



*Completion of the North Orange
By-pass from Astill Drive (North)
to Chinaman's Bend, Orange*

Air Quality Assessment

Prepared by

PAEHolmes

March 2009

Specialist Consultant Studies Compendium: Part 4

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By-pass from Astill Drive (North)
to Chinaman's Bend, Orange*

Air Quality Assessment

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March 2009

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CONTENTS

	Page
EXECUTIVE SUMMARY	4-7
1 INTRODUCTION.....	4-9
1.1 Scope.....	4-9
1.2 Report Objectives.....	4-9
2 PROJECT OVERVIEW	4-9
3 AIR QUALITY CRITERIA.....	4-10
3.1 Introduction	4-10
3.2 Carbon Monoxide.....	4-11
3.3 Oxides of Nitrogen.....	4-11
3.4 Particulate Matter	4-12
4 METEOROLOGY, CLIMATE AND EXISTING AIR QUALITY	4-13
4.1 Introduction	4-13
4.2 Meteorological Data	4-13
4.2.1 Wind Data.....	4-13
4.2.2 Rainfall, Temperature and Humidity.....	4-13
4.3 Existing Air Quality	4-14
4.4 Vehicle Emissions and Photochemical Smog.....	4-15
5 CONSTRUCTION IMPACTS AND SAFEGUARDS	4-16
5.1 Construction Impacts.....	4-16
5.2 Construction Safeguards.....	4-17
5.3 Monitoring	4-18
6 IMPACT ASSESSMENT OF ROAD TRAFFIC.....	4-18
6.1 Introduction	4-18
6.2 Approach to Assessment.....	4-18
6.3 Emission Estimates	4-19
6.4 Impact Assessment.....	4-22
6.4.1 Introduction.....	4-22
6.4.2 Proposed Road.....	4-22
6.4.3 Carbon Monoxide	4-23
6.4.4 Nitrogen Dioxide	4-23
6.4.5 Particulate Matter.....	4-24
6.4.6 Intersecting Roads.....	4-24
7 CONCLUSIONS	4-26
8 REFERENCES.....	4-27

ANNEXURES

Annexure 1 Bathurst PM ₁₀ Monitoring Data.....	4-33
Annexure 2 Vehicle Emissions Calculations.....	4-35

FIGURES

Figure 1 Locality Plan.....	4-29
Figure 2 Annual and Seasonal Wind Roses	4-30

CONTENTS

Page

TABLES

Table 1	NSW DECC air quality goals.....	4-11
Table 2	Temperature, humidity and rainfall data for Orange Airport.....	4-14
Table 3	Monthly average TEOM PM ₁₀ data for Bathurst 2002 – 2006 (µg/m ³)	4-15
Table 4	Monthly maximum ozone data for Bathurst 2003 to 2006	4-16
Table 5	NSW DECC criteria for dust fallout	4-18
Table 6	Vehicle emission rates for each vehicle category.....	4-20
Table 7	Vehicle emission rates for the proposed road	4-20
Table 8	Vehicle emission rates for intersecting roads	4-21
Table 9	Morning peak hour traffic projections for the proposed road in 2009 and 2019 .	4-21
Table 10	Morning peak hour traffic projections for intersecting roads in 2009 and 2019 ..	4-21
Table 11	Predicted increase in ground level concentrations at the time of opening	4-22
Table 12	Predicted increase in ground level concentrations 10 years after opening	4-23
Table 13	Predicted increase in 1-hour CO concentration on intersecting roads.....	4-25
Table 14	Predicted increase in 1-hour NO ₂ concentration on intersecting roads.....	4-25
Table 15	Predicted increase in 24-hour average PM ₁₀ concentration on intersecting roads	4-26

EXECUTIVE SUMMARY

Orange City Council proposes to construct the final stages of the North Orange By-pass to facilitate improved local traffic movement and to provide an alternate route around the Orange CBD. The first four stages comprised 5.8 km of road which was constructed between Leeds Parade and The Escort Way. A further two stages are now proposed to complete the proposed roadway. These stages will extend the roadway a further 5.9 km from Astill Drive to the Mitchell Highway on the eastern outskirts of the city of Orange. The North Orange By-pass will be a two lane road, with one lane in each direction.

This report provides an assessment of air quality impacts from the construction of the road, particularly dust that would be generated from earthworks associated with the construction of the proposed road. Several dust emission mitigation measures recommended by the DECC are adopted. It is recommended that dust monitoring should be carried out in the vicinity of the proposed road corridor during construction to determine compliance with dust deposition goals.

Predicted motor vehicle emissions of carbon monoxide (CO), oxides of nitrogen (NO_x) and particulate matter (PM₁₀) at the opening of the North Orange By-pass and 10 years after the opening are also considered. The predicted concentrations are compared with air quality standards for the three pollutants considered. Background concentrations of PM₁₀ have come from DECC monitoring data at Bathurst. The predicted concentrations adjacent to the proposed road, as well as along existing intersecting roads, were below the air quality goals for CO, NO_x and PM₁₀.

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1 INTRODUCTION

1.1 Scope

This report has been prepared by PAEHolmes for R.W. Corkery & Co. Pty. Limited on behalf of Orange City Council. Council proposes to construct a two lane rural road from the eastern end of the Northern Distributor Road (NDR) at Astill Drive (North) to Chinaman's Bend on the Mitchell Highway (the "proposed road"). The proposed road will complete the North Orange By-pass and will allow local and through traffic to travel from the eastern sections of Orange to the western sections and visa versa without travelling through the centre of Orange (see **Figure 1**). The first four stages of the NDR comprise 6.8 km of road between Leeds Parade and The Escort Way, for which an air quality assessment was completed in 2004 (**HAS, 2004**). The current assessment is for the proposed road from Astill Drive to Mitchell Highway, approximately 5.9km in length.

1.2 Report Objectives

This report provides an air quality assessment of the proposed road. The report includes construction impacts from the NDR, as well as motor vehicle emissions predicted for the opening of the road and 10 years after the opening.

The assessment of the impacts of motor vehicle emissions is based on the use of a computer model to determine the dispersion of emissions and to predict ground-level concentrations of the various exhaust components in the area close to the proposed road. The primary pollutants of concern are carbon monoxide (CO), nitrogen oxides (NO_x) and particulate matter (PM₁₀). With regard to the assessment of lead, there has been a steady decline in lead air levels in Australian cities since the introduction of unleaded petrol. The new National Standard for Fuel Quality has resulted in a ban on the supply of leaded petrol containing more the 0.005 g/L of lead from 1 January 2002. Lead levels in urban areas, without other local sources of lead, will therefore continue to decline. Lead has not been considered in this assessment.

2 PROJECT OVERVIEW

The remaining sections of the North Orange By-pass (the "proposed road") would involve the following components (**Figure 1**).

- Construction of two creek crossings, one over Blackman's Swamp Creek and one over Dairy Creek.
- Construction of the road formation suitable for a sealed, two lane rural road to NSW Roads and Traffic Authority standards within the road corridor, including establishing appropriate cut and fill areas and drainage structures.
- Construction of the following intersections.
 - Astill Drive (North): T-Intersection.
 - Astill Drive (South): T-intersection (left-in and left-out only).
 - Ophir Road: roundabout.

- Icely Road: right left T-Intersection.
- Mitchell Highway: T-intersection with an east-bound slip lane.
- Construct appropriate bunding and other noise-mitigation structures to manage the impact of operational noise on residents in the vicinity of the road corridor.
- Undertake appropriate landscaping and revegetation operations to minimise the visual impact of the proposed road on nearby residents of the road corridor.
- Construct the intersections and stabilise and seal the proposed road during a limited time period towards the end of the construction period. This would result in the entire length of the proposed road being opened at once to minimise the impacts of inappropriate funnelling of additional traffic onto urban roads should the proposed road be opened in a staged manner.
- Implement and maintain comprehensive systems to manage noise, visibility, air quality, surface water, flora, fauna and Aboriginal and European heritage issues during construction and use of the proposed road.
- The road will have a speed limit of 100km per hour from the intersection with the Mitchell Highway to approximately 150 metres south of the intersection with Ophir Road. The remaining sections of the proposed road are anticipated to have a speed limit of 80km per hour

3 AIR QUALITY CRITERIA

3.1 Introduction

Motor vehicles emit a number of pollutants that are known to be potentially harmful to human health. The main pollutants of concern are carbon monoxide (CO), nitrogen oxides (NO_x) including nitrogen dioxide (NO₂) and particulate matter less than 10 µm in diameter (PM₁₀). Each of these pollutants has the capacity to adversely affect human health if the concentration is too great over a particular exposure period. The health effects associated with these pollutants are discussed in detail in the following sections.

The New South Wales Department of Environment and Climate Change (DECC), which encompasses the New South Wales Environment Protection Authority (EPA), has historically noted air quality goals for NO₂, CO and PM₁₀ determined by the World Health Organisation (WHO), the United States Environmental Protection Agency (US EPA) and the National Health and Medical Research Council of Australia (NHMRC).

The National Environment Protection Council of Australia (NEPC) has determined a set of air quality goals for adoption at a national level, which are part of the National Environment Protection Measures (NEPM). In its publication "Action for Air" (EPA, 1998), the DECC adopted air quality goals for particulate matter and nitrogen dioxide. These made the NSW standards for these pollutants numerically consistent with the NEPM standards. In 2005 the NSW DECC published a document entitled "Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales", which includes assessment criteria for air pollutants.

Table 1 lists the DECC's impact assessment criteria for CO, NO₂, PM₁₀ and ozone in New South Wales that will be used to assess air quality in this report.

Table 1
NSW DECC air quality goals

Pollutant	Goal	Averaging period	Source
Carbon monoxide (CO)	30 mg/m ³	1-hour	WHO (2000)
	9 mg/m ³	8-hour	NEPC (2003)
Nitrogen dioxide (NO ₂)	246 µg/m ³	1-hour	NEPC (2003)
	62 µg/m ³	Annual	NEPC (2003)
Particulate matter < 10 µm (PM ₁₀)	50 µg/m ³	24-hour	NEPC (2003)
	30 µg/m ³	Annual	EPA (1998)

Notes: µg/m³ – micrograms per cubic metre

3.2 Carbon Monoxide

Carbon monoxide is produced from incomplete combustion of fuels, where carbon is only partially oxidised instead of being fully oxidised to form carbon dioxide.

Carbon monoxide can be harmful to humans because its affinity for haemoglobin is more than 200 times greater than that of oxygen. When it is inhaled it is taken up by the blood and therefore reduces the capacity of the blood to transport oxygen. This process is reversible and reducing the exposure will lead to the establishment of a new equilibrium with a period of three hours being the approximate time required to reach 50 percent of the equilibrium value.

Symptoms of carbon monoxide intoxication are lassitude and headaches, however these are generally not reported until the concentrations of carboxyhaemoglobin in the blood are in excess of 10 percent of saturation. This is approximately the equilibrium value achieved with an ambient atmospheric concentration of 70 mg/m³ for a person engaged in light activity. However, there is evidence that there is a risk for individuals with cardiovascular disease when the carboxyhaemoglobin concentration reaches 4 percent and the WHO recommends that ambient concentrations be kept to values that would protect individuals from exceeding the 4 percent level.

The 15-minute, 1-hour and 8-hour goals noted by the DECC provide a significant margin for safety to protect a wide range of people in the community including the very young and elderly. The 15-minute, 1-hour and 8-hour goals are 100 mg/m³, 30 mg/m³ and 10 mg/m³ respectively.

3.3 Oxides of Nitrogen

Oxides of nitrogen are produced by motor vehicles when nitrogen from the air is oxidised at high temperature and pressure in the combustion chamber.

Nitrogen oxides (NO_x) emitted by motor vehicles are comprised mainly of nitric oxide (NO, approximately 95 percent at the point of emission) and nitrogen dioxide (NO₂, approximately 5 percent at the point of emission). Nitric oxide is much less harmful to humans than nitrogen dioxide and is not generally considered a pollutant at the concentrations normally found in urban environments. Monitoring data collected in Sydney (RTA, 1997) indicate that close to the roadways, nitrogen dioxide would make up from 5 to 20 percent by weight of the total oxides of nitrogen.

Concern with nitric oxide is related to its transformation to nitrogen dioxide and its role in the formation of photochemical smog. Nitrogen dioxide has been reported to have an effect on respiratory function, although the evidence concerning effects has been mixed and conflicting.

The DECC has not set any air quality goals for nitric oxide, however it has set 1-hour and annual average goals for nitrogen dioxide. It has adopted the NEPM standard of 0.12 ppm or 246 $\mu\text{g}/\text{m}^3$ and the WHO 1-hour goal of 0.11 ppm or 200 $\mu\text{g}/\text{m}^3$ as a long term reporting goal. The annual average goal is 0.03 ppm or 62 $\mu\text{g}/\text{m}^3$.

3.4 Particulate Matter

Particulate matter is emitted by motor vehicles due to incomplete combustion of fuels, additives in fuels and lubricants, worn material that accumulates in the engine lubricant, and brake and tyre wear.

The presence of particulate matter in the atmosphere can have an adverse effect on health and amenity. Larger particles, that is, those greater than 10 μm , generally adhere to the mucus in the nose, mouth, pharynx and larger bronchi and from there are removed by either swallowing or expectorating. Finer particles can enter bronchial and pulmonary regions of the respiratory tract, with increased deposition during mouth breathing, which increases during exercise. The health effects of particulate matter are further complicated by the chemical nature of the particles and by the possibility of synergistic effects with other air pollutants such as sulfur dioxide.

Much of the recent concern over the health effects of fine particulate matter is based on investigations carried out in the United States, with the view to quantifying the health risks associated with both long-term and short-term exposure to airborne particulate matter. The study is colloquially referred to as "The Six Cities Study", from the original work by **Dockery et al. (1993)**, which determined a relationship between fine particulate matter (defined as particles smaller than 2.5 μm in diameter) in the air and mortality in six United States cities.

The basic finding of the Six Cities Study is that there is an increase in mortality with increasing concentrations of fine particulate matter. The conclusions appear to be robust and have been supported by subsequent studies and, as far as can be determined, are not confounded by other known variables. However, subsequent analysis of the Six Cities Study data (**HEI, 2000**) suggests that the increase in mortality is not as large as previously thought.

The DECC has historically noted the US EPA 24-hour average air quality standard of 150 $\mu\text{g}/\text{m}^3$ and annual average standard of 50 $\mu\text{g}/\text{m}^3$ for PM_{10} . It has now adopted the NEPM 24-hour standard of 50 $\mu\text{g}/\text{m}^3$, and references an annual average of 30 $\mu\text{g}/\text{m}^3$ as a long-term reporting goal. The current proposal will be assessed using the NEPM standards, adopted by the DECC.

4 METEOROLOGY, CLIMATE AND EXISTING AIR QUALITY

4.1 Introduction

This section describes the dispersion meteorology, general climate and air quality in the vicinity of the Road Corridor. As well as information on prevailing wind patterns, historical data on temperature, humidity and rainfall are presented to give a more complete picture of the local climate. Air quality issues relating to emissions from motor vehicles are also discussed.

4.2 Meteorological Data

The following sections provide information on data available from Orange Airport meteorological monitoring station.

4.2.1 Wind Data

Figure 2 presents annual and seasonal wind rose diagrams created from continuous meteorological data collected at Orange Airport approximately 8km south of the southern most section of the Road Corridor (Bureau of Meteorology, 2008) in 1999. Even though these data are ten years old they provide a good representation of the seasonal patterns of wind directions in the area. These patterns do not tend to change significantly from year to year as they are dependent on large scale synoptic variations as well as local terrain features and landuse. Seasonal wind pattern distributions are therefore likely to be similar in 2009 as they were in 1999.

On an annual basis the winds are predominantly from the east, east-northeast and southwest. This is also the case for autumn and winter. In summer, winds are mainly from the east, and in spring the wind blows predominantly from the southwest, east and north.

4.2.2 Rainfall, Temperature and Humidity

Table 2 presents the temperature, humidity and rainfall data for Orange Airport, Temperature and humidity data consist of monthly averages of 9 am and 3 pm readings. Also presented are monthly averages of maximum and minimum temperatures. Rainfall data consist of mean and median monthly rainfall and the average number of raindays per month.

The annual average maximum and minimum temperatures experienced at Orange are 17.6°C and 6.2°C respectively. On average, January is the hottest month with an average maximum temperature of 25.9°C. July is the coldest month, with average minimum temperature of 0.7°C.

The annual average humidity reading collected at 9 am from Orange Airport is 75 percent, and at 3 pm is 57 percent. The month with the highest humidity on average is June with a 9 am average of 87 percent, and the lowest is January with a 3 pm average of 45 percent.

Rainfall data collected at Orange Airport shows that August is the wettest month, with an average rainfall of 92.3 mm over 10.1 days. The average annual rainfall is 887.8 mm falling over an average of 93.8 raindays.

Table 2
Temperature, humidity and rainfall data for Orange Airport

(Station Number 063231 Latitude 33 Deg 23 Min S Longitude 149 Deg 7 Min E, records from 1968 to 2008)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
9 am Mean Temperatures (°C) and Relative Humidity (%)													
Mean Temperature	18.5	17.8	15.9	13.1	9.3	5.8	4.8	6.3	9.2	12.5	14.5	17.1	12.1
Humidity	67	73	73	74	83	87	86	80	74	68	70	65	75
3 pm Mean Temperatures (°C) and Relative Humidity (%)													
Mean Temperature	24.5	23.9	21.2	17.2	12.8	9.3	8.2	9.7	12.4	16.0	19.0	22.5	16.4
Humidity	45	49	51	55	64	70	70	65	61	56	54	46	57
Daily Maximum Temperature (°C)													
Mean	25.9	25.3	22.4	18.3	13.9	10.4	9.3	10.7	13.6	17.2	20.3	23.9	17.6
Daily Minimum Temperature (°C)													
Mean	12.1	12.2	9.6	6.2	3.6	1.4	0.7	1.4	3.2	5.7	7.8	10.0	6.2
Rainfall (mm)													
Mean	87.6	81.8	50.4	53.8	64.7	66.5	88.0	92.3	78.1	77.7	74.4	72.5	887.8
Raindays (Number of days of rain ≥ 1 mm)													
Mean	6.7	6.6	5.2	5.3	7.5	8.9	10.6	10.1	9.3	8.6	8.2	6.8	93.8
<i>Source: Bureau of Meteorology (2008)</i>													

4.3 Existing Air Quality

There has been no air quality monitoring undertaken specifically for the proposed road, however, there are suitable data available from the DECC monitoring network. The closest operating monitoring station to the route is at Bathurst, located at the Sewage Treatment Plant off Morrisset Street. The station monitors ozone and particulate matter less than 10µm (PM₁₀). PM₁₀ is measured by tapered element oscillating microbalance (TEOM PM₁₀) and are continuous recordings. TEOM data from Bathurst are available from 2002 in the DECC's Quarterly Air Quality Monitoring Reports (**DECC, 2008**) and the monthly average and maximum measurements are listed in **Annexure 1**. An annual summary of these data is shown in **Table 3**.

PM₁₀ pollutants are emitted from anthropogenic (man-made) sources such as motor vehicles and wood heaters, and natural sources such as bushfires and dust storms. The relatively cold winters and prevalence of wood heating in Bathurst can also result in elevated levels of PM₁₀, although it would appear from the data that bushfires and dust storms were the main causes of exceedances at Bathurst.

Table 3
Monthly average TEOM PM₁₀ data for Bathurst 2002 – 2006 (µg/m³)

	Average (Exceedances)	Average (Exceedances)	Average (Exceedances)	Average (Exceedances)	Average (Exceedances)
	2002	2003	2004	2005	2006
January	23 (1)	76 (10)	20 (0)	18 (0)	14 (0)
February	11 (0)	16 (0)	22 (0)	16 (0)	18 (0)
March	18 (0)	39 (1)	25 (1)	16 (0)	20 (0)
April	14 (0)	12 (0)	32 (0)	21 (0)	18 (0)
May	13 (0)	13 (0)	27 (0)	18 (0)	16 (0)
June	13 (1)	11 (0)	8 (0)	17 (0)	11 (0)
July	14 (0)	11 (0)	10 (0)	10 (0)	9 (0)
August	18 (0)	11 (0)	11 (0)	11 (0)	14 (0)
September	16 (0)	15 (0)	13 (1)	10 (0)	17 (0)
October	31 (3)	13 (1)	12 (0)	10 (0)	24 (0)
November	49 (7)	13 (0)	13 (0)	11 (0)	24 (1)
December	33 (3)	14 (0)	16 (0)	20 (0)	26 (1)
Annual Average	21	20	17	15	18

It can be seen from **Table 3** that the highest monthly average PM₁₀ level for 2002 of 49 µg/m³ occurred in November, and that there were seven exceedances of the 24-hour goal in that month. Of the 15 exceedances of the goal in 2002, 13 occurred during spring and summer. There were also a large number of exceedances in January 2002. NSW was experiencing extensive bushfire activity at the end of 2002 and early 2003, as well as a dust storm on 23rd October, that would have contributed to the elevated levels of PM₁₀ at those times. There are only a total of 6 exceedances in the 47 months from February 2003 to December 2006.

The annual average PM₁₀ values range from 15 µg/m³ to 21 µg/m³ from 2002 to 2006, below the DECC goal of 30 µg/m³. In the years when there were no extreme bushfire events (2004, 2005 and 2006), the highest annual average is 18 µg/m³ which is a reasonable indication of ambient PM₁₀ levels. These dust levels are likely to be similar at Orange.

4.4 Vehicle Emissions and Photochemical Smog

Motor vehicle emissions have the potential to contribute to photochemical smog. Photochemical smog is formed by the reaction between NO_x and reactive hydrocarbons in the presence of sunlight. Models for the formation of photochemical smog envisage hydrocarbon emissions mostly from motor cars, facilities for the storage of hydrocarbons or spray painting operations and so on, mixing with nitrogen oxides from either industrial sources or from motor cars. The mixture of pollution from these sources then reacts photochemically to form photochemical smog comprising mainly ozone, but also including other oxidants. At concentrations of 0.1 ppm and above the smog can affect the eyes and respiratory system and can adversely affect plants and building materials.

Ozone is not emitted directly from motor vehicles but results from photochemical reactions that take some time to occur. Concentrations close to roadways are low because fresh emissions of nitric oxide titrate out any ozone that may be present.

Photochemical smog is more of a problem in urban areas where there are large volumes of motor vehicles emitting nitrogen oxides and hydrocarbons. It is not generally an issue in rural towns.

To further develop screening arguments for ozone in regional centres, NSW commenced monitoring ozone in Bathurst in 2003 and **Table 4** shows the maximum 1- and 4-hour concentrations measured from 2003 to 2006. It can be seen in **Table 4** that ozone pollution is not usually a problem in rural areas, however there were some exceedances of both goals in the summer months when sunlight is more prevalent. Because the production of ozone by photochemical processes takes some hours, it is unlikely that emissions in rural areas like Orange could be retained in sufficient concentrations for enough time to generate significantly elevated concentrations.

Table 4
Monthly maximum ozone data for Bathurst 2003 to 2006

	2003		2004		2005		2006	
	Maximum – pphm (Exceedances)		Maximum – pphm (Exceedances)		Maximum – pphm (Exceedances)		Maximum – pphm (Exceedances)	
	1-hour	4-hour	1-hour	4-hour	1-hour	4-hour	1-hour	4-hour
January	*	*	9.2 (4)	6.7 (1)	5.5 (0)	5.3 (0)	7.1 (0)	6.6 (7)
February	*	*	7.6 (0)	6.5 (1)	5.6 (0)	5.4 (0)	5.5 (0)	5.3 (0)
March	5.1 (0)	4.9 (0)	5.8 (0)	5.5 (0)	5.4 (0)	5.3 (0)	5.9 (0)	4.8 (0)
April	4.2 (0)	4.1 (0)	4.9 (0)	4.7 (0)	4.6 (0)	4.4 (0)	4.2 (0)	3.9 (0)
May	3.8 (0)	3.7 (0)	4.9 (0)	4.8 (0)	3.6 (0)	3.5 (0)	4.5 (0)	4.3 (0)
June	3.4 (0)	3.3 (0)	3.5 (0)	3.3 (0)	3.9 (0)	3.8 (0)	3.5 (0)	3.4 (0)
July	3.7 (0)	3.6 (0)	3.4 (0)	3.2 (0)	3.3 (0)	3.3 (0)	3.6 (0)	3.5 (0)
August	3.8 (0)	3.7 (0)	3.8 (0)	3.7 (0)	4.1 (0)	3.8 (0)	4.1 (0)	4.1 (0)
September	4.1 (0)	3.8 (0)	4.5 (0)	4.4 (0)	4.2 (0)	4.1 (0)	4.7 (0)	4.5 (0)
October	4.3 (0)	4.0 (0)	5.1 (0)	5.1 (0)	4.4 (0)	4.4 (0)	5.4 (0)	5.3 (0)
November	6.0 (0)	5.7 (0)	5.4 (0)	5.3 (0)	4.6 (0)	4.5 (0)	6.6 (0)	6.3 (1)
December	7.3 (0)	5.7 (0)	7.0 (0)	5.2 (0)	5.2 (0)	4.5 (0)	7.5 (0)	7.1 (1)
* Data not available Source: DECC 2008 DECC 1-hour goal = 8 pphm. DECC 4-hour goal = 6 pphm								

5 CONSTRUCTION IMPACTS AND SAFEGUARDS

5.1 Construction Impacts

Dust would be generated from earthworks associated with the construction of the proposed road. The earthworks would involve vegetation removal, topsoil and subsoil removal/replacement/storage, excavation of cut materials and placement in designated fill areas, delivery and placement/compaction of construction materials, drainage installation, construction of earth mounds for the noise barriers, and rehabilitation activities. The major

sources of dust would be the earthmoving equipment and wind erosion from the exposed surfaces. The total amount of dust generated would depend on the types of activities carried out, the silt and moisture content in the materials excavated and used in road construction and the effectiveness of the air quality mitigation measures. The equipment to be used includes bulldozers, scrapers, excavators, graders, concrete trucks, backhoes, rollers and trucks.

As the construction activity would be limited in duration at any given location it is not feasible to undertake a detailed quantitative assessment of the impacts. The approach adopted has been to identify the potential risks and provide recommendations for mitigation measures.

5.2 Construction Safeguards

An Air Quality Management Plan (AQMP) for the proposed works is recommended as part of an overall Environmental Management Plan (EMP). The plan should provide details of how each of the mitigation measures should be applied to each section of the proposed road during construction operations. Mitigation measures could include the following.

- All disturbed areas would be stabilised as soon as practicable to prevent or minimise wind blown dust.
- Progressive revegetation of completed areas not required for development of the road as soon as practicable following the completion of construction.
- All unsealed trafficable areas would be kept sufficiently damp during working hours to minimise wind blown or traffic generated dust emissions.
- Minimise the area disturbed by limiting points of entry to the construction areas and internal tracks, and flagging off “no go” areas.
- Water sprays, sprinklers and water carts would be used if needed to adequately dampen stockpiles, work areas and exposed soils to prevent the emission of dust from the site.
- Stockpiles and handling areas would be maintained in a condition that minimises wind blown or traffic generated dust. Areas that may be inaccessible by water carts would be kept in a condition which minimised wind blown or traffic generated dust using other means.
- Watering of disturbed areas, if required, outside normal operating hours in the event of hot weather conditions.
- Watering all soil stockpiles at the completion of construction to form a “skin” on the stockpile surface to reduce dust emissions.
- All equipment for dust control would be kept in good operating condition. The equipment would be operable at all times with the exception of shutdowns required for maintenance. Construction equipment would be properly maintained to ensure exhaust emissions comply with the Protection of the Environment Operations Act.
- The adoption of shut-down provisions in all contracts for all operations during periods of high winds.

- Silt would be removed from behind filter fences and other erosion control structures on a regular basis, so that collected silt does not become a source of dust.
- Any dust, soil or mud deposited on public roads by sub contractors construction activities and vehicle movements would be removed as soon as practicable and disposed of appropriately.

5.3 Monitoring

It is recommended that deposited dust monitoring should be carried out in the vicinity of the road corridor from at least two months before construction until the road is sealed, to determine the compliance with dust deposition goals currently noted by the NSW DECC and summarised in **Table 5** below. The interpretation of these goals is that the maximum total dust deposited should be no more than 4 g/m²/month over a twelve month period, but that there should be not more than an additional 2 g/m²/month above the pre-existing level.

Table 5
NSW DECC criteria for dust fallout

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

6 IMPACT ASSESSMENT OF ROAD TRAFFIC

6.1 Introduction

The impact of traffic using the proposed road on local air quality has been assessed for the completion of the proposed road and for 10 years after the completion.

6.2 Approach to Assessment

The Caline4 dispersion model has been used to estimate the concentration of oxides of nitrogen, carbon monoxide and particulate matter that are likely to be produced in the vicinity of the proposed road.

This model is an upgrade of Caline3, the most recent US EPA approved model, and is a steady state Gaussian model that can determine concentrations at receptor locations downwind of "at grade", "fill", "bridges" and "cut section" highways located in relatively uncomplicated terrain. The model is applicable for any wind direction, highway orientation and receptor location.

It is technically possible to assess air quality impacts at every sensitive receptor in the vicinity of the road corridor to take account of local terrain, road grade and distance of the receptor from the proposed road. However, it is neither feasible nor necessary to do so for this proposal. The very detailed approach is warranted when model validations are being carried out, where actual traffic counts and identification of vehicle types can be matched with monitoring data of the same period. Such a study, which validated the Caline4 model used in this report, has been undertaken in Sydney by **Williams et al. (1994)** for the RTA.

The approach taken for this project has been to carry out a worst-case assessment using vehicle emission rates provided by the DECC. These are described in more detail in **Section 6.3**. The emission rates were used to assess the impacts on air quality in the vicinity of the Northern Distributor Road.

Receptors were placed at fixed distances of 0 m, 10 m, 20 m, 30 m and 50 m from the kerb.

6.3 Emission Estimates

This section provides a brief description of the methods used to calculate the major emissions from vehicles, namely carbon monoxide, nitrogen oxides and particulate matter. This information is required as input to the dispersion models used to predict ground-level concentrations of the various pollutants.

A comprehensive emissions inventory that relates vehicle emissions to different travel conditions in NSW was prepared for the Sydney Metropolitan Air Quality Study (**Carnovale et al., 1997**). These data are continually being developed and updated by the DECC Motor Vehicle Emission Projection System (MVEPS) and this study uses the most recent emission estimates for 2008 and 2016 (**EPA 2002**), as these years represent the closest available years to 2009 and 2019 (see discussion below) being assessed in this study. The data are applicable for use in this study as the emission rates are provided per vehicle and local traffic estimates were used in this assessment.

MVEPS takes into account vehicle fleet age structures, fleet turnover, implementation of new emission standards and major changes in relevant fuel characteristics. The emission rates presented in **Table 6** show that all these factors result in emission rates per vehicle decreasing between 2009 and 2019. These emission rates have been combined with traffic flow estimates for the proposed road and used in a computer dispersion model to determine the worst-case air quality levels due to vehicle emissions at the opening of the proposed road and 10 years after opening, nominally in 2009 and 2019.

The emissions inventory prepared for MAQS divided roads into different categories and emissions from the mix of traffic on that type of road is determined. The different categories are:

- Freeway / Highway
- Arterial
- Commercial – Arterial
- Commercial – Highway
- Residential / Minor

For this assessment, arterial conditions have been assumed for the proposed road and the intersecting roads.

Emission rates for each hour are calculated from the traffic volume and emission rate per vehicle. Vehicle emission rates from the MVEPS for different vehicle categories are presented in **Table 6**. These emission rates are then used to calculate a value for the traffic mix, depending on the percentage of heavy vehicles on each section of road. These final emission rates for the proposed road and intersecting roads are presented in **Table 7** and **Table 8** respectively. Further explanation of vehicle emission calculations are detailed in **Annexure 2**.

Table 6
Vehicle emission rates for each vehicle category

	Petrol vehicles (g/km/vehicle)		Heavy Duty Diesel Vehicles (g/km/vehicle)	
	2009	2019	2009	2019
CO	7.471	3.725	3.378	2.109
NO _x	1.023	0.882	9.275	6.598
PM ₁₀	0.022	0.017	0.193	0.091

Table 7
Vehicle emission rates for the proposed road

Section of NDR Road	Pollutant	Emission Rates (g/km/vehicle)	
		2009	2019
Leeds Parade to Astill Drive (Stage 5)	CO	6.52	3.36
	NO _x	2.02	1.52
	PM10	0.07	0.04
Astill Drive to Ophir Road (Stage 5)	CO	6.70	3.42
	NO _x	1.88	1.40
	PM10	0.07	0.04
Ophir Road to Icely Road (Stage 6)	CO	6.73	3.44
	NO _x	1.78	1.36
	PM10	0.06	0.04
Icely Road to Mitchell Highway (Stage 6)	CO	6.75	3.43
	NO _x	1.81	1.41
	PM10	0.06	0.04

Peak hour traffic flows (vehicles/h) for the proposed road are summarised in **Table 9** and for intersecting roads in **Table 10**.

Table 8
Vehicle emission rates for intersecting roads

Section of NDR Road	Pollutant	Emission Rates (g/km/vehicle)				
		Existing	With NDR		Without NDR	
			2009	2019	2009	2019
Ophir Road	CO	7.05	7.08	3.56	7.07	3.57
	NOx	1.29	1.41	1.07	1.28	0.99
	PM10	0.05	0.05	0.03	0.05	0.03
Icely Road	CO	7.05	7.34	3.64	7.06	3.57
	NOx	1.29	0.99	0.92	1.28	1.00
	PM10	0.05	0.04	0.03	0.05	0.03
Mitchell Highway	CO	6.98	6.95	3.52	6.97	3.53
	NOx	1.4	1.45	1.12	1.40	1.09
	PM10	0.05	0.05	0.04	0.05	0.03

Table 9
Morning peak hour traffic projections for the proposed road in 2009 and 2019

Section of Northern Distributor Road		2009		2019	
		All Vehicles	Heavy Vehicles	All Vehicles	Heavy Vehicles
Leeds Parade to Astill Dr (Stage 5)	NB	116	27	144	33
	SB	121	28	150	35
Astill Dr to Ophir Road (Stage 5)	NB	82	17	102	21
	SB	74	14	91	17
Ophir Road to Icely Road (Stage 6)	NB	84	16	104	20
	SB	72	13	90	16
Icely Road to Mitchell Highway (Stage 6)	NB	71	13	88	16
	SB	82	16	102	20

Note: NB = Northbound; SB = Southbound
Source: Northern Transport Planning and Engineering, 2009

Table 10
Morning peak hour traffic projections for intersecting roads in 2009 and 2019

		Existing (2008)		2009 Without By-pass		2009 With By-pass		2019 Without By-pass		2019 With By-pass	
		All	Heavy	All	Heavy	All	Heavy	All	Heavy	All	Heavy
Ophir Road	EB	136	14	139	14	121	15	173	17	151	18
	WB	167	17	171	17	167	16	213	21	208	21
Icely Road	EB	39	4	40	4	20	1	50	5	25	2
	WB	48	5	49	5	31	1	61	6	39	2
Mitchell Highway	EB	417	51	427	52	348	46	531	65	433	57
	WB	528	64	541	66	382	49	673	82	475	61

Note: EB = Eastbound; WB = Westbound
Source: Northern Transport Planning and Engineering, 2009

6.4 Impact Assessment

6.4.1 Introduction

This section assesses the local air quality impacts of the proposed road by comparing the predicted ground-level concentrations of roadway emissions with the air quality goals identified in **Table 1**. Predictions have been made for the proposed road and intersecting roads in 2009 and 2019.

As described in **Section 6.3**, the vehicle emission estimates for the future years take into account vehicle fleet age structures, fleet turnover, implementation of new emission standards and major changes in relevant fuel characteristics.

The maximum predicted concentrations have been calculated using the updated MVEPS emissions data and do not include background levels. Background pollutant concentration levels are required to assess the cumulative impact of the proposed roadway, but are only available for PM₁₀ (as described in **Section 4.3**). It should be noted however, that most of the emissions will already be accounted for in the assessment as the majority of the modelled traffic already uses existing roads. Adding background levels is therefore a very conservative approach as emissions can potentially be counted twice.

6.4.2 Proposed Road

Table 11 presents the maximum predicted ground-level concentrations of carbon monoxide, nitrogen oxides, nitrogen dioxide and particulate matter at the opening of the proposed road. **Table 12** presents the same information 10 years after opening. For each scenario, the concentrations are predicted at 0 m, 10 m, 20 m, 30 m, and 50 m from the kerb.

Table 11
Predicted increase in ground level concentrations at the time of opening

	Distance from kerb	1-hour CO (mg/m ³)	1-hour NO _x (µg/m ³)	1-hour NO ₂ (µg/m ³)	24-hour PM ₁₀ (µg/m ³)
Astill Drive to Ophir Road	0m	0.40	110.1	11.0	1.96
	10m	0.17	47.5	7.12	0.84
	20m	0.12	33.9	6.78	0.60
	30m	0.10	27.5	5.50	0.49
	50m	0.08	20.8	4.16	0.37
Ophir Road to Icely Road	0m	0.40	105.9	10.59	1.90
	10m	0.17	45.7	6.85	0.82
	20m	0.12	32.6	6.51	0.58
	30m	0.10	26.5	5.29	0.47
	50m	0.08	20.0	4.00	0.36
Icely Road to Mitchell Highway	0m	0.40	104.3	10.4	1.87
	10m	0.17	45.0	6.75	0.81
	20m	0.11	32.1	6.42	0.57
	30m	0.10	26.1	5.21	0.47
	50m	0.08	19.7	3.94	0.35

Table 12
Predicted increase in ground level concentrations 10 years after opening

	Distance from kerb	1-hour CO (mg/m ³)	1-hour NO _x (µg/m ³)	1-hour NO ₂ (µg/m ³)	24-hour PM ₁₀ (µg/m ³)
Leeds Parade to Astill Drive	0m	0.35	158.2	15.82	2.25
	10m	0.15	65.7	9.85	0.93
	20m	0.10	46.7	9.34	0.66
	30m	0.08	38.0	7.59	0.54
	50m	0.06	28.8	5.75	0.41
Astill Drive to Ophir Road	0m	0.25	99.6	9.96	1.46
	10m	0.11	42.5	6.37	0.62
	20m	0.08	30.3	6.05	0.44
	30m	0.06	24.6	4.91	0.36
	50m	0.05	18.6	3.72	0.27
Ophir Road to Icely Road	0m	0.25	97.7	9.77	1.45
	10m	0.11	41.6	6.24	0.62
	20m	0.08	29.6	5.92	0.44
	30m	0.06	24.0	4.80	0.36
	50m	0.05	18.2	3.64	0.27
Icely Road to Mitchell Highway	0m	0.24	98.4	9.84	1.45
	10m	0.10	41.9	6.29	0.62
	20m	0.07	29.8	5.96	0.44
	30m	0.06	24.2	4.84	0.36
	50m	0.05	18.3	3.66	0.27

6.4.3 Carbon Monoxide

It can be seen in **Table 11** and **Table 12** that the highest predicted 1-hour carbon monoxide concentration along the NDR is 0.56 mg/m³ in 2009 and 0.35 mg/m³ 10 years after opening between Leeds Parade and Astill Drive. This level is more than halved at 10m from the kerb.

All predicted CO concentrations are well below the DECC's 1-hour goal of 30 mg/m³. The highest kerbside prediction of 0.56 mg/m³ at opening represents 1.9 % of the goal. In the absence of any monitoring data it is not possible to determine the cumulative impact of the proposed road, however, given that the road corridor is outside a relatively small urban area in an otherwise low traffic environment, the background CO levels are likely to be very low. It is therefore highly unlikely that the proposed road would result in a cumulative CO level exceeding the 1-hour 30 mg/m³ goal.

6.4.4 Nitrogen Dioxide

Estimating nitrogen dioxide concentrations is more complicated than estimating carbon monoxide concentrations. Nitrogen oxides are initially emitted as a mixture of nitric oxide and other oxides of nitrogen, which are subsequently oxidised in the atmosphere to nitrogen dioxide. At the point of emissions the mixture is generally about 5% nitrogen dioxide by mass. However, while the maximum concentrations of total oxides of nitrogen generally occur during peak hour, this is not necessarily the case for nitrogen dioxide as it can take time for the emissions to oxidise into nitrogen dioxide. An extensive monitoring program undertaken by the RTA (RTA, 1997) indicated that during peak hour the percentage of nitrogen dioxide at 10 m

from the roadway edge is likely to be about 5%. The conversion rate from nitric oxide to nitrogen dioxide at other times of the day may be significantly higher than this although the total oxides of nitrogen levels may be significantly lower than peak hour levels. It is therefore necessary to assume some intermediate value for a worst-case assessment.

Data from the RTA program indicated that at 10 m from the roadway a conversion rate of 15% by weight is conservative (i.e. an overestimate), but more realistic than the 20% assumed in previous studies. At distances of 20-60 m from the kerbside, the 20% conversion rate appears to be appropriate. There are no monitoring data from the kerbside location in the present study, but it is considered that a 15% conversion at 10 m is likely to still be conservative. Conversions of 10% and 15% have been used at 0 m and 10 m respectively, while 20% has been assumed for the distances of 20 m, 30 m, and 50 m.

Taking this into consideration, it can be seen from **Table 11** and **Table 12** that the highest predicted 1-hour nitrogen dioxide concentrations are $17.47 \mu\text{g}/\text{m}^3$ at opening, and $15.82 \mu\text{g}/\text{m}^3$ 10 years after opening, between Leeds Parade and Astill Drive.

All the predicted values are well below the NEPM and DECC goal of $246 \mu\text{g}/\text{m}^3$.

6.4.5 Particulate Matter

The assessment of PM_{10} concentration has been undertaken using the Caline4 model. These predicted levels, however, are for 1-hour and annual averaging periods. For purposes of this study, predicted 24-hour maximum values are required. Comparing the 1-hour and 24-hour maximum values is therefore a conservative approach (that is an over-prediction) as the maximum predicted 24-hour average would always be lower than the predicted maximum 1-hour average, which is based on the peak traffic hour combined with the worst-case meteorology. The relationship between the predicted 1-hour maximum and the 24-hour average will vary with meteorology and daily traffic flow, but work done on the proposed Western Sydney Orbital suggests a time correction factor of approximately 0.47 to convert 1-hour averages to 24-hour predictions (HAS, 1999). This correction has been made for the results listed in **Table 11** and **Table 12**.

It can be seen from **Table 11** and **Table 12** that the highest predicted 24-hour concentration of PM_{10} is $3.06 \mu\text{g}/\text{m}^3$ at opening and $2.25 \mu\text{g}/\text{m}^3$ 10 years after opening. These levels are well below the DECC's 24-hour assessment criterion of $50 \mu\text{g}/\text{m}^3$. Therefore, it is unlikely that the air quality goal would be exceeded for the reasons identified previously.

6.4.6 Intersecting Roads

Tables 13 to **15** present the maximum predicted ground level concentrations of carbon monoxide, nitrogen dioxide and PM_{10} at the opening of the proposed road (2009) and 10 years after opening (2019). An estimate of the current concentration of these pollutants is also provided.

Table 13
Predicted increase in 1-hour CO concentration on intersecting roads

	Distance from kerb	Existing	With By-pass		Without By-pass	
			2009	2019	2009	2019
1-hour CO NEPM goal 30 (mg/m ³)						
Ophir Road	0m	0.76	0.73	0.45	0.78	0.48
	10m	0.31	0.30	0.18	0.32	0.20
	20m	0.22	0.21	0.13	0.23	0.14
	30m	0.18	0.17	0.11	0.18	0.11
	50m	0.14	0.13	0.08	0.14	0.08
Icely Road	0m	0.25	0.16	0.10	0.26	0.16
	10m	0.11	0.07	0.04	0.11	0.07
	20m	0.08	0.05	0.03	0.08	0.05
	30m	0.07	0.04	0.03	0.07	0.04
	50m	0.05	0.03	0.02	0.05	0.03
Mitchell Highway	0m	1.96	1.52	0.94	2.00	1.23
	10m	0.80	0.64	0.39	0.82	0.50
	20m	0.56	0.45	0.27	0.58	0.35
	30m	0.46	0.37	0.22	0.47	0.28
	50m	0.35	0.28	0.17	0.36	0.22

Table 14
Predicted increase in 1-hour NO₂ concentration on intersecting roads

	Distance from kerb	Existing	With By-pass		Without By-pass	
			2009	2019	2009	2019
1-hour NO ₂ DECC goal 246 (µg/m ³)						
Ophir Road	0m	13.9	13.6	13.1	14.0	13.4
	10m	8.59	8.45	7.99	8.66	8.15
	20m	8.13	7.98	7.54	8.17	7.68
	30m	6.59	6.49	6.12	6.64	6.23
	50m	4.99	4.92	4.63	5.04	4.73
Icely Road	0m	4.62	2.06	2.32	4.66	4.41
	10m	3.08	1.41	1.57	3.10	2.90
	20m	2.94	1.35	1.50	2.97	2.77
	30m	2.39	1.09	1.22	2.41	2.25
	50m	1.8	0.82	0.92	1.82	1.70
Mitchell Highway	0m	39.0	31.5	29.7	40.0	37.9
	10m	24.1	19.9	18.5	24.6	23.1
	20m	22.5	18.8	17.5	23.1	21.5
	30m	18.4	15.3	14.2	18.7	17.5
	50m	14.0	11.7	10.8	14.3	13.4

Table 15
Predicted increase in 24-hour average PM₁₀ concentration on intersecting roads

	Distance from kerb	Existing	With By-pass		Without By-pass	
			2009	2019	2009	2019
24-hour PM ₁₀ DECC goal 50 (µg/m ³)						
Ophir Road	0m	2.64	2.57	2.15	2.66	2.24
	10m	1.09	1.06	0.88	1.10	0.91
	20m	0.77	0.75	0.62	0.78	0.64
	30m	0.62	0.61	0.50	0.63	0.52
	50m	0.47	0.46	0.38	0.48	0.39
Icely Road	0m	0.87	0.42	0.42	0.88	0.74
	10m	0.39	0.19	0.19	0.39	0.32
	20m	0.28	0.14	0.13	0.28	0.23
	30m	0.23	0.11	0.11	0.23	0.19
	50m	0.17	0.08	0.08	0.17	0.14
Mitchell Highway	0m	7.29	5.85	4.72	7.46	6.10
	10m	2.99	2.47	1.97	3.06	2.47
	20m	2.10	1.74	1.39	2.15	1.73
	30m	1.71	1.42	1.13	1.75	1.41
	50m	1.30	1.09	0.86	1.34	1.08

Predicted concentrations for all pollutants are well below their respective goals for all intersecting roads and for each scenario. Also, concentrations are lower when the proposed road becomes operational. This is not surprising given that some of the existing traffic on these intersecting roads would be diverted to the by-pass. These diversions are shown in **Table 10** where it can be seen that traffic volumes are lower in 2009 with the by-pass than without.

The lower concentrations predicted for 10 years after opening, relative to at opening, are due to improvements in vehicle design and fuel efficiency assumed by MVEPS. Therefore, total emissions can be lower even when traffic volumes are higher.

7 CONCLUSIONS

The results of the air quality assessment undertaken for this project conclude that:

- dust monitoring should be carried out in the vicinity of the road corridor from two months before construction until the road is sealed, to confirm the compliance with dust deposition goals;
- an Air Quality Management Plan (AQMP) for the proposed works be formulated as part of an overall Environmental Management Plan (EMP); and
- due to the present emission controls on motor vehicles and the projected traffic conditions for the years 2009 and 2019, it is not expected that the DECC's carbon monoxide, nitrogen dioxide or PM₁₀ goals would be exceeded due to traffic on the proposed roadway or any intersecting roads. Rather, predicted concentrations of carbon monoxide, nitrogen dioxide and PM₁₀ are expected to be slightly lower in the vicinity of intersecting roads with the proposed North Orange By-pass in place.

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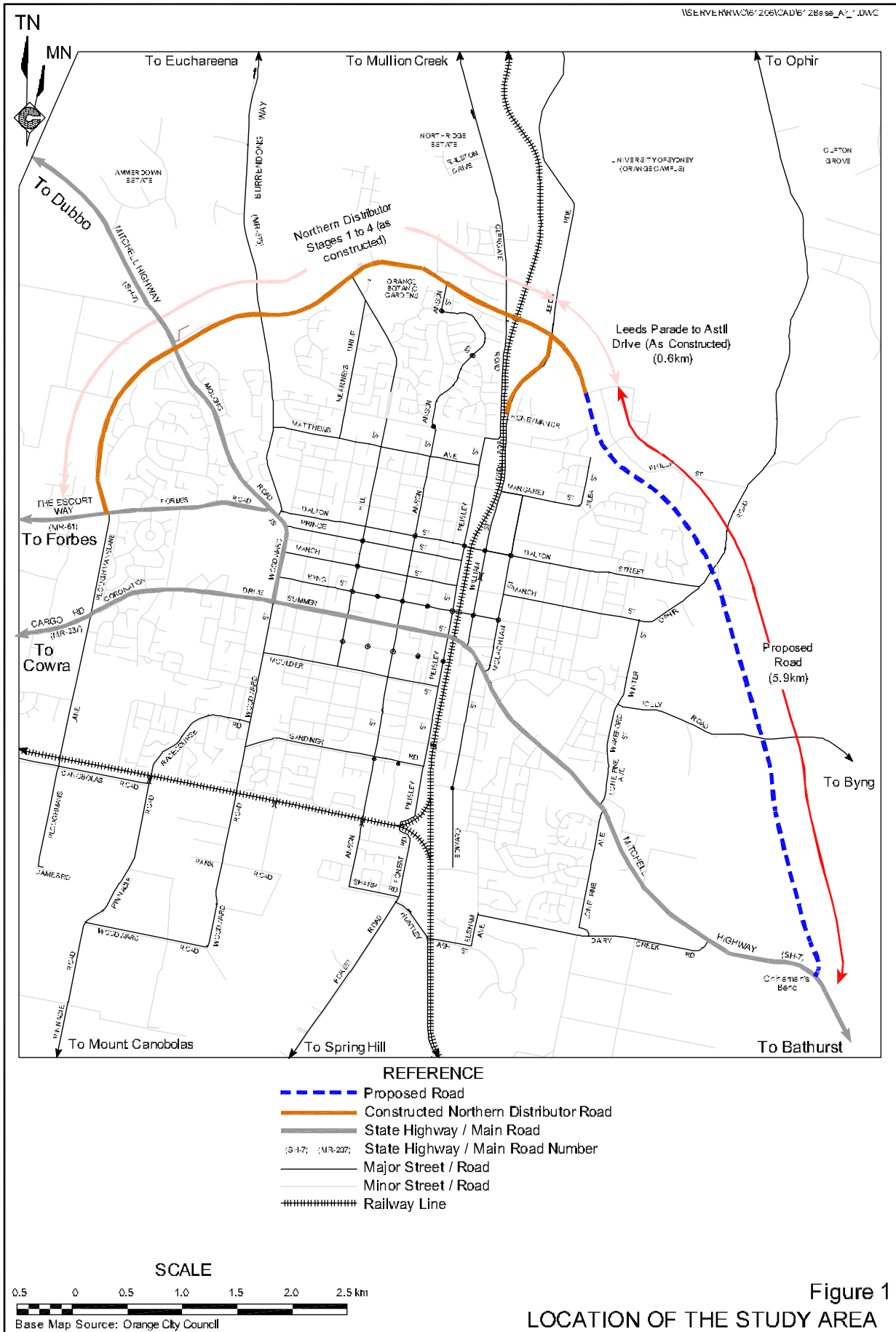


Figure 1
LOCATION OF THE STUDY AREA

Note: A colour version of this figure is available on the project CD

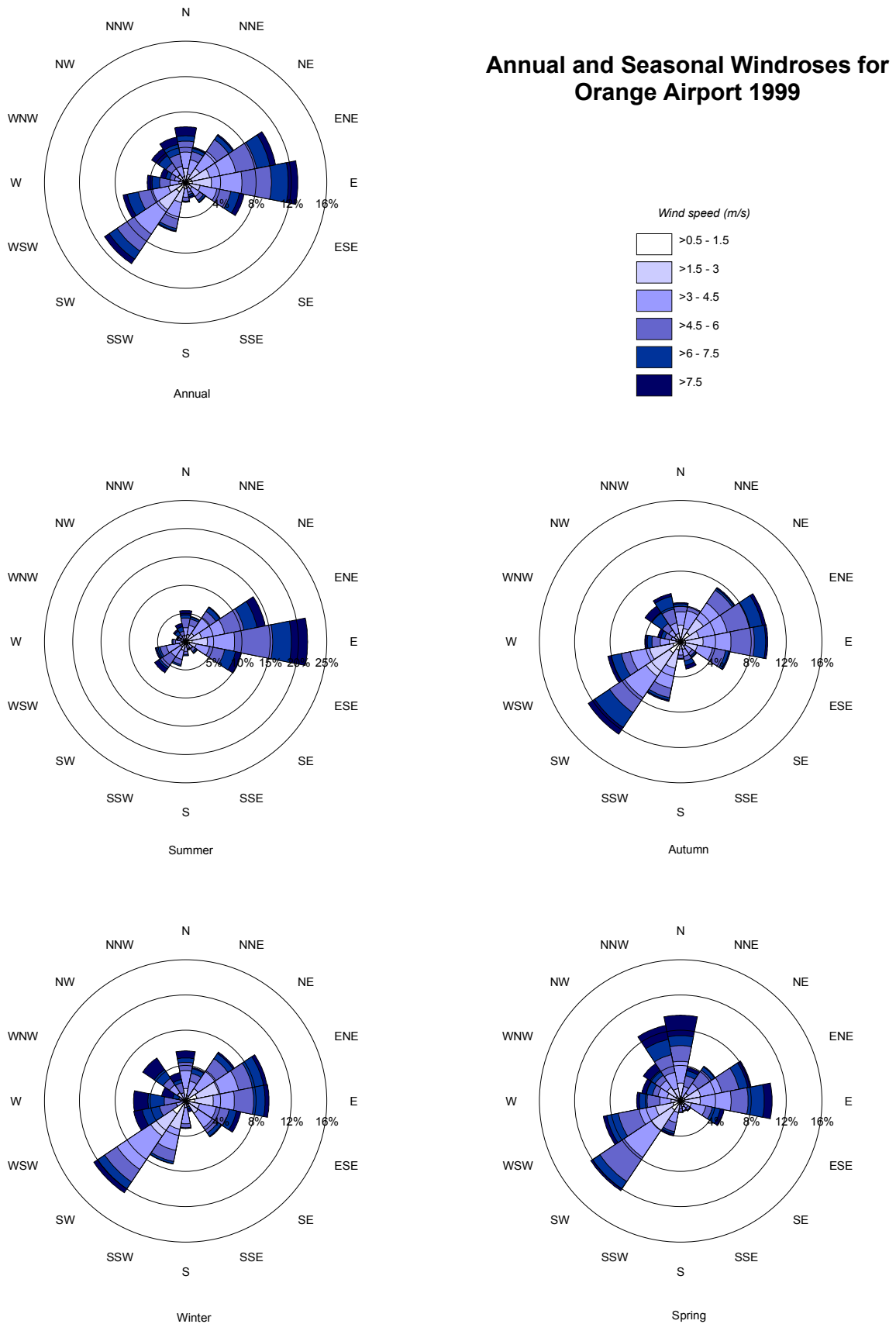


Figure 2

ANNEXURES

(No. of pages excluding this page = 4)

Annexure 1 Bathurst PM₁₀ Monitoring Data

Annexure 2 Vehicle Emissions Calculations

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Annexure 1

Bathurst PM₁₀ Monitoring Data

(No. of pages excluding this page = 1)

Monthly Average and Maximum TEOM PM₁₀ Data for Bathurst 2002

Month	Monthly average ($\mu\text{g}/\text{m}^3$) (DECC annual goal 30 $\mu\text{g}/\text{m}^3$)	Maximum 1-hour value ($\mu\text{g}/\text{m}^3$)	Maximum 24-hour value ($\mu\text{g}/\text{m}^3$) (DECC goal 50 $\mu\text{g}/\text{m}^3$)	Exceedances
January	23	140	66	1
February	11	47	20	0
March	18	97	35	0
April	14	106	24	0
May	13	92	32	0
June	13	178	52	1
July	14	55	32	0
August	18	78	29	0
September	16	138	30	0
October	31	329	73	3
November	49	1026	258	7
December	33	326	115	3
Annual Av	21			
Maximum		1026	258	
<i>Source: DEC 2002-2003</i>				

Annexure 2

Vehicle Emissions Calculations

(No. of pages excluding this page = 1)

The emissions from vehicles on the NDR were assumed to all fit into two classes:

1. Passenger petrol vehicles (PPV)
2. Heavy duty diesel vehicles (HDDV)

These classes of vehicles account for more than 99 percent of all vehicle kilometres travelled on Sydney's roads (Pengilley, 1989) and it is likely to be similar for Orange.

The emission of particulate matter from vehicles is made up of lead salts, organic and sulphate components. The total emissions comprise exhaust emission plus airborne brake wear particulate emission and airborne tyre wear particulate emissions.

The emissions of CO, NO_x and PM₁₀ were taken from estimate of emission rates provided by EPA (**EPA, 2002**). Emission rates are affected by speed and stop /start conditions. It was assumed that traffic on the Orange Northern Distributor Road would be travelling in arterial mode which would approach the driving conditions likely to be experienced on this road.

Calculation of vehicle emission rates

Table 6 in the main body of the document, lists the vehicle emission rates for each vehicle category, light duty petrol and heavy duty diesel, and for each year of assessment. Depending on the percentages of light and heavy vehicles along each section of road, a final emission rate was determined and these are summarised in **Table 7** and **Table 8**.

For example; the light duty petrol CO emission rate for 2009 is estimated to be approximately 7.471 g/km/vehicle and the corresponding heavy duty diesel emission rate is 3.378 g/km/vehicle (as listed in **Table 6**). For the section of the NDR from Leeds Parade to Astill Drive, the percentage of heavy vehicles was approximately 23.2% (average of northbound and southbound). Therefore to calculate the final emission rate for this section, the following calculation was done:

(Light duty petrol emission rate x 76.7%) + (Heavy duty diesel emission rate x 23.3%), or

$(7.471 \text{ g/km/vehicle} \times 0.767) + (3.378 \text{ g/km/vehicle} \times 0.233) = 6.52 \text{ g/km/vehicle}$ (as shown in **Table 7**)