</td></tr>
<tr><td>Switzerland</td><td>Any</td><td>70</td><td>0.005</td><td>200[(e)]</td><td>0.012[(e)]</td></tr>
<tr><td rowspan="3">UK[(f)]</td><td>Tunnel <500 m</td><td>10</td><td>PIARC</td><td>-</td><td>-</td></tr>
<tr><td>Tunnel 500 m to 1,000 m</td><td>50</td><td>PIARC</td><td>-</td><td>-</td></tr>
<tr><td>Tunnel 1,000 m to 2,500 m</td><td>35</td><td>PIARC</td><td>-</td><td>-</td></tr>
<tr><td rowspan="3">USA</td><td>Fluid peak traffic, 60 km/h</td><td>100</td><td><0.009</td><td rowspan="3">150</td><td rowspan="3">0.012</td></tr>
<tr><td>Fluid peak traffic, 80-100 km/h</td><td>100</td><td><0.007</td></tr>
<tr><td>Congested traffic</td><td>100</td><td><0.009</td></tr>
</table>

(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 2,500 m are derived from first principles.

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

PIARC has not released definitive recommendations for 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, 2012).

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.

Examples of in-tunnel NO_2 values for ventilation control from several countries are summarised in Table C-3. It is noted in PIARC (2012) 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 time frames, and it appears that some of these are quite stringent. In the UK, consideration was given to lowering the NO_2 limit to 1 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 1 ppm and 5 ppm. A typical ambient peak NO_2 concentration would be 200 $\mu g/m^3$. 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, 2012).

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 C-3 International in-tunnel NO_2 limits

Country	NO_2 (ppm)	Notes	Source
PIARC	1.0	Averaged over tunnel length	PIARC (2012)
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 1,000 m	
	1.5	Tunnel 1,000 m to 2,500 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 2,500 m are derived from first principles.

C.4 Ambient air quality standards and goals

C.4.1 Criteria pollutants

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

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

Pollutant or metric	Criterion		Calculation	Source
	Concentration	Averaging period		
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 and the AAQ NEPM from February 2016 are compared with the WHO guidelines and the standards in other countries/organisations in Table C-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. However, 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, for example). 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 C-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	-	30[(i)]	10(1)	200(9)	100[(i)]	-	50(1)	20[(i)]	25[(i)]	-
UK	-	-	10(0)[(j)]	200(18)	-	40	50(35)	40	-	25
UK (Scotland)	-	-	10(0)[(k)]	200(18)	-	40	50(7)	18	-	12
United States (USEPA)	-	39(1)	10(1)	190[(l)]	-	100	150(1)	-	35[(m,n)]	12[(m)]
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) By 2020.
(j) Maximum daily running 8-hour mean.
(k) Running 8-hour mean.
(l) 98th percentile, averaged over 3 years.
(m) Averaged over three years.
(n) Stated as 98th percentile.

C.4.2 Air toxics

The investigation levels in the Air Toxics NEPM are summarised in Table C-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 C-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	24 hours
		0.1 ppm	1 year[(a)]
	Xylenes	0.25 ppm	24 hours
		0.20 ppm	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 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 BTEX compounds: benzene, toluene, ethylbenzene, and xylenes. The impact assessment criteria in the NSW Approved Methods for priority air toxics and BTEX compounds are given in Table C-7.

Table C-7 Impact assessment criteria for air toxics

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

(a) Odour criterion

Annexure D - Examples of previous ambient air quality assessments

D.1 Road tunnel assessments

Table D-1 WestConnex New M5, Sydney

Project (type of assessment)	WestConnex New M5 (EIS)
Project description	A tolled road link featuring twin motorway tunnels between the existing M5 East Motorway (between King Georges Road and Bexley Road) and St Peters. Each tunnel will be about nine kilometres in length and would comprise two lanes of traffic, with the potential to be upgraded. The project will also include an interchange at St Peters and connections to the existing road network. The impacts of the closure and remediation of the Alexandria Landfill to accommodate the St Peters interchange site were also considered in the EIS.
Pollutants/metrics modelled	PM_{10}, $PM_{2.5}$, TSP, NO_x, CO, air toxics
Approach	Consideration given to each tunnel ventilation outlet and around 6,000 surface roads.
Scenarios	The scenarios evaluated for in-tunnel air quality reflected the potential modes of operation of the tunnel ventilation system. These were: - Expected traffic scenarios. - Capacity (maximum) traffic flow scenarios. - Vehicle breakdown scenario. Two types of scenario were considered for ambient air quality: - Expected traffic scenarios: 2014 - Base Year (existing conditions) 2021 - Do Minimum (no project) 2021 - Do Something (with project) 2031 - Do Minimum (no project) 2031 - Do Something (with project) 2031 - Do Something Cumulative (with project and M4-M5 Link) - Regulatory worst case scenarios.
Traffic data	WestConnex Road Traffic Model
Background air quality	Background concentrations were based on measurements from all air quality monitoring stations at urban background locations in the study area. Maps of background annual mean concentrations of NO_X and PM_{10} were developed for the WestConnex study area. For $PM_{2.5}$ the annual mean background concentration was assumed to be fixed at 8 µg/m^3. For each short-term air quality metric a synthetic time series of background concentrations was determined. Background concentrations were assumed to remain unchanged in future years.
Emission factors	PIARC (tunnel ventilation outlets) and EPA (surface roads).
Met/dispersion model(s)	GRAMM (met) and GRAL (dispersion). Meteorological grid domain: 25 kilometres x 20 kilometres Meteorological grid resolution: 200 metres. Dispersion grid domain: 15 kilometres x 14 kilometres Dispersion grid resolution: 10 metres. One surface met station.
Receptors	A total of 46,219 discrete residential, workplace and recreational (RWR) receptors were defined. In addition, 35 community receptors were treated in more detail.
Model validation	The performance of the full model chain was evaluated through comparison of predictions with measurements at two Roads and Maritime roadside sites.
Construction assessment	Semi-quantitative, risk-based approach based on IAQM (2014).
Reference	Manansala et al. (2015)

Table D-2 WestConnex M4 East, Sydney

Project (type of assessment)	WestConnex M4 East (EIS)
Project description	Upgrade and extension of the M4 Motorway from Homebush Bay Drive at Homebush to Parramatta Road and City West Link (Wattle Street) at Haberfield, including twin tunnels about 5.5 kilometres long and associated surface works to connect to the existing road network.
Pollutants/metrics modelled	PM_{10}, $PM_{2.5}$, TSP, NO_x, CO, air toxics
Approach	Consideration given to each tunnel ventilation outlet and around 6,000 surface roads.
Scenarios	The scenarios evaluated for in-tunnel air quality reflected the potential modes of operation of the tunnel ventilation system. These were: - Expected traffic scenarios. - Capacity (maximum) traffic flow scenarios. - Vehicle breakdown scenario. Two types of scenario were considered for ambient air quality: - Expected traffic scenarios: 2014 - Base Year (existing conditions) 2021 - Do Minimum (no project) 2021 - Do Something (with project) 2031 - Do Minimum (no project) 2031 - Do Something (with project) 2031 - Do Something Cumulative (with project and M4-M5 Link) - Regulatory worst case scenarios.
Traffic data	WestConnex Road Traffic Model
Background air quality	Background concentrations were based on measurements from all air quality monitoring stations at urban background locations in the study area. Maps of background annual mean concentrations of NO_X and PM_{10} were developed for the WestConnex study area. For $PM_{2.5}$ the annual mean background concentration was assumed to be fixed at 8 $\mu g/m^3$. For each short-term air quality metric a synthetic time series of background concentrations was determined. Background concentrations were assumed to remain unchanged in future years.
Emission factors	PIARC (tunnel ventilation outlets) and EPA (surface roads).
Met/dispersion model(s)	GRAMM (met) and GRAL (dispersion). Meteorological grid domain: 25 kilometres x 20 kilometres Meteorological grid resolution: 200 metres. Dispersion grid domain: 15 kilometres x 14 kilometres Dispersion grid resolution: 10 metres. One surface met station.
Receptors	A total of 10,362 discrete residential, workplace and recreational (RWR) receptors were defined. In addition, 31 community receptors were treated in more detail.
Model validation	The performance of the full model chain was evaluated through comparison of predictions with measurements at two Roads and Maritime roadside sites.
Construction assessment	Semi-quantitative, risk-based approach based on IAQM (2014).
Reference	Boulter et al. (2015)

Table D-3 NorthConnex, Sydney

Project (type of assessment)	NorthConnex (EIS)
Project description	A proposed nine-kilometre toll tunnel linking the M1 Pacific Motorway at Wahroonga to the Hills M2 Motorway at West Pennant Hills. During operation, the ventilation system would draw fresh air into the tunnels and emit air from within the tunnels via two ventilation facilities. One of the ventilation facilities would be located near the northern tunnel portal and one would be located near the southern tunnel portal.
Pollutants/metrics modelled	PM_{10}, $PM_{2.5}$, TSP, NO_x, CO, PAHs and VOCs
Approach	- Assessment scenarios. - The dispersion models. - Meteorological data. - Terrain and land use data. - Sensitive receivers. - Model input parameters. - Emissions assumptions (estimation and rates). - Ventilation outlet parameters. - Cumulative assessment.
Scenarios	Three principal air quality scenarios were evaluated: - Comparison of air quality with and without the project. - Assessment of air quality at the expected opening of the project (2019), and after ten years of operation (2029). - Assessment of air quality in the event of a breakdown in one of the tunnels.
Traffic data	Strategic Sydney traffic model
Background air quality	For PM_{10}, $PM_{2.5}$ and NO_2, the ambient concentrations were determined by taking the maximum of the concentrations predicted by CAL3QHCR (with the project) and those measured by the OEH at its Lindfield and Prospect monitoring stations. For CO the maximum concentration recorded at the OEH monitoring station at Prospect was used.
Emission factors	PIARC.
Met/dispersion model(s)	MM5/CALMET/CALPUFF (ventilation stacks) and CAL3QHCR (surface roads). Meteorological grid domain: 60 kilometres x 62.5 kilometres Meteorological grid resolution: 250 metre resolution. Five surface met stations.
Receptors	A total of 6,919 discrete receptors were assessed. Of these, 3,332 were located along the project corridor.
Model validation	Not specified.
Construction assessment	Potential construction air quality impacts associated with the project were assessed qualitatively by describing the nature of proposed works, plant and equipment, potential emissions sources and levels.
Reference	AECOM (2014a,b)

Table D-4 East-West Link, Eastern Section, Melbourne

Project (type of assessment)	East West Link: Eastern Section, Melbourne. (project cancelled)
Project description	Six-lane tunnel from the Eastern Freeway in Clifton Hill to CityLink in Parkville.
Pollutants/metrics modelled	Peak and mean CO Peak and mean NO_2 Peak and mean PM_{10} Peak and mean $PM_{2.5}$ AQ criteria from Victoria's State Environment Protection Policy (Air Quality Management 2001) (SEPP (Air Quality Management)).
Approach	Regional impacts were downscaled to the local level to identify potential hot-spots within a few hundred metres (major intersection level) and to quantify the changes from 'no-build' to 'build' scenarios. Compared model predictions to design criteria for the predicted ground-level concentration at portal locations and elevated/depressed road sections. Consideration was given to the possibility of turning down/off the forced ventilation during low-usage overnight conditions to achieve minimal portal emission impact (this was subsequently adopted as an operational practice). For tunnel vent emissions, a point source assessment was undertaken to establish performance requirements. Risk assessment matrix included.
Scenarios	2021 without project 2021 with project 2031 with project
Traffic data	Traffic model AM peak, PM peak, mid-day, off-peak
Background air quality	Hourly varying values for NO_2 and PM_{10} (TEOM) were taken from two EPA Victoria monitoring sites. The data for 2008 were used to match the concentrations with the meteorological data. Background values for other pollutants were taken from other recent road projects in Victoria.
Emission factors	PIARC
Met/dispersion model(s)	AUSPLUME 6.0 and AUSROADS 1.0
Receptors	Hoddle Street Overpass: roadside receptors. A series of discrete receptors was placed across transects from the Eastern Freeway for the location of maximum ground-level concentrations for NO_2 to a distance of 250 metres away. The dominating line source was CityLink, at a height of around 10 metres above ground level, and as such receptors were placed at this height to obtain worst case results. Gridded receptors were modelled with ±1.0 km domain and 20 m resolution Total number of receptors was not given.
Model validation	Not specified.
Construction assessment	Environmental management plan created for construction, but only qualitatively assessed.
Notes	Strategic transport modelling (VLC 2013) was undertaken for the purpose of estimating the amounts and types of vehicles that could potentially use East West Link – Eastern Section roads. Assessed future scenarios with and without the Project.
Reference	GHD (2013)

Table D-5 Waterview Connection, Auckland

Project (type of assessment)	Western Ring Route: Waterview Connection, Auckland, New Zealand
Project description	Two tunnels between Great North Road Interchange and the Alan Wood Reserve. Separate tunnels for northbound and southbound traffic. Longitudinal ventilation.
Pollutants/metrics modelled	Max 8-hour mean CO Max 1-hour mean CO Max 1-hour mean NO_x Max 1-hour mean NO_2 Max 24-hour mean PM_{10} Annual mean PM_{10} Max 24-hour mean $PM_{2.5}$ Annual mean benzene Criteria from National Environmental Standards (AQNES), New Zealand Air Quality Guidelines (NZAAQG) and Auckland Regional Air Quality Targets (ARAQT).
Approach	Only portal emissions modelled.
Scenarios	Base year of 2006 2016 With Project 2016 Do Nothing 2026 With Project 2026 Do Nothing
Traffic data	EMME/3 traffic model
Background air quality	The baseline scenario was the cumulative air quality for the 2006 base year. PM_{10}: hourly 2007 data from the mean of 1-hour average concentrations from 5 sites. $PM_{2.5}$ hourly 2007 data from the mean of 1-hr average concentrations from 3 sites. CO: hourly 2007 data from the mean of 1-hr average concentrations from 6 sites. Benzene: Baseline derived from passive monitoring conducted for the Project.
Emission factors	Detailed emissions factors have been derived from VEPM. Portal emission rates varied with respect to traffic volume and ambient wind speed.
Met/dispersion model(s)	GRAL (tunnel portals), VEPM, CALMET, CALPUFF, AUSROADS (surface roads)
Model validation	The 2006 base year scenario was used for validation of the dispersion model. Data on meteorology and measured background concentrations were taken from 2007, although the traffic volumes used in the model were based on 2006 census data.
Receptors	Sensitive receptors within 2km of either tunnel ventilation stack or within 300 m of a major surface road. 25 schools 38 early-learning centres 11 healthcare centres 10 residential 6 sports fields 8 receptors with “Existing SH20 Designation”
Construction assessment	Compliant with the raft NZTA Standard Producing Air Quality Assessments for State Highway Projects and the NZ Ministry for Environment’s Good Practice Guide for Assessing and Managing the Environmental Effects of Dust Emissions”
Reference	BECA (2010)

Table D-6 Lane Cove Tunnel, Sydney

Project (type of assessment)	Lane Cove Tunnel, Sydney
Project description	Tunnel consists of twin tubes ventilated by two ventilation outlets.
Pollutants/metrics modelled	Max 8-hour mean CO Max 1-hour mean CO Max 1-hour mean NO_2 Annual men NO_2 Max 24-hour mean PM_{10} Annual mean PM_{10} 1-hour mean HC Annual mean HC Criteria: EPA/AAQ NEPM.
Approach	Validation of the ambient air quality assessment undertaken for the tunnel ventilation system as assessed in the Environmental Assessment for the Revised Ventilation Design for the Lane Cove Tunnel Project, utilising actual monitoring data. Two modelling scenarios: using estimated emissions from the EIS and using measured stack emissions data.
Scenarios	Emissions data from in-stack monitoring. Modelling included normal and congested conditions.
Traffic data	Traffic volume data for the period of October 2007 to September 2008.
Background air quality	Background air quality monitoring was undertaken at Epping Road, Mowbray Road and Military Road for the Proposal. In addition, the OEH air quality monitoring site at Lindfield was used.
Emission factors	PIARC (2006 taken to be worst case scenario)
Met/dispersion model(s)	TAPM/CALMET/CALPUFF
Receptors	Concentrations at receptors at both ground and elevated levels.
Model validation	Predicted results using stack monitoring data were compared with the predicted results using emission estimations from the EIS.
Construction assessment	Emissions from construction were estimated using SPCC and USEPA emission factors. No dispersion modelling was undertaken.
Reference	PAEHolmes (2010)

Table D-7 Northern Link, Brisbane

Project (type of assessment)	Northern Link (Legacy Way), Brisbane (EIS)
Project description	The Project involved the construction and operation of an underground toll road (tunnel) between the Western Freeway, in Toowong, and the Inner City Bypass (ICB), at Kelvin Grove. Longitudinal tunnel, two ventilation outlets.
Pollutants/metrics modelled	Max 8-hour mean CO Max 1-hour mean NO_2 Annual mean NO_2 Max 24-hour mean PM_{10} Annual mean PM_{10}
Scenarios	See below.
Traffic data	- Annualised Average Daily Traffic (AADT) for years 2007 (existing), 2014, 2016, 2021 and 2026. - Scenarios with and without project. - Modelled 2007 (existing), 2014, 2016, 2021 and 2026 AADT for selected surface roads and in tunnel sections. - Indicative flow profiles for light and heavy vehicles by hour of day for each section of tunnel and for surface roads.
Background air quality	The background data were constructed from air quality monitoring data, specifically, those collected from the Bowen Hills and Rocklea sites.
Emission factors	National Pollutant Inventory (2000)
Met/dispersion model(s)	CALMET/ CALPUFF, CAL3QHCR
Receptors	Exact receptor locations not specified.
Model validation	Not specified
Construction assessment	Qualitative assessment of potential impacts of specific activities and mitigation measures.
Reference	Holmes Air Sciences (2008b)

Table D-8 Airport Link, Brisbane

Project (type of assessment)	Airport Link, Brisbane (EIS)
Project description	Twin-bore, 6 km road tunnel from Bowen Hills to Wooloowin in Brisbane. Longitudinal ventilation, three elevated outlets near each end as well as an intermediate outlet at Kedron.
Pollutants/metrics modelled	Max 8-hour mean CO Max 1-hour mean NO_2 Annual mean NO_2 Max 24-hour mean PM_{10} Annual mean PM_{10} Criteria: EPA/AAQNEPM
Approach	Emissions estimated for each ventilation outlet and all surface roads.
Emission factors	PIARC, modified to account for age, vehicle mix, speed etc. No potential future improvements in vehicle technology or fuel standards included. SEQ inventory EFs compared with PIARC EFs.
Background air quality	2004 was chosen for both the background meteorological and ambient air quality monitoring records. The monitoring sites are summarised as follows: - Eagle Farm, operated by the EPA but now decommissioned, included measurements of NOx, O_3, SO_2 and PM_{10}. - Bowen Hills, operated by Simtars but now decommissioned, included measurements of CO, NOx, PM_{10} and $PM_{2.5}$. - Kedron, currently monitoring and operated by Simtars. Measurements include CO, NOx, PM_{10} and $PM_{2.5}$.
Met/dispersion model(s)	CALMET/ CALPUFF; CAL3QHCR for near-road impacts.
Receptors	Not specified.
Model validation	Not specified.
Construction assessment	Not considered, as modelled for the feasibility assessment.
Reference	Holmes Air Sciences (2006b)

Table D-9 Vic Park Tunnel, Auckland

Project (type of assessment)	Vic Park Tunnel, Auckland
Project description	Realignment of State Highway 1 between Harbour Bridge and Wellington St, including tunnel and widening of existing carriageway.
Pollutants/metrics modelled	Max 8-hour mean CO Max 1-hour mean CO Max 1-hour mean NO_2 Max 24-hour mean NO_2 Max 24-hour mean PM_{10} Annual mean PM_{10} Annual mean benzene Criteria from NZ National Environmental Standards (NES) for Air Quality.
Approach	Modelled both the surface roads and the proposed tunnel portal.
Scenarios	In total four scenarios were modelled: - 2010 without the VPT project - 2010 with the VPT project - 2021 without the VPT project - 2021 with the VPT project
Traffic data	Traffic models developed by BECA.
Background air quality	Takapuna. The monitoring station is located approximately 8-kilometres from the site and about 25 m from a major intersection. It is important to note that the concentrations measured at both these sites are already influenced by traffic emissions.
Emission factors	New Zealand Transport Emission Rate model (NZTER). Assumed that tunnel was a motorway, with EFs being derived for free, interrupted and congested flow conditions.
Met/dispersion model(s)	CALINE 4/CAL3QHCR applied to both surface roads and tunnel portals
Receptors	10 ground-level receptors, 15 elevated receptors at heights up to 14 m.
Model validation	In the modelling validation study, the total NOx concentrations were modelled and the NO_2 concentrations were calculated based on the NSW accepted practice which assumes that NO_2 concentrations are 10% of NOx by weight at the kerbside, 15% by weight at 10 m and 20% by weight at 30 m and beyond.
Construction assessment	Construction impacts were not assessed in the study.
Notes	Breakdown of vehicles by fuel type based on NZ Motor Vehicle Registration Statistics, Land Transport Safety Authority (LTSA), 2004. Fleet composition assumed to be constant for future scenarios.
Reference	Holmes Air Sciences (2006a)

Table D-10 M5 East Tunnel, Sydney

Project (type of assessment)	M5 East Tunnel, Sydney (partial portal emissions and trial of tunnel filtration technology). The filtration trial proceeded without partial portal emissions.
Project description	Potential impacts of regular partial portal emissions from the tunnel to manage in-tunnel haze. Four-kilometre long twin tunnels from Bexley to Arncliffe, with a recirculating ventilation system with a single ventilation outlet located at Turrella (approximately 800 m from the tunnel).
Pollutants/metrics modelled	Max 8-hour mean CO Max 1-hour mean CO Max 15-min mean CO Max 30-min mean CO Max 1-hour mean NO_2 Annual mean NO_2 Max 24-hour mean PM_{10} Annual mean PM_{10} 24-hour mean PM2.5 Annual mean $PM_{2.5}$ VOCs/PAH
Approach	Model the dispersion of emissions from the M5 East tunnel portals by computational fluid dynamics (CFD), and a health risk assessment.
Scenarios	Varying air volumes emitted from the portals.
Traffic data	Modelled emissions based on fleet average emission data (NPI 2000).
Background air quality	Background concentration for the criteria pollutants, PM_{10}, CO and NO_2, were derived from the ambient monitoring stations located adjacent to the Bexley Road (F1) and Marsh Street (M1) portals for each 5-minute period throughout the whole of the calendar year 2005.
Emission factors	Pollutant concentrations in the air discharged during portal emissions determined using measurements from sensors within the tunnel and other reported emission factors.
Met/dispersion model(s)	CFD (FLUENT) Varying portal outflow rates were modelled, with the maximum outflow rate being continuous from 5 am and 7 pm for conservatism.
Receptors	At Bexley Rd, a closely-spaced (30m spacing) rectangular shaped modelling receptor grid was employed covering all relevant residences within the range of 0 to 150 m of the portal. At the Marsh St portal, to ensure that the whole of the residential area was modelled a selection of individual residences covering all residences within 200 m of the portal were modelled.
Model validation	State-of-the-art CFD modelling software, FLUENT Version 6.2d, with current ISO 9001 certification and guaranteed model validity was used.
Construction assessment	Construction impacts not quantitatively assessed, although an environmental management plan was created to include construction activities (only relevant to the construction of the filtration plant).
Reference	Synergetics (2006)

Table D-11 Cross City Tunnel, Sydney

Project (type of assessment)	Cross City Tunnel, Sydney
Project description	Twin two-lane road tunnels for traffic travelling east–west across Central Sydney between Darling Harbour and Kings Cross.
Pollutants/metrics modelled	Max 8-hour mean CO Max 1-hour mean CO Max 1-hour mean NO_2 Max 24-hour mean PM_{10} Annual mean benzene Criteria: EPA/AAQ NEPM.
Approach	Modelled 3 ventilation options: - 2 ventilation outlets (one near the exit portal of each tunnel) - 2 ventilation outlets (one near the exit portal of each tunnel with a cross-over vent stack near the eastern portals). - 1 stack (at western end with recirculation at the eastern end). Adopted option was a single outlet at the western end with an additional ventilation tunnel from the eastern end of the project.
Scenarios	With construction Without tunnel construction and minor road improvements
Traffic data	Traffic volume data collected in 1998, and 2006, and projected for 2016. Details of traffic model given in “Technical Paper No. 8”
Background air quality	Details given in "Technical Paper No. 16 Air Quality"
Emission factors	Details not given in report, but in "Technical Paper No. 16 Air Quality"
Met/dispersion model(s)	AUSPLUME
Receptors	Elevated receptors: Darling Walk (15 metres), IMAX Theatre (30 metres), Park Royal Hotel (40 metres) Millennium Towers (60 metres), Darling Park Stage 3 (70 metres), Darling Park Stage 2 (145 metres) 37 Street receptors around Sydney CBD.
Model validation	Details not given.
Construction assessment	Described on an area by area basis in precincts: Darling Harbour, Central, Hyde Park.
Notes	All emissions assumed to vent through a ventilation outlet. A single outlet option was adopted.
Reference	PPK (2000)

D.2 Surface road assessments

Table D-12 WestConnex M4 Widening

Project (type of assessment)	WestConnex M4 Widening
Project description	- M4 Widening including: - Construction of a new two lane viaduct for westbound traffic, on the southern side of the existing viaduct structure between Church Street, Parramatta and Wentworth Street, Granville. - Reconfiguration of the traffic lanes on the existing viaduct structure to four lanes eastbound and two lanes westbound. - Construction of a new bridge/viaduct over Duck River at Auburn.
Pollutants/metrics modelled	Max 8-hour mean CO Max 1-hour mean CO Max 1-hour mean NO_2 Annual mean NO_2 Max 24-hour mean PM_{10} Annual mean PM_{10} 24-hour mean $PM_{2.5}$ Annual mean $PM_{2.5}$ VOCs/PAH
Approach	To determine whether there is any significant change in the existing levels of emissions from the road, and where the change occurs and the relative scale of the change.
Scenarios	Four scenarios were assessed: - Base 'do minimum' (2017) - without the M4 Widening project. - M4 Widening (2017) - project opening year. - Future 'do minimum' (2027) - 10 years after the Base 'do minimum', but not including the M4 Widening or the WestConnex schemes. - Full WestConnex (2027) – development of the full WestConnex Scheme represented by adding all stages of the scheme to the Future 'do minimum' case.
Traffic data	Source of traffic volumes not specified.
Background air quality	The background monitoring data includes data for NO_2, CO (Rozelle and Chullora) and PM_{10}.
Emission factors	TRAQ (derived from method in NSW GMR emissions inventory).
Met/dispersion model(s)	TRAQ (CALINE 4)
Receptors	7 Receptors along a transect of the proposed widening. At these receptors, air quality was assessed at 20m, 50m and 100m from the nearest lane of the motorway
Model validation	Not specified
Construction assessment	Assessed quantitatively using USEPA AP42 Emissions Factors
Notes	None.
Reference	Todoroski Air Sciences (2014)

Table D-13 Pacific Highway, Ballina Bypass

Project (type of assessment)	Pacific Highway Ballina Bypass (EIS).
Project description	Upgrade between Hexham and the QLD border by constructing a four lane duel carriageway bypass of Ballina.
Pollutants/metrics modelled	Max 1-hour mean CO Max 1-hour mean NO_x Max 1-hour mean HC Max 1-hour mean PM_{10} Max 1-hour mean lead Criteria: NEPM, NHMRC
Approach	Model the impacts of the potential bypass construction and compare this to existing air quality.
Scenarios	Bypass construction in 2016. No bypass construction (existing air quality)
Traffic data	EMME/2 transport model using 1994 as a base year and the future scenario in 2016
Background air quality	CO was monitored over a two week period from 21/7/1997 at a location 50 m away from the Pacific Highway and 200m east of Teven Road.
Emission factors	Not stated in main report.
Met/dispersion model(s)	CALINE 4
Receptors	8 receptors along the proposed bypass and three receptors in Ballina.
Model validation	Not specified.
Construction assessment	Construction emissions estimated using SPCC and USEPA EFs.
Notes	Emission rates for morning and afternoon peak hours for 2 scenarios.
Reference	Connell Wagner (1998)

Table D-14 Pacific Highway Upgrade, Banora Point

Project (type of assessment)	Pacific Highway Upgrade, Banora Point
Project description	Freeway-standard link between the Chinderah bypass and the Tweed Heads bypass, bypassing an existing section of the Pacific Highway.
Pollutants/metrics modelled	Max 8-hour mean CO Max 1-hour mean CO Max 1-hour mean NO_2 Annual mean NO_2 Max 24-hour mean PM_{10} Annual mean PM_{10} Criteria: NEPM, DECC.
Approach	PIARC (2004), adjusted to reflect the NSW vehicle fleet and grades, speed, and %HDV.
Scenarios	• A base case (2010, no upgrade). • With the proposed upgrade in 2010. • With the proposed upgrade 2020.
Traffic data	Traffic flow data was calculated based on predicted annual average traffic flow data for the three scenarios. Hourly traffic volumes were calculated using a generic profile from traffic count data collected on the Pacific Highway north of Terranora Road in February 2007. For modelling purposes, the route (proposed upgrade and existing highway) was split into southern, mid and northern sections. Traffic on the on and off-ramps and on the existing Pacific Highway was also modelled as part of the proposed upgrade 2010 and 2020 scenarios.
Background air quality	No air quality monitoring data available for the study area. However, monitoring data collected by the Department of Environment and Climate Change at Newcastle swimming pool in Wallsend and at the Newcastle sportsground (on Dumaresq Street) is considered indicative of air quality in a coastal town like Banora Point.
Emission factors	Dust emission rates from US EPA (1995) *AP-42 Compilation of Air Pollutant Emission Factors* and the NSW Mineral Council (2000) Particulate Matter and *Mining Interim Report.* Vehicle emissions rates, using vehicle emission data from PIARC (2004).
Met/dispersion model(s)	CAL3QHCR
Receptors	Receptor locations were chosen to represent the residential areas closest to the proposed upgrade and positioned at ground level, at fixed distances of 0, 10, 20, 30 and 50 metres from the road in the following locations : Receptor Location 1: northbound carriageway close to the southern off-ramp. Receptor Location 2: northbound carriageway of the Old Pacific Highway, just north of Terranora Road. Receptor Location 3: north and southbound carriageways close to Short Street. Receptor Location 4: north and southbound carriageways close to Minjungbal Drive.
Model validation	Not specified
Construction assessment	Qualitative construction scenario.
Reference	Holmes Air Sciences (2008a)

Table D-15 Pacific Highway Upgrade, Bulahdelah

Project (type of assessment)	Pacific Highway Upgrade, Bulahdelah
Project description	Around 8.5 km of dual carriageway.
Pollutants/metrics modelled	Max 8-hour mean CO Max 1-hour mean CO Max 1-hour mean NO_2 Max 24-hour mean PM_{10} Annual mean PM_{10} Annual mean benzene Criteria: NEPM, WHO, DEC, NHMRC.
Approach	Metropolitan Air Quality Study (1997) provided by DEC.
Scenarios	Only one scenario for proposed road works considered
Traffic data	Traffic flow data for 2008 and 2018
Background air quality	No monitoring undertaken specifically for this project, but there are data available from the DEC monitoring network and earlier data from north of Bulahdelah. The station closest to the route is near the Pacific Highway at Beresfield near Newcastle
Emission factors	Metropolitan Air Quality Study (MAQS) (Carnovale et al, 1997) and rates provided by the DEC.
Met/dispersion model(s)	CALINE 4 with BREEZE ROADS package used to assess impacts.
Receptors	Receptors were placed at fixed distances of 0 m, 10 m, 30 m and 50 m from sections of the roads closest to residences and other sensitive areas including Bulahdelah Central School and St. Joseph's Primary School.
Model validation	Williams et al. (1994)
Construction assessment	Construction qualitatively assessed.
Reference	Holmes Air Sciences (2004)

Table D-16 M2 Upgrade

Project (type of assessment)	M2 Upgrade
Project description	Widening sections of the motorway and additional access/egress points.
Pollutants/metrics modelled	Max 1-hour mean NO_2 Max 8-hour mean CO Max 24-hour mean PM_{10} Max 24-hour mean $PM_{2.5}$ Criteria: DECCW.
Approach	A cumulative impact assessment has been undertaken to determine the combined effect of the project with other proposed activities within the region.
Scenarios	2021 no M2 upgrade 2021 with M2 upgrade
Traffic data	The Transurban Sydney Strategic Traffic Model (TUSTM)
Background air quality	CSIRO Lindfield Laboratories at West Lindfield, approximately 1.5 kilometres southeast of the intersection of Lane Cove Road and the M2 Motorway. For PM10 and PM2.5, data from other locations in Sydney has been assessed (Liverpool and Lucas Heights, and Magdala Park in North Ryde).
Emission factors	Provided by DECCW for light and heavy vehicles assume no improvement in vehicle exhaust standards to the assessment year of 2021.
Met/dispersion model(s)	TAPM, CAL3QHCR
Receptors	65 receptors including residential, commercial, institutional and recreational receptors locations along the length of the M2 Motorway.
Model validation	Not specified.
Construction assessment	Construction qualitatively assessed.
Notes	Air quality within the tunnel and associated with emission from the tunnel openings has been assessed. Modelled a 'do nothing' and 'upgrade' scenario.
Reference	Heggies (2009)

Table D-17 M80 Upgrade

Project (type of assessment)	M80 Upgrade Project. VIC
Project description	Widening the existing M80 freeway
Pollutants/metrics modelled	* NO_2 * PM_{10} Criteria from EPA’s State Environment Protection Policy – Air Quality Management Intervention Levels.
Approach	VicRoads Screening Tool detailed in the “Technical Guidelines for Assessing the Air Quality Impacts of Road Developments” was used for the assessment of the impacts of the M80 Upgrade Project.
Scenarios	Modelled existing traffic volumes (2008) and estimated traffic volumes in 2021
Traffic data	Traffic volumes supplied by VicRoads
Background air quality	Measured NO_2 and PM_{10} concentrations at Footscray and Alphington for the years 2002 to 2007.
Emission factors	VicRoads Screening Tool detailed in the “Technical Guidelines for Assessing the Air Quality Impacts of Road Developments” was used for the assessment.
Met/dispersion model(s)	VicRoads Screening Tool
Receptors	17 residences located < 100 m to the M80
Model validation	Not specified.
Construction assessment	Not specified.
Reference	Bassett Consulting Engineers (2009)

Table D-18 Pacific Highway Upgrade, Tintenbar to Ewingsdale

Project (type of assessment)	The Project involves the construction and operation of approximately 17 km of dual carriageway including twin 430 m long tunnels, commencing from the northern section of the Ballina Bypass, through to Ewingsdale Road
Project description	Upgrade of the Pacific Highway from Tintenbar to Ewingsdale.
Pollutants/metrics modelled	Max 1-hour mean CO Max 1-hour mean NO_2 Max 1-hour mean PM_{10} Criteria: DECC, NEPM, EPA.
Approach	Use of a dispersion model that simulates worst case meteorology.
Scenarios	With Project 2012 Without project 2012 With Project 2022
Traffic data	Traffic data supplied by Arup for 2012 and 2022; traffic counts south of Ivy Lane, south of Bangalow and north of Bangalow Road; Light and heavy vehicle traffic volumes by hour of day
Background air quality	Monitoring data have been collected by the RTA at the Pacific Highway near Coffs Harbour.
Emission factors	PIARC. Assessment is based on emission rates assuming that the roadway is flat. No potential future improvements in vehicle technology or fuel standards have been included in the PIARC emission estimates which will result in some overestimation of emission rates for future years. Assumed reductions in the proportion of older vehicles in the fleet has simulated some improvement to vehicle emissions in future years.
Met/dispersion model(s)	CALINE 4
Receptors	A total of 18 receptors, whereby at 3 locations, air quality was assessed at kerb, and 10, 20, 30, 50, and 100 m away from road.
Model validation	Not specified
Construction assessment	Construction qualitatively assessed.
Notes	Pollutant emissions have been estimated for each tunnel ventilation outlet and for all surface roads.
Reference	Holmes Air Sciences (2008c)

Table D-19 Foxground and Berry Bypass, NSW

Project (type of assessment)	Foxground and Berry Bypass. NSW
Project description	Upgrade of 11.6 km of the Princes Highway between Toolijooa Road north of Foxground and Schofields Lane south of Berry, to achieve a four lane divided highway (two lanes in each direction) with median separation. The project includes bypasses of Foxground and Berry.
Pollutants/metrics modelled	Max 1-hour CO Max 8-hour CO Max 1-hour NO_2 Annual average NO_2 Max 24-hour average PM_{10} Annual average PM_{10} AQ criteria from WHO, NEPC and EPA.
Scenarios	For 2017, and 2037: Do Nothing Do Minimum
Traffic data	- Average speed by road type sourced from the Traffic and Transport Assessment Technical Paper (AECOM,2012) - Average Annual Daily Traffic (AADT) and VKT, for light and heavy vehicles, were sourced from the Traffic and Transport Assessment Technical Paper (AECOM, 2012). - Rate of fuel consumption calculated for each road type within the traffic impact footprint using the basic fuel-speed formula (Equation 1 in Austroads Guide to Project Evaluation Part 4: Project Evaluation Data part 6).
Background air quality	1997-2005 data: Croom Road in Albion Park, 2005-2007 data: Terry Reserve in Albion Park South
Emission factors	Vehicle emissions data from PIARC were adjusted to reflect NSW fleet. No future improvements in vehicle technology or fuel standards have been included in the emission estimates.
Met/dispersion model(s)	CAL3QHCR
Receptors	69 receptors
Model validation	Williams et. al. (1994)
Construction assessment	Construction semi-qualitatively assessed (emissions estimated but not modelling).
Reference	PAEHolmes (2012)

Table D-20 Pacific Highway Upgrade, Woolgoolga to Ballina

Project (type of assessment)	Pacific Highway Upgrade, Woolgoolga to Ballina. NSW
Project description	The Woolgoolga to Ballina upgrade would involve upgrading ~155 km of highway. Starting from the southern end, the project would ‘tie in’ to the northern extent of the Sapphire to Woolgoolga upgrade (about five kilometres north of Woolgoolga), which is currently being constructed. At its northern end, the project would tie in to the southern extent of the recently opened Ballina bypass.
Pollutants/metrics modelled	Max 1-hour CO Max 8-hour CO Max 1-hour NO_2 Annual average NO_2 Max 24-hour average PM_{10} Annual average PM_{10}
Approach	Assessment of greenhouse gas emissions as part of the Transport Authorities Greenhouse Group, 2011.
Scenarios	2016, and 2026 with and without the project.
Traffic data	Average daily traffic on the Pacific Highway at the time of monitoring was around 19,700 vehicles (RTA, 2004).
Background air quality	Roads and Maritime monitored air quality at a site adjacent to the Pacific Highway at Korora between Korora Public School and the Korora Rural Fire Brigade, north of Coffs Harbour.
Emission factors	Emissions associated with traffic from the project have been calculated using the Road and Maritime Services Tool for Roadside Air Quality (TRAQ).
Met/dispersion model(s)	TRAQ
Receptors	11 sections of the Pacific Highway.
Model validation	Not specified
Construction assessment	Construction qualitatively assessed.
Notes	Various scenarios were considered, in terms of the project’s intended year of opening (2016), 10 years after opening, and with and without the project.
Reference	NSW Roads and Maritime Services (2012)

Annexure E - Description and evaluation of NSW EPA emission model

E.1 Overview

A spatial emissions inventory was developed for the road traffic sources in the WestConnex 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 (2012). This part of the work is described in Annexure L 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). This part of the work is described in this Annexure.

A description of the NSW EPA model, and an evaluation of its performance, is provided in the following sections.

E.2 NSW EPA model

E.2.1 Hot running exhaust emissions

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

- Six pollutants (CO, NO_X, NO_2, PM_{10}, $PM_{2.5}$, THC)[2].
- Nine vehicle types: petrol passenger vehicles, diesel passenger vehicles, light-duty commercial petrol vehicles (<=3,500 kg), light-duty commercial diesel vehicles (<=3,500 kg), heavy-duty commercial petrol vehicles (>3,500 kg), rigid trucks (3.5-25 t, diesel), articulated trucks (> 25 t, diesel), heavy public transport buses (diesel only), and motorcycles. The composite emission factor for each vehicle type took into account 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 GMR emissions inventory have been mapped to Roads and Maritime functional classes by NSW EPA (Table E-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.

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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 Roads and Maritime air quality screening model TRAQ.

[2] It is assumed that $PM_{2.5}$ is equivalent to PM_{10}, which is appropriate for exhaust emissions.

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 australia, the ‘without Euro VI’ emission factors were used in he assessment.

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

NSW GMR inventory road type	Roads and Maritime 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 50-70 kilometres per hour, 1-2 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 60-80 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 70-90 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 (i.e. no direct property access). Speed limit 80-110 kilometres per hour, predominantly 2+ 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 E2

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

Where:

$\mathbf{EF_{HotSpd}}$ is the composite emission factor (in g/km) for the defined speed

$\mathbf{EF_{HotBasSpd}}$ is the composite emission factor (in g/km) 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 6th 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 E-1 shows how NO_X emissions (per vehicle-km) 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 E-2 shows how emissions (again, per vehicle-km) of different pollutants from petrol cars will decrease in the future as emission-control technology improves. 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.

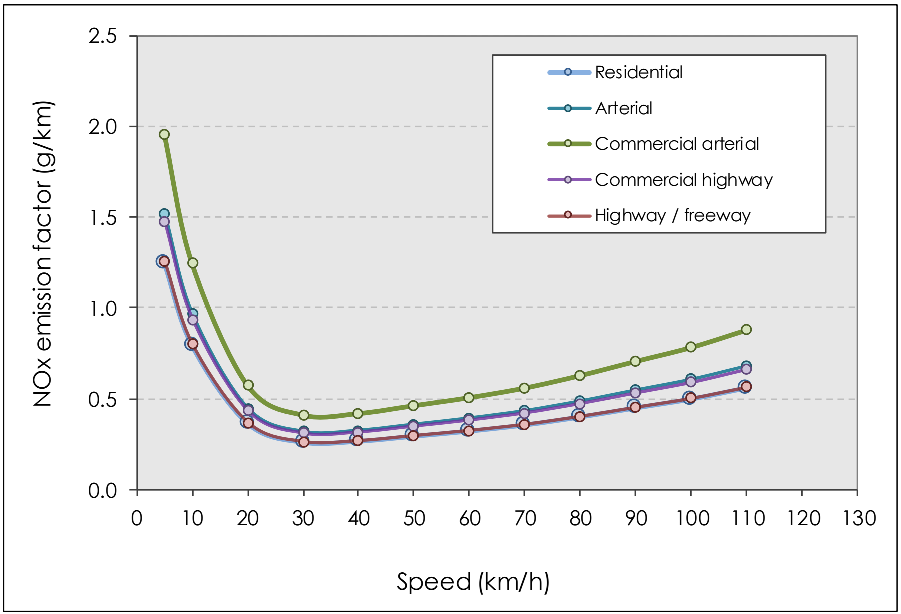

Figure E-1 NO_X emission factors for petrol cars in 2014

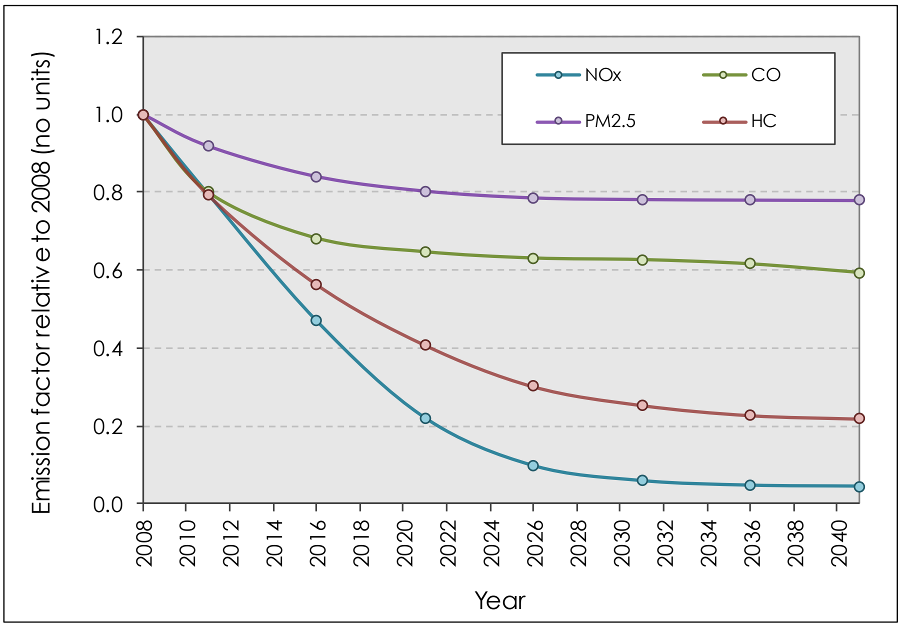

Figure E-2 Emission factors for petrol cars at 80 kilometres per hour, normalised to 2008

[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.

E.2.2 Gradient factors

Correction factors were applied to allow for the effects of road gradient on hot running emissions.

NSW EPA did not develop gradient correction factors for the GMR inventory. Some factors were determined separately by Sinclair Knight Merz (SKM) for use in the TRAQ model. However, the gradient factors for TRAQ were taken from the (now superseded) version of the PIARC tunnel ventilation guidance from 2004, and therefore revised factors were determined for the M4-M5 Link assessment using the emission rates in the PIARC guidance from 2012. 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 E3

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

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.

E.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 E4

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

Where:

EF_{Cold} is the cold-start emission factor (in g/km)

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

E.2.4 Primary NO_2 emissions

No primary NO_2 emission factors were available for Australian vehicles. Primary NO_2 emissions were therefore determined by NSW EPA using the f-NO_2 values for the various vehicle types and emission standards that have recently been developed for the EMEP/EEA Air Pollutant Emission Inventory Guidebook and the COPERT 4 model (Pastramas et al., 2014).

E.2.5 Non-exhaust PM emissions

The method for non-exhaust PM_{10} and $PM_{2.5}$ emissions was drawn from the EMEP/EEA Air Pollutant Emission Inventory Guidebook (EEA, 2013), and included tyre wear, brake wear and road surface wear. Emission factors (in g/km) 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).

E.2.6 Evaporative emissions

Evaporative emissions of 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 link 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 model and the M4-M5 Link 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.

E.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 LCVs. This was also assumed to be the same for all road types.
- The sub-division of HDVs into rigid 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, and these splits were used in the assessments for the M4 East and New M5 projects. More recently, Roads and Maritime has provided a revised fleet model to support the calculation of in-tunnel emissions for the M4-M5 Link project (O’Kelly, 2016).

The fuel splits for cars and LCVs from the Roads and Maritime work were used by Pacific Environment to update the fleet data provided by NSW EPA. Figure E-3 and Figure E-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 Roads and Maritime is very similar to that estimated by NSW EPA. Between 2027 and 2036 the projections diverge, with the diesel percentage in the Roads and Maritime fleet model being higher than that in the NSW EPA fleet model. In the case of LCVs, the Roads and Maritime fleet model has a consistently larger percentage of diesel vehicles than the NSW EPA model between 2012 and 2036. The difference also increases with time, from around 10 percentage points in 2012 to around 30 percentage points in 2036.

The Roads and Maritime 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 E-5.

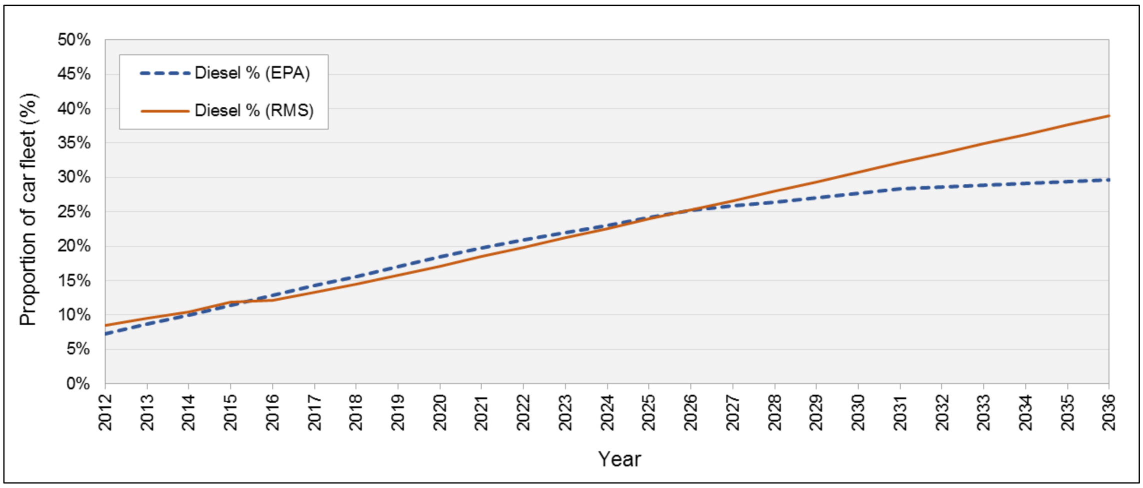

Figure E-3 **Fuel split for cars: comparison between original NSW EPA data and Roads and Maritime data**

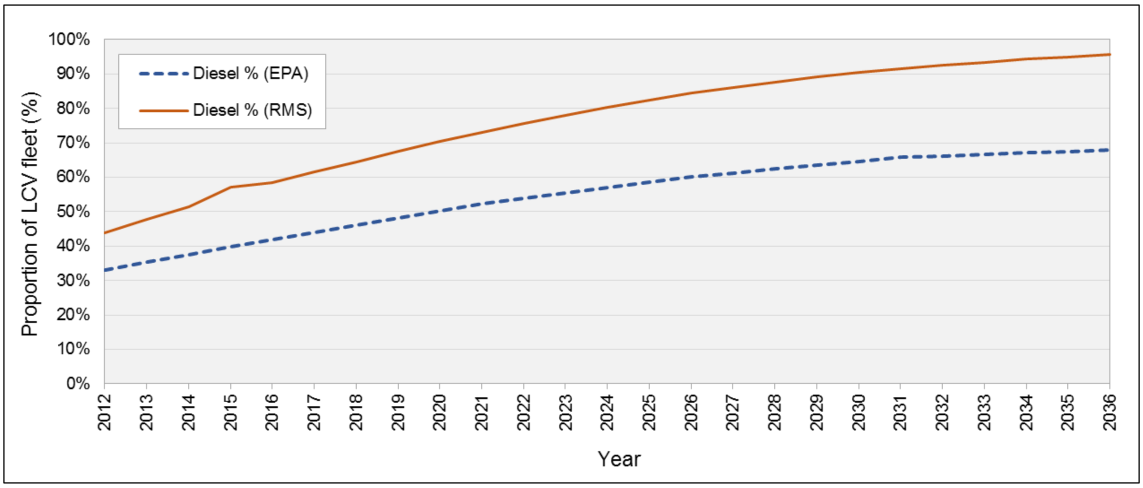

Figure E-4 **Fuel split for LCVs: comparison between original NSW EPA data and Roads and Maritime data**

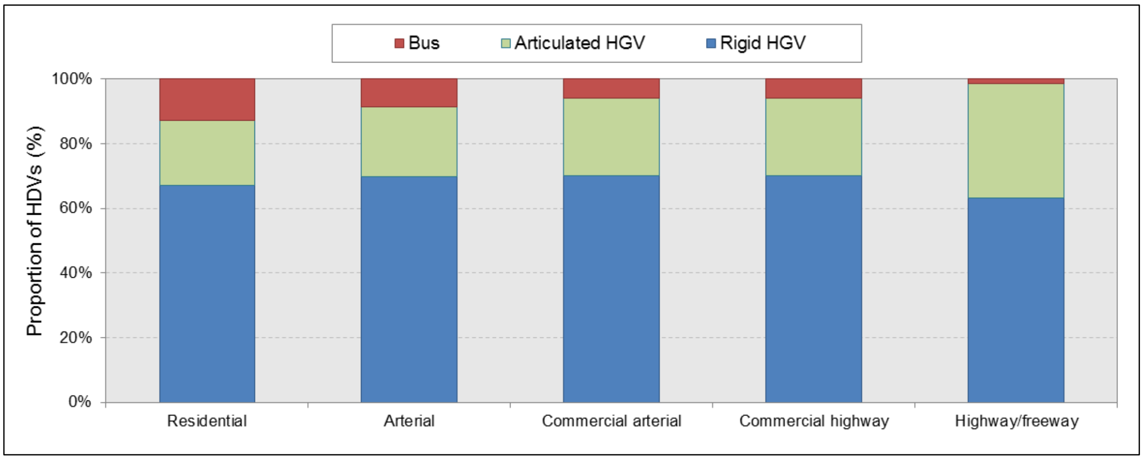

Figure E-5 **Vehicle type split by road type for HDVs (year = 2026)**

E.4 Model summary

The algorithms in the NSW EPA model were converted into a spreadsheet tool which could be readily used for air quality assessments of road projects, including the processing of data from the WestConnex Road Traffic Model. The content of the NSW EPA model is summarised in Table E-2.

Table E-2 Summary of NSW EPA model

Parameter		Model content
Years		2008-2041
Emission processes	Hot exhaust	✓
	Cold-start	✓
	Evaporative	✗
	Non-exhaust	✓(a)
Pollutants included	CO	✓
	NO_X	✓
	NO_2	✓
	PM_{10}	✓
	$PM_{2.5}$	✓
	THC/VOC	✓
	CO_2 (exhaust)	✓
	$CO_{2\text{-}e}$	✓
Vehicle categories	Petrol car	✓
	Diesel car	✓
	Petrol LCV	✓
	Diesel LCV	✓
	Petrol HGV	✓
	Rigid HGV	✓(b)
	Articulated HGV	✓(b)
	Bus	✓(b)
	Motorcycle	✓
Effects on emissions	Road type	✓
	Average speed	✓
	Road gradient	✓(c)
Fuel splits for each year	Cars: petrol/diesel	✓
	LCVs: petrol/diesel	✓
Limitation of HGV speed to 100 km/h		✓
Interpolation of emission factors for actual speed and road gradient		✓
Calculations for any time period		✓
Unlimited road links		✓
Output units	Avg. g/vehicle-km	✓
	g/h from traffic	✓
	g/km/h from traffic	✓

a) Based on full implementation of the method for non-exhaust PM in EEA (2013).
b) Results available with and without ADR80/04 (Euro VI) for HDVs.
c) Using gradient scaling factors from PIARC (2012).

E.5 Model validation

E.5.1 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 by Boulter and Manansala (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 E-6. Laboratory-grade instruments compliant with Australian Standards were used for measuring in-stack concentrations, and these are summarised in Table E-3. The air flows in the stacks were measured using pitot tubes; to minimise artefacts, the measurements were taken at a point approximately 2 metres from the stack walls.

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

Table E-3 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/m^3 / 0.06 µg/m^3
$PM_{2.5}$	TEOM	Thermo Scientific TEOM 1400ab	0-5 g/m^3 / 0.06 µg/m^3
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 Roads and Maritime fleet model revision in 2016.

The predicted and observed total (i.e. for all traffic) emission rates in the Lane Cove Tunnel were compared using a linear regression approach. The regression plots are shown in Figure E-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 E-4.

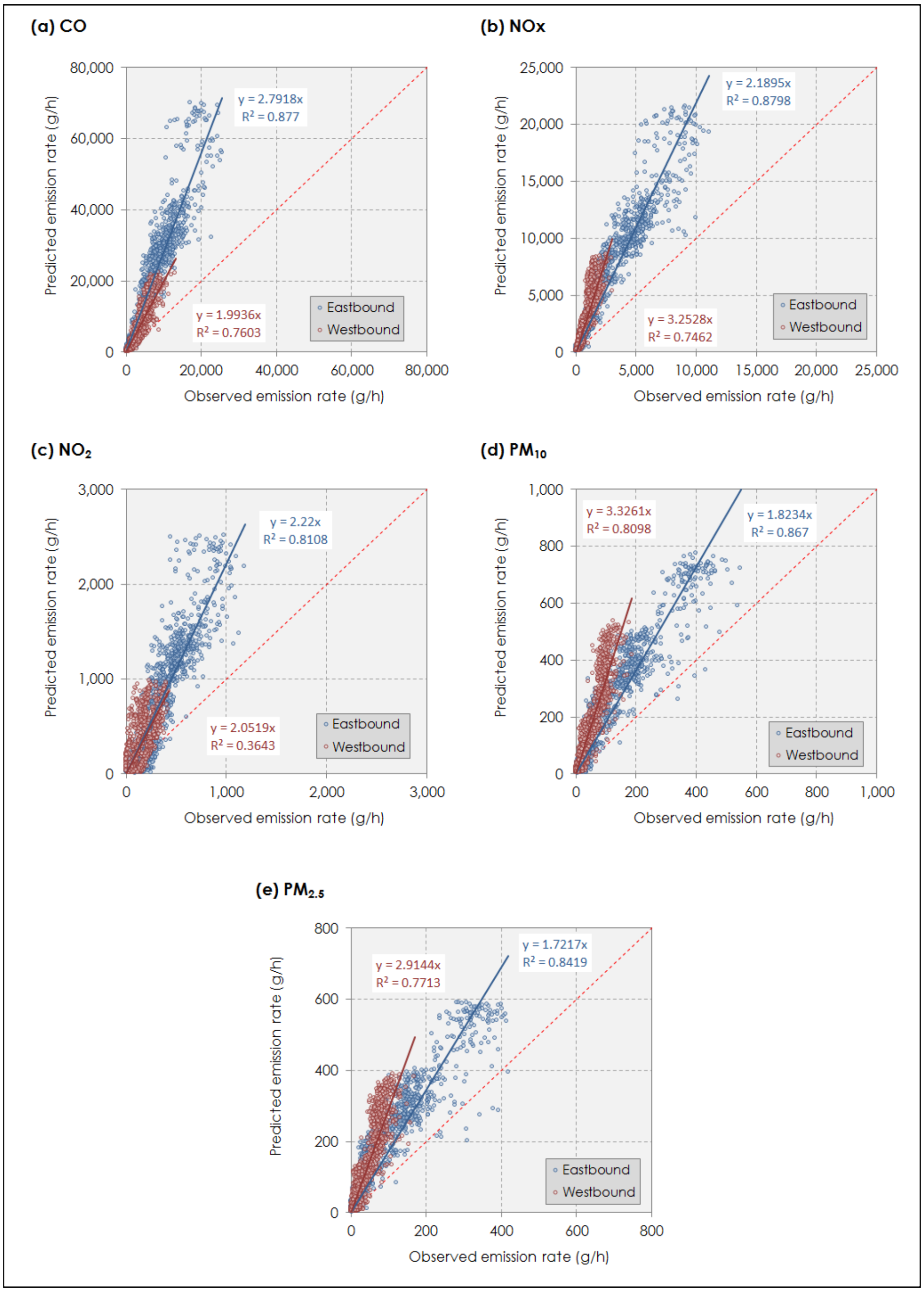

Figure E-7 Predicted vs observed emission rates – NSW EPA model

[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.

Table E-4 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

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).

  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 (*i.e.* traffic composition, speed) in the Lane Cove Tunnel. In fact, the modelled emission rates were more or less directly proportional to the traffic volume. The variability in the regression plots was therefore linked to the variability of the measurements in the ventilation outlets with 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.

E.5.2 Emission factors by vehicle type

A multiple linear regression (MLR) approach was used to determine mean emission factors (in g/km) 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 E5

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

where:

EF_{total} = the hourly mean emission factor for all traffic in the tunnel, as determined from the tunnel ventilation outlet measurements (g/km/h)

N_{LDV} = the number of LDVs in the tunnel per hour (vehicles/hour)

N_{HDV} = the number of HDVs in the tunnel per hour (vehicles/hour)

EF_{LDV} = the emission factor per LDV in the tunnel (g/vehicle.km)

EF_{HDV} = the emission factor per HDV in the tunnel (g/vehicle.km)

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 km), with the on- and off-ramps being ignored. The emissions on the ramps were negligible (less than around 2 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 E-5, and the predicted/observed ratios are given in Table E-6.

It has already been observed that the NSW EPA model overestimated emissions in the Lane Cove Tunnel. It was noted by Boulter and Manansala (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 E-5 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 E-6 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.

E.6 Primary NO_2 emissions

Inside a road tunnel most of the NO_2 in the air is primary in origin; it is emitted directly from vehicle exhaust pipes rather than being formed in the tunnel atmosphere. Although it is possible that certain reactions could lead to the formation of NO_2 in longer tunnels, the NO_2/NO_X proportion in the air from the ventilation outlets of most tunnels ought to provide a reliable indication of the overall average NO_2/NO_X proportion in vehicle exhaust (Boulter et al., 2007). The measurements from the Lane Cove Tunnel ventilation outlets provided useful information on primary NO_2 emissions from the vehicles in the tunnel, and the observed values of *f*-NO_2 calculated from the MLR analysis are given in Table E-7. Clearly, given the uncertainty in the absolute emission estimates and the general model overprediction, these primary NO_2 estimates are also rather uncertain.

The average measured values of *f*-NO_2 for all vehicles were 13 per cent in the eastbound tunnel and 17 per cent in the westbound tunnel. The models were broadly in agreement with the measurements on average, giving a value of around 12 per cent (the same method for calculating NO_2 was used in both models). However, the models did not reproduce the observed difference in *f*-NO_2 between LDVs and HDVs. For the former, *f*-NO_2 was underestimated, whereas for the latter it was overestimated.

Table E-7 Primary NO_2 values

Vehicle type	Model	Eastbound			Westbound		
		NO_X (g/vkm)	NO_2 (g/vkm)	*f*-NO_2	NO_X (g/vkm)	NO_2 (g/vkm)	*f*-NO_2
LDV	Observed	0.29	0.06	**19%**	0.13	0.03	**19%**
	NSW EPA	1.18	0.14	**12%**	0.51	0.06	**11%**
HDV	Observed	8.42	0.37	**4%**	1.07	0.03	**3%**
	NSW EPA	6.93	0.85	**12%**	2.78	0.34	**12%**
All Vehicles(a)	Observed	0.61	0.08	**13%**	0.18	0.03	**17%**
	NSW EPA	1.39	0.16	**12%**	0.60	0.07	**11%**

(a) Weighted for traffic volume.

A recent update of the evidence for vehicles on the road in Sydney was provided by Boulter and Bennett (2015). Although a range of different data sets and methods were used, the level of agreement in both the *f*-NO_2 values and the trend was found to be good. The evidence suggested that there has been a gradual increase in *f*-NO_2 in recent years for highways, from less than 10 per cent before 2008 to around 15 per cent in 2014. It was also concluded that the approach of incorporating the European values for *f*-NO_2 in models for Sydney produced a satisfactory agreement with measurements.

Annexure F - Existing air quality and background concentrations

F.1 Introduction

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).

This Annexure provides the results of a thorough analysis of the air quality monitoring data that were available for the WestConnex study area. The analysis was based mainly on measurements conducted during the 12-year period between 2004 and 2015, the principal aim being to establish background pollutant concentrations for use in the M4-M5 Link assessment, taking into account factors such as those identified above. The analysis dealt with temporal and spatial patterns in the data, and contributed to the general understanding of air quality in Sydney.

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 site. As this is extremely rare, data is typically obtained from a monitoring site as close as possible to the proposed location where the sources of air pollution resemble the existing sources at the proposal site.' (NSW EPA, 2016)

Background concentrations 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

Background concentrations of 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 G).

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.

The approaches described here for establishing background concentrations, and combining these with model predictions, were very similar to those developed to support the EISs for the WestConnex M4 East and New M5 projects (Boulter et al., 2015; Manansala et al., 2015).

F.2 Monitoring sites

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 sites as follows based on functional requirements:

- Peak sites. These are located where the highest concentrations and exposures are expected to occur (such as near busy roads or industrial sources).
- Neighbourhood sites. These are located in areas which have a broadly uniform land use and activity (e.g. residential areas or commercial zones).
- Background sites. These sites 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 site 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.

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. To support the M4-M5 Link assessment, data were obtained for the monitoring sites and periods listed in Table F-1. The locations of these sites are shown in Figure F-1, along with the modelling domain for GRAL.

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 sites in Sydney that are operated by OEH are located in such environments, and these have provided a long and vital record of regional air quality. The closest active OEH monitoring sites to the M4-M5 Link project are those at Chullora, Earlwood, Randwick and Rozelle. These sites are between around two and eight kilometres from the above-surface components of the project. The OEH sites at Lindfield, Liverpool and Prospect are further away (between around 10 and 25 kilometres) from the project, but were still considered to be important in terms of characterising air quality in the wider Sydney region.

Roads and Maritime Services 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 Roads and Maritime sites (CBMS, T1, U1, X1) are in the vicinity of the ventilation outlet. Sites 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 sites are very small in practice, and these could effectively be considered as urban background sites. Two Roads and Maritime sites (F1 and M1) are much closer to busy roads near the M5 East tunnel portals.

Consideration was also given to shorter-term data from other Roads and Maritime air quality monitoring stations. Several monitoring sites were established for the NorthConnex project (AECOM, 2014a), with data being available from December 2013 to January 2015. Data were also available from an additional Roads and Maritime roadside site ('Aristocrat'), located near the junction of Epping Road and Longueville Road. The Aristocrat site was only operational between 2008 and 2009, but given the low number of roadside monitoring sites in Sydney the data were still considered to be valuable to the analysis.

Sydney Motorway Corporation (SMC) has established a WestConnex monitoring network to address some of the gaps in the OEH and Roads and Maritime monitoring in terms of pollutants and locations, and SMC has engaged Pacific Environment to operate and maintain the network. The WestConnex network includes monitoring stations at both urban background and near-road sites. Five new monitoring stations were introduced in the M4 East area, seven new stations in the New M5 area, and two new stations in the M4-M5 Link area to support the development and assessment of the respective projects. Some of the M4 East and New M5 monitoring stations were subsequently relocated or decommissioned. The M4-M5 Link monitoring stations became operational in April 2016, and therefore the time period covered was too short for them to be included in the development of background concentrations for the assessment. However, the data collected for all the WestConnex monitoring stations to February 2017 are summarised at the end of this Annexure.

Table F-1 Air quality monitoring sites used in the assessment

Organisation	Project	Site name	Location	Site type	Easting	Northing	Period covered in analysis	Status as of September 2016
OEH	N/A	Chullora	Southern Sydney TAFE - Worth St	Urban background	319315	6248145	Jan 2004 to Jun 2016	Operational
		Earlwood	Beaman Park	Urban background	327663	6245576	Jan 2004 to Jun 2016	Operational
		Lindfield	Bradfield Road	Urban background	328802	6260577	Jan 2004 to Jun 2016	Operational
		Liverpool	Rose Street	Urban background	306573	6243485	Jan 2004 to Jun 2016	Operational
		Prospect	William Lawson Park	Urban background	306901	6258703	Jan 2004 to Jun 2016	Operational
		Randwick	Randwick Barracks	Urban background	337588	6244021	Jan 2004 to Jun 2016	Operational
		Rozelle	Rozelle Hospital	Urban background	330169	6251372	Jan 2004 to Jun 2016	Operational
RMS	M5 East tunnel	M5E: CBMS	Gipps Street, Bardwell Valley	Urban background	327713	6243517	Jan 2008 to Jun 2016	Operational
		M5E: T1	Thompson Street, Turrella	Urban background	328820	6244172	Jan 2008 to Jun 2016	Operational
		M5E: U1	Jackson Place, Earlwood	Urban background	328277	6244422	Jan 2008 to Jun 2016	Operational
		M5E: X1	Wavell Parade, Earlwood	Urban background	327923	6244507	Jan 2008 to Jun 2016	Operational
		M5E: F1	Flat Rock Rd, Kingsgrove (M5 East F'way)	Peak (roadside)	325204	6243339	Jan 2008 to Jun 2016	Operational
		M5E: M1	M5 East tunnel portal	Peak (roadside)	329258	6243283	Jan 2008 to Jun 2016	Operational
	NorthConnex	NC-01	Headen Sports Park	Urban background	322016	6266696	Dec 2013 to Jan 2015	Decommissioned (Feb 2015)
		NC-02	Rainbow Farm Reserve	Urban background	318901	6262641	Dec 2013 to Jan 2015	Decommissioned (Feb 2015)
		NC-03	James Park	Urban background	325165	6269440	Dec 2013 to Jan 2015	Decommissioned (Feb 2015)
		NC-04	Observatory Park	Peak (roadside)	320643	6264950	Dec 2013 to Jan 2015	Decommissioned (Feb 2015)
		NC-05	Brickpit Park	Peak (roadside)	323027	6266847	Dec 2013 to Jan 2015	Decommissioned (Feb 2015)
	Lane Cove Tunnel	Aristocrat	Longueville Road / Epping Road	Peak (roadside)	330661	6257118	Oct 2008 to Nov 2009	Decommissioned 2009
SMC	WestConnex M4 East	M4E: 01	Wattle Street, Haberfield	Peak (roadside)	327563	6250234	Aug 2014 to Mar 2016	Relocated to M4-M5 Link (Mar 2016)
		M4E: 02	Edward Street, Concord	Peak (near-road)[(a)]	323764	6251146	Sep 2014 to Mar 2016	Relocated to M4-M5 Link (Mar 2016)
		M4E: 03	Bill Boyce Reserve, Homebush	Peak (near-road)[(a)]	322467	6251602	Sep 2014 to Mar 2016	Decommissioned (Mar 2016)
		M4E: 04	Concord Oval, Concord	Peak (roadside)	325030	6250752	Nov 2014 to Feb 2017	Operational
		M4E: 05	St Lukes Park, Concord	Urban background	325187	6251158	Nov 2014 to Feb 2017	Operational
	WestConnex New M5	New M5: 01	St Peters Public Sch., Church St, St Peters	Urban Background	331330	6246007	Aug 2015 to Feb 2017	Operational: retained for M4-M5 Link
		New M5: 02	Princes Highway, St Peters	Peak (roadside)	331661	6246053	Jul 2015 to Feb 2016	Decommissioned (Apr 2016)
		New M5: 03	West Botany St, Arncliffe	Peak (roadside)	329182	6243268	Aug 2015 to Jun 2016	Decommissioned (Sep 2016)
		New M5: 04	Bestic St, Rockdale	Urban Background	329175	6241749	Jul 2015 to Jun 2016	Decommissioned (Sep 2016)
		New M5: 05	Bexley Rd, Kingsgrove	Peak (roadside)	325359	6243491	Jul 2015 to Feb 2016	Decommissioned (Apr 2016)
		New M5: 06	Beverly Hills Park, Beverly Hills	Urban Background	323296	6242297	Jul 2015 to Jun 2016	Decommissioned (Sep 2016)
		New M5: 07	Canal Rd, St Peters	Peak (road/industrial)	331520	6245420	Jul 2015 to Feb 2016	Decommissioned (Apr 2016)
	WestConnex M4-M5 Link	M4-M5: 01	Rozelle, City W Link	Peak (roadside)	331142	6250768	Apr 2016 to Feb 2017	Operational
		M4-M5: 02	Haberfield, Ramsay Street	Peak (roadside)	327363	6250306	Apr 2016 to Feb 2017	Operational

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

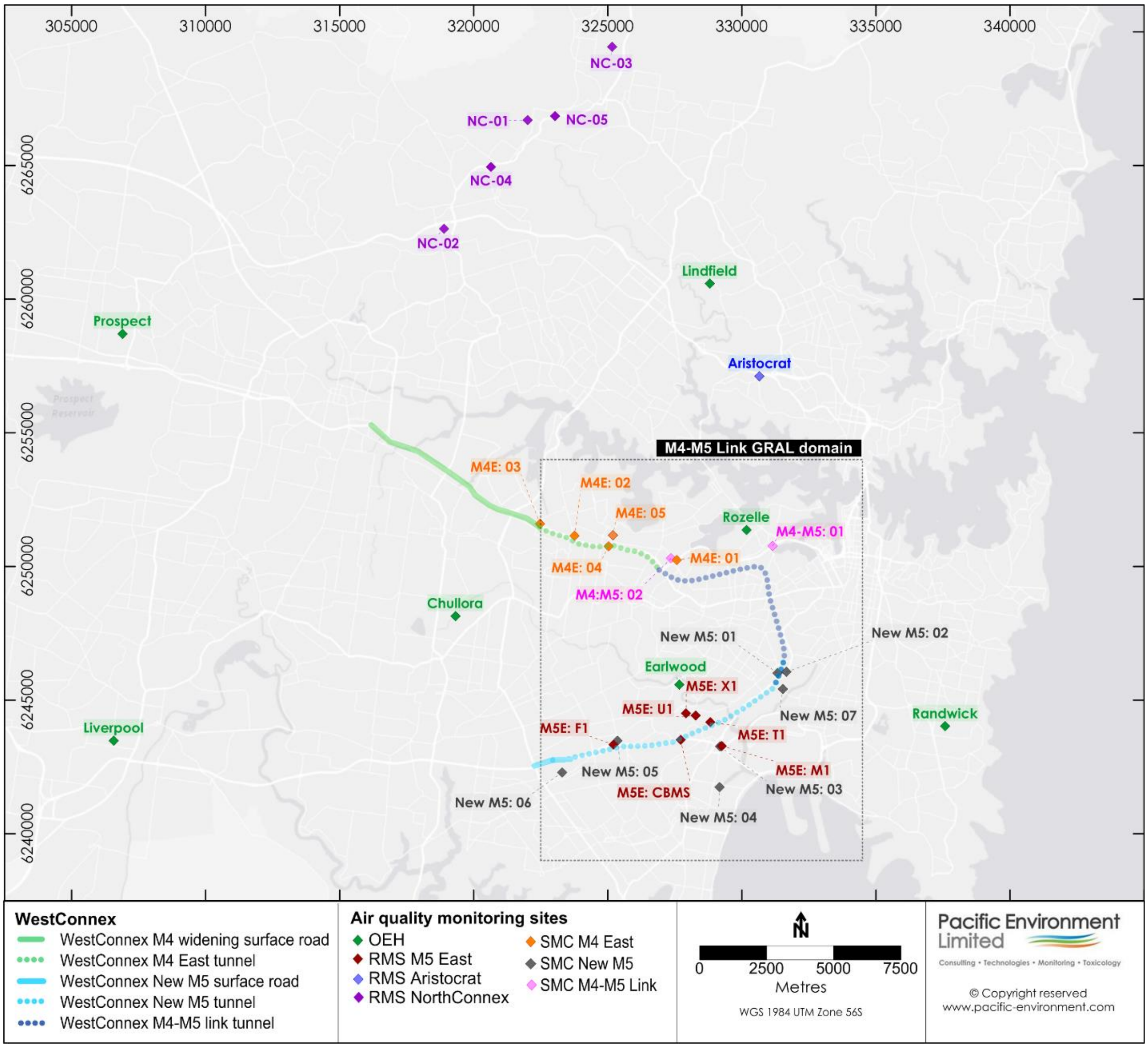

Figure F-1 **Locations of air quality monitoring sites**

For the purpose of the analysis the air quality monitoring data were separated according to site type. Given the main purpose of the work described in this Chapter (i.e. to determine background concentrations for the project assessment), the main emphasis was placed on the background monitoring sites. However, the air quality data from the monitoring sites near roads have been used for the development of empirical NO_X-to-NO_2 conversion methods (Annexure G) and/or dispersion model evaluation (see Annexure J). For convenience, all the monitoring sites which have been considered or used in the assessment in some way are identified in this Annexure.

F.3 Measured parameters and methods

The parameters measured at each site are given in Table F-2. The coverage of pollutants was variable. NO, NO_2 and NO_X were measured at all sites, and CO was measured at most sites. Ozone was measured at the OEH, SMC and Roads and Maritime NorthConnex sites, but not at the Roads and Maritime M5 East and Aristocrat sites. PM_{10} was measured at all sites but one[1]. $PM_{2.5}$ was measured at fewer sites, and there was only a longer-term record of $PM_{2.5}$ at three OEH sites.

[1] PM_{10} was actually monitored at the Aristocrat site, but the record was relatively short and incomplete.

Although not shown in Table F-2, hydrocarbons[2] are measured continuously at the SMC sites. Hydrocarbons are not measured routinely at the OEH and Roads and Maritime sites.

Table F-2 Parameters by monitoring station (roadside sites are shown by shading)

Monitoring station		Pollutants: CO	Pollutants: NO, NO_2, NO_X	Pollutants: O_3	Pollutants: PM_{10} (a)	Pollutants: $PM_{2.5}$ (a)	Meteorological parameters: WS, WD (b)	Meteorological parameters: Temp.	Meteorological parameters: Humidity	Meteorological parameters: Solar radiation
OEH	Chullora	✓	✓	✓	✓†	✓§	✓	✓	✓	✓
	Earlwood	-	✓	✓	✓†	✓§	✓	✓	✓	-
	Lindfield	-	✓	✓	✓†	-	✓	✓	✓	-
	Liverpool	✓	✓	✓	✓†	✓§	✓	✓	✓	✓
	Prospect	✓	✓	✓	✓†	✓‡	✓	✓	✓	✓
	Randwick	-	✓	✓	✓†	-	✓	✓	✓	-
	Rozelle	✓	✓	✓	✓†	✓‡	✓	✓	✓	✓
RMS	M5E: CBMS	✓	✓	-	✓†	-	✓	✓	✓	✓
	M5E: T1	✓	✓	-	✓†	-	✓	✓	✓	✓
	M5E: U1	✓	✓	-	✓†	-	✓	✓	✓	✓
	M5E: X1	✓	✓	-	✓†	-	✓	✓	✓	✓
	M5E: F1	✓	✓	-	✓†	-	✓	✓	✓	✓
	M5E: M1	✓	✓	-	✓†	-	✓	✓	✓	✓
	NC-01	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	NC-02	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	NC-03	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	NC-04	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	NC-05	✓	✓	✓	✓‡	✓‡	✓	✓	✓	✓
	Aristocrat	✓	✓	-	-	-	✓	✓	✓	✓
SMC	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 site 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 values obtained are sensitive to the measurement method 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 Roads and Maritime M5 East sites, whereas BAMs were used at the NorthConnex and WestConnex sites. For the measurement of $PM_{2.5}$ at the OEH sites, 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.

F.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 OEH.

All data were handled using a consistent time base 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 there was a sufficient amount of data; any given period was taken to have sufficient data where the data capture rate was greater than 75 per cent[4].

F.5 Long-term trends at background sites

In this part of the analysis the long-term trends in air pollution at background monitoring sites in Sydney were investigated. Only the OEH and Roads and Maritime monitoring sites with a multi-year record were considered, and the following aspects were examined:

- Trends in annual mean concentration.
- Trends in monthly mean concentration, to identify any seasonal patterns.
- Trends in other relevant short-term criteria specified in the NSW Approved Methods.
- Exceedances of the air quality criteria in the NSW Approved Methods.

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

[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).

F.5.1 Carbon monoxide

F.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 OEH and Roads and Maritime monitoring sites are shown in Figure F-2, and the corresponding statistics are provided in Table F-3. The Mann–Kendall nonparametric test was used to determine the statistical significance of trends at the 90 per cent confidence level.

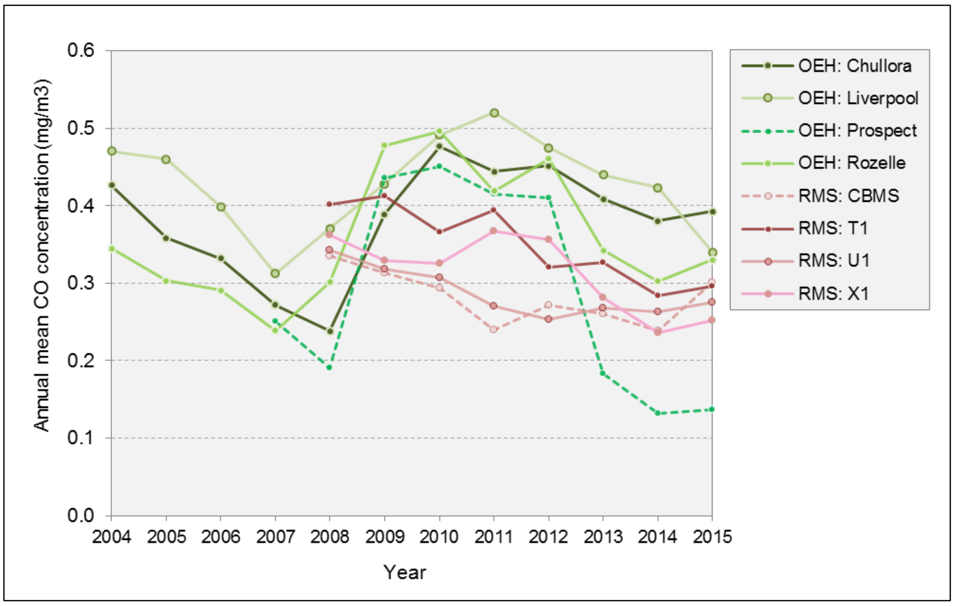

Figure F-2 **Trend in annual mean CO concentration**

Table F-3 **Annual mean CO concentration at OEH and Roads and Maritime background sites**

Year	Annual mean concentration (mg/m^3)(a)										
	OEH Chullora	OEH Earlwood	OEH Lindfield	OEH Liverpool	OEH Prospect	OEH Randwick	OEH 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
Mean (2008-15)	**0.40**	-	-	**0.44**	**0.29**	-	**0.39**	**0.28**	**0.35**	**0.29**	**0.31**
Mean (2004-15)	**0.38**	-	-	**0.43**	-	-	**0.36**	-	-	-	-
Significance(c)	◀▶	-	-	◀▶	▼	-	◀▶	▼	▼	▼	▼

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

(b) Average of year from October 2008 to September 2009.

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

At the OEH sites the annual mean concentration decreased between 2004 and the start of 2008, but then began to increase again during 2008, and continued to do so until around 2010[5]. CO concentrations then decreased again between 2010 and 2015. There was a net overall decrease of less than 10 per cent between 2004 and 2015. A different pattern was apparent in the data from the Roads and Maritime sites, where there was a more systematic downward trend in concentrations between 2008 and 2015. The Mann-Kendall test showed that there was a significant downward trend in annual mean CO concentration at the Roads and Maritime sites.

The concentrations at the Roads and Maritime background sites were within the range of values observed at the OEH sites. Although CO was not measured at Earlwood, the concentration profiles at the other OEH monitoring stations closest to WestConnex – Chullora and Rozelle were similar, and the long-term average (2008-2015) concentrations were almost the same (0.38 and 0.36 mg/m^3 respectively). By comparison, the long-term mean CO concentrations at the Roads and Maritime roadside sites (F1 and M1) were 0.53 and 0.44 mg/m^3 respectively.

F.5.1.2 Monthly mean concentration

Monthly mean concentrations provide additional data on seasonal patterns in air pollution. An example of the seasonal variation in CO concentrations at a monitoring site – in this case OEH's Chullora site - is given in Figure F-3. The Figure was produced using the 'smooth trend' function in the Openair[6] software, and the shading around the trend line gives the 95 per cent confidence intervals.

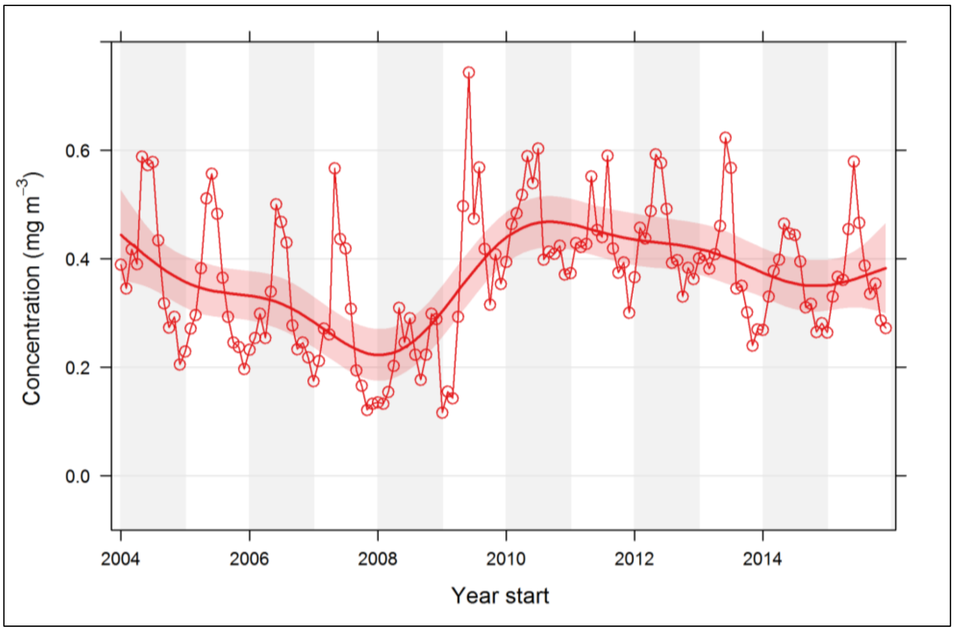

Figure F-3 Monthly mean CO concentration at OEH Chullora monitoring site

There is a strong seasonal influence on CO concentrations, with the values being much higher in winter than in summer. This is commonly observed for CO, and 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. It was desirable to ensure that such seasonal effects were represented in the assumed background concentrations for the M4-M5 Link project.

[5] This change coincided with a programme of instrument replacement.
[6] http://www.openair-project.org/Default.aspx

F.5.1.3 Maximum one-hour mean concentration

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

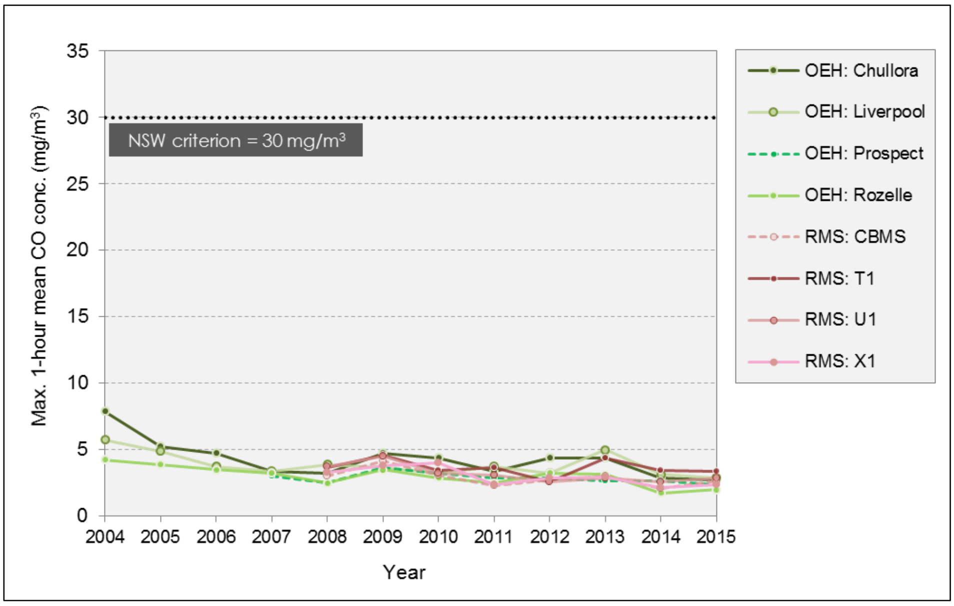

Figure F-4 Trend in maximum one-hour mean CO concentration

Table F-4 Maximum one-hour mean CO at OEH and Roads and Maritime background sites

Year	Annual mean concentration (mg/m^3)[(a)]										
	OEH Chullora	OEH Earlwood	OEH Lindfield	OEH Liverpool	OEH Prospect	OEH Randwick	OEH 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
Mean (2008-15)	**3.76**	-	-	**3.59**	**2.84**	-	**2.69**	**2.88**	**3.63**	**3.17**	**2.96**
Mean (2004-15)	**4.28**	-	-	**3.87**	-	-	**3.03**	-	-	-	-
Significance[(c)]	▼	-	-	▼	▼	-	▼	▼	◀▶	▼	▼

(a) Only years with >75 per cent complete data shown
(b) Average of year from October 2008 to September 2009.
(c) ▼ = significantly decreasing, ▲ = significantly increasing, ◀▶ = stable/no trend

F.5.1.4 Maximum rolling 8-hour mean concentration

The trends in the maximum rolling 8-hour mean CO concentration by year are shown in Figure F-5 and Table F-5. All maximum values were well below the air quality criterion of 10 mg/m^3; the long-term averages were between around 2 and 3 mg/m^3. By comparison, the long-term mean values at the Roads and Maritime roadside sites (F1 and M1) were 3.4 and 2.5 mg/m^3 respectively. The patterns at all background sites were broadly similar; there was a general downward trend that was statistically significant at all sites. Although there was some spatial variation in CO, it was not systematic, and the between-site variation was small compared with the criterion.

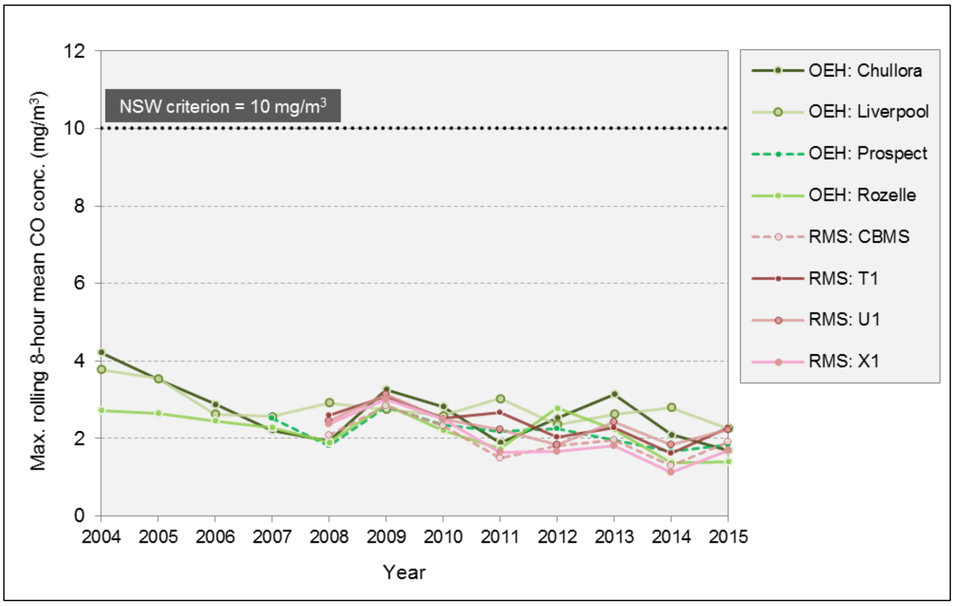

Figure F-5 **Trend in maximum rolling 8-hour mean CO concentration**

Table F-5 **Maximum rolling 8-hour mean CO at OEH and Roads and Maritime background sites**

Year	Annual mean concentration (mg/m^3)[a]										
	OEH Chullora	OEH Earlwood	OEH Lindfield	OEH Liverpool	OEH Prospect	OEH Randwick	OEH 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	-	-	2027	1.84	-	1.41	1.91	2.27	2.22	1.69
Mean (2008-15)	**2.42**	-	-	**2.67**	**2.11**	-	**2.07**	**1.97**	**2.38**	**2.33**	**1.98**
Mean (2004-15)	**2.69**	-	-	**2.82**	-	-	**2.22**	-	-	-	-
Significance[c]	▼	-	-	▼	▼	-	▼	▼	▼	▼	▼

(a) Only years with >75 per cent complete data shown
(b) Average of year from October 2008 to September 2009.
(c) ▼ = significantly decreasing, ▲ = significantly increasing, ◄► = stable/no trend

F.5.1.5 Exceedances of air quality criteria

Between 2004 and 2015 there were no exceedances of the rolling 8-hour mean criterion for CO of 10 mg/m^3, or the one-hour criterion of 30 mg/m^3, at any of the background sites.

F.6 Nitrogen oxides

F.6.1.1 Annual mean concentration

The annual mean NO_X concentrations at the monitoring sites are shown in Figure F-6, and the corresponding statistics are provided in Table F-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 G).

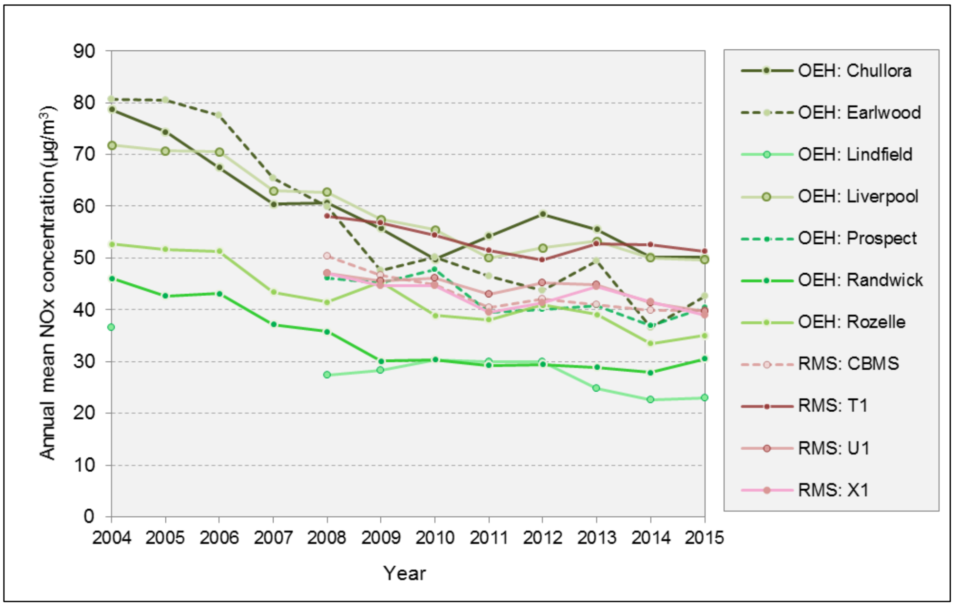

Figure F-6 Trend in annual mean NO_X concentration

Table F-6 Annual mean NO_X concentration at OEH and Roads and Maritime background sites

Year	Annual mean concentration (µg/m³)(a)										
	OEH Chullora	OEH Earlwood	OEH Lindfield	OEH Liverpool	OEH Prospect	OEH Randwick	OEH 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
Mean (2008-15)	**54.4**	**47.1**	**27.0**	**53.8**	**41.5**	**30.3**	**39.0**	**43.1**	**53.3**	**44.1**	***42.7***
Mean (2004-15)	**59.6**	**56.7**	**28.1**	**58.9**	-	**34.3**	**42.6**	-	-	-	-
Significance(c)	▼	▼	▼	▼	◀▶	▼	▼	▼	▼	▼	▼

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

(b) Average of year from October 2008 to September 2009.

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

The Roads and Maritime T1 site had a systematically higher NO_X concentration than the other Roads and Maritime sites, which all had very similar concentrations. Given that all the Roads and Maritime sites are relatively close together, the measurements at the T1 site could have been influenced by a local source. The site 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 site was not representative of background NO_X concentrations in this part of Sydney.

There was a general tendency for annual mean NO_X concentrations to decrease between 2004 and 2015. At the OEH sites concentrations typically decreased by around 35 per cent overall between 2004 and 2015, although there was a 50 per cent reduction at the Earlwood site. The Mann-Kendall test showed that the downward trend in concentrations was statistically significant at all sites except Prospect. There is, however, a suggestion of a levelling-off of concentrations in recent years.

There were some quite systematic spatial variations in the annual mean NO_X concentration when the results were considered for a consistent time period (2008-2015). For example, at the OEH Chullora, Earlwood and Liverpool sites the long-term mean concentration during this period was around 50 µg/m^3, compared with around 40 µg/m^3 at Prospect and Rozelle, and 30 µg/m^3 at Randwick and Lindfield. The long-term concentration at the Roads and Maritime T1 site was around 50 µg/m^3, with concentrations at the Roads and Maritime sites CBMS, U1 and X1 being slightly lower (around 45 µg/m^3). This spatial variation was taken into account in the derivation of background NO_X concentrations for the M4-M5 Link project.

Although not shown, the long-term mean (2008-2015) NO_X concentrations at the Roads and Maritime roadside sites (F1 and M1) were substantially higher than those at the background sites, and very similar at 105 and 105 µg/m^3 respectively. The road increment – the average roadside concentration minus the average background concentration remained relatively stable, at around 60 µg/m^3, between 2008 and 2015. This illustrates the ongoing contribution of NO_X emissions from road transport.

F.6.1.2 Monthly mean concentration

Figure F-7 provides an example of the monthly mean NO_X concentrations, in this case showing the significant downward trend at the Earlwood site. The reduction in concentrations with time can clearly be seen. As with CO there is a strong seasonal influence on NO_X concentrations, with the values being much higher in winter than in summer. This is again likely to be due to an increase in emissions from combustion sources and more frequent temperature inversions in winter. 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. As before, it was desirable to ensure that such seasonal variations were represented in the assumed background concentrations for the M4-M5 Link.

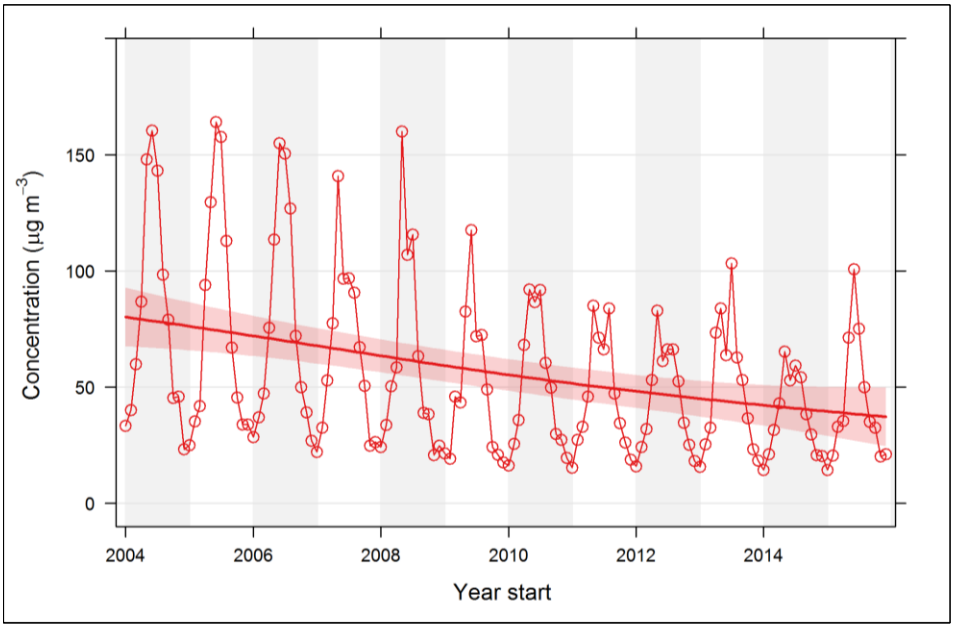

Figure F-7 Monthly mean NOx concentration at OEH Earlwood monitoring site

F.6.1.3 Maximum one-hour mean concentration

The long-term trends in the maximum one-hour mean NO_X concentration are shown in Figure F-8. 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.

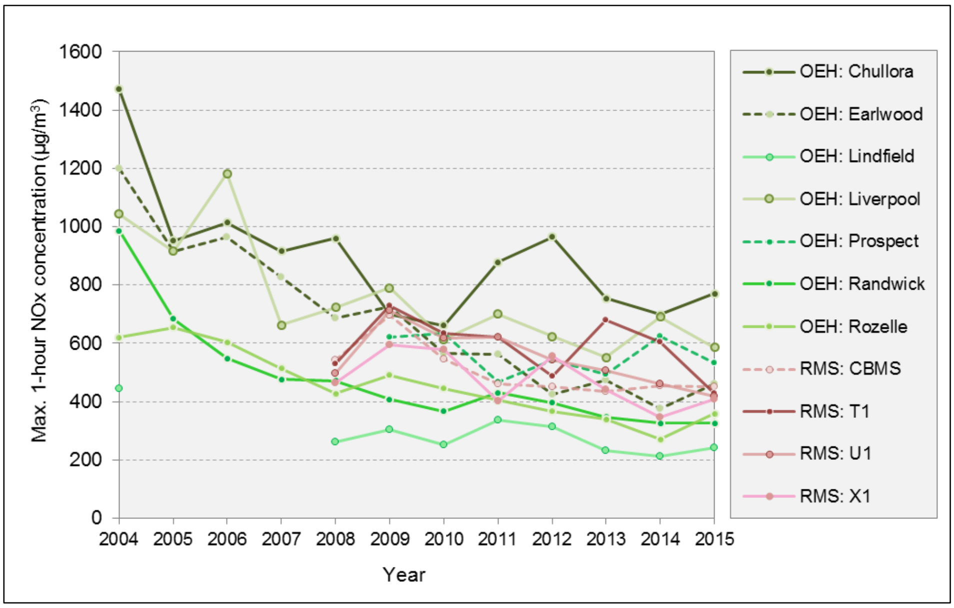

Figure F-8 Trend in maximum one-hour mean NO_X concentration

For comparison, the maximum one-hour mean NO_X concentrations at the Roads and Maritime roadside sites (F1 and M1) in 2015 were 871 and 620 μg/m^3 respectively. These values are close to the upper end of the range of values for the background sites.

F.6.2 Nitrogen dioxide

F.6.2.1 Annual mean concentration

The long-term trends in annual mean NO_2 concentrations are shown in Figure F-9, and the corresponding statistics are provided in Table F-7. The concentrations at all sites were well below the NSW air quality assessment criterion of 62 μg/m^3.

The NO_2 concentrations at the OEH sites exhibited a systematic downward trend - with a reduction of between around 20 per cent and 40 per cent between 2008 and 2015, depending on the site - and one that was statistically significant at six of the sites. However, in recent years the concentrations at some sites appear to have stabilised. At the Roads and Maritime background sites there was a significant downward trend at two sites (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 sites was not quite the same. Nevertheless, concentrations were again generally highest at the Chullora site and lowest at Lindfield and Randwick.

The long-term average NO_2 concentrations at the Roads and Maritime roadside sites (F1 and M1) were 35 and 38 μg/m^3 respectively, and therefore around 10-15 μg/m^3 higher than those at the background sites. Even so, the NO_2 concentrations at roadside were also well below the assessment criterion.

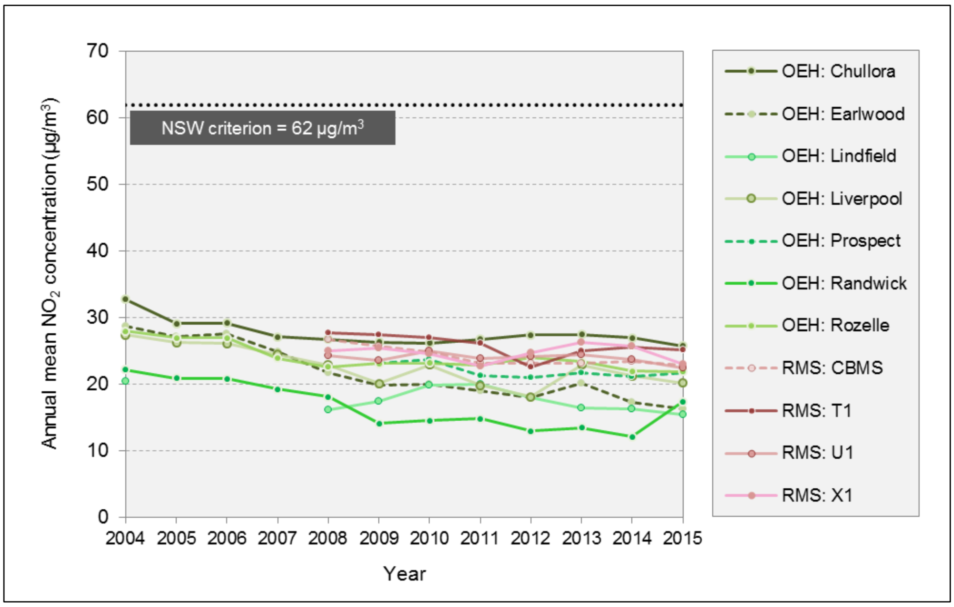

Figure F-9 Trend in annual mean NO_2 concentration

Table F-7 Annual mean NO_2 concentration at OEH and Roads and Maritime background sites

Year	Annual mean concentration (µg/m³)[(a)]										
	OEH Chullora	OEH Earlwood	OEH Lindfield	OEH Liverpool	OEH Prospect	OEH Randwick	OEH 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
Mean (2008-15)	**26.7**	**19.0**	**17.5**	**21.0**	**21.9**	**14.7**	**22.9**	**24.1**	**25.8**	**23.9**	**24.7**
Mean (2004-15)	**27.7**	**21.7**	**17.8**	**22.7**	-	**16.7**	**24.1**	-	-	-	-
Significance[(c)]	▼	▼	▼	▼	◀▶	▼	▼	▼	▼	◀▶	◀▶

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

(b) Average of year from October 2008 to September 2009.

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

F.6.2.2 Monthly mean concentration

The seasonal variation in NO_X was mirrored by that for NO_2. This is illustrated in the data for Earlwood in Figure F-10. This Figure also shows more clearly that NO_2 concentrations at this site have stabilised in recent years.

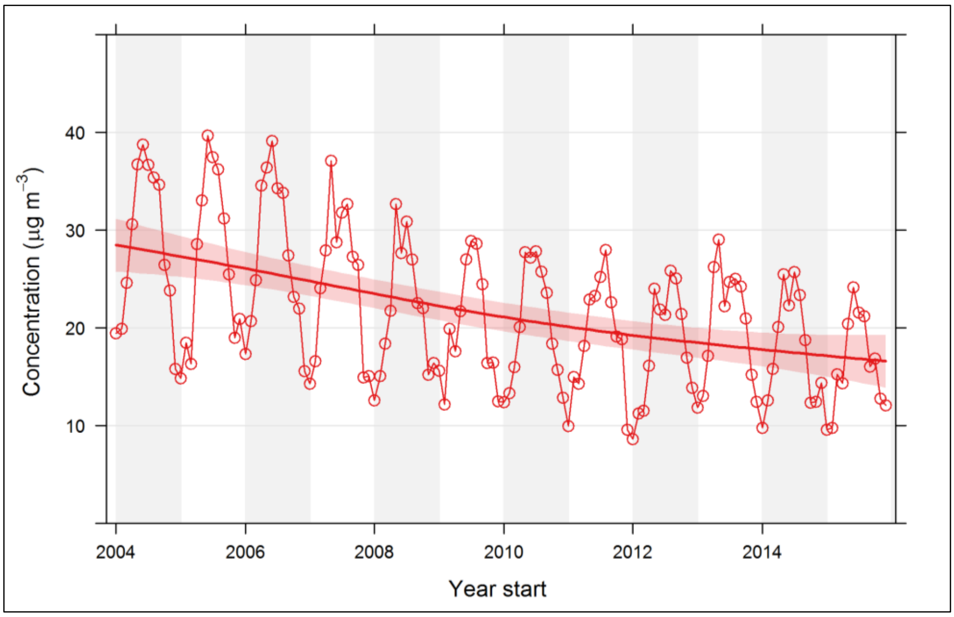

Figure F-10 Monthly mean NO_2 concentration at OEH Earlwood monitoring site

F.6.2.3 Maximum one-hour mean concentration

The trends in the maximum one-hour mean NO_2 concentration by year are given in Figure F-11. The within-site variation for this metric is similar to the between site variation, but when viewed overall the values have been quite stable with time (varying around 100 µg/m^3), and are all below the NSW air quality assessment criterion of 246 µg/m^3. The maximum one-hour mean NO_2 concentrations at both of the Roads and Maritime roadside sites (F1 and M1) in 2015 was 123 µg/m^3. As with NO_X, these values are similar to the highest values for the background sites.

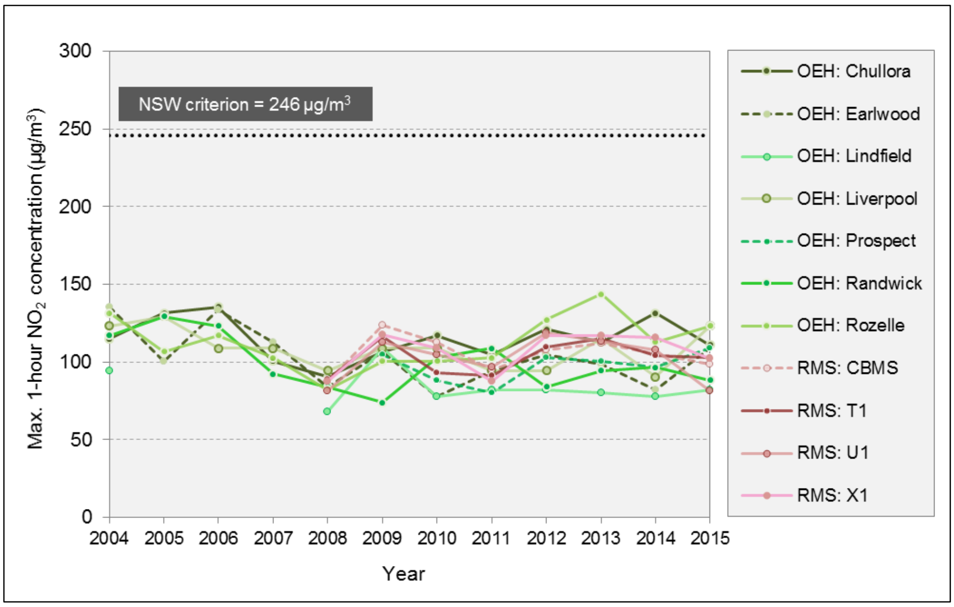

Figure F-11 Trend in maximum one-hour mean NO_2 concentration

F.6.2.4 Exceedances of air quality criteria

There were no exceedances of the annual mean criterion for NO_2 of 62 µg/m^3 (Table F-7). In fact, annual mean concentrations were well below the criterion at all sites and in all years. There were also no exceedances of the one-hour mean criterion for NO_2 (246 µg/m^3).

F.6.3 Ozone

F.6.3.1 Annual mean concentration

Annual mean ozone concentrations at the OEH sites - presented in Figure F-12 and Table F-8 - were relatively stable between 2004 and 2015, being typically around 30-35 µg/m³. The main exception was the Randwick site, 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 F-6).

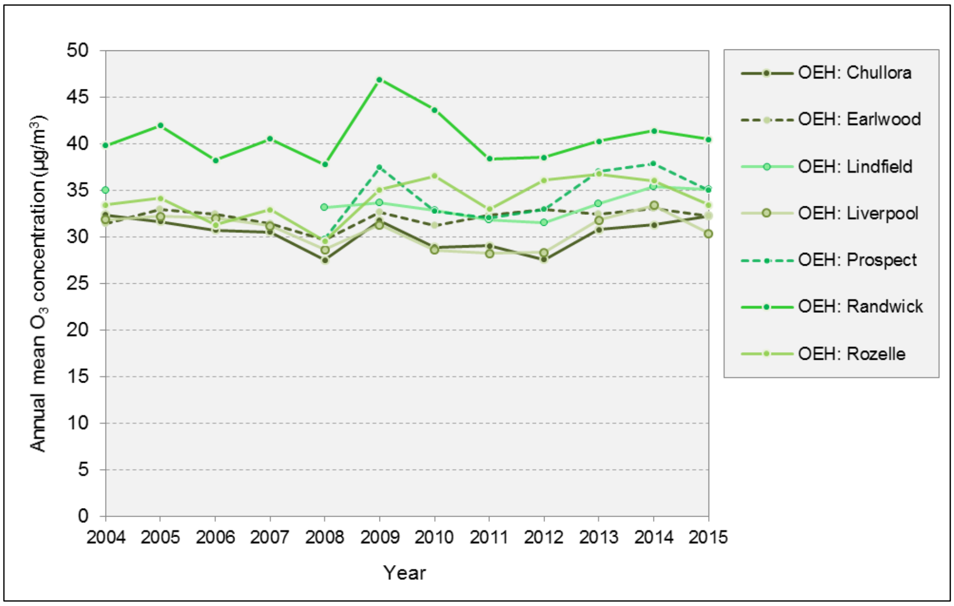

Figure F-12 Trend in annual mean O_3 concentration

Table F-8 Annual mean O_3 concentration at OEH background sites

Year	Annual mean concentration (µg/m³) [(a)] Chullora	Earlwood	Lindfield	Liverpool	Prospect	Randwick	Rozelle
2004	323.	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
Mean (2008-15)	**29.9**	**32.1**	**33.4**	**30.1**	-	**40.9**	**34.6**
Mean (2004-15)	**30.4**	**32.1**	**33.6**	**30.7**	**34.3**	**40.7**	**34.0**
Significance[(b)]	◄►	◄►	◄►	◄►	◄►	◄►	▲

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

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

F.6.3.2 Monthly mean concentration

As with NO_X and NO_2, ozone concentrations vary according to the season. They are highest in the late spring and early summer – when photochemical activity is high - and lowest in the autumn and winter. An example profile - for the Earlwood site – shown in Figure F-13.

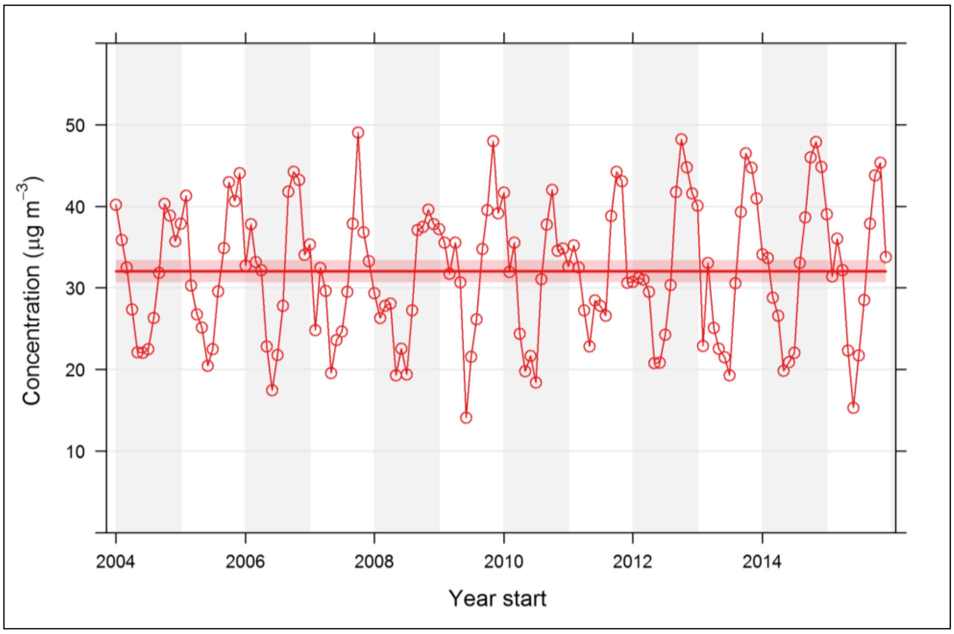

Figure F-13 Monthly mean O_3 concentration at OEH Earlwood monitoring site

F.6.3.3 Exceedances of air quality criteria

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

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

Year	Number of exceedances of rolling 4-hour standard per year (171 µg/m^3)						
	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

Table F-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

F.6.4 PM_{10}

F.6.4.1 Annual mean concentration

Annual mean PM_{10} concentrations at the OEH and Roads and Maritime sites are given in Figure F-14 and Table F-11. Concentrations at the OEH sites showed a net decrease between 2004 and 2015, by as much as 23-24 per cent in the case of the Chullora and Earlwood sites. Several sites had a statistically significant downward trend in concentrations.

In recent years the annual mean PM_{10} concentration at the OEH sites has been between 17 µg/m³ and 20 µg/m³, except at Lindfield where the concentration is substantially lower (around 14 µg/m³). The concentration at the Roads and Maritime sites in recent years appears to have stabilised at around 15 µg/m³. These values can be compared with air quality criterion of 25 µg/m³ in the NSW Approved Methods.

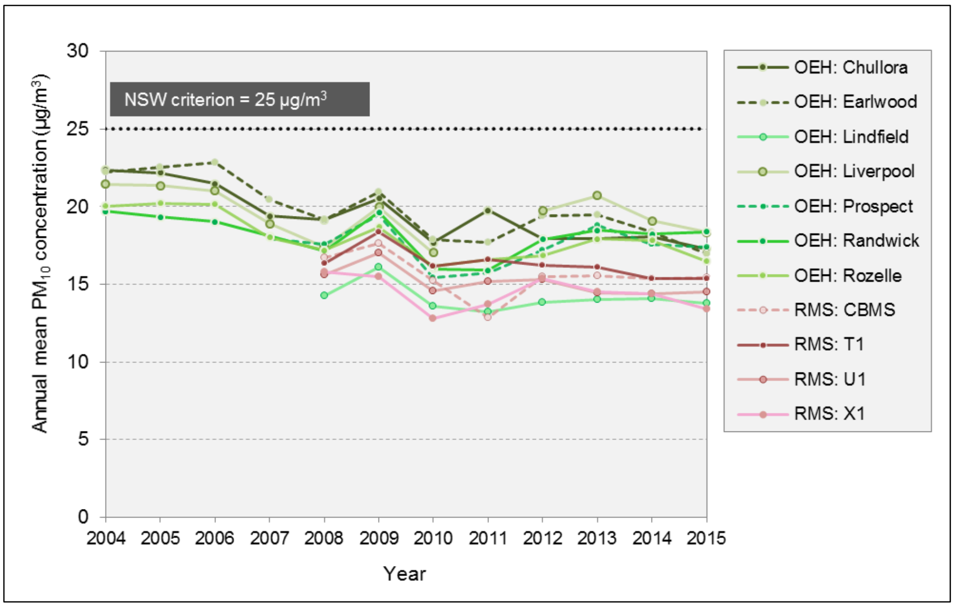

Figure F-14 **Trend in annual mean PM_{10} concentration**

Table F-11 Annual mean PM_{10} concentration at OEH and Roads and Maritime background sites

Year	Annual mean concentration (µg/m³)[(a)]										
	OEH Chullora	OEH Earlwood	OEH Lindfield	OEH Liverpool	OEH Prospect	OEH Randwick	OEH 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	22.9	-	21.0	-	19.0	20.2	-	-	-	-
2007	19.4	20.4	-	18.9	18.0	18.1	18.0	-	-	-	-
2008	19.4	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	19.8	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	20.7	18.8	18.5	17.9	15.7	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	14.4
2015	17.3	17.0	13.8	18.3	17.4	18.4	16.5	15.4	15.4	14.7	13.4
Mean (2008-15)	**18.5**	**18.7**	**14.1**	**18.9**	**17.4**	**17.7**	**17.2**	**15.5**	**16.3**	**15.1**	**14.4**
Mean (2004-15)	**19.5**	**19.8**	**14.1**	**19.5**	**17.4**	**18.1**	**18.0**	**15.5**	**16.3**	**15.1**	**14.4**
Significance[(b)]	▼	▼	◀▶	▼	◀▶	▼	▼	◀▶	▼	▼	▼

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

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

F.6.4.2 Monthly mean concentration

The monthly mean concentrations at the Chullora site are shown in Figure F-15**.** 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.

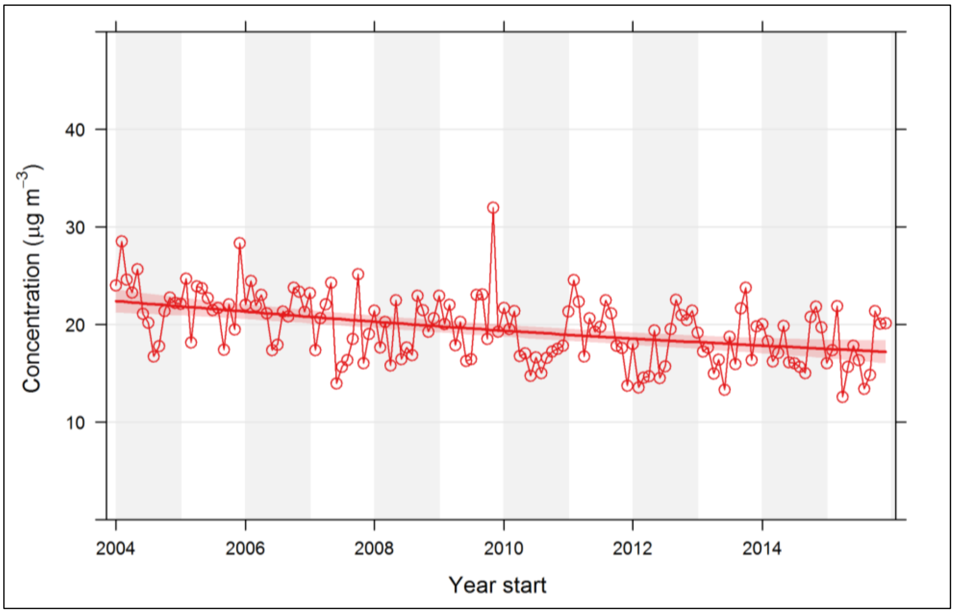

Figure F-15 Monthly mean PM_{10} concentration at OEH Chullora monitoring site

F.6.4.3 24-hour mean concentration

The maximum 24-hour mean PM_{10} concentrations are shown in Figure F-16. These appear to exhibit a slight downward trend overall, but there is a large variation from year to year at most sites. In 2014 and 2015 the concentrations at the various sites were clustered around 40 µg/m³, but the historical patterns suggest that this would be unlikely to continue into the future.

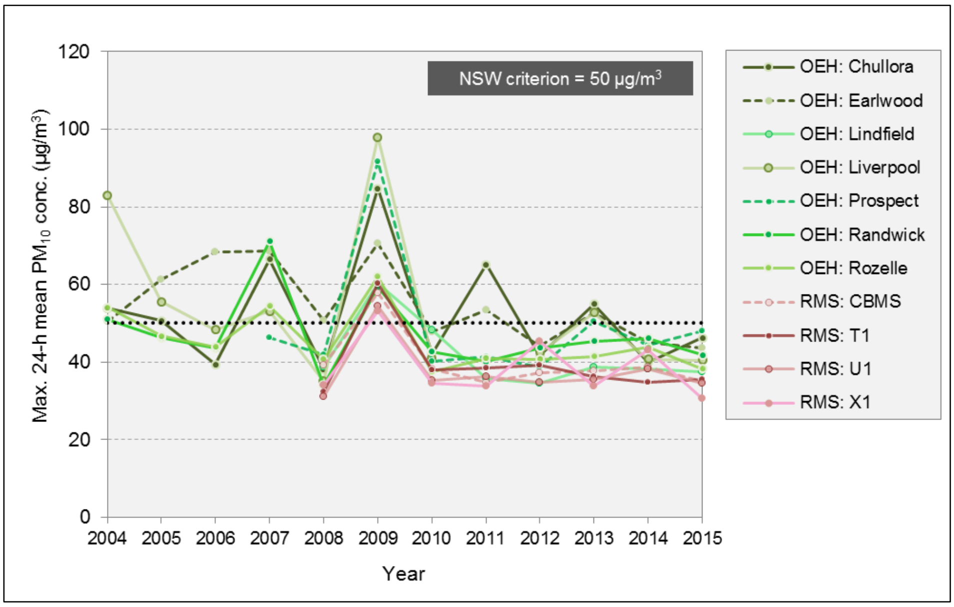

Figure F-16 **Trend in maximum 24-hour mean PM_{10} concentration**

F.6.4.4 Exceedances of air quality criteria

There were no exceedances of the annual mean criterion for PM_{10} in the NSW Approved Methods of 25 µg/m³, but Table F-12 shows that there were exceedances of the 24-hour criterion of 50 µg/m³, notably in the warm, dry year of 2009 (days with bush fires and dust storms were excluded from this analysis).

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

Year	Number of exceedances of 24-hour criterion per year (50 µg/m³)						
	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

F.6.5 $PM_{2.5}$

F.6.5.1 Annual mean concentration

An extensive time series of $PM_{2.5}$ measurements was only available for three monitoring sites in the wider study area: Chullora, Earlwood and Liverpool (Figure F-17 and Table F-13). Concentrations at the two OEH sites closest to WestConnex – Chullora and Earlwood - showed a broadly similar pattern, with a systematic reduction between 2004 and 2012 being followed by a substantial increase in 2013. Here, it is important to recognise the following:

- As noted earlier, during 2012 OEH 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 in recent years. It is well documented that there are considerable uncertainties in the measurement of $PM_{2.5}$ (e.g. AQEG, 2012).
- The increases meant that background $PM_{2.5}$ concentrations in the study area during 2014 and 2015 were already very close to or above the NSW criterion of 8 µg/m³, as well as the AAQ NEPM long-term goal of 7 µg/m³. $PM_{2.5}$ was also measured at Prospect and Rozelle in 2015, and the annual mean concentrations at these sites were 8.1 µg/m³ and 7.1 µg/m³ respectively. Although the value for Rozelle is below the NSW criterion, it is based on a low level of data capture (76%).

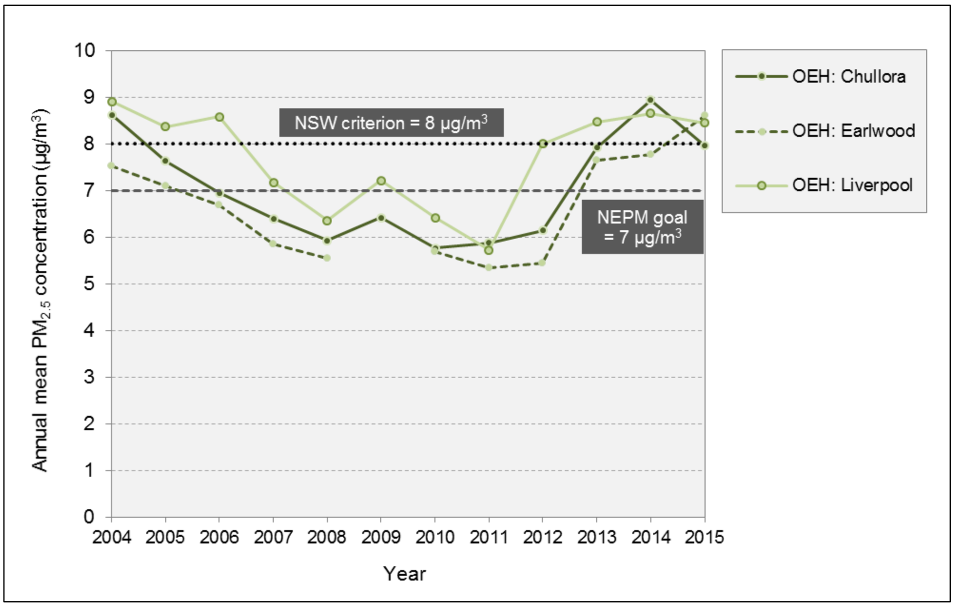

Figure F-17 Long-term trends in annual mean $PM_{2.5}$ concentration

Table F-13 Annual mean $PM_{2.5}$ concentration at OEH background sites

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	7.0	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	-	8.5	-	-	-
2014	8.9	7.8	-	8.7	-	-	-
2015	8.0	8.6	-	8.4	8.1		7.1
Mean (2004-15)	**7.0**	**6.7**	**-**	**7.7**	**-**	**-**	**-**
Significance[b]	◀▶	◀▶	-	◀▶	-	-	-

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

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

F.6.5.2 Monthly mean concentration

The monthly mean $PM_{2.5}$ concentrations at the Chullora site are shown in Figure F-18. There are some differences between seasons, but they are not systematic.

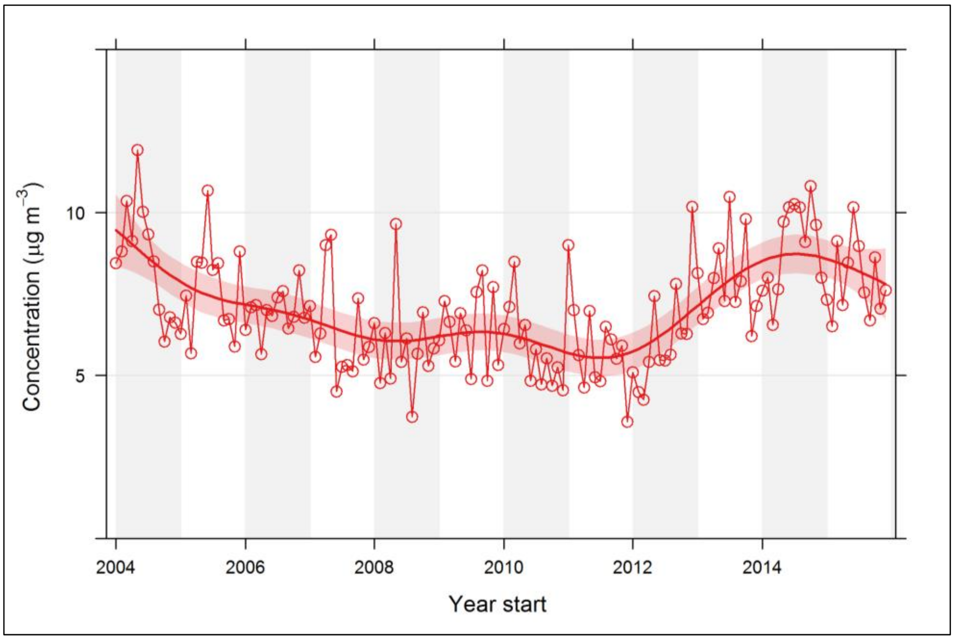

Figure F-18 Monthly mean $PM_{2.5}$ concentration at OEH Chullora monitoring site

F.6.5.3 24-hour mean concentration

The maximum 24-hour mean $PM_{2.5}$ concentrations at the three long-term $PM_{2.5}$ monitoring sites are shown in Figure F-19. 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/m^3, and in some cases significantly above it. In most cases the maximum concentrations have been above the NEPM long-term goal of 20 µg/m^3.

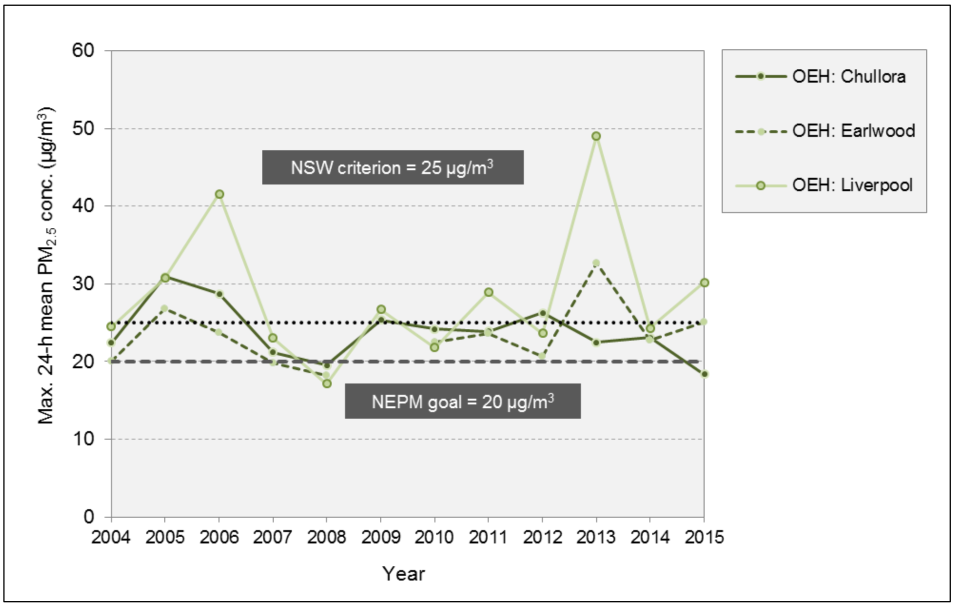

Figure F-19 Trend in maximum 24-hour mean $PM_{2.5}$ concentration

F.6.5.4 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/m^3, and these seem to be more likely in the future given the change in monitoring method.

Table F-14 summarises the exceedances of the NSW criterion for 24-hour mean $PM_{2.5}$ of 25 µg/m^3, as well as the long-term NEPM goal of 20 µg/m^3.

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

Year	Number of exceedances of 24-hour criterion per year (25 µg/m^3) (exceedances of the NEPM goal of 20 µg/m^3 are given in brackets)						
	Chullora	Earlwood	Lindfield	Liverpool	Prospect	Randwick	Rozelle
2004	0 (4)	0 (1)	-	0 (8)	-	-	-
2005	**3** (**5**)	**2** (**4**)	-	**2** (**7**)	-	-	-
2006	0 (**1**)	0 (1)	-	0 (4)	-	-	-
2007	0 (2)	0 (0)	-	0 (2)	-	-	-
2008	0 (0)	0 (0)	-	0 (0)	-	-	-
2009	**1** (**1**)	0 (1)	-	**1** (**3**)	-	-	-
2010	0 (3)	0 (1)	-	0 (2)	-	-	-
2011	0 (1)	0 (2)	-	**1** (**3**)	-	-	-
2012	**1** (**6**)	0 (1)	-	0 (3)	-	-	-
2013	0 (2)	**2** (**8**)	-	**4** (**13**)	-	-	-
2014	0 (4)	0 (1)	-	0 (5)	0 (0)	-	-
2015	0 (0)	**1** (**8**)	-	**1** (**7**)	**1** (**5**)	-	0 (0)

F.6.6 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 F-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 F-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 F-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 F-16. In many cases the concentration for a given compound was lower than the corresponding limit of reporting (LOR)[7]. The results were therefore similar to those from the earlier studies, and confirmed that the concentrations of air toxics in Sydney remain very low.

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

Table F-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

F.7 Bivariate polar plots

F.7.1 Overview

Polar plots for each of the OEH monitoring sites were created using the *Openair* software. These plots were not used directly in the determination of the background concentrations for the M4-M5 Link project, but they did assist in the understanding of differences between pollutant concentrations at the different sites.

Some examples of polar plots are shown in Figure F-20. These indicate how concentrations vary by wind speed and wind direction, with statistical smoothing techniques giving a continuous surface. The monitoring station is located at the centre of each plot. The axes show the directions from which the wind is coming, and the distance from the origin indicates the wind speed; the further from the centre that concentrations appear, the higher the wind speeds when they were measured. Calm conditions appear close to the centre. The examples are for $PM_{2.5}$ at the Chullora site in 2015. The Figure shows that in 2015 the highest $PM_{2.5}$ concentrations were associated with light-moderate winds (2-5 metres per second) from the north-west and during the summer months.

The polar plot is a useful diagnostic tool for understanding potential sources of air pollutants at a given site. For many situations an increasing wind speed generally results in lower concentrations due to increased dilution through advection and increased turbulence. Ground-level, non-buoyant sources - such as road traffic – therefore tend to have highest concentrations under low wind speed conditions, but various processes can lead to other concentration-wind speed dependencies. For example, buoyant plumes from tall outlets can be brought down to ground level, resulting in high concentrations under high wind speed conditions. Wind-blown dust (*e.g.* from exposed areas of soil) also increases with increasing wind speed, and particle suspension can be important close to coastal areas where higher wind speeds generate more sea spray (Carslaw, 2015).

Some typical features of polar plots include the following:

- A maximum concentration, or a 'smeared' peak, at low wind speed, which is indicative of a local, ground-level source such as road traffic. As the wind speed increases concentrations due to a road source will tend to decrease due to the increased dilution of the plume.
- Highly resolved features at high wind speeds, but possibly low concentrations, which indicate more distant sources.
- Relationships between pollutants which provide information on the emission characteristics of different sources. For example, a site with high 'smeared' NO_X concentrations at low wind speeds, is likely to be a nearby road.

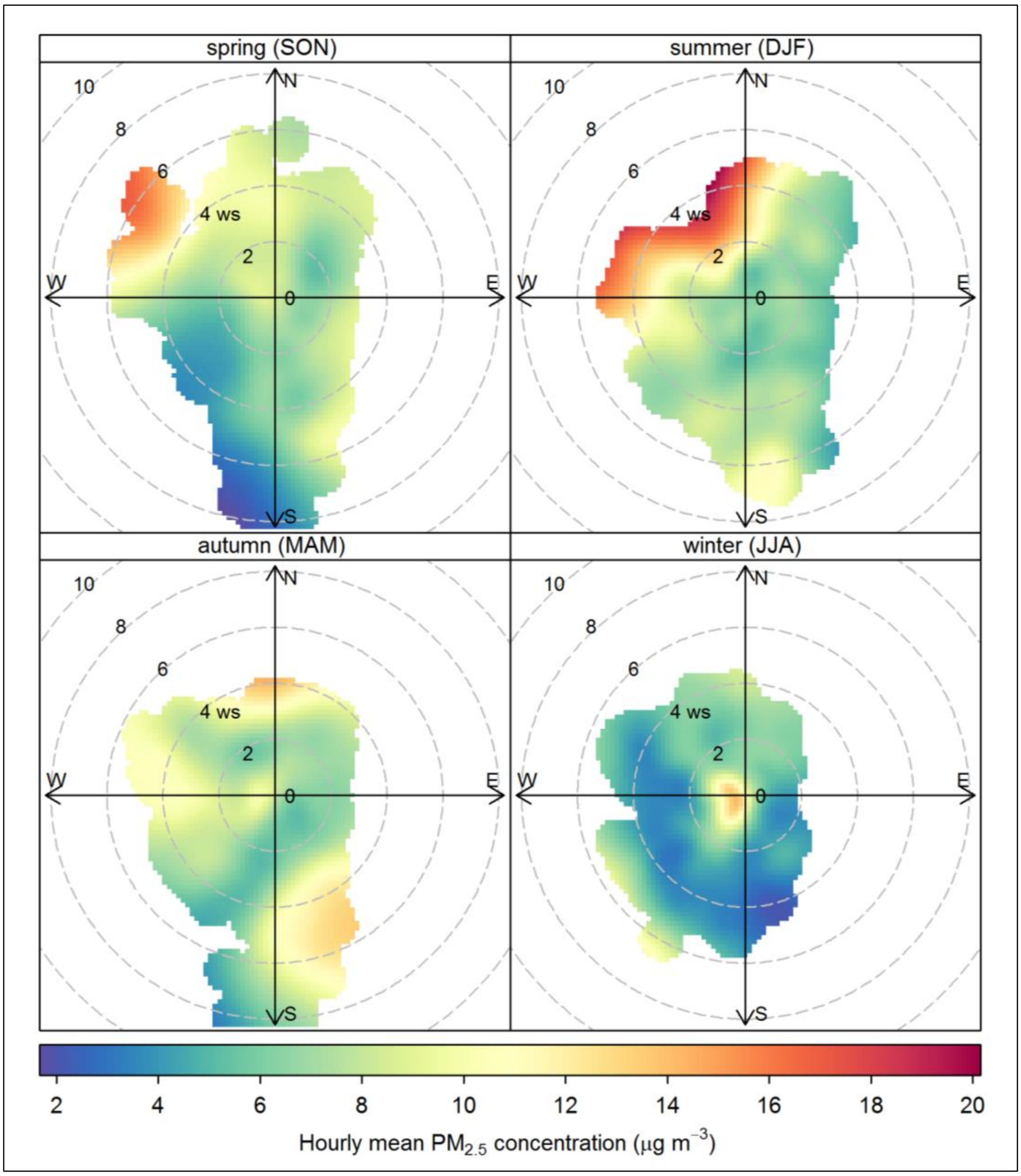

Figure F-20 Polar plots of $PM_{2.5}$ concentration by season at Chullora in 2015

The Openair polar plots for the OEH sites have been interpreted below. Each plot is based upon all the available data for the period 2004-2015. The interpretation is qualitative, and to some degree speculative. One feature of some of these plots is an apparent influence of road traffic. This suggests some overall conservatism in the modelling approach.

F.7.2 Chullora

The polar plots for the Chullora site – covering all years - are shown in Figure F-21. The plots for CO, NO_X and NO_2 show strong similarities, with the highest concentrations occurring at low wind speeds and a tendency for elevated concentrations along a broad north-south wind direction axis. There also appears to be a strong source of these pollutants to the east. The similarities between these plots indicate a common combustion source - probably the local road network.

The plots for O_3 and NO_X show the well-established inverse relationship between these pollutants. This is also apparent in the data from the other OEH monitoring sites, and is not commented upon further.

The patterns for CO and NO_X do not show up strongly in the PM_{10} and $PM_{2.5}$ plots. This is likely to be due to contributions from multiple types of source. PM_{10} concentrations appear to be influenced by a source to the west of the monitoring site under higher wind speeds. This may be wind-blown dust from open land to the west of the monitoring station. For $PM_{2.5}$ there are strong sources to the north-west and south under high wind conditions. There were also seasonal differences in the PM_{10} and $PM_{2.5}$ data; the highest PM_{10} concentrations were in winter, whereas the highest $PM_{2.5}$ concentrations were in summer.

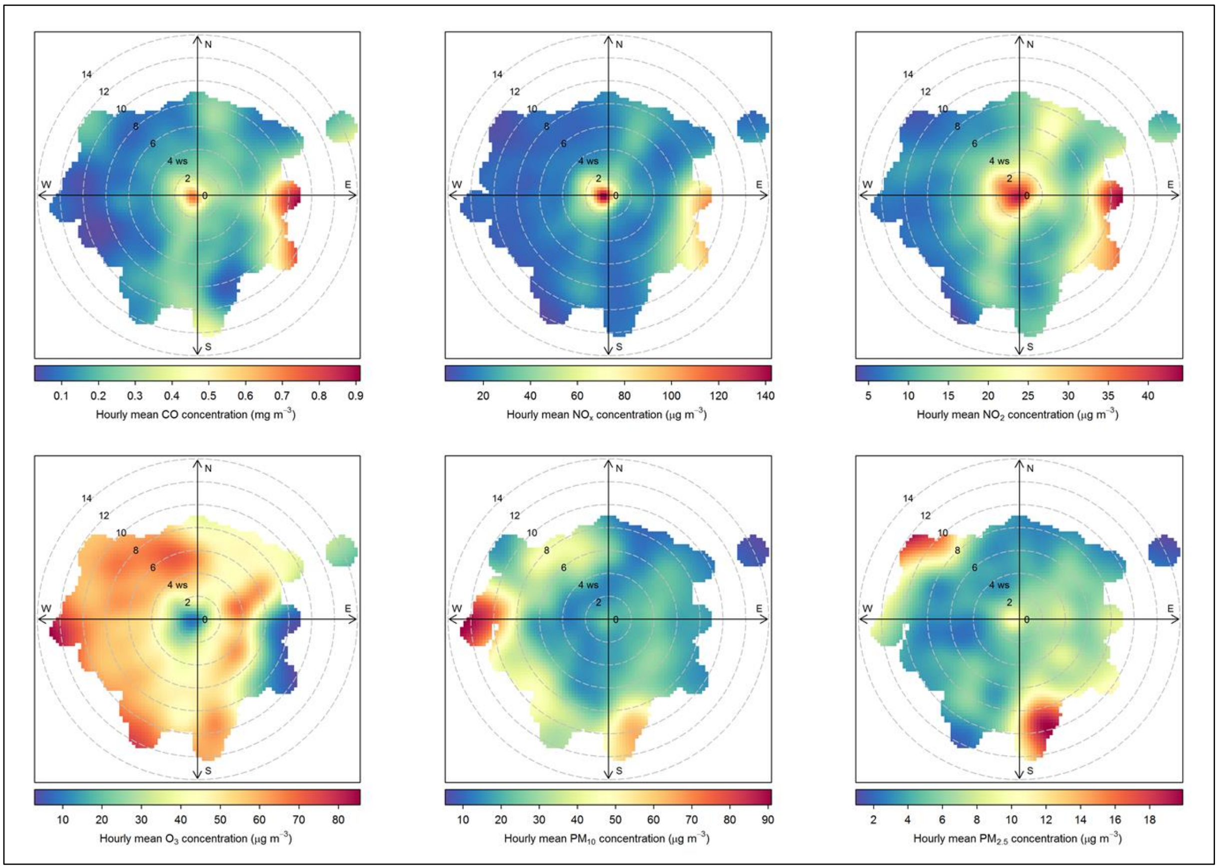

Figure F-21 Polar plots – Chullora (2004-2015)

F.7.3 Earlwood

The polar plots for the Earlwood site are shown in Figure F-22. NO_X and NO_2 concentrations are highest when the winds are strong and from an easterly direction. The seasonal data showed that this influence was especially strong during winter, hinting that this is an effect of combustion for heating purposes.

PM_{10} concentrations are highest when the winds are strong and from a westerly direction (especially in winter and spring). $PM_{2.5}$ concentrations, while more evenly distributed than PM_{10}, are high when the winds are strong from a southerly direction (especially in summer). The reasons for these patterns were not investigated further, but different sources and effects are evidently influencing PM_{10} and $PM_{2.5}$.

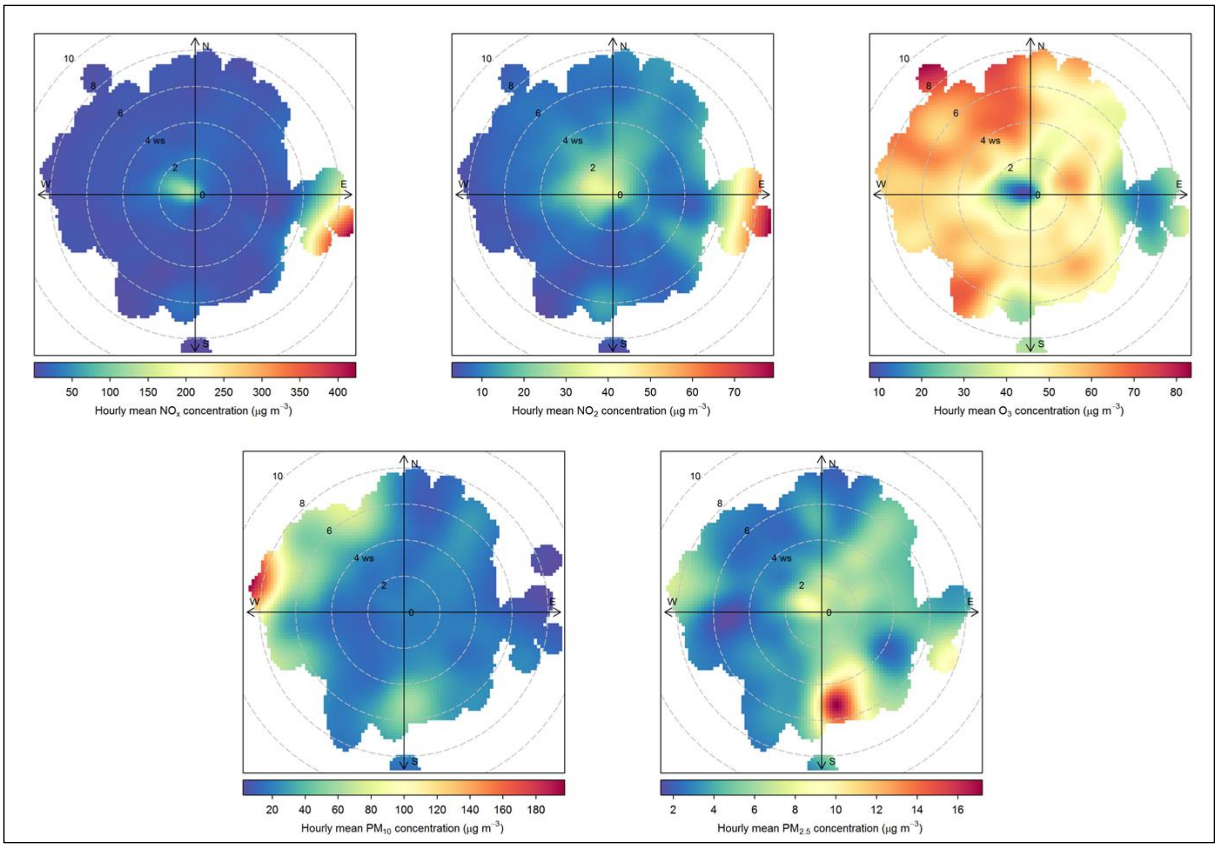

Figure F-22 Polar plots – Earlwood (2004-2015)

F.7.4 Lindfield

Figure F-23 shows the polar plots for Lindfield. The smeared NO_X and NO_2 concentrations at the plot origin indicate the presence of a local ground-level source, as well as a broad source further afield to the north. This probably reflects the population distribution around the monitoring site. There is also an influence further way and to the west, which may be the M2 Motorway and Lane Cove Road.

PM_{10} concentrations are high when there is a strong westerly wind. This may be due to wind-blown dust from the open land immediately to the west of the monitoring site.

There are no strong seasonal effects at the Lindfield site, 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.

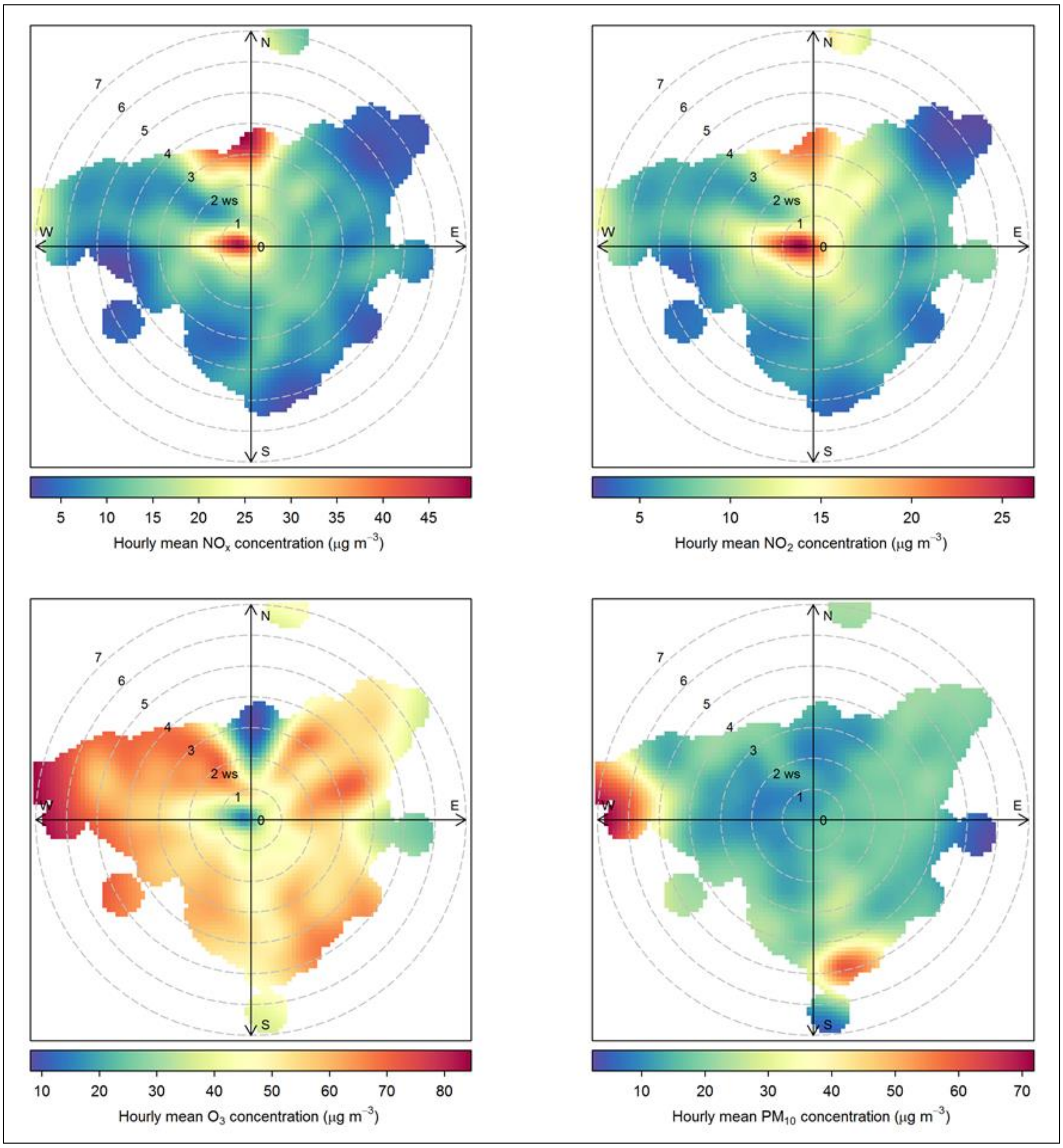

Figure F-23 Polar plots – Lindfield (2004-2015)

F.7.5 Liverpool

At the Liverpool monitoring site the concentrations of CO, NO_X, NO_2 and $PM_{2.5}$ for low wind speeds are not particularly high (Figure F-24). There is, however, a distinct influence form a north-westerly direction, indicating a common combustion source. This may involve a contribution from Hoxton Park Road. However the effect is most prominent in winter, and this is more indicative of combustion for heating purposes, probably from the commercial centre of Liverpool. The M5 Motorway, around 500 metres south of the monitoring site, does not appear to have a significant influence on the measured concentrations.

PM_{10} concentrations are influenced by a source to the north-north-west of the monitoring site, but only under strong wind conditions and during the winter months. Again, this coincides with open land to the north-west of the site, and could be a result of wind-blown dust.

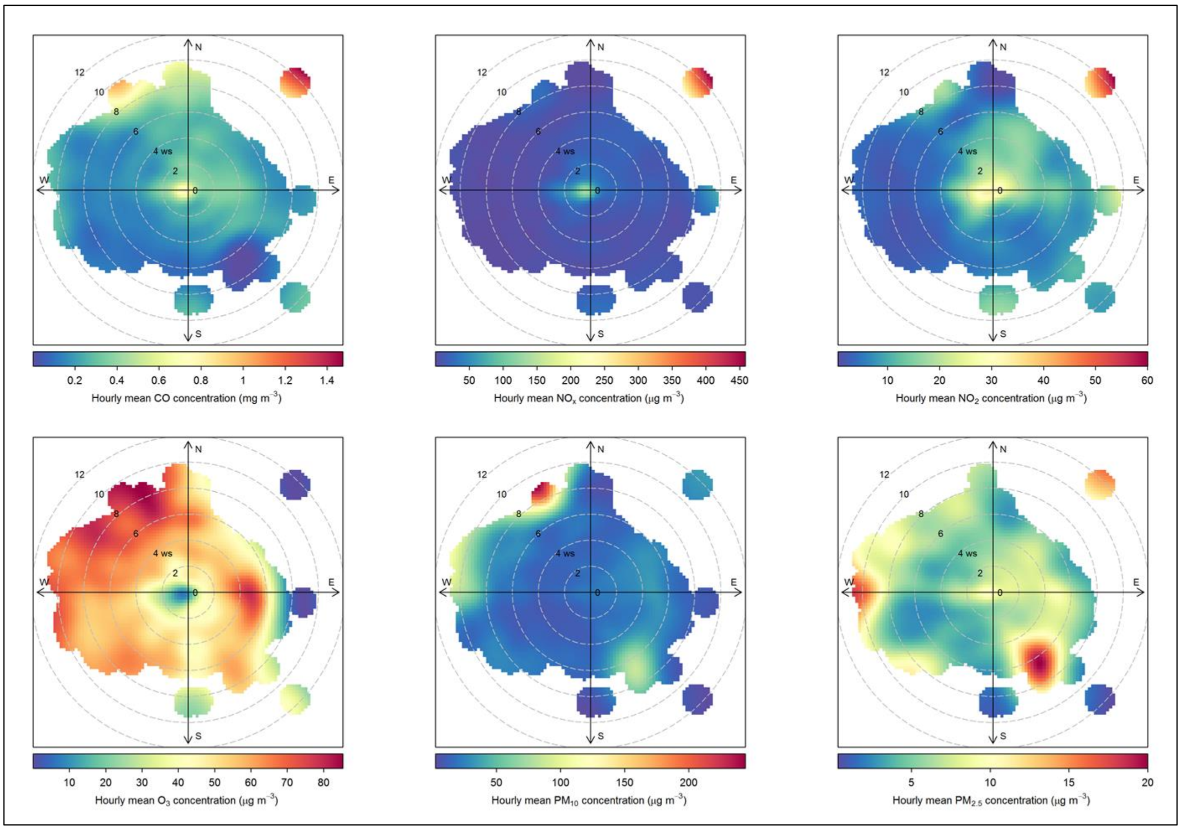

Figure F-24 Polar plots – Liverpool (2004-2015)

F.7.6 Prospect

Concentrations of CO, NO_X and NO_2 at the Prospect site (Figure F-25) are highest when wind speeds are low, and the high concentration are almost centred on the monitoring station. There are, however, sources of NO_X to the east and south-east under high wind speeds. This may be associated with the transport of NO_X from major roads in the area, although these are some distance away (Prospect Highway, 500 metres to the east; Great Western Highway, 800 metres to the south; M4 Motorway, 1.2 kilometres to the south). There is no strong seasonal influence on NO_X at the site, suggesting that it is not affected by combustion for heating purposes.

PM_{10} seems to be strongly influenced – under high winds - by sources which are spread out quite widely to the west of the monitoring site. As at the other sites, this may be due to wind-blown dust from the open land, gravel and sand areas adjacent to the site.

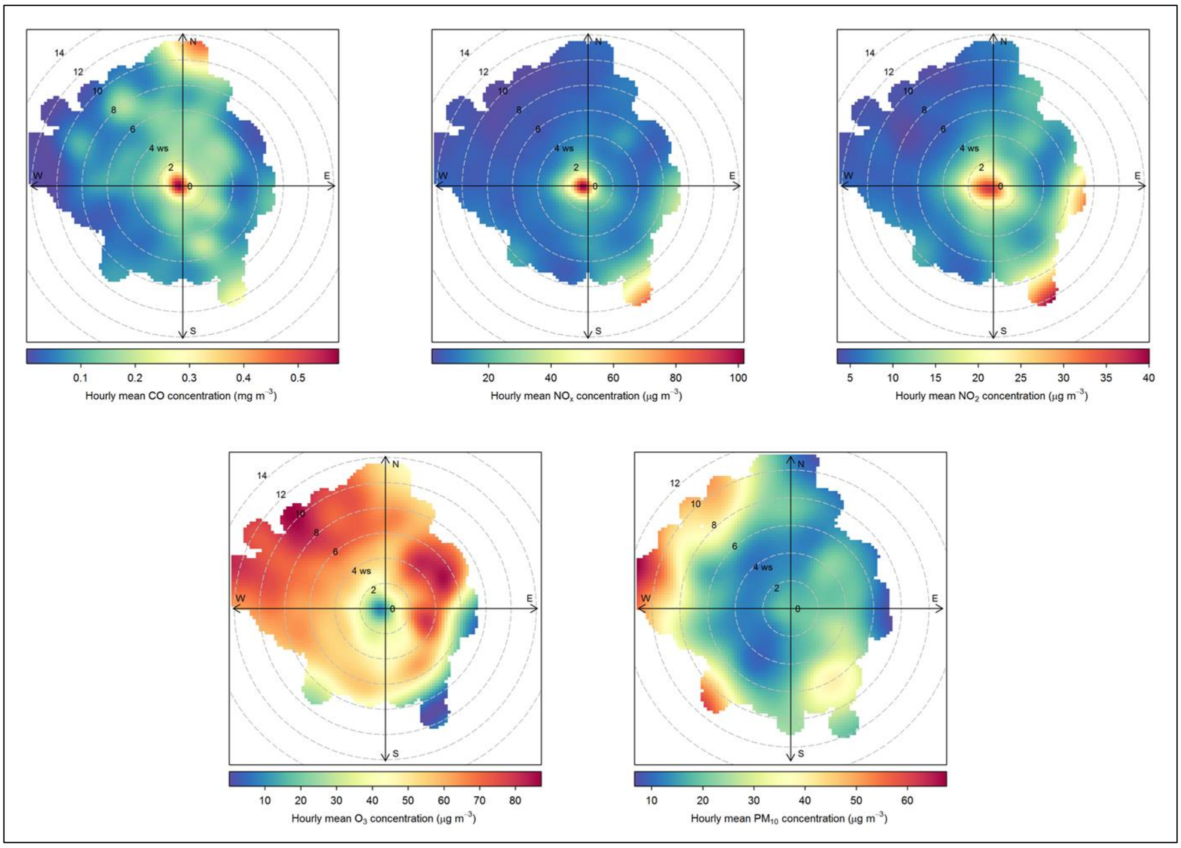

Figure F-25 Polar plots – Prospect (2004-2015)

F.7.7 Randwick

At the Randwick site, NO_X and NO_2 concentrations are highest when the wind speed is low and the wind is coming from the west, with dispersion under stronger winds. There is no seasonal effect in the polar plot for NO_X. This indicates the presence of a road near to the monitoring site, which could be Anzac Parade and/or Avoca Street. Sydney Airport, around 5 kilometres to the west of the monitoring site, may also be affecting NO_X concentrations in this area.

The PM_{10} plot for Randwick shows that the highest concentrations occur when the wind speed is high and is blowing from three distinct directions. Given that these directions coincide 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.

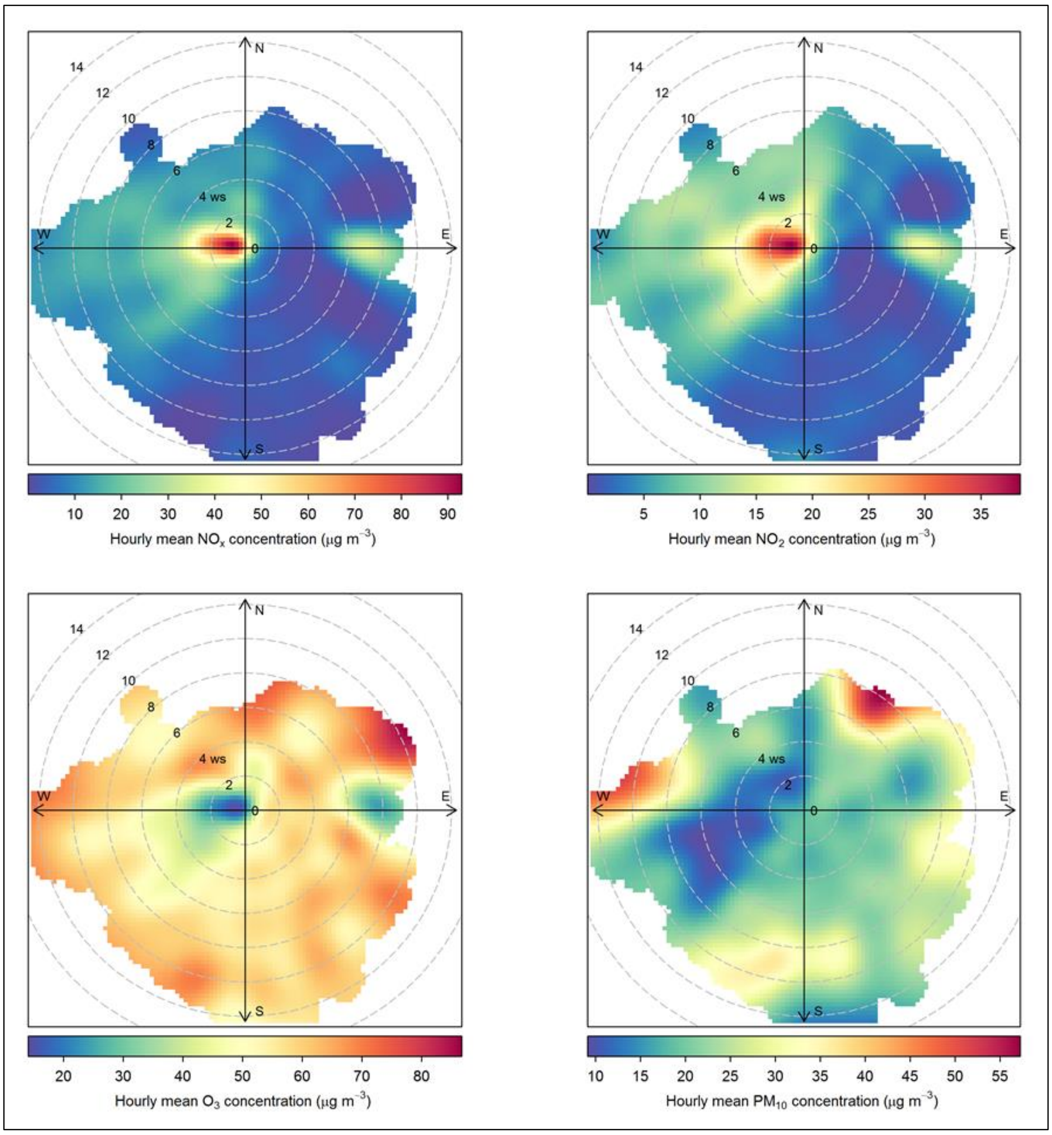

Figure F-26 Polar plots – Randwick (2004-2015)

F.7.8 Rozelle

The polar plot for CO at the Rozelle site indicates that there are multiple combustion sources affecting the site. These are 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 occur when winds are along an east-west axis, which suggests contributions from the University campus and residential areas. The peak associated with easterly winds may also be linked to Victoria Road.

The highest PM_{10} concentrations at the monitoring site are associated with strong southerly winds, especially in summer. As at the other OEH monitoring sites, this seems to be due to wind-blown dust from open land to the south of the Rozelle site.

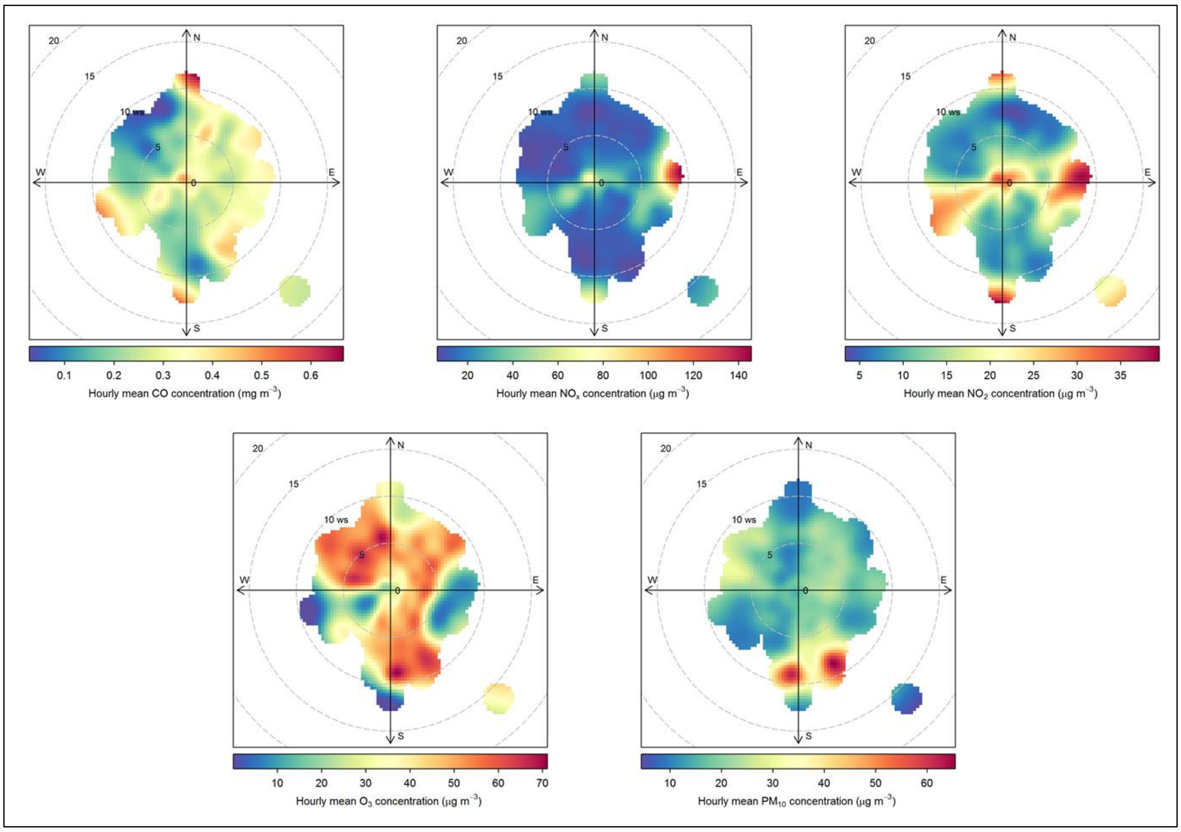

Figure F-27 Polar plots – Rozelle (2004-2015)

F.8 Assumed background concentrations

F.8.1 General approaches in M4-M5 Link assessment

Various approaches have been used in previous air quality assessments 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. The general approaches used in the M4-M5 Link assessment are introduced below. The specific approaches for the various pollutants and metrics are then described in the subsequent sections. Background concentrations **for 2015** were developed using the data from the OEH sites at Chullora, Earlwood, Randwick and Rozelle sites, the Roads and Maritime M5 East background sites, and the M4 East St Lukes Park site.

F.8.1.1 Annual mean concentrations

In the case of annual mean concentrations (such as those for PM_{10} and $PM_{2.5}$) 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 WestConnex, 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 some pollutants were therefore developed for the WestConnex study area. When developing these maps the data from any non-background sites were excluded.

F.8.1.2 Short-term concentrations

It is more difficult to accurately predict short-term concentration peaks, as these vary considerably in magnitude, in time of occurrence, and in location. In some previous assessments a single value has been used for short-term concentrations, such as the maximum measured 24-hour mean PM_{10} concentration. This is the ‘Level 1’ method in the NSW Approved Methods. However, such an approach is very conservative, and results in unrealistically high cumulative concentrations; it is very unlikely that the maximum background values will coincide in space and time with the maximum predicted values. This approach was therefore considered to be inappropriate for the M4-M5 Link project.

The approach used for community receptors in the M4-M5 Link assessment was broadly consistent with the ‘Level 2’ method in the Approved methods. This 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 site. 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 M4-M5 Link project this approach was applied to the short-term concentration metrics for CO (rolling 8-hour mean), NO_X (1-hour mean), PM_{10} (24-hour mean) and $PM_{2.5}$ (24-hour mean). NO_X was used in place of NO_2 for the reasons given in Annexure G. It would not have been practical to define both the spatial and temporal variation in short-term background concentrations in detail. As the temporal variation is generally more pronounced than the spatial variation, this was considered to be more important. For each short-term air quality metric a *synthetic time series* of background concentrations was therefore determined.

F.8.2 Carbon monoxide : one-hour mean

Figure F-28 shows examples of one-hour mean CO concentration profiles at the OEH Chullora and Rozelle sites, the Roads and Maritime CBMS, T1, U1 and X1 sites, anfd the SMC M4 East St Lukes Park site during June of 2015. Peak concentrations generally occurred simultaneously at the different sites, indicating a regional background influence.

Given that there was a slight downward trend in the maximum one-hour mean CO values, the concentrations in 2015 were considered to be appropriate for use in the M4-M5 Link assessment, with the likelihood that the 2015 values would be slightly conservative in future years. Because of the seasonal variation in CO concentrations, a background profile of the one-hour mean CO concentration during 2015 was determined. To maintain a margin of safety a synthetic profile was constructed, with each value for a time period being the maximum of those at the OEH, Roads and Maritime and SMC sites. This profile is shown in Figure F-29.

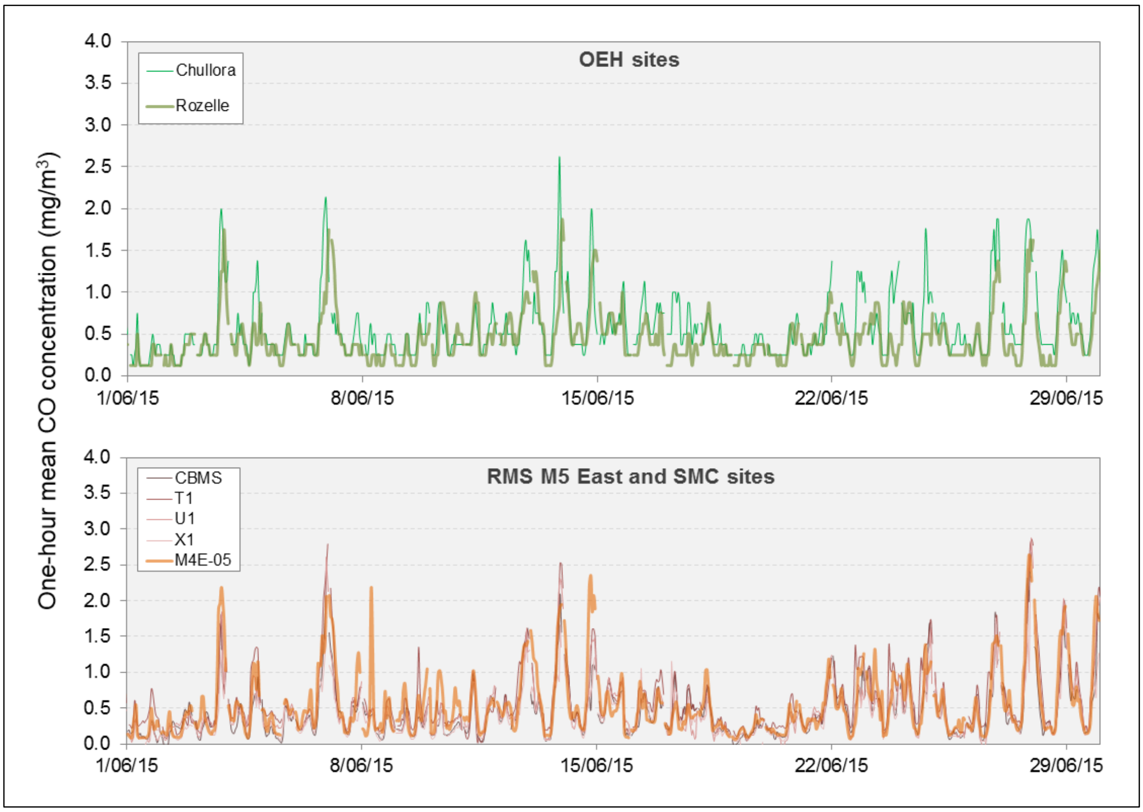

Figure F-28 **One-hour mean CO concentration at OEH, Roads and Maritime M5 East and SMC sites (example for June 2015)**

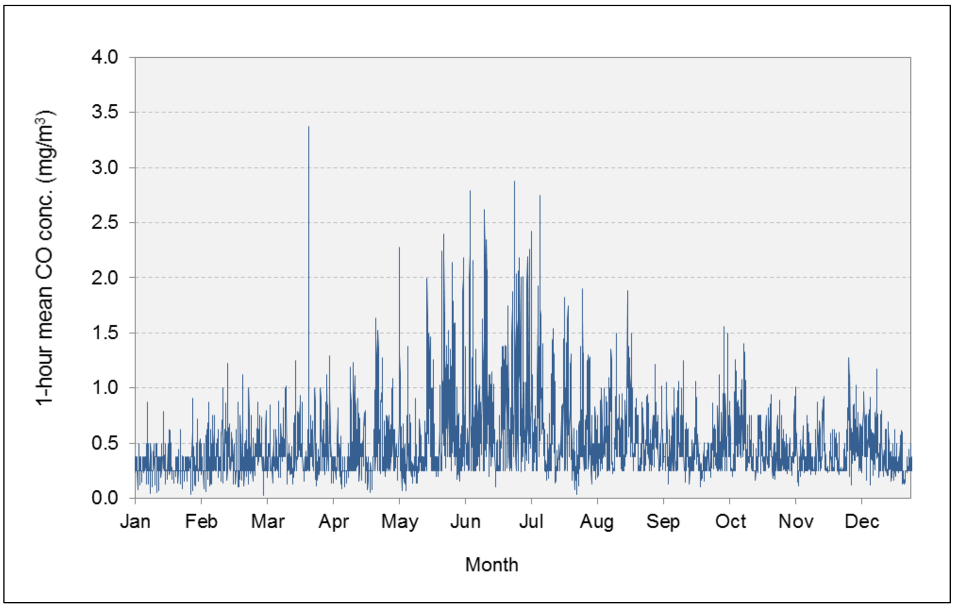

Figure F-29 **Synthetic background concentration profile for one-hour mean CO**

F.8.3 Carbon monoxide : rolling 8-hour mean

The rationale for the rolling 8-hour mean CO concentration was similar to that for the one-hour mean. A synthetic profile was constructed for 2015, with each value for a time period being the maximum of those at the OEH, Roads and Maritime and SMC sites. This profile is shown in Figure F-30.

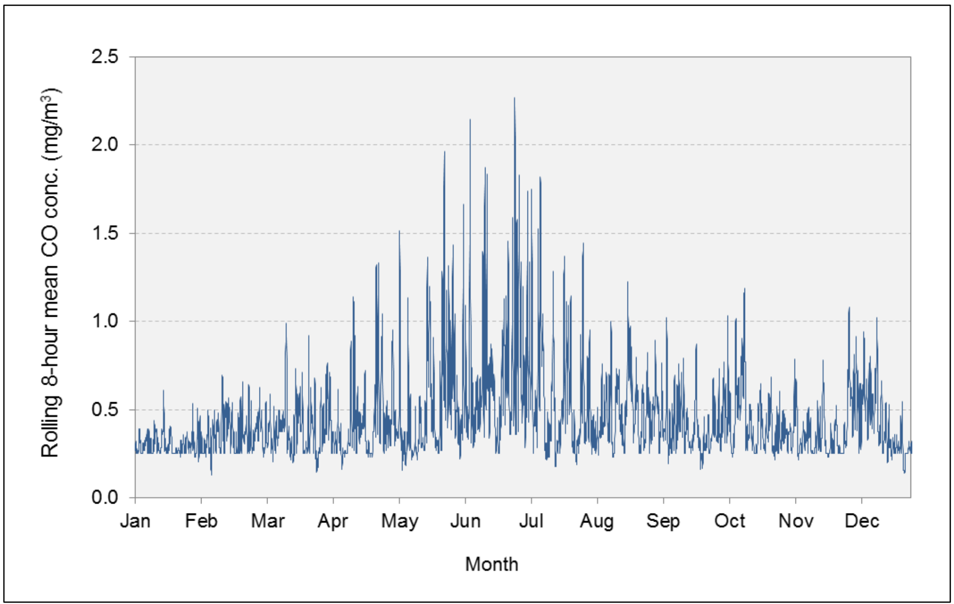

Figure F-30 Synthetic background concentration profile for rolling 8-hour mean CO

F.8.4 NO_X : annual mean

Annual mean concentrations of NO_X at the OEH and Roads and Maritime sites have shown an overall downward trend since 2004, but with an apparent stabilisation at some sites in recent years (Figure F-6). On balance, it was considered that the concentrations in 2015 would represent typical (but probably slightly conservative) background concentration going forward into the future.

It was also noted earlier that there was quite a systematic spatial pattern in NO_X concentrations. To allow for this spatial variation, the data from the OEH, Roads and Maritime and SMC background monitoring sites were used to determine a background map for annual mean NO_X across Sydney in 2015, as shown in Figure F-31. The area covered by the WestConnex modelling (GRAL) domain is shown in more detail in Figure F-32. The background map was 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. The Roads and Maritime site T1 was excluded from the dataset as NO_X concentrations at this location were systematically higher than those at the other Roads and Maritime M5 East sites and may have been affected by a local source. To determine background NO_X concentrations for discrete receptor locations within the modelling domain that did not coincide with grid nodes, 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).

The background map shows that in the WestConnex GRAL domain there is a decreasing NO_X concentration gradient from the south-west to the north-west. However, there is only a small concentration gradient along the alignment of the M4-M5 Link project.

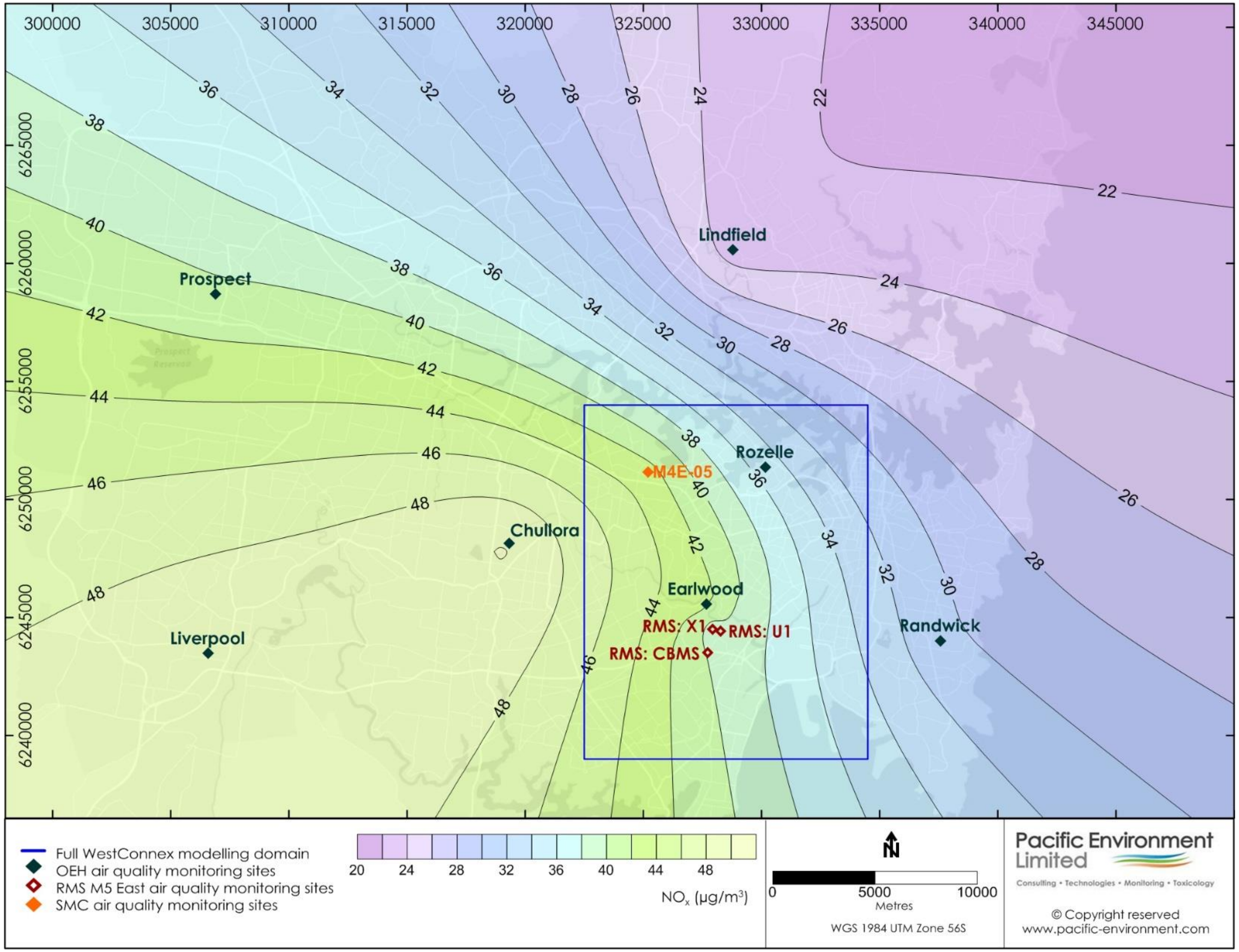

Figure F-31 **Background map for annual mean NO_X concentration across Sydney in 2015**

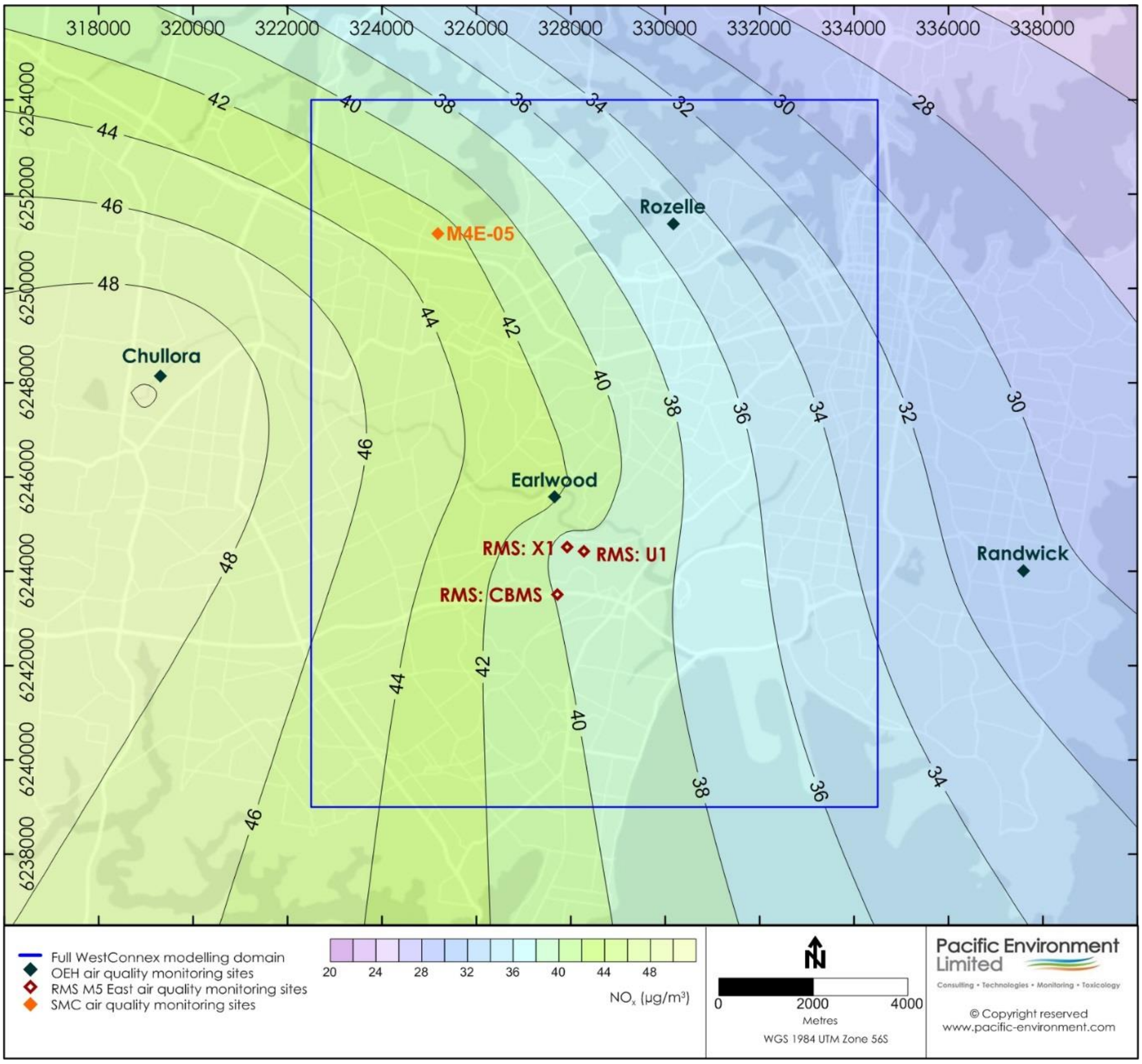

Figure F-32 **Background map for annual mean NO_X concentration in 2015 (detail for WestConnex GRAL modelling domain)**

F.8.5 NO_X : one-hour mean

The approach for one-hour mean NO_X was similar to that used for CO, with a synthetic concentration profile for 2015 being determined to allow for seasonal and spatial variation. Figure F-33 shows examples of one-hour concentration profiles at the OEH Chullora, Earlwood, Rozelle and Randwick sites, the Roads and Maritime CBMS, U1 and X1 sites, and the SMC M5 East St Lukes Park site during June of 2015. Peak concentrations regularly occurred simultaneously at the different sites, indicating a regional influence.

In order to introduce a margin of safety the maximum concentration across the seven sites in each one-hour time step was used to define a synthetic background concentration profile for M4-M5 Link project in future years. The final synthetic background concentration profile for 2015 is shown in Figure F-34.

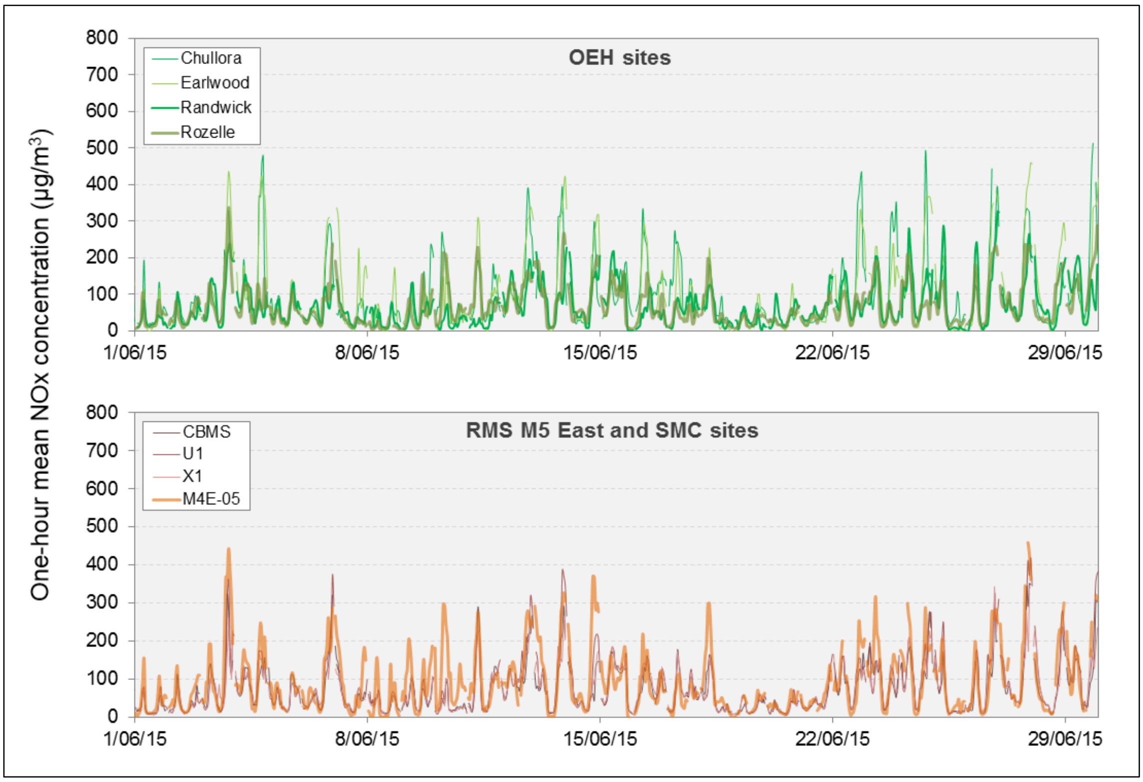

Figure F-33 **One-hour mean NO_X concentration at OEH, Roads and Maritime M5 East and SMC sites (example for June 2015)**

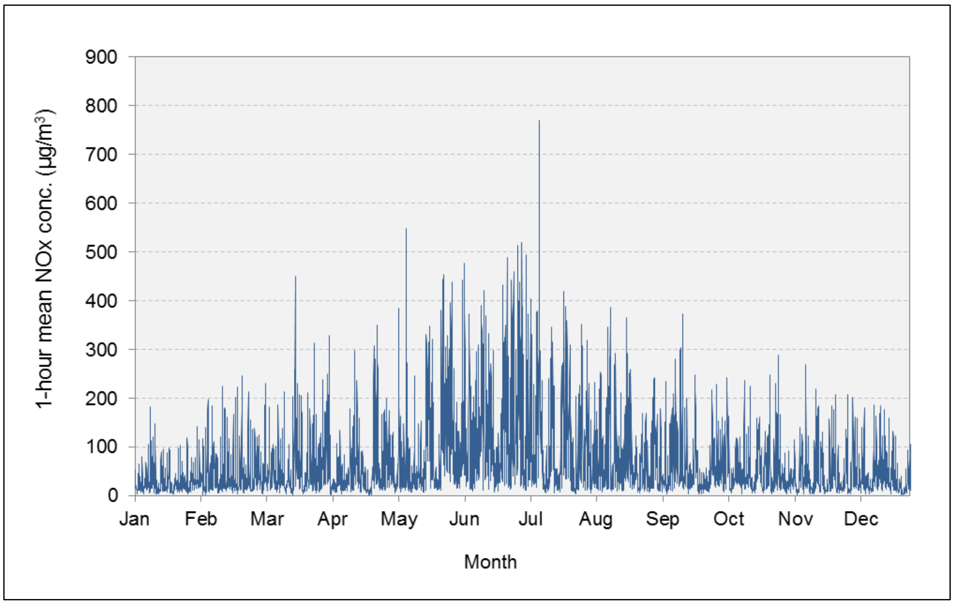

Figure F-34 **Synthetic background concentration profile for one-hour mean NO_X in 2015**

F.8.6 PM_{10} : annual mean

The mapping approach for annual mean PM_{10} was the same as that used for annual mean NO_X. The background PM_{10} map for Sydney in 2015 is shown in Figure F-35, and the area covered by the WestConnex GRAL domain is shown in Figure F-36. Although there are some localised concentraion low points (which may be real or may be related to differences in the PM_{10} measurement technique), there is only a small concentration gradient along the alignment of the M4-M5 Link project.

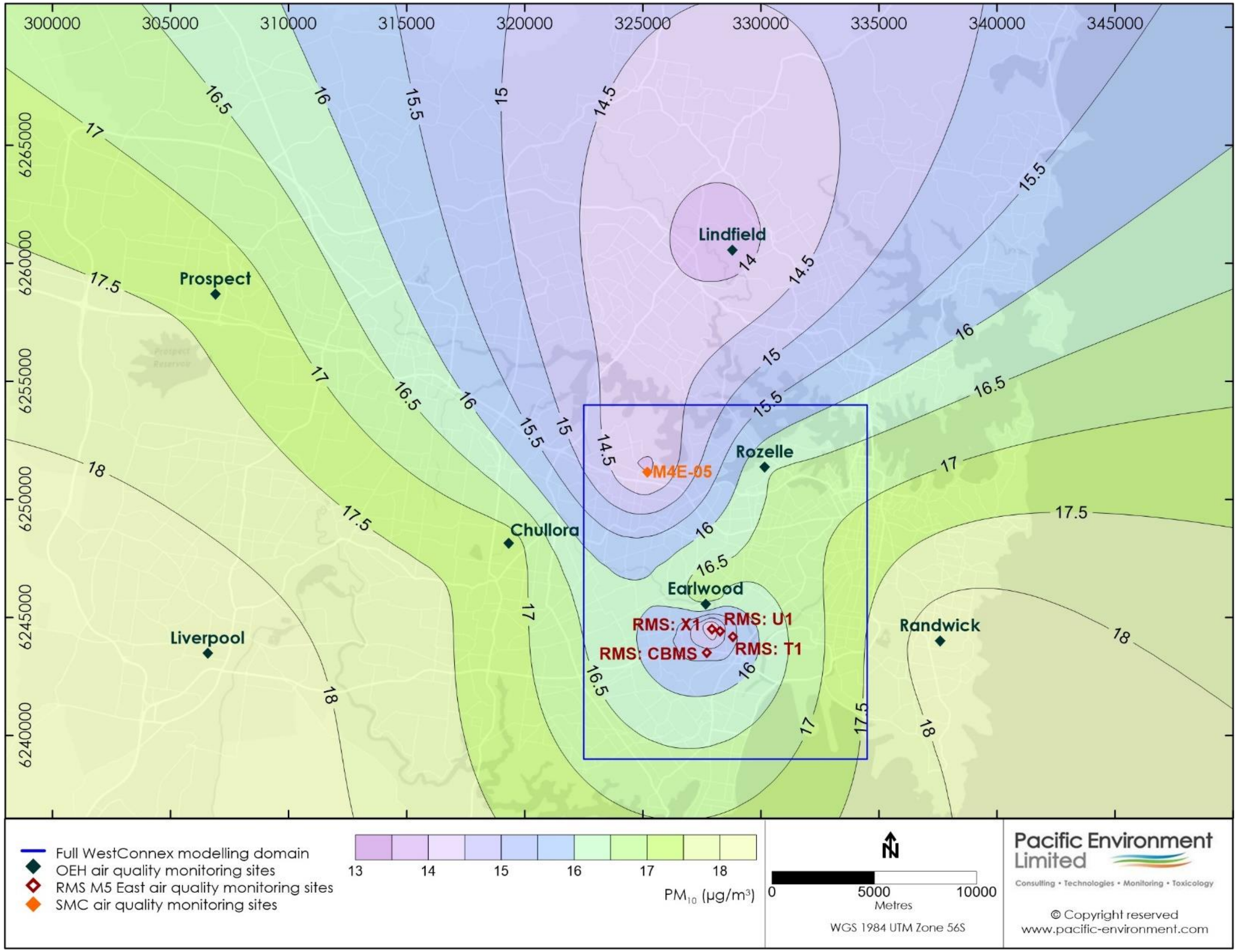

Figure F-35 **Background map for annual mean PM_{10} concentration across Sydney in 2015**

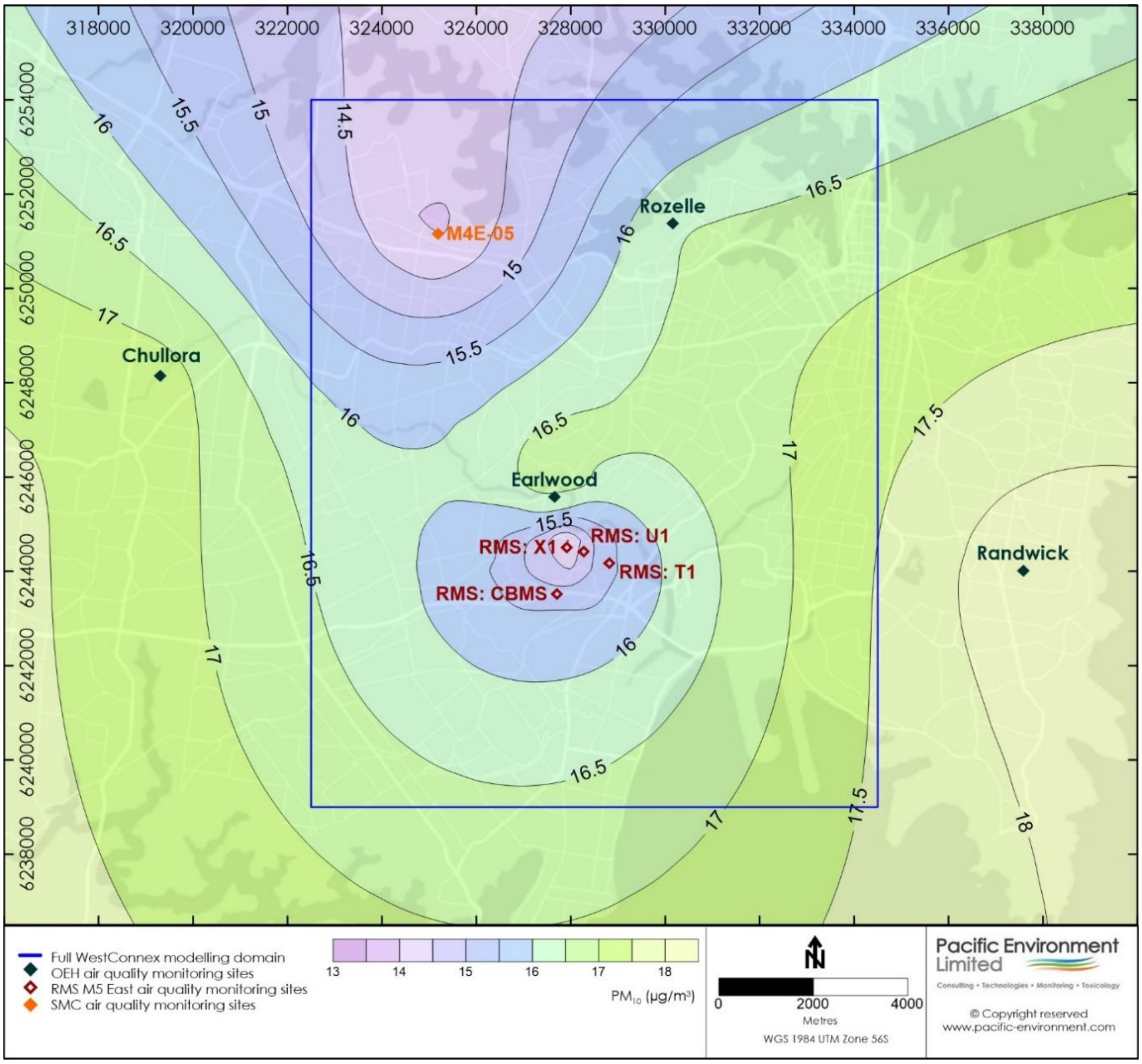

Figure F-36 Background map for annual mean PM_{10} concentration in 2015 (detail for WestConnex GRAL modelling domain)

F.8.7 PM_{10} : 24-hour mean

Figure F-37 shows the concentration profiles for 24-hour mean PM_{10} during 2015 at four OEH sites, four Roads and Maritime sites and the one SMC site. The strong similarities between the peaks and troughs in the profiles at the three sites show that the sites are characterising the same (*i.e*. regional) patterns in PM_{10}, although the absolute values vary slightly.

A synthetic 24-hour mean PM_{10} concentration profile for 2015 was also determined. This was based on the maximum concentration across the eight sites during each 24-hour time step. The final concentration profile is shown in Figure F-38.

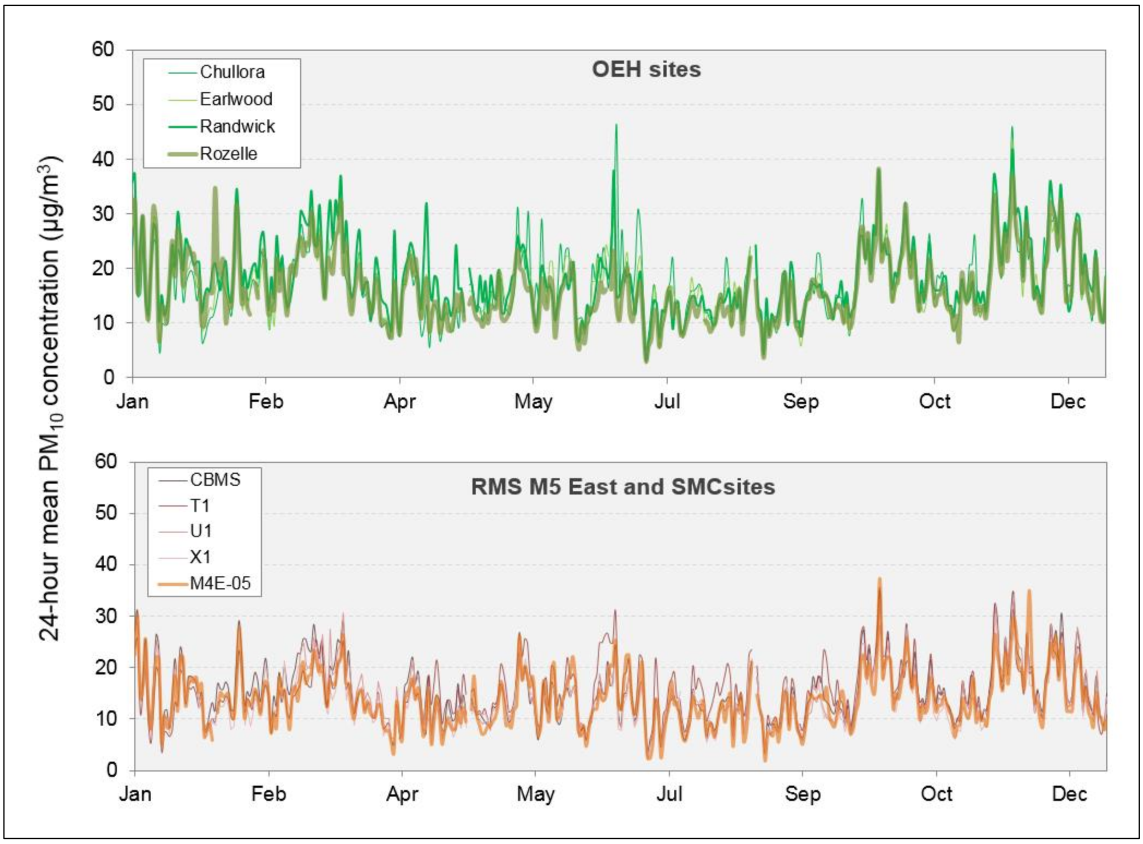

Figure F-37 **24-hour mean PM_{10} concentration at OEH, Roads and Maritime and SMC sites during 2015**

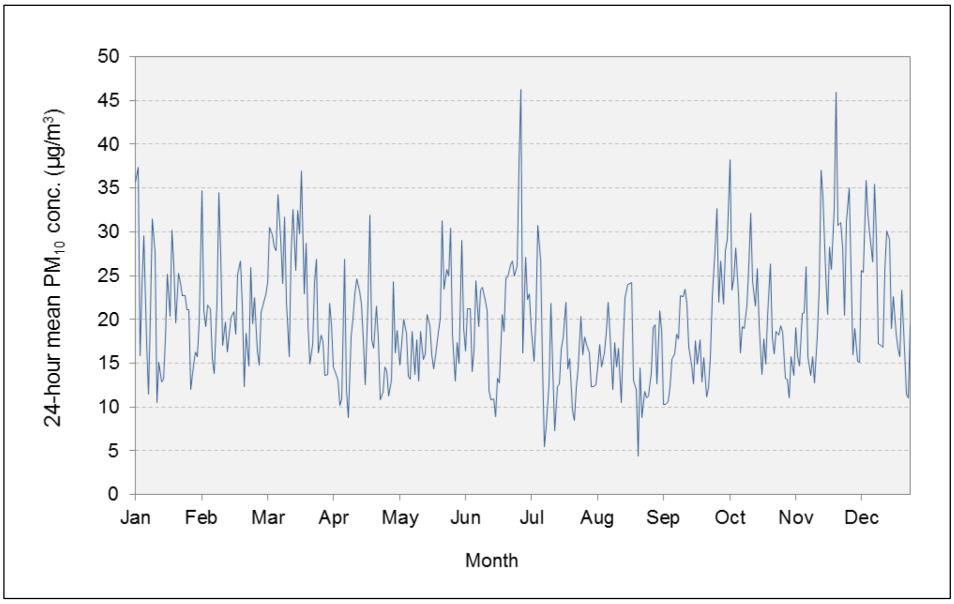

Figure F-38 **Synthetic background concentration profile for 24-hour mean PM_{10} in 2015**

F.8.8 $PM_{2.5}$: annual mean

The observations in Section F.6.5.1 render any assessment of the impacts of the M4-M5 Link project against the annual mean standard somewhat meaningless. For example, there are considerable uncertainties in the measurement of $PM_{2.5}$, given that results are instrument-dependent. There is a historical record of PM2.5 at only a small number of monitoring stations in the study area (insufficient for mapping), and the concentrations at these stations are also very close to (or above) the NSW criterion of 8 µg/m³ and above the AAQ NEPM long-term goal of 7 µg/m³. In addition, the change in annual mean $PM_{2.5}$ ($\Delta PM_{2.5}$) has emerged as a key metric for the assessment of health impacts. Consequently, rather than attempting to define a precise background concentration for annual mean $PM_{2.5}$, for the purpose of the assessment a nominal $PM_{2.5}$ concentration of 8 µg/m³ has been assumed, and any incremental changes due to the project have been assessed in relation to this concentration.

F.8.9 $PM_{2.5}$: 24-hour mean

The approach for $PM_{2.5}$ also involved the development of a synthetic concentration profile for 2015, based on the data from the OEH Chullora, Earlwood and Rozelle sites, as well as the M4 East St Lukes Park site. The concentrations from the two sites are shown in Figure F-39, and the synthetic profile in Figure F-40. The monitoring of $PM_{2.5}$ at the Rozelle site only began in March 2015.

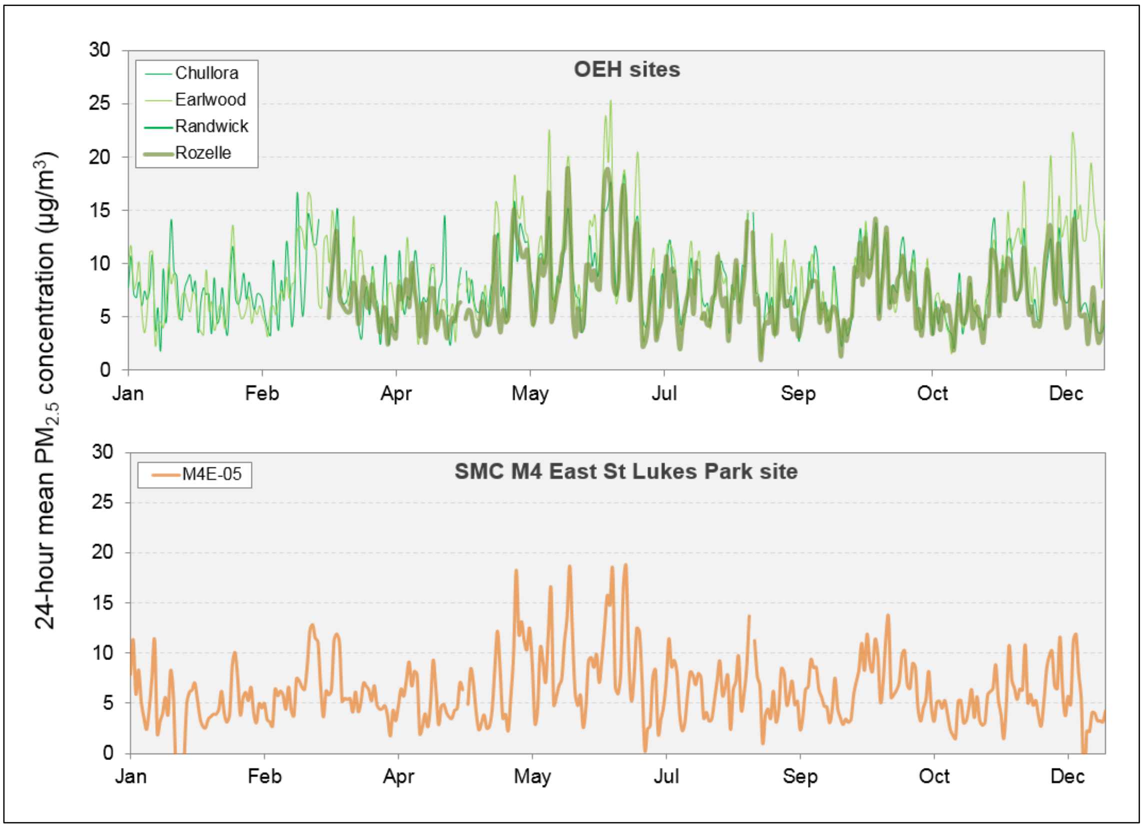

Figure F-39 24-hour mean $PM_{2.5}$ concentration at OEH and SMC sites during 2015

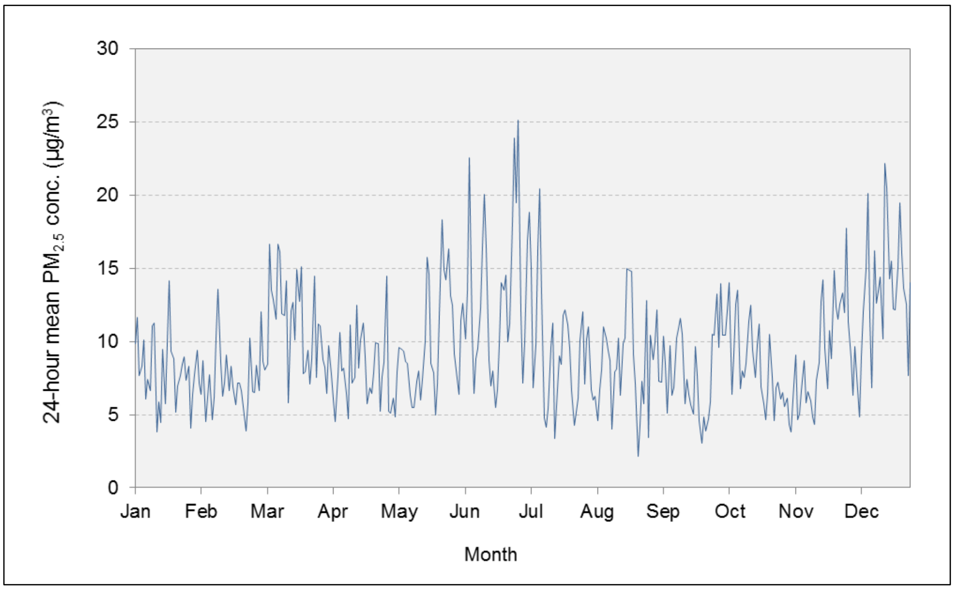

Figure F-40 Synthetic background concentration profile for 24-hour mean $PM_{2.5}$ in 2015

F.8.10 Background concentration statistics

The basic characteristics of the assumed background concentrations, and the forms of the concentrations, are provided in Table F-17. Because of their nature the synthetic profiles had slightly higher annual mean concentrations than the sites used to develop the maps. However, the synthetic profiles were only designed for the evaluation of short-term criteria.

Table F-17 Characteristics of assumed background concentrations (2015)

Pollutant/ metric	Averaging period	Form	Units	Statistical descriptors		
				Mean	Max	98th %ile
CO	1 hour	Synthetic profile	mg/m^3	0.48	3.37	1.41
	8 hours (rolling)	Synthetic profile	mg/m^3	0.46	2.27	1.21
NO_X	Annual	Map	µg/m^3	Spatially varying	-	-
	1 hour	Synthetic profile	µg/m^3	65.9	769.6	301.4
PM_{10}	Annual	Map	µg/m^3	Spatially varying	-	-
	24 hours	Synthetic profile	µg/m^3	20.0	46.2	35.8
$PM_{2.5}$	Annual	Single value	µg/m^3	8.0	-	-
	24 hours	Synthetic profile	µg/m^3	9.5	25.1	19.9

F.9 Summary of measurements at WestConnex sites

Air quality monitoring has been undertaken at a range of sites to support the WestConnex M4 East, New M5 and M4-M5 Link projects (see Table F-1). The data collected from August 2014 to February 2017 have been evaluated for this report, the aim being to assess the general representativeness of the data from the OEH and Roads and Maritime sites that were used to characterise background and roadside air quality in the WestConnex modelling domain.

For background air quality, only the OEH sites closest to the M4-M5 Link project (i.e. Chullora, Earlwood, Randwick and Rozelle) and the Roads and Maritime M5 East sites (T1, U1, X1, CBMS), were included in the evaluation. This reflected the approach used to establish background concentrations in the main air quality assessment.

The Roads and Maritime M5 East roadside sites that were included were F1 and M1.

Figure F-41 to Figure F-52 on the following pages show the time series of concentrations for several pollutants (CO, NO_X, NO_2, O_3, PM_{10} and $PM_{2.5}$) at the WestConnex monitoring sites. The figures provide the following:

- Separate information for background and roadside sites.
- The mean concentration by week. Although none of the air quality criteria relate to a one-week averaging period, this was chosen as a convenient way of representing the whole monitoring period while retaining some of the temporal detail.
- The mean, 75th percentile, 98th percentile and maximum 1-hour concentrations by month. Air quality data are not normally distributed. Most of the measurements tend to be at fairly low velues, but there is usually a tail containing higher values (i.e. short-term peaks). The percentile plots were included to show underlying patterns in the data by excluding the highest values.
- Comparisons with the measurements (shown as ranges across stations) from the OEH/Roads and Maritime background sites and Roads and Maritime roadside sites.

It is worth noting that background sites are located so as to characterise regional air quality, and therefore the data ought to show similar patterns from site to site, albeit with some variation in absolute concentrations. The data from roadside sites 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.

The results are summarised below by pollutant. Given that the various monitoring stations are located at a range of sites 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 sites.

F.9.1 Carbon monoxide

F.9.1.1 Background sites

The CO data for the background sites are presented in Figure F-41. CO is measured at the OEH Chullora and Rozelle background sites and the Roads and Maritime CSMS, T1, U1, and X1 sites. The blue shading shows range of values obtained at these sites. The WestConnex background sites are shown individually. The only WestConnex site prior to mid-2015 was the M4 East one at St Lukes Park (M4E:05). Although it was originally established for the New M5 project the site New M5:01 (St Peters Public School) was retained for the M4-M5 Link.

The mean weekly concentrations at the OEH/Roads and Maritime sites were broadly comparable to those at those at the WestConnex sites. The 98th percentile and maximum concentrations were very close to those at the WestConnex sites. It is worth observing that all the measured 1-hour CO concentrations were well below the corresponding criterion of 30 mg/m^3, and any differences between the OEH/Roads and Maritime and WestConnex data would not have had a material impact on the outcomes of the assessment for this pollutant.

F.9.1.2 Roadside sites

Figure F-42 shows the CO concentrations at the roadside sites. The green shading shows the range of values obtained at the two Roads and Maritime M5 East roadside sites (F1 and M1). Again, the individual WestConnex background sites are identified in the legend, including the two sites established specifically for the M4-M4 Link (M4-M5:01 and M4-M5:02).

The data from the two Roads and Maritime roadside sites again followed the general patterns in the WestConnex roadside data, in spite of the range of locations included. High wintertime concentrations and low summertime concentrations were well represented. Again, all the measured 1-hour concentrations were well below the criterion of 30 mg/m^3.

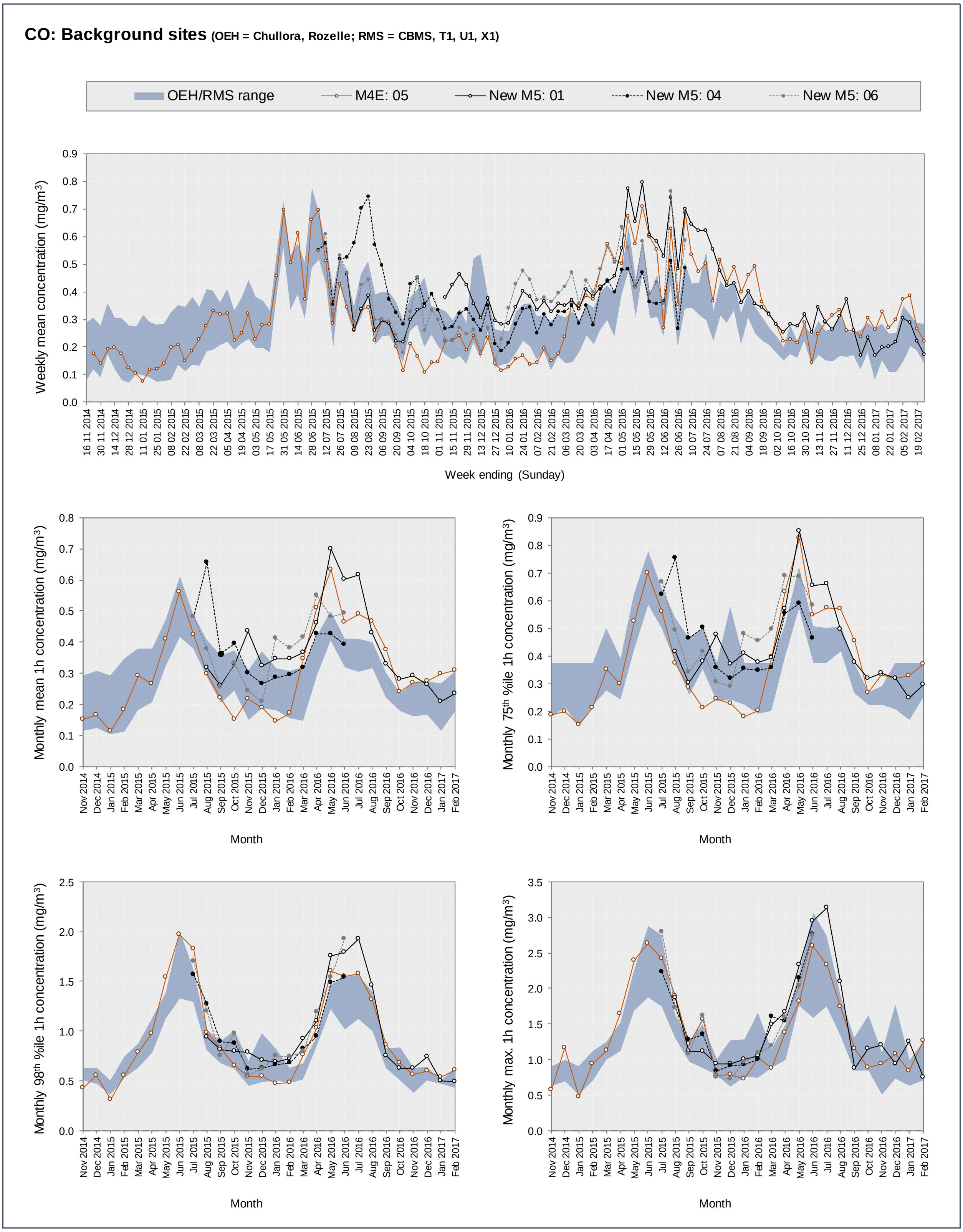

Figure F-41 CO concentrations at WestConnex background air quality monitoring sites (blue shading shows range of values at OEH/Roads and Maritime background sites)

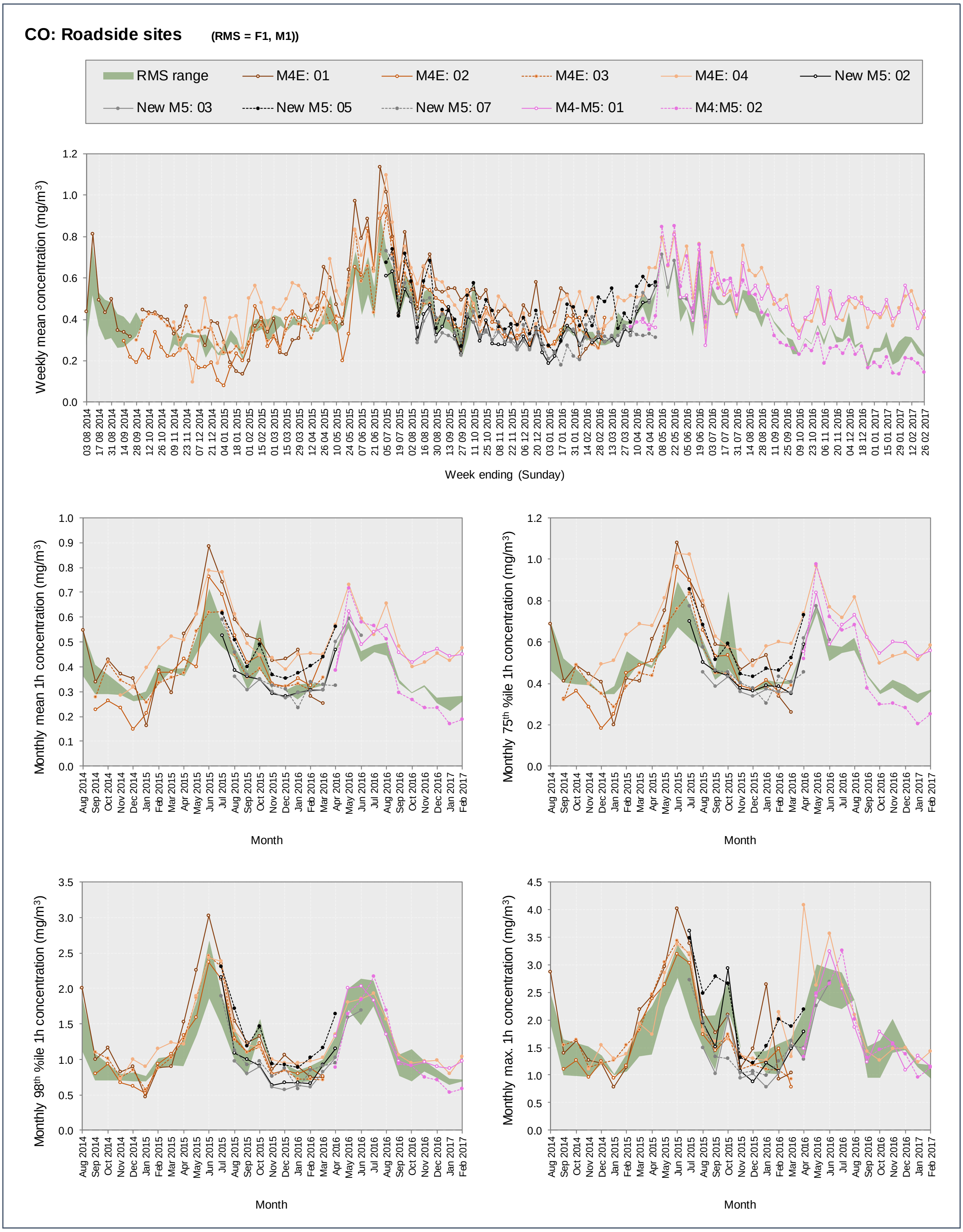

Figure F-42 **CO concentrations at WestConnex roadside air quality monitoring sites (green shading shows range of values at Roads and Maritime roadside sites)**

F.9.2 Nitrogen oxides, nitrogen dioxide and ozone

F.9.2.1 Background sites

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). These pollutants are measured at the OEH Chullora, Earlwood, Randwick and Rozelle sites, and at the Roads and Maritime CBMS, T1, U1, and X1 sites.

The NO_X, NO_2 and ozone data for background sites are presented in Figure F-43, Figure F-44 and Figure F-45 respectively. NO_X concentrations at the WestConnex sites – and in particular the upper envelope of concentrations - were well represented by the OEH/Roads and Maritime data. It is worth noting that the highest maximum and 98th percentile 1-hour NOx concentrations at the OEH/Roads and Maritime sites during the whole monitoring period were higher than the highest values at any of the WestConnex sites. The highest 1-hour average NO_X concentration at the OEH/Roads and Maritime sites was 770 µg/m^3, compared with 604 µg/m^3 at the WestConnex sites.

NO_2 concentrations at the OEH/Roads and Maritime sites also generally covered the range of values at the WestConnex sites.

In general, the results for ozone agreed well with those from the WestConnex sites. Some of the WestConnex sites had concentrations that were below the lowest values from the OEH/Roads and Maritime sites.

F.9.2.2 Roadside sites

The measurements from the roadside sites are presented in Figure F-46 to Figure F-48.

For NO_X and NO_2 there were some discrepancies between the values at the Roads and Maritime sites and those at the WestConnex sites. As noted earlier, these results will be infuenced by site type and location, and the characteristics of the WestConnex sites are more varied than those of the Roads and Maritime sites.

The highest mean NO_X concentrations were often measured at the WestConnex site M4E:04 (Concord Oval, near Parramatta Road), whereas some of the other WestConnex sites are rather too far away from roads to be properly classified as ‘roadside’ and therefore the concentrations were considerably lower.

Prior to around the start of 2016 there were some marked differences between the mean NO_2 concentrations recorded at the different WestConnex M4 East sites. Following the decommissioning of some of the M4 East sites in 2016 there was a slightly better general agreement between the Roads and Maritime and WestConnex data.

Ozone is not measured at any of the Roads and Maritime M5 East sites. It can be seen from Figure F-48 that very similar patterns in ozone concentration were recorded at the various WestConnex sites.

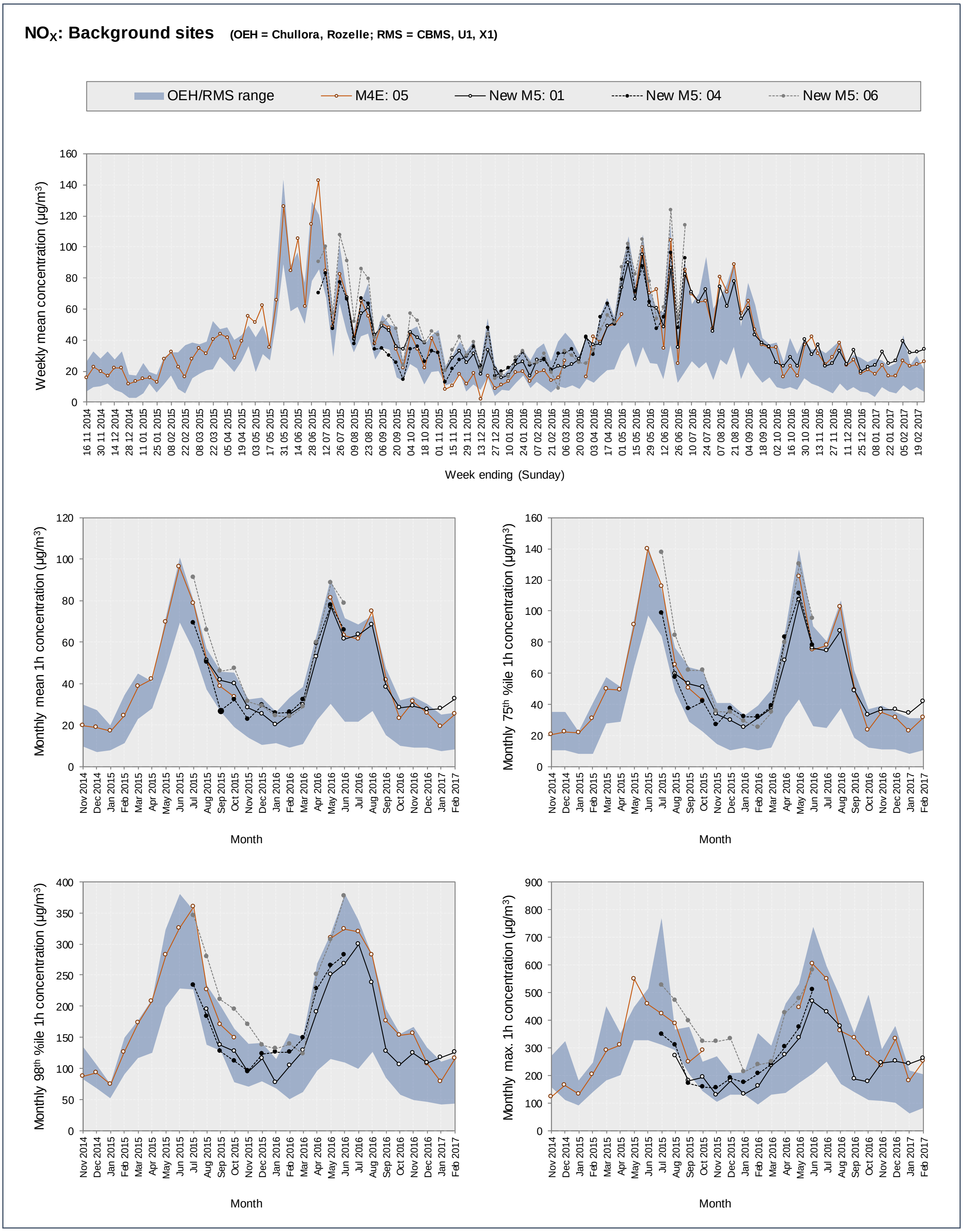

Figure F-43 NOx concentrations at WestConnex background air quality monitoring sites (blue shading shows range of values at OEH/Roads and Maritime background sites)

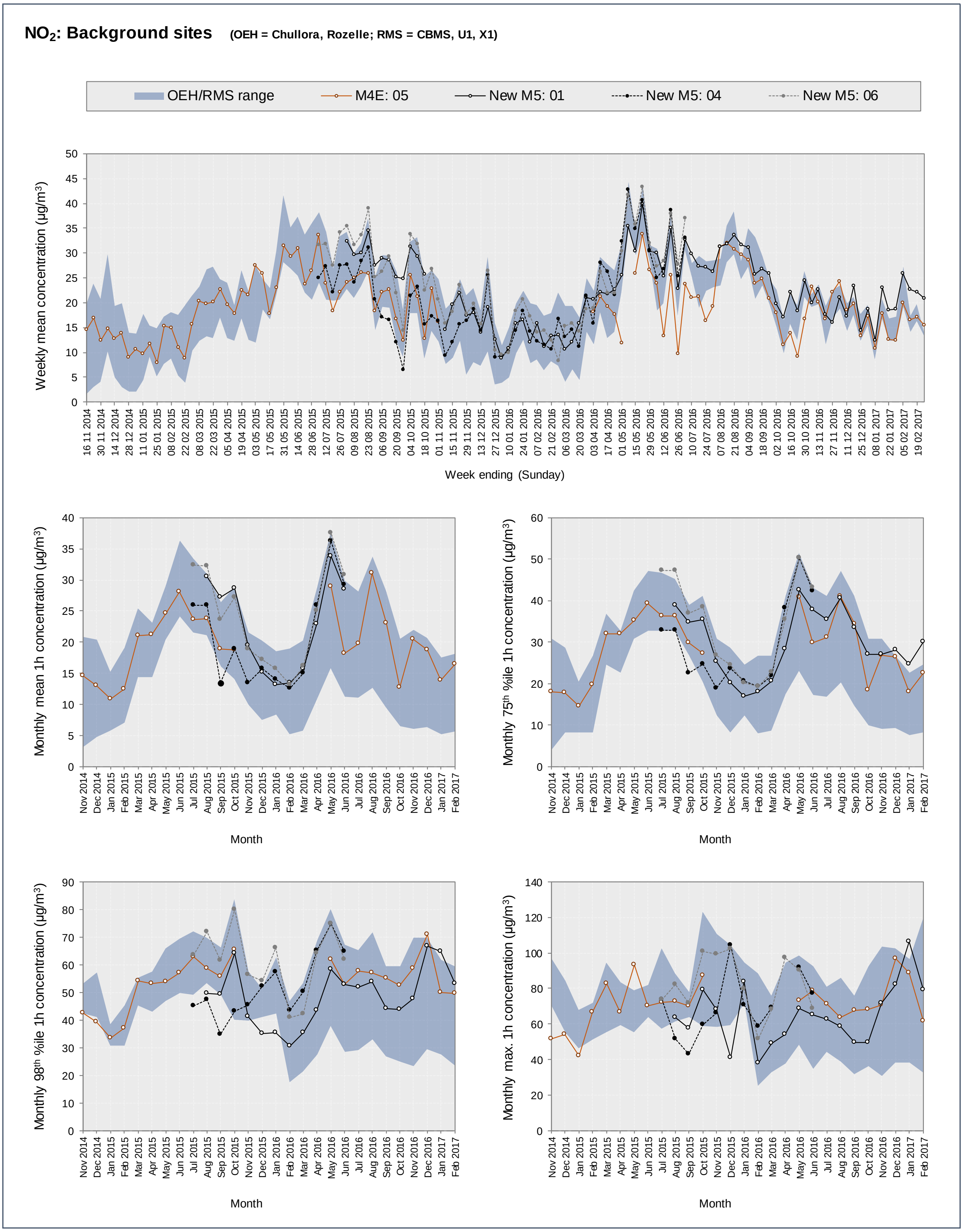

Figure F-44 NO₂ concentrations at WestConnex background air quality monitoring sites (blue shading shows range of values at OEH/Roads and Maritime background sites)

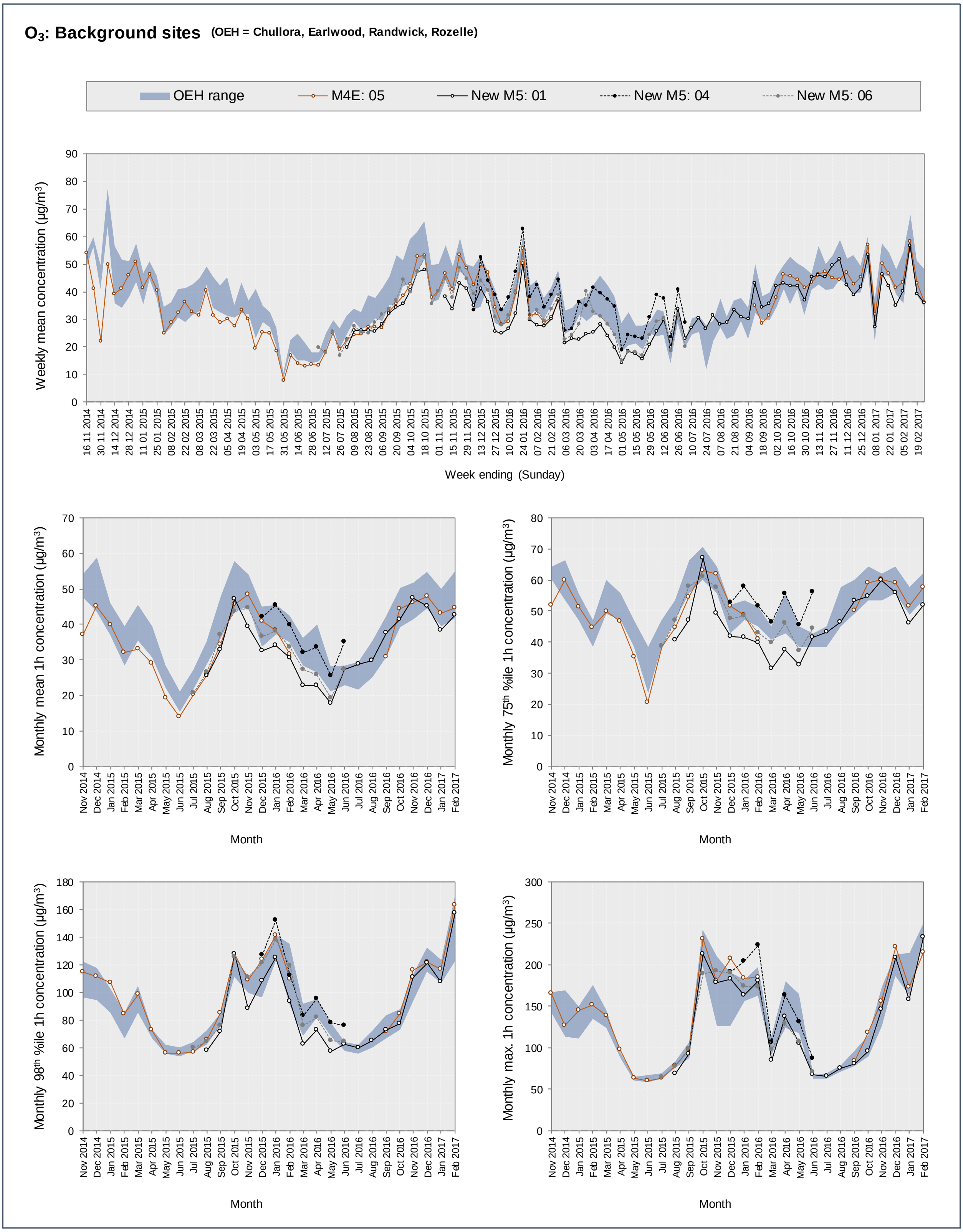

Figure F-45 **O_3 concentrations at WestConnex background air quality monitoring sites (blue shading shows range of values at OEH background sites)**

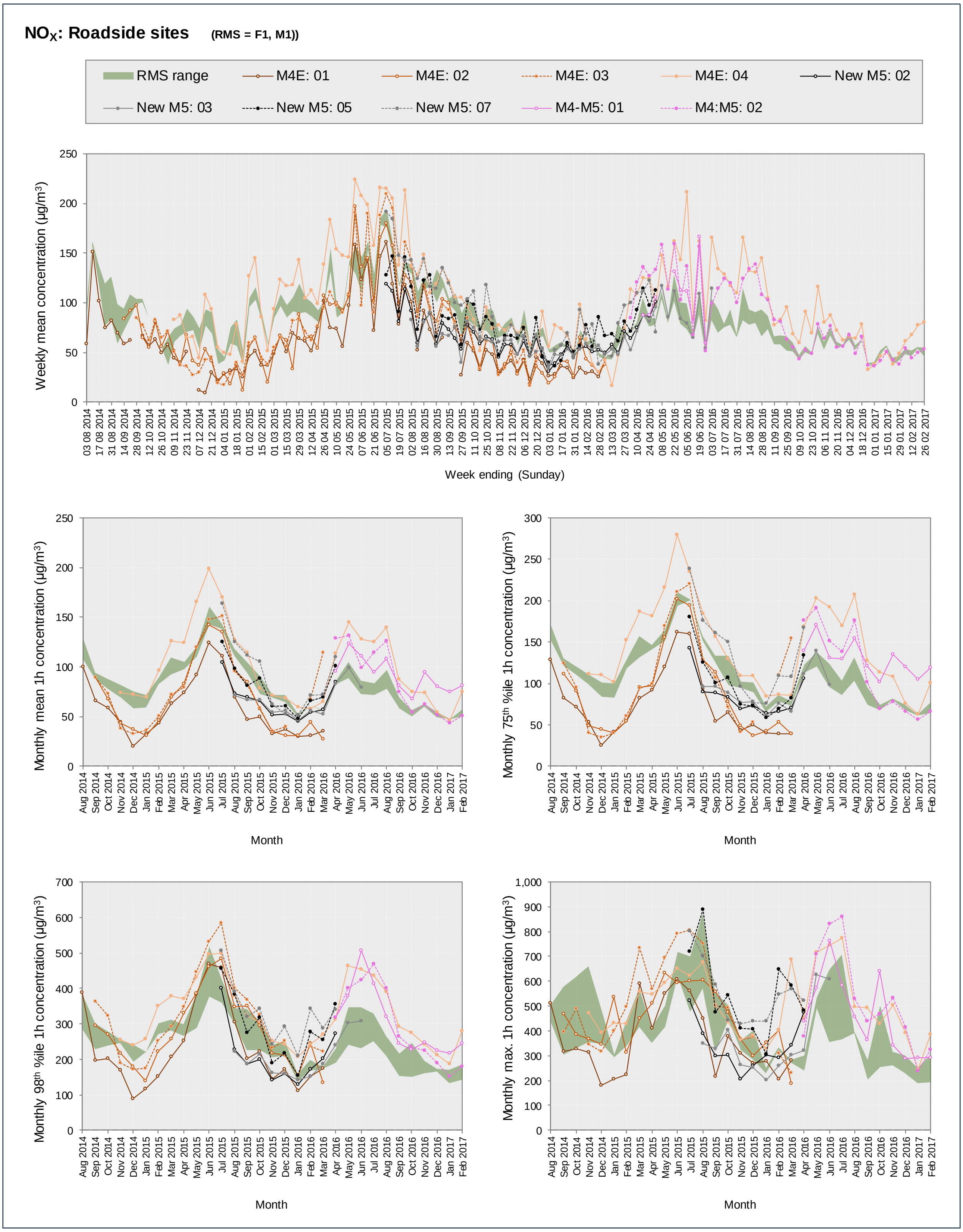

Figure F-46 NOx concentrations at WestConnex roadside air quality monitoring sites (green shading shows range of values at Roads and Maritime roadside sites)

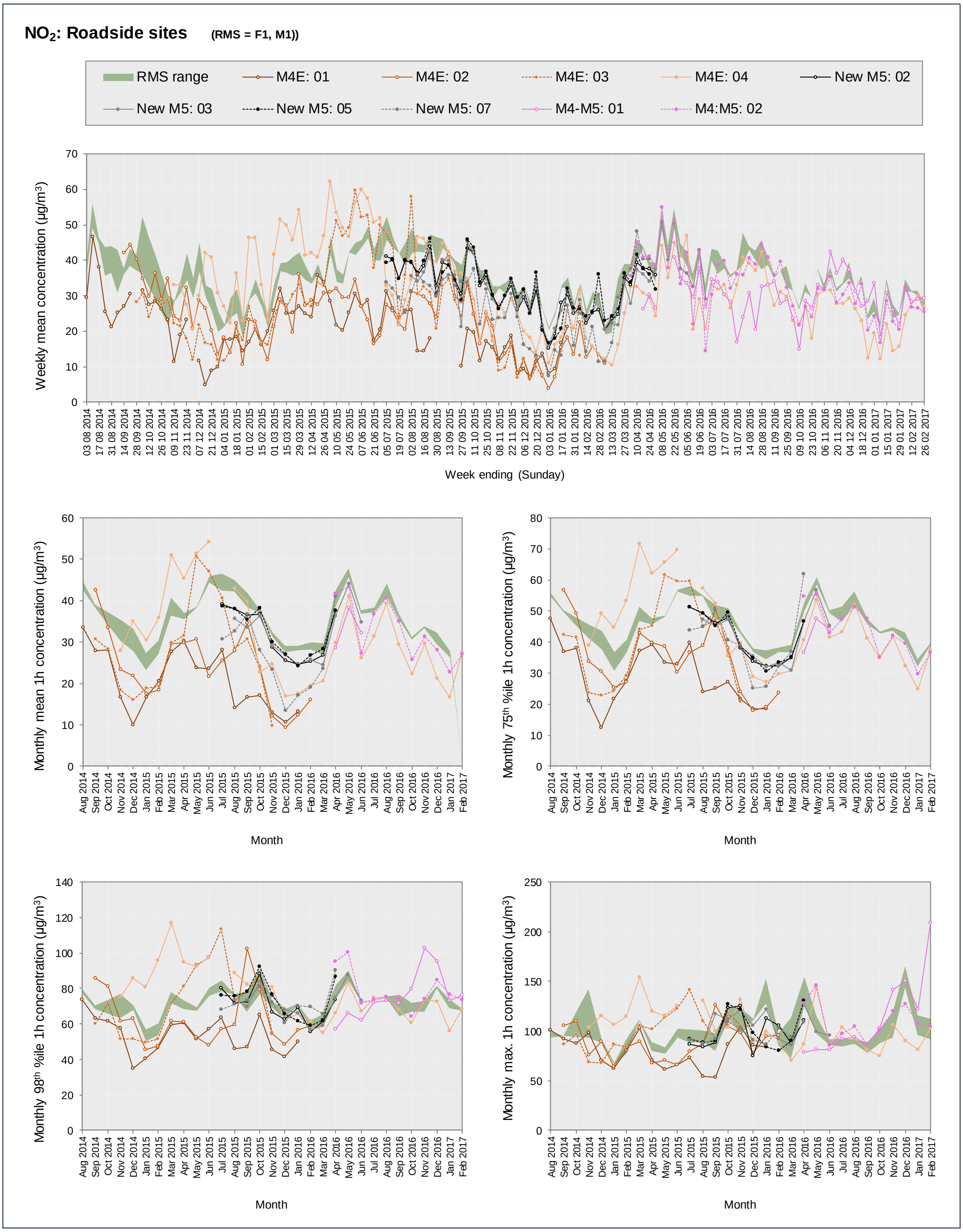

Figure F-47 NO_2 concentrations at WestConnex roadside air quality monitoring sites (green shading shows range of values at Roads and Maritime roadside sites)

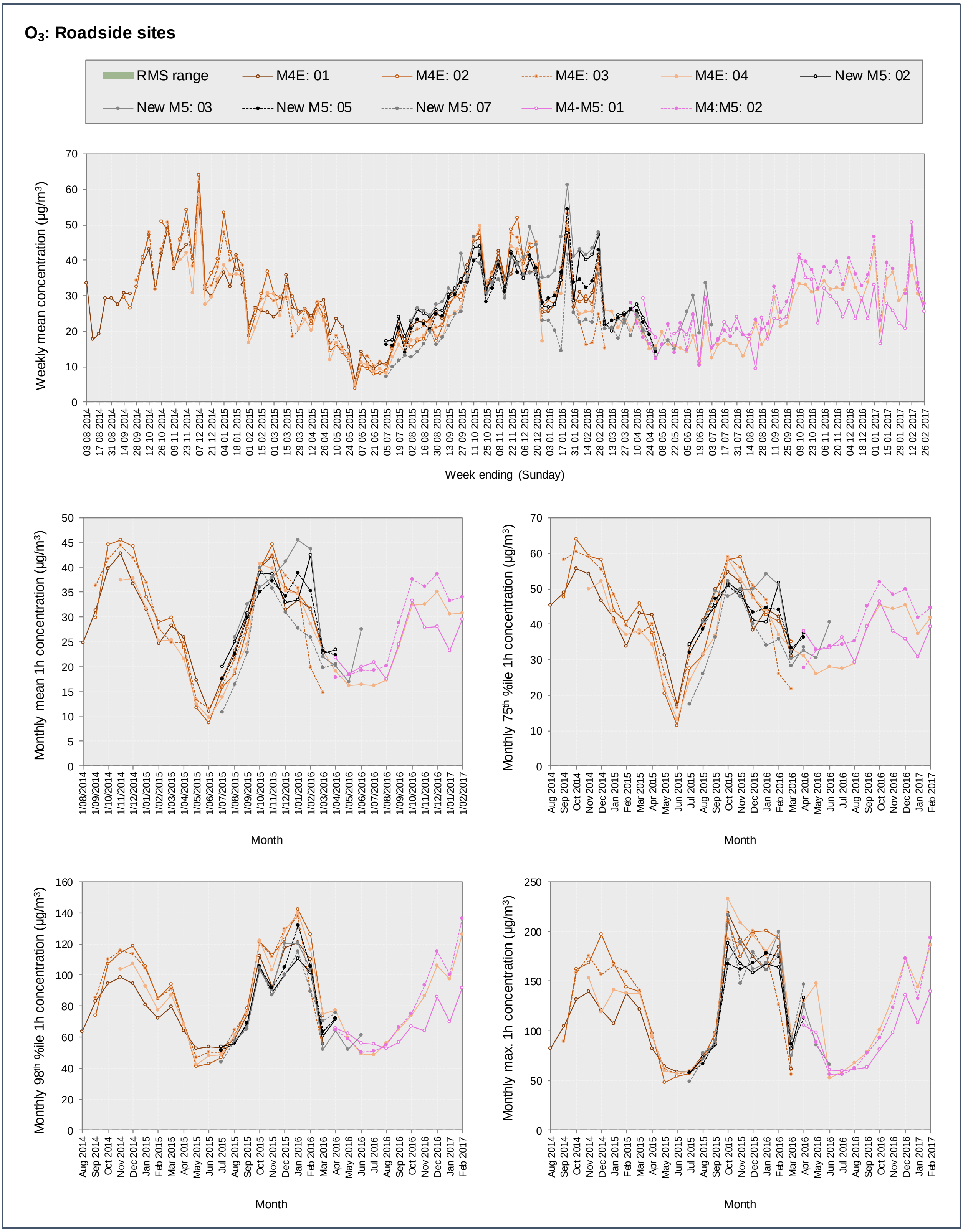

Figure F-48 **O_3 concentrations at WestConnex roadside air quality monitoring sites (ozone is not measured at Roads and Maritime roadside sites)**

F.9.3 PM_{10} and $PM_{2.5}$

F.9.3.1 Background sites

The PM_{10} and $PM_{2.5}$ data for the background sites are presented in Figure F-49 and Figure F-50. As noted in section F.3, the variation in the results from different sites will be influenced to some extent by the differences in measurement technique.

The PM_{10} data from the OEH/Roads and Maritime background monitoring sites were broadly representative of the WestConnex M4 East background site. However, prior to 2016 (during the winter of 2015) the concentrations at the New M5 sites were above the upper envelope of the values from the OEH/Roads and Maritime sites. During 2016 the concentrations at all WestConnex sites had a better level of agreement, and were near the upper limit of the range of values at the OEH/Roads and Maritime sites. This effect can be seen clearly in, for example, the 98th percentile plots for PM_{10} and $PM_{2.5}$. In the absence of a longer-term data set it is unclear whether the high values during 2015 at the New M5 sites was a specific winter-time phenomenon in the area.

A similar pattern is evident in the $PM_{2.5}$ data; that is, high values at the New M5 sites during 2015, and a general convergence of concentrations across all sites during 2016.

F.9.3.2 Roadside sites

The PM_{10} and $PM_{2.5}$ data for roadside sites are shown in Figure F-51 and Figure F-52.

The PM_{10} concentrations at the WestConnex sites covered a wider range of values than those at the Roads and Maritime sites. Again, concentrations were markedly higher at some of the New M5 sites (notably New M5:02, New M5:03 and New M5:07) than at the the other sites.

$PM_{2.5}$ is not measured at any of the Roads and Maritime M5 East sites. Concentrations varied across the WestConnex sites, and were again distinctly higher at some of the New M5 sites.

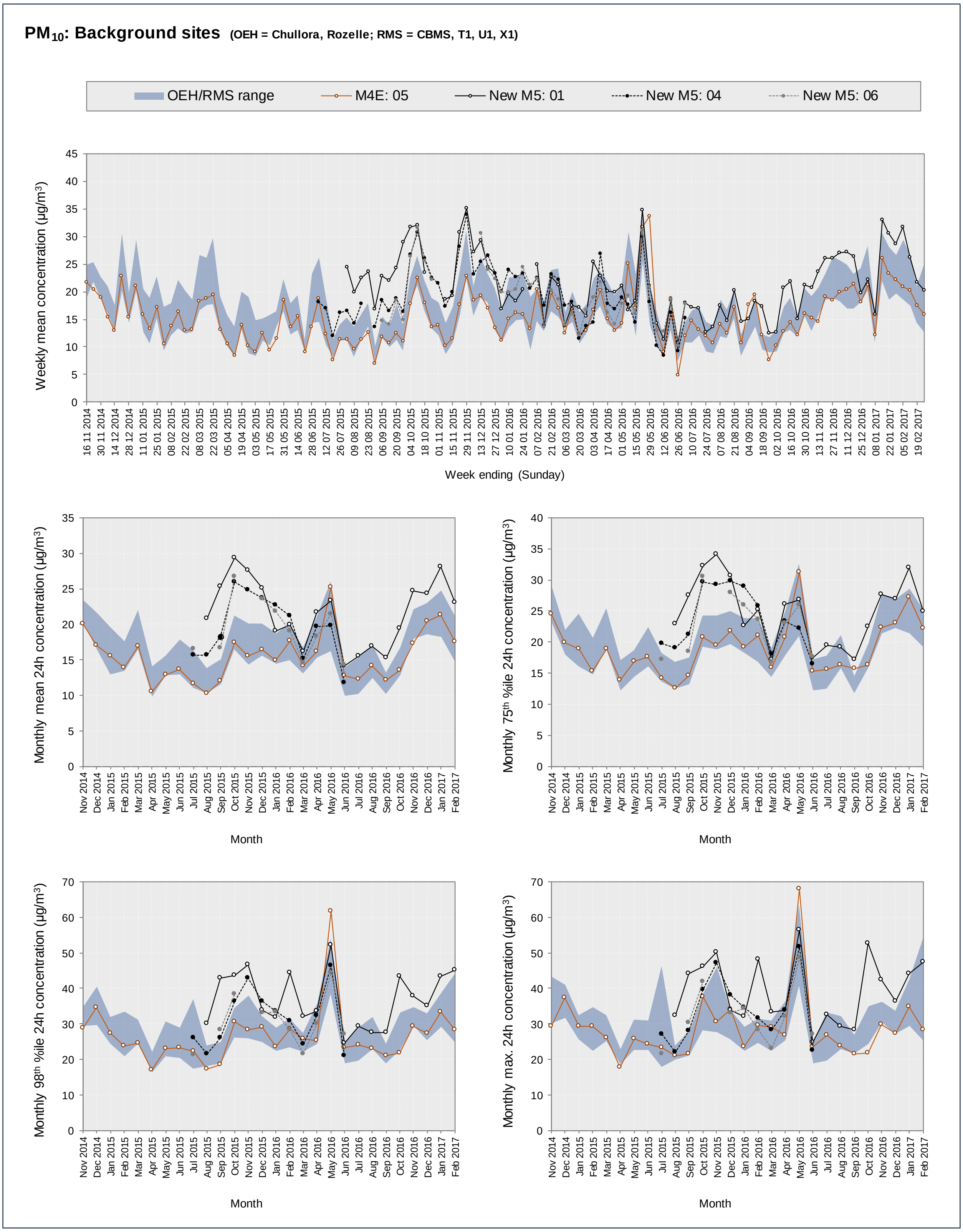

Figure F-49 **PM_{10} concentrations at WestConnex background air quality monitoring sites (blue shading shows range of values at OEH/Roads and Maritime background sites)**

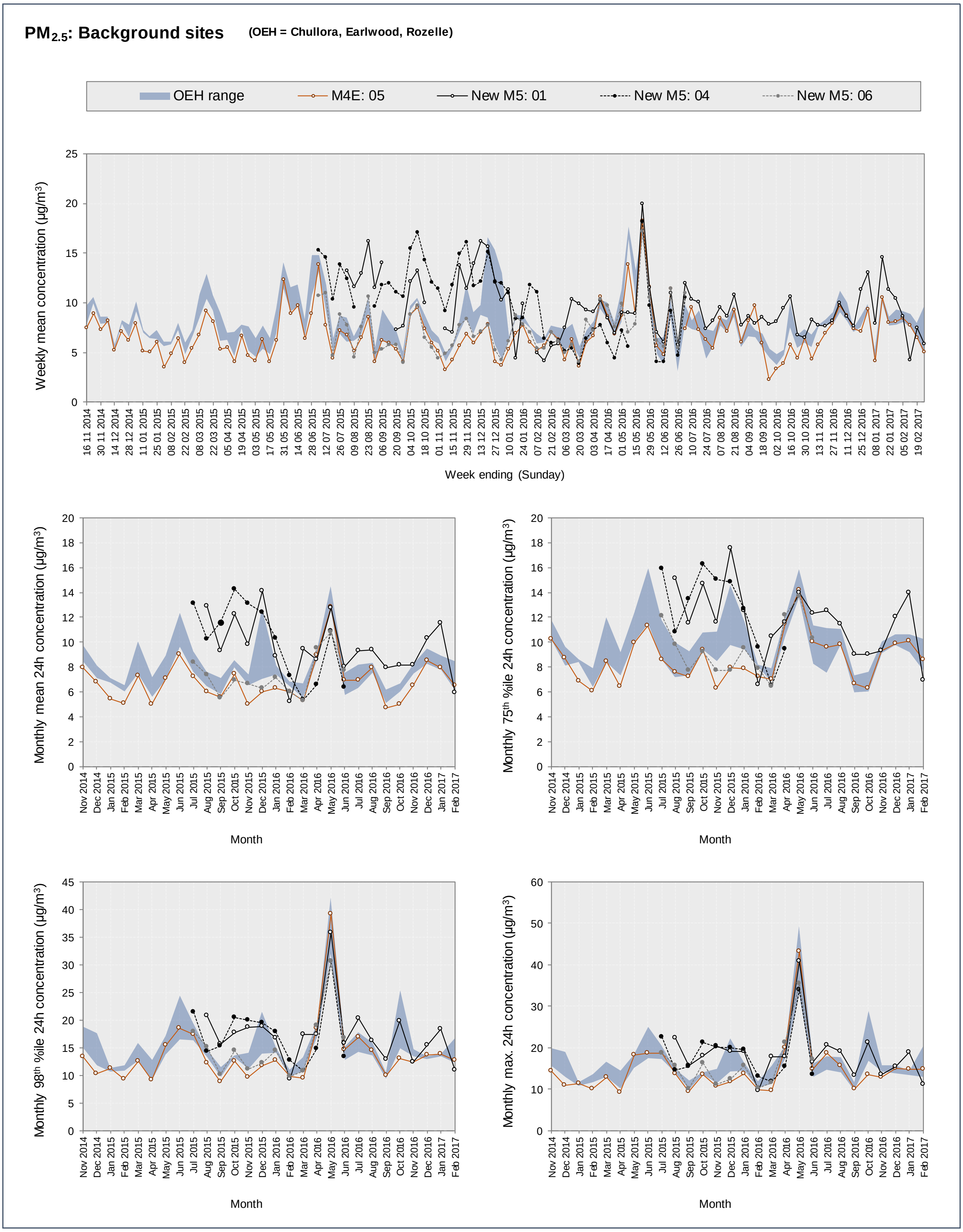

Figure F-50 PM$_{2.5}$ concentrations at WestConnex background air quality monitoring sites (blue shading shows range of values at OEH background sites)

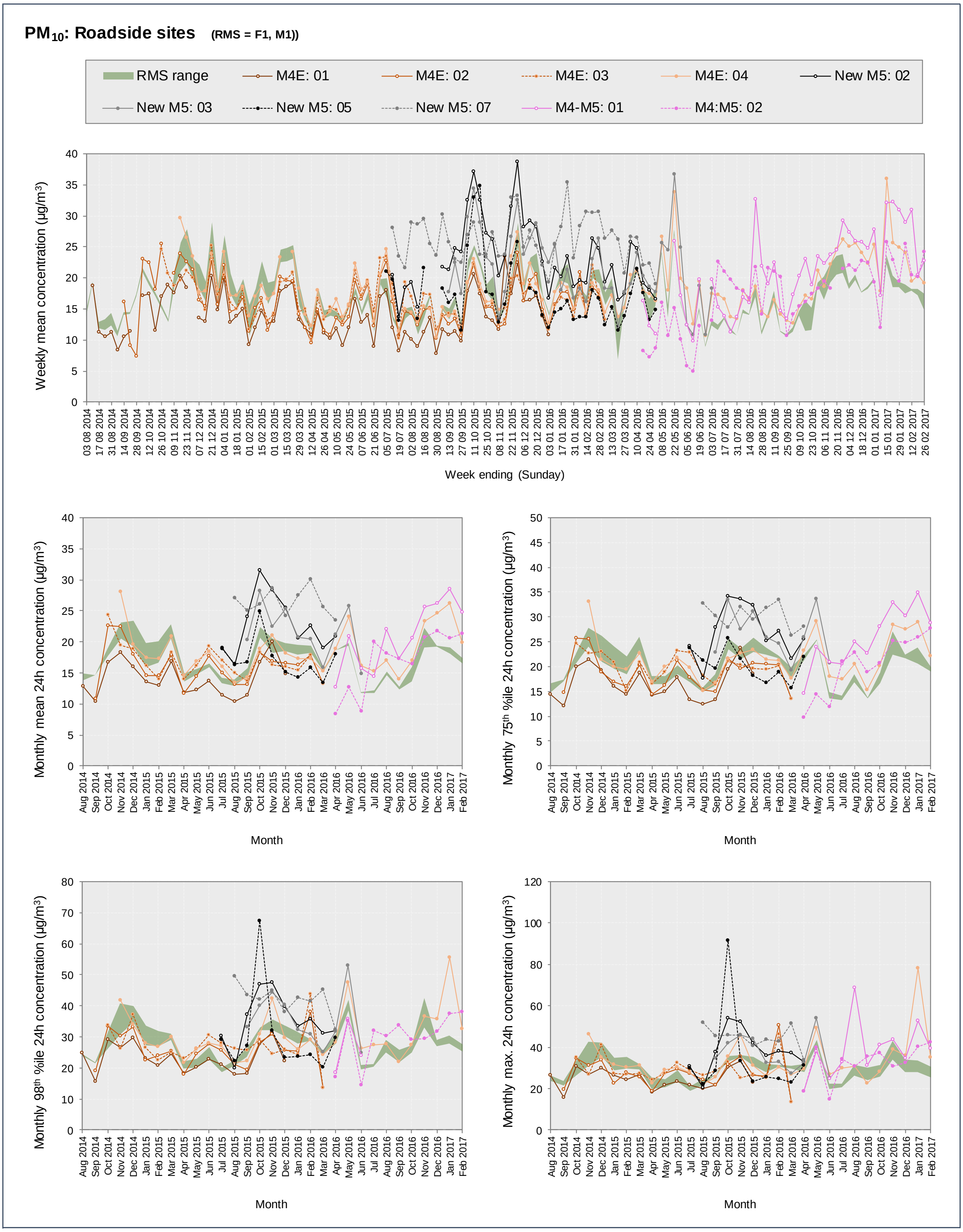

Figure F-51 **PM_{10} concentrations at WestConnex roadside air quality monitoring sites (green shading shows range of values at Roads and Maritime roadside sites)**

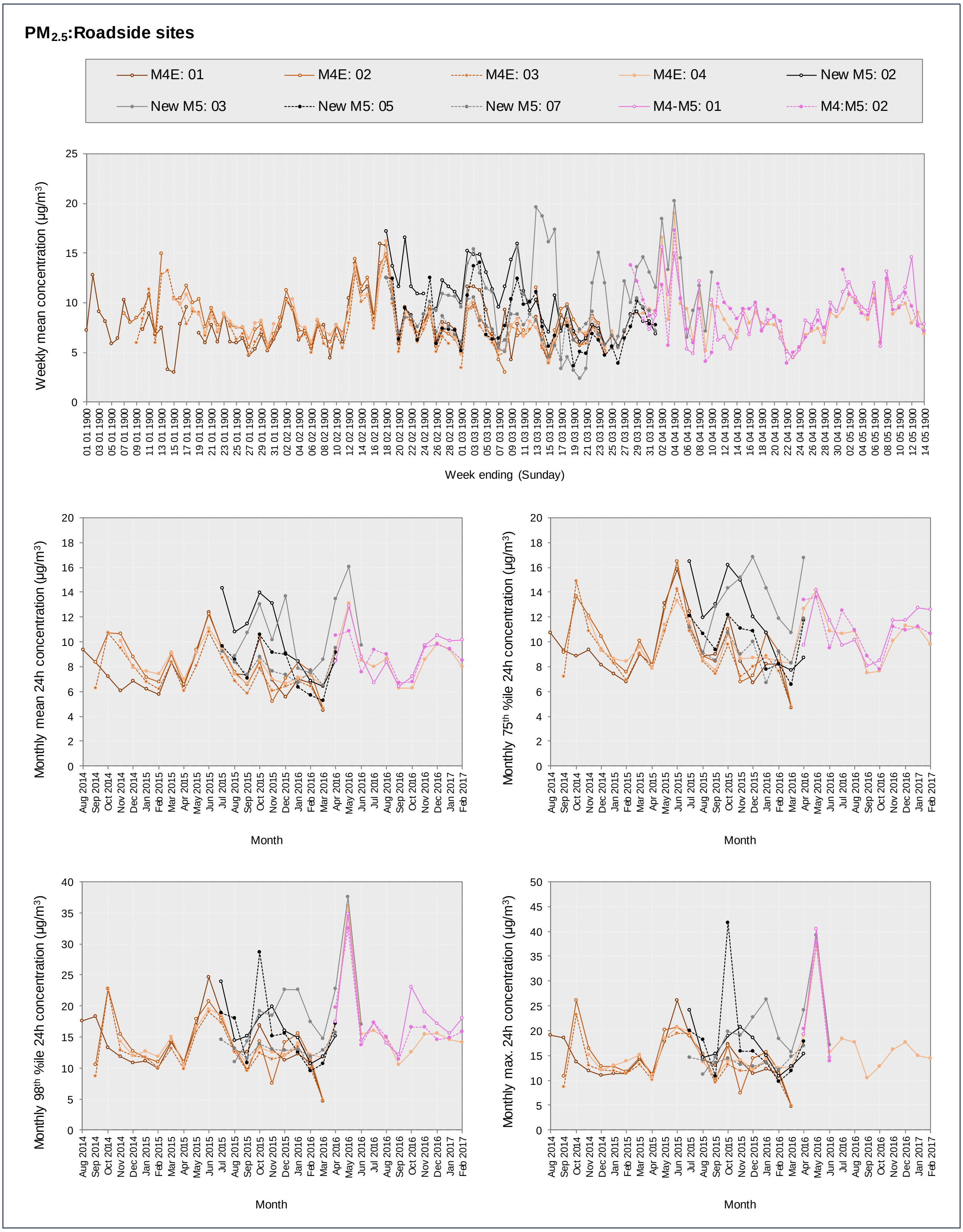

Figure F-52 **$PM_{2.5}$ concentrations at WestConnex roadside air quality monitoring sites ($PM_{2.5}$ is not measured at Roads and Maritime roadside sites)**

Annexure G- NO_X-to-NO_2 conversion

G.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 M4-M5 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 M4-M5 Link assessment, a review of the literature and data was undertaken. 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 M4-M5 Link project. This analysis was used to estimate NO_X-to-NO_2 conversion methods for the specific purpose of the M4-M5 Link assessment, and more widely for complex road projects in Sydney.

G.2 Guidance on NO_2 estimation

G.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.

G.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).

G.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.

G.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(09) (Defra, 2009). 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.

G.3 Estimation methods

G.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 G1

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

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 G2

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

Equation G3

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

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 G4

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

G.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.

G.3.3 Total conversion of NO to NO_2

G.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 G5

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

Equation G6

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

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.

G.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.

G.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.

G.3.4 NO_2/NO_X ratio methods

G.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 G7

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

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 then updated in 2007[3]. In 2009 Defra published a revised approach for predicting NO_2 from NO_X concentrations at roadside sites, which 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.

G.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 M4-M5 Link assessment.

[3] http://laqm1.defra.gov.uk/review/tools/monitoring/calculator.php

G.3.5 Reactant-limited methods

G.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 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.

G.3.5.2 Implementation in NSW Approved Methods

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

Equation G8

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

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 G8.

- 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 $\mathbf{[NO_2]_{total}}$ is then calculated for every hour of the dispersion model simulation by substituting the hourly values of $\mathbf{[NO_X]_{road}}$, $\mathbf{[NO_2]_{background}}$ and $\mathbf{[O_3]_{background}}$ into Equation G8.

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 G9

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

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.

G.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).

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

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

G.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.

G.4 Development of empirical conversion methods for Sydney

G.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 sites across Sydney, as described in Annexure F. A substantial amount of data from these sites was used to develop empirical NO_X-to-NO_2 conversion functions for the WestConnex M4 East and New M5 projects (Boulter et al., 2015; Manansala et al., 2015), with separate approaches for annual mean and 1-hour mean NO_2. These functions were also used for the M4-M5 Link assessment, although the supporting data were updated. 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 for the WestConnex projects will also be applicable to other complex road projects in the airshed.

The methods that were developed are described below.

G.4.2 Methods used in the project assessment

G.4.2.1 Annual mean concentrations

Figure G-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 $\mathbf{[NO_X]_{total}}$ and $\mathbf{[NO_2]_{total}}$. 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.

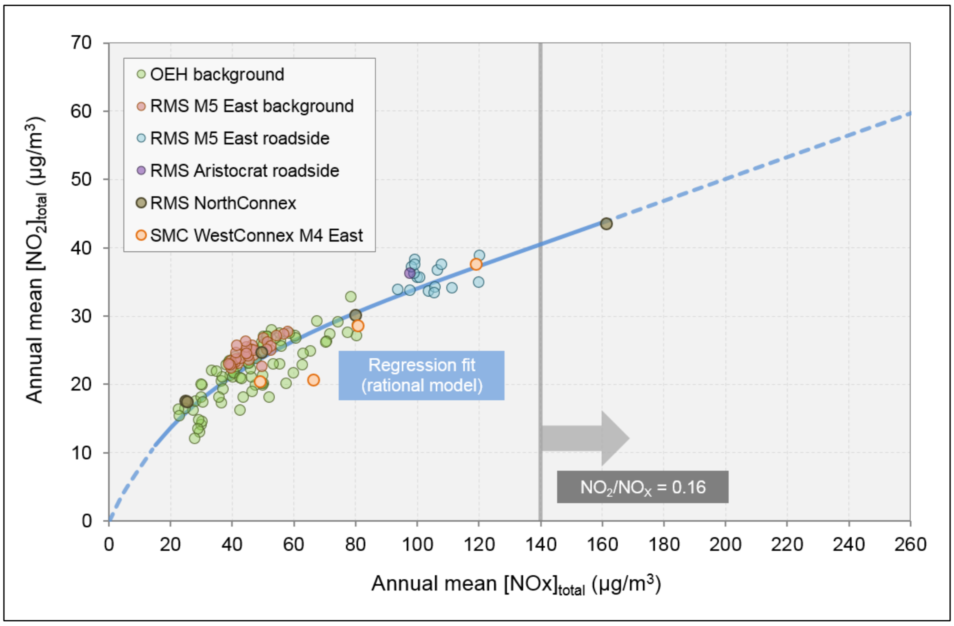

Figure G-1 Annual mean NO_X and NO_2 concentrations at monitoring sites in Sydney

The solid blue in Figure G-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 M4-M5 Link assessment, is described by the following equations:

For $[NO_X]_{total}$ values less than or equal to 140 μg/m^3:

Equation G10

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

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/m^3 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 G11

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

The work presented by Boulter and Bennett (2015) suggests that an annual average value for f-NO_2 of 0.16 is an overestimate for the 2015 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 G13

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

Where both $[NO_2]_{total}$ and $[NO_2]_{background}$ were determined using Equations G10 and G11.

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 $\mu g/m^3$. However, a very high annual mean NO_X concentration - more than 260 $\mu g/m^3$ - would be required. This is much higher than the measurements in Sydney have yielded to date.

G.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 sites – including the M4-M5 Link sites - in Figure G-2 to Figure G-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 site 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 M4-M5 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:

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

  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.

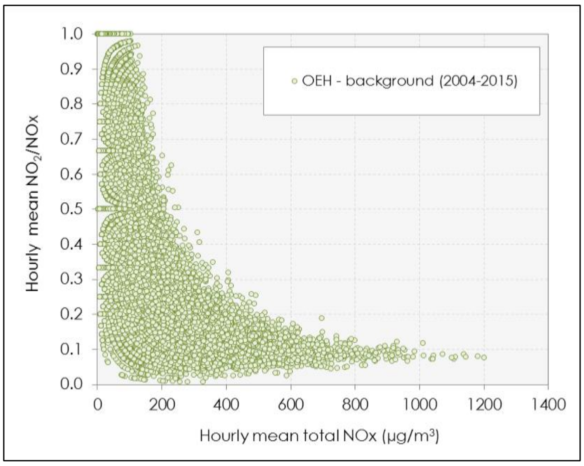

Figure G-2 **Hourly mean NO_2/NO_X and NO_X at OEH background sites**

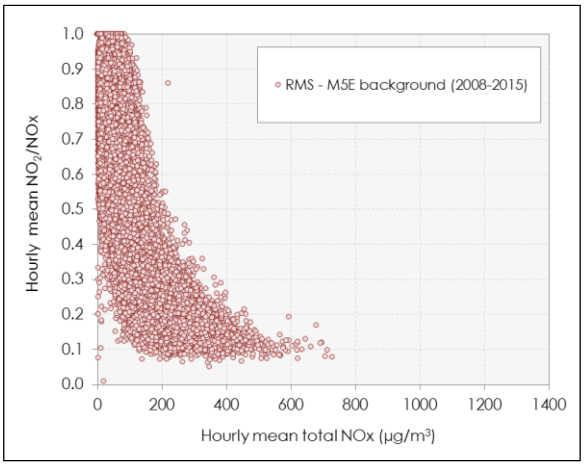

Figure G-3 **Hourly mean NO_2/NO_X and NO_X at Roads and Maritime M5 East background sites**

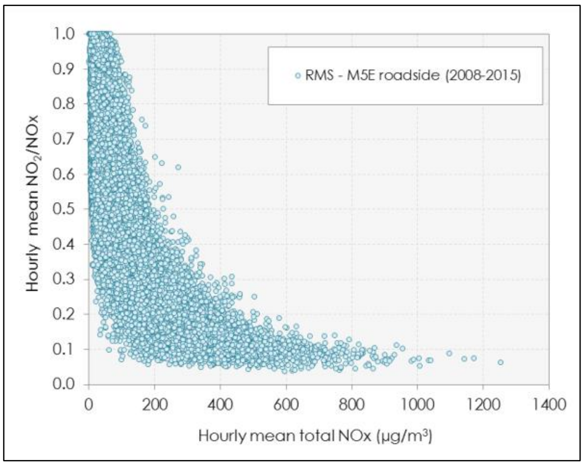

Figure G-4 **Hourly mean NO_2/NO_X and NO_X at Roads and Maritime M5 East roadside sites**

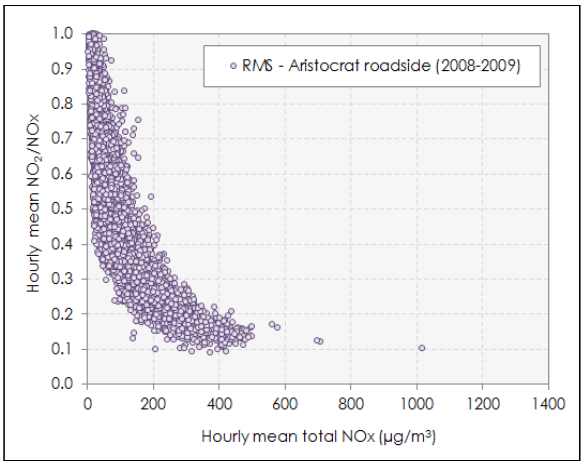

Figure G-5 **Hourly mean NO_2/NO_X and NO_X at Roads and Maritime Aristocrat (roadside) site**

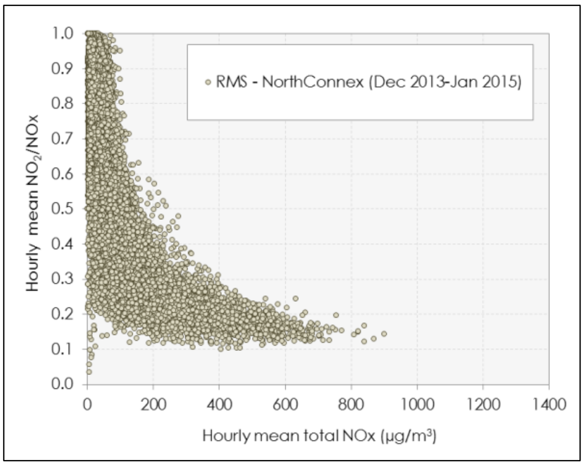

Figure G-6 **Hourly mean NO_2/NO_X and NO_X at Roads and Maritime NorthConnex sites**

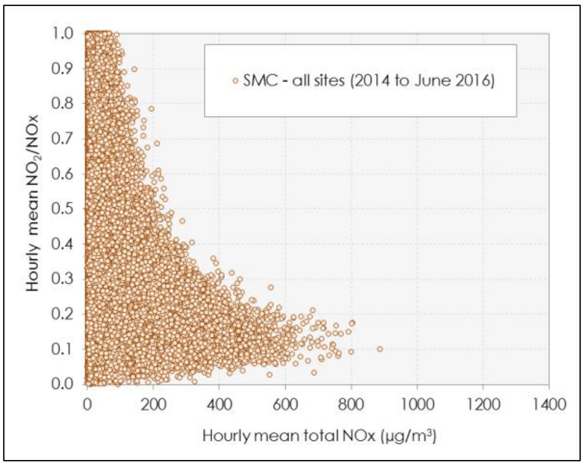

Figure G-7 **Hourly mean NO_2/NO_X and NO_X at SMC sites**

The data from all Sydney monitoring sites between 2004 and 2015 (and in the case of the WestConnex sites, June 2016) – a total of more than 1.1 million data points – are shown in Figure G-8, and the steps described above have been applied. Around 20% of the data points were for roadside monitoring sites.

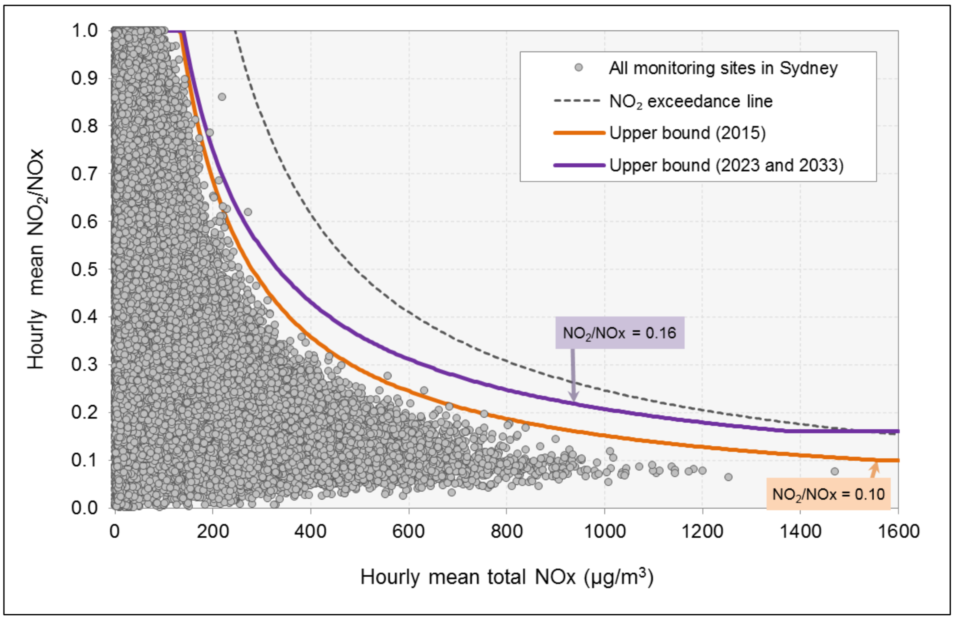

Figure G-8 **Hourly mean NO_X and NO_2/NO_X ratio for monitoring sites at various locations in Sydney**

The solid orange line in Figure G-8 represents the outer envelope of all data points, and approximates to a conservative upper bound estimate for 2015, or in other words the maximum NO_2/NO_X ratio for a given NO_X concentration in 2015. This is described by the following equations:

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

Equation G14

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

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

Equation G15

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

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 G16

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

The dashed red line in Figure G-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 G-8 that an exceedance of the 1-hour criterion for NO_2 cannot be predicted using the upper bound curve for 2015 across a wide range of NO_X concentrations.

For future years it is possible that the upper bound estimate for 2015 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 2031 (Boulter and Bennett, 2015). 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 2021 and 2031 scenarios, and a corresponding (conservative) upper bound function is shown as a purple line in Figure G-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 G14 applies.

For $\mathbf{[NO_X]_{total}}$ values greater than 140 µg/m^3 and less than or equal to 1,375 µg/m^3, Equation 15 applies with the following coefficients:

a = 52

b = -0.80

For $\mathbf{[NO_X]_{total}}$ values greater than 1,375 µg/m^3 a cut-off for the NO_2/NO_X ratio of 0.16 has been assumed. That is:

Equation G17

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

Even this assumption would only result in an exceedance of the NO_2 criterion at very high NO_X concentrations (above around 1,500 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 G-8 would be around 1,200 µg/m^3.

Given that the background NO_X concentrations developed for the M4-M5 Link assessment were also slightly conservative (see Annexure G), it is likely that there will be a conservative overall estimate of NO_2 using this approach.

G.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).

G.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 2015) were compared with some alternative approaches (Boulter et al., 2015). The results of these comparisons for both annual mean and 1-hour mean NO_2 concentration are given below.

G.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 by Boulter et al. (2015) 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 G-9.

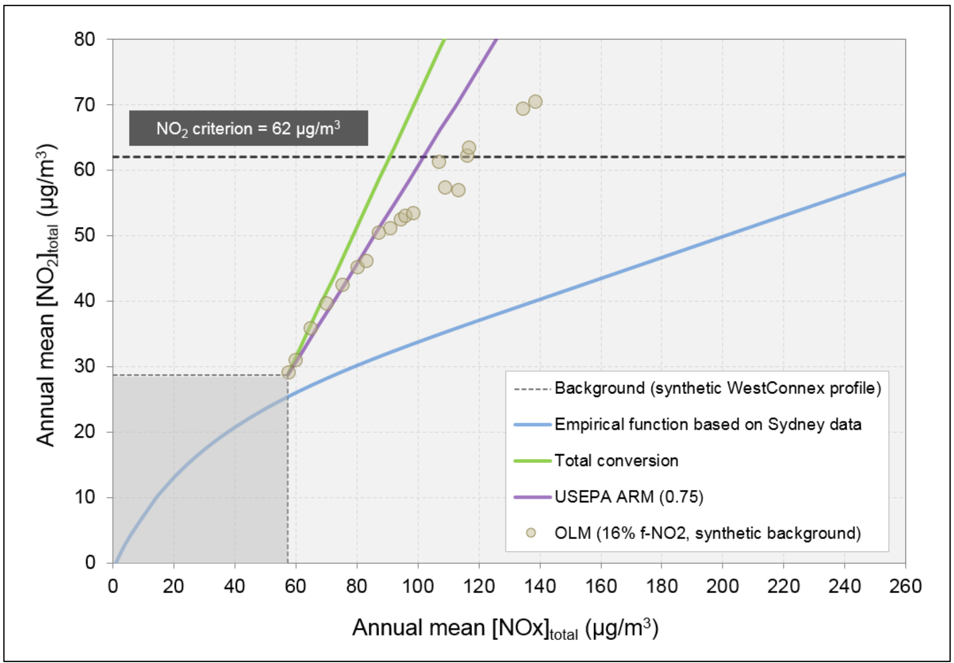

Figure G-9 Comparison of methods for calculating annual mean NO_2 concentration

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/m^3 when the total NO_X concentration was around 90 µg/m^3. 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 M4-M5 Link assessment.

G.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 G-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.

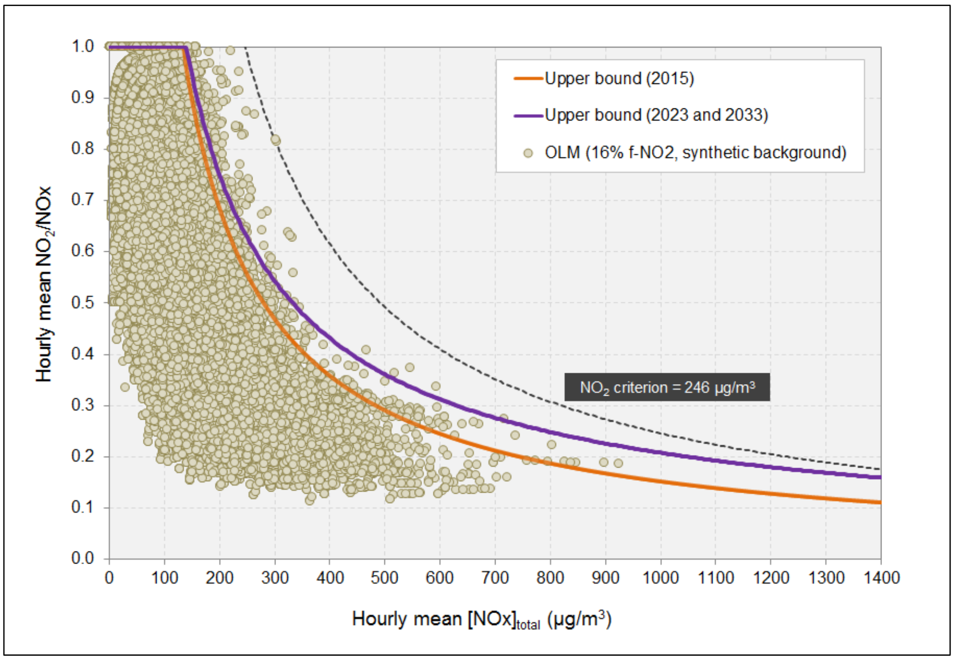

Figure G-10 Comparison of OLM and empirical methods for calculating 1-hour mean NO_2 concentration

Annexure H - Analysis of meteorological data and GRAMM evaluation

H.1 Analysis of meteorological data

H.1.1 Monitoring stations

Meteorological data were obtained and analysed for the following seven OEH and BoM weather stations in the GRAMM domain, and for the years 2009 to 2015 inclusive:

- OEH meteorological stations:
  - Chullora
  - Earlwood
  - Rozelle
- BoM meteorological stations:
  - Canterbury Racecourse Automatic Weather Station (AWS) (Station No. 066194)
  - Fort Denison (Station No. 066022)
  - Sydney Airport AMO (Station No. 066037)
  - Sydney Olympic Park AWS (Archery Centre) (Station No. 066212)

The parameters that were obtained were wind speed, wind direction, temperature and cloud cover.

H.1.2 Summary statistics

Table H-1 provides a summary of the annual data recovery, average wind speed and percentage of calms (wind speeds < 0.5 m/s) for each meteorological station and year.

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. For the Canterbury Racecourse station used for modelling in the air quality assessment (see section H.2), the original data recovery was 89%. Gap filling techniques were used to increase the data recovery from 89% to 90%.

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 and BoM Sydney Airport station were relatively high, with annual averages of 4.2-4.4 m/s and 5.5-5.7 m/s, respectively. This is not unusual given the exposed nature of these stations and their proximity to large coastal waterbodies (Sydney Harbour and Botany Bay respectively) (see section H.3.1). Wind speeds at Chullora, Earlwood and Rozelle were the lowest, with annual averages of 1.7-2.3 m/s, 1.3-1.6 m/s and 1.7-1.8 m/s. Wind speeds at Canterbury Racecourse were towards the middle of the range for all stations with an annual average of 3.2-3.3 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 and Earlwood stations showed an increasing trend between 2009 and 2015. There were few calm conditions at Fort Denison and Sydney Airport.

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

Site and parameter	2009	2010	2011	2012	2013	2014	2015
OEH Chullora							
Data recovery (%)	100	100	100	100	97	100	99
Average wind speed (m/s)	2.3	2.2	2.1	1.9	1.9	1.8	1.7
Annual calms (%)	7.6	7.0	7.4	10.4	11.5	11.6	12.7
OEH Earlwood							
Data recovery (%)	100	100	97	100	99	100	100
Average wind speed (m/s)	1.6	1.6	1.4	1.4	1.4	1.3	1.3
Annual calms (%)	18.1	16.8	17.5	22.0	23.1	22.0	23.6
OEH Rozelle							
Data recovery (%)	69	94	100	100	98	99	97
Average wind speed (m/s)	1.8	1.8	1.8	1.7	1.8	1.7	1.7
Annual calms (%)	21.7	23.1	21.3	24.9	23.1	22.1	24.7
BoM Canterbury Racecourse AWS							
Data recovery (%)	61	88	91	89	89	90	90[(a)]
Average wind speed (m/s)	3.3	3.2	3.3	3.3	3.3	3.3	3.2[(a)]
Annual calms (%)	9.4	8.4	8.0	8.7	8.8	8.6	9.1[(a)]
BoM Fort Denison AWS							
Data recovery (%)	97	96	100	100	98	100	99
Average wind speed (m/s)	4.3	4.4	4.4	4.4	4.4	4.3	4.2
Annual calms (%)	1.6	0.8	0.5	0.2	0.4	0.3	0.3
BoM Sydney Airport AMO							
Data recovery (%)	67	66	100	100	100	100	100
Average wind speed (m/s)	5.7	5.7	5.7	5.6	5.7	5.5	5.5
Annual calms (%)	0.3	0.2	0.2	0.3	0.1	0.1	0.2
BoM Sydney Olympic Park AWS (Archery Centre)							
Data recovery (%)	N/A	N/A	31[(b)]	90	89	90	89
Average wind speed (m/s)	N/A	N/A	2.9	2.7	2.7	2.6	2.6
Annual calms (%)	N/A	N/A	8.8	11.1	11.4	10.2	12.0

(a) Gap filling was used to increase the data recovery from 89% to 90%.
(b) Monitoring began in August 2011.

H.1.3 Wind roses

Annual and seasonal wind roses were created for all seven stations and for all years to illustrate the general wind patterns across the GRAMM domain. These are shown in Figure H-1 to Figure H-13. The wind patterns at most stations were reasonably consistent from year to year, with some slight variation in the seasonal distribution between 2009 and 2015. However, there were some exceptions to this. For example, at the OEH Chullora station the wind patterns between 2009 and 2011 had a general west-south-westerly dominance, but between 2012 and 2015 there was significant change in wind pattern - both annually and by season - with very dominant north-easterly/south-westerly winds not seen in the earlier years. The winter wind roses in particular showed a shift in the dominant winds from mostly westerlies in 2009-2011 to south-westerlies in 2012-2015.

At the OEH Rozelle station the wind roses for 2009, 2010, 2014 and 2015 showed similar patterns, with dominant winds from the north-west, north-east and south to varying degrees in all seasons. In contrast, in 2011, 2012 and 2013 the dominant winds were from the west-northwest, north-northeast and south-southeast. Additional information regarding these stations was provided by OEH. This showed that the changes in the wind patterns were probably due to a variety of factors, including a change in surroundings (i.e. new buildings and trees in the area surrounding the stations), sensor alignment issues, and instrument replacements which occurred around the same time that the data analysis showed a shift in the dominant wind patterns (i.e. 2011/2012).

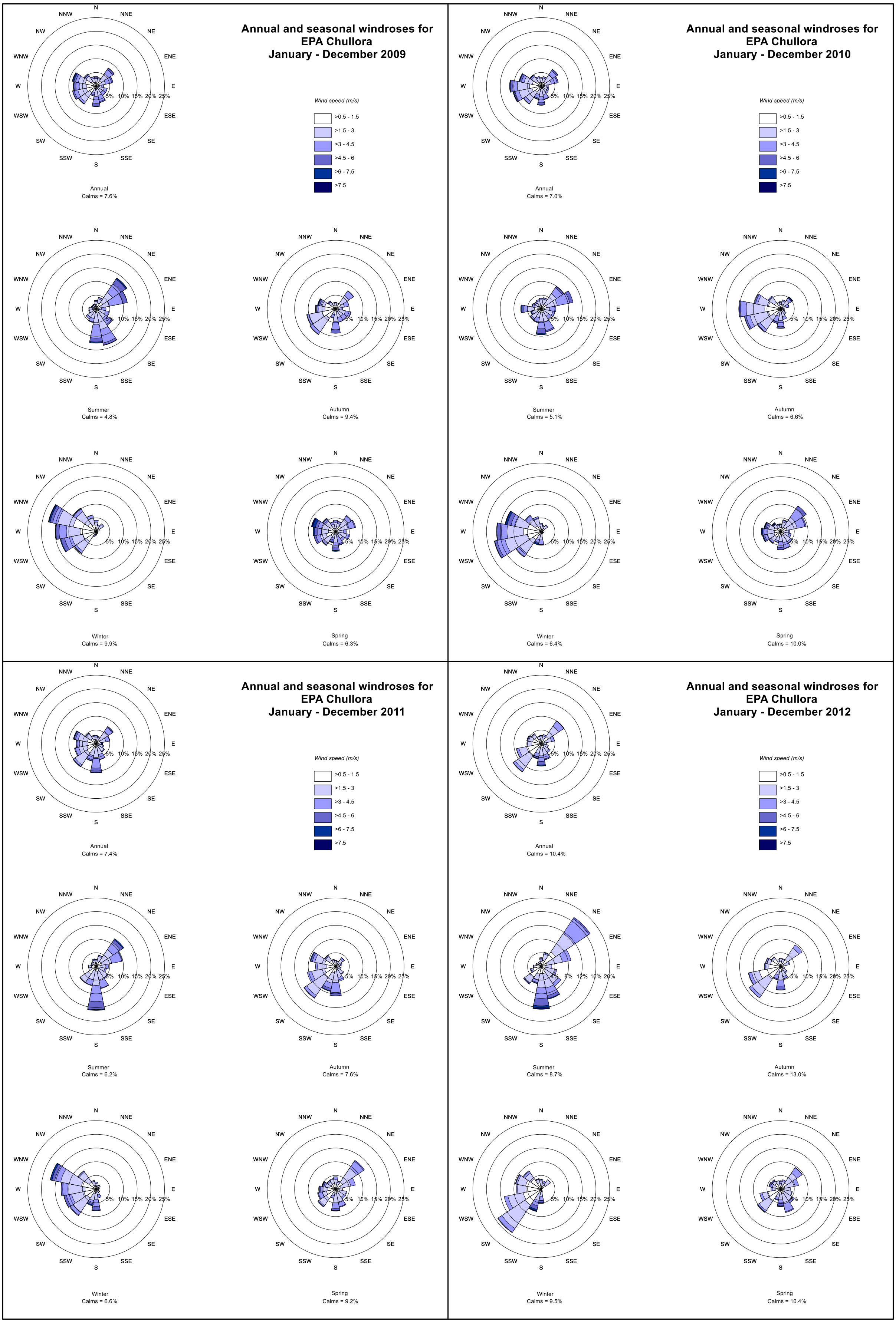

Figure H-1 Annual and seasonal wind roses for OEH meteorological station Chullora (2009-2012)

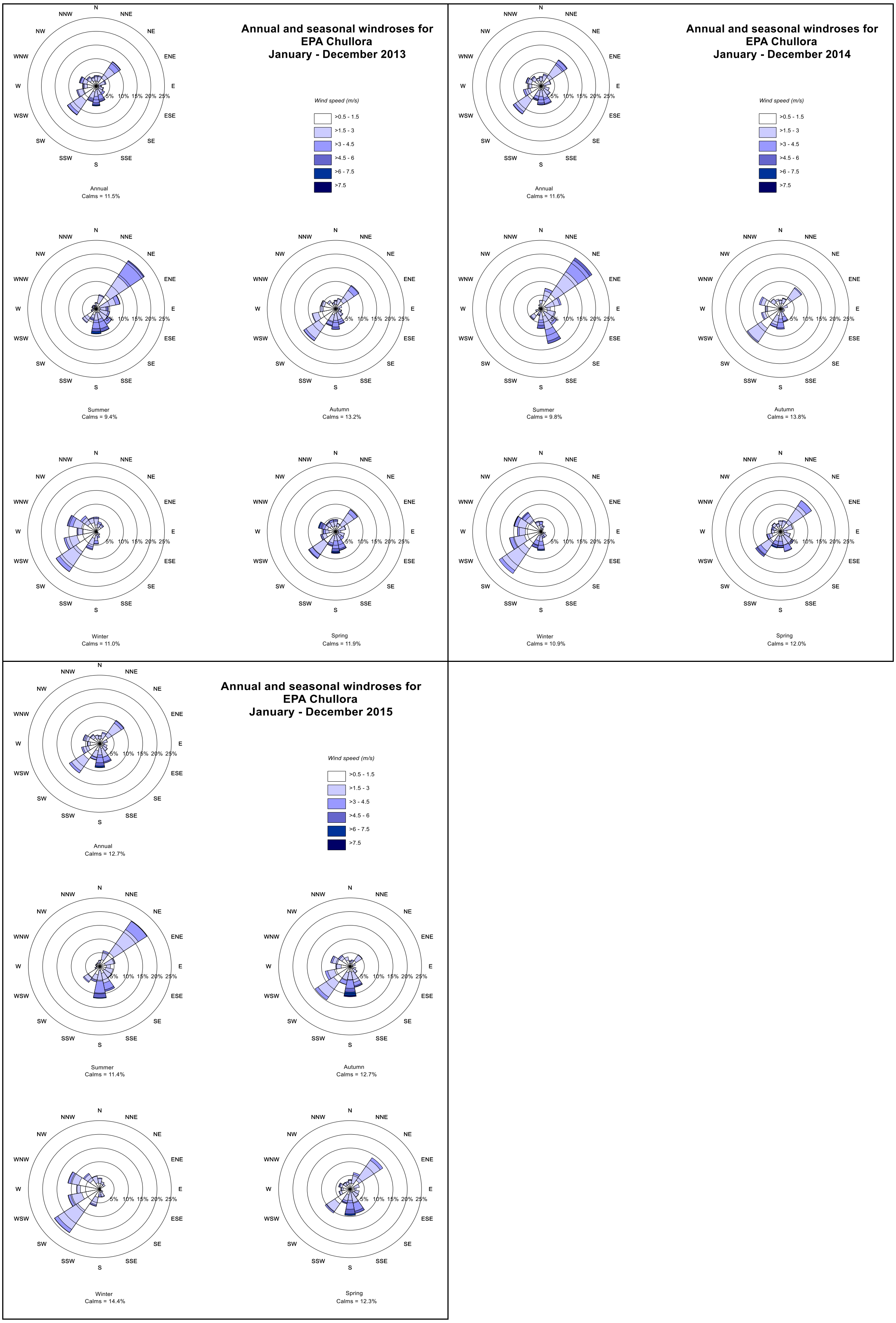

Figure H-2 Annual and seasonal wind roses for OEH meteorological station Chullora (2013-2015)

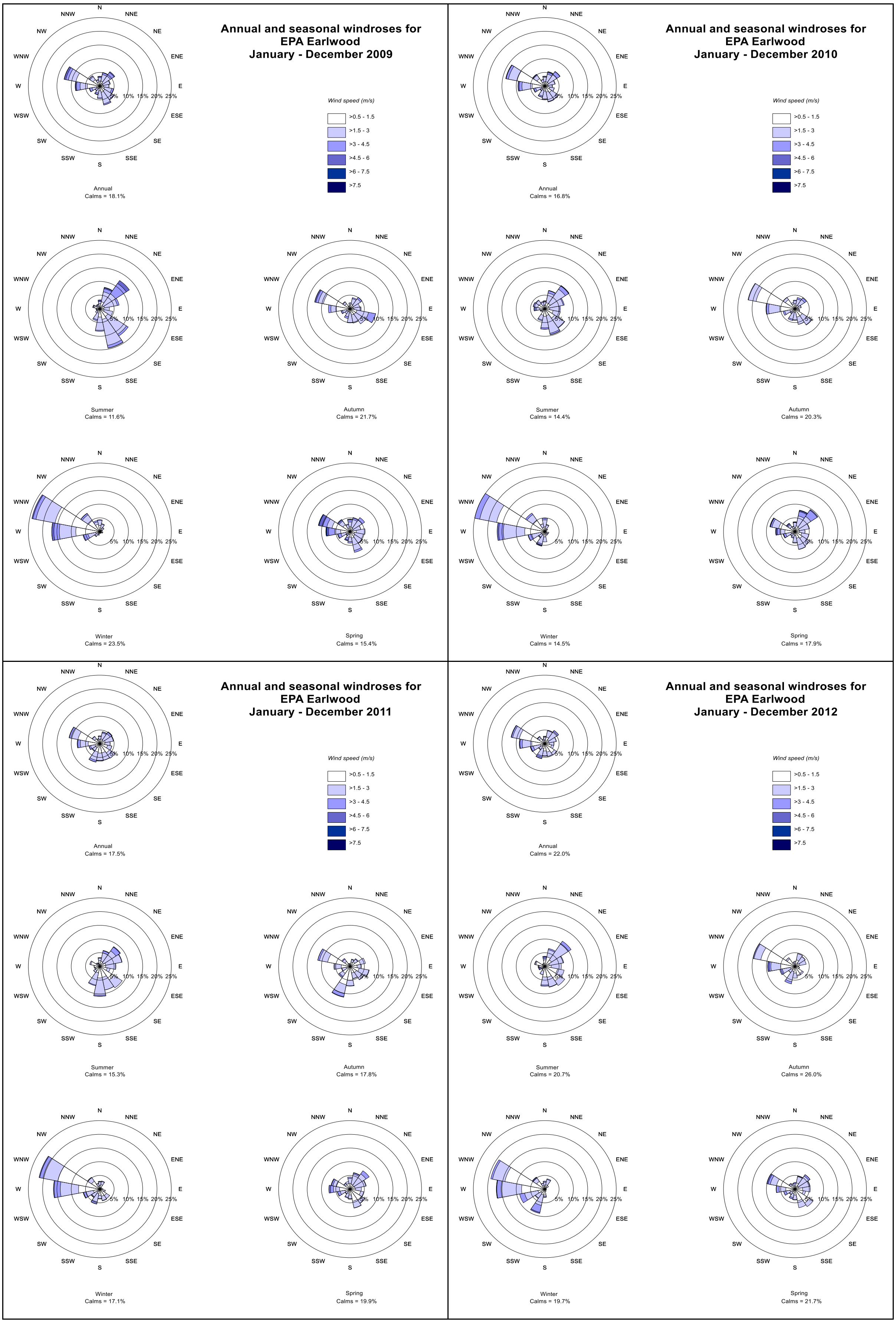

Figure H-3 Annual and seasonal wind roses for OEH meteorological station Earlwood (2009-2012)

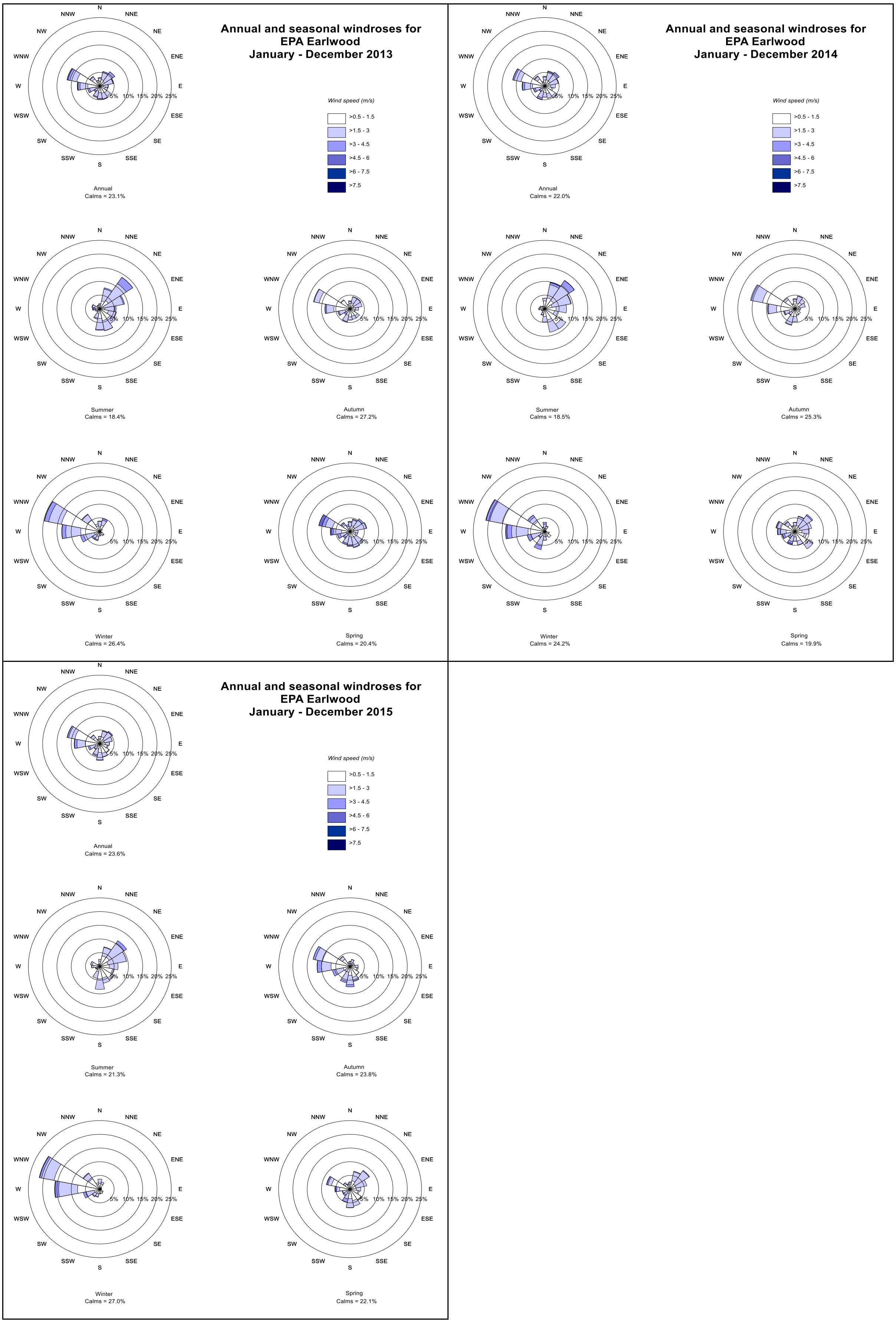

Figure H-4 Annual and seasonal wind roses for OEH meteorological station Earlwood (2013-2015)

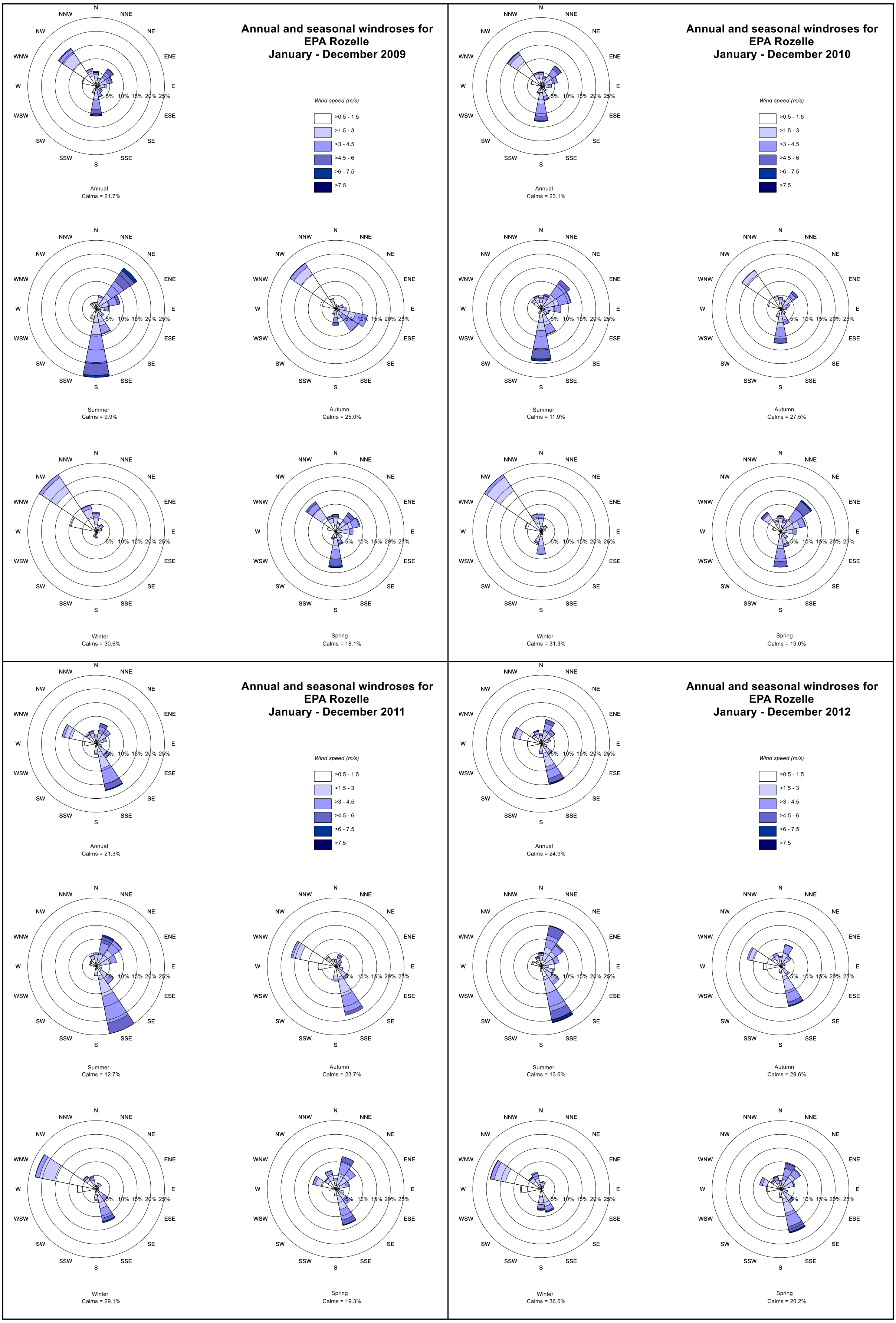

Figure H-5 Annual and seasonal wind roses for OEH meteorological station Rozelle (2009-2012)

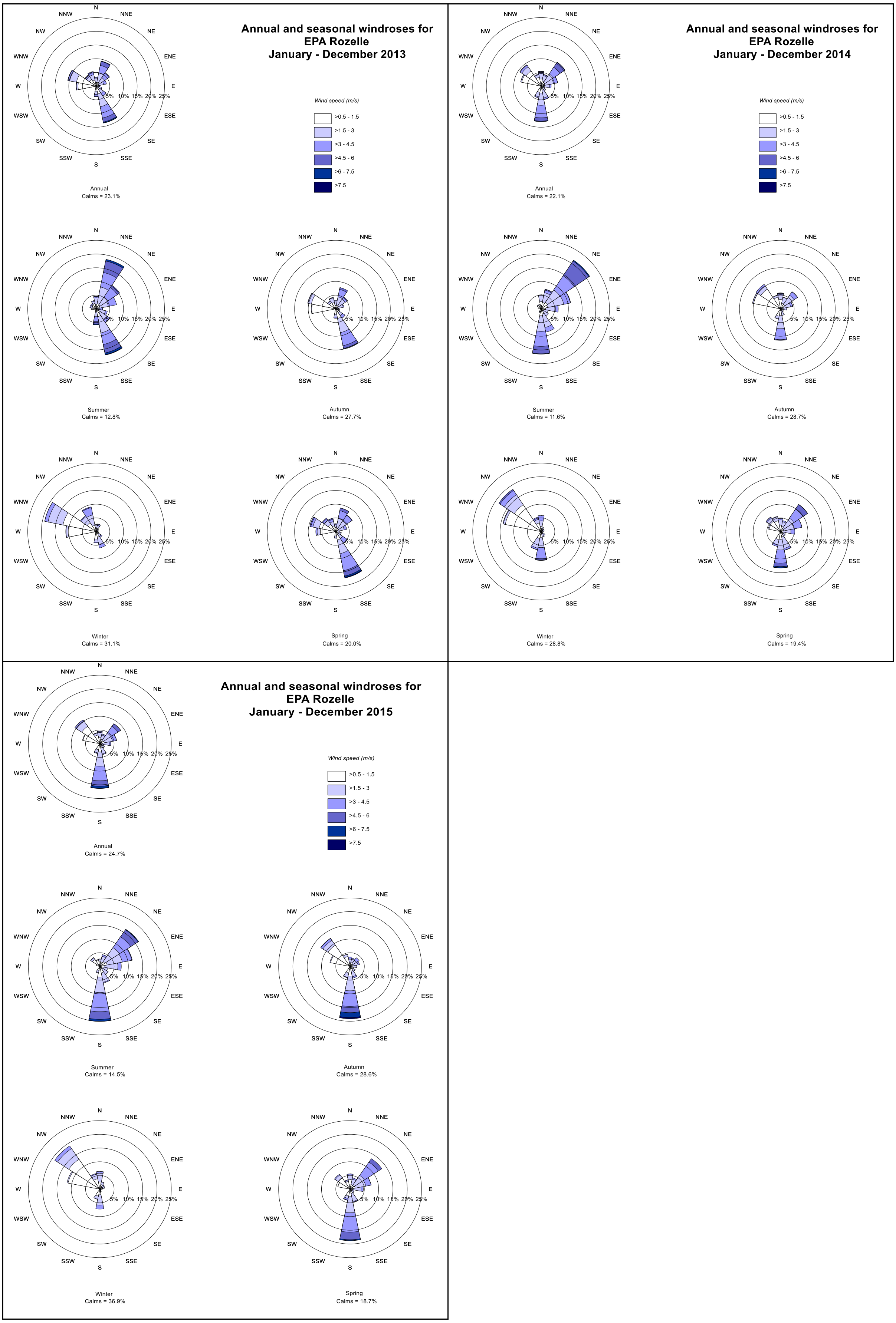

Figure H-6 Annual and seasonal wind roses for OEH meteorological station Rozelle (2013-2015)

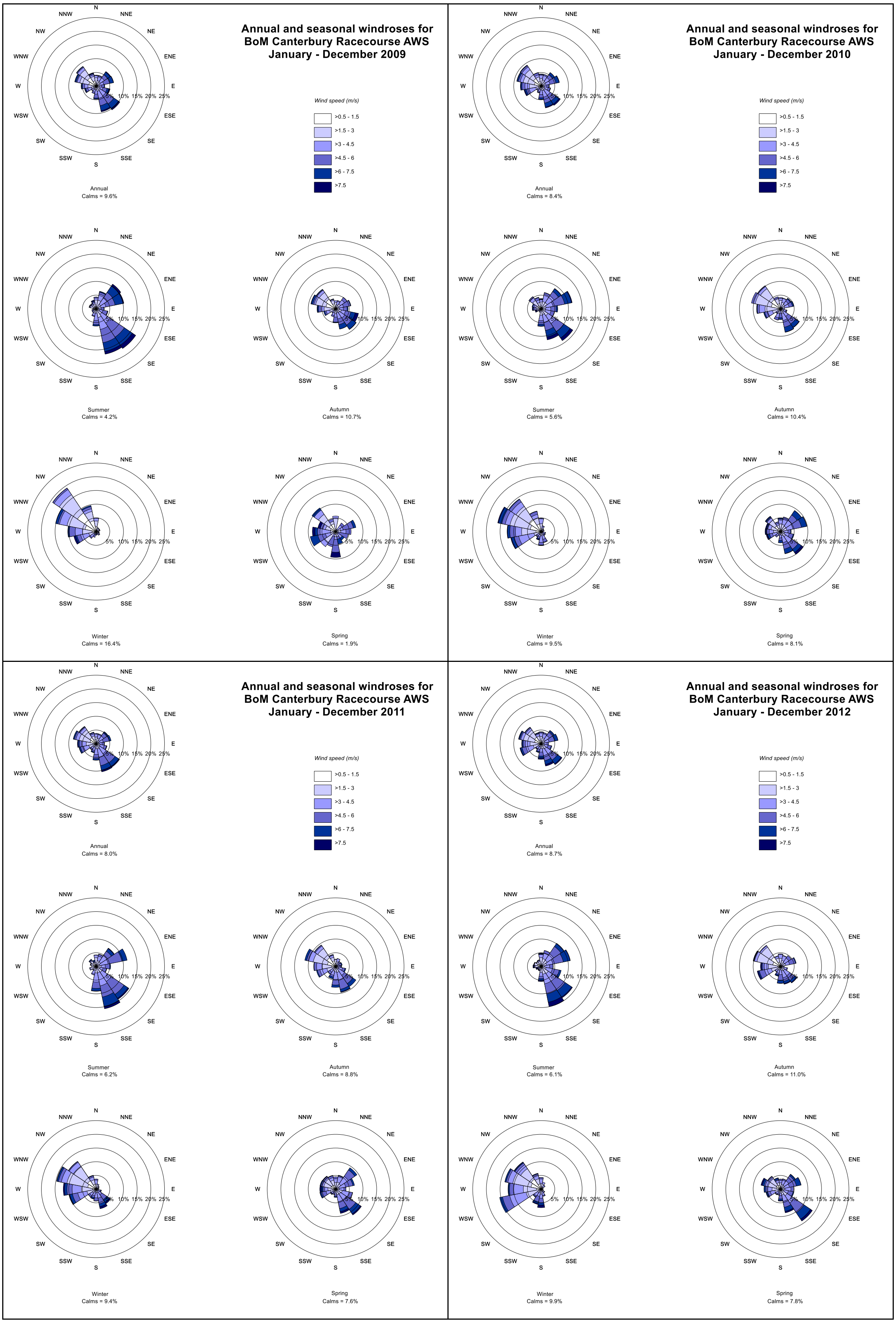

Figure H-7 Annual and seasonal wind roses for BoM Canterbury Racecourse AWS (2009 – 2012)

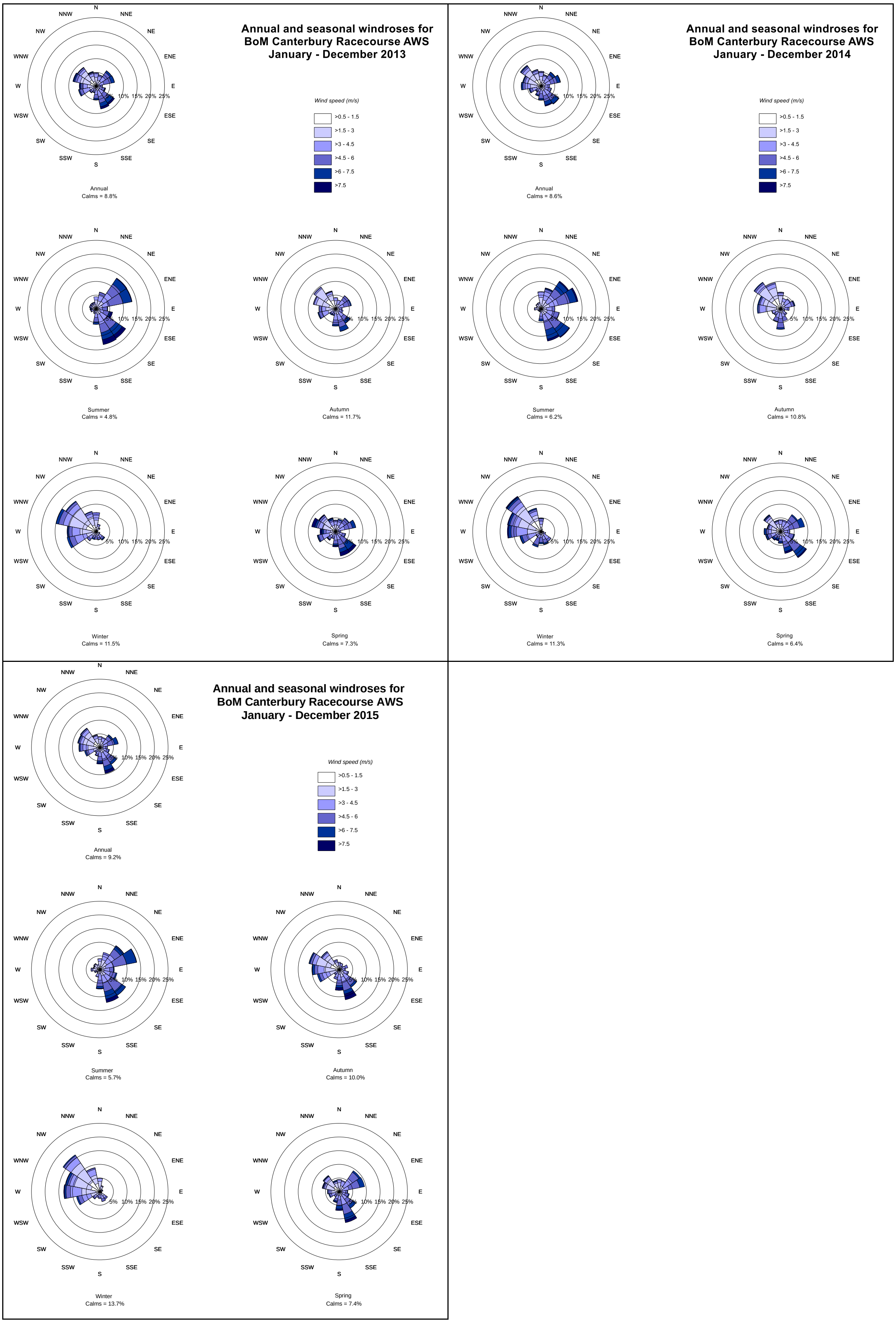

Figure H-8 Annual and seasonal wind roses for BoM Canterbury Racecourse AWS (2013 – 2015)

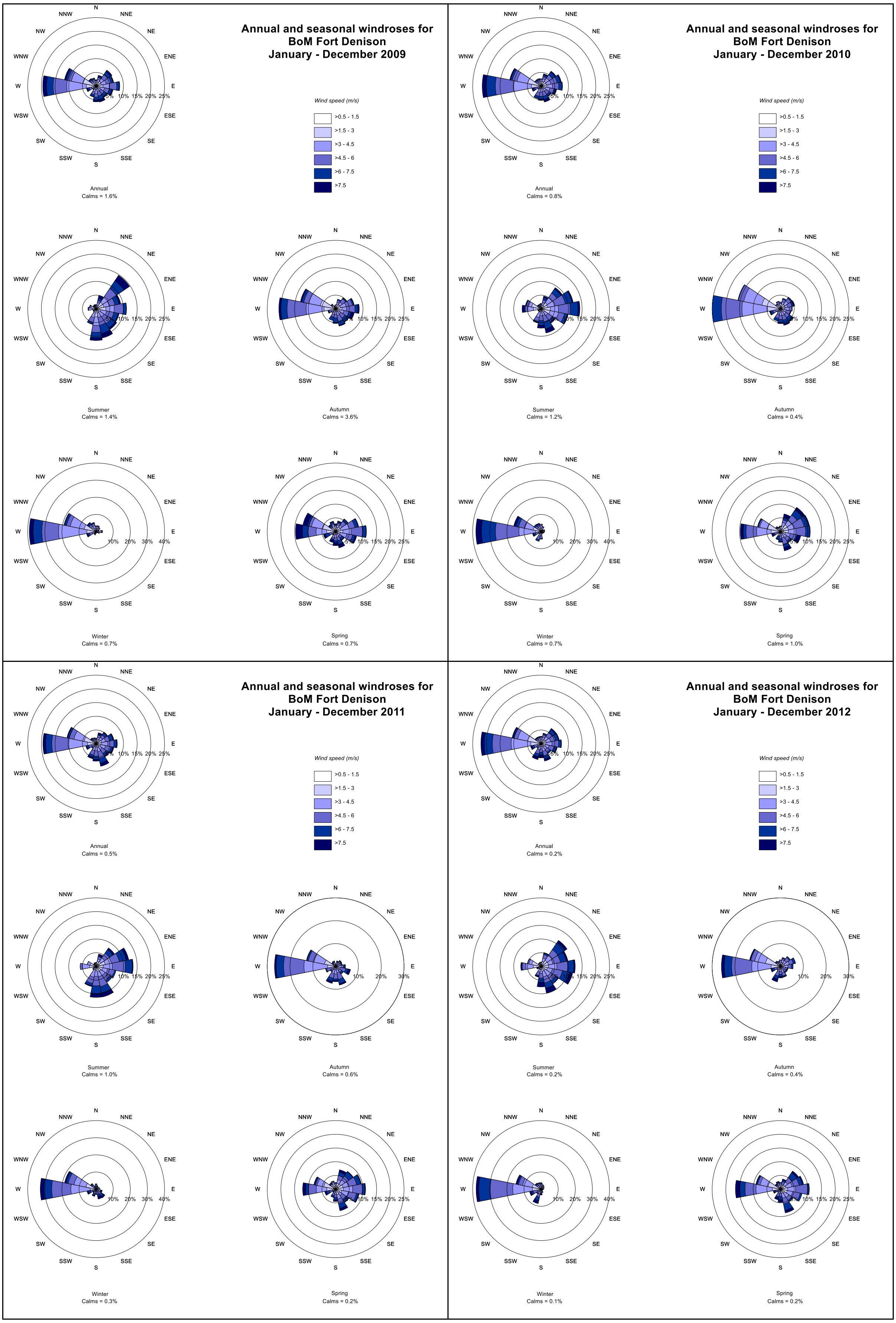

Figure H-9 Annual and seasonal wind roses for BoM Fort Denison AWS (2009 – 2012)

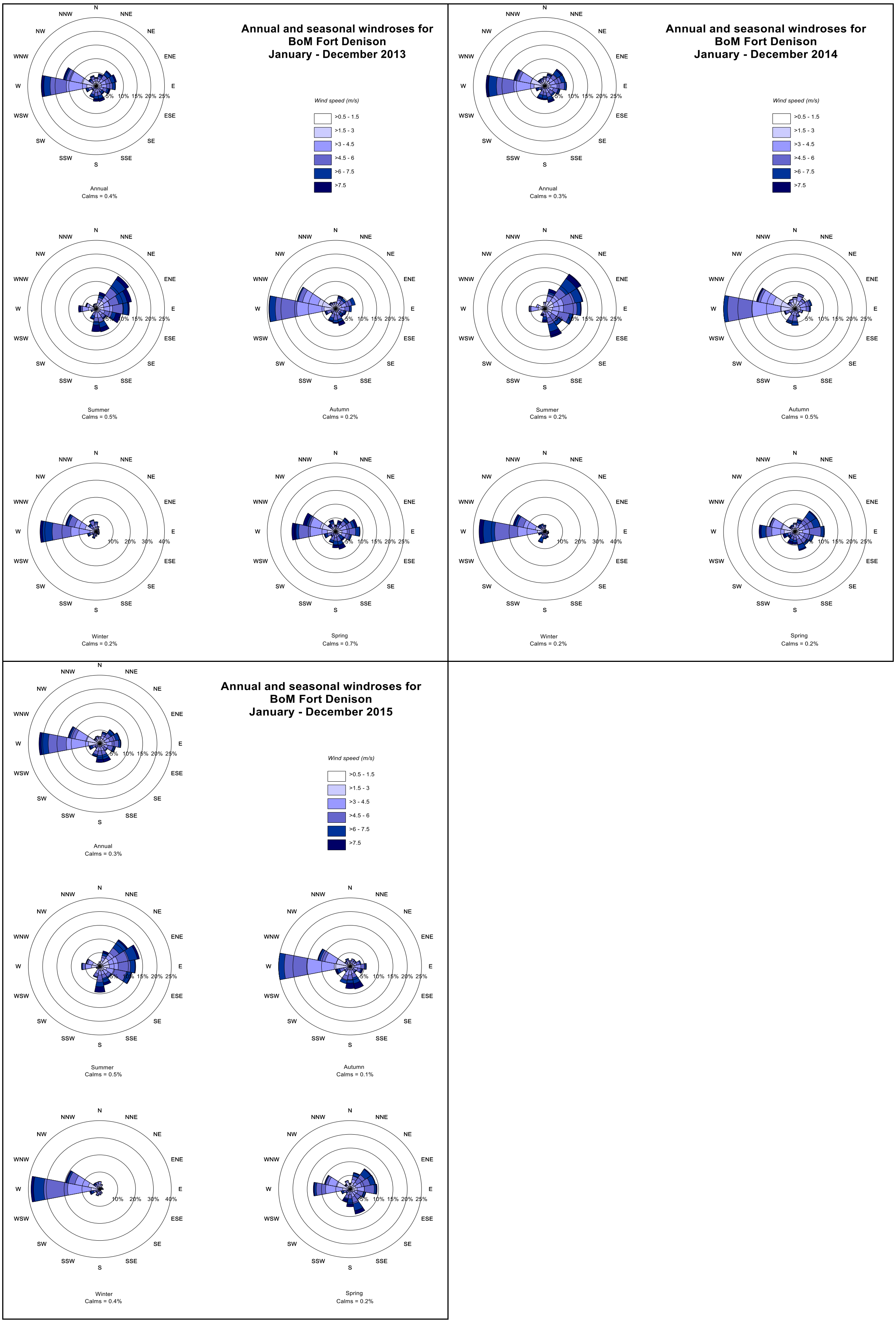

Figure H-10 Annual and seasonal wind roses for BoM Fort Denison AWS (2013 – 2015)

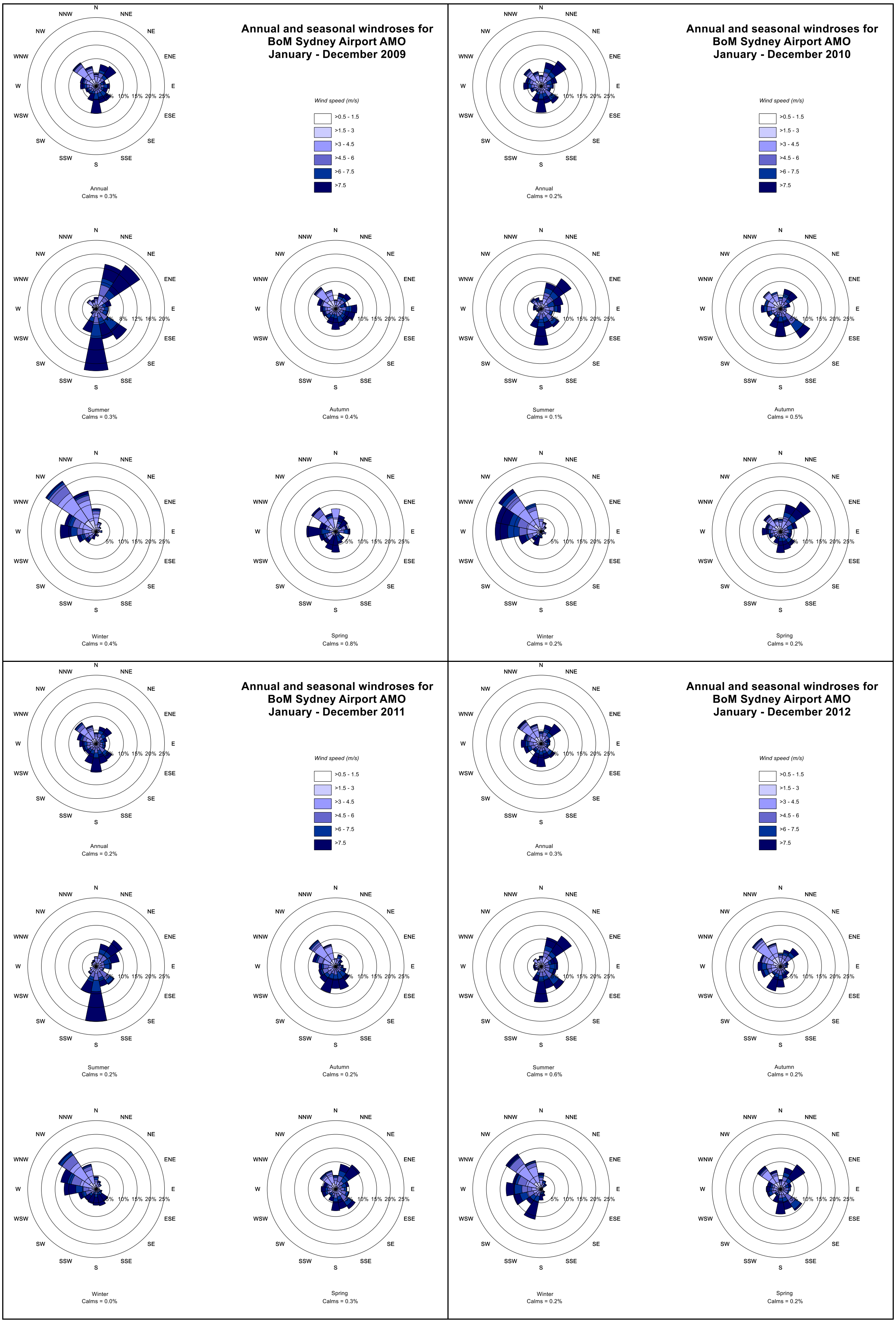

Figure H-11 Annual and seasonal wind roses for BoM Sydney Airport AMO (2009 – 2012)

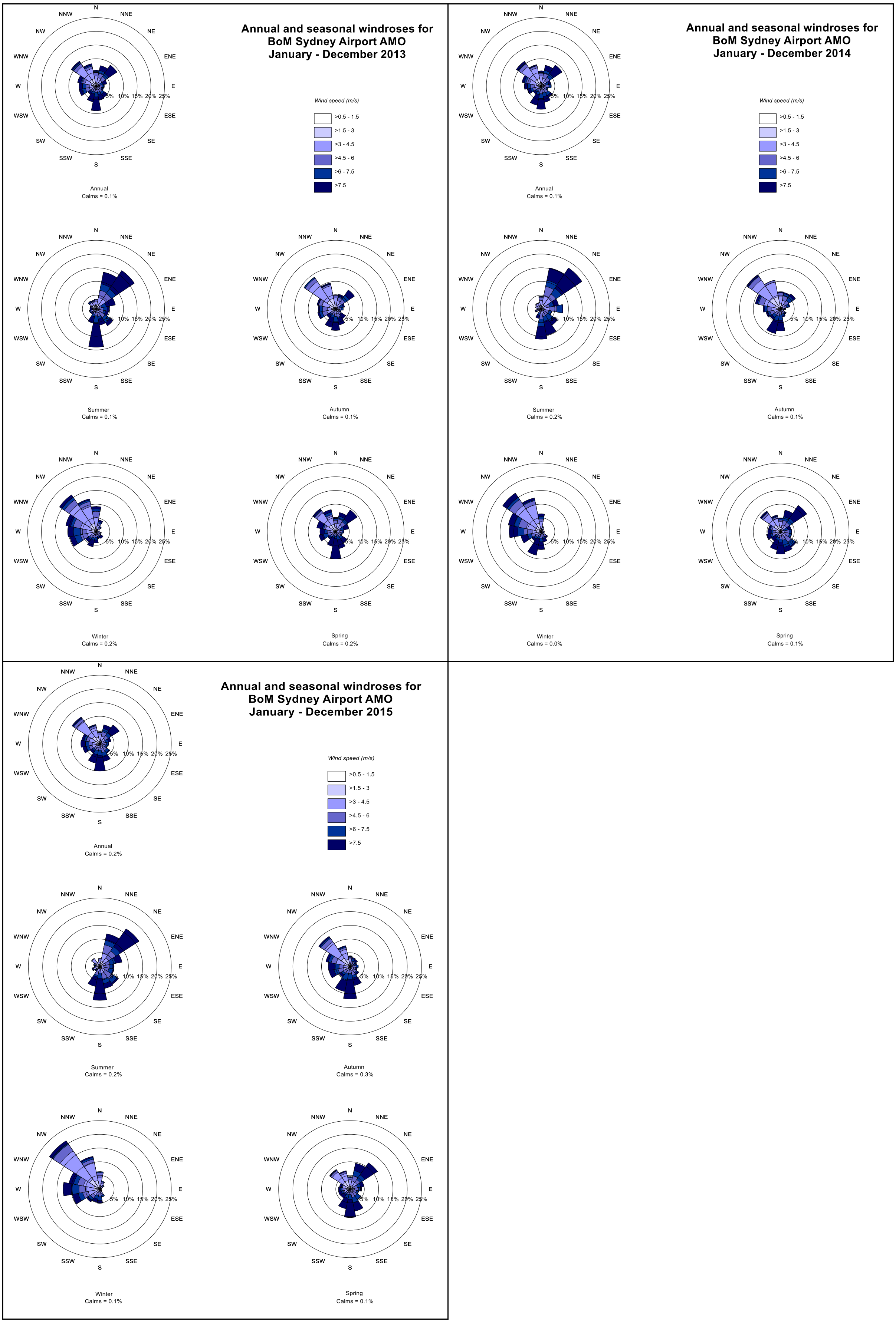

Figure H-12 Annual and seasonal wind roses for BoM Sydney Airport AMO (2013 – 2015)

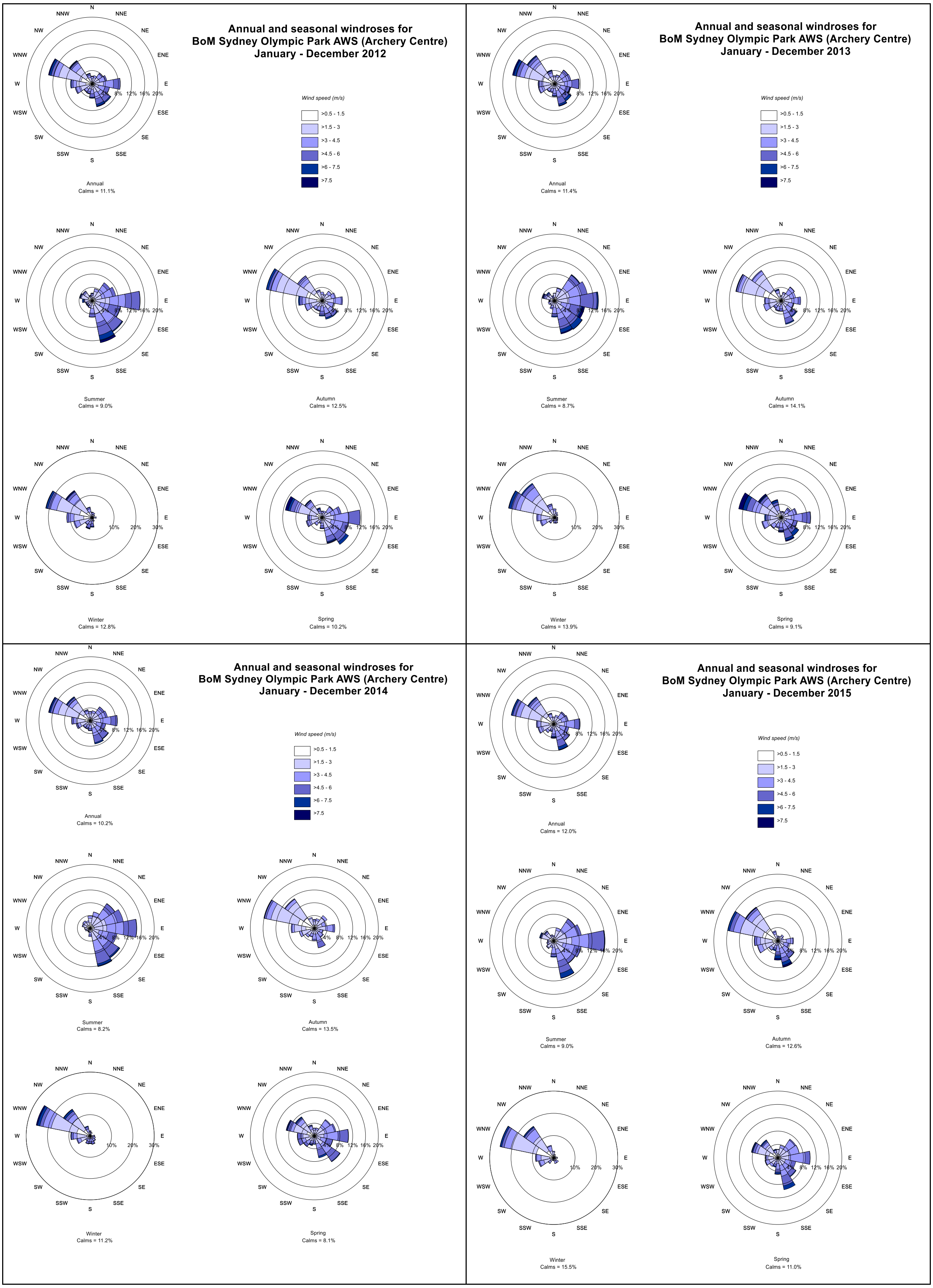

Figure H-13 Annual and seasonal wind roses for BoM Olympic Park AWS (Archery) (2012 – 2015)

H.2 Rationale for selection of reference station and year for modelling

The measurements from the Canterbury Racecourse station in 2015 were chosen as the best available reference meteorological data for modelling across the GRAMM domain. The reasons for the selection of this station and this year are given below.

H.2.1 Station selection

The reasons for the selection of the Canterbury Racecourse station were as follows:

- The station is compliant with Australian Standards for siting
- The station is centrally located with respect to the GRAMM domain and is within the GRAL domain. It is also well situated with respect to the spatial coverage of the full WestConnex scheme (see section 6.5)
- The station was considered to be representative of the land use and meteorology in the domain. For example:
    - Wind speed and direction patterns between 2009 and 2015 were relatively consistent. Average wind speed ranged from 3.2 m/s to 3.3 m/s, and the annual percentage of calms ranged from 8.0% to 9.4% (from 8.6% to 8.8% in the three most recent years)
    - Wind speeds were in the middle of the range of values across the stations in Sydney
    - Wind speed patterns reflected those at the other stations. For example, Figure H-14 shows the monthly average wind speeds at each station between 2014 and 2015.

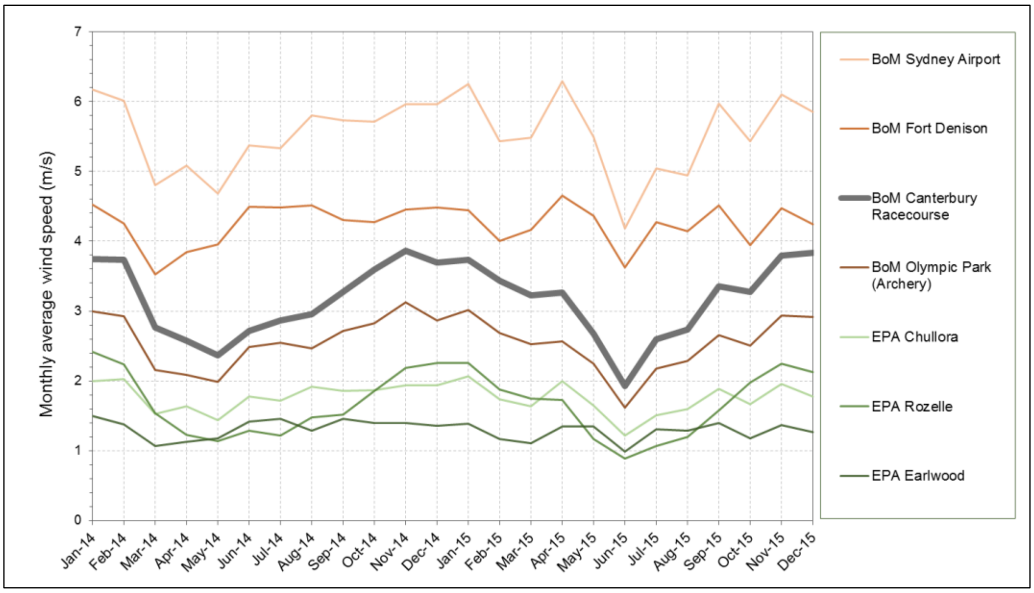

Figure H-14 Monthly average winds speeds in 2014 and 2015 at BoM and OEH monitoring stations

The factors weighing against the selection of other monitoring stations were considered in the submissions report for the New M5 project (Roads and Maritime Services, 2016), and are summarised below:

- The OEH Chullora and Rozelle stations showed inconsistencies in dominant wind direction across years, as noted earlier. The stations were also not compliant with the Australian Standards for siting[1].

[1] According to the OEH website (http://www.environment.nsw.gov.au/AQMS/sitesyd.htm), neither of these sites currently comply with Australian Standard AS/NZS 3580.1.1:2007, as the clear sky angle is < 120˚ due to trees within 20 metres of both monitoring sites.

- The OEH Earlwood station was not selected for modelling as it was not considered to be representative of the GRAMM domain. The station is located in a valley surrounded by a densely populated residential area, which may explain the low wind speed data from this station. The station has a very low annual average wind speed and a high percentage of calms compared with the BoM stations. Further analysis of the stability class data from this station showed an unusually high percentage (around 40%) of G stability class (very stable) conditions and a low percentage (around 2%) of D class (neutral) conditions.
- At the BoM Fort Denison and Sydney Airport stations the annual average wind speeds were very high and the percentages of calms were very low due to the local topography (e.g. large fetch, open water). Although the data from these stations may be reliable, they were only considered to be representative of their specific locations and not of the wider GRAMM domain.
- The BoM Sydney Olympic Park (Archery Centre) data were potentially suitable for modelling. However, data were only available for five years, as the station was commissioned in 2011, and the station is outside the GRAL domain.

H.2.2 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.

For the air quality assessments in the EISs for the M4 East and New M5 projects, the base year was 2014 (the latest complete year at the time). The base year for the M4-M5 Link air quality assessment was taken to be 2015. 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 of the assessment was 2015.
- The use of 2015 data allowed for a WestConnex monitoring station (St Lukes Park) to be included in the definition of background concentrations.
- The used of 2015 allowed more roadside sites to be included in the dispersion model evaluation exercise than other years.
- The monitoring data for 2015 are representative of the trends in the longer-term air quality data.
- The switch to 2015 had no material effect on the background maps for NO_X and PM_{10}. In terms of mean and peak values, the synthetic background profiles for 1-hour NO_X, 24-hour PM_{10} and 24-hour $PM_{2.5}$ were slightly more conservative than the corresponding profiles for 2014.

With respect to the BoM Canterbury Racecourse meteorological data for 2015:

- The dataset for 2015 was sufficiently complete.
- The data were representative, and broadly followed the same patterns as the 2014 data.
- An evaluation of the predicted meteorological parameters using these data determined that GRAMM simulates the meteorology within an acceptable degree of accuracy (see section H.3).

H.3 Meteorological model evaluation

The GRAMM predictions of wind speed and wind direction based on the Canterbury Racecourse reference site were compared with the measurements in the GRAMM domain.

H.3.1 Wind speed

Table H-2 provides, for 2015, a comparison between the predicted and measured annual average wind speed, standard deviation of wind speed, and percentage of calms at five meterological stations. 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 BoM Canterbury Racecourse reference site, but a poorer agreement at locations further away from the reference site. Notably, the model did not fully reflect the range of wind speed conditions in the GRAMM domain. The average wind speed was underpredicted at Sydney Airport, where the measurement was high, and overpredicted at Chullora and Rozelle, where the measurments were low. For Sydney Airport the underprediction is probably due to the coastal nature of the site, where wind speeds are typically higher due to the relatively uninterrupted nature of on-shore winds. The standard deviation of wind speed was generally well represented by the model. The percentage of calm conditions in the model results covered a much narrow range than the measurements; calms were considerably overestimated at Sydney Airport and underestimated at Rozelle, but the predictions at the other sites were acceptable.

Table H-2 Summary statistics – observed and predicted (2015)

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
BoM Canterbury Racecourse	3.4	1.9	5.5	3.1	1.5	5.5
BoM Sydney Airport	6.1	2.7	0.0	4.1	2.2	3.2
BoM Sydney Olympic Park	2.7	1.6	8.9	3.5	1.7	3.9
OEH Rozelle	1.9	1.4	15.2	3.4	1.6	4.3
OEH Chullora	1.9	1.2	3.3	3.2	1.4	5.3

For selected GRAMM evaluation sites, time series, regression and percentile plots of wind speed in 2015 are shown in Figure H-15.

The results of the regression analysis (predicted wind speed versus observed wind speed) are summarised below:

- BoM Canterbury Racecourse $R^2 = 0.89$
- BoM Sydney Airport $R^2 = 0.53$
- BoM Sydney Olympic Park (Archery Centre) $R^2 = 0.58$
- OEH Rozelle $R^2 = 0.39$
- OEH Chullora $R^2 = 0.47$

The analysis showed a very good agreement between the predicted and observed wind speeds at the Canterbury Racecourse station, which was the site used for modelling. There was a fair agreement at Sydney Olympic Park (Archery Centre) and Sydney Airport, but a poorer agreement at the OEH sites. These results are not unusual, as GRAMM (like other models such as CAL3CHQR) uses meteorological data from one location to represent the domain. The use of a single meteorological dataset is not uncommon in studies with domains the size of that applied to the WestConnex program of works, and with predominantly uniform land use and relatively flat terrain. As discussed previously, the validity of the Rozelle and Chullora meteorological data is uncertain, and therefore it is not possible to provide a definitive test of the GRAMM performance at these locations. On balance, the level of agreement for the sites other than Canterbury Racecourse is considered to be fair given that these data were not included in the GRAMM modelling.

The percentile plots shown in Figure H-15 demonstrate an under-prediction of high wind speeds at Canterbury Racecourse. There is also an under prediction at Sydney Olympic Park at the highest wind speeds, and a slight over prediction in the low to mid range. Percentile plots at these two sites show a much closer agreement between the predictions and measurements than for sites further away from the project.

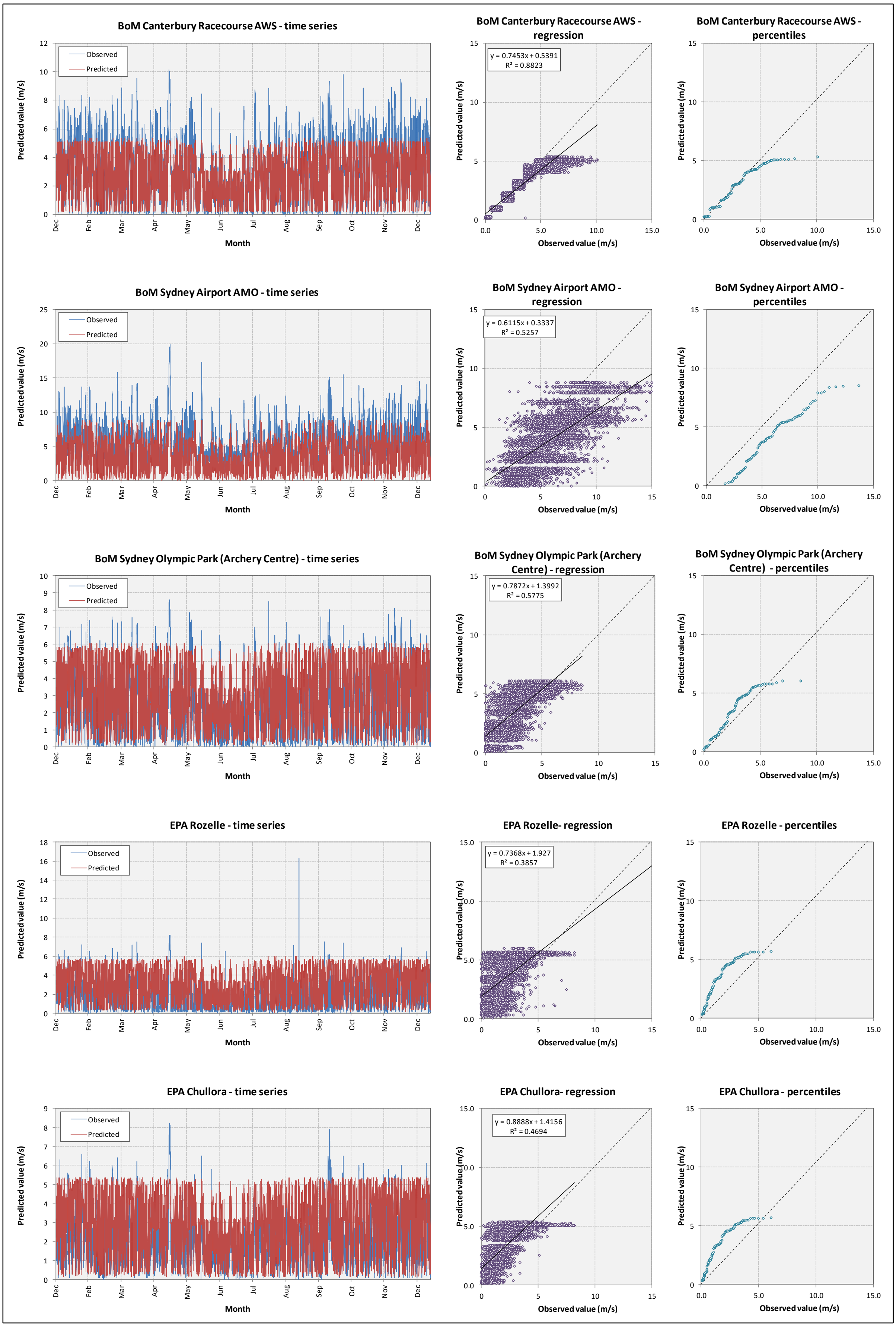

Figure H-15 GRAMM predicted and observed hourly average wind speed (time series, regression and percentile plots) (2015)

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 J of the report provides a validation of the GRAL predictions as compared with measured data. The analysis shows a good agreement between predictions and measurements, and that the model is slightly over predicting at all locations (which is as expected and generally desirable in an assessment of this nature). This shows that 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 varying locations in the study area (see Annexure J).

A plot of predicted and observed average wind speeds by hour of day at Canterbury Racecourse shows good agreement (Figure H-16). As mentioned previously, 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.

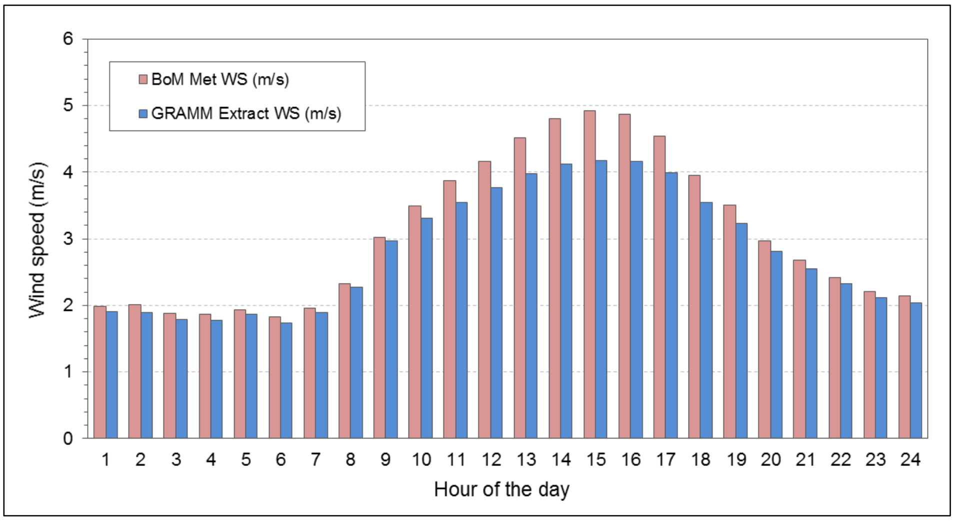

Figure H-16 **Average wind speeds by hour of day for observed and predicted at Canterbury Racecourse (2015)**

H.3.2 Wind direction

Annual and seasonal wind roses for the measurements at the Canterbury Racecourse station are presented in Figure H-17. The predicted winds from GRAMM are presented for comparison with the observations. In section 8.4.4 of the main report there is an explanation of how the re-order function was used to refine the simulated GRAMM wind fields. Both the GRAMM extract and the GRAMM extract re-ordered compared very well with the observations at the annual and seasonal levels.

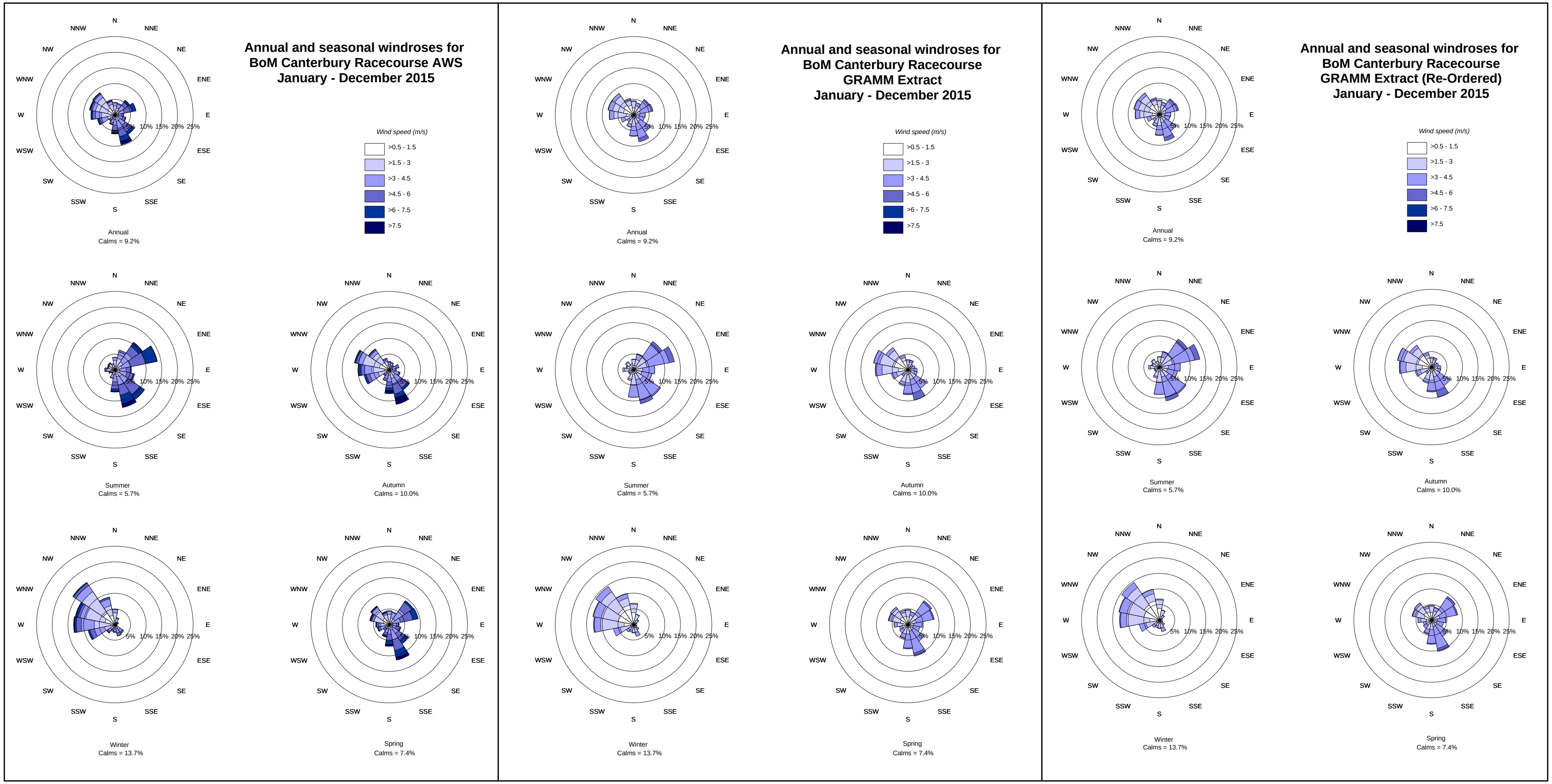

Figure H-17 **Annual and seasonal wind roses for observed and predicted at Canterbury Racecourse**

H.3.3 Performance against benchmarks

Several statistical measures also were used to evaluate the performance of GRAMM in relation to the differences between model predictions and observations. These measures were taken from the BOOT Statistical Model Evaluation Software Package (Chang and Hanna, 2005) and assessed against performance benchmarks set for model evaluation (Emery et al., 2001). The BoM Canterbury Racecourse data for 2015 were included in this analysis.

The metrics used were as follows:

- Index of agreement. This measures how well the predictions and measurements are matched in terms of how they deviate from the mean.
- Mean bias. This is the average of the errors in a group of predicted values.
- Mean gross error. This measures how much of the prediction error is so large that it cannot be due to errors that are normally expected in measurements.
- Fractional bias. This is similar to mean bias but is 'non-dimensional', meaning values.
- Skill v. This compares the amount of scatter in the modelled and measured data.
- Skill r. This compares overall error in the predictions to scatter in the measured values. If this value is <1 then it shows the model is predicting well.

These statistical measures are summarised in Table H-3, along with the performance benchmarks adopted for the study.

Table H-3 Statistical measures used to evaluate GRAMM performance

Statistical measure	Description	Parameter	Ideal value	Benchmark
Index of agreement (IOA)	$IOA = 1 - \frac{\sum_{i=1}^{n}(P_i - O_i)^2}{\sum_{i=1}^{n}(\lvert P_i - \bar{O}\rvert + \lvert O_i - \bar{O}\rvert)^2}$	Wind speed	1	≥ 0.6
Mean bias (MB)	$MB = \frac{1}{n}\sum_{i=1}^{N}\lvert P_i - O_i\rvert$	Wind speed	0	≤ ± 0.5 m/s
		Wind direction	0	≤ 10º
Mean gross error (MGE)	$MGE = \frac{1}{N}\sum_{i=1}^{N}\lvert P_i - O_i\rvert$	Wind speed	0	≤ 2 m/s
		Wind direction	0	≤ 30º
Fractional bias	$FBIAS = \frac{2}{n}\sum_{i=1}^{n}\left(\frac{P_i - O_i}{P_i - O_i}\right) \times 100\%$	Wind speed	0	≤ ± 0.67
Skill v		Wind speed	1	1
Skill r		Wind speed	-	< 1

N = number of observations $\bar{O}$ = mean of observed values
P = predicted value $\bar{P}$ = mean of predicted values
O = observed value   i = time period

The evaluation of GRAMM performance against these benchmarks is presented in Table H-4. For the IOA the model compared well against the benchmark for wind speed, approaching the ideal score of 1. The results for the fractional bias, skill v and skill r tests all fell within the acceptable ranges. For the MGE the model compared well against the benchmark for both variables, in particular for wind direction. Model performance against MB also fell within the acceptable benchmark for wind direction, but was slightly outside the range for wind speed.

Overall, it can be concluded that GRAMM generally simulates the meteorology with an acceptable degree of accuracy.

Table H-4 Statistical evaluation of GRAMM performance

Statistical measure	Ideal value	Wind speed		Wind direction	
		Benchmark	Result	Benchmark	Result
IOA	1	≥ 0.6	0.90	-	-
Mean bias	0	≤ ± 0.5 m/s	0.95	≤ 10º	4.8
Mean gross error	0	≤ 2 m/s	1.34	≤ 30º	6.7
Fractional bias	0	≤ ± 0.67	0.35	-	-
Skill v	-	1	0.61	-	-
Skill r	-	< 1	0.87	-	-

H.3.4 Sensitivity to selection of reference meteorological data

The submissions report for the New M5 project included a sensitivity of the GRAL predictions to meteorological input assumptions (NSW Roads and Maritime Services, 2016). This involved re-running GRAMM using the 2014 data from the OEH Earlwood station. The Earlwood data were selected to provide a contrast with the BoM Canterbury Racecourse data, and as 'worst case' meteorology (i.e. the Earlwood station had a much lower average wind speed and much higher percentage of calms). The re-run GRAMM was then used in conjunction with GRAL to predict annual mean $PM_{2.5}$ and maximum 1-hour NO_2.

The annual mean $PM_{2.5}$ concentrations at the RWR receptors obtained using the Earlwood meteorological data were, on average, 0.6 µg/m^3 higher than those obtained using the Canterbury Racecourse data. It is important to note, however, that although the results using the Earlwood data show an increase in absolute concentrations at RWR receivers, there was actually a higher percentage of receivers for which there was predicted to be a benefit due to the project.

For most receptors the change in the meteorology had little effect on the maximum 1-hour NO_2 concentrations. While there would be more predicted exceedances using the Earlwood data, both in the 'Do Minimum' and 'Do Something' scenarios, there would be a reduction in the number of exceedances with the project.

Annexure I – Ventilation outlet parameters

This Annexure provides the following for each expected traffic and regulatory worst case scenario, each ventilation outlet and each source group:

- Air flows and temperatures
- Effective diameters and exit velocities
- Emissions
- Concentrations (in each outlet) (these are fixed for the regulatory worst case)

I.1 Expected traffic scenarios

I.1.1 Air flows and temperatures

Table I-1 Ventilation air flows and temperatures: 2015-BY

Ventilation facility	Tunnel project	Location	GRAL source group	Time period(s) (hour start)	No. of outlets	Total air flow (m^3/s)	Air flow per outlet (m^3/s)	Outlet temp. (ºC)
A	M5 East	Turrella	A-1	Hours 22 to 04	1	419	419	30.0
			A-2	Hours 05 to 21	1	837	837	

Table I-2 Ventilation air flows and temperatures: 2023-DM

Ventilation facility	Tunnel project	Location	GRAL source group	Time period(s) (hour start)	No. of outlets	Total air flow (m^3/s)	Air flow per outlet (m^3/s)	Outlet temp. (ºC)
A	M5 East	Turrella	A-1	Hours 22 to 04	1	419	419	30.0
			A-2	Hours 05 to 21	1	837	837	
B	M4 East	Parramatta Road	B-1	Hours 23 to 04	1	380	380	18.6
			B-2	Hours 05 to 06 Hours 19 to 22	1	570	570	
			B-3	Hours 07 to 18	1	710	710	
C	M4 East	Underwood Road	C-1	Hours 23 to 04	1	380	380	27.5
			C-2	Hour 05 Hours 20 to 22	1	520	520	
			C-3	Hours 06 to 19	1	660	660	
D	New M5	St Peters Interchange	D-1	Hours 22 to 04	3	225	75	16.5
			D-2	Hour 05 Hours 17 to 21	3	300	100	
			D-3	Hours 06 to 16	4	425	106	
E	New M5	Arncliffe	E-1	Hours 22 to 04	3	190	63	16.8
			E-2	Hour 05 Hours 17 to 21	4	280	70	
			E-3	Hours 06 to 16	4	380	95	
F	New M5	Kingsgrove	F-1	Hours 22 to 05	1	225	225	21.6
			F-2	Hours 06 to 12 Hours 18 to 21	1	380	380	
			F-3	Hours 13 to 17	1	470	470	

Table I-3 Ventilation air flows and temperatures: 2023-DS

Ventilation facility	Tunnel project	Location	GRAL source group	Time period(s) (hour start)	No. of outlets	Total air flow (m^3/s)	Air flow per outlet (m^3/s)	Outlet temp. (ºC)
A	M5 East	Turrella	A-1	Hour 22 to 04	1	419	419	30.0
			A-2	Hour 05 to 21	1	837	837	
B	M4 East	Parramatta Road	B-1	Hours 22 to 06	1	275	275	18.6
			B-2	Hours 18 to 21	1	305	305	
			B-3	Hours 07 to 17	1	340	340	
C	M4 East	Underwood Road	C-1	Hours 23 to 04	1	410	410	27.5
			C-2	Hour 05 Hours 21 to 22	1	680	680	
			C-3	Hours 06 to 20	1	840	840	
D	New M5	St Peters Interchange	D-1	Hours 22 to 05	2	150	75	27.5
			D-2	Hours 17 to 21	2	210	105	
			D-3	Hours 06 to 16	3	280	93	
E	New M5	Arncliffe	E-1	Hours 22 to 04	3	140	47	16.8
			E-2	Hour 05 Hours 17 to 21	4	280	70	
			E-3	Hours 06 to 16	4	420	105	
F	New M5	Kingsgrove	F-1	Hours 22 to 05	1	220	220	21.6
			F-2	Hours 06 to 13 Hours 18 to 21	1	380	380	
			F-3	Hours 14 to 17	1	490	490	
G	M4-M5 Link	Parramatta Road	G-1	Hours 22 to 04	1	170	170	18.9
			G-2	Hour 05 Hours 19 to 21	1	240	240	
			G-3	Hours 06 to 18	1	290	290	
I	M4-M5 Link/Iron Cove Link	Rozelle (east)*	I-1	Hours 01 to 04	1	500	500	18.2
			I-2	Hours 23 to 00	1	620	620	
J	M4-M5 Link/Iron Cove Link	Rozelle (mid)*	J-1	Hours 05, 22	1	830	830	18.2
			J-2	Hour 06 Hours 14-21	1	1030	1030	
			J-3	Hours 07 to 13	1	1130	1130	
K	M4-M5 Link	St Peters Interchange	K-1	Hours 23 to 05	2	260	130	24.6
			K-2	Hour 06 Hours 16 to 22	2	450	225	
			K-3	Hours 07 to 15	2	600	300	
L	Iron Cove Link	Rozelle near Iron Cove	L-1	Hours 00 to 04	1	250	250	17.3
			L-2	Hours 05 to 06 Hours 22 to 23	1	360	360	
			L-3	Hours 07 to 21	1	470	470	

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

Table I-4 Ventilation air flows and temperatures: 2023-DSC

Ventilation facility	Tunnel project	Location	GRAL source group	Time period(s) (hour start)	No. of outlets	Total air flow (m^3/s)	Air flow per outlet (m^3/s)	Outlet temp. (ºC)
A	M5 East	Turrella	A-1	Hours 22 to 04	1	419	419	30.0
			A-2	Hours 05 to 21	1	837	837	
B	M4 East	Parramatta Road	B-1	Hours 19 to 08	1	280	280	21.0
			B-2	Hours 09 to 18	1	330	330	
C	M4 East	Underwood Road	C-1	Hours 23 to 04	1	450	450	28.9
			C-2	Hour 05 Hours 19 to 22	1	640	640	
			C-3	Hours 06 to 18	1	870	870	
D	New M5	St Peters Interchange	D-1	Hours 22 to 05	2	150	75	19.0
			D-2	Hours 16 to 21	2	220	110	
			D-3	Hours 06 to 15	3	300	100	
E	New M5	Arncliffe	E-1	Hours 22 to 05	3	160	53	18.4
			E-2	Hour 06 Hours 17 to 21	4	300	75	
			E-3	Hours 07 to 16	4	440	110	
F	New M5	Kingsgrove	F-1	Hours 23 to 04	1	230	230	22.8
			F-2	Hours 05 to 06 Hours 20 to 22	1	330	330	
			F-3	Hours 07 to 19	1	450	450	
G	M4-M5 Link	Parramatta Road	G-1	Hours 21 to 05	1	170	170	20.8
			G-2	Hours 06 to 15 Hours 17 to 20	1	300	300	
			G-3	Hour 16	1	450	450	
H	WHT	Rozelle (west)	H-1	Hours 22 to 04	1	300	300	21.0
			H-2	Hour 05 Hours 18 to 21	1	450	450	
			H-3	Hours 06 to 17	1	660	660	
I	M4-M5 Link/Iron Cove Link	Rozelle (east)*	I-1	Hours 06 to 17	1	520	520	20.8
			I-2	Hours 01 to 04	1	640	640	
J	M4-M5 Link/Iron Cove Link	Rozelle (mid)*	J-1	Hours 23 to 00 Hour 06 Hours 08 to 17	1	810	810	20.8
			J-2	Hours 05, 07, 22	1	1000	1000	
			J-3	Hours 18 to 21	1	1200	1200	
K	M4-M5 Link	St Peters Interchange	K-1	Hours 00 to 04	2	300	150	26.2
			K-2	Hours 05, 23	2	580	290	
			K-3	Hours 06 to 22	3	700	233	
L	Iron Cove Link	Rozelle near Iron Cove	L-1	Hours 23 to 04	1	280	280	20.0
			L-2	Hours 05 to 07, 22	1	380	380	
			L-3	Hours 08 to 21	1	470	470	

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

Table I-5 Ventilation air flows and temperatures: 2033-DM

Ventilation facility	Tunnel project	Location	GRAL source group	Time period(s) (hour start)	No. of outlets	Total air flow (m^3/s)	Air flow per outlet (m^3/s)	Outlet temp. (ºC)
A	M5 East	Turrella	A-1	Hours 22 to 04	1	419	419	30.0
			A-2	Hours 05 to 21	1	837	837	
B	M4 East	Parramatta Road	B-1	Hours 23 to 04	1	400	400	19.5
			B-2	Hours 05 to 06 Hours 19 to 22	1	600	600	
			B-3	Hours 07 to 18	1	750	750	
C	M4 East	Underwood Road	C-1	Hours 23 to 04	1	400	400	30.2
			C-2	Hour 05 Hours 20 to 22	1	550	550	
			C-3	Hours 06 to 19	1	700	700	
D	New M5	St Peters Interchange	D-1	Hours 22 to 04	3	240	80	18.5
			D-2	Hour 05 Hours 17 to 21	3	320	107	
			D-3	Hours 06 to 16	4	450	113	
E	New M5	Arncliffe	E-1	Hours 22 to 04	3	200	67	16.7
			E-2	Hour 05 Hours 17 to 21	4	300	75	
			E-3	Hours 06 to 16	4	400	100	
F	New M5	Kingsgrove	F-1	Hours 22 to 05	1	240	240	22.7
			F-2	Hours 06 to 12 Hours 18 to 21	1	380	380	
			F-3	Hours 13 to 17	1	500	500	

Table I-6 Ventilation air flows and temperatures: 2033-DS

Ventilation facility	Tunnel project	Location	GRAL source group	Time period(s) (hour start)	No. of outlets	Total air flow (m^3/s)	Air flow per outlet (m^3/s)	Outlet temp. (ºC)
A	M5 East	Turrella	A-1	Hour 22 to 04	1	419	419	30.0
			A-2	Hour 05 to 21	1	837	837	
B	M4 East	Parramatta Road	B-1	Hours 22 to 05	1	270	270	19.5
			B-2	Hours 18 to 21	1	310	310	
			B-3	Hours 06 to 17	1	350	350	
C	M4 East	Underwood Road	C-1	Hours 23 to 04	1	430	430	30.2
			C-2	Hour 05 Hours 21 to 22	1	700	700	
			C-3	Hours 06 to 20	1	850	850	
D	New M5	St Peters Interchange	D-1	Hours 22 to 05	2	160	80	18.5
			D-2	Hours 17 to 21	2	220	110	
			D-3	Hours 06 to 16	3	290	97	
E	New M5	Arncliffe	E-1	Hours 22 to 04	3	140	47	16.7
			E-2	Hour 05 Hours 17 to 21	4	300	75	
			E-3	Hours 06 to 16	4	440	110	
F	New M5	Kingsgrove	F-1	Hours 22 to 05	1	250	250	22.7
			F-2	Hours 06 to 13 Hours 18 to 21	1	410	410	
			F-3	Hours 14 to 17	1	520	520	
G	M4-M5 Link	Parramatta Road	G-1	Hours 22 to 04	1	180	180	19.9
			G-2	Hour 05 Hours 19 to 21	1	250	250	
			G-3	Hours 06 to 18	1	300	300	
I	M4-M5 Link/Iron Cove Link	Rozelle (east)*	I-1	Hours 01 to 03	1	530	530	19.5
			I-2	Hours 00, 04, 23	1	630	630	
J	M4-M5 Link/Iron Cove Link	Rozelle (mid)*	J-1	Hours 05, 22	1	840	840	19.5
			J-2	Hour 06 Hours 14-21	1	1050	1050	
			J-3	Hours 07 to 13	1	1180	1180	
K	M4-M5 Link	St Peters Interchange	K-1	Hours 00 to 04	2	270	135	26.6
			K-2	Hour 05 Hours 22 to 23	2	420	210	
			K-3	Hours 06 to 21	2	600	300	
L	Iron Cove Link	Rozelle near Iron Cove	L-1	Hours 00 to 04	1	250	250	17.6
			L-2	Hours 05 to 06 Hours 22 to 23	1	360	360	
			L-3	Hours 07 to 21	1	470	470	

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

Table I-7 Ventilation air flows and temperatures: 2033-DSC

Ventilation facility	Tunnel project	Location	GRAL source group	Time period(s) (hour start)	No. of outlets	Total air flow (m^3/s)	Air flow per outlet (m^3/s)	Outlet temp. (ºC)
A	M5 East	Turrella	A-1	Hour 22 to 04	1	419	419	30.0
			A-2	Hour 05 to 21	1	837	837	
B	M4 East	Parramatta Road	B-1	Hours 22 to 05 Hours 07 to 08	1	270	270	21.9
			B-2	Hour 06 Hours 09 to 21	1	300	300	
C	M4 East	Underwood Road	C-1	Hours 00 to 04	1	450	450	31.6
			C-2	Hour 05 Hours 20 to 23	1	650	650	
			C-3	Hours 06 to 19	1	880	880	
D	New M5	St Peters Interchange	D-1	Hours 22 to 05	2	160	80	21.2
			D-2	Hour 06 Hours 12 to 21	3	300	100	
			D-3	Hours 07 to 11	3	380	127	
E	New M5	Arncliffe	E-1	Hours 22 to 05	3	180	60	18.3
			E-2	Hour 06 Hours 17 to 21	4	300	75	
			E-3	Hours 07 to 16	4	450	113	
F	New M5	Kingsgrove	F-1	Hours 23 to 04	1	210	210	23.9
			F-2	Hour 05 Hours 19 to 22	1	330	330	
			F-3	Hours 06 to 18	1	400	400	
G	M4-M5 Link	Parramatta Road	G-1	Hours 22 to 05	1	170	170	21.9
			G-2	Hour 06 Hours 08 to 15 Hours 17 to 21	1	300	300	
			G-3	Hours 07, 16	1	450	450	
H	WHT	Rozelle (west)	H-1	Hours 23 to 04	1	330	330	22.2
			H-2	Hour 05 Hours 18 to 22	1	500	500	
			H-3	Hours 06 to 17	1	750	750	
I	M4-M5 Link/Iron Cove Link	Rozelle (east)*	I-1	Hours 06 to 21	1	550	550	21.8
			I-2	Hours 01 to 03	1	700	700	
J	M4-M5 Link/Iron Cove Link	Rozelle (mid)*	J-1	Hours 04, 06 Hours 08 to 21 Hours 23 to 00	1	810	810	21.8
			J-2	Hours 05, 07, 22	1	1000	1000	
K	M4-M5 Link	St Peters Interchange	K-1	Hours 00 to 04	2	270	135	28.3
			K-2	Hour 05 Hours 22 to 23	2	450	225	
			K-3	Hours 06 to 21	2	620	310	
L	Iron Cove Link	Rozelle near Iron Cove	L-1	Hours 23 to 04	1	280	280	20.3
			L-2	Hours 05 to 07 Hour 22	1	380	380	
			L-3	Hours 08 to 21	1	470	470	
M	F6 Extension	Arncliffe	M-1	Hours 22 to 05	3	260	87	17.6
			M-2	Hours 17 to 21	4	450	113	
			M-3	Hours 06 to 16	4	600	150	
N	F6 Extension	Rockdale	N-1	Hours 22 to 06	3	300	100	23.1
			N-2	Hours 07 to 12 Hours 19 to 21	4	450	113	
			N-3	Hours 13 to 18	4	600	150	

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

I.1.2 Effective diameters and exit velocities

Table I-8 Effective diameters and exit velocities: 2015-BY

Ventilation facility	Tunnel project	Location	GRAL source group	No. of outlets	No. of fans per outlet	Air flow per outlet (m^3/s)	CSA per outlet (m^2)	Effective diameter per outlet (m)	Exit velocity (m/s)
A	M5 East	Turrella	A-1	1	-	419	42.2	7.3	10.0
			A-2	1	-	837	42.2	7.3	20.0

Table I-9 Effective diameters and exit velocities: 2023-DM

Ventilation facility	Tunnel project	Location	GRAL source group	No. of outlets	No. of fans per outlet	Air flow per outlet (m^3/s)	CSA per outlet (m^2)	Effective diameter per outlet (m)	Exit velocity (m/s)
A	M5 East	Turrella	A-1	1	-	419	42.2	7.3	10.0
			A-2	1	-	837	42.2	7.3	20.0
B	M4 East	Parramatta Road	B-1	1	-	380	77.0	9.9	4.9
			B-2	1	-	570	77.0	9.9	7.4
			B-3	1	-	710	77.0	9.9	9.2
C	M4 East	Underwood Road	C-1	1	2	380	40.0	7.1	9.5
			C-2	1	3	520	60.0	8.7	8.7
			C-3	1	4	660	80.0	10.1	8.3
D	New M5	St Peters Interchange	D-1	3	-	75	25.0	5.6	3.0
			D-2	3	-	100	25.0	5.6	4.0
			D-3	4	-	106	25.0	5.6	4.3
E	New M5	Arncliffe	E-1	3	-	63	15.8	4.5	4.0
			E-2	4	-	70	15.8	4.5	4.4
			E-3	4	-	95	15.8	4.5	6.0
F	New M5	Kingsgrove	F-1	1	2	225	40.6	7.2	5.5
			F-2	1	2	380	40.6	7.2	9.4
			F-3	1	3	470	60.9	8.8	7.7

Table I-10 Effective diameters and exit velocities: 2023-DS

Ventilation facility	Tunnel project	Location	GRAL source group	No. of outlets	No. of fans per outlet	Air flow per outlet (m^3/s)	CSA per outlet (m^2)	Effective diameter per outlet (m)	Exit velocity (m/s)
A	M5 East	Turrella	A-1	1	-	419	42.2	7.3	10.0
			A-2	1	-	837	42.2	7.3	20.0
B	M4 East	Parramatta Road	B-1	1	-	275	77.0	9.9	3.6
			B-2	1	-	305	77.0	9.9	4.0
			B-3	1	-	340	77.0	9.9	4.4
C	M4 East	Underwood Road	C-1	1	3	410	60.0	8.7	3.6
			C-2	1	4	680	80.0	10.1	4.0
			C-3	1	4	840	80.0	10.1	4.4
D	New M5	St Peters Interchange	D-1	2	-	75	25.0	5.6	3.0
			D-2	2	-	105	25.0	5.6	4.2
			D-3	3	-	93	25.0	5.6	3.7
E	New M5	Arncliffe	E-1	3	-	47	15.8	4.5	3.0
			E-2	4	-	70	15.8	4.5	4.4
			E-3	4	-	105	15.8	4.5	6.6
F	New M5	Kingsgrove	F-1	1	2	220	40.6	7.2	5.4
			F-2	1	2	380	40.6	7.2	9.4
			F-3	1	3	490	60.9	8.8	8.0
G	M4-M5 Link	Parramatta Road	G-1	1	-	170	77.0	9.9	2.2
			G-2	1	-	240	77.0	9.9	3.1
			G-3	1	-	290	77.0	9.9	3.8
I	M4-M5 Link/Iron Cove Link	Rozelle (east)	I-1	1	-	500	113.1	12.0	4.4
			I-2	1	-	620	113.1	12.0	5.5
J	M4-M5 Link/Iron Cove Link	Rozelle (mid)	J-1	1	-	830	176.7	15.0	4.7
			J-2	1	-	1030	176.7	15.0	5.8
			J-3	1	-	1130	176.7	15.0	6.4
K	M4-M5 Link	St Peters Interchange	K-1	2	-	130	64.0	9.0	2.0
			K-2	2	-	225	64.0	9.0	3.5
			K-3	2	-	300	64.0	9.0	4.7
L	Iron Cove Link	Rozelle near Iron Cove	L-1	1	-	250	38.5	7.0	6.5
			L-2	1	-	360	38.5	7.0	9.4
			L-3	1	-	470	38.5	7.0	12.2

Table I-11 Effective diameters and exit velocities: 2023-DSC

Ventilation facility	Tunnel project	Location	GRAL source group	No. of outlets	No. of fans per outlet	Air flow per outlet (m^3/s)	CSA per outlet (m^2)	Effective diameter per outlet (m)	Exit velocity (m/s)
A	M5 East	Turrella	A-1	1	-	419	42.2	7.3	10.0
			A-2	1	-	837	42.2	7.3	20.0
B	M4 East	Parramatta Road	B-1	1	-	280	77.0	9.9	3.6
			B-2	1	-	330	77.0	9.9	4.3
C	M4 East	Underwood Road	C-1	1	3	450	60.0	8.7	7.5
			C-2	1	4	640	80.0	10.1	8.0
			C-3	1	4	870	80.0	10.1	10.9
D	New M5	St Peters Interchange	D-1	2	-	75	25.0	5.6	3.0
			D-2	2	-	110	25.0	5.6	4.4
			D-3	3	-	100	25.0	5.6	4.0
E	New M5	Arncliffe	E-1	3	-	53	15.8	4.5	3.4
			E-2	4	-	75	15.8	4.5	4.7
			E-3	4	-	110	15.8	4.5	7.0
F	New M5	Kingsgrove	F-1	1	2	230	40.6	7.2	5.7
			F-2	1	2	330	40.6	7.2	8.1
			F-3	1	3	450	60.9	8.8	7.4
G	M4-M5 Link	Parramatta Road	G-1	1	-	170	77.0	9.9	2.2
			G-2	1	-	300	77.0	9.9	3.9
			G-3	1	-	450	77.0	9.9	5.8
H	WHT	Rozelle (west)	H-1	1	-	300	154.0	14.0	1.9
			H-2	1	-	450	154.0	14.0	2.9
			H-3	1	-	660	154.0	14.0	4.3
I	M4-M5 Link/Iron Cove Link	Rozelle (east)	I-1	1	-	520	113.1	12.0	4.6
			I-2	1	-	640	113.1	12.0	5.7
J	M4-M5 Link/Iron Cove Link	Rozelle (mid)	J-1	1	-	810	176.7	15.0	4.6
			J-2	1	-	1000	176.7	15.0	5.7
			J-3	1	-	1200	176.7	15.0	6.8
K	M4-M5 Link	St Peters Interchange	K-1	2	-	150	64.0	9.0	2.3
			K-2	2	-	290	64.0	9.0	4.5
			K-3	3	-	233	64.0	9.0	3.6
L	Iron Cove Link	Rozelle near Iron Cove	L-1	1	-	280	38.5	7.0	7.3
			L-2	1	-	380	38.5	7.0	9.9
			L-3	1	-	470	38.5	7.0	12.2

Table I-12 Effective diameters and exit velocities: 2033-DM

Ventilation facility	Tunnel project	Location	GRAL source group	No. of outlets	No. of fans per outlet	Air flow per outlet (m^3/s)	CSA per outlet (m^2)	Effective diameter per outlet (m)	Exit velocity (m/s)
A	M5 East	Turrella	A-1	1	-	419	42.2	7.3	10.0
			A-2	1	-	837	42.2	7.3	20.0
B	M4 East	Parramatta Road	B-1	1	-	400	77.0	9.9	5.2
			B-2	1	-	600	77.0	9.9	7.8
			B-3	1	-	750	77.0	9.9	9.7
C	M4 East	Underwood Road	C-1	1	2	400	40.0	7.1	10.0
			C-2	1	3	550	60.0	8.7	9.2
			C-3	1	4	700	80.0	10.1	8.8
D	New M5	St Peters Interchange	D-1	3	-	80	25.0	5.6	3.2
			D-2	3	-	107	25.0	5.6	4.3
			D-3	4	-	113	25.0	5.6	4.5
E	New M5	Arncliffe	E-1	3	-	67	15.8	4.5	4.2
			E-2	4	-	75	15.8	4.5	4.7
			E-3	4	-	100	15.8	4.5	6.3
F	New M5	Kingsgrove	F-1	1	2	240	40.6	7.2	5.9
			F-2	1	2	380	40.6	7.2	9.4
			F-3	1	3	500	60.9	8.8	8.2

Table I-13 Effective diameters and exit velocities: 2033-DS

Ventilation facility	Tunnel project	Location	GRAL source group	No. of outlets	No. of fans per outlet	Air flow per outlet (m^3/s)	CSA per outlet (m^2)	Effective diameter per outlet (m)	Exit velocity (m/s)
A	M5 East	Turrella	A-1	1	-	419	42.2	7.3	10.0
			A-2	1	-	837	42.2	7.3	20.0
B	M4 East	Parramatta Road	B-1	1	-	270	77.0	9.9	3.5
			B-2	1	-	310	77.0	9.9	4.0
			B-3	1	-	350	77.0	9.9	4.5
C	M4 East	Underwood Road	C-1	1	3	430	60.0	8.7	7.2
			C-2	1	4	700	80.0	10.1	8.8
			C-3	1	4	850	80.0	10.1	10.6
D	New M5	St Peters Interchange	D-1	2	-	80	25.0	5.6	3.2
			D-2	2	-	110	25.0	5.6	4.4
			D-3	3	-	97	25.0	5.6	3.9
E	New M5	Arncliffe	E-1	3	-	47	15.8	4.5	3.0
			E-2	4	-	75	15.8	4.5	4.7
			E-3	4	-	110	15.8	4.5	7.0
F	New M5	Kingsgrove	F-1	1	2	250	40.6	7.2	6.2
			F-2	1	3	410	60.9	8.8	6.7
			F-3	1	3	520	60.9	8.8	8.5
G	M4-M5 Link	Parramatta Road	G-1	1	-	180	77.0	9.9	2.3
			G-2	1	-	250	77.0	9.9	3.2
			G-3	1	-	300	77.0	9.9	3.9
I	M4-M5 Link/Iron Cove Link	Rozelle (east)	I-1	1	-	530	113.1	12.0	4.7
			I-2	1	-	630	113.1	12.0	5.6
J	M4-M5 Link/Iron Cove Link	Rozelle (mid)	J-1	1	-	840	176.7	15.0	4.8
			J-2	1	-	1050	176.7	15.0	5.9
			J-3	1	-	1180	176.7	15.0	6.7
K	M4-M5 Link	St Peters Interchange	K-1	2	-	135	64.0	9.0	2.1
			K-2	2	-	210	64.0	9.0	3.3
			K-3	2	-	300	64.0	9.0	4.7
L	Iron Cove Link	Rozelle near Iron Cove	L-1	1	-	250	38.5	7.0	6.5
			L-2	1	-	360	38.5	7.0	9.4
			L-3	1	-	470	38.5	7.0	12.2

Table I-14 Effective diameters and exit velocities: 2033-DSC

Ventilation facility	Tunnel project	Location	GRAL source group	No. of outlets	No. of fans per outlet	Air flow per outlet (m^3/s)	CSA per outlet (m^2)	Effective diameter per outlet (m)	Exit velocity (m/s)
A	M5 East	Turrella	A-1	1	-	419	42.2	7.3	10.0
			A-2	1	-	837	42.2	7.3	20.0
B	M4 East	Parramatta Road	B-1	1	-	270	77.0	9.9	3.5
			B-2	1	-	300	77.0	9.9	3.9
C	M4 East	Underwood Road	C-1	1	3	450	60.0	8.7	7.5
			C-2	1	4	650	80.0	10.1	8.1
			C-3	1	4	880	80.0	10.1	11.0
D	New M5	St Peters Interchange	D-1	2	-	80	25.0	5.6	3.2
			D-2	3	-	100	25.0	5.6	4.0
			D-3	3	-	127	25.0	5.6	5.1
E	New M5	Arncliffe	E-1	3	-	60	15.8	4.5	3.8
			E-2	4	-	75	15.8	4.5	4.7
			E-3	4	-	113	15.8	4.5	7.1
F	New M5	Kingsgrove	F-1	1	2	210	40.6	7.2	5.2
			F-2	1	2	330	40.6	7.2	8.1
			F-3	1	4	400	81.2	10.2	4.9
G	M4-M5 Link	Parramatta Road	G-1	1	-	170	77.0	9.9	2.2
			G-2	1	-	300	77.0	9.9	3.9
			G-3	1	-	450	77.0	9.9	5.8
H	WHT	Rozelle (west)	H-1	1	-	330	154.0	14.0	2.1
			H-2	1	-	500	154.0	14.0	3.2
			H-3	1	-	750	154.0	14.0	4.9
I	M4-M5 Link/Iron Cove Link	Rozelle (east)	I-1	1	-	550	113.1	12.0	4.9
			I-2	1	-	700	113.1	12.0	6.2
J	M4-M5 Link/Iron Cove Link	Rozelle (mid)	J-1	1	-	810	176.7	15.0	4.6
			J-2	1	-	1000	176.7	15.0	5.7
K	M4-M5 Link	St Peters Interchange	K-1	2	-	135	64.0	9.0	2.1
			K-2	2	-	225	64.0	9.0	3.5
			K-3	2	-	310	64.0	9.0	4.8
L	Iron Cove Link	Rozelle near Iron Cove	L-1	1	-	280	38.5	7.0	7.3
			L-2	1	-	380	38.5	7.0	9.9
			L-3	1	-	470	38.5	7.0	12.2
M	F6 Extension	Arncliffe	M-1	3	-	87	15.8	4.5	5.5
			M-2	4	-	113	15.8	4.5	7.1
			M-3	4	-	150	15.8	4.5	9.5
N	F6 Extension	Rockdale	N-1	3	-	100	12.5	4.0	8.0
			N-2	4	-	113	12.5	4.0	9.0
			N-3	4	-	150	12.5	4.0	12.0

I.1.3 Emissions

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: 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.

It should be noted that 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.

I.1.3.1 Outlet A (M5 East Tunnel, Turrella)

Table I-15 Outlet A, 2015-BY

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	1.579	0.891	0.032	0.025	0.093
01	1.215	0.686	0.024	0.018	0.072
02	1.131	0.638	0.022	0.017	0.067
03	1.421	0.801	0.031	0.024	0.084
04	2.647	1.493	0.077	0.059	0.156
05	4.588	2.589	0.157	0.120	0.271
06	5.673	3.201	0.225	0.172	0.335
07	5.984	4.136	0.268	0.197	0.510
08	6.198	4.285	0.292	0.215	0.528
09	6.534	2.956	0.306	0.230	0.407
10	6.820	3.085	0.324	0.243	0.425
11	7.030	3.180	0.340	0.255	0.438
12	7.355	3.328	0.358	0.269	0.458
13	7.436	3.364	0.360	0.270	0.463
14	7.147	3.234	0.324	0.243	0.445
15	6.609	5.100	0.276	0.206	0.466
16	5.757	4.443	0.214	0.160	0.406
17	5.015	3.870	0.166	0.124	0.354
18	4.487	2.532	0.133	0.102	0.265
19	3.686	2.080	0.099	0.076	0.218
20	3.149	1.777	0.076	0.058	0.186
21	2.840	1.602	0.065	0.050	0.168
22	2.253	1.271	0.048	0.036	0.133
23	2.017	1.138	0.041	0.032	0.119
Average emission rates by source group used in GRAL **(kg/h)**					
A-1	***6.307***	***3.558***	***0.141***	***0.108***	***0.372***
A-2	***20.395***	***11.597***	***0.844***	***0.633***	***1.343***
Emissions released from 1 outlet					

Table I-16 Outlet A, 2023-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.332	0.125	0.008	0.006	0.011
01	0.255	0.096	0.006	0.004	0.008
02	0.238	0.089	0.006	0.004	0.008
03	0.298	0.112	0.008	0.005	0.010
04	0.556	0.209	0.020	0.013	0.018
05	0.964	0.362	0.041	0.027	0.032
06	1.192	0.448	0.058	0.039	0.039
07	2.075	1.728	0.115	0.075	0.105
08	2.149	1.790	0.125	0.082	0.108
09	1.923	0.777	0.100	0.067	0.059
10	2.007	0.811	0.106	0.071	0.061
11	2.069	0.836	0.111	0.075	0.063
12	2.165	0.874	0.117	0.079	0.066
13	2.189	0.884	0.118	0.079	0.067
14	2.104	0.849	0.106	0.071	0.064
15	2.342	1.559	0.133	0.087	0.110
16	2.040	1.358	0.103	0.067	0.096
17	1.777	1.183	0.080	0.052	0.084
18	0.943	0.354	0.035	0.023	0.031
19	0.774	0.291	0.026	0.017	0.026
20	0.662	0.249	0.020	0.013	0.022
21	0.597	0.224	0.017	0.011	0.020
22	0.473	0.178	0.012	0.008	0.016
23	0.424	0.159	0.011	0.007	0.014
Average emission rates by source group used in GRAL **(kg/h)**					
A-1	***1.325***	***0.498***	***0.037***	***0.024***	***0.044***
A-2	***5.923***	***3.087***	***0.299***	***0.198***	***0.223***
Emissions released from 1 outlet					

Table I-17 Outlet A, 2023-DS

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.230	0.127	0.006	0.004	0.008
01	0.177	0.098	0.004	0.003	0.006
02	0.165	0.091	0.004	0.003	0.006
03	0.207	0.115	0.005	0.004	0.007
04	0.385	0.213	0.014	0.009	0.014
05	0.668	0.370	0.028	0.019	0.024
06	0.826	0.457	0.040	0.027	0.030
07	1.637	1.689	0.087	0.058	0.085
08	1.696	1.750	0.095	0.063	0.088
09	1.347	0.667	0.069	0.046	0.043
10	1.406	0.697	0.073	0.049	0.044
11	1.450	0.718	0.076	0.052	0.046
12	1.517	0.751	0.080	0.054	0.048
13	1.533	0.760	0.081	0.055	0.048
14	1.474	0.730	0.073	0.049	0.047
15	1.620	1.493	0.090	0.059	0.082
16	1.411	1.300	0.070	0.046	0.072
17	1.230	1.133	0.054	0.036	0.062
18	0.653	0.362	0.024	0.016	0.024
19	0.537	0.297	0.018	0.012	0.019
20	0.458	0.254	0.013	0.009	0.017
21	0.413	0.229	0.012	0.008	0.015
22	0.328	0.182	0.008	0.006	0.012
23	0.294	0.163	0.007	0.005	0.011
Average emission rates by source group used in GRAL **(kg/h)**					
A-1	***0.918***	***0.508***	***0.025***	***0.017***	***0.033***
A-2	***4.209***	***2.892***	***0.208***	***0.139***	***0.168***
Emissions released from 1 outlet					

Table I-18 Outlet A, 2023-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.197	0.114	0.005	0.003	0.007
01	0.151	0.088	0.004	0.002	0.006
02	0.141	0.082	0.003	0.002	0.005
03	0.177	0.103	0.005	0.003	0.007
04	0.329	0.192	0.012	0.008	0.012
05	0.571	0.332	0.024	0.016	0.021
06	0.706	0.411	0.034	0.023	0.026
07	1.421	1.529	0.077	0.051	0.077
08	1.472	1.584	0.084	0.056	0.080
09	1.134	0.601	0.059	0.040	0.038
10	1.183	0.627	0.062	0.042	0.039
11	1.220	0.646	0.065	0.044	0.040
12	1.276	0.676	0.069	0.046	0.042
13	1.290	0.683	0.069	0.047	0.043
14	1.240	0.657	0.062	0.042	0.041
15	1.375	1.337	0.077	0.051	0.073
16	1.197	1.165	0.060	0.040	0.063
17	1.043	1.015	0.046	0.031	0.055
18	0.558	0.325	0.020	0.014	0.021
19	0.459	0.267	0.015	0.010	0.017
20	0.392	0.228	0.012	0.008	0.015
21	0.353	0.206	0.010	0.007	0.013
22	0.280	0.163	0.007	0.005	0.010
23	0.251	0.146	0.006	0.004	0.009
Average emission rates by source group used in GRAL **(kg/h)**					
A-1	***0.785***	***0.456***	***0.022***	***0.015***	***0.029***
A-2	***3.577***	***2.602***	***0.179***	***0.120***	***0.149***
Emissions released from 1 outlet					

Table I-19 Outlet A, 2033-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.382	0.078	0.010	0.006	0.007
01	0.294	0.060	0.008	0.005	0.006
02	0.273	0.056	0.007	0.004	0.005
03	0.344	0.070	0.010	0.006	0.006
04	0.640	0.130	0.025	0.015	0.012
05	1.110	0.226	0.050	0.032	0.021
06	1.372	0.279	0.072	0.045	0.026
07	2.140	0.769	0.134	0.083	0.065
08	2.216	0.796	0.145	0.090	0.067
09	2.180	0.514	0.122	0.077	0.038
10	2.276	0.537	0.129	0.082	0.039
11	2.346	0.553	0.135	0.086	0.040
12	2.454	0.579	0.143	0.091	0.042
13	2.481	0.585	0.143	0.091	0.043
14	2.385	0.563	0.129	0.082	0.041
15	2.503	1.089	0.156	0.097	0.075
16	2.180	0.949	0.121	0.076	0.066
17	1.899	0.827	0.094	0.059	0.057
18	1.085	0.221	0.043	0.027	0.020
19	0.892	0.181	0.032	0.020	0.017
20	0.762	0.155	0.024	0.015	0.014
21	0.687	0.140	0.021	0.013	0.013
22	0.545	0.111	0.015	0.010	0.010
23	0.488	0.099	0.013	0.008	0.009
Average emission rates by source group used in GRAL **(kg/h)**					
A-1	***1.526***	***0.310***	***0.045***	***0.028***	***0.029***
A-2	***6.558***	***1.898***	***0.358***	***0.226***	***0.145***
Emissions released from 1 outlet					

Table I-20 Outlet A, 2033-DS

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.275	0.083	0.007	0.005	0.006
01	0.211	0.064	0.005	0.003	0.004
02	0.197	0.059	0.005	0.003	0.004
03	0.247	0.074	0.007	0.004	0.005
04	0.461	0.138	0.017	0.011	0.009
05	0.799	0.240	0.035	0.023	0.016
06	0.987	0.297	0.051	0.032	0.020
07	1.714	1.136	0.101	0.064	0.055
08	1.775	1.176	0.110	0.070	0.057
09	1.469	0.459	0.082	0.052	0.028
10	1.533	0.479	0.087	0.055	0.029
11	1.580	0.493	0.091	0.058	0.030
12	1.653	0.516	0.096	0.061	0.031
13	1.671	0.522	0.096	0.062	0.031
14	1.607	0.502	0.087	0.055	0.030
15	1.703	1.109	0.107	0.067	0.057
16	1.484	0.966	0.083	0.052	0.050
17	1.292	0.841	0.064	0.040	0.044
18	0.781	0.235	0.030	0.019	0.016
19	0.642	0.193	0.022	0.014	0.013
20	0.548	0.165	0.017	0.011	0.011
21	0.494	0.149	0.015	0.009	0.010
22	0.392	0.118	0.011	0.007	0.008
23	0.351	0.106	0.009	0.006	0.007
Average emission rates by source group used in GRAL **(kg/h)**					
A-1	***1.098***	***0.330***	***0.032***	***0.020***	***0.022***
A-2	***4.602***	***2.007***	***0.248***	***0.158***	***0.112***
Emissions released from 1 outlet					

Table I-21 Outlet A, 2033-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.223	0.076	0.006	0.004	0.005
01	0.172	0.059	0.004	0.003	0.004
02	0.160	0.055	0.004	0.003	0.004
03	0.201	0.069	0.006	0.004	0.004
04	0.374	0.128	0.014	0.009	0.008
05	0.648	0.221	0.030	0.019	0.014
06	0.801	0.274	0.042	0.027	0.018
07	1.497	1.065	0.091	0.058	0.053
08	1.551	1.104	0.099	0.063	0.055
09	1.180	0.423	0.068	0.044	0.025
10	1.232	0.442	0.072	0.046	0.026
11	1.270	0.455	0.076	0.048	0.027
12	1.329	0.476	0.080	0.051	0.028
13	1.343	0.482	0.080	0.051	0.029
14	1.291	0.463	0.072	0.046	0.028
15	1.446	1.039	0.094	0.059	0.054
16	1.260	0.905	0.073	0.046	0.047
17	1.097	0.788	0.057	0.036	0.041
18	0.634	0.216	0.025	0.016	0.014
19	0.521	0.178	0.019	0.012	0.012
20	0.445	0.152	0.014	0.009	0.010
21	0.401	0.137	0.012	0.008	0.009
22	0.318	0.109	0.009	0.006	0.007
23	0.285	0.097	0.008	0.005	0.006
Average emission rates by source group used in GRAL **(kg/h)**					
A-1	***0.891***	***0.304***	***0.027***	***0.017***	***0.020***
A-2	***3.801***	***1.868***	***0.213***	***0.135***	***0.104***
Emissions released from 1 outlet					

I.1.3.2 Outlet B (M4 East Tunnel, Parramatta Road)

Table I-22 Outlet B, 2023-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.266	0.434	0.041	0.027	0.011
01	0.175	0.291	0.027	0.018	0.007
02	0.153	0.253	0.024	0.016	0.006
03	0.155	0.263	0.024	0.016	0.006
04	0.198	0.347	0.032	0.021	0.008
05	0.389	0.666	0.062	0.041	0.016
06	0.991	1.672	0.158	0.103	0.040
07	1.735	2.751	0.269	0.176	0.069
08	1.623	2.606	0.252	0.165	0.065
09	1.485	2.464	0.234	0.153	0.059
10	1.400	2.388	0.223	0.146	0.056
11	1.347	2.349	0.217	0.142	0.054
12	1.310	2.324	0.213	0.139	0.052
13	1.140	2.277	0.198	0.129	0.046
14	1.030	2.286	0.190	0.124	0.041
15	1.031	2.421	0.198	0.129	0.041
16	1.090	2.672	0.217	0.142	0.044
17	0.972	2.180	0.180	0.118	0.039
18	0.877	1.722	0.151	0.099	0.035
19	0.847	1.583	0.142	0.093	0.034
20	0.839	1.534	0.139	0.091	0.034
21	0.813	1.437	0.132	0.086	0.033
22	0.403	0.708	0.065	0.042	0.016
23	0.278	0.481	0.044	0.029	0.011
Average emission rates by source group used in GRAL **(kg/h)**					
B-1	***0.735***	***1.241***	***0.115***	***0.075***	***0.029***
B-2	***2.569***	***4.561***	***0.419***	***0.274***	***0.103***
B-3	***4.511***	***8.532***	***0.762***	***0.498***	***0.180***
Emissions released from 1 outlet					

Table I-23 Outlet B, 2023-DS

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.119	0.212	0.018	0.012	0.007
01	0.080	0.153	0.013	0.009	0.005
02	0.065	0.134	0.011	0.008	0.004
03	0.074	0.140	0.012	0.008	0.004
04	0.106	0.182	0.016	0.011	0.006
05	0.217	0.318	0.030	0.020	0.013
06	0.427	0.750	0.065	0.044	0.026
07	0.831	1.354	0.120	0.082	0.050
08	0.707	1.259	0.108	0.074	0.042
09	0.667	1.182	0.101	0.069	0.040
10	0.645	1.129	0.096	0.066	0.039
11	0.627	1.097	0.094	0.064	0.038
12	0.608	1.076	0.091	0.063	0.037
13	0.578	1.078	0.089	0.061	0.035
14	0.534	1.122	0.088	0.060	0.032
15	0.555	1.297	0.097	0.066	0.033
16	0.625	1.592	0.115	0.079	0.038
17	0.500	1.146	0.086	0.059	0.030
18	0.404	0.810	0.065	0.044	0.024
19	0.369	0.693	0.057	0.039	0.022
20	0.352	0.644	0.054	0.037	0.021
21	0.337	0.603	0.051	0.035	0.020
22	0.241	0.352	0.033	0.023	0.014
23	0.139	0.245	0.021	0.014	0.008
Average emission rates by source group used in GRAL **(kg/h)**					
B-1	***0.587***	***0.994***	***0.088***	***0.060***	***0.035***
B-2	***1.316***	***2.475***	***0.204***	***0.140***	***0.079***
B-3	***2.251***	***4.363***	***0.355***	***0.243***	***0.135***
Emissions released from 1 outlet					

Table I-24 Outlet B, 2023-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.127	0.215	0.019	0.013	0.008
01	0.093	0.153	0.014	0.010	0.006
02	0.077	0.134	0.012	0.008	0.005
03	0.079	0.139	0.012	0.009	0.005
04	0.113	0.182	0.017	0.012	0.007
05	0.211	0.321	0.030	0.021	0.013
06	0.431	0.709	0.064	0.044	0.026
07	0.700	1.087	0.096	0.066	0.042
08	0.666	1.104	0.098	0.067	0.040
09	0.671	1.105	0.099	0.068	0.040
10	0.659	1.084	0.097	0.067	0.040
11	0.649	1.066	0.095	0.065	0.039
12	0.629	1.057	0.093	0.064	0.038
13	0.569	1.054	0.089	0.061	0.034
14	0.537	1.115	0.089	0.061	0.032
15	0.562	1.288	0.098	0.067	0.034
16	0.612	1.525	0.112	0.077	0.037
17	0.499	1.120	0.086	0.059	0.030
18	0.409	0.806	0.066	0.045	0.025
19	0.376	0.688	0.058	0.040	0.023
20	0.357	0.635	0.054	0.037	0.021
21	0.347	0.598	0.052	0.036	0.021
22	0.250	0.381	0.035	0.024	0.015
23	0.145	0.234	0.022	0.015	0.009
Average emission rates by source group used in GRAL **(kg/h)**					
B-1	***1.022***	***1.692***	***0.150***	***0.103***	***0.061***
B-2	***2.087***	***4.039***	***0.333***	***0.228***	***0.125***
B-3	***-***	***-***	***-***	***-***	***-***
Emissions released from 1 outlet					

Table I-25 Outlet B, 2033-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.189	0.346	0.039	0.025	0.008
01	0.141	0.257	0.029	0.019	0.006
02	0.127	0.226	0.026	0.017	0.005
03	0.135	0.248	0.028	0.018	0.005
04	0.181	0.332	0.037	0.024	0.007
05	0.364	0.668	0.075	0.049	0.015
06	0.753	1.480	0.163	0.107	0.030
07	0.364	0.668	0.075	0.049	0.015
08	0.753	1.480	0.163	0.107	0.030
09	1.388	2.348	0.278	0.182	0.056
10	1.162	2.092	0.241	0.157	0.046
11	1.081	1.990	0.226	0.148	0.043
12	1.058	1.957	0.222	0.145	0.042
13	1.039	1.931	0.218	0.143	0.042
14	1.017	1.919	0.216	0.141	0.041
15	0.939	1.881	0.207	0.135	0.038
16	0.885	1.883	0.203	0.133	0.035
17	0.854	1.936	0.205	0.134	0.034
18	0.875	2.150	0.225	0.147	0.035
19	0.719	1.352	0.151	0.099	0.029
20	0.710	1.305	0.147	0.096	0.028
21	0.699	1.257	0.143	0.094	0.028
22	0.441	0.703	0.083	0.054	0.018
23	0.285	0.473	0.055	0.036	0.011
Average emission rates by source group used in GRAL **(kg/h)**					
B-1	***0.636***	***1.130***	***0.128***	***0.084***	***0.025***
B-2	***2.211***	***4.058***	***0.458***	***0.299***	***0.088***
B-3	***3.556***	***7.011***	***0.779***	***0.509***	***0.142***
Emissions released from 1 outlet					

Table I-26 Outlet B, 2033-DS

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.094	0.182	0.019	0.013	0.004
01	0.076	0.135	0.015	0.010	0.003
02	0.064	0.114	0.013	0.009	0.003
03	0.066	0.118	0.013	0.009	0.003
04	0.092	0.156	0.018	0.012	0.004
05	0.167	0.287	0.032	0.021	0.007
06	0.355	0.699	0.074	0.049	0.014
07	0.724	1.228	0.133	0.087	0.029
08	0.629	1.116	0.120	0.079	0.025
09	0.590	1.062	0.115	0.075	0.024
10	0.569	1.020	0.111	0.072	0.023
11	0.553	0.992	0.108	0.070	0.022
12	0.536	0.973	0.105	0.069	0.021
13	0.495	0.953	0.100	0.066	0.020
14	0.467	0.968	0.100	0.065	0.019
15	0.478	1.068	0.107	0.070	0.019
16	0.521	1.282	0.122	0.080	0.021
17	0.421	0.940	0.094	0.061	0.017
18	0.349	0.707	0.073	0.048	0.014
19	0.315	0.601	0.064	0.042	0.013
20	0.306	0.567	0.061	0.040	0.012
21	0.294	0.530	0.058	0.038	0.012
22	0.204	0.323	0.037	0.024	0.008
23	0.112	0.199	0.022	0.014	0.004
Average emission rates by source group used in GRAL **(kg/h)**					
B-1	***0.394***	***0.680***	***0.076***	***0.050***	***0.016***
B-2	***1.137***	***2.164***	***0.231***	***0.151***	***0.045***
B-3	***1.902***	***3.690***	***0.387***	***0.253***	***0.076***
Emissions released from 1 outlet					

Table I-27 Outlet B, 2033-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.102	0.182	0.021	0.013	0.004
01	0.073	0.133	0.015	0.010	0.003
02	0.067	0.123	0.014	0.009	0.003
03	0.069	0.130	0.014	0.009	0.003
04	0.101	0.166	0.019	0.013	0.004
05	0.186	0.293	0.034	0.022	0.007
06	0.406	0.669	0.077	0.050	0.016
07	0.679	0.929	0.097	0.064	0.027
08	0.561	0.903	0.099	0.065	0.022
09	0.539	0.889	0.098	0.064	0.022
10	0.538	0.894	0.099	0.065	0.022
11	0.539	0.900	0.100	0.065	0.022
12	0.539	0.901	0.100	0.065	0.022
13	0.520	0.903	0.099	0.065	0.021
14	0.482	0.935	0.098	0.064	0.019
15	0.468	1.013	0.100	0.065	0.019
16	0.508	1.178	0.110	0.072	0.020
17	0.430	0.929	0.095	0.062	0.017
18	0.345	0.668	0.071	0.046	0.014
19	0.317	0.578	0.063	0.041	0.013
20	0.312	0.551	0.061	0.040	0.012
21	0.308	0.532	0.059	0.039	0.012
22	0.205	0.323	0.038	0.025	0.008
23	0.123	0.211	0.024	0.016	0.005
Average emission rates by source group used in GRAL **(kg/h)**					
B-1	***0.780***	***1.222***	***0.135***	***0.088***	***0.031***
B-2	***1.608***	***2.967***	***0.316***	***0.207***	***0.064***
B-3	***-***	***-***	***-***	***-***	***-***
Emissions released from 1 outlet					

I.1.3.3 Outlet C (M4 East Tunnel, Underwood Road)

Table I-28 Outlet C, 2023-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.251	0.506	0.039	0.026	0.010
01	0.180	0.371	0.029	0.019	0.007
02	0.150	0.278	0.023	0.015	0.006
03	0.149	0.275	0.022	0.015	0.006
04	0.186	0.358	0.028	0.019	0.007
05	0.451	1.002	0.075	0.049	0.018
06	0.897	2.222	0.158	0.104	0.036
07	1.640	3.652	0.276	0.180	0.066
08	1.511	3.063	0.239	0.156	0.060
09	1.456	2.765	0.222	0.145	0.058
10	1.438	2.662	0.217	0.142	0.058
11	1.443	2.626	0.215	0.141	0.058
12	1.440	2.597	0.214	0.140	0.058
13	1.322	2.541	0.203	0.133	0.053
14	1.287	2.549	0.201	0.131	0.051
15	1.310	2.658	0.207	0.135	0.052
16	1.362	2.961	0.224	0.146	0.054
17	1.003	2.311	0.170	0.111	0.040
18	0.913	2.058	0.153	0.100	0.037
19	0.862	1.936	0.144	0.094	0.034
20	0.831	1.867	0.139	0.091	0.033
21	0.790	1.802	0.133	0.087	0.032
22	0.535	1.161	0.088	0.057	0.021
23	0.395	0.797	0.062	0.041	0.016
Average emission rates by source group used in GRAL **(kg/h)**					
C-1	***0.787***	***1.550***	***0.122***	***0.080***	***0.031***
C-2	***2.348***	***5.248***	***0.391***	***0.255***	***0.094***
C-3	***4.599***	***9.412***	***0.731***	***0.478***	***0.184***
Emissions released from 1 outlet					

Table I-29 Outlet C, 2023-DS

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.456	0.673	0.061	0.042	0.027
01	0.348	0.494	0.045	0.031	0.021
02	0.284	0.395	0.037	0.025	0.017
03	0.279	0.390	0.036	0.025	0.017
04	0.420	0.622	0.056	0.038	0.025
05	1.073	1.647	0.146	0.100	0.064
06	2.929	6.068	0.475	0.325	0.176
07	5.294	8.279	0.756	0.518	0.318
08	5.061	7.392	0.685	0.469	0.304
09	4.892	6.776	0.642	0.440	0.294
10	4.794	6.400	0.617	0.423	0.288
11	4.740	6.199	0.603	0.413	0.284
12	4.750	6.128	0.601	0.411	0.285
13	4.767	6.179	0.604	0.414	0.286
14	4.840	6.453	0.623	0.427	0.290
15	5.081	7.443	0.693	0.474	0.305
16	5.370	8.400	0.773	0.529	0.322
17	4.037	6.564	0.577	0.395	0.242
18	3.186	4.847	0.434	0.297	0.191
19	2.767	4.178	0.375	0.257	0.166
20	2.558	3.853	0.346	0.237	0.153
21	2.350	3.624	0.321	0.220	0.141
22	1.245	2.040	0.174	0.119	0.075
23	0.645	0.918	0.085	0.058	0.039
Average emission rates by source group used in GRAL **(kg/h)**					
C-1	***1.459***	***2.095***	***0.191***	***0.131***	***0.088***
C-2	***5.603***	***8.774***	***0.770***	***0.527***	***0.336***
C-3	***15.616***	***22.838***	***2.113***	***1.447***	***0.937***
Emissions released from 1 outlet					

Table I-30 Outlet C, 2023-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.557	0.857	0.076	0.052	0.033
01	0.430	0.604	0.056	0.038	0.026
02	0.343	0.475	0.044	0.030	0.021
03	0.332	0.470	0.043	0.029	0.020
04	0.492	0.719	0.065	0.044	0.030
05	1.269	1.925	0.172	0.118	0.076
06	3.417	6.477	0.530	0.363	0.205
07	6.103	8.882	0.861	0.590	0.366
08	5.895	8.269	0.798	0.546	0.354
09	5.741	7.744	0.753	0.516	0.344
10	5.707	7.482	0.735	0.504	0.342
11	5.696	7.262	0.723	0.495	0.342
12	5.687	7.108	0.714	0.489	0.341
13	5.849	7.275	0.734	0.503	0.351
14	6.099	7.618	0.768	0.526	0.366
15	6.724	8.437	0.861	0.590	0.403
16	7.134	8.951	0.925	0.634	0.428
17	5.186	7.685	0.714	0.489	0.311
18	3.547	5.264	0.478	0.328	0.213
19	3.108	4.469	0.411	0.282	0.186
20	2.885	4.168	0.382	0.262	0.173
21	2.684	3.981	0.360	0.247	0.161
22	1.621	2.568	0.224	0.154	0.097
23	0.804	1.139	0.106	0.073	0.048
Average emission rates by source group used in GRAL **(kg/h)**					
C-1	***1.775***	***2.559***	***0.234***	***0.160***	***0.107***
C-2	***8.329***	***12.320***	***1.117***	***0.765***	***0.500***
C-3	***20.156***	***27.264***	***2.657***	***1.820***	***1.209***
Emissions released from 1 outlet					

Table I-31 Outlet C, 2033-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.198	0.464	0.043	0.028	0.008
01	0.148	0.317	0.030	0.020	0.006
02	0.127	0.281	0.026	0.017	0.005
03	0.137	0.302	0.028	0.019	0.005
04	0.193	0.440	0.041	0.027	0.008
05	0.400	0.975	0.089	0.058	0.016
06	0.725	1.695	0.156	0.102	0.029
07	1.232	2.864	0.269	0.176	0.049
08	1.136	2.356	0.227	0.149	0.045
09	1.109	2.229	0.217	0.142	0.044
10	1.099	2.193	0.214	0.140	0.044
11	1.102	2.181	0.214	0.140	0.044
12	1.102	2.168	0.213	0.139	0.044
13	0.996	2.076	0.199	0.130	0.040
14	0.979	2.052	0.197	0.129	0.039
15	0.984	2.098	0.200	0.131	0.039
16	1.013	2.361	0.219	0.143	0.041
17	0.849	1.980	0.183	0.119	0.034
18	0.738	1.700	0.157	0.103	0.030
19	0.681	1.601	0.147	0.096	0.027
20	0.661	1.553	0.143	0.093	0.026
21	0.640	1.491	0.137	0.090	0.026
22	0.352	0.899	0.080	0.053	0.014
23	0.199	0.513	0.046	0.030	0.008
Average emission rates by source group used in GRAL **(kg/h)**					
C-1	***0.601***	***1.391***	***0.129***	***0.084***	***0.024***
C-2	***1.848***	***4.427***	***0.404***	***0.264***	***0.074***
C-3	***3.534***	***7.599***	***0.723***	***0.473***	***0.141***
Emissions released from 1 outlet					

Table I-32 Outlet C, 2033-DS

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.385	0.584	0.067	0.044	0.015
01	0.308	0.445	0.052	0.034	0.012
02	0.241	0.349	0.040	0.026	0.010
03	0.239	0.347	0.040	0.026	0.010
04	0.358	0.537	0.061	0.040	0.014
05	0.920	1.419	0.161	0.105	0.037
06	2.664	5.288	0.557	0.364	0.107
07	4.971	7.058	0.874	0.571	0.199
08	4.656	6.722	0.805	0.526	0.186
09	4.350	6.082	0.730	0.477	0.174
10	4.208	5.714	0.692	0.453	0.168
11	4.127	5.514	0.672	0.439	0.165
12	4.108	5.479	0.668	0.437	0.164
13	4.063	5.487	0.666	0.435	0.163
14	4.047	5.631	0.676	0.442	0.162
15	4.108	6.065	0.715	0.467	0.164
16	4.427	6.986	0.818	0.534	0.177
17	3.673	5.496	0.642	0.420	0.147
18	2.793	4.386	0.497	0.325	0.112
19	2.495	3.870	0.440	0.287	0.100
20	2.346	3.607	0.411	0.268	0.094
21	2.182	3.300	0.378	0.247	0.087
22	1.236	1.843	0.211	0.138	0.049
23	0.564	0.790	0.093	0.061	0.023
Average emission rates by source group used in GRAL **(kg/h)**					
C-1	***1.257***	***1.831***	***0.212***	***0.138***	***0.050***
C-2	***5.205***	***7.874***	***0.899***	***0.588***	***0.208***
C-3	***13.689***	***20.012***	***2.367***	***1.547***	***0.548***
Emissions released from 1 outlet					

Table I-33 Outlet C, 2033-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.511	0.750	0.087	0.057	0.020
01	0.412	0.576	0.068	0.044	0.016
02	0.331	0.454	0.054	0.035	0.013
03	0.327	0.449	0.053	0.035	0.013
04	0.483	0.682	0.079	0.052	0.019
05	1.203	1.747	0.203	0.133	0.048
06	3.220	5.779	0.632	0.413	0.129
07	6.156	7.349	0.931	0.609	0.246
08	6.047	7.616	0.978	0.639	0.242
09	5.723	7.221	0.911	0.596	0.229
10	5.566	6.935	0.878	0.574	0.223
11	5.499	6.823	0.865	0.566	0.220
12	5.536	6.832	0.868	0.567	0.221
13	5.516	6.836	0.867	0.567	0.221
14	5.592	6.967	0.883	0.577	0.224
15	5.993	7.522	0.954	0.623	0.240
16	6.350	7.422	0.930	0.608	0.254
17	4.885	6.736	0.822	0.537	0.195
18	3.321	4.844	0.566	0.370	0.133
19	2.845	4.136	0.482	0.315	0.114
20	2.693	3.932	0.457	0.299	0.108
21	2.549	3.778	0.436	0.285	0.102
22	1.469	2.231	0.253	0.166	0.059
23	0.739	1.030	0.122	0.080	0.030
Average emission rates by source group used in GRAL **(kg/h)**					
C-1	***1.486***	***2.097***	***0.246***	***0.161***	***0.059***
C-2	***6.230***	***9.157***	***1.060***	***0.693***	***0.249***
C-3	***18.579***	***23.919***	***2.975***	***1.944***	***0.743***
Emissions released from 1 outlet					

I.1.3.4 Outlet D (New M5 Tunnel, SPI)

Table I-34 Outlet D, 2023-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.121	0.207	0.014	0.009	0.005
01	0.073	0.127	0.008	0.005	0.003
02	0.060	0.108	0.007	0.004	0.002
03	0.060	0.108	0.007	0.004	0.002
04	0.084	0.147	0.009	0.006	0.003
05	0.159	0.266	0.017	0.011	0.006
06	0.396	0.654	0.043	0.028	0.016
07	1.097	1.987	0.129	0.084	0.044
08	0.628	1.045	0.069	0.045	0.025
09	0.544	0.867	0.059	0.038	0.022
10	0.542	0.859	0.058	0.038	0.022
11	0.537	0.850	0.058	0.038	0.021
12	0.532	0.841	0.057	0.037	0.021
13	0.477	0.803	0.053	0.034	0.019
14	0.450	0.762	0.050	0.033	0.018
15	0.428	0.715	0.047	0.031	0.017
16	0.411	0.682	0.045	0.030	0.016
17	0.308	0.487	0.033	0.022	0.012
18	0.246	0.386	0.026	0.017	0.010
19	0.230	0.354	0.024	0.016	0.009
20	0.212	0.326	0.022	0.015	0.008
21	0.180	0.279	0.019	0.013	0.007
22	0.093	0.192	0.011	0.007	0.004
23	0.076	0.141	0.009	0.006	0.003
Average emission rates by source group used in GRAL **(kg/h)**					
D-1	***0.293***	***0.530***	***0.034***	***0.022***	***0.012***
D-2	***0.801***	***1.259***	***0.086***	***0.056***	***0.032***
D-3	***1.978***	***3.294***	***0.219***	***0.143***	***0.079***
D-1 = 3 outlets; D-2 = 3 outlets; D-3 = 4 outlets					

Table I-35 Outlet D, 2023-DS

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.029	0.065	0.004	0.002	0.002
01	0.019	0.041	0.002	0.002	0.001
02	0.013	0.028	0.002	0.001	0.001
03	0.015	0.028	0.002	0.001	0.001
04	0.024	0.042	0.003	0.002	0.001
05	0.078	0.118	0.008	0.005	0.005
06	0.253	0.460	0.027	0.019	0.015
07	0.423	0.931	0.051	0.035	0.025
08	0.363	0.688	0.040	0.027	0.022
09	0.349	0.619	0.037	0.025	0.021
10	0.356	0.604	0.037	0.025	0.021
11	0.354	0.588	0.036	0.025	0.021
12	0.354	0.575	0.036	0.025	0.021
13	0.331	0.554	0.034	0.023	0.020
14	0.315	0.535	0.033	0.022	0.019
15	0.293	0.517	0.031	0.021	0.018
16	0.272	0.488	0.029	0.020	0.016
17	0.198	0.309	0.020	0.013	0.012
18	0.161	0.242	0.016	0.011	0.010
19	0.144	0.219	0.014	0.010	0.009
20	0.132	0.202	0.013	0.009	0.008
21	0.121	0.194	0.012	0.008	0.007
22	0.050	0.111	0.006	0.004	0.003
23	0.024	0.056	0.003	0.002	0.001
Average emission rates by source group used in GRAL **(kg/h)**					
D-1	***0.114***	***0.220***	***0.013***	***0.009***	***0.007***
D-2	***0.544***	***0.839***	***0.053***	***0.037***	***0.033***
D-3	***1.199***	***2.146***	***0.127***	***0.087***	***0.072***
D-1 = 2 outlets; D-2 = 2 outlets; D-3 = 3 outlets					

Table I-36 Outlet D, 2023-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.030	0.065	0.004	0.002	0.002
01	0.020	0.041	0.002	0.002	0.001
02	0.013	0.027	0.002	0.001	0.001
03	0.012	0.027	0.001	0.001	0.001
04	0.018	0.038	0.002	0.001	0.001
05	0.045	0.099	0.005	0.004	0.003
06	0.252	0.432	0.026	0.018	0.015
07	0.476	1.087	0.058	0.040	0.029
08	0.396	0.743	0.043	0.029	0.024
09	0.372	0.640	0.039	0.026	0.022
10	0.362	0.598	0.037	0.025	0.022
11	0.357	0.580	0.036	0.025	0.021
12	0.355	0.567	0.035	0.024	0.021
13	0.342	0.551	0.034	0.023	0.020
14	0.319	0.532	0.032	0.022	0.019
15	0.304	0.516	0.031	0.021	0.018
16	0.275	0.488	0.029	0.020	0.016
17	0.190	0.319	0.019	0.013	0.011
18	0.158	0.260	0.016	0.011	0.009
19	0.137	0.229	0.014	0.010	0.008
20	0.127	0.206	0.013	0.009	0.008
21	0.112	0.180	0.011	0.008	0.007
22	0.042	0.102	0.005	0.003	0.002
23	0.025	0.054	0.003	0.002	0.001
Average emission rates by source group used in GRAL **(kg/h)**					
D-1	***0.091***	***0.204***	***0.011***	***0.007***	***0.005***
D-2	***0.599***	***1.009***	***0.061***	***0.042***	***0.036***
D-3	***1.272***	***2.248***	***0.134***	***0.092***	***0.076***
D-1 = 2 outlets; D-2 = 2 outlets; D-3 = 3 outlets					

Table I-37 Outlet D, 2033-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.101	0.176	0.014	0.009	0.004
01	0.065	0.112	0.009	0.006	0.003
02	0.058	0.098	0.008	0.005	0.002
03	0.058	0.098	0.008	0.005	0.002
04	0.072	0.125	0.010	0.007	0.003
05	0.148	0.248	0.020	0.013	0.006
06	0.394	0.761	0.058	0.038	0.016
07	1.042	1.787	0.155	0.101	0.042
08	0.498	0.857	0.069	0.045	0.020
09	0.472	0.773	0.063	0.041	0.019
10	0.465	0.753	0.062	0.040	0.019
11	0.463	0.752	0.062	0.040	0.019
12	0.458	0.738	0.061	0.040	0.018
13	0.420	0.705	0.057	0.037	0.017
14	0.407	0.680	0.055	0.036	0.016
15	0.383	0.636	0.052	0.034	0.015
16	0.373	0.602	0.050	0.032	0.015
17	0.277	0.459	0.037	0.024	0.011
18	0.221	0.334	0.028	0.018	0.009
19	0.206	0.304	0.026	0.017	0.008
20	0.183	0.280	0.024	0.015	0.007
21	0.156	0.238	0.020	0.013	0.006
22	0.091	0.156	0.013	0.008	0.004
23	0.065	0.113	0.009	0.006	0.003
Average emission rates by source group used in GRAL **(kg/h)**					
D-1	***0.263***	***0.451***	***0.036***	***0.024***	***0.011***
D-2	***0.715***	***1.117***	***0.093***	***0.061***	***0.029***
D-3	***1.759***	***2.959***	***0.243***	***0.159***	***0.070***
D-1 = 3 outlets; D-2 = 3 outlets; D-3 = 4 outlets					

Table I-38 Outlet D, 2033-DS

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.025	0.049	0.004	0.002	0.001
01	0.014	0.030	0.002	0.001	0.001
02	0.009	0.020	0.001	0.001	0.000
03	0.009	0.019	0.001	0.001	0.000
04	0.014	0.029	0.002	0.001	0.001
05	0.037	0.081	0.006	0.004	0.001
06	0.208	0.393	0.030	0.019	0.008
07	0.392	0.857	0.063	0.041	0.016
08	0.323	0.613	0.047	0.031	0.013
09	0.304	0.534	0.042	0.027	0.012
10	0.292	0.494	0.039	0.025	0.012
11	0.285	0.471	0.037	0.024	0.011
12	0.282	0.462	0.037	0.024	0.011
13	0.277	0.453	0.036	0.024	0.011
14	0.269	0.451	0.036	0.023	0.011
15	0.256	0.443	0.035	0.023	0.010
16	0.235	0.417	0.032	0.021	0.009
17	0.160	0.274	0.021	0.014	0.006
18	0.130	0.212	0.017	0.011	0.005
19	0.115	0.190	0.015	0.010	0.005
20	0.108	0.175	0.014	0.009	0.004
21	0.101	0.164	0.013	0.008	0.004
22	0.057	0.095	0.007	0.005	0.002
23	0.017	0.043	0.003	0.002	0.001
Average emission rates by source group used in GRAL **(kg/h)**					
D-1	***0.082***	***0.165***	***0.012***	***0.008***	***0.003***
D-2	***0.442***	***0.731***	***0.057***	***0.037***	***0.018***
D-3	***1.022***	***1.829***	***0.142***	***0.093***	***0.041***
D-1 = 2 outlets; D-2 = 2 outlets; D-3 = 3 outlets					

Table I-39 Outlet D, 2033-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.043	0.107	0.007	0.005	0.002
01	0.027	0.063	0.004	0.003	0.001
02	0.024	0.048	0.004	0.002	0.001
03	0.024	0.048	0.004	0.002	0.001
04	0.029	0.065	0.005	0.003	0.001
05	0.068	0.185	0.012	0.008	0.003
06	0.303	0.778	0.053	0.034	0.012
07	0.635	1.575	0.120	0.078	0.025
08	0.512	1.233	0.087	0.057	0.020
09	0.453	1.049	0.074	0.048	0.018
10	0.427	0.953	0.068	0.044	0.017
11	0.411	0.899	0.064	0.042	0.016
12	0.394	0.844	0.061	0.040	0.016
13	0.382	0.818	0.059	0.038	0.015
14	0.372	0.791	0.057	0.037	0.015
15	0.360	0.763	0.055	0.036	0.014
16	0.348	0.742	0.053	0.035	0.014
17	0.264	0.652	0.044	0.029	0.011
18	0.229	0.579	0.039	0.026	0.009
19	0.206	0.527	0.036	0.023	0.008
20	0.191	0.491	0.033	0.022	0.008
21	0.180	0.467	0.031	0.020	0.007
22	0.065	0.194	0.012	0.008	0.003
23	0.042	0.112	0.007	0.005	0.002
Average emission rates by source group used in GRAL **(kg/h)**					
D-1	***0.145***	***0.371***	***0.025***	***0.016***	***0.006***
D-2	***1.021***	***2.379***	***0.166***	***0.108***	***0.041***
D-3	***1.700***	***3.931***	***0.284***	***0.186***	***0.068***
D-1 = 2 outlets; D-2 = 3 outlets; D-3 = 3 outlets					

I.1.3.5 Outlet E (New M5 Tunnel, Arncliffe)

Table I-40 Outlet E, 2023-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.091	0.139	0.023	0.015	0.004
01	0.055	0.085	0.014	0.009	0.002
02	0.045	0.072	0.012	0.008	0.002
03	0.045	0.072	0.012	0.008	0.002
04	0.063	0.099	0.016	0.011	0.003
05	0.118	0.179	0.030	0.020	0.005
06	0.295	0.440	0.075	0.049	0.012
07	0.834	1.330	0.225	0.147	0.033
08	0.468	0.703	0.119	0.078	0.019
09	0.405	0.584	0.100	0.066	0.016
10	0.403	0.579	0.100	0.065	0.016
11	0.400	0.573	0.099	0.064	0.016
12	0.396	0.567	0.098	0.064	0.016
13	0.356	0.540	0.091	0.059	0.014
14	0.336	0.512	0.086	0.056	0.013
15	0.319	0.481	0.081	0.053	0.013
16	0.307	0.459	0.078	0.051	0.012
17	0.229	0.329	0.057	0.037	0.009
18	0.183	0.261	0.045	0.029	0.007
19	0.171	0.239	0.042	0.027	0.007
20	0.157	0.220	0.038	0.025	0.006
21	0.134	0.188	0.033	0.021	0.005
22	0.070	0.128	0.020	0.013	0.003
23	0.057	0.094	0.015	0.010	0.002
Average emission rates by source group used in GRAL **(kg/h)**					
E-1	***0.219***	***0.355***	***0.058***	***0.038***	***0.009***
E-2	***0.596***	***0.849***	***0.147***	***0.096***	***0.024***
E-3	***1.479***	***2.214***	***0.376***	***0.246***	***0.059***
E-1 = 3 outlets; E-2 = 4 outlets; E-3 = 4 outlets					

Table I-41 Outlet E, 2023-DS

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.046	0.093	0.013	0.009	0.003
01	0.029	0.054	0.008	0.006	0.002
02	0.020	0.036	0.006	0.004	0.001
03	0.022	0.036	0.006	0.004	0.001
04	0.035	0.058	0.009	0.006	0.002
05	0.107	0.151	0.025	0.017	0.006
06	0.330	0.606	0.091	0.062	0.020
07	0.714	1.305	0.201	0.138	0.043
08	0.548	0.915	0.141	0.097	0.033
09	0.489	0.776	0.122	0.084	0.029
10	0.474	0.725	0.116	0.079	0.028
11	0.465	0.697	0.112	0.077	0.028
12	0.460	0.678	0.110	0.075	0.028
13	0.432	0.656	0.105	0.072	0.026
14	0.419	0.646	0.103	0.071	0.025
15	0.402	0.639	0.101	0.069	0.024
16	0.382	0.621	0.097	0.066	0.023
17	0.259	0.377	0.062	0.042	0.016
18	0.211	0.298	0.049	0.034	0.013
19	0.190	0.272	0.045	0.031	0.011
20	0.175	0.255	0.042	0.028	0.011
21	0.154	0.233	0.037	0.026	0.009
22	0.062	0.123	0.018	0.012	0.004
23	0.031	0.060	0.009	0.006	0.002
Average emission rates by source group used in GRAL **(kg/h)**					
E-1	***0.126***	***0.237***	***0.035***	***0.024***	***0.008***
E-2	***0.658***	***0.952***	***0.156***	***0.107***	***0.039***
E-3	***1.674***	***2.705***	***0.425***	***0.291***	***0.100***
E-1 = 3 outlets; E-2 = 4 outlets; E-3 = 4 outlets					

Table I-42 Outlet E, 2023-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.048	0.090	0.013	0.009	0.003
01	0.029	0.051	0.008	0.005	0.002
02	0.018	0.033	0.005	0.003	0.001
03	0.015	0.031	0.004	0.003	0.001
04	0.023	0.046	0.007	0.005	0.001
05	0.066	0.130	0.019	0.013	0.004
06	0.305	0.509	0.079	0.054	0.018
07	0.722	1.389	0.211	0.145	0.043
08	0.561	0.951	0.146	0.100	0.034
09	0.504	0.782	0.124	0.085	0.030
10	0.484	0.722	0.117	0.080	0.029
11	0.474	0.698	0.113	0.078	0.028
12	0.463	0.675	0.110	0.075	0.028
13	0.446	0.661	0.107	0.073	0.027
14	0.423	0.646	0.103	0.071	0.025
15	0.406	0.632	0.100	0.069	0.024
16	0.375	0.605	0.095	0.065	0.023
17	0.275	0.428	0.068	0.047	0.016
18	0.227	0.354	0.056	0.039	0.014
19	0.192	0.304	0.048	0.033	0.012
20	0.174	0.268	0.043	0.029	0.010
21	0.152	0.232	0.037	0.025	0.009
22	0.061	0.133	0.019	0.013	0.004
23	0.027	0.055	0.008	0.006	0.002
Average emission rates by source group used in GRAL **(kg/h)**					
E-1	***0.129***	***0.257***	***0.037***	***0.026***	***0.008***
E-2	***0.795***	***1.257***	***0.198***	***0.136***	***0.048***
E-3	***1.749***	***2.793***	***0.442***	***0.303***	***0.105***
E-1 = 3 outlets; E-2 = 4 outlets; E-3 = 4 outlets					

Table I-43 Outlet E, 2033-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.080	0.126	0.026	0.017	0.003
01	0.051	0.080	0.016	0.011	0.002
02	0.046	0.070	0.014	0.009	0.002
03	0.046	0.070	0.014	0.009	0.002
04	0.057	0.089	0.018	0.012	0.002
05	0.116	0.177	0.037	0.024	0.005
06	0.310	0.543	0.107	0.070	0.012
07	0.866	1.353	0.286	0.187	0.035
08	0.392	0.613	0.126	0.082	0.016
09	0.371	0.554	0.115	0.075	0.015
10	0.366	0.540	0.112	0.074	0.015
11	0.364	0.539	0.112	0.073	0.015
12	0.360	0.529	0.110	0.072	0.014
13	0.331	0.505	0.104	0.068	0.013
14	0.320	0.487	0.100	0.066	0.013
15	0.301	0.455	0.094	0.062	0.012
16	0.294	0.431	0.090	0.059	0.012
17	0.218	0.328	0.068	0.044	0.009
18	0.174	0.240	0.051	0.033	0.007
19	0.162	0.218	0.047	0.031	0.006
20	0.144	0.201	0.043	0.028	0.006
21	0.122	0.171	0.036	0.024	0.005
22	0.072	0.112	0.023	0.015	0.003
23	0.051	0.081	0.016	0.011	0.002
Average emission rates by source group used in GRAL **(kg/h)**					
E-1	***0.207***	***0.323***	***0.066***	***0.043***	***0.008***
E-2	***0.562***	***0.802***	***0.169***	***0.110***	***0.022***
E-3	***1.399***	***2.143***	***0.444***	***0.290***	***0.056***
E-1 = 3 outlets; E-2 = 4 outlets; E-3 = 4 outlets					

Table I-44 Outlet E, 2033-DS

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.040	0.067	0.013	0.009	0.002
01	0.020	0.036	0.007	0.005	0.001
02	0.011	0.022	0.004	0.003	0.000
03	0.010	0.021	0.004	0.003	0.000
04	0.018	0.033	0.006	0.004	0.001
05	0.052	0.102	0.020	0.013	0.002
06	0.296	0.593	0.113	0.074	0.012
07	0.874	1.434	0.295	0.193	0.035
08	0.619	1.036	0.211	0.138	0.025
09	0.504	0.807	0.165	0.108	0.020
10	0.449	0.696	0.143	0.093	0.018
11	0.418	0.637	0.131	0.086	0.017
12	0.411	0.625	0.129	0.084	0.016
13	0.404	0.619	0.127	0.083	0.016
14	0.395	0.617	0.126	0.083	0.016
15	0.380	0.616	0.125	0.082	0.015
16	0.359	0.596	0.120	0.078	0.014
17	0.233	0.357	0.074	0.048	0.009
18	0.183	0.276	0.057	0.037	0.007
19	0.162	0.248	0.051	0.033	0.006
20	0.151	0.232	0.048	0.031	0.006
21	0.139	0.213	0.044	0.029	0.006
22	0.069	0.100	0.021	0.014	0.003
23	0.020	0.044	0.008	0.005	0.001
Average emission rates by source group used in GRAL **(kg/h)**					
E-1	***0.096***	***0.166***	***0.033***	***0.022***	***0.004***
E-2	***0.552***	***0.857***	***0.176***	***0.115***	***0.022***
E-3	***1.672***	***2.709***	***0.552***	***0.361***	***0.067***
E-1 = 3 outlets; E-2 = 4 outlets; E-3 = 4 outlets					

Table I-45 Outlet E, 2033-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.034	0.059	0.012	0.008	0.001
01	0.028	0.048	0.010	0.006	0.001
02	0.022	0.038	0.007	0.005	0.001
03	0.021	0.035	0.007	0.005	0.001
04	0.028	0.049	0.010	0.006	0.001
05	0.059	0.110	0.021	0.014	0.002
06	0.214	0.289	0.062	0.040	0.009
07	0.422	0.824	0.160	0.105	0.017
08	0.392	0.609	0.125	0.082	0.016
09	0.390	0.575	0.120	0.078	0.016
10	0.389	0.563	0.118	0.077	0.016
11	0.389	0.557	0.117	0.077	0.016
12	0.385	0.548	0.116	0.075	0.015
13	0.375	0.543	0.114	0.074	0.015
14	0.363	0.536	0.112	0.073	0.015
15	0.354	0.537	0.111	0.073	0.014
16	0.337	0.537	0.109	0.071	0.013
17	0.237	0.414	0.082	0.054	0.009
18	0.199	0.317	0.064	0.042	0.008
19	0.166	0.246	0.051	0.033	0.007
20	0.147	0.208	0.044	0.029	0.006
21	0.133	0.191	0.040	0.026	0.005
22	0.036	0.068	0.013	0.009	0.001
23	0.025	0.051	0.010	0.006	0.001
Average emission rates by source group used in GRAL **(kg/h)**					
E-1	***0.113***	***0.206***	***0.040***	***0.026***	***0.005***
E-2	***0.659***	***0.998***	***0.206***	***0.135***	***0.026***
E-3	***1.367***	***2.099***	***0.432***	***0.283***	***0.055***
E-1 = 3 outlets; E-2 = 4 outlets; E-3 = 4 outlets					

I.1.3.6 Outlet F (New M5 Tunnel, Kingsgrove)

Table I-46 Outlet F, 2023-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.261	0.449	0.036	0.024	0.010
01	0.167	0.286	0.024	0.016	0.007
02	0.137	0.239	0.020	0.013	0.005
03	0.136	0.237	0.019	0.013	0.005
04	0.212	0.371	0.029	0.019	0.008
05	0.488	0.823	0.068	0.044	0.020
06	0.581	1.004	0.081	0.053	0.023
07	0.623	1.092	0.088	0.057	0.025
08	0.679	1.110	0.093	0.061	0.027
09	0.736	1.139	0.098	0.064	0.029
10	0.868	1.220	0.111	0.073	0.035
11	1.041	1.343	0.128	0.084	0.042
12	1.144	1.442	0.140	0.091	0.046
13	1.183	1.611	0.149	0.098	0.047
14	1.242	1.955	0.167	0.109	0.050
15	1.341	2.474	0.194	0.127	0.054
16	1.470	3.210	0.232	0.152	0.059
17	1.015	2.365	0.166	0.108	0.041
18	0.789	1.693	0.123	0.080	0.032
19	0.686	1.389	0.104	0.068	0.027
20	0.629	1.258	0.095	0.062	0.025
21	0.562	1.146	0.085	0.056	0.022
22	0.376	0.648	0.052	0.034	0.015
23	0.236	0.353	0.032	0.021	0.009
Average emission rates by source group used in GRAL **(kg/h)**					
F-1	***0.906***	***1.533***	***0.126***	***0.083***	***0.036***
F-2	***2.729***	***4.528***	***0.375***	***0.245***	***0.109***
F-3	***4.500***	***8.363***	***0.653***	***0.427***	***0.180***
Emissions released from 1 outlet					

Table I-47 Outlet F, 2023-DS

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.361	0.671	0.054	0.037	0.022
01	0.200	0.410	0.031	0.021	0.012
02	0.206	0.354	0.031	0.021	0.012
03	0.173	0.301	0.025	0.017	0.010
04	0.187	0.331	0.027	0.018	0.011
05	0.308	0.552	0.043	0.030	0.018
06	0.606	1.106	0.089	0.061	0.036
07	1.177	2.459	0.193	0.132	0.071
08	1.395	2.573	0.216	0.148	0.084
09	1.483	2.493	0.216	0.148	0.089
10	1.543	2.461	0.218	0.149	0.093
11	1.605	2.451	0.221	0.151	0.096
12	1.629	2.435	0.221	0.152	0.098
13	1.691	2.691	0.236	0.162	0.101
14	1.811	3.248	0.267	0.183	0.109
15	2.000	4.169	0.317	0.217	0.120
16	2.244	5.133	0.381	0.261	0.135
17	1.415	3.472	0.245	0.168	0.085
18	1.101	2.487	0.182	0.125	0.066
19	0.938	1.991	0.150	0.103	0.056
20	0.841	1.757	0.133	0.091	0.050
21	0.750	1.555	0.118	0.081	0.045
22	0.623	1.149	0.094	0.064	0.037
23	0.377	0.622	0.056	0.038	0.023
Average emission rates by source group used in GRAL **(kg/h)**					
F-1	***1.095***	***1.976***	***0.162***	***0.111***	***0.066***
F-2	***4.427***	***7.937***	***0.658***	***0.450***	***0.266***
F-3	***6.723***	***14.419***	***1.089***	***0.746***	***0.403***
Emissions released from 1 outlet					

Table I-48 Outlet F, 2023-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.450	0.800	0.067	0.046	0.027
01	0.286	0.537	0.043	0.030	0.017
02	0.236	0.408	0.035	0.024	0.014
03	0.212	0.369	0.031	0.021	0.013
04	0.267	0.505	0.039	0.027	0.016
05	0.442	0.889	0.068	0.046	0.027
06	0.868	1.706	0.135	0.093	0.052
07	1.584	3.170	0.265	0.181	0.095
08	1.850	3.075	0.277	0.190	0.111
09	1.942	2.923	0.273	0.187	0.117
10	2.023	2.868	0.274	0.188	0.121
11	2.053	2.820	0.274	0.188	0.123
12	2.074	2.815	0.275	0.188	0.124
13	2.088	3.074	0.285	0.196	0.125
14	2.223	3.805	0.324	0.222	0.133
15	2.489	4.919	0.390	0.267	0.149
16	2.790	5.979	0.468	0.321	0.167
17	1.629	3.700	0.273	0.187	0.098
18	1.272	2.673	0.205	0.140	0.076
19	1.108	2.195	0.173	0.118	0.066
20	1.024	1.961	0.157	0.107	0.061
21	0.943	1.814	0.145	0.099	0.057
22	0.781	1.384	0.116	0.079	0.047
23	0.423	0.609	0.059	0.041	0.025
Average emission rates by source group used in GRAL **(kg/h)**					
F-1	***1.125***	***1.937***	***0.165***	***0.113***	***0.068***
F-2	***2.922***	***5.583***	***0.446***	***0.306***	***0.175***
F-3	***6.958***	***12.189***	***1.040***	***0.713***	***0.417***
Emissions released from 1 outlet					

Table I-49 Outlet F, 2033-DM

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.170	0.273	0.028	0.019	0.007
01	0.136	0.192	0.022	0.014	0.005
02	0.125	0.173	0.019	0.013	0.005
03	0.124	0.173	0.019	0.012	0.005
04	0.155	0.244	0.025	0.016	0.006
05	0.312	0.594	0.056	0.037	0.012
06	0.472	0.918	0.086	0.056	0.019
07	0.566	1.068	0.102	0.067	0.023
08	0.601	1.090	0.106	0.069	0.024
09	0.697	1.160	0.117	0.077	0.028
10	0.809	1.223	0.129	0.085	0.032
11	0.931	1.288	0.142	0.093	0.037
12	1.022	1.354	0.153	0.100	0.041
13	1.082	1.560	0.169	0.110	0.043
14	1.163	1.953	0.196	0.128	0.047
15	1.285	2.456	0.234	0.153	0.051
16	1.446	3.058	0.288	0.188	0.058
17	1.030	2.206	0.199	0.130	0.041
18	0.731	1.563	0.141	0.092	0.029
19	0.623	1.306	0.119	0.078	0.025
20	0.547	1.133	0.104	0.068	0.022
21	0.469	0.972	0.089	0.058	0.019
22	0.345	0.613	0.060	0.039	0.014
23	0.210	0.333	0.035	0.023	0.008
Average emission rates by source group used in GRAL **(kg/h)**					
F-1	***0.710***	***1.168***	***0.119***	***0.078***	***0.028***
F-2	***2.444***	***4.279***	***0.422***	***0.276***	***0.098***
F-3	***4.325***	***8.088***	***0.782***	***0.511***	***0.173***
Emissions released from 1 outlet					

Table I-50 Outlet F, 2033-DS

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.333	0.621	0.065	0.043	0.013
01	0.190	0.406	0.039	0.026	0.008
02	0.177	0.340	0.036	0.024	0.007
03	0.150	0.278	0.029	0.019	0.006
04	0.170	0.339	0.033	0.022	0.007
05	0.259	0.560	0.053	0.035	0.010
06	0.548	1.147	0.113	0.074	0.022
07	1.094	2.377	0.242	0.158	0.044
08	1.258	2.436	0.259	0.169	0.050
09	1.330	2.385	0.259	0.169	0.053
10	1.363	2.328	0.257	0.168	0.055
11	1.403	2.296	0.257	0.168	0.056
12	1.445	2.341	0.263	0.172	0.058
13	1.526	2.640	0.287	0.187	0.061
14	1.658	3.197	0.329	0.215	0.066
15	1.935	4.051	0.411	0.268	0.077
16	2.218	4.979	0.505	0.330	0.089
17	1.477	3.379	0.324	0.212	0.059
18	1.029	2.264	0.220	0.144	0.041
19	0.810	1.738	0.171	0.111	0.032
20	0.721	1.521	0.150	0.098	0.029
21	0.658	1.340	0.135	0.088	0.026
22	0.483	0.883	0.095	0.062	0.019
23	0.282	0.441	0.053	0.034	0.011
Average emission rates by source group used in GRAL **(kg/h)**					
F-1	***0.920***	***1.740***	***0.182***	***0.119***	***0.037***
F-2	***3.956***	***7.444***	***0.784***	***0.512***	***0.158***
F-3	***6.560***	***14.045***	***1.412***	***0.923***	***0.262***
Emissions released from 1 outlet					

Table I-51 Outlet F, 2033-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.240	0.452	0.048	0.031	0.010
01	0.183	0.319	0.035	0.023	0.007
02	0.148	0.260	0.028	0.018	0.006
03	0.139	0.250	0.027	0.017	0.006
04	0.191	0.380	0.037	0.024	0.008
05	0.370	0.832	0.078	0.051	0.015
06	0.855	1.825	0.180	0.118	0.034
07	1.206	2.478	0.254	0.166	0.048
08	1.361	2.420	0.258	0.169	0.054
09	1.373	2.267	0.252	0.165	0.055
10	1.423	2.176	0.251	0.164	0.057
11	1.506	2.177	0.258	0.169	0.060
12	1.574	2.198	0.265	0.173	0.063
13	1.569	2.249	0.269	0.176	0.063
14	1.562	2.525	0.287	0.187	0.062
15	1.677	3.206	0.341	0.223	0.067
16	1.930	4.262	0.447	0.292	0.077
17	1.297	2.718	0.276	0.180	0.052
18	0.979	1.955	0.199	0.130	0.039
19	0.852	1.635	0.169	0.110	0.034
20	0.770	1.477	0.152	0.099	0.031
21	0.730	1.404	0.144	0.094	0.029
22	0.601	1.080	0.115	0.075	0.024
23	0.358	0.656	0.070	0.046	0.014
Average emission rates by source group used in GRAL **(kg/h)**					
F-1	***0.755***	***1.390***	***0.147***	***0.096***	***0.030***
F-2	***2.393***	***4.629***	***0.473***	***0.309***	***0.096***
F-3	***5.071***	***8.988***	***0.979***	***0.640***	***0.203***
Emissions released from 1 outlet					

I.1.3.7 Outlet G (M4-M5 Link Tunnel, Parramatta Road)

Table I-52 Outlet G, 2023-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	-	-	-	-	-
Outlet not included in scenario					

Table I-53 Outlet G, 2023-DS

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.070	0.130	0.012	0.008	0.004
01	0.058	0.102	0.009	0.006	0.003
02	0.048	0.080	0.008	0.005	0.003
03	0.050	0.087	0.008	0.006	0.003
04	0.073	0.130	0.012	0.008	0.004
05	0.149	0.272	0.024	0.017	0.009
06	0.412	0.975	0.075	0.051	0.025
07	0.715	1.348	0.115	0.079	0.043
08	0.648	1.161	0.102	0.070	0.039
09	0.604	1.044	0.093	0.064	0.036
10	0.579	0.970	0.088	0.060	0.035
11	0.565	0.931	0.085	0.058	0.034
12	0.557	0.909	0.084	0.057	0.033
13	0.562	0.926	0.085	0.058	0.034
14	0.579	0.986	0.089	0.061	0.035
15	0.615	1.137	0.100	0.068	0.037
16	0.667	1.334	0.115	0.079	0.040
17	0.500	0.972	0.084	0.057	0.030
18	0.405	0.747	0.065	0.044	0.024
19	0.359	0.660	0.057	0.039	0.022
20	0.333	0.613	0.053	0.036	0.020
21	0.302	0.568	0.048	0.033	0.018
22	0.140	0.252	0.022	0.015	0.008
23	0.086	0.148	0.014	0.009	0.005
Average emission rates by source group used in GRAL **(kg/h)**					
G-1	***0.270***	***0.478***	***0.044***	***0.030***	***0.016***
G-2	***1.028***	***1.901***	***0.164***	***0.112***	***0.062***
G-3	***2.051***	***3.721***	***0.326***	***0.223***	***0.123***
Emissions released from 1 outlet					

Table I-54 Outlet G, 2023-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.079	0.144	0.013	0.009	0.005
01	0.067	0.112	0.011	0.007	0.004
02	0.055	0.090	0.009	0.006	0.003
03	0.055	0.093	0.009	0.006	0.003
04	0.076	0.135	0.013	0.009	0.005
05	0.162	0.297	0.027	0.018	0.010
06	0.431	0.954	0.078	0.053	0.026
07	0.779	1.478	0.131	0.089	0.047
08	0.727	1.298	0.117	0.080	0.044
09	0.696	1.196	0.109	0.075	0.042
10	0.686	1.153	0.106	0.073	0.041
11	0.681	1.121	0.104	0.071	0.041
12	0.672	1.091	0.102	0.070	0.040
13	0.686	1.116	0.104	0.071	0.041
14	0.713	1.175	0.110	0.075	0.043
15	0.781	1.310	0.123	0.084	0.047
16	1.274	2.064	0.207	0.142	0.076
17	0.613	1.134	0.102	0.070	0.037
18	0.442	0.814	0.071	0.049	0.026
19	0.386	0.689	0.061	0.042	0.023
20	0.357	0.631	0.056	0.038	0.021
21	0.331	0.589	0.052	0.036	0.020
22	0.174	0.291	0.027	0.019	0.010
23	0.100	0.166	0.016	0.011	0.006
Average emission rates by source group used in GRAL **(kg/h)**					
G-1	***0.440***	***0.767***	***0.071***	***0.048***	***0.026***
G-2	***2.224***	***3.898***	***0.353***	***0.242***	***0.133***
G-3	***4.585***	***7.432***	***0.747***	***0.512***	***0.275***
Emissions released from 1 outlet					

Table I-55 Outlet G, 2033-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	-	-	-	-	-
Outlet not included in scenario					

Table I-56 Outlet G, 2033-DS

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.058	0.109	0.013	0.008	0.002
01	0.050	0.086	0.010	0.007	0.002
02	0.040	0.068	0.008	0.005	0.002
03	0.041	0.070	0.009	0.006	0.002
04	0.058	0.103	0.012	0.008	0.002
05	0.118	0.218	0.025	0.016	0.005
06	0.362	0.848	0.087	0.057	0.014
07	0.682	1.248	0.140	0.091	0.027
08	0.603	1.089	0.122	0.080	0.024
09	0.547	0.948	0.108	0.071	0.022
10	0.515	0.870	0.101	0.066	0.021
11	0.493	0.819	0.096	0.062	0.020
12	0.489	0.809	0.095	0.062	0.020
13	0.487	0.820	0.095	0.062	0.019
14	0.494	0.862	0.099	0.065	0.020
15	0.518	0.961	0.108	0.071	0.021
16	0.560	1.125	0.126	0.082	0.022
17	0.450	0.819	0.094	0.061	0.018
18	0.342	0.640	0.072	0.047	0.014
19	0.305	0.563	0.063	0.041	0.012
20	0.289	0.530	0.059	0.039	0.012
21	0.271	0.492	0.055	0.036	0.011
22	0.128	0.207	0.025	0.016	0.005
23	0.077	0.125	0.015	0.010	0.003
Average emission rates by source group used in GRAL **(kg/h)**					
G-1	***0.233***	***0.394***	***0.048***	***0.031***	***0.009***
G-2	***0.885***	***1.622***	***0.182***	***0.119***	***0.035***
G-3	***1.812***	***3.284***	***0.371***	***0.243***	***0.072***
Emissions released from 1 outlet					

Table I-57 Outlet G, 2033-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.073	0.135	0.016	0.010	0.003
01	0.063	0.108	0.013	0.008	0.003
02	0.054	0.089	0.011	0.007	0.002
03	0.055	0.090	0.011	0.007	0.002
04	0.076	0.133	0.016	0.010	0.003
05	0.157	0.286	0.033	0.021	0.006
06	0.428	0.908	0.098	0.064	0.017
07	1.291	2.063	0.260	0.170	0.052
08	0.752	1.274	0.150	0.098	0.030
09	0.696	1.145	0.136	0.089	0.028
10	0.672	1.083	0.129	0.084	0.027
11	0.659	1.050	0.126	0.082	0.026
12	0.660	1.044	0.126	0.082	0.026
13	0.654	1.047	0.126	0.082	0.026
14	0.665	1.088	0.130	0.085	0.027
15	0.718	1.204	0.144	0.094	0.029
16	1.351	2.013	0.262	0.171	0.054
17	0.568	1.005	0.118	0.077	0.023
18	0.397	0.719	0.082	0.054	0.016
19	0.346	0.621	0.070	0.046	0.014
20	0.325	0.580	0.066	0.043	0.013
21	0.306	0.550	0.062	0.041	0.012
22	0.147	0.252	0.030	0.019	0.006
23	0.091	0.157	0.019	0.012	0.004
Average emission rates by source group used in GRAL **(kg/h)**					
G-1	***0.322***	***0.562***	***0.066***	***0.043***	***0.013***
G-2	***2.017***	***3.425***	***0.402***	***0.263***	***0.081***
G-3	***4.757***	***7.336***	***0.940***	***0.615***	***0.190***
Emissions released from 1 outlet					

I.1.3.8 Outlet H (WHT, Rozelle (west))

Table I-58 Outlet H, 2023-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	-	-	-	-	-
Outlet not included in scenario					

Table I-59 Outlet H, 2023-DS

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	-	-	-	-	-
Outlet not included in scenario					

Table I-60 Outlet H, 2023-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.125	0.283	0.030	0.020	0.007
01	0.072	0.170	0.018	0.012	0.004
02	0.046	0.111	0.011	0.008	0.003
03	0.056	0.115	0.013	0.009	0.003
04	0.100	0.238	0.025	0.017	0.006
05	0.225	0.617	0.061	0.042	0.013
06	0.607	1.700	0.168	0.115	0.036
07	1.330	2.982	0.330	0.226	0.080
08	1.209	2.457	0.276	0.189	0.073
09	1.137	2.141	0.244	0.167	0.068
10	1.086	1.903	0.223	0.153	0.065
11	1.047	1.713	0.207	0.142	0.063
12	1.043	1.654	0.203	0.139	0.063
13	1.171	1.815	0.225	0.154	0.070
14	1.417	2.240	0.276	0.189	0.085
15	1.832	2.978	0.370	0.253	0.110
16	2.413	3.951	0.527	0.361	0.145
17	1.120	2.394	0.263	0.180	0.067
18	0.513	1.306	0.131	0.090	0.031
19	0.359	0.866	0.089	0.061	0.022
20	0.290	0.665	0.070	0.048	0.017
21	0.246	0.574	0.060	0.041	0.015
22	0.165	0.431	0.043	0.030	0.010
23	0.102	0.269	0.027	0.018	0.006
Average emission rates by source group used in GRAL **(kg/h)**					
H-1	***0.300***	***0.711***	***0.074***	***0.050***	***0.018***
H-2	***1.079***	***2.676***	***0.273***	***0.187***	***0.065***
H-3	***4.623***	***8.378***	***0.993***	***0.680***	***0.277***
Emissions released from 1 outlet					

Table I-61 Outlet H, 2033-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	-	-	-	-	-
Outlet not included in scenario					

Table I-62 Outlet H, 2033-DS

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	-	-	-	-	-
Outlet not included in scenario					

Table I-63 Outlet H, 2033-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.125	0.290	0.041	0.027	0.005
01	0.085	0.188	0.027	0.018	0.003
02	0.063	0.152	0.021	0.014	0.003
03	0.071	0.167	0.024	0.015	0.003
04	0.114	0.270	0.038	0.025	0.005
05	0.239	0.648	0.088	0.058	0.010
06	0.600	1.795	0.246	0.161	0.024
07	1.453	2.773	0.449	0.294	0.058
08	1.245	2.351	0.365	0.239	0.050
09	1.124	2.015	0.315	0.206	0.045
10	1.064	1.826	0.288	0.188	0.043
11	1.030	1.738	0.275	0.180	0.041
12	1.036	1.718	0.273	0.179	0.041
13	1.096	1.772	0.285	0.186	0.044
14	1.281	2.027	0.331	0.216	0.051
15	1.540	2.640	0.424	0.277	0.062
16	2.140	3.486	0.547	0.358	0.086
17	1.019	2.030	0.308	0.201	0.041
18	0.423	1.005	0.142	0.093	0.017
19	0.310	0.736	0.104	0.068	0.012
20	0.277	0.628	0.090	0.059	0.011
21	0.259	0.584	0.084	0.055	0.010
22	0.182	0.451	0.063	0.041	0.007
23	0.116	0.309	0.042	0.027	0.005
Average emission rates by source group used in GRAL **(kg/h)**					
H-1	***0.344***	***0.827***	***0.116***	***0.076***	***0.014***
H-2	***1.014***	***2.431***	***0.342***	***0.224***	***0.041***
H-3	***4.388***	***7.851***	***1.232***	***0.805***	***0.176***
Emissions released from 1 outlet					

I.1.3.9 Outlet I (M4-M5 Link/Iron Cove Link Tunnel, Rozelle (east))

Table I-64 Outlet I, 2023-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	-	-	-	-	-
Outlet not included in scenario					

Table I-65 Outlet I, 2023-DS

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)**					
I-1	***0.590***	***1.146***	***0.093***	***0.064***	***0.035***
I-2	***1.374***	***2.174***	***0.198***	***0.135***	***0.082***
I-3	-	-	-	-	-
Emissions released from 1 outlet					

Table I-66 Outlet I, 2023-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	0.913	1.663	0.147	0.101	0.055
07	0.000	0.000	0.000	0.000	0.000
08	1.426	2.390	0.228	0.156	0.086
09	1.262	2.063	0.198	0.135	0.076
10	1.208	1.942	0.186	0.128	0.073
11	1.180	1.885	0.181	0.124	0.071
12	1.129	1.839	0.174	0.119	0.068
13	1.029	1.792	0.165	0.113	0.062
14	0.963	1.782	0.161	0.110	0.058
15	0.928	1.825	0.162	0.111	0.056
16	0.915	1.903	0.168	0.115	0.055
17	0.772	1.490	0.133	0.091	0.046
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	0.000	0.000	0.000	0.000	0.000
Average emission rates by source group used in GRAL **(kg/h)**					
I-1	***4.043***	***7.092***	***0.658***	***0.451***	***0.243***
I-2	***0.844***	***1.462***	***0.131***	***0.089***	***0.051***
I-3	-	-	-	-	-
Emissions released from 1 outlet					

Table I-67 Outlet I, 2033-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	-	-	-	-	-
Outlet not included in scenario					

Table I-68 Outlet I, 2033-DS

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)**					
I-1	***0.605***	***0.962***	***0.111***	***0.073***	***0.024***
I-2	***1.029***	***1.743***	***0.195***	***0.128***	***0.041***
I-3	-	-	-	-	-
Emissions released from 1 outlet					

Table I-69 Outlet I, 2033-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)**					
I-1	***3.616***	***6.162***	***0.737***	***0.482***	***0.145***
I-2	***0.708***	***1.328***	***0.146***	***0.095***	***0.028***
I-3	-	-	-	-	-
Emissions released from 1 outlet					

I.1.3.10 Outlet J (M4-M5 Link/Iron Cove Link Tunnel, Rozelle (mid))

Table I-70 Outlet J, 2023-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	-	-	-	-	-
Outlet not included in scenario					

Table I-71 Outlet J, 2023-DS

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)**					
J-1	***3.248***	***4.674***	***0.446***	***0.305***	***0.195***
J-2	***5.990***	***11.273***	***0.974***	***0.667***	***0.359***
J-3	***8.513***	***14.772***	***1.344***	***0.921***	***0.511***
Emissions released from 1 outlet					

Table I-72 Outlet J, 2023-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	1.479	2.694	0.239	0.164	0.089
07	0.000	0.000	0.000	0.000	0.000
08	2.310	3.871	0.370	0.253	0.139
09	2.045	3.342	0.320	0.219	0.123
10	1.957	3.145	0.302	0.207	0.117
11	1.911	3.053	0.293	0.201	0.115
12	1.828	2.979	0.282	0.193	0.110
13	1.666	2.902	0.267	0.183	0.100
14	1.560	2.887	0.260	0.178	0.094
15	1.503	2.956	0.262	0.179	0.090
16	1.483	3.082	0.272	0.186	0.089
17	1.250	2.414	0.216	0.148	0.075
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	0.000	0.000	0.000	0.000	0.000
Average emission rates by source group used in GRAL **(kg/h)**					
J-1	***5.486***	***9.614***	***0.888***	***0.608***	***0.329***
J-2	***5.686***	***9.619***	***0.908***	***0.622***	***0.341***
J-3	-	-	-	-	-
Emissions released from 1 outlet					

Table I-73 Outlet J, 2033-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	-	-	-	-	-
Outlet not included in scenario					

Table I-74 Outlet J, 2033-DS

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)**					
J-1	***2.596***	***4.068***	***0.472***	***0.309***	***0.104***
J-2	***5.188***	***10.027***	***1.100***	***0.719***	***0.208***
J-3	***7.530***	***13.277***	***0.472***	***1.004***	***0.301***
Emissions released from 1 outlet					

Table I-75 Outlet J, 2033-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)**					
J-1	***4.805***	***8.268***	***0.982***	***0.642***	***0.192***
J-2	***5.464***	***8.934***	***1.080***	***0.706***	***0.219***
J-3	-	-	-	-	-
Emissions released from 1 outlet					

I.1.3.11 Outlet K (M4-M5 Link Tunnel, SPI)

Table I-76 Outlet K, 2023-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	-	-	-	-	-
Outlet not included in scenario					

Table I-77 Outlet K, 2023-DS

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.233	0.301	0.031	0.021	0.014
01	0.163	0.200	0.021	0.015	0.010
02	0.133	0.170	0.017	0.012	0.008
03	0.173	0.206	0.021	0.015	0.010
04	0.326	0.363	0.039	0.026	0.020
05	0.709	0.742	0.085	0.058	0.043
06	1.294	1.878	0.180	0.123	0.078
07	2.297	3.878	0.345	0.236	0.138
08	2.457	3.574	0.339	0.232	0.147
09	2.453	3.335	0.326	0.223	0.147
10	2.430	3.177	0.317	0.217	0.146
11	2.430	3.109	0.314	0.215	0.146
12	2.466	3.100	0.316	0.216	0.148
13	2.400	3.067	0.309	0.212	0.144
14	2.164	2.987	0.289	0.198	0.130
15	1.951	2.928	0.272	0.186	0.117
16	1.809	2.881	0.261	0.179	0.109
17	1.616	2.372	0.224	0.153	0.097
18	1.474	1.962	0.194	0.133	0.088
19	1.390	1.772	0.180	0.123	0.083
20	1.356	1.680	0.173	0.119	0.081
21	1.338	1.630	0.170	0.116	0.080
22	0.992	1.088	0.120	0.082	0.060
23	0.370	0.452	0.048	0.033	0.022
Average emission rates by source group used in GRAL **(kg/h)**					
K-1	***1.084***	***1.252***	***0.135***	***0.092***	***0.065***
K-2	***5.071***	***6.868***	***0.676***	***0.463***	***0.304***
K-3	***8.419***	***11.662***	***1.131***	***0.774***	***0.505***
K-1 = 2 outlets; K-2 = 2 outlets; K-3 = 2 outlets					

Table I-78 Outlet K, 2023-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.446	0.571	0.057	0.039	0.027
01	0.263	0.354	0.035	0.024	0.016
02	0.191	0.276	0.026	0.018	0.011
03	0.218	0.310	0.029	0.020	0.013
04	0.423	0.548	0.054	0.037	0.025
05	0.973	1.172	0.121	0.083	0.058
06	2.233	3.605	0.319	0.218	0.134
07	3.513	5.633	0.530	0.363	0.211
08	3.520	4.928	0.478	0.327	0.211
09	3.550	4.674	0.463	0.317	0.213
10	3.549	4.583	0.458	0.314	0.213
11	3.552	4.529	0.455	0.312	0.213
12	3.519	4.485	0.450	0.309	0.211
13	3.138	4.337	0.417	0.285	0.188
14	2.800	4.211	0.388	0.265	0.168
15	2.562	4.206	0.372	0.255	0.154
16	2.470	4.304	0.373	0.256	0.148
17	2.330	3.747	0.333	0.228	0.140
18	2.101	2.985	0.281	0.193	0.126
19	1.962	2.572	0.253	0.173	0.118
20	1.883	2.449	0.242	0.166	0.113
21	1.873	2.381	0.238	0.163	0.112
22	1.374	1.624	0.169	0.116	0.082
23	0.727	0.871	0.090	0.061	0.044
Average emission rates by source group used in GRAL **(kg/h)**					
K-1	***1.110***	***1.482***	***0.144***	***0.099***	***0.067***
K-2	***3.059***	***3.677***	***0.379***	***0.260***	***0.184***
K-3	***9.726***	***13.818***	***1.317***	***0.902***	***0.584***
K-1 = 4 outlets; K-2 = 4 outlets; K-3 = 4 outlets					

Table I-79 Outlet K, 2033-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	-	-	-	-	-
Outlet not included in scenario					

Table I-80 Outlet K, 2033-DS

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.254	0.320	0.042	0.027	0.010
01	0.200	0.242	0.032	0.021	0.008
02	0.154	0.196	0.025	0.016	0.006
03	0.137	0.183	0.023	0.015	0.005
04	0.213	0.285	0.035	0.023	0.009
05	0.571	0.688	0.091	0.059	0.023
06	1.091	1.679	0.200	0.131	0.044
07	1.806	3.087	0.354	0.231	0.072
08	1.935	2.844	0.344	0.225	0.077
09	1.993	2.761	0.342	0.223	0.080
10	2.082	2.769	0.348	0.228	0.083
11	2.150	2.790	0.354	0.232	0.086
12	2.184	2.791	0.357	0.233	0.087
13	2.129	2.763	0.351	0.229	0.085
14	2.009	2.723	0.339	0.222	0.080
15	1.849	2.683	0.326	0.213	0.074
16	1.679	2.645	0.313	0.204	0.067
17	1.556	2.198	0.268	0.175	0.062
18	1.500	1.941	0.246	0.161	0.060
19	1.436	1.794	0.231	0.151	0.057
20	1.372	1.688	0.220	0.144	0.055
21	1.297	1.575	0.206	0.135	0.052
22	0.980	1.125	0.151	0.099	0.039
23	0.393	0.515	0.065	0.043	0.016
Average emission rates by source group used in GRAL **(kg/h)**					
K-1	***0.690***	***0.883***	***0.113***	***0.074***	***0.028***
K-2	***2.333***	***2.793***	***0.368***	***0.241***	***0.093***
K-3	***6.315***	***8.714***	***1.080***	***0.706***	***0.253***
K-1 = 2 outlets; K-2 = 2 outlets; K-3 = 2 outlets					

Table I-81 Outlet K, 2033-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.379	0.493	0.061	0.040	0.015
01	0.203	0.285	0.034	0.023	0.008
02	0.159	0.227	0.027	0.018	0.006
03	0.164	0.230	0.028	0.018	0.007
04	0.303	0.406	0.049	0.032	0.012
05	0.837	1.018	0.130	0.085	0.033
06	1.790	3.044	0.340	0.222	0.072
07	2.476	3.969	0.468	0.306	0.099
08	2.525	3.680	0.442	0.289	0.101
09	2.681	3.595	0.444	0.290	0.107
10	2.745	3.572	0.446	0.292	0.110
11	2.819	3.588	0.452	0.295	0.113
12	2.847	3.584	0.453	0.296	0.114
13	2.810	3.577	0.450	0.294	0.112
14	2.503	3.427	0.417	0.273	0.100
15	2.291	3.418	0.404	0.264	0.092
16	2.171	3.544	0.413	0.270	0.087
17	1.923	2.896	0.339	0.221	0.077
18	1.759	2.326	0.284	0.186	0.070
19	1.668	2.147	0.266	0.174	0.067
20	1.644	2.083	0.260	0.170	0.066
21	1.625	2.048	0.257	0.168	0.065
22	1.109	1.375	0.174	0.114	0.044
23	0.549	0.692	0.087	0.057	0.022
Average emission rates by source group used in GRAL **(kg/h)**					
K-1	***0.870***	***1.181***	***0.144***	***0.094***	***0.035***
K-2	***2.994***	***3.702***	***0.469***	***0.307***	***0.120***
K-3	***8.162***	***11.362***	***1.380***	***0.902***	***0.326***
K-1 = 2 outlets; K-2 = 2 outlets; K-3 = 2 outlets					

I.1.3.12 Outlet L (Iron Cove Link Tunnel, Iron Cove)

Table I-82 Outlet L, 2023-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)**					
L-1	-	-	-	-	-
L-2	-	-	-	-	-
L-3	-	-	-	-	-
Outlet not included in scenario					

Table I-83 Outlet L, 2023-DS

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)**					
L-1	***0.276***	***0.689***	***0.036***	***0.024***	***0.017***
L-2	***0.735***	***2.231***	***0.105***	***0.072***	***0.044***
L-3	***1.986***	***4.709***	***0.274***	***0.187***	***0.119***
Emissions released from 1 outlet					

Table I-84 Outlet L, 2023-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.131	0.286	0.016	0.011	0.008
01	0.104	0.218	0.012	0.009	0.006
02	0.087	0.185	0.011	0.007	0.005
03	0.083	0.195	0.011	0.007	0.005
04	0.097	0.281	0.013	0.009	0.006
05	0.162	0.625	0.025	0.017	0.010
06	0.272	1.030	0.045	0.031	0.016
07	0.349	1.271	0.059	0.041	0.021
08	0.470	1.360	0.074	0.051	0.028
09	0.593	1.369	0.085	0.058	0.036
10	0.637	1.378	0.088	0.061	0.038
11	0.657	1.379	0.090	0.062	0.039
12	0.672	1.384	0.092	0.063	0.040
13	0.674	1.389	0.093	0.064	0.040
14	0.665	1.417	0.094	0.065	0.040
15	0.587	1.477	0.092	0.063	0.035
16	0.578	1.594	0.097	0.067	0.035
17	0.543	1.412	0.084	0.058	0.033
18	0.516	1.263	0.075	0.051	0.031
19	0.494	1.198	0.069	0.047	0.030
20	0.479	1.168	0.065	0.045	0.029
21	0.455	1.149	0.061	0.042	0.027
22	0.353	0.899	0.045	0.031	0.021
23	0.155	0.323	0.019	0.013	0.009
Average emission rates by source group used in GRAL **(kg/h)**					
L-1	***0.394***	***0.892***	***0.049***	***0.034***	***0.024***
L-2	***1.022***	***3.443***	***0.158***	***0.108***	***0.061***
L-3	***2.062***	***4.870***	***0.298***	***0.204***	***0.124***
Emissions released from 1 outlet					

Table I-85 Outlet L, 2033-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)**					
L-1	**-**	**-**	**-**	**-**	**-**
L-2	**-**	**-**	**-**	**-**	**-**
L-3	**-**	**-**	**-**	**-**	**-**
Outlet not included in scenario					

Table I-86 Outlet L, 2033-DS

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)**					
L-1	***0.228***	***0.567***	***0.038***	***0.025***	***0.009***
L-2	***0.614***	***1.844***	***0.115***	***0.075***	***0.025***
L-3	***1.571***	***3.822***	***0.289***	***0.189***	***0.063***
Emissions released from 1 outlet					

Table I-87 Outlet L, 2033-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)**					
L-1	***0.309***	***0.783***	***0.053***	***0.034***	***0.012***
L-2	***0.761***	***2.597***	***0.155***	***0.101***	***0.030***
L-3	***1.615***	***3.882***	***0.306***	***0.200***	***0.065***
Emissions released from 1 outlet					

I.1.3.13 Outlet M (F6 Extension Tunnel, Arncliffe)

Table I-88 Outlet M, 2023-DM

Hour start	NOx (g/s)	CO (g/s)	PM10 (g/s)	PM2.5 (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)**					
M-1	-	-	-	-	-
M-2	-	-	-	-	-
M-3	-	-	-	-	-
Outlet not included in scenario					

Table I-89 Outlet M, 2023-DS

Hour start	NOx (g/s)	CO (g/s)	PM10 (g/s)	PM2.5 (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)**					
M-1	-	-	-	-	-
M-2	-	-	-	-	-
M-3	-	-	-	-	-
Outlet not included in scenario					

Table I-90 Outlet M, 2023-DSC

Hour start	NOx (g/s)	CO (g/s)	PM10 (g/s)	PM2.5 (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)**					
M-1	**-**	**-**	**-**	**-**	**-**
M-2	**-**	**-**	**-**	**-**	**-**
M-3	**-**	**-**	**-**	**-**	**-**
Outlet not included in scenario					

Table I-91 Outlet M, 2033-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)**					
M-1	-	-	-	-	-
M-2	-	-	-	-	-
M-3	-	-	-	-	-
Outlet not included in scenario					

Table I-92 Outlet M, 2033-DS

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)**					
M-1	-	-	-	-	-
M-2	-	-	-	-	-
M-3	-	-	-	-	-
Outlet not included in scenario					

Table I-93 Outlet M, 2033-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.028	0.070	0.011	0.008	0.001
01	0.017	0.039	0.007	0.004	0.001
02	0.017	0.029	0.005	0.003	0.001
03	0.017	0.029	0.005	0.003	0.001
04	0.019	0.040	0.007	0.005	0.001
05	0.034	0.105	0.016	0.011	0.001
06	0.147	0.507	0.078	0.051	0.006
07	0.499	1.255	0.214	0.140	0.020
08	0.318	0.832	0.135	0.089	0.013
09	0.223	0.609	0.098	0.064	0.009
10	0.189	0.505	0.081	0.053	0.008
11	0.173	0.461	0.074	0.049	0.007
12	0.164	0.428	0.069	0.045	0.007
13	0.156	0.402	0.065	0.043	0.006
14	0.152	0.380	0.062	0.041	0.006
15	0.148	0.358	0.059	0.039	0.006
16	0.146	0.338	0.056	0.037	0.006
17	0.104	0.314	0.049	0.032	0.004
18	0.086	0.302	0.046	0.030	0.003
19	0.083	0.298	0.045	0.030	0.003
20	0.076	0.280	0.042	0.028	0.003
21	0.069	0.260	0.039	0.026	0.003
22	0.039	0.142	0.022	0.014	0.002
23	0.022	0.069	0.011	0.007	0.001
Average emission rates by source group used in GRAL **(kg/h)**					
M-1	***0.087***	***0.236***	***0.038***	***0.025***	***0.003***
M-2	***0.302***	***1.047***	***0.160***	***0.105***	***0.012***
M-3	***0.758***	***1.988***	***0.325***	***0.213***	***0.030***
M-1 = 3 outlets; M-2 = 4 outlets; M-3 = 4 outlets					

I.1.3.14 Outlet N (F6 Extension Tunnel, Rockdale)

Table I-94 Outlet N, 2023-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)**					
N-1	-	-	-	-	-
N-2	-	-	-	-	-
N-3	-	-	-	-	-
Outlet not included in scenario					

Table I-95 Outlet N, 2023-DS

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)**					
N-1	-	-	-	-	-
N-2	-	-	-	-	-
N-3	-	-	-	-	-
Outlet not included in scenario					

Table I-96 Outlet N, 2023-DSC

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)**					
N-1	-	-	-	-	-
N-2	-	-	-	-	-
N-3	-	-	-	-	-
Outlet not included in scenario					

Table I-97 Outlet N, 2033-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)**					
N-1	-	-	-	-	-
N-2	-	-	-	-	-
N-3	-	-	-	-	-
Outlet not included in scenario					

Table I-98 Outlet N, 2033-DS

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)**					
N-1	-	-	-	-	-
N-2	-	-	-	-	-
N-3	-	-	-	-	-
Outlet not included in scenario					

Table I-99 Outlet N, 2033-DSC

Hour start	NO_X (g/s)	CO (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	THC (g/s)
00	0.259	0.657	0.058	0.038	0.010
01	0.183	0.485	0.042	0.027	0.007
02	0.137	0.412	0.034	0.022	0.005
03	0.131	0.410	0.033	0.021	0.005
04	0.172	0.519	0.042	0.027	0.007
05	0.319	0.843	0.074	0.048	0.013
06	0.544	1.407	0.132	0.087	0.022
07	0.770	1.990	0.192	0.125	0.031
08	0.953	2.249	0.214	0.140	0.038
09	1.013	2.409	0.226	0.148	0.041
10	1.097	2.661	0.244	0.160	0.044
11	1.164	2.839	0.258	0.168	0.047
12	1.236	3.013	0.272	0.178	0.049
13	1.362	3.466	0.304	0.199	0.054
14	1.609	4.427	0.382	0.250	0.064
15	1.898	5.355	0.482	0.315	0.076
16	2.215	4.995	0.594	0.388	0.089
17	1.496	4.697	0.391	0.255	0.060
18	1.039	3.320	0.259	0.169	0.042
19	0.838	2.524	0.203	0.132	0.034
20	0.691	1.946	0.163	0.106	0.028
21	0.571	1.534	0.133	0.087	0.023
22	0.471	1.255	0.110	0.072	0.019
23	0.280	0.673	0.062	0.041	0.011
Average emission rates by source group used in GRAL **(kg/h)**					
N-1	***0.998***	***2.665***	***0.234***	***0.153***	***0.040***
N-2	***3.333***	***8.466***	***0.762***	***0.498***	***0.133***
N-3	***5.772***	***15.756***	***1.448***	***0.946***	***0.231***
N-1 = 3 outlets; N-2 = 4 outlets; N-3 = 4 outlets					

I.1.4 Concentrations

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

I.1.4.1 Outlet A (M5 East Tunnel, Turrella)

Table I-100 Outlet A, 2015-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	3.773	2.129	0.077	0.059	0.223
01	2.903	1.638	0.057	0.043	0.171
02	2.701	1.524	0.052	0.040	0.160
03	3.394	1.915	0.074	0.057	0.200
04	6.323	3.568	0.184	0.140	0.373
05	5.481	3.092	0.187	0.143	0.324
06	6.777	3.824	0.269	0.206	0.400
07	7.147	4.940	0.320	0.236	0.609
08	7.404	5.118	0.349	0.256	0.631
09	7.805	3.531	0.366	0.275	0.486
10	8.146	3.685	0.387	0.291	0.507
11	8.397	3.799	0.406	0.305	0.523
12	8.786	3.975	0.428	0.321	0.547
13	8.882	4.018	0.430	0.323	0.553
14	8.537	3.863	0.387	0.291	0.531
15	7.894	6.092	0.330	0.246	0.557
16	6.877	5.307	0.256	0.191	0.485
17	5.990	4.623	0.198	0.148	0.422
18	5.360	3.024	0.159	0.122	0.317
19	4.403	2.484	0.118	0.090	0.260
20	3.761	2.122	0.090	0.069	0.222
21	3.392	1.914	0.078	0.060	0.200
22	5.383	3.037	0.114	0.087	0.318
23	4.819	2.719	0.099	0.076	0.285

Table I-101 Outlet A, 2023-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	0.793	0.298	0.020	0.013	0.026
01	0.610	0.229	0.015	0.010	0.020
02	0.567	0.213	0.014	0.009	0.019
03	0.713	0.268	0.019	0.013	0.024
04	1.328	0.499	0.048	0.032	0.044
05	1.151	0.433	0.048	0.032	0.038
06	1.424	0.535	0.070	0.046	0.047
07	2.478	2.064	0.137	0.090	0.125
08	2.567	2.138	0.149	0.098	0.129
09	2.298	0.928	0.120	0.080	0.070
10	2.398	0.968	0.127	0.085	0.073
11	2.472	0.998	0.133	0.089	0.075
12	2.586	1.044	0.140	0.094	0.079
13	2.614	1.056	0.141	0.094	0.080
14	2.513	1.015	0.127	0.085	0.077
15	2.797	1.862	0.158	0.104	0.132
16	2.437	1.622	0.123	0.081	0.115
17	2.123	1.413	0.095	0.062	0.100
18	1.126	0.423	0.041	0.027	0.037
19	0.925	0.348	0.031	0.020	0.031
20	0.790	0.297	0.023	0.016	0.026
21	0.713	0.268	0.020	0.013	0.024
22	1.131	0.425	0.030	0.020	0.037
23	1.012	0.380	0.026	0.017	0.033

Table I-102 Outlet A, 2023-DS

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	0.549	0.304	0.014	0.009	0.020
01	0.423	0.234	0.010	0.007	0.015
02	0.393	0.218	0.009	0.006	0.014
03	0.494	0.274	0.013	0.009	0.018
04	0.920	0.510	0.033	0.022	0.033
05	0.798	0.442	0.033	0.022	0.029
06	0.986	0.546	0.048	0.032	0.036
07	1.956	2.017	0.104	0.069	0.102
08	2.026	2.090	0.113	0.075	0.106
09	1.610	0.797	0.082	0.056	0.051
10	1.680	0.832	0.087	0.059	0.053
11	1.732	0.858	0.091	0.062	0.055
12	1.812	0.897	0.096	0.065	0.057
13	1.832	0.907	0.097	0.065	0.058
14	1.761	0.872	0.087	0.059	0.056
15	1.936	1.783	0.107	0.071	0.098
16	1.686	1.553	0.083	0.055	0.085
17	1.469	1.353	0.064	0.043	0.074
18	0.780	0.432	0.028	0.019	0.028
19	0.641	0.355	0.021	0.014	0.023
20	0.548	0.303	0.016	0.011	0.020
21	0.494	0.274	0.014	0.009	0.018
22	0.784	0.434	0.020	0.014	0.028
23	0.701	0.389	0.018	0.012	0.025

Table I-103 Outlet A, 2023-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	0.469	0.273	0.012	0.008	0.018
01	0.361	0.210	0.009	0.006	0.014
02	0.336	0.195	0.008	0.005	0.013
03	0.422	0.246	0.011	0.008	0.016
04	0.787	0.458	0.028	0.019	0.029
05	0.682	0.397	0.029	0.019	0.026
06	0.843	0.490	0.041	0.028	0.032
07	1.697	1.827	0.092	0.061	0.093
08	1.758	1.892	0.100	0.066	0.096
09	1.354	0.717	0.070	0.047	0.045
10	1.414	0.749	0.074	0.050	0.047
11	1.457	0.772	0.078	0.053	0.048
12	1.525	0.808	0.082	0.055	0.050
13	1.541	0.816	0.082	0.056	0.051
14	1.481	0.785	0.074	0.050	0.049
15	1.642	1.597	0.092	0.061	0.087
16	1.430	1.392	0.071	0.047	0.076
17	1.246	1.212	0.055	0.037	0.066
18	0.667	0.388	0.024	0.016	0.025
19	0.548	0.319	0.018	0.012	0.021
20	0.468	0.272	0.014	0.009	0.018
21	0.422	0.245	0.012	0.008	0.016
22	0.670	0.390	0.017	0.012	0.025
23	0.600	0.349	0.015	0.010	0.022

Table I-104 Outlet A, 2033-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	0.913	0.186	0.025	0.016	0.017
01	0.702	0.143	0.018	0.011	0.013
02	0.653	0.133	0.017	0.011	0.012
03	0.821	0.167	0.024	0.015	0.015
04	1.530	0.311	0.059	0.037	0.029
05	1.326	0.270	0.060	0.038	0.025
06	1.639	0.333	0.086	0.054	0.031
07	2.556	0.918	0.160	0.099	0.077
08	2.648	0.951	0.174	0.108	0.080
09	2.604	0.614	0.146	0.093	0.045
10	2.718	0.641	0.154	0.098	0.047
11	2.802	0.661	0.162	0.103	0.048
12	2.932	0.692	0.170	0.108	0.050
13	2.964	0.699	0.171	0.109	0.051
14	2.849	0.672	0.154	0.098	0.049
15	2.989	1.301	0.186	0.116	0.090
16	2.604	1.134	0.145	0.090	0.078
17	2.268	0.987	0.112	0.070	0.068
18	1.297	0.264	0.051	0.032	0.024
19	1.065	0.217	0.038	0.024	0.020
20	0.910	0.185	0.029	0.018	0.017
21	0.821	0.167	0.025	0.016	0.015
22	1.302	0.265	0.036	0.023	0.025
23	1.166	0.237	0.032	0.020	0.022

Table I-105 Outlet A, 2033-DS

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	0.657	0.197	0.017	0.011	0.013
01	0.505	0.152	0.013	0.008	0.010
02	0.470	0.141	0.012	0.008	0.009
03	0.591	0.177	0.017	0.011	0.012
04	1.101	0.331	0.041	0.026	0.022
05	0.954	0.287	0.042	0.027	0.019
06	1.179	0.354	0.061	0.039	0.024
07	2.047	1.357	0.121	0.076	0.066
08	2.121	1.405	0.132	0.083	0.069
09	1.754	0.548	0.098	0.063	0.033
10	1.831	0.572	0.104	0.066	0.034
11	1.887	0.589	0.109	0.069	0.035
12	1.975	0.616	0.114	0.073	0.037
13	1.996	0.623	0.115	0.074	0.038
14	1.919	0.599	0.103	0.066	0.036
15	2.035	1.325	0.127	0.080	0.069
16	1.772	1.154	0.099	0.062	0.060
17	1.544	1.005	0.077	0.048	0.052
18	0.933	0.280	0.036	0.023	0.019
19	0.766	0.230	0.027	0.017	0.015
20	0.655	0.197	0.020	0.013	0.013
21	0.590	0.177	0.018	0.011	0.012
22	0.937	0.282	0.026	0.016	0.019
23	0.839	0.252	0.022	0.014	0.017

Table I-106 Outlet A, 2033-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	0.533	0.182	0.015	0.009	0.012
01	0.410	0.140	0.011	0.007	0.009
02	0.382	0.130	0.010	0.006	0.008
03	0.479	0.164	0.014	0.009	0.011
04	0.893	0.305	0.035	0.022	0.020
05	0.774	0.264	0.035	0.022	0.017
06	0.957	0.327	0.051	0.032	0.021
07	1.789	1.273	0.109	0.069	0.063
08	1.853	1.318	0.119	0.075	0.065
09	1.410	0.506	0.081	0.052	0.030
10	1.472	0.528	0.086	0.055	0.031
11	1.517	0.544	0.091	0.058	0.032
12	1.587	0.569	0.095	0.061	0.034
13	1.604	0.575	0.096	0.061	0.034
14	1.542	0.553	0.086	0.055	0.033
15	1.727	1.241	0.112	0.071	0.064
16	1.505	1.081	0.087	0.055	0.056
17	1.311	0.942	0.068	0.043	0.049
18	0.757	0.259	0.030	0.019	0.017
19	0.622	0.212	0.022	0.014	0.014
20	0.531	0.181	0.017	0.011	0.012
21	0.479	0.164	0.015	0.009	0.011
22	0.760	0.260	0.022	0.014	0.017
23	0.681	0.232	0.019	0.012	0.015

I.1.4.2 Outlet B (M4 East Tunnel, Parramatta Road)

Table I-107 Outlet B, 2023-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.701	1.143	0.108	0.070	0.028
01	0.462	0.766	0.072	0.047	0.018
02	0.402	0.666	0.062	0.041	0.016
03	0.408	0.691	0.064	0.042	0.016
04	0.521	0.912	0.083	0.055	0.021
05	0.682	1.169	0.109	0.071	0.027
06	1.738	2.933	0.277	0.181	0.070
07	2.444	3.874	0.379	0.248	0.098
08	2.286	3.670	0.355	0.232	0.091
09	2.091	3.471	0.329	0.215	0.084
10	1.971	3.363	0.314	0.205	0.079
11	1.897	3.308	0.305	0.200	0.076
12	1.845	3.273	0.300	0.196	0.074
13	1.605	3.207	0.279	0.182	0.064
14	1.450	3.219	0.268	0.175	0.058
15	1.452	3.410	0.278	0.182	0.058
16	1.535	3.763	0.305	0.199	0.061
17	1.369	3.070	0.254	0.166	0.055
18	1.235	2.426	0.212	0.139	0.049
19	1.487	2.778	0.249	0.163	0.059
20	1.471	2.692	0.244	0.159	0.059
21	1.426	2.522	0.232	0.152	0.057
22	0.707	1.243	0.114	0.074	0.028
23	0.731	1.266	0.116	0.076	0.029

Table I-108 Outlet B, 2023-DS

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.432	0.769	0.066	0.045	0.026
01	0.290	0.556	0.047	0.032	0.017
02	0.237	0.488	0.040	0.028	0.014
03	0.270	0.509	0.044	0.030	0.016
04	0.386	0.661	0.059	0.040	0.023
05	0.790	1.156	0.109	0.074	0.047
06	1.551	2.726	0.235	0.161	0.093
07	2.443	3.982	0.353	0.242	0.147
08	2.080	3.703	0.316	0.217	0.125
09	1.962	3.476	0.296	0.202	0.118
10	1.896	3.321	0.283	0.194	0.114
11	1.843	3.226	0.275	0.189	0.111
12	1.789	3.165	0.269	0.184	0.107
13	1.700	3.170	0.262	0.180	0.102
14	1.571	3.299	0.259	0.177	0.094
15	1.634	3.816	0.286	0.196	0.098
16	1.839	4.684	0.338	0.231	0.110
17	1.470	3.370	0.253	0.173	0.088
18	1.326	2.654	0.212	0.145	0.080
19	1.209	2.273	0.187	0.128	0.073
20	1.153	2.112	0.177	0.121	0.069
21	1.106	1.976	0.167	0.115	0.066
22	0.875	1.281	0.120	0.082	0.053
23	0.506	0.892	0.077	0.052	0.030

Table I-109 Outlet B, 2023-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.452	0.769	0.069	0.047	0.027
01	0.333	0.545	0.051	0.035	0.020
02	0.276	0.479	0.044	0.030	0.017
03	0.284	0.495	0.044	0.030	0.017
04	0.405	0.649	0.060	0.041	0.024
05	0.754	1.147	0.107	0.073	0.045
06	1.541	2.534	0.228	0.156	0.092
07	2.500	3.881	0.343	0.235	0.150
08	2.378	3.943	0.351	0.240	0.143
09	2.034	3.349	0.301	0.206	0.122
10	1.998	3.284	0.294	0.202	0.120
11	1.965	3.231	0.289	0.198	0.118
12	1.908	3.203	0.283	0.194	0.114
13	1.724	3.193	0.269	0.184	0.103
14	1.627	3.380	0.270	0.185	0.098
15	1.704	3.903	0.298	0.204	0.102
16	1.856	4.622	0.340	0.233	0.111
17	1.512	3.393	0.260	0.178	0.091
18	1.240	2.442	0.198	0.136	0.074
19	1.343	2.456	0.207	0.142	0.081
20	1.276	2.266	0.193	0.133	0.077
21	1.241	2.137	0.185	0.127	0.074
22	0.892	1.360	0.125	0.085	0.053
23	0.518	0.834	0.077	0.053	0.031

Table I-110 Outlet B, 2033-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	0.473	0.865	0.097	0.063	0.019
01	0.353	0.643	0.072	0.047	0.014
02	0.319	0.566	0.064	0.042	0.013
03	0.337	0.620	0.070	0.046	0.013
04	0.454	0.830	0.093	0.061	0.018
05	0.607	1.113	0.125	0.082	0.024
06	1.255	2.467	0.272	0.178	0.050
07	0.485	0.890	0.100	0.065	0.019
08	1.004	1.973	0.217	0.142	0.040
09	1.850	3.131	0.371	0.243	0.074
10	1.550	2.789	0.321	0.210	0.062
11	1.441	2.654	0.302	0.197	0.058
12	1.410	2.610	0.296	0.193	0.056
13	1.386	2.574	0.291	0.190	0.055
14	1.356	2.558	0.288	0.188	0.054
15	1.252	2.507	0.276	0.180	0.050
16	1.181	2.511	0.271	0.177	0.047
17	1.138	2.581	0.274	0.179	0.046
18	1.166	2.866	0.301	0.196	0.047
19	1.198	2.254	0.252	0.165	0.048
20	1.183	2.174	0.245	0.160	0.047
21	1.165	2.094	0.239	0.156	0.047
22	0.735	1.172	0.138	0.090	0.029
23	0.713	1.183	0.138	0.090	0.029

Table I-111 Outlet B, 2033-DS

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	0.348	0.673	0.071	0.047	0.014
01	0.283	0.498	0.057	0.037	0.011
02	0.237	0.420	0.049	0.032	0.009
03	0.245	0.436	0.050	0.033	0.010
04	0.340	0.577	0.067	0.043	0.014
05	0.618	1.061	0.117	0.077	0.025
06	1.015	1.999	0.212	0.139	0.041
07	2.068	3.507	0.381	0.249	0.083
08	1.798	3.188	0.344	0.225	0.072
09	1.685	3.033	0.329	0.215	0.067
10	1.626	2.913	0.317	0.207	0.065
11	1.581	2.833	0.308	0.201	0.063
12	1.533	2.781	0.300	0.196	0.061
13	1.415	2.722	0.287	0.188	0.057
14	1.335	2.767	0.284	0.186	0.053
15	1.367	3.052	0.306	0.200	0.055
16	1.488	3.662	0.349	0.228	0.060
17	1.203	2.685	0.268	0.175	0.048
18	1.127	2.281	0.236	0.154	0.045
19	1.015	1.939	0.206	0.135	0.041
20	0.986	1.828	0.197	0.129	0.039
21	0.948	1.710	0.186	0.122	0.038
22	0.755	1.197	0.136	0.089	0.030
23	0.416	0.736	0.081	0.053	0.017

Table I-112 Outlet B, 2033-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	0.378	0.674	0.076	0.050	0.015
01	0.269	0.492	0.056	0.037	0.011
02	0.248	0.457	0.052	0.034	0.010
03	0.255	0.483	0.054	0.035	0.010
04	0.374	0.613	0.071	0.046	0.015
05	0.690	1.086	0.126	0.082	0.028
06	1.353	2.229	0.257	0.168	0.054
07	2.517	3.439	0.361	0.236	0.101
08	2.079	3.345	0.367	0.240	0.083
09	1.795	2.962	0.325	0.213	0.072
10	1.795	2.979	0.330	0.216	0.072
11	1.798	3.000	0.333	0.218	0.072
12	1.795	3.005	0.334	0.218	0.072
13	1.734	3.011	0.329	0.215	0.069
14	1.606	3.116	0.327	0.214	0.064
15	1.560	3.376	0.334	0.218	0.062
16	1.694	3.928	0.368	0.241	0.068
17	1.433	3.097	0.317	0.207	0.057
18	1.151	2.228	0.236	0.154	0.046
19	1.057	1.925	0.210	0.137	0.042
20	1.042	1.838	0.203	0.133	0.042
21	1.026	1.773	0.198	0.130	0.041
22	0.761	1.196	0.139	0.091	0.030
23	0.455	0.783	0.089	0.058	0.018

I.1.4.3 Outlet C (M4 East Tunnel, Underwood Road)

Table I-113 Outlet C, 2023-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.661	1.332	0.104	0.068	0.026
01	0.474	0.975	0.075	0.049	0.019
02	0.395	0.732	0.059	0.039	0.016
03	0.393	0.723	0.059	0.038	0.016
04	0.488	0.941	0.075	0.049	0.020
05	0.868	1.926	0.144	0.094	0.035
06	1.360	3.366	0.240	0.157	0.054
07	2.484	5.534	0.418	0.273	0.099
08	2.290	4.641	0.362	0.237	0.092
09	2.206	4.189	0.337	0.220	0.088
10	2.178	4.033	0.328	0.214	0.087
11	2.186	3.979	0.326	0.213	0.087
12	2.182	3.935	0.324	0.212	0.087
13	2.004	3.850	0.307	0.201	0.080
14	1.950	3.862	0.304	0.199	0.078
15	1.984	4.028	0.313	0.205	0.079
16	2.063	4.486	0.339	0.221	0.083
17	1.520	3.502	0.257	0.168	0.061
18	1.384	3.118	0.231	0.151	0.055
19	1.306	2.934	0.218	0.143	0.052
20	1.512	3.394	0.252	0.165	0.060
21	1.437	3.276	0.242	0.158	0.057
22	0.974	2.111	0.159	0.104	0.039
23	1.039	2.097	0.164	0.107	0.042

Table I-114 Outlet C, 2023-DS

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.113	1.640	0.148	0.101	0.067
01	0.848	1.205	0.111	0.076	0.051
02	0.692	0.964	0.089	0.061	0.042
03	0.679	0.951	0.087	0.060	0.041
04	1.026	1.517	0.136	0.093	0.062
05	1.579	2.422	0.215	0.147	0.095
06	3.487	7.224	0.565	0.387	0.209
07	6.303	9.856	0.900	0.616	0.378
08	6.025	8.800	0.816	0.559	0.362
09	5.824	8.066	0.765	0.524	0.349
10	5.707	7.619	0.734	0.503	0.342
11	5.642	7.380	0.718	0.492	0.339
12	5.654	7.295	0.715	0.490	0.339
13	5.675	7.355	0.720	0.493	0.341
14	5.761	7.683	0.742	0.508	0.346
15	6.049	8.861	0.825	0.565	0.363
16	6.393	10.000	0.920	0.630	0.384
17	4.806	7.814	0.687	0.471	0.288
18	3.793	5.771	0.517	0.354	0.228
19	3.294	4.974	0.446	0.306	0.198
20	3.045	4.587	0.412	0.282	0.183
21	3.456	5.329	0.472	0.324	0.207
22	1.832	3.001	0.256	0.175	0.110
23	1.574	2.238	0.207	0.142	0.094

Table I-115 Outlet C, 2023-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.239	1.905	0.169	0.116	0.074
01	0.956	1.343	0.124	0.085	0.057
02	0.762	1.056	0.098	0.067	0.046
03	0.738	1.045	0.096	0.066	0.044
04	1.093	1.598	0.144	0.099	0.066
05	1.983	3.008	0.269	0.185	0.119
06	3.928	7.445	0.609	0.417	0.236
07	7.015	10.209	0.990	0.678	0.421
08	6.776	9.504	0.917	0.628	0.407
09	6.599	8.902	0.865	0.593	0.396
10	6.560	8.600	0.845	0.579	0.394
11	6.547	8.348	0.831	0.569	0.393
12	6.536	8.170	0.821	0.562	0.392
13	6.723	8.362	0.843	0.578	0.403
14	7.010	8.757	0.883	0.605	0.421
15	7.729	9.697	0.990	0.678	0.464
16	8.200	10.289	1.064	0.728	0.492
17	5.961	8.833	0.821	0.562	0.358
18	4.078	6.050	0.550	0.376	0.245
19	4.856	6.982	0.643	0.440	0.291
20	4.508	6.512	0.598	0.409	0.271
21	4.194	6.221	0.563	0.386	0.252
22	2.533	4.013	0.350	0.240	0.152
23	1.786	2.530	0.235	0.161	0.107

Table I-116 Outlet C, 2033-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	0.495	1.161	0.107	0.070	0.020
01	0.369	0.793	0.075	0.049	0.015
02	0.318	0.703	0.066	0.043	0.013
03	0.342	0.756	0.071	0.046	0.014
04	0.483	1.100	0.102	0.067	0.019
05	0.727	1.774	0.161	0.105	0.029
06	1.036	2.421	0.223	0.146	0.041
07	1.760	4.091	0.385	0.251	0.070
08	1.623	3.366	0.325	0.212	0.065
09	1.584	3.184	0.311	0.203	0.063
10	1.570	3.133	0.306	0.200	0.063
11	1.574	3.116	0.306	0.200	0.063
12	1.574	3.097	0.304	0.199	0.063
13	1.423	2.966	0.285	0.186	0.057
14	1.398	2.932	0.281	0.184	0.056
15	1.406	2.997	0.286	0.187	0.056
16	1.447	3.373	0.312	0.204	0.058
17	1.213	2.828	0.261	0.170	0.049
18	1.054	2.429	0.225	0.147	0.042
19	0.973	2.287	0.210	0.137	0.039
20	1.201	2.823	0.260	0.170	0.048
21	1.164	2.710	0.250	0.163	0.047
22	0.640	1.635	0.146	0.096	0.026
23	0.498	1.283	0.114	0.075	0.020

Table I-117 Outlet C, 2033-DS

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	0.894	1.357	0.155	0.101	0.036
01	0.716	1.034	0.120	0.078	0.029
02	0.560	0.812	0.094	0.061	0.022
03	0.556	0.807	0.093	0.061	0.022
04	0.832	1.250	0.142	0.093	0.033
05	1.314	2.026	0.230	0.150	0.053
06	3.134	6.221	0.655	0.428	0.125
07	5.849	8.303	1.028	0.672	0.234
08	5.478	7.909	0.947	0.619	0.219
09	5.118	7.155	0.858	0.561	0.205
10	4.951	6.722	0.815	0.532	0.198
11	4.855	6.487	0.791	0.517	0.194
12	4.833	6.446	0.786	0.514	0.193
13	4.780	6.455	0.784	0.512	0.191
14	4.761	6.624	0.796	0.520	0.190
15	4.833	7.136	0.841	0.550	0.193
16	5.208	8.219	0.962	0.629	0.208
17	4.322	6.466	0.756	0.494	0.173
18	3.286	5.160	0.585	0.382	0.131
19	2.936	4.553	0.517	0.338	0.117
20	2.760	4.244	0.483	0.316	0.110
21	3.118	4.715	0.539	0.353	0.125
22	1.765	2.632	0.301	0.197	0.071
23	1.312	1.837	0.217	0.142	0.052

Table I-118 Outlet C, 2033-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	1.136	1.667	0.193	0.126	0.045
01	0.915	1.281	0.151	0.099	0.037
02	0.736	1.010	0.120	0.078	0.029
03	0.726	0.999	0.118	0.077	0.029
04	1.074	1.516	0.177	0.115	0.043
05	1.850	2.688	0.313	0.204	0.074
06	3.659	6.567	0.718	0.470	0.146
07	6.996	8.351	1.058	0.692	0.280
08	6.871	8.655	1.111	0.726	0.275
09	6.503	8.206	1.036	0.677	0.260
10	6.325	7.881	0.998	0.652	0.253
11	6.249	7.754	0.983	0.643	0.250
12	6.291	7.764	0.987	0.645	0.252
13	6.269	7.769	0.986	0.644	0.251
14	6.354	7.917	1.004	0.656	0.254
15	6.811	8.547	1.084	0.708	0.272
16	7.216	8.434	1.056	0.690	0.289
17	5.552	7.655	0.934	0.610	0.222
18	3.774	5.505	0.643	0.420	0.151
19	3.233	4.700	0.548	0.358	0.129
20	4.143	6.049	0.703	0.460	0.166
21	3.922	5.812	0.671	0.438	0.157
22	2.260	3.432	0.390	0.255	0.090
23	1.137	1.585	0.188	0.123	0.045

I.1.4.4 Outlet D (New M5 Tunnel, SPI)

Table I-119 Outlet D, 2023-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.540	0.921	0.060	0.039	0.022
01	0.326	0.564	0.037	0.024	0.013
02	0.267	0.479	0.030	0.020	0.011
03	0.267	0.479	0.030	0.020	0.011
04	0.373	0.655	0.042	0.028	0.015
05	0.529	0.885	0.058	0.038	0.021
06	0.932	1.539	0.102	0.067	0.037
07	2.582	4.676	0.304	0.199	0.103
08	1.478	2.459	0.162	0.106	0.059
09	1.280	2.041	0.138	0.090	0.051
10	1.275	2.020	0.137	0.090	0.051
11	1.264	2.000	0.136	0.089	0.051
12	1.252	1.978	0.134	0.088	0.050
13	1.123	1.889	0.124	0.081	0.045
14	1.059	1.794	0.117	0.077	0.042
15	1.007	1.683	0.111	0.073	0.040
16	0.968	1.604	0.106	0.069	0.039
17	1.027	1.625	0.110	0.072	0.041
18	0.821	1.288	0.088	0.057	0.033
19	0.767	1.181	0.081	0.053	0.031
20	0.706	1.088	0.075	0.049	0.028
21	0.601	0.930	0.064	0.042	0.024
22	0.415	0.854	0.051	0.033	0.017
23	0.340	0.628	0.039	0.026	0.014

Table I-120 Outlet D, 2023-DS

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.193	0.436	0.023	0.016	0.012
01	0.129	0.273	0.015	0.010	0.008
02	0.090	0.189	0.011	0.007	0.005
03	0.097	0.188	0.011	0.008	0.006
04	0.162	0.283	0.017	0.012	0.010
05	0.521	0.784	0.051	0.035	0.031
06	0.904	1.642	0.097	0.066	0.054
07	1.510	3.325	0.181	0.124	0.091
08	1.298	2.457	0.142	0.098	0.078
09	1.247	2.212	0.132	0.090	0.075
10	1.271	2.156	0.131	0.090	0.076
11	1.263	2.100	0.129	0.089	0.076
12	1.264	2.052	0.128	0.088	0.076
13	1.183	1.977	0.121	0.083	0.071
14	1.126	1.912	0.116	0.080	0.068
15	1.048	1.845	0.110	0.075	0.063
16	0.970	1.741	0.103	0.070	0.058
17	0.945	1.472	0.093	0.064	0.057
18	0.766	1.151	0.074	0.051	0.046
19	0.685	1.042	0.067	0.046	0.041
20	0.626	0.964	0.061	0.042	0.038
21	0.577	0.922	0.057	0.039	0.035
22	0.333	0.739	0.039	0.027	0.020
23	0.157	0.373	0.019	0.013	0.009

Table I-121 Outlet D, 2023-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.201	0.435	0.024	0.016	0.012
01	0.130	0.272	0.015	0.010	0.008
02	0.085	0.183	0.010	0.007	0.005
03	0.077	0.179	0.010	0.007	0.005
04	0.117	0.254	0.014	0.009	0.007
05	0.302	0.659	0.035	0.024	0.018
06	0.839	1.441	0.086	0.059	0.050
07	1.586	3.624	0.193	0.132	0.095
08	1.322	2.475	0.143	0.098	0.079
09	1.239	2.132	0.128	0.088	0.074
10	1.208	1.992	0.122	0.084	0.072
11	1.190	1.932	0.120	0.082	0.071
12	1.182	1.891	0.118	0.081	0.071
13	1.138	1.837	0.114	0.078	0.068
14	1.064	1.772	0.108	0.074	0.064
15	1.013	1.721	0.104	0.071	0.061
16	1.250	2.217	0.130	0.089	0.075
17	0.863	1.448	0.088	0.060	0.052
18	0.716	1.184	0.072	0.050	0.043
19	0.625	1.040	0.063	0.043	0.037
20	0.578	0.938	0.058	0.039	0.035
21	0.508	0.818	0.050	0.034	0.030
22	0.278	0.677	0.034	0.023	0.017
23	0.164	0.363	0.019	0.013	0.010

Table I-122 Outlet D, 2033-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.422	0.733	0.059	0.038	0.017
01	0.272	0.467	0.037	0.024	0.011
02	0.241	0.408	0.033	0.022	0.010
03	0.241	0.408	0.033	0.022	0.010
04	0.301	0.521	0.042	0.027	0.012
05	0.461	0.775	0.063	0.041	0.018
06	0.876	1.690	0.130	0.085	0.035
07	2.315	3.971	0.345	0.225	0.093
08	1.108	1.905	0.153	0.100	0.044
09	1.048	1.717	0.140	0.092	0.042
10	1.034	1.674	0.138	0.090	0.041
11	1.029	1.670	0.137	0.090	0.041
12	1.018	1.640	0.135	0.088	0.041
13	0.934	1.566	0.127	0.083	0.037
14	0.904	1.512	0.123	0.080	0.036
15	0.851	1.413	0.115	0.075	0.034
16	0.829	1.337	0.110	0.072	0.033
17	0.866	1.433	0.117	0.076	0.035
18	0.691	1.044	0.088	0.058	0.028
19	0.645	0.949	0.081	0.053	0.026
20	0.572	0.874	0.074	0.048	0.023
21	0.486	0.745	0.063	0.041	0.019
22	0.379	0.652	0.052	0.034	0.015
23	0.272	0.469	0.038	0.025	0.011

Table I-123 Outlet D, 2033-DS

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.154	0.307	0.023	0.015	0.006
01	0.090	0.189	0.014	0.009	0.004
02	0.058	0.125	0.009	0.006	0.002
03	0.054	0.121	0.009	0.006	0.002
04	0.085	0.179	0.013	0.008	0.003
05	0.233	0.505	0.036	0.023	0.009
06	0.716	1.356	0.103	0.067	0.029
07	1.352	2.955	0.218	0.142	0.054
08	1.114	2.113	0.162	0.106	0.045
09	1.047	1.840	0.144	0.094	0.042
10	1.006	1.704	0.134	0.088	0.040
11	0.984	1.624	0.129	0.084	0.039
12	0.971	1.593	0.127	0.083	0.039
13	0.954	1.564	0.125	0.081	0.038
14	0.927	1.554	0.123	0.080	0.037
15	0.882	1.527	0.119	0.078	0.035
16	0.811	1.437	0.111	0.072	0.032
17	0.728	1.245	0.096	0.063	0.029
18	0.589	0.965	0.076	0.050	0.024
19	0.523	0.862	0.068	0.044	0.021
20	0.490	0.797	0.063	0.041	0.020
21	0.460	0.746	0.059	0.039	0.018
22	0.357	0.591	0.046	0.030	0.014
23	0.109	0.268	0.018	0.012	0.004

Table I-124 Outlet D, 2033-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.269	0.671	0.045	0.030	0.011
01	0.170	0.396	0.027	0.018	0.007
02	0.151	0.303	0.022	0.015	0.006
03	0.152	0.300	0.022	0.015	0.006
04	0.179	0.405	0.028	0.019	0.007
05	0.422	1.159	0.076	0.050	0.017
06	1.009	2.595	0.175	0.115	0.040
07	1.671	4.144	0.315	0.206	0.067
08	1.348	3.244	0.230	0.150	0.054
09	1.193	2.761	0.195	0.127	0.048
10	1.125	2.507	0.178	0.117	0.045
11	1.082	2.365	0.169	0.110	0.043
12	1.314	2.813	0.202	0.132	0.053
13	1.274	2.727	0.196	0.128	0.051
14	1.241	2.637	0.190	0.124	0.050
15	1.200	2.544	0.183	0.120	0.048
16	1.159	2.473	0.177	0.116	0.046
17	0.879	2.174	0.148	0.097	0.035
18	0.764	1.930	0.131	0.085	0.031
19	0.688	1.757	0.118	0.077	0.028
20	0.637	1.635	0.110	0.072	0.025
21	0.599	1.556	0.104	0.068	0.024
22	0.403	1.214	0.077	0.050	0.016
23	0.262	0.699	0.046	0.030	0.010

I.1.5 Outlet E (New M5 Tunnel, Arncliffe)

Table I-125 Outlet E, 2023-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.477	0.732	0.122	0.080	0.019
01	0.288	0.449	0.075	0.049	0.012
02	0.236	0.379	0.062	0.041	0.009
03	0.237	0.379	0.062	0.041	0.009
04	0.330	0.521	0.086	0.056	0.013
05	0.423	0.638	0.107	0.070	0.017
06	0.777	1.158	0.196	0.128	0.031
07	2.195	3.499	0.592	0.387	0.088
08	1.232	1.849	0.312	0.204	0.049
09	1.065	1.538	0.264	0.172	0.043
10	1.061	1.523	0.262	0.171	0.042
11	1.052	1.508	0.259	0.170	0.042
12	1.042	1.491	0.257	0.168	0.042
13	0.937	1.420	0.239	0.156	0.037
14	0.884	1.348	0.226	0.148	0.035
15	0.840	1.266	0.213	0.139	0.034
16	0.807	1.207	0.204	0.133	0.032
17	0.819	1.174	0.202	0.132	0.033
18	0.655	0.931	0.161	0.105	0.026
19	0.611	0.854	0.149	0.097	0.024
20	0.562	0.787	0.137	0.089	0.022
21	0.478	0.672	0.117	0.076	0.019
22	0.370	0.674	0.106	0.069	0.015
23	0.301	0.497	0.081	0.053	0.012

Table I-126 Outlet E, 2023-DS

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.329	0.664	0.096	0.066	0.020
01	0.207	0.383	0.057	0.039	0.012
02	0.145	0.258	0.040	0.027	0.009
03	0.159	0.258	0.040	0.028	0.010
04	0.249	0.414	0.064	0.044	0.015
05	0.382	0.540	0.089	0.061	0.023
06	0.786	1.444	0.216	0.148	0.047
07	1.700	3.108	0.479	0.328	0.102
08	1.304	2.178	0.337	0.231	0.078
09	1.165	1.847	0.291	0.200	0.070
10	1.129	1.725	0.276	0.189	0.068
11	1.106	1.660	0.268	0.183	0.066
12	1.095	1.615	0.262	0.179	0.066
13	1.029	1.561	0.250	0.172	0.062
14	0.997	1.539	0.245	0.168	0.060
15	0.956	1.520	0.239	0.164	0.057
16	0.909	1.480	0.231	0.158	0.055
17	0.926	1.347	0.220	0.151	0.056
18	0.752	1.065	0.176	0.120	0.045
19	0.680	0.970	0.160	0.109	0.041
20	0.625	0.910	0.149	0.102	0.038
21	0.552	0.833	0.134	0.092	0.033
22	0.446	0.875	0.128	0.087	0.027
23	0.220	0.432	0.063	0.043	0.013

Table I-127 Outlet E, 2023-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.297	0.566	0.083	0.057	0.018
01	0.179	0.321	0.049	0.033	0.011
02	0.110	0.206	0.031	0.021	0.007
03	0.093	0.191	0.028	0.019	0.006
04	0.143	0.288	0.041	0.028	0.009
05	0.415	0.813	0.119	0.081	0.025
06	1.016	1.698	0.262	0.180	0.061
07	1.640	3.156	0.480	0.329	0.098
08	1.276	2.161	0.332	0.228	0.077
09	1.146	1.777	0.283	0.194	0.069
10	1.101	1.641	0.265	0.182	0.066
11	1.076	1.586	0.257	0.176	0.065
12	1.053	1.534	0.250	0.171	0.063
13	1.015	1.502	0.243	0.167	0.061
14	0.961	1.467	0.235	0.161	0.058
15	0.923	1.436	0.228	0.156	0.055
16	0.853	1.376	0.216	0.148	0.051
17	0.916	1.427	0.227	0.155	0.055
18	0.757	1.180	0.187	0.128	0.045
19	0.641	1.014	0.160	0.110	0.038
20	0.581	0.893	0.143	0.098	0.035
21	0.507	0.774	0.124	0.085	0.030
22	0.380	0.833	0.117	0.080	0.023
23	0.171	0.347	0.050	0.034	0.010

Table I-128 Outlet E, 2033-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	0.399	0.629	0.128	0.084	0.016
01	0.256	0.401	0.082	0.054	0.010
02	0.228	0.350	0.072	0.047	0.009
03	0.228	0.350	0.072	0.047	0.009
04	0.284	0.447	0.091	0.060	0.011
05	0.387	0.592	0.122	0.080	0.015
06	0.775	1.356	0.269	0.176	0.031
07	2.164	3.382	0.715	0.467	0.087
08	0.980	1.533	0.314	0.205	0.039
09	0.928	1.384	0.287	0.188	0.037
10	0.915	1.350	0.281	0.184	0.037
11	0.910	1.347	0.280	0.183	0.036
12	0.900	1.323	0.276	0.180	0.036
13	0.826	1.262	0.260	0.170	0.033
14	0.800	1.218	0.251	0.164	0.032
15	0.753	1.139	0.235	0.154	0.030
16	0.734	1.078	0.225	0.147	0.029
17	0.726	1.095	0.227	0.148	0.029
18	0.580	0.800	0.170	0.111	0.023
19	0.541	0.728	0.156	0.102	0.022
20	0.480	0.669	0.142	0.093	0.019
21	0.408	0.570	0.121	0.079	0.016
22	0.358	0.560	0.114	0.075	0.014
23	0.256	0.403	0.082	0.054	0.010

Table I-129 Outlet E, 2033-DS

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	0.286	0.478	0.096	0.063	0.011
01	0.142	0.260	0.052	0.034	0.006
02	0.078	0.155	0.030	0.020	0.003
03	0.070	0.147	0.028	0.018	0.003
04	0.126	0.239	0.046	0.030	0.005
05	0.173	0.338	0.065	0.043	0.007
06	0.672	1.347	0.257	0.168	0.027
07	1.987	3.258	0.671	0.439	0.079
08	1.407	2.355	0.480	0.314	0.056
09	1.146	1.834	0.374	0.244	0.046
10	1.020	1.582	0.325	0.212	0.041
11	0.951	1.448	0.299	0.195	0.038
12	0.933	1.420	0.293	0.192	0.037
13	0.919	1.406	0.290	0.189	0.037
14	0.897	1.403	0.287	0.188	0.036
15	0.864	1.401	0.284	0.185	0.035
16	0.817	1.356	0.273	0.178	0.033
17	0.776	1.192	0.245	0.160	0.031
18	0.610	0.921	0.190	0.124	0.024
19	0.540	0.827	0.170	0.111	0.022
20	0.505	0.772	0.159	0.104	0.020
21	0.464	0.711	0.146	0.096	0.019
22	0.491	0.716	0.150	0.098	0.020
23	0.145	0.316	0.059	0.039	0.006

Table I-130 Outlet E, 2033-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	0.186	0.328	0.065	0.042	0.007
01	0.154	0.269	0.053	0.035	0.006
02	0.121	0.209	0.042	0.027	0.005
03	0.117	0.194	0.039	0.026	0.005
04	0.155	0.272	0.054	0.035	0.006
05	0.326	0.611	0.119	0.078	0.013
06	0.715	0.962	0.207	0.135	0.029
07	0.938	1.832	0.356	0.232	0.038
08	0.872	1.352	0.278	0.181	0.035
09	0.868	1.279	0.267	0.174	0.035
10	0.864	1.251	0.262	0.171	0.035
11	0.865	1.238	0.260	0.170	0.035
12	0.856	1.217	0.257	0.168	0.034
13	0.832	1.206	0.253	0.165	0.033
14	0.808	1.191	0.248	0.162	0.032
15	0.787	1.194	0.247	0.161	0.031
16	0.749	1.194	0.243	0.159	0.030
17	0.791	1.380	0.274	0.179	0.032
18	0.664	1.055	0.215	0.140	0.027
19	0.554	0.820	0.171	0.112	0.022
20	0.491	0.694	0.147	0.096	0.020
21	0.445	0.635	0.134	0.087	0.018
22	0.198	0.378	0.073	0.048	0.008
23	0.140	0.285	0.054	0.035	0.006

I.1.5.1 Outlet F (New M5 Tunnel, Kingsgrove)

Table I-131 Outlet F, 2023-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.160	1.995	0.162	0.106	0.046
01	0.741	1.269	0.107	0.070	0.030
02	0.610	1.060	0.087	0.057	0.024
03	0.605	1.055	0.085	0.056	0.024
04	0.944	1.651	0.131	0.086	0.038
05	2.168	3.656	0.301	0.196	0.087
06	1.613	2.789	0.226	0.148	0.065
07	1.731	3.033	0.244	0.160	0.069
08	1.885	3.082	0.257	0.168	0.075
09	2.045	3.165	0.272	0.178	0.082
10	2.412	3.389	0.308	0.201	0.096
11	2.891	3.730	0.357	0.233	0.116
12	3.178	4.005	0.389	0.254	0.127
13	2.517	3.428	0.317	0.207	0.101
14	2.642	4.159	0.355	0.232	0.106
15	2.853	5.264	0.412	0.270	0.114
16	3.127	6.829	0.494	0.323	0.125
17	2.160	5.032	0.352	0.230	0.086
18	2.077	4.454	0.324	0.212	0.083
19	1.806	3.655	0.273	0.179	0.072
20	1.655	3.309	0.249	0.163	0.066
21	1.479	3.015	0.225	0.147	0.059
22	1.671	2.880	0.233	0.152	0.067
23	1.051	1.571	0.142	0.092	0.042

Table I-132 Outlet F, 2023-DS

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.639	3.048	0.248	0.170	0.098
01	0.907	1.866	0.141	0.096	0.054
02	0.936	1.611	0.139	0.095	0.056
03	0.788	1.370	0.115	0.078	0.047
04	0.850	1.504	0.121	0.083	0.051
05	1.401	2.509	0.198	0.135	0.084
06	1.593	2.911	0.233	0.160	0.096
07	3.097	6.470	0.507	0.347	0.186
08	3.671	6.771	0.568	0.389	0.220
09	3.901	6.560	0.568	0.389	0.234
10	4.060	6.476	0.573	0.392	0.244
11	4.223	6.451	0.581	0.398	0.253
12	4.286	6.408	0.583	0.399	0.257
13	4.451	7.081	0.621	0.426	0.267
14	3.697	6.628	0.544	0.373	0.222
15	4.082	8.507	0.648	0.444	0.245
16	4.580	10.475	0.777	0.532	0.275
17	2.887	7.086	0.501	0.343	0.173
18	2.898	6.545	0.479	0.328	0.174
19	2.468	5.238	0.394	0.270	0.148
20	2.213	4.624	0.350	0.240	0.133
21	1.973	4.092	0.311	0.213	0.118
22	2.830	5.224	0.427	0.292	0.170
23	1.715	2.829	0.252	0.173	0.103

Table I-133 Outlet F, 2023-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.957	3.480	0.291	0.199	0.117
01	1.243	2.335	0.188	0.129	0.075
02	1.028	1.773	0.153	0.105	0.062
03	0.923	1.603	0.134	0.092	0.055
04	1.162	2.197	0.171	0.117	0.070
05	1.339	2.694	0.205	0.140	0.080
06	2.630	5.169	0.410	0.281	0.158
07	3.521	7.044	0.588	0.403	0.211
08	4.111	6.832	0.617	0.422	0.247
09	4.316	6.496	0.607	0.416	0.259
10	4.495	6.373	0.610	0.418	0.270
11	4.562	6.266	0.608	0.417	0.274
12	4.608	6.256	0.611	0.418	0.276
13	4.640	6.831	0.634	0.434	0.278
14	4.939	8.455	0.720	0.493	0.296
15	5.531	10.932	0.867	0.594	0.332
16	6.200	13.287	1.040	0.713	0.372
17	3.619	8.221	0.607	0.416	0.217
18	2.826	5.941	0.455	0.312	0.170
19	2.462	4.877	0.384	0.263	0.148
20	3.104	5.942	0.475	0.325	0.186
21	2.858	5.496	0.438	0.300	0.171
22	2.366	4.194	0.351	0.240	0.142
23	1.839	2.649	0.258	0.176	0.110

Table I-134 Outlet F, 2033-DM

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.708	1.137	0.118	0.077	0.028
01	0.568	0.799	0.090	0.059	0.023
02	0.519	0.723	0.080	0.052	0.021
03	0.517	0.722	0.080	0.052	0.021
04	0.644	1.016	0.103	0.068	0.026
05	1.298	2.475	0.235	0.154	0.052
06	1.243	2.415	0.227	0.149	0.050
07	1.490	2.811	0.268	0.175	0.060
08	1.581	2.868	0.278	0.182	0.063
09	1.833	3.051	0.308	0.201	0.073
10	2.130	3.219	0.340	0.223	0.085
11	2.450	3.390	0.375	0.245	0.098
12	2.690	3.563	0.403	0.264	0.108
13	2.164	3.121	0.338	0.221	0.087
14	2.327	3.907	0.393	0.257	0.093
15	2.570	4.912	0.467	0.305	0.103
16	2.893	6.115	0.576	0.376	0.116
17	2.061	4.413	0.399	0.261	0.082
18	1.925	4.112	0.372	0.243	0.077
19	1.638	3.437	0.313	0.205	0.066
20	1.440	2.982	0.273	0.179	0.058
21	1.234	2.558	0.234	0.153	0.049
22	1.439	2.555	0.250	0.163	0.058
23	0.876	1.389	0.144	0.094	0.035

Table I-135 Outlet F, 2033-DS

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.331	2.484	0.260	0.170	0.053
01	0.762	1.622	0.158	0.103	0.030
02	0.708	1.359	0.144	0.094	0.028
03	0.599	1.112	0.117	0.077	0.024
04	0.678	1.355	0.133	0.087	0.027
05	1.036	2.241	0.212	0.139	0.041
06	1.336	2.798	0.276	0.181	0.053
07	2.667	5.798	0.591	0.386	0.107
08	3.069	5.940	0.632	0.413	0.123
09	3.245	5.816	0.632	0.413	0.130
10	3.325	5.677	0.627	0.410	0.133
11	3.423	5.599	0.628	0.410	0.137
12	3.524	5.710	0.641	0.419	0.141
13	3.723	6.439	0.699	0.457	0.149
14	3.188	6.147	0.633	0.414	0.128
15	3.722	7.790	0.790	0.516	0.149
16	4.266	9.574	0.971	0.635	0.171
17	2.841	6.499	0.623	0.407	0.114
18	2.510	5.522	0.537	0.351	0.100
19	1.974	4.239	0.416	0.272	0.079
20	1.759	3.710	0.367	0.240	0.070
21	1.606	3.269	0.328	0.214	0.064
22	1.931	3.531	0.379	0.248	0.077
23	1.130	1.763	0.211	0.138	0.045

Table I-136 Outlet F, 2033-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.141	2.151	0.226	0.148	0.046
01	0.873	1.518	0.167	0.109	0.035
02	0.704	1.238	0.135	0.088	0.028
03	0.661	1.189	0.126	0.083	0.026
04	0.908	1.810	0.178	0.117	0.036
05	1.120	2.520	0.237	0.155	0.045
06	2.138	4.561	0.450	0.294	0.086
07	3.015	6.195	0.635	0.415	0.121
08	3.401	6.050	0.646	0.422	0.136
09	3.432	5.668	0.630	0.412	0.137
10	3.556	5.440	0.628	0.410	0.142
11	3.764	5.441	0.645	0.421	0.151
12	3.935	5.494	0.662	0.433	0.157
13	3.923	5.622	0.671	0.439	0.157
14	3.906	6.313	0.717	0.469	0.156
15	4.193	8.015	0.852	0.557	0.168
16	4.824	10.655	1.118	0.731	0.193
17	3.242	6.796	0.689	0.451	0.130
18	2.448	4.888	0.498	0.325	0.098
19	2.582	4.955	0.511	0.334	0.103
20	2.334	4.477	0.460	0.301	0.093
21	2.212	4.255	0.435	0.284	0.088
22	1.821	3.273	0.349	0.228	0.073
23	1.704	3.122	0.332	0.217	0.068

I.1.5.2 Outlet G (M4-M5 Link Tunnel, Parramatta Road)

Table I-137 Outlet G, 2023-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 I-138 Outlet G, 2023-DS

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.412	0.766	0.068	0.047	0.025
01	0.341	0.600	0.055	0.038	0.020
02	0.282	0.472	0.045	0.031	0.017
03	0.295	0.510	0.048	0.033	0.018
04	0.430	0.766	0.070	0.048	0.026
05	0.620	1.132	0.100	0.069	0.037
06	1.420	3.363	0.259	0.177	0.085
07	2.465	4.648	0.397	0.272	0.148
08	2.235	4.004	0.351	0.240	0.134
09	2.083	3.600	0.321	0.220	0.125
10	1.995	3.344	0.303	0.207	0.120
11	1.947	3.210	0.293	0.201	0.117
12	1.922	3.134	0.288	0.197	0.115
13	1.937	3.193	0.292	0.200	0.116
14	1.995	3.399	0.306	0.210	0.120
15	2.122	3.920	0.345	0.236	0.127
16	2.300	4.600	0.396	0.271	0.138
17	1.725	3.350	0.289	0.198	0.104
18	1.396	2.574	0.223	0.153	0.084
19	1.495	2.748	0.236	0.162	0.090
20	1.387	2.553	0.219	0.150	0.083
21	1.260	2.365	0.201	0.138	0.076
22	0.826	1.484	0.132	0.090	0.050
23	0.505	0.869	0.081	0.055	0.030

Table I-139 Outlet G, 2023-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.467	0.848	0.078	0.053	0.028
01	0.395	0.659	0.063	0.043	0.024
02	0.326	0.532	0.052	0.036	0.020
03	0.324	0.545	0.052	0.036	0.019
04	0.445	0.794	0.074	0.050	0.027
05	0.953	1.747	0.157	0.107	0.057
06	1.438	3.181	0.259	0.177	0.086
07	2.597	4.926	0.436	0.298	0.156
08	2.424	4.325	0.390	0.267	0.145
09	2.322	3.987	0.364	0.249	0.139
10	2.286	3.843	0.353	0.242	0.137
11	2.269	3.736	0.346	0.237	0.136
12	2.240	3.636	0.339	0.232	0.134
13	2.287	3.720	0.348	0.238	0.137
14	2.376	3.915	0.365	0.250	0.143
15	2.605	4.367	0.410	0.280	0.156
16	2.830	4.587	0.461	0.316	0.170
17	2.042	3.779	0.338	0.232	0.123
18	1.472	2.714	0.237	0.162	0.088
19	1.288	2.298	0.203	0.139	0.077
20	1.191	2.104	0.187	0.128	0.071
21	1.948	3.465	0.307	0.211	0.117
22	1.022	1.714	0.161	0.110	0.061
23	0.590	0.978	0.093	0.064	0.035

Table I-140 Outlet G, 2033-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	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table I-141 Outlet G, 2033-DS

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	0.322	0.604	0.070	0.046	0.013
01	0.280	0.478	0.058	0.038	0.011
02	0.224	0.377	0.047	0.030	0.009
03	0.228	0.389	0.048	0.031	0.009
04	0.320	0.570	0.068	0.044	0.013
05	0.472	0.871	0.100	0.065	0.019
06	1.208	2.826	0.290	0.189	0.048
07	2.273	4.160	0.466	0.305	0.091
08	2.011	3.629	0.407	0.266	0.080
09	1.822	3.159	0.360	0.235	0.073
10	1.716	2.900	0.335	0.219	0.069
11	1.642	2.730	0.318	0.208	0.066
12	1.629	2.697	0.315	0.206	0.065
13	1.625	2.734	0.318	0.208	0.065
14	1.648	2.875	0.329	0.215	0.066
15	1.726	3.204	0.360	0.235	0.069
16	1.868	3.749	0.419	0.274	0.075
17	1.499	2.731	0.312	0.204	0.060
18	1.141	2.133	0.239	0.156	0.046
19	1.222	2.252	0.252	0.165	0.049
20	1.156	2.120	0.237	0.155	0.046
21	1.085	1.967	0.220	0.144	0.043
22	0.710	1.150	0.139	0.091	0.028
23	0.428	0.693	0.085	0.056	0.017

Table I-142 Outlet G, 2033-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	0.427	0.794	0.092	0.060	0.017
01	0.370	0.635	0.076	0.050	0.015
02	0.315	0.525	0.064	0.042	0.013
03	0.323	0.531	0.065	0.042	0.013
04	0.448	0.783	0.091	0.060	0.018
05	0.925	1.680	0.192	0.125	0.037
06	1.426	3.026	0.325	0.213	0.057
07	2.870	4.585	0.579	0.378	0.115
08	2.508	4.247	0.500	0.327	0.100
09	2.321	3.818	0.453	0.296	0.093
10	2.241	3.611	0.431	0.282	0.090
11	2.197	3.501	0.420	0.274	0.088
12	2.200	3.481	0.419	0.274	0.088
13	2.179	3.490	0.419	0.274	0.087
14	2.217	3.628	0.433	0.283	0.089
15	2.392	4.013	0.481	0.314	0.096
16	3.003	4.473	0.582	0.380	0.120
17	1.893	3.349	0.394	0.258	0.076
18	1.324	2.397	0.273	0.179	0.053
19	1.152	2.071	0.235	0.153	0.046
20	1.083	1.933	0.220	0.144	0.043
21	1.020	1.834	0.208	0.136	0.041
22	0.863	1.480	0.174	0.114	0.035
23	0.536	0.921	0.110	0.072	0.021

I.1.5.3 Outlet H (WHT, Rozelle (west))

Table I-143 Outlet H, 2023-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	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table I-144 Outlet H, 2023-DS

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 I-145 Outlet H, 2023-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	0.415	0.943	0.099	0.068	0.025
01	0.238	0.567	0.058	0.040	0.014
02	0.155	0.370	0.038	0.026	0.009
03	0.186	0.383	0.042	0.029	0.011
04	0.332	0.792	0.082	0.056	0.020
05	0.500	1.370	0.135	0.092	0.030
06	0.920	2.575	0.254	0.174	0.055
07	2.016	4.518	0.499	0.342	0.121
08	1.832	3.723	0.418	0.286	0.110
09	1.723	3.243	0.370	0.253	0.103
10	1.645	2.883	0.339	0.232	0.099
11	1.586	2.596	0.314	0.215	0.095
12	1.580	2.507	0.308	0.211	0.095
13	1.774	2.750	0.341	0.234	0.106
14	2.147	3.394	0.419	0.287	0.129
15	2.775	4.512	0.560	0.384	0.167
16	3.656	5.986	0.798	0.546	0.219
17	1.697	3.627	0.398	0.272	0.102
18	1.140	2.903	0.292	0.200	0.068
19	0.798	1.925	0.198	0.136	0.048
20	0.644	1.479	0.155	0.106	0.039
21	0.547	1.276	0.134	0.091	0.033
22	0.551	1.436	0.144	0.099	0.033
23	0.339	0.897	0.089	0.061	0.020

Table I-146 Outlet H, 2033-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 I-147 Outlet H, 2033-DS

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 I-148 Outlet H, 2033-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.378	0.879	0.124	0.081	0.015
01	0.259	0.571	0.082	0.053	0.010
02	0.192	0.462	0.065	0.042	0.008
03	0.214	0.507	0.071	0.047	0.009
04	0.346	0.820	0.115	0.075	0.014
05	0.477	1.295	0.176	0.115	0.019
06	0.799	2.394	0.328	0.215	0.032
07	1.938	3.697	0.599	0.392	0.078
08	1.659	3.134	0.487	0.318	0.066
09	1.498	2.687	0.420	0.274	0.060
10	1.419	2.434	0.384	0.251	0.057
11	1.373	2.317	0.367	0.240	0.055
12	1.381	2.291	0.364	0.238	0.055
13	1.462	2.363	0.380	0.249	0.058
14	1.708	2.702	0.441	0.288	0.068
15	2.053	3.519	0.566	0.370	0.082
16	2.854	4.648	0.729	0.477	0.114
17	1.359	2.707	0.411	0.269	0.054
18	0.846	2.010	0.283	0.185	0.034
19	0.619	1.471	0.208	0.136	0.025
20	0.554	1.257	0.180	0.118	0.022
21	0.518	1.168	0.168	0.110	0.021
22	0.365	0.902	0.126	0.082	0.015
23	0.351	0.937	0.127	0.083	0.014

I.1.5.4 Outlet I (M4-M5 Link/Iron Cove Link Tunnel, Rozelle (east))

Table I-149 Outlet I, 2023-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	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table I-150 Outlet I, 2023-DS

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 I-151 Outlet I, 2023-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	-	-	-	-	-
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	-	-	-	-	-
06	1.756	3.199	0.284	0.194	0.105
07	0.000	0.000	0.000	0.000	0.000
08	2.742	4.596	0.439	0.301	0.165
09	2.428	3.968	0.380	0.260	0.146
10	2.324	3.734	0.358	0.245	0.139
11	2.269	3.625	0.348	0.238	0.136
12	2.171	3.537	0.334	0.229	0.130
13	1.978	3.445	0.317	0.217	0.119
14	1.852	3.427	0.309	0.212	0.111
15	1.785	3.509	0.311	0.213	0.107
16	1.760	3.659	0.322	0.221	0.106
17	1.484	2.866	0.257	0.176	0.089
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table I-152 Outlet I, 2033-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 I-153 Outlet I, 2033-DS

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 I-154 Outlet I, 2033-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	-	-	-	-	-

I.1.5.5 Outlet J (M4-M5 Link/Iron Cove Link Tunnel, Rozelle (mid))

Table I-155 Outlet J, 2023-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	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table I-156 Outlet J, 2023-DS

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	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 I-157 Outlet J, 2023-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	0.000	0.000	0.000	0.000	0.000
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	0.000	0.000	0.000	0.000	0.000
06	1.826	3.326	0.295	0.202	0.110
07	0.000	0.000	0.000	0.000	0.000
08	2.852	4.779	0.457	0.313	0.171
09	2.525	4.126	0.395	0.271	0.151
10	2.416	3.883	0.373	0.255	0.145
11	2.360	3.769	0.361	0.248	0.142
12	2.257	3.678	0.348	0.238	0.135
13	2.057	3.583	0.329	0.226	0.123
14	1.926	3.564	0.321	0.220	0.116
15	1.856	3.649	0.324	0.222	0.111
16	1.831	3.805	0.335	0.230	0.110
17	1.544	2.980	0.267	0.183	0.093
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	0.000	0.000	0.000	0.000	0.000

Table I-158 Outlet J, 2033-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 I-159 Outlet J, 2033-DS

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 I-160 Outlet J, 2033-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
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

I.1.5.6 Outlet K (M4-M5 Link Tunnel, SPI)

Table I-161 Outlet K, 2023-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	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table I-162 Outlet K, 2023-DS

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	0.898	1.159	0.119	0.081	0.054
01	0.629	0.769	0.082	0.056	0.038
02	0.510	0.654	0.067	0.046	0.031
03	0.665	0.792	0.082	0.056	0.040
04	1.253	1.398	0.149	0.102	0.075
05	2.727	2.853	0.326	0.223	0.164
06	2.876	4.172	0.399	0.273	0.173
07	3.829	6.463	0.575	0.394	0.230
08	4.095	5.957	0.565	0.387	0.246
09	4.089	5.558	0.543	0.372	0.245
10	4.050	5.295	0.528	0.362	0.243
11	4.051	5.182	0.523	0.358	0.243
12	4.111	5.167	0.526	0.361	0.247
13	3.999	5.111	0.516	0.353	0.240
14	3.606	4.979	0.482	0.330	0.216
15	3.251	4.879	0.453	0.310	0.195
16	4.019	6.403	0.580	0.397	0.241
17	3.592	5.272	0.497	0.340	0.215
18	3.277	4.360	0.432	0.296	0.197
19	3.089	3.938	0.400	0.274	0.185
20	3.014	3.733	0.385	0.264	0.181
21	2.972	3.623	0.377	0.258	0.178
22	2.205	2.417	0.266	0.182	0.132
23	1.422	1.739	0.185	0.127	0.085

Table I-163 Outlet K, 2023-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	1.488	1.904	0.190	0.130	0.089
01	0.878	1.179	0.116	0.079	0.053
02	0.637	0.921	0.086	0.059	0.038
03	0.727	1.032	0.097	0.066	0.044
04	1.411	1.828	0.179	0.122	0.085
05	1.677	2.020	0.208	0.143	0.101
06	3.190	5.149	0.455	0.312	0.191
07	5.018	8.048	0.758	0.519	0.301
08	5.029	7.039	0.682	0.467	0.302
09	5.072	6.677	0.662	0.453	0.304
10	5.070	6.547	0.654	0.448	0.304
11	5.074	6.469	0.650	0.445	0.304
12	5.028	6.407	0.644	0.441	0.302
13	4.482	6.195	0.595	0.408	0.269
14	4.000	6.015	0.554	0.379	0.240
15	3.661	6.009	0.532	0.364	0.220
16	3.528	6.149	0.533	0.365	0.212
17	4.017	6.461	0.574	0.393	0.241
18	3.623	5.146	0.485	0.332	0.217
19	3.382	4.434	0.436	0.299	0.203
20	3.246	4.223	0.417	0.286	0.195
21	3.230	4.106	0.411	0.281	0.194
22	2.370	2.800	0.292	0.200	0.142
23	2.423	2.904	0.299	0.205	0.145

Table I-164 Outlet K, 2033-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 I-165 Outlet K, 2033-DS

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.942	1.187	0.154	0.101	0.038
01	0.739	0.896	0.119	0.078	0.030
02	0.570	0.725	0.093	0.061	0.023
03	0.508	0.677	0.085	0.055	0.020
04	0.789	1.055	0.131	0.085	0.032
05	1.358	1.637	0.216	0.141	0.054
06	1.818	2.799	0.334	0.218	0.073
07	3.011	5.146	0.590	0.385	0.120
08	3.225	4.739	0.574	0.375	0.129
09	3.322	4.601	0.569	0.372	0.133
10	3.471	4.615	0.580	0.379	0.139
11	3.584	4.649	0.591	0.386	0.143
12	3.640	4.652	0.595	0.389	0.146
13	3.548	4.604	0.584	0.382	0.142
14	3.349	4.538	0.565	0.369	0.134
15	3.082	4.472	0.543	0.355	0.123
16	2.798	4.409	0.521	0.341	0.112
17	2.593	3.663	0.447	0.292	0.104
18	2.500	3.235	0.410	0.268	0.100
19	2.393	2.990	0.386	0.252	0.096
20	2.286	2.814	0.366	0.239	0.091
21	2.161	2.626	0.344	0.225	0.086
22	2.333	2.677	0.359	0.235	0.093
23	0.936	1.227	0.155	0.101	0.037

Table I-166 Outlet K, 2033-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	1.404	1.826	0.226	0.148	0.056
01	0.751	1.057	0.128	0.083	0.030
02	0.587	0.840	0.100	0.066	0.023
03	0.609	0.851	0.102	0.067	0.024
04	1.123	1.503	0.183	0.120	0.045
05	1.861	2.262	0.290	0.189	0.074
06	2.887	4.909	0.548	0.358	0.115
07	3.993	6.402	0.754	0.493	0.160
08	4.072	5.935	0.713	0.466	0.163
09	4.324	5.799	0.716	0.468	0.173
10	4.428	5.761	0.719	0.470	0.177
11	4.547	5.788	0.729	0.476	0.182
12	4.593	5.781	0.731	0.478	0.184
13	4.532	5.770	0.726	0.474	0.181
14	4.036	5.528	0.673	0.440	0.161
15	3.695	5.512	0.651	0.426	0.148
16	3.502	5.716	0.666	0.435	0.140
17	3.102	4.671	0.546	0.357	0.124
18	2.837	3.752	0.459	0.300	0.113
19	2.691	3.462	0.429	0.280	0.108
20	2.652	3.359	0.420	0.274	0.106
21	2.620	3.303	0.414	0.271	0.105
22	2.463	3.056	0.386	0.253	0.099
23	1.219	1.538	0.193	0.126	0.049

I.1.5.7 Outlet L (Iron Cove Link Tunnel, Iron Cove)

Table I-167 Outlet L, 2023-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	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table I-168 Outlet L, 2023-DS

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 I-169 Outlet L, 2023-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	0.469	1.022	0.056	0.038	0.028
01	0.370	0.778	0.045	0.031	0.022
02	0.309	0.660	0.038	0.026	0.019
03	0.297	0.695	0.038	0.026	0.018
04	0.348	1.003	0.048	0.033	0.021
05	0.427	1.645	0.066	0.045	0.026
06	0.715	2.711	0.120	0.082	0.043
07	0.919	3.346	0.157	0.107	0.055
08	0.999	2.893	0.157	0.108	0.060
09	1.262	2.913	0.180	0.123	0.076
10	1.355	2.933	0.188	0.129	0.081
11	1.397	2.934	0.191	0.131	0.084
12	1.430	2.944	0.195	0.134	0.086
13	1.434	2.954	0.198	0.136	0.086
14	1.414	3.015	0.201	0.138	0.085
15	1.250	3.143	0.196	0.134	0.075
16	1.230	3.392	0.207	0.142	0.074
17	1.156	3.005	0.179	0.123	0.069
18	1.098	2.688	0.159	0.109	0.066
19	1.050	2.550	0.146	0.100	0.063
20	1.019	2.485	0.139	0.095	0.061
21	0.969	2.445	0.131	0.089	0.058
22	0.929	2.366	0.119	0.081	0.056
23	0.555	1.155	0.067	0.046	0.033

Table I-170 Outlet L, 2033-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 I-171 Outlet L, 2033-DS

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 I-172 Outlet L, 2033-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

I.1.5.8 Outlet M (F6 Extension Tunnel, Arncliffe)

Table I-173 Outlet M, 2023-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	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table I-174 Outlet M, 2023-DS

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 I-175 Outlet M, 2023-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	-	-	-	-	-
01	-	-	-	-	-
02	-	-	-	-	-
03	-	-	-	-	-
04	-	-	-	-	-
05	-	-	-	-	-
06	-	-	-	-	-
07	-	-	-	-	-
08	-	-	-	-	-
09	-	-	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-

Table I-176 Outlet M, 2033-DM

Hour start	NOx (mg/m³)	CO (mg/m³)	PM2.5 (mg/m³)	PM10 (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 I-177 Outlet M, 2033-DS

Hour start	NOx (mg/m³)	CO (mg/m³)	PM2.5 (mg/m³)	PM10 (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 I-178 Outlet M, 2033-DSC

Hour start	NOx (mg/m³)	CO (mg/m³)	PM2.5 (mg/m³)	PM10 (mg/m³)	THC (mg/m³)
00	0.106	0.270	0.044	0.029	0.004
01	0.065	0.151	0.025	0.016	0.003
02	0.065	0.112	0.020	0.013	0.003
03	0.065	0.112	0.020	0.013	0.003
04	0.075	0.155	0.027	0.017	0.003
05	0.130	0.404	0.063	0.041	0.005
06	0.245	0.845	0.129	0.085	0.010
07	0.832	2.092	0.357	0.233	0.033
08	0.530	1.387	0.226	0.148	0.021
09	0.371	1.015	0.163	0.107	0.015
10	0.315	0.841	0.136	0.089	0.013
11	0.289	0.768	0.124	0.081	0.012
12	0.274	0.713	0.116	0.076	0.011
13	0.260	0.669	0.109	0.071	0.010
14	0.253	0.634	0.104	0.068	0.010
15	0.246	0.597	0.099	0.064	0.010
16	0.244	0.563	0.094	0.061	0.010
17	0.232	0.699	0.110	0.072	0.009
18	0.191	0.671	0.102	0.067	0.008
19	0.184	0.662	0.101	0.066	0.007
20	0.170	0.622	0.094	0.062	0.007
21	0.154	0.577	0.087	0.057	0.006
22	0.151	0.546	0.083	0.054	0.006
23	0.084	0.263	0.041	0.027	0.003

I.1.5.9 Outlet N (F6 Extension Tunnel, Rockdale)

Table I-179 Outlet N, 2023-DM

Hour start	NOx (mg/m3)	CO (mg/m3)	PM2.5 (mg/m3)	PM10 (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 I-180 Outlet N, 2023-DS

Hour start	NOx (mg/m3)	CO (mg/m3)	PM2.5 (mg/m3)	PM10 (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 I-181 Outlet N, 2023-DSC

Hour start	NOx (mg/m3)	CO (mg/m3)	PM2.5 (mg/m3)	PM10 (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 I-182 Outlet N, 2033-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 I-183 Outlet N, 2033-DS

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 I-184 Outlet N, 2033-DSC

Hour start	NO_X (mg/m³)	CO (mg/m³)	$PM_{2.5}$ (mg/m³)	PM_{10} (mg/m³)	THC (mg/m³)
00	0.862	2.189	0.193	0.126	0.034
01	0.609	1.615	0.140	0.091	0.024
02	0.457	1.373	0.112	0.073	0.018
03	0.438	1.368	0.109	0.071	0.018
04	0.575	1.730	0.139	0.091	0.023
05	1.062	2.811	0.245	0.160	0.042
06	1.812	4.691	0.441	0.288	0.072
07	1.712	4.421	0.426	0.279	0.068
08	2.118	4.999	0.476	0.311	0.085
09	2.250	5.353	0.503	0.329	0.090
10	2.437	5.913	0.542	0.355	0.097
11	2.588	6.310	0.573	0.374	0.104
12	2.747	6.696	0.604	0.395	0.110
13	2.271	5.776	0.507	0.332	0.091
14	2.682	7.378	0.637	0.416	0.107
15	3.164	8.925	0.804	0.525	0.127
16	3.692	8.325	0.990	0.647	0.148
17	2.494	7.828	0.651	0.426	0.100
18	1.731	5.534	0.432	0.282	0.069
19	1.862	5.610	0.450	0.294	0.074
20	1.534	4.325	0.362	0.237	0.061
21	1.268	3.409	0.296	0.193	0.051
22	1.569	4.182	0.366	0.239	0.063
23	0.933	2.244	0.208	0.136	0.037

I.2 Regulatory worst case scenarios

Table I-185 Ventilation outlet assumptions for regulatory worst case scenarios (RWC-2023-DS scenario - only used for NO_2 assessment)

Ventilation facility	Total air flow per facility (m^3/s)	Number of outlets built	Air flow per outlet (m^3/s)	CSA per outlet (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
B (M4 East, Parramatta Road)	275.0	1	275.0	77.0	9.9	3.6	25	*1.09*	*1.09*	19.80	*39.60*	*3.96*
C (M4 East, Underwood Road)	546.6	1	546.6	80.0[(a)]	10.1	6.8	25	*2.16*	*2.16*	39.36	*78.72*	*7.87*
D (New M5, SPI)	300.0	4	75.0	25.0	5.6	3.0	25	*0.30*	*0.30*	5.40	*10.80*	*1.08*
E (New M5, Arncliffe)	186.7	4	46.7	15.8	4.5	3.0	25	*0.18*	*0.18*	3.36	*6.72*	*0.67*
F (New M5, Kingsgrove)	440.0	1	440.0	81.2[(b)]	10.2	5.4	25	*1.74*	*1.74*	31.68	*63.36*	*6.34*
G (M4-M5 Link, Parramatta Rd)	170.0	1	170.0	77.0	9.9	2.2	25	*0.67*	*0.67*	12.24	*24.48*	*2.45*
I (M4-M5 Link/IC, Rozelle east)	500.0	1	500.0	113.1	12.0	4.4	25	*1.98*	*1.98*	36.00	*71.99*	*7.20*
J (M4-M5 Link/IC, Rozelle mid)	830.0	1	830.0	176.7	15.0	4.7	25	*3.29*	*3.29*	59.76	*119.51*	*11.95*
K (M4-M5 Link, SPI)	390.0	4	97.5	64.0	9.0	1.5	25	*0.39*	*0.39*	7.02	*14.04*	*1.40*
L (Iron Cove Link)	250.0	1	250.0	38.5	7.0	6.5	25	*0.99*	*0.99*	18.00	*36.00*	*3.60*

(a) Assuming four fans in operation, with a CSA of 20.0 m^2 per fan.
(b) Assuming four fans in operation, with a CSA of 20.25 m^2 per fan.

Table I-186 Ventilation outlet assumptions for regulatory worst case scenarios (RWC-2023-DSC scenario - only used for NO_2 assessment)

Ventilation facility	Total air flow per facility (m^3/s)	Number of outlets operating	Air flow per outlet (m^3/s)	CSA per outlet (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
B (M4 East, Parramatta Road)	280.0	1	280.0	77.0	9.9	3.6	25	*1.11*	*1.11*	20.16	*40.32*	*4.03*
C (M4 East, Underwood Road)	600.0	1	600.0	80.0[(a)]	10.1	7.5	25	*2.38*	*2.38*	43.20	*86.40*	*8.64*
D (New M5, SPI)	300.0	4	75.0	25.0	5.6	3.0	25	*0.30*	*0.30*	5.40	*10.80*	*1.08*
E (New M5, Arncliffe)	213.4	4	53.3	15.8	4.5	3.4	25	*0.21*	*0.21*	3.84	*7.68*	*0.77*
F (New M5, Kingsgrove)	460.0	1	460.0	81.2[(b)]	10.2	5.7	25	*1.82*	*1.82*	33.12	*66.24*	*6.62*
G (M4-M5 Link, Parramatta Rd)	170.0	1	170.0	77.0	9.9	2.2	25	*0.67*	*0.67*	12.24	*24.48*	*2.45*
H (WHT, Rozelle west)	300.1	1	300.1	154.0	14.0	1.9	25	*1.19*	*1.19*	21.60	*43.21*	*4.32*
I (M4-M5 Link/IC, Rozelle east)	520.0	1	520.0	113.1	12.0	4.6	25	*2.06*	*2.06*	37.44	*74.88*	*7.49*
J (M4-M5 Link/IC, Rozelle mid)	810.0	1	810.0	176.7	15.0	4.6	25	*3.21*	*3.21*	58.32	*116.64*	*11.66*
K (M4-M5 Link, SPI)	450.0	4	112.5	64.0	9.0	1.8	25	*0.45*	*0.45*	8.10	*16.20*	*1.62*
L (Iron Cove Link)	280.0	1	280.0	38.5	7.0	7.3	25	*1.11*	*1.11*	20.16	*40.32*	*4.03*

(a) Assuming four fans in operation, with a CSA of 20.0 m^2 per fan.
(b) Assuming four fans in operation, with a CSA of 20.25 m^2 per fan.

Table I-187 **Ventilation outlet assumptions for regulatory worst case scenarios (RWC-2033-DS scenario - only used for NO_2 assessment)**

Ventilation facility	Total air flow per facility (m^3/s)	Number of outlets operating	Air flow per outlet (m^3/s)	CSA per outlet (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
B (M4 East, Parramatta Road)	270.0	1	270.0	77.0	9.9	3.5	25	*1.07*	*1.07*	19.44	*38.87*	*3.89*
C (M4 East, Underwood Road)	573.4	1	573.4	80.0[(a)]	10.1	7.2	25	*2.27*	*2.27*	41.28	*82.56*	*8.26*
D (New M5, SPI)	320.0	4	80.0	25.0	5.6	3.2	25	*0.32*	*0.32*	5.76	*11.52*	*1.15*
E (New M5, Arncliffe)	163.9	4	41.0	15.8	4.5	2.6	25	*0.16*	*0.16*	2.95	*5.90*	*0.59*
F (New M5, Kingsgrove)	500.0	1	500.0	81.2[(b)]	10.2	6.2	25	*1.98*	*1.98*	36.00	*72.00*	*7.20*
G (M4-M5 Link, Parramatta Rd)	180.0	1	180.0	77.0	9.9	2.3	25	*0.71*	*0.71*	12.96	*25.92*	*2.59*
I (M4-M5 Link/IC, Rozelle east)	530.0	1	530.0	113.1	12.0	4.7	25	*2.10*	*2.10*	38.16	*76.33*	*7.63*
J (M4-M5 Link/IC, Rozelle mid)	840.0	1	840.0	176.7	15.0	4.8	25	*3.33*	*3.33*	60.48	*120.96*	*12.10*
K (M4-M5 Link, SPI)	404.9	4	101.2	64.0	9.0	1.6	25	*0.40*	*0.40*	7.29	*14.58*	*1.46*
L (Iron Cove Link)	250.0	1	250.0	38.5	7.0	6.5	25	*0.99*	*0.99*	18.00	*36.00*	*3.60*

(a) Assuming four fans in operation, with a CSA of 20.0 m^2 per fan.
(b) Assuming four fans in operation, with a CSA of 20.25 m^2 per fan.

Table I-188 Ventilation outlet assumptions for regulatory worst case scenarios (RWC-2033-DSC scenario – used for all pollutants)

Ventilation facility	Total air flow per facility (m^3/s)	Number of outlets operating	Air flow per outlet (m^3/s)	CSA per outlet (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
B (M4 East, Parramatta Road)	270.0	1	270.0	77.0	9.9	3.5	25	1.07	1.07	19.44	38.87	3.89
C (M4 East, Underwood Road)	600.0	1	600.0	80.0[(a)]	10.1	7.5	25	2.38	2.38	43.20	86.40	8.64
D (New M5, SPI)	320.0	4	80.0	25.0	5.6	3.2	25	0.32	0.32	5.76	11.52	1.15
E (New M5, Arncliffe)	240.0	4	60.0	15.8	4.5	3.8	25	0.24	0.24	4.32	8.64	0.86
F (New M5, Kingsgrove)	400.0	1	400.0	81.2[(b)]	10.2	4.9	25	1.58	1.58	28.80	57.60	5.76
G (M4-M5 Link, Parramatta Rd)	170.0	1	170.0	77.0	9.9	2.2	25	0.67	0.67	12.24	24.48	2.45
H (WHT, Rozelle west)	329.9	1	329.9	154.0	14.0	2.1	25	1.31	1.31	23.76	47.51	4.75
I (M4-M5 Link/IC, Rozelle east)	550.0	1	550.0	113.1	12.0	4.9	25	2.18	2.18	39.60	79.19	7.92
J (M4-M5 Link/IC, Rozelle mid)	810.0	1	810.0	176.7	15.0	4.6	25	3.21	3.21	58.32	116.64	11.66
K (M4-M5 Link, SPI)	404.9	4	101.2	64.0	9.0	1.6	25	0.40	0.40	7.29	14.58	1.46
L (Iron Cove Link)	280.0	1	280.0	38.5	7.0	7.3	25	1.11	1.11	20.16	40.32	4.03
M (F6 Extension, Arncliffe)	346.7	4	86.7	15.8	4.5	5.5	25	0.34	0.34	6.24	12.48	1.25
N (F6 Extension, Rockdale)	400.0	4	100.0	12.5	4.0	8.0	25	0.40	0.40	7.20	14.40	1.44

(a) Assuming four fans in operation, with a CSA of 20.0 m^2 per fan.
(b) Assuming four fans in operation, with a CSA of 20.25 m^2 per fan.