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North West Transport Links East

Environmental Impact Statement

Working Paper

AIR QUALITY ASSESSMENT

Peter W Stephenson & Associates Pty Ltd

Prepared for
Maunsell Pty Ltd

on behalf of
The Roads and Traffic Authority of NSW
Sydney Western Region

April 1992

Stephenson

Industrial Pollution & Environmental Control

Peter W Stephenson & Associates Pty Ltd
A.C.N. 002 600 526 (Incorporated in NSW)

Suite 3 73 Albert Avenue Chatswood NSW 2067
PO Box 88 Chatswood NSW Australia 2057
Telephone (02) 413 4711, 411 2114
Facsimile (02) 411 8183

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WORKING PAPER

AIR QUALITY STUDY

NORTH WEST TRANSPORT LINKS

ENVIRONMENTAL IMPACT STATEMENT

PENNANT HILLS ROAD

TO EPPING ROAD, NORTH RYDE

MARCH 1992

P.W. STEPHENSON

DR. K. HOLMES

DR. N. HOLMES

J.M. BROOKS

**Prepared for Maunsell Pty Limited
on behalf of the Roads and Traffic Authority**

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1.0 STUDY FRAMEWORK

Stephenson & Associates, in conjunction with Nigel Holmes & Associates was requested by Maunsell Pty. Limited on behalf of the RTA to assess the existing air quality and quantify possible changes associated with a number of transport options proposed for the North West Sector of Sydney, N.S.W..

1.1 Nature of Air Pollution From Roadway Systems

In the context of this study, air pollution from roadway systems can be considered in two categories as follows:-

- construction phase, and:
- operations phase

1.1.1 Construction Phase Impacts

Impacts during construction are simple to assess and relate primarily to the temporary generation of dust, which occurs as a result of earth moving operations.

1.1.2 Operational Phase Impacts

During the operational phase of an expressway the most significant emissions typically are:-

- Hydrocarbons
- Carbon monoxide
- Oxides of nitrogen
- Sulfur compounds
- Particulate matter
- Odours

Emissions may be classed as having air impacts on a local or regional scale, for example:-

Local Impact

- In areas proximal to roadside
- Odours
- Carbon monoxide
- Oxides of nitrogen

1.2 Review of Methodology

To assess the impact of these emissions it is necessary to know:

(i) the existing air quality in the vicinity of a route,

(ii) the dispersion meteorology in the area surrounding a route,

(iii) the general dispersion characteristics of the air shed in which the emissions from an expressway route will finally disperse during the course of a day,

(iv) the traffic density, and

(v) the nature of the traffic using the expressway including its variation with time, that is, diurnal variations including heavy vehicle usages at night.

1.2.1 Study of Geography, Topography and Methodology of Route

1.2.1.1 Establish Existing Environment

The first task in analysing the air quality impacts was to analyse the route and to characterise each section in terms of terrain, surrounding land use and expected meteorological conditions for each section of the route. This involved the establishment of a meteorological station in areas where no suitable information was available.

1.2.1.2 Establish Existing Air Quality

The second task was to establish the existing concentration of relevant pollutants in the ambient air at key points along the route. The most crucial parameter from the point of view of local air quality effects would be the concentrations of carbon monoxide and oxides of nitrogen. These were measured at twelve sites selected to provide representative air quality data along each of expressway and arterial routes.

Carbon Monoxide is the ideal descriptor of motor vehicle emissions and can be referenced against other emissions' components. Carbon monoxide was measured by sampling into evacuated bottles which bleed air-samples over one hour. The sampled air is analysed for carbon monoxide concentration by infrared absorption.

Oxides of nitrogen are a major precursor of photochemical smog. They have suspected but inconclusive health effects and have been referred to in detail by the Commission of Inquiry. Oxides of nitrogen were measured using a chemiluminescent analyser. One hour concentrations were estimated from spot samples collected similarly to carbon monoxide.

1.2.2 Assess Viable Transport Alternative
and
1.2.3 Quantify Relative Impacts of these Alternatives

1.2.3.1 Predictions of Future Motor Vehicle Emissions

To estimate future air quality it is necessary to estimate future emissions of pollution. These would be estimated using emission factors developed by the USEPA (1985) and SPCC (1989) for motor vehicles with different levels of air pollution control equipment. The estimation methods are complex and must take account of the type of controls on the vehicle, the ages of the vehicles, the expected vehicle speeds, traffic density and vehicle type for different times of the day (diurnal variations). This would be undertaken for each of the emissions, i.e. carbon monoxide, hydrocarbon, oxides of nitrogen and particulate matter.

1.2.3.2 Emissions from Electric Powered Alternatives

In addition to the above, a qualitative assessment would be made of the expected reductions in emissions of electric powered vehicles, e.g. if light rail was used. This assessment would also reference the power generating plant necessary to power such a system.

1.2.3.3 Modelling of the Dispersion of These Emissions

Future air quality would be estimated at a grid of points in the vicinity of the road by using the General Motors (GM) dispersion model to predict concentrations for different averaging periods.

1.2.3.4 Calibration of Model

An integral part of the study was the testing and calibration of the model. This was undertaken by comparing the estimated pollutant concentrations with measured concentrations made with known traffic flow rates and meteorological conditions. The meteorological data was collected at the same time as the concentrations were measured.

This point regarding calibration was the first criticism of the previous RTA EIS re air quality mentioned by the Commission of Inquiry. There is a body of evidence, however which refutes short term calibration of models.

1.2.4 Total Emissions to Sydney Airshed

From a public perception point of view and from and air quality management point of view it is useful to quantify the total contribution of emissions from a nominated expressway to the overall emissions load in the Sydney Airshed.

Typically, this work has been conducted or funded by SPCC and CSIRO with the express aim of determining movement of parcels of air around the Sydney Basin and the reactivity of those air masses and their potential to form photochemical smog. CSIRO developed the revolutionary Airtrack analyser to perform this work.

1.3 Transport Options for the Study Area

After the consideration of many possible routes, four were selected as being viable from an engineering viewpoint.

These four development options are described in detail below and are referred to as Expressway (toll), Expressway (no toll), Upgraded Arterial Route (East and West) and Upgraded Arterial Route (East only).

.	Expressway	-	No toll with public transport
.	Expressway (tolled)	-	Toll with public transport
.	Upgraded Arterial Route	-	Upgraded arterial routes (East and West)
.	Upgraded Arterial Route (East only)	-	Expressway in West to Pennant Hills Road and upgraded arterial route (Carlingford and Epping Roads) East of Pennant Hills Road
.	Base Case	-	No change to existing route system

1.4 Motor Vehicle Emissions and the Greenhouse Effect

The "Greenhouse Effect", or "Global Warming", refers to the theory suggesting the enhanced effect of atmospheric warming by the sun's energy caused by emissions from human developed sources of atmospheric gases. Humans are putting carbon dioxide (CO_2), one of the principal greenhouse gases, back into the atmosphere at a million times the rate at which nature removes it (Coghill, 1990). The effect arises because some of the sun's energy enters the atmosphere as short wave energy, is absorbed by the earth's surface and is then reflected as radiant energy which is partially absorbed by atmospheric gases and partially emitted out of the atmosphere. As the quantity of these heat absorbing, or so-called greenhouse gases increases, so the atmosphere becomes warmer. If this occurs to a marked degree there will be concomitant climatic and lifestyle implications for people of all countries.

The primary gases contributing to the greenhouse effect are water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs) and tropospheric (lower atmospheric) ozone (O_3) (ANZEC, 1990, p9). These gases, which occur naturally in the atmosphere, are generated by sources such as volcanoes and marshlands and render our earth habitable. Another important characteristic of these gases when considering the greenhouse effect is their long residence time. This means that once they have reached the atmosphere they persist for a long time before being broken down or absorbed by other sources.

The major human-induced sources of greenhouse gases and their contributions to global warming are presented in Table 1.

TABLE 1 GREENHOUSE GASES ATTRIBUTABLE TO HUMAN ACTIVITIES

(from Leggett (ed), 1990 p17)

Gas *	Principal Sources	Current Rate of Annual Increase & Concentration	Contribution to Global Warming (%) ++
Carbon dioxide (CO_2)	Fossil fuel burning (c.77%) Deforestation (c.23%)	0.5% (353 ppmv) ¶	55
Chlorofluorocarbons (CFCs) ^	Various industrial uses: refrigerants foam blowing solvents	4% (280 pptv CFC-11 484 pptv CFC-12)	24
Methane (CH_4)	Rice paddies Enteric fermentation Gas leakage	0.98% (1.72 ppmv)	15
Nitrous oxide (N_2O)	Biomass burning Fertiliser use Fossil-fuel combustion	0.8% (310 ppbv)	6

SOURCES AND NOTES:

* The contribution from tropospheric ozone is also significant, but is very difficult to quantify. Ozone forms in the troposphere as a result of chemical interactions between uncombusted hydrocarbons and oxides of nitrogen, produced by fossil-fuel burning, in the presence of sunlight.

\+ IPCC, Working Group 1 Report, Policymakers' Summary, p6.

++ ibid., estimates for the decade of the 1980s

Δ ibid., Section 1, p. 12, rounded (see original table for error margins)

^ Note that production of CFCs began only a few years before the Second World War. Now that these gases are known to deplete ozone, the chemical industry is preparing replacements - hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs). Though these do not deplete ozone so badly (and are yet to be produced in commercial quantities) they are also greenhouse gases.

¶ ppmv = parts per million volume
ppbv = parts per billion volume
pptv = parts per trillion volume

Motor vehicle emissions consist of CO_2, CH_4, N_2O, CFCs (from air conditioners) and the precursors to ozone-hydrocarbons (HC) and oxides of nitrogen (NO_x) (DeLuchi et al, 1988; Pearman, 1989). It is estimated that motor vehicles account for 26% of Australia's emission of carbon dioxide (Greene, 1991). Table 2 shows average values calculated for 1985 and 1988 in Australian cities.

In accordance with the recommendations of the 1988 Toronto Conference, "The Changing Atmosphere: Implications of Global Security", the Australian government through the Australian and New Zealand Environment Council (ANZEC) has set as an objective a reduction of CO_2 emissions by 20% (from 1988 levels) by the year 2005. As shown, vehicle emissions are a major part of total emissions of CO_2. It may be concluded that this source should be explicitly targeted to help achieve the overall CO_2 reduction objective.

The Greenpeace Report (Leggett (ed) 1990) found that if state-of-the-art emissions controls were introduced to all motor vehicles around the world, emissions (HC, CO and NO_x) could be reduced to approximately half of the 1980 levels for some gases by 2005, even accounting for an increase in vehicle numbers in the period.

These predictions have been made by Greenpeace based on three developing scenarios. The scenarios are:

SCENARIO 1

Base Case Currently Adopted Requirements: - where all existing emission standards worldwide which are either in effect or are estimated to come into effect in the next several years are implemented. Refer Appendix 0, Figure 1.

TABLE 2 AVERAGE VALUES CALCULATED FOR 1985 AND 1988 IN AUSTRALIAN CITIES

MODES OF TRANSPORT	ENERGY INTENSIVENESS (MJ/pass km)		RATE OF CO_2 EMISSIONS (grams/pass km)	
	1985	1988	1985	1988
Cars	2.44	2.42	173.4	172.0
Buses	1.99	2.05	146.2	150.6
Light Commercial Vehicles	3.12	3.12	222.5	222.5
Trams	1.80	n.a.	180.0	n.a.
Electric Trains	1.97	1.94	189.9	187.1
Diesel Trains	2.00	1.94	147.2	143.1

SCENARIO 2
State of the Art Controls: - where all vehicles around the world introduce state of the art emission controls. Refer to Appendix 0, Figures 2 to 7.

SCENARIO 3
Reduction in Mileage Growth: - where a modest reduction in projected mileage growth is implemented; for example, the Netherlands strategy on road pricing to restrain vehicle growth - a further variation on "traffic calming". Refer to Appendix 0, Figure 8.

It is unlikely that all vehicles will be fitted with these emission control devices worldwide (due to age, relative cost and availability). However, a combination of incorporating these controls in new cars with increased fuel efficiency (already occurring due to consumer demand) and new fuel technology, would lead to motor vehicle emissions being effectively controlled (Pearman, CSIRO 1989).

Further motor vehicle transport growth, however, will continue to put pressure on these levels. After 2030, emissions will start to line-up again unless growth is constrained or technology advances sufficiently to lower emissions per mile driven even further.

Recent research by the Bureau of Transport and Communications Economics (BTCE 1990) supports the above. Data collected from a number of sources have been aggregated to provide a valuable comparison of performance of various modes of urban transport with respect to energy and greenhouse gas emission efficiency.

BTCE estimates that the reduction in total carbon dioxide emissions arising from a doubling of peak period public transport patronage (through a reduction in private car use) would be roughly equivalent to the effect of improving the average emissions efficiency of the Australian car fleet by only 2 percent, an effect which could be relatively easily achieved by improved fuel efficiency, higher car occupancies and shorter trip lengths.

2.0 EXISTING AIR QUALITY

To assess the existing air quality or any impacts of the proposed road development, it is necessary to discuss the range of pollutants that can be expected in the Sydney Region and the health criteria that apply to those pollutants. The meteorology of the region and its influence on the dispersion of pollutants also affects this regional air quality.

The range of pollutants that can be expected in the vicinity of the proposed development is discussed in Sections 2.1 to 2.3. The meteorology of the area is discussed in Section 2.4.

2.1 Regional Air Quality

2.1.1 Characteristics of Major Air Pollutants in the Sydney Region

The major air pollutants that influence the quality of air in the Sydney Region are hydrocarbons, sulfur dioxide, oxides of nitrogen, particulate matter, acid gases carbon monoxide, lead and ozone. The characteristics of these are discussed below and accepted standards for the concentration of these pollutants in the atmosphere are given in Section 2.2.

A major problem encountered when assessing regional Air Quality of the Sydney Basin is the concentration of available data in the eastern section of Sydney. The findings of a major regional study by Hyde & Johnson (1990) recognised that the extrapolation of this data to other areas, seriously underestimated pollutant levels in some cases particularly in the south west. Data provided by the SPCC has therefore been used in this study to give an indication of general air quality only and can not be applied directly to the study area.

The N.S.W. Government recognised the problem of poor air quality in some areas of western Sydney in the recent Smog Summit, June 1990. In an attempt to obtain air quality data for the western region, the Water Board undertook, in this Summit, to establish meteorological stations in all of their Sewage treatment Plants (STP) throughout the area. It should be noted, however, that many of these STPs are situated in valleys which would affect the applicability of the meteorological data to the area as a whole.

Hydrocarbons (HC)

Hydrocarbons alone do not generally pose a problem in the urban environment and they have no known adverse effects on human health.

Hydrocarbons are associated with the processing and use of petroleum products and constitute the major portion of the reactive organic substances that eventually cause photochemical smog. Hydrocarbons may consist of products formed during the process of combustion or as unburnt fuel components. When present in the air, hydrocarbons produce a distinctive petrol or kerosene type odour. Methane based hydrocarbons are not photochemically reactive.

Sulfur dioxide (SO_2)

Sulfur dioxide is a product of combustion. The concentration of SO_2 in an emission will vary according the level of sulfur content in the fuel.

Oxides of nitrogen (NO_x)

Nitrogen oxide (NO_2) and nitric oxide (NO) are formed during all combustion reactions. Nitric oxide can undergo oxidation to nitrogen dioxide in the urban atmosphere. In the presence of sunlight this NO_2 is then involved in the reaction to produce photochemical smog. The rate of the oxidation reaction of NO to NO_2 can be increased significantly in the presence of hydrocarbons.

Oxides of nitrogen (NO_x) emitted by motor vehicles are comprised mainly of nitric oxide (NO, approximately 98%) and nitrogen dioxide (NO_2, approximately 5%). Nitric oxide is much less harmful to man at the concentrations normally found in urban environments. Nitrogen dioxide has been reported to have an effect on respiratory function although the results have been mixed and conflicting.

Suspended Particulate Matter and Total Suspended Particulate Matter

There are a range of sources of particulate matter ranging from combustion reactions to the particulate matter associated with industrial processes and biological decay. Total suspended particulate matter includes particle ranging from 5 μm to 10 μm in diameter suspended in the atmosphere. Suspended particulate matter relates to particles mainly below 5 μm in diameter but up to 10 μm in size.

Acid Gases

The major acid gases are sulfur dioxide and oxides of nitrogen which are discussed above.

Carbon Monoxide (CO)

Carbon monoxide is formed during the incomplete combustion of fuels. Concentrations of carbon monoxide tend to be localised with high values being recorded in high traffic density areas with poor dispersion.

Lead

The major source of lead in Sydney's atmosphere is from lead additives in petrol. The overall level of lead emissions however has reduced significantly with the introduction of unleaded petrol in all new cars since 1986.

Ozone

Ozone is the major constituent of photochemical smog and is the principal product when reactive organic compounds and oxides of nitrogen are exposed to sunlight in high concentrations.

Photochemical Smog

Photochemical smog is formed by the reaction between oxides of nitrogen 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 oxides of nitrogen from either industrial sources or from motor cars. The mixture of pollution from these sources then reacts photochemically to form photochemical smog which comprises mainly ozone.

Photochemical smog can be controlled by either reducing the amount of hydrocarbons or by reducing the amount of oxides of nitrogen. In the past the State Pollution Control Commission (SPCC) has decided to control smog by reducing the amount of hydrocarbons emitted into the Sydney air, mainly through the use of catalytic converters on motor cars using unleaded petrol. This has led to a substantial reduction in hydrocarbon emissions and despite the increase in motor vehicles in the Sydney area hydrocarbon emissions have declined slightly.

However, at the same time as hydrocarbon emissions have held steady or undergone a slight decline, emissions of oxides of nitrogen from industry and motor cars has substantially increased. Total emissions of hydrocarbons in 1976 were estimated to be 192,530 tons per annum (Eiser and Koo, 1984); in 1980 the figure was estimated to be 178,610; and in 1986 the figure was estimated to be 159,100 which represents a substantial decrease in hydrocarbon emissions. As far as emissions of oxides of nitrogen are concerned 1976 emissions were estimated to be 62,985; in 1980 66,972; and in 1986 76,175 tons per annum. This represents a fairly substantial increase over that decade. The increase is continuing while the change in hydrocarbon emissions will begin to trend upwards again as the effect of increasing number of cars tends to overwhelm the effect of reduced emissions from each individual vehicle.

The significance to the formation of photochemical smog in this change in the balance of hydrocarbons to oxides of nitrogens, that is the hydrocarbon:NO_x ratio is as follows. The rate at which photochemical smog forms depends on the ratio of hydrocarbon to NO_x. If the ratio favours oxides of nitrogen, the process by which ozone or smog is produced is delayed in onset until all the nitrogen oxide is consumed. The reaction then proceeds and the photochemical smog is formed. The amount that is formed depends on the temperature and the sunlight, and the concentration that occurs depends on the dilution that takes place as the reacting components are carried downwind. For the Sydney Basin the dispersion will stay more or less constant from year to year although the annual variations appear to be quite significant. The rate will also depend on the temperature and the amount of solar radiation available to promote the reaction. These factors will affect the location of the areas affected by high concentrations of smog.

The effect of the SPCC's control strategy of reducing hydrocarbon emission while leaving oxides of nitrogen relatively unchecked has been to move the areas affected by photochemical smog outwards from the centre of the city. This is because there is a delay in the reaction when the ratio of NO_x : hydrocarbon is high.

The Hyde and Johnson (1990) report argues that the SPCC smog-monitoring network is located too close to the city so that the maximum concentrations are not being recorded. In the absence of monitoring data Johnson has undertaken a mathematical prediction of what has happened to photochemical smog. His predictions are in broad agreement in areas where monitoring is already taking place and in the outer areas where there are no monitoring data his predictions show an increasing trend in photochemical smog. This is caused by the increased oxides of nitrogen concentrations which, have longer to react by the time they get to the outer suburbs, give rise to higher concentrations at those locations.

While these predictions have yet to be validated in the outer suburbs, there is clearly some cause for concern over photochemical smog impacts in the Sydney Basin. These impacts will occur largely as a result of increased motor vehicle emissions and any proposed transport options need to be viewed in the light of their effects on nitrogen oxide emissions.

2.1.2 Existing Air Quality in the Sydney Region

Tables A 1.1 - A 1.11 of Appendix 1 present a summary of the concentration of pollutants for the years 1979 to 1988 for the Sydney Region. These results should be qualified in the light of the results from a (pilot) study of Sydney regional air movement by Hyde and Johnson (1990).

In the study this area was found to have higher levels of HC and NO_x (photochemical smog precursors) than were recorded at the SPCC monitoring stations, as well as ozone concentrations above the recognised Health Standards a number of occasions.

From the SPCC data, ozone and smog levels appear to have decreased over the past twelve years. However, Hyde and Johnson (1990) suggest that these figures are misleading as the areas of ozone and smog formation have moved downwind from the industrial and traffic associated pollutant sources, in this case to the south west.

From monitoring by the SPCC it appears that acid gas levels in Sydney peaked in the early 1970's, then decreased, and have now levelled out. In recent years, acid gas concentrations have seldom exceeded the WHO's long term goal of 60 $\mu g/m^3$ (annual mean).

Suspended matter levels in Sydney are usually well below the standards in Table 3. However, total suspended particle matter levels may be exceeded from time to time due to localised events. Motor vehicles are a major source of suspended particulates in Sydney (Hyde and Johnson, 1990).

Lead concentrations in the atmosphere around the Sydney region appear to have reduced in recent years. This is probably a result of the use of unleaded petrol in all petrol engined vehicles manufactured since 1986.

As discussed above the SPCC carries out a programme of air quality monitoring at selected sites in Sydney. The results of these indicate that on occasions the air quality goals are exceeded for all the pollutants associated with motor vehicles.

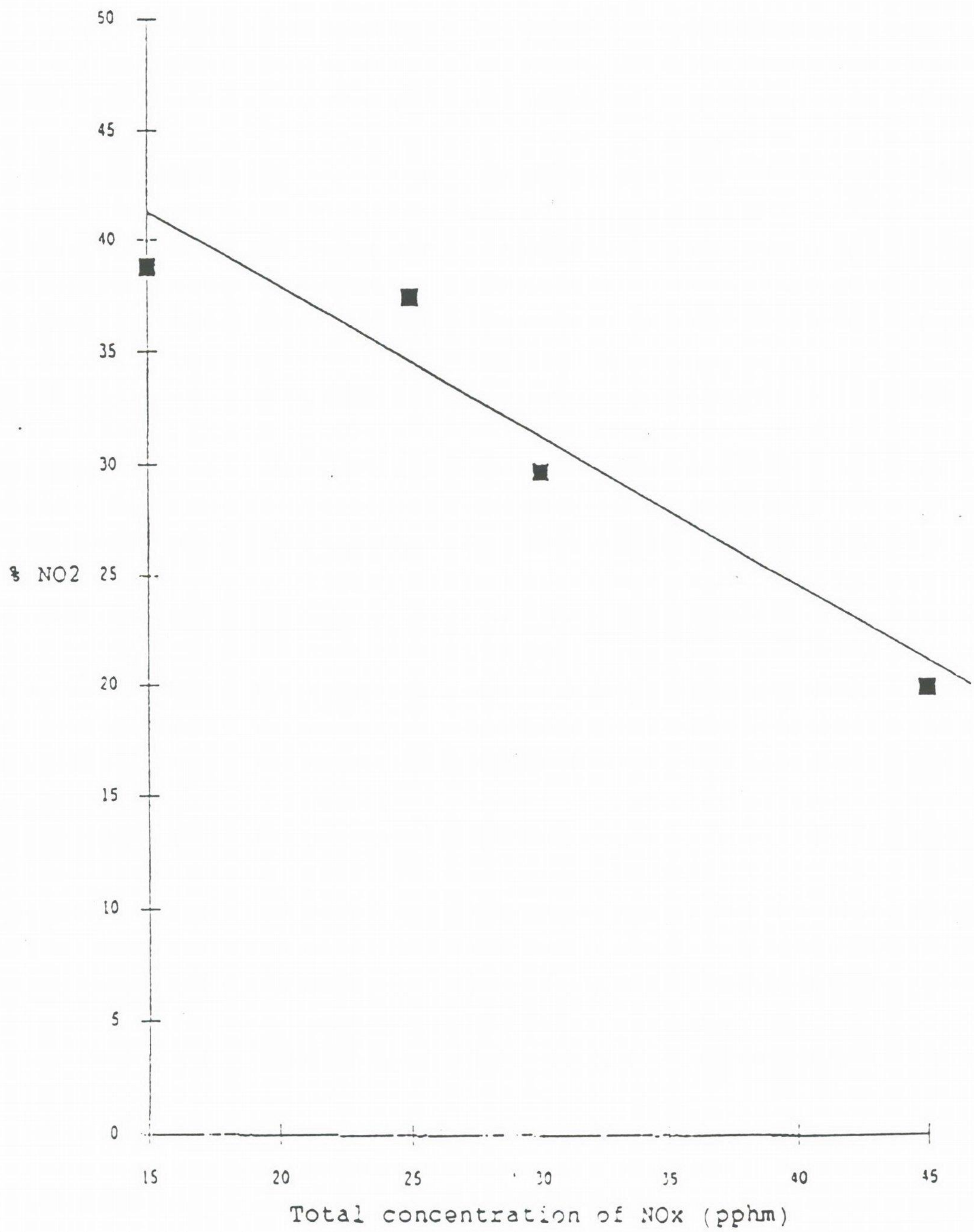
Some values recorded in 1989 are presented below.

Site	Pollutant	Ambient concentration
Rozelle	NO_x	60.0 pphm (maximum 1-hour average)
Rozelle	NO_2	26.5 pphm (maximum 1-hour average)
Rozelle	non-methane hydrocarbons	1.0 ppm (annual average)
George St	CO	18.8 ppm (maximum 1-hour average)

An analysis of the 1989 monitoring data for oxides of nitrogen reveals that the percentage of NO_2 in the mix is inversely proportional to the total NO_x concentration. Figure 1 presents a plot of the mean percentage NO_2 against the mean NO concentration (maximum 1-hour averages) recorded at four sites in Sydney, namely Earlwood, Eagle Vale, Kensington and Rozelle.

The trend in the graph presumably reflects the distance of the monitor from the NO_x source. For example the Earlwood site which is close to the road has the highest concentration of oxides of nitrogen and the lowest proportion of NO_2. The converse is true of the Eagle Vale site which has contributions from industrial sources some distance from the monitor. Emissions

FIGURE 1 **CORRELATION BETWEEN PERCENTAGE NO_2 AND TOTAL NO_x CONCENTRATION**



of NO_x typically contain 5-10 % NO_2 at the point of emission, the proportion increasing with time as the pollutant disperses and the total NO_x decreases. Percentages of NO_2 range from 5 to 50% with a mean value of about 30 %. Some reductions may be expected from the stricter statutory emission controls placed on vehicles in recent years and the associated catalytic converters.

Generally, air quality in the Sydney region has improved since the introduction of the Clean Air Act 1961.

2.1.3 Sources of Air Pollution in Sydney

Motor vehicles are considered the major source of air pollution in Sydney. In the mid 1980's they accounted for half of all hydrocarbon emissions and about 90% of carbon monoxide emissions, (SPCC 1987). These values are likely to decrease with the increased use of catalyst technology on all new motor vehicles and stricter regulations covering individual vehicle emissions.

Industrial activities also contribute significantly to the levels of pollutants in the atmosphere.

2.2 Air Quality Criteria - Standards and Legislation

Air quality criteria including overseas, National, State/regional and local (where appropriate) have been referenced.

Appropriate air quality criteria have been established by reference to State Pollution Control Commission air quality goals and other internationally recognised goals. These criteria include goals for carbon monoxide (CO), oxides of nitrogen (NO_x), hydrocarbons (HC) and particulate matter (PM). The hydrocarbon criteria have been set primarily for the management of photochemical smog rather than to protect directly against health effects. These criterion have recently been abandoned because they are not specific for reactive species which are the important element in the formation of photochemical smog. For the sake of completeness the previous standards are included here and the emissions of hydrocarbons have been considered.

Particulate matter criteria should be used primarily to assess the areas affected by dust emissions during construction. Particulate matter emissions from traffic moving over a normal freeway surface are not expected to be significant.

The following is an extract of the N.S.W. SPCC's position on current air quality standards in N.S.W. (SPCC, 1989):-

> Air quality standards for urban air pollutants have not been defined in New South Wales since there is insufficient Australian data on the health effects of these pollutants to allow their adequate determination. In the absence of such standards, the Commission adopts as objectives National Health and Medical Research Council (NH&MRC) Guidelines supplemented by World Health Organisation (WHO) Long Term Goals and U.S. Environmental Protection Agency (USEPA) Air Quality Standards.

These air quality guidelines have been determined in light of current international knowledge on the adverse effects of air pollutants on health. Damage to plants and materials and reduction to visibility have not been considered in establishing these guidelines. Selected air quality criteria together with their agency sources are listed in Table 3.

2.3 Meteorology: A Summary of Climatic Conditions in the Study Area

2.3.1 Climate

The best overall description of meteorological conditions of the study area (except for winds) is the climatic survey published by the Bureau of Meteorology for North Parramatta. This contains details on temperatures, rainfall and humidity at 9 a.m. and 3 p.m., plus daily maximum and daily minimum temperatures for each month of the year (Appendix 2, Table A 2.1).

Temperatures

Table A 2.1 shows that the mean maximum temperatures in the Study Area range from 29.0°C in January to 17.1°C in July. Mean minimum temperatures are 17.6°C in February falling to 6.2° in July.

Rainfall

Mean annual rainfall for the year in the Study Area (based on 24 years of records) is 973 mm. Conditions are wetter on average in the first six months of the year, with average monthly rainfalls between 69 mm in May and 128 mm in March. In the second half of the year, mean monthly rainfall is lower but relatively similar each month with values between 44 mm in July and 90 mm in November.

TABLE 3 SELECTED AIR QUALITY CRITERIA AND SOURCE

POLLUTANT	STANDARD	AGENCY
Carbon Monoxide ¶	25 ppm - 31 mg/m^3 (1 hour max)	WHO/USEPA
	9 ppm - 11 mg/m^3 (8 hour max)	WHO/USEPA
Nitrogen Dioxide	16 pphm - 330 $\mu g/m^3$ (1 hour max)	NH&MRC
	5 pphm - 100 $\mu g/m^3$ (annual mean)	USEPA
Non Methane Hydrocarbons +	24 pphm - 0.17 mg/m^3 (3 hour max)	USEPA
Total Suspended Particles#	90 $\mu g/m^3$ (annual mean)	NH&MRC
	260 $\mu g/m^3$ (24 hour max)	USEPA
Particulate Matter (less than 10 μ)	50 $\mu g/m^3$ (annual mean)	USEPA
	150 $\mu g/m^3$ (24 hour max)	USEPA
Lead	1.5 $\mu g/m^3$ (90 day average)	NH&MRC
Suspended Matter *	40 $\mu g/m^3$ (annual mean)	WHO
	120 $\mu g/m^3$ (24 hour max)	WHO
Ozone	12 pphm - 0.26 mg/m^3	NH&MRC
Sulfur Dioxide #	14 pphm - 0.40 mg/m^3 (24 hour max)	USEPA
	25 pphm - 0.71 mg/m^3 (1 hour max)	NH&MRC
Acid Gases *	60 $\mu g/m^3$ (annual mean)	WHO
	200 $\mu g/m^3$ (24 hour max)	WHO

CONVERSIONS OF POLLUTANTS HAVE BEEN REFERENCED TO 0°C

¶	This standard has recently been changed from 35 ppm - 44 mg/m^3
+	This standard has recently been abandoned by the USEPA and NSW SPCC. However, it does still appear in the latest air quality review from the SPCC.
*	24 hour values. Acid Gases and suspended matter are to be considered in conjunction with one another
#	Total suspended particulates and sulfur dioxide are to be considered in conjunction with one another
$\mu g/m^3$	micrograms (10^{-6}g) per cubic metre
mg/m^3	milligrams (10^{-3}g)
ppm	parts per million
pphm	parts per hundred million

2.3.2 Winds, Calms and Drainage Flows

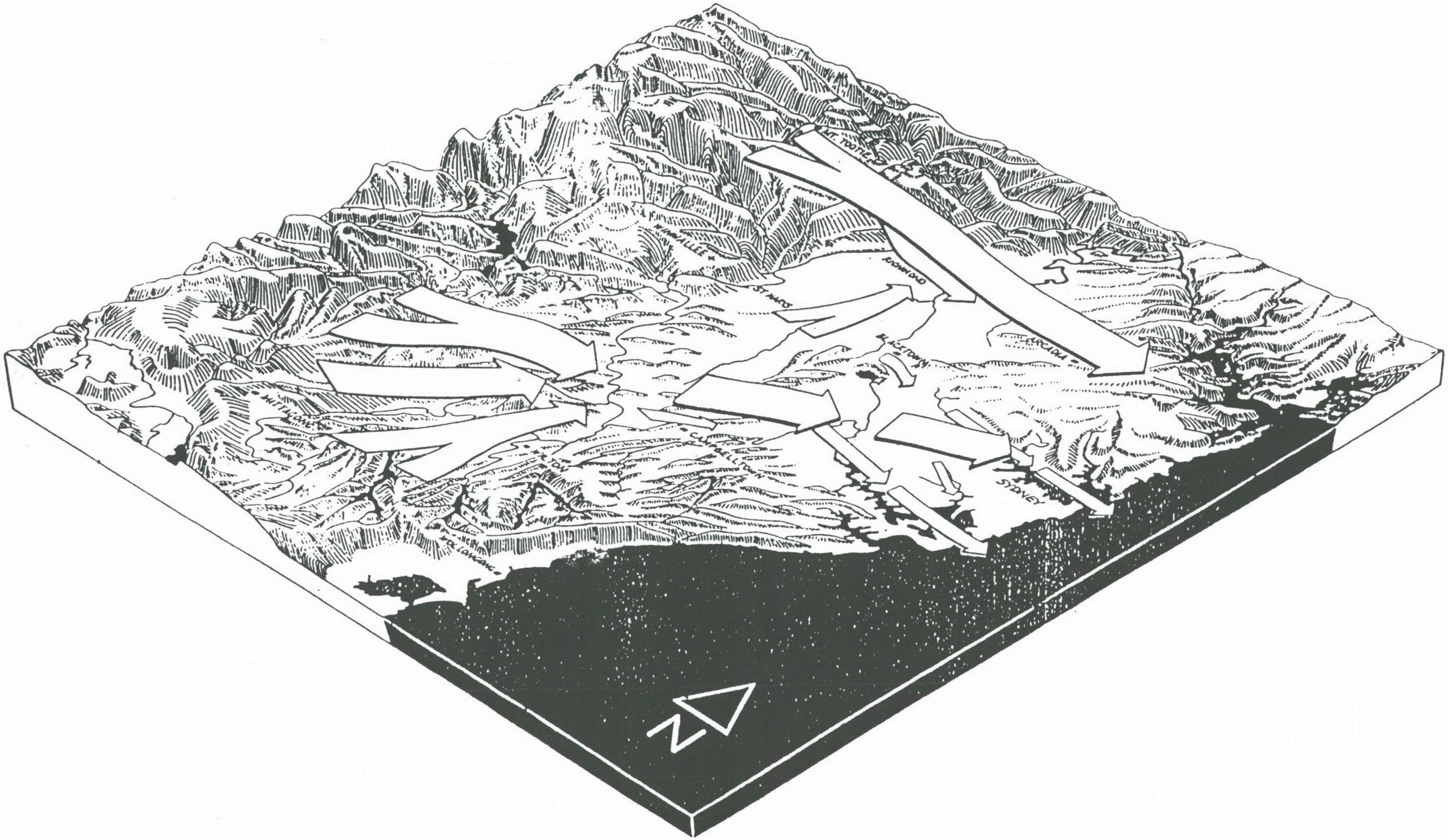
Sydney and the surrounding developed areas are built in a basin formed by high ground rising to over 1000 m (above sea level) in the west, over 500 m to the north and over 800 m to the south. The basin opens to the sea in the east. The north-west extent of the basin is approximately 80 km and its east-west extent is approximately 60 km. This topographical environment is important in determining the movement of air within the Sydney area, particularly at night. Figure 2 shows the extent of the basin.

A set of wind frequency tables compiled from data collected by the Bureau of Meteorology at their North Parramatta station is presented in Appendix 2 (Tables A 2.2 - 2.4).

Prevailing winds in Sydney are a combination of synoptic (pressure driven) flows and meso-scale (local) flows. Synoptic conditions are dominated by regions of high pressure which continuously migrate across the continent from west to east with the average period of six to seven days. In summer, the average track of these high pressure systems is well to the south of Sydney and synoptic winds are predominantly onshore. During autumn the path of the high pressure systems shifts northwards as the sun moves into the northern hemisphere, and by winter in Sydney their path crosses the continent to the north of Sydney and westerly winds prevail.

Superimposed on the synoptic winds are two meso-scale flows. Firstly wind is deflected by terrain features which steer, or channel the wind. The more stable the atmosphere the greater the effect.

FIGURE 2 TOPOGRAPHY OF THE S̄.DNEY BASIN (From: Hyde et al, 1980)

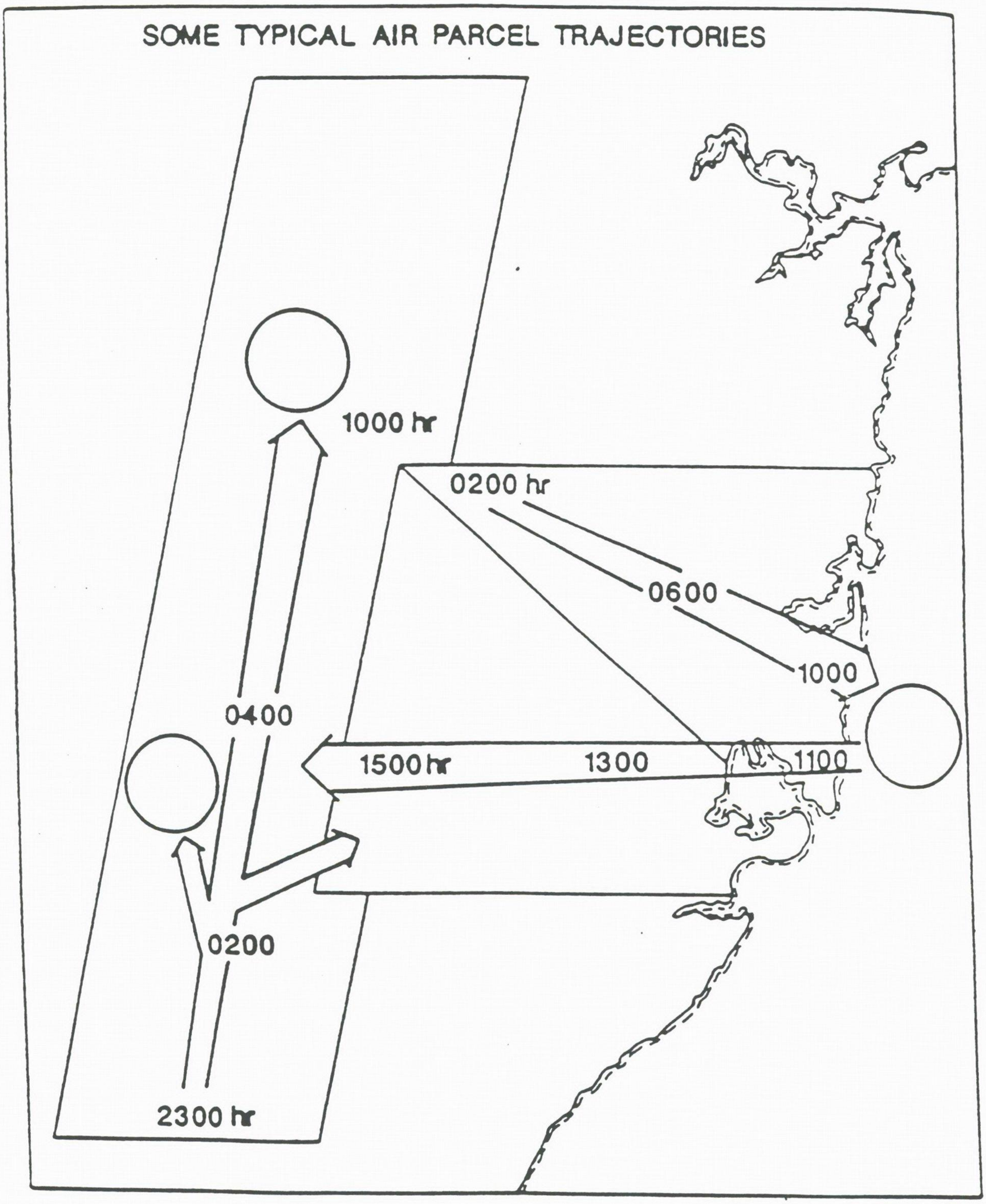


The terrain structure can also affect the movement of air by generating so-called katabatic, or drainage flows. These are generally generated at night when the wind is light and the skies are clear. Under these conditions the ground will cool by radiating heat to space. The cooled ground will then chill the air close to it making that air denser than the air further from the ground. If the ground is sloping then the air close to the ground will be denser than the nearby air at the same height above sea level, but a different height above the ground. The result will be that the dense air close to the surface will begin to drift down the slope.

Because the drainage flows are comprised of stable air which suppresses vertical movement they can flow as discrete entities, one sheet of air flowing at a different speed and in a different direction over the other.

A model for the drainage flow in the Sydney Basin has been developed over the past decade by Hyde and is discussed in detail in the recent evaluation of air quality issues in the south-west region of Sydney (Hyde and Johnson, 1990). The basin components of the model involve drainage flows which move downward from the high ground at night, travel initially from the south in a northward direction and fill up the Sydney Basin, or travel initially from the south in a northward direction and fill up the Sydney Basin, or the western portion of the Sydney Basin, and cause air to flow out towards the east and out to the sea during the night. Similarly, air from the west would undertake the same sort of movement as would air from the northern high ground in the Sydney Basin. Thus the ultimate movement of air is from the high ground into the basin, and then out to sea (refer Figure 3).

FIGURE 3 SCHEMATIC REPRESENTATION OF AIR PARCEL TRAJECTORIES TYPICAL OF THE HIGH POLLUTION DAYS IN SYDNEY (Hyde & Johnson, 1990)



During the day the sun warms the land and a sea breeze is developed. Air which has flowed out of the basin at night on to the sea is then returned into the basin and is transported

generally towards the west and the south. The significance of this effect for the air quality in the Sydney Basin is that pollutants which are produced in the eastern and northern regions of Sydney may be transported to the south and west. This issue is particularly relevant to the formation of photochemical smog.

In January the low frequency of winds from the western sectors is apparent, while afternoon sea breezes (NE to SE) are present during the afternoon and evening.

By April, the spread of winds is more diffuse, but late afternoon sea breezes and southerly changes are still present.

In winter (July) winds are predominantly from the western sectors, with a high frequency of light winds at night. During the daytime westerly winds predominate. In October, as the sun moves south into the southern hemisphere, low frequency westerly winds still occur, but the wind roses show the re-emergence of late afternoon and evening sea breezes.

2.4 Existing Air Quality in the Study Area

2.4.1 Methods of Assessment

The principle aim of this study is to assess the impact of motor vehicles on air quality in the study area. Typically, emissions from vehicles consist of carbon monoxide (CO), burnt and unburnt hydrocarbons, oxides of nitrogen (NO_x) and lead.

The pollutants that are most characteristic of motor vehicle emissions however are CO and NO_x.

For this reason, CO and NO_x have been used as the main chemical constituents to assess air quality in the study area.

Carbon monoxide

CO has been measured by sampling into evacuated bottles which bleed air-samples over pre-set time intervals ranging from one hour to eight hours. The sampled air was then analysed for CO concentrations by gas filter correlation spectroscopy.

A series of correlation curves of other pollutants compared with CO are presented in Appendix 3.

Oxides of nitrogen

Measurements were made of total NO_x only, without a NO/NO_2 split, using a chemiluminescent analyser. One hour average concentrations were estimated from a continuous chart record or from spot samples collected similarly to CO.

In urban environments NO_x generally contains between 30% and 60% NO_2. Thus, the use of the NH&MRC standard for NO_2 in this study is appropriate when estimating worst case conditions although under normal conditions the NO_x is unlikely to comprise solely of NO_2.

2.4.1.1 Monitoring Site Locations

To date, roadside emission concentrations have been measured at 21 locations within the North West Transport Links Study and EIS corridor and along the major arterial roads that may be proposed for possible upgrading.

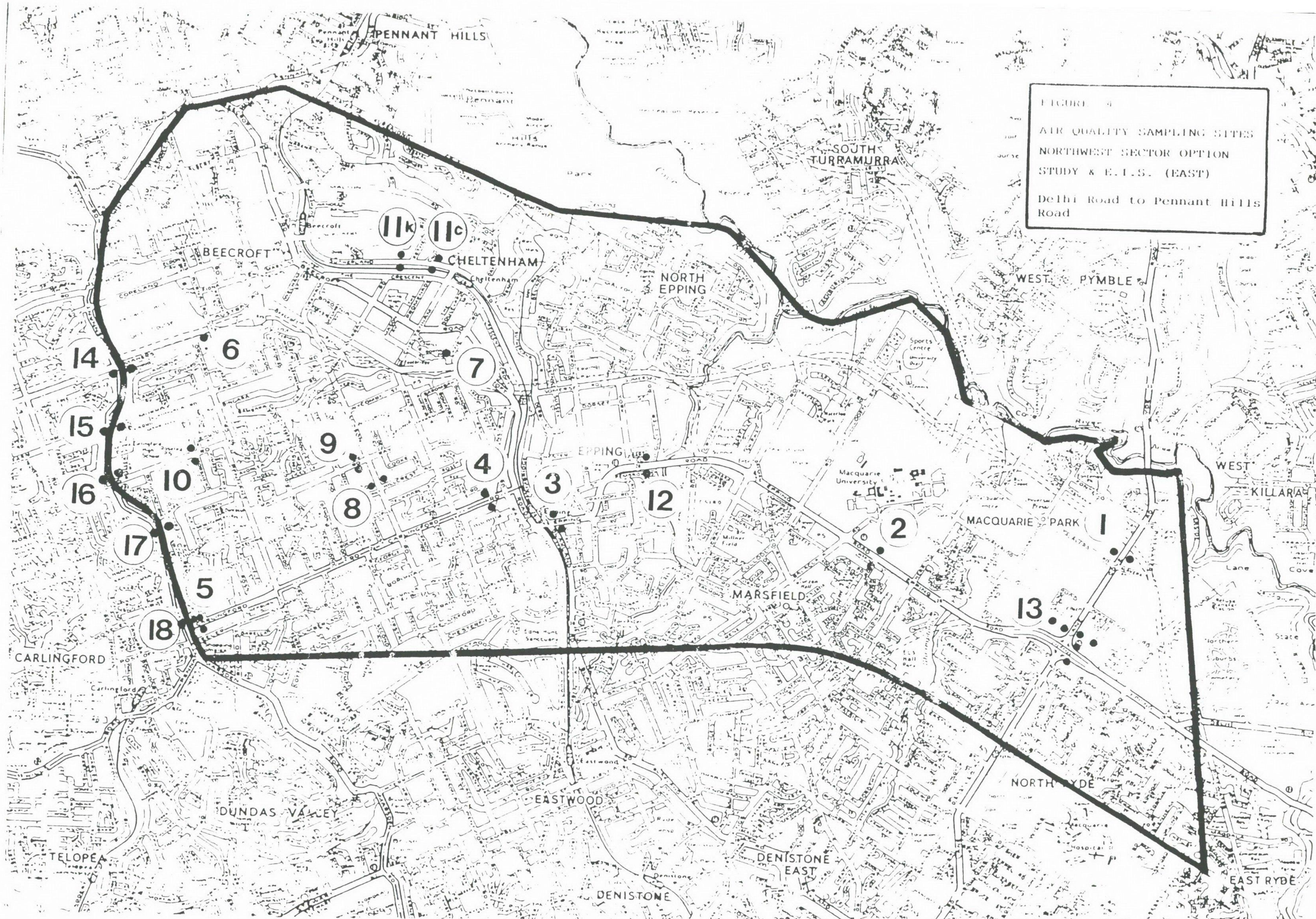
The location of the 21 sampling sites is presented in Figure 4.

At most of these sites, air samples were collected on both sides of the road.

Each sampling site was chosen to resemble a typical or representative site within the North West Sector Transport Options study area. Each site is representative of a particular combination of road lane configuration, road traffic volume and speed coupled with a specific set of topographical and meteorological parameters. Hence, although the data is referred to by road name, these air quality measurements may be transferred to other similar locations along the route.

Sampling site characteristics are detailed in Table 4.

The samples were collected over peak traffic and minimal wind periods, between 10 and 18 December 1990, and 18 to 19 April 1991.



STEPHENSON & ASSOC P/L

1208/90/AQWP/2

TABLE 4 **SUMMARY OF SAMPLING SITE CHARACTERISTICS - TRAFFIC DATA AND EMISSION CHARACTERISTICS**

Sampling Site +	Topographical & Meteorological Type	Road Configuration	Vehicle Type	Traffic Volume South or East # (a.m.)	Traffic Volume South or East # (p.m.)	Traffic Volume North or West # (a.m.)	Traffic Volume North or West # (p.m.)	Range of Traffic Speeds (km/hr)	Typical Range of Values CO (mg/m^3)	Typical Range of Values NO_x (as 100% NO_2) ($\mu g/m^3$)	Typical Range of Values NO_2 +++ ($\mu g/m^3$)
1	Medium Slope N/S orientation	7 lanes 4/3 (1 turning lane)	* ** ***	3449 196 31	1976 153 18	1488 212 48	2918 160 16	N (a.m.) 20 - 30 ++ S (a.m.) 0 - 20 - 40 N (p.m.) 20 - 40 S (p.m.) 20 - 35	8.7 - 15	62 - 185	22 - 65
2	Valley E/W orientation	6 lanes 3/3	* ** ***	3241 89 22	1728 33 6	1447 57 33	2930 77 18	E (a.m.) 0 - 50 - 80 W (a.m.) 40 - 45 E (p.m.) 0 - 25 W (p.m.) 40	7.5 - 11	62 - 123	22 - 43
3	Top of Hill E/W orientation but more ventilated	4 lanes 2/2	* ** ***	2146 54 19	1056 22 5	876 35 23	1931 41 9	E (a.m.) 30 - 40 W (a.m.) 20 - 30 E (p.m.) 20 - 45 W (p.m.) 0 - 30	12 - 19	62 - 164	22 - 57
4	Poorly ventilated hollow E/W orientation	4 lanes 2/2	* ** ***	1492 152 18	831 77 8	753 86 22	1122 116 13	E (a.m.) 0 - 20 - 27 W (a.m.) 20 - 50 E (p.m.) 21 - 25 W (p.m.) 20 - 50	8.7 - 15	41 - 133	14 - 47
5	Top of slope to N/S ventilated corridor E/W orientation	6 lanes 3/3	* ** ***	1039 67 18	899 25 5	822 39 18	835 44 8	E (a.m.) 30 - 45 W (a.m.) 20 - 40 E (p.m.) 20 - 50 W (p.m.) 20 - 23	8.7 - 12	41 - 103	14 - 36

* * Cars / ** Diesel 2 axles (6 wheels) / *** Diesel > 2 axles
\+ See Figure 3
++ Traffic Speed (Platoon front - mid stream average - peak (maximum measured))
+++ Calculated from 35% of total oxides of nitrogen in Sydney suburban atmosphere
\# Traffic Volume is stated in Vehicles Per Hour averaged over 3 days
(S, E, N, W refers to the direction traffic is flowing to)

TABLE 4 (cont.) SUMMARY OF SAMPLING SITE CHARACTERISTICS - TRAFFIC DATA AND EMISSION CHARACTERISTICS

Sampling Site +	Topographical & Meteorological Type	Road Configuration	Vehicle Type	Traffic Volume South or East # (a.m.)	Traffic Volume South or East # (p.m.)	Traffic Volume North or West # (a.m.)	Traffic Volume North or West # (p.m.)	Range of Traffic Speeds (km/hr)	Typical Range of Values CO (mg/m^3)	NO_x (as 100% NO_2) ($\mu g/m^3$)	NO_2 +++ ($\mu g/m^3$)
6¶	Background E/W orientation	2 lanes	* ** ***	N/A	N/A	N/A	N/A	N/A	0.37-3.1	41 - 82	14 - 29
7¶	Background ** N/S orientation	2 lanes	* ** ***	N/A	N/A	N/A	N/A	N/A	0.37-2.8	41 - 62	14 - 22
8	Medium Slope N/S orientation	2 lanes 1/1	* ** ***	768 8 1	310 4 1	292 4 1	717 5 0	N (a.m.) 21 - 60 ++ S (a.m.) 0 - 56 N (p.m.) 33 - 61 S (p.m.) 39 - 61	1.5 - 11	26 - 118	9.1 - 41
9	Ridge Top E/W orientation	2 lanes 1/1	* ** ***	911 11 1	324 5 2	271 10 1	761 4 1	E (a.m.) 34 - 60 W (a.m.) 28 - 38 E (p.m.) 37 - 59 W (p.m.) 29 - 54	1.4 - 6.6	25 - 118	8.8 - 41
10	Ridge Top E/W orientation	2 lanes 1/1	* ** ***	645 17 2	370 8 0	514 9 2	659 9 1	E (a.m.) 38 - 56 W (a.m.) 49 - 64 E (p.m.) 58 - 67 W (p.m.) 57 - 68	1.0 - 3.2	12 - 82	4.2 - 29

*   * Cars / ** Diesel 2 axles (6 wheels) / *** Diesel > 2 axles
¶   Background samples, taken to represent air quality conditions without through traffic
\+   See Figure 3
++   Traffic Speed (Platoon front - mid stream average - peak (maximum measured))
+++   Calculated from 35% of total oxides of nitrogen in Sydney suburban atmosphere
\#   Traffic Volume is stated in Vehicles Per Hour averaged over 3 days
(S, E, N, W refers to the direction traffic is flowing to)

TABLE 4 (cont.) SUMMARY OF SAMPLING SITE CHARACTERISTICS - TRAFFIC DATA AND EMISSION CHARACTERISTICS

Sampling Site +	Topographical & Meteorological Type	Road Configuration	Vehicle Type	Traffic Volume South or East #		Traffic Volume North or West #		Range of Traffic Speeds	Typical Range of Values		
				(a.m.)	(p.m.)	(a.m.)	(p.m.)	(km/hr)	CO (mg/m^3)	NO_x (as 100% NO_2) ($\mu g/m^3$)	NO_2 +++ ($\mu g/m^3$)
11	Hill Top/ Trough N/S orientation	2 lanes 1/1	* ** ***	943 0 0	364 1 0	320 1 0	626 1 1	N (a.m.) 58 - 69 h S (a.m.) 0 - 50 - 83 N (p.m.) 63 - 87 S (p.m.) 56 - 85 t	0.75 -6.7 0.37 -5.0	21-108 21 - 67	5.6 - 38 5.6 - 24
12	Valley E/W orientation	4 lanes 2/2	* ** ***	3617 78 30	1529 39 5	1261 60 23	2678 64 9	E (a.m.) 55 - 66 W (a.m.) 22 - 65 E (p.m.) 60 - 75 W (p.m.) 23 - 30 - 68	5.0 - 23	51 - 436	18 - 153
13A	E/W orientation	6 lanes 3/3	* ** ***	2222 18 3	1255 9 1	1170 24 1	2244 20 3	E (a.m.) 0 - 12 W (a.m.) 55 - 65 E (p.m.) 68 - 81 W (p.m.) 71 - 78	3.7 - 13	62 - 251	22 - 88
13B	N/S orientation	9 lanes 6/3	* ** ***	2551 83 47	2757 146 53	2543 152 50	2476 42 18	N (a.m.) 0 - 35 S (a.m.) 35 - 49 N (p.m.) 45 - 72 S (p.m.) 44 - 74	1.6 - 8.1	65 - 280	23 - 98
13C	Between A & B	N/A	* ** ***	N/A	N/A	N/A	N/A	N/A	0.87- 6.6	10 - 75	3.5 - 26

*   * Cars / ** Diesel 2 axles (6 wheels) / *** Diesel > 2 axles
\+   See Figure 3
++   Traffic Speed (Platoon front - mid stream average - peak (maximum measured))
+++   Calculated from 35% of total oxides of nitrogen in Sydney suburban atmosphere
\#   Traffic Volume is stated in Vehicles Per Hour averaged over 3 days
(S, E, N, W refers to the direction traffic is flowing to)

TABLE 4 (cont.) SUMMARY OF SAMPLING SITE CHARACTERISTICS - TRAFFIC DATA AND EMISSION CHARACTERISTICS

Sampling Site +	Topographical & Meteorological Type	Road Configuration	Vehicle Type	Traffic Volume South or East # (a.m.)	(p.m.)	Traffic Volume North or West # (a.m.)	(p.m.)	Range of Traffic Speeds (km/hr)	Typical Range of Values CO (mg/m^3)	NO_x (as 100% NO_2) ($\mu g/m^3$)	NO_2 +++ ($\mu g/m^3$)
14	Ridge N/S orientation	4 lanes 2/2	* ** ***	1447 81 62	1127 75 35	857 114 54	1062 44 36	E (a.m.) 18 - 50 - 80++ W (a.m.) 50 - 76 E (p.m.) 45 - 64 W (p.m.) 7 - 60	3.7-5.6	140-280	49-98
15	Ridge N/S orientation	4 lanes 2/2	* ** ***	1536 51 48	1116 62 39	993 39 32	1154 39 23	E (a.m.) 39 - 67 W (a.m.) 47 - 63 E (p.m.) 53 - 59 W (p.m.) 48 - 68	2.5-3.7	62-120	22-42
16	Ridge N/S orientation	4 lanes 2/2	* ** ***	N/A	N/A	N/A	N/A	E (a.m.) 21 - 48 W (a.m.) 0 - 22 - 45 E (p.m.) 25 - 35 - 41 W (p.m.) 28 - 43	2.5-10	62-340	22-119
17	Ridge N/S orientation	4 lanes 2/2	* ** ***	2039 82 67	1295 69 29	891 125 63	1572 75 48	E (a.m.) 50 - 63 - 73 W (a.m.) 60 - 85 E (p.m.) 55 - 62 W (p.m.) 0 - 15 - 36	1.2-3.7	21-110	7.4 - 39
18	Ridge N/S orientation	5 lanes 3/2 (1 turning lane)	* ** ***	1796 75 69	1263 56 65	1825 131 21	1706 51 36	E (a.m.) 25 - 45 W (a.m.) 0 - 20 - 45 E (p.m.) 15 - 33 - 58 W (p.m.) 28 - 43	1.2-7.5	41-180	14-63

*   * Cars / ** Diesel 2 axles (6 wheels) / *** Diesel > 2 axles
+   See Map 1
++   Traffic Speed (Platoon front - mid stream average - peak (maximum measured))
+++   Calculated from 35% of total oxides of nitrogen in Sydney suburban atmosphere
#   Traffic Volume is stated in Vehicles Per Hour averaged over 3 days
(S, E, N, W refers to the direction traffic is flowing to)

KEY TO LOCATION- OF AIR QUALITY SAMPLING POSITIONS ON FIGURE 4

1	Lane Cove Road intersection with Talavera Road
2	Epping Road (cnr Waring Street)
3	Epping Road (east of Blaxland Road)
4	Carlingford Road (west of Ray Road)
5	Carlingford Road (east of Pennant Hills Road)
6	Mahers Road (east of Pennant Hills Road)
7	Lyne Road, Beecroft (west of Beecroft Road)
8	Midson Road (south of Ray Road)
9	Ray Road (west of Midson Road)
10	North Rocks Road (outside Roselea Public School)
11c	Cnr. Sutherland Road and Chorley Avenue
11k	Cnr. Sutherland Road and Kethel Avenue
12	Epping Road (east of Pembroke Street near Terry's Creek
13A	Epping Road overpass (intersection with Lane Cove Road)
13B	Lane Cove Road (north of overpass)
13C	Lane Cove Road (north west of overpass)
13D	Lane Cove Road (north east of overpass)
14	Pennant Hills Rd, at Mahers Rd
15	Pennant Hills Rd, at Murray Farm Rd
16	Pennant Hills Rd, at North Rocks Rd
17	Pennant Hills Rd, at Alamein Ave
18	Pennant Hills Rd, at Carlingford Rd

2.4.2 Summary of Results

The results of the existing ambient air quality testing for each sampling period are presented in Appendix 4 and 5. These results are referenced against the New South Wales State Pollution Control Commission (SPCC) position on current air quality standards in N.S.W. which has been discussed in Section 2.2 and Table 3 of this report.

The prevailing meteorological conditions along with relative traffic density combined to produce conditions approximating "worst case" conditions on 18 December for the morning traffic peak, and 14 December for the evening peak.

It appears from the results so far that the chosen measurement locations of highest pollutant concentration are:-

Site 12 Epping Road, near Terry's Creek
- heavy traffic, 4 lane road in steep valley

Site 1 Lane Cove Road, north of Talavera Road
- heavy traffic, 6 lane road plus turning lanes, slight slope

Site 13 Intersection of Epping Road, Lane Cove Road and Ryde Road
- heavy traffic, overbridge, major interchange

Site 3 Epping Road, east of Blaxland Road
- heavy traffic, 4 lane road, steep slope

Site 4 Carlingford Road, west of Rawson Road
- heavy traffic, 4 lane road, shallow valley

Site 14 Pennant Hills Road, at Mahers Road
- heavy traffic, 4 lane road on ridge top

Site 15 Pennant Hills Road, at Murray Farm Road
- heavy traffic, 4 lane road in saddle on ridge

Site 16 Pennant Hills Road, at North Rocks Road
- heavy traffic, 4 lane road on ridge top.

These sites were also, as expected, the areas of greatest traffic congestion. Pollutant concentrations also varied from one side of the road to the other, with the highest concentrations generally occurring on the side of the road with the densest traffic flow. The exception to this occurred where there was a slight breeze blowing across the roadway from the side with dense traffic to the side carrying less traffic.

2.4.3 Discussion of Roadside Pollutant Concentrations

For the purposes of this study, the sample points can be divided into three main groups according to traffic volume and roadside pollutant concentrations.

The points in each of these groups can then be used to represent the air quality at different sites within the North West Sector Road Corridor depending on road configuration and traffic flow. These three groups are:-

- Heavy Traffic Roads
- Suburban Traffic Roads
- Quiet Suburban and Bushland Settings

2.4.3.1 Heavy Traffic Roads
Sample Points 1,2,3,4,5,12,13,14,15,16,17 and 18

Although air pollutant (CO and NO_x) concentrations measured at these sampling sites were relatively high compared to the other sites they did not exceed the selected air quality criteria. The exceptions however, were Sample Points 12 and 16 which will be discussed later in this section.

CO roadside concentrations at all of the above sampling points averaged between 8.7 and 19 mg/m^3 (ranging between 1.6 mg/m^3 and 22 mg/m^3) which are well below the WHO/USEPA 1 hour maximum of 31 mg/m^3.

Thus existing air quality in regard to CO concentrations appears to be good.

NO_x concentration, with the exception of Sample Points 12 and 16, averaged between 48 and 217 μg/m^3. These higher readings are approaching the 330 μg/m^3 NH&MRC 1 hour maximum air quality standard which would indicate that existing air quality in regards to NO_x concentration would be considered fair.

Roadside concentrations of NO_x measured at Sample Point 12, on Epping Road near Terry's Creek, were occasionally higher than the 330 mg/m^3 1 hour maximum. This is due to heavy traffic congestion from all directions into the intersection, particularly during the morning peak. Thus this Sample Point would be considered to have poor existing air quality.

Similarly, roadside concentrations of NO_x measured at Sample Point 14, at the intersection of Pennant Hills Road and North Rocks Road, were often approaching the 330 μg/m^3 1 hour maximum. This is due to heavy traffic congestion from all directions into the intersection, particularly during the morning peak. Thus this Sample Point would be considered to have fair existing air quality.

It should be noted however that these measurements are total NO_x (35% NO_2) compared to the NH&MRC standard for NO_2 only. Thus NO_2 measurements could reasonably be expected to be lower than the total NO_x concentrations measured.

2.4.3.2 Suburban Traffic Roads
Sample Points 8, 9, 10 and 11

CO and NO_x roadside concentrations measured at these Sample Points were generally about half of those measurements recorded on the Heavy Traffic Roads.

CO measurements averaged between 0.75 and 5.6 mg/m^3 (ranging between 0.37 and 11 mg/m^3). These levels can be considered minimal, and thus general air quality on these suburban thoroughfares can be considered to be good.

Roadside concentrations of NO_x confirm this trend with average concentrations of 18 to 107 $\mu g/m^3$ (ranging between 7.7 and 107 $\mu g/m^3$).

2.4.3.3 Quiet Suburban and Bushland Settings
Sample Points 6 and 7

With a lack of industrial activity nearby and minimal traffic, the general air quality in these areas would be expected to be good.

3.0 LITERATURE REVIEW: MOTOR VEHICLE EMISSIONS AND AMBIENT AIR QUALITY

The following annotated literature review is presented as an indicator of the scope of the most recent reports on the topic of motor vehicle emissions and ambient air quality.

The review is not presented as an exhaustive survey but rather as a summary of recent work.

AGPS (1991) Ecologically Sustainable Development Working Groups: Final Reports - Energy Production
- Energy Use
- Transport

Australian Government Publishing Service
Canberra: November 1991

- (Refer Appendix 8)

Al-Omishy H K, and Al-Samarrai H S, (1988) Road Traffic Simulation Model for Predicting Pollutant Emissions Atmospheric Environment 22(4): 769-774

- Has simulation model to predict NO_2, CH_3 emissions from different vehicles in free flowing traffic. Then sums total emissions.

Anon (1985) Motor Vehicle Emissions Control: Spotlight on the Compliance Program League of Women Voters Education Fund Report, July 1984.

. Denounces proposed amendments the Mobile Source Emission Program established under the Clean Air Act which will mean emission standards will be reached on average from a class of vehicle manufactured rather than for each vehicle. They estimate this will increase HC's 7%, CO 22%, NO_x 22% according to EPA estimates.

Atkinson R (1988) Atmospheric Transformations of Automotive Emissions in Watson A.Y., Bates R.R. & Kennedy D. (eds) 'Air Pollution, The Automobile, and Public Health' National Academy Press, Washington, D.C.

. Investigates atmospheric transformation of emission compounds. Research Recommendations:-

High Priority

i) Investigations of NO_x transformations

ii) Products arising from OH radical initiated reactions for the aromatic hydrocarbons.

iii) Atmospheric transformations of PAH's and their O, N and S containing analogues.

Medium Priority

iv) Wet and dry deposition of gases and particles

v) Products arising from OH radical initiated reactions of alkanes.

vi) Investigations, under atmospheric conditions, of the reaction products for partially oxidised automotive emissions and their health impacts on humans.

Australian Environment Council (1983) Reducing Pollution from Vehicles in Urban Areas - A Report on Supplementary Strategies to Control at Source AEC Report No. 11, Australian Government Publishing Service, Canberra.

- Suggests 6 strategies for decreasing car pollution:
  i) Public Transport (PT)
  ii) Road supply - free flow
  iii) Road traffic demand
  iv) Fiscal - ownership
  v) Town Planning
  vi) Social and other

Australian and New Zealand Environment Council (1990) Towards a National Greenhouse Strategy for Australia. Australian Government Publishing Service, Canberra.

- Goal: - 20% reduction in CO_2 emissions by 2005.
  - stabilise CO_2 emissions to 1988 levels
  - development and substitution of lower CO_2 sources
  - promote renewable energy

Bates R R, and Watson A R (1988) Motor Vehicle Emissions: A Strategy for Quantifying Risk in Watson A.Y., Bates R.R. & Kennedy D. (eds) 'Air Pollution, The Automobile, and Public Health' National Academy Press, Washington, D.C.

- Assesses health effects of air pollution from cars in US. Found that air pollution in general can affect health especially respiratory system but that very hard to separate pollution from cars from other ambient pollution and cigarette smoke. Other minor pollutants need to be researched (eg. PAH's, nitro PAH's) to see whether negligible concentration found in car emissions have any effect on health or if some highly toxic chemicals harm health at minimal concentrations. Very difficult to isolate differences.

Becker K (1989) Overall Programme for Monitoring the Emission Behaviour of New and In-Traffic Motor Vehicles, in EPA US-Dutch 3rd International Symposium 'Atmospheric Ozone: Its Policy Implications.' Elsevier Press.

- Guidelines proposed for Manufacturers for Emission Control Devices (EEC)
  - i) Approval of prototype
  - ii) Testing for conformity of production
  - iii) Continued revisal of 1 and 2 to maintain lowest possible emissions
  - iv) Regular spot checks of cars in traffic
  - v) Requiring proof of efficiency for emission relevant components for all cars in traffic on regular basis

Beiruti A A R, and Al-Omishy H K, (1985) Traffic Atmospheric Diffusion Model Atmospheric Environment 19(9): 1519-1524

- Uses Gaussian dispersion point source plane with above. Tested correlations coefficient 0.94821.

Black F M (1989) Motor Vehicles as Sources of Compounds Important to Tropospheric and Stratospheric Ozone, in EPA US-Dutch 3rd International Symposium 'Atmospheric Ozone: Its Policy Implications.' Elsevier Press.

- Transportation sources responsible for (1985 US):

34%	HC (could be more)	emissions
70%	CO	
45%	NO_x	
24%	Non aerosol CFC's	
14%	CO_2	

HC + CO emissions minimised at 24°c.

Black J A (1990) "Road Traffic - Trends and Prospects for Future Reduction." Vehicle: Energy and Environmental Impacts Seminar Report, 10 October 1990. Energy Research, Development and Information Centre, University of New South Wales.

- Concerns of 1980 have had no dramatic effect on Australian cities although transport (and vehicle) improvements have been made. Multifunction polis offers an opportunity of re-examining radically different urban forms. (Spatial relationships between activities and the resultant savings in travel and therefore emissions).; Telecommunications is thought to offer little reduction in travel in the short term.

Bresnitz E A and Rest K M (1988) Epidemiologic Studies of Effects of Oxidant Exposure on Human Populations in Watson A.Y., Bates R.R. & Kennedy D. (eds) 'Air Pollution, The Automobile, and Public Health' National Academy Press, Washington, D.C.

- Research Recommendations:

  High Priority

  i) Oxidant exposure
     - children, normal, adults & sensitive individuals
     - small airway function in non smokers in high oxidant areas in cities
     - sensitive individuals at various exposures
     - non smokers vs smokers in high oxidant areas

  Medium Priority

  ii) Extant data bases used in studying air pollution and health

  iii) New point source emissions identified and assessed

  Low Priority

  iv) Assessing past cumulative exposure

  v) Relationship between specific diseases and air pollution exposure

Clark A I, McIntyre A E, Reynolds G L, Kirk P W, Lester J N, and Perry R, (1988) Statistical Analysis of Gaseous Air Pollutant Concentrations at Urban, Rural and Motorway Locations Environmental Technology Letters 9: 1303-1312

- Concentration of primary transport related pollutants (CO, NMHC, O_2 + SO_2, NO_x) measured at Motorway, Urban and Rural sites.

  CO, NMHC + NO_x elevated on M + U compared to R

  O_2 " " R " " M + V

  + (for SO_2) R - Data Log normal - high autocorrelation

Coghill K (ed) (1990) Greenhouse: What's to be Done? Pluto Press in association with the Australian Fabian Society, Sydney.

- Stresses need to conserve energy especially in transport fuel sector. Onus on car industry to provide more efficient cars and trucks and to introduce LNG and CNG as factory options.
- Low octane rather than high octane unleaded.
- Possibilities of ethanol, methanol and MTBE from biomass wastes must be researched.

Commissioners of Inquiry for Environment and Planning (1990) A Proposed Expressway from Pennant Hills Road, Beecroft to Pittwater Rd, Ryde known as F2 Stage 1. Department of Environment and Planning, Sydney.

Davies G P, and Pearce T (1990) Exhaust Emissions at High Speeds from Advanced Technology Cars Transport and Road Research Laboratory Research Report 243, Berkshire, UK.

- Tested emissions from 3 (Non-catalyst, 3 way catalyst, + lean burn + oxidation catalyst) cars. Emissions from latter consistently lower than others. At speeds >100 km/h, all car emissions increased substantially. Fuel consumption of lean burn car consistently lower than others.

DeLuchi M A, Johnston R A, and Sperling D (1988) <u>Transportation Fuels and the Greenhouse Effect</u> Transportation Research Record 1175, Transportation Research Board, National Research Council, Washington, D.C.

- Vehicle emissions (from initial extraction to use in vehicle) assessed for different fuels (petroleum [base case], diesel electricity, methanol, natural gas and hydrogen).
- electricity from coal - highest emissions relative to petrol.
- N. Gas slight reduction from petrol
- Biofuels, electrolytic H_2 on non fossil fuel elect, greatly less than |.

Di Lorenzo A, Poletta A, Ciccioli P, Cicinato A, Brancaleoni E, Di Palo C and Bianchi L (1986) Paper presented at 7th World IUAPPA Clean Air Congress, Sydney, August 1986. (Vol 4 p 311).

- Diesel vehicles should be encouraged to high speed long range transportation and discouraged from urban transport.

- Research should be directed to increasing internal combustion temperature to better control emissions.
- Chemical indicators (e.g. nitro- and keto- PAH) used to investigate combustion processes.

Energy Research, Development and Information Centre (1990) Energy and the Greenhouse Effect: Commercial Opportunities for Research and Development Seminar Report, 3 August 1990. ERDIC, University of New South Wales.

- Improved fuel economy over the last decade. Due to improved engine designs, engine management and emission control systems, additional gear ratios, reduced rolling resistance (eg front wheel drives) and improved aerodynamics. However driver education and traffic management have been neglected.

- Environmentalism and consumerism main factors of change. Automotive industry planned to release a Greenhouse reduction strategy in October 1990. Anticipate further radical change in vehicle technology (engine transmission, mass, aerodynamics, drag, control), fuels and lubricants.

- Petrol based fuels have high energy density but substantial environmental impacts. Reformulated petrols will not substantially reduce environmental impacts. Alcohol can be mixed in fractions up to 85%, but give reduced range and other problems. CNG gives best air quality improvements and is cheaper. However driving range reduced and industry infrastructure changes drastic. Advantages of electric vehicles depend on energy source and technology developments needed.

- Improvements not expected in vehicle or fuel technology to give substantial reductions in Greenhouse emissions in the near or medium term.

Energy Research, Development and Information Centre (1990) Vehicles: Energy and Environmental Impacts Seminar Report, 10 October 1990. ERDIC, University of New South Wales.

Gillies G, Pengilley M, and Shortland J W (1986) Unleaded Petrol put to the Test in 'Proceedings of the 7th World IUAPPA Clean Air Congress, Sydney, August 1986, 5, 299-300

Graedel T E (1988) Ambient Levels of Anthropogenic Emissions and Their Atmospheric Transformation Products in Watson A.Y., Bates R.R. & Kennedy D. (eds) 'Air Pollution, The Automobile, and Public Health' National Academy Press, Washington, D.C.

- Research Recommendations:

  High Priority

  i) Indoor (vehicle) air quality

  ii) Formaldehydes

  Medium Priority

  iii) Unregulated species - particle phase

  iv) Monitor for NMHC's

  v) Unregulated species - gas phase

Low Priority

vi) Alkanic alcohol monitoring

vii) Personal exposure monitors

Henderson-Sellers A, and Blong R (1989) The Greenhouse Effect: Living in a Warmer Australia. New South Wales University Press, Sydney.

- Aimed at non specialist readers. Derivative, mainly from Graeme Pearman (CSIRO) book. Therefore fairly general. Predicts Australia's climate in Greenhouse.

Hickman A J (1989) Personal Exposures to Carbon Monoxide and Oxides of Nitrogen Transport and Road Research Laboratory Research Report 206, Berkshire, UK.

- 8 nominal semi-rural workers monitored for CO + NO_x over normal activities.

  CO - traffic, cooking, tobacco smoke

  NO_x - smoking + traffic

  Smokers : 15% CO from traffic

  Non Smokers : 25% CO from traffic

  Physiological effects of given exposure

Hickman A J (1989) Measurement of Particulate Lead on the M4 Motorway at Harlington, Middlesex (Fifth Report) Transport and Road Research Laboratory Research Report 184, Berkshire, UK.

- Airborne lead on Motorway monitored 84-87, in this time petrol lead reduced from 0.4 to 0.15 mg/1. Corresponding reduction in airborne lead from av 9 mg/m^3 to <3 $\mu g/m^3$.

Hickman A J, and Colwill D M, (1982) The Estimation of Air Pollution Concentration from Road Traffic Transport and Road Research Laboratory Report No. 1052, Crowthorne.

Hyde R, and Johnson G M, (1990) Pilot Study: Evaluation of air quality issues for the development of Macarthur South and South Creek Valley regions of Sydney CSIRO MRL Restricted Investigation Report 1885R, Second Printing.

- Investigation of air movement in and around the Sydney Basin concluded that on high pollution days air accumulated in three places: 1 - coast/offshore, 2 - SW region, around Camden, and 3 - NW region around Richmond. The regional pattern of air movement modelled in the Hyde and Johnson (1990) report is illustrated in Figure 3. The report observes that during the early morning (0200 - 1000 hours) pollutant emissions are trapped in the drainage flow as it moves down the Parramatta River Valley to the coast. This air is returned inland in the sea breeze collecting further pollutants along its trajectory towards the Hawkesbury Basin, where it arrives in the late afternoon (1500 - 1800 hours).

  During the night, a second drainage flow event can transport pollutants from the southern end of the Hawkesbury Basin either into the Liverpool Basin via Campbelltown or northwards through South Creek Valley

towards Penrith, St. Marys, Richmond and Windsor, which includes the North West Sector.

This suggests that no more extensive development should occur in the Hawkesbury Basin, as air pollutants may persist for more than one day. Also recommends that strategies to reduce NO_x emissions should be adopted to reduce photochemical smog. Whereas the photochemical smog control strategy currently being applied in Sydney which is based on control of hydrocarbon emissions is probably not very effective.

Hyman W A, Miller T R, and Walker J C (1989) Impacts of the Greenhouse Effect on Urban Transportation Transportation Research Record 1240, Transportation Research Board, National Research Council, Washington, D.C.

- Mainly construction changes which will be needed in Miami and Cleveland if S.L. rises.

Ingram G K, and Pellechio A (1976) Air Quality Impacts of Changes in Land Use Patterns: Some Simulation Results for Mobile Source Pollutants Discussion Paper D76-2, Department of City and Regional Planning, Harvard University, Cambridge Massachusetts.

- Suburbanisation and associated planning car reduce local emissions but may raise aggregate emissions by increasing emissions in urban core. Finds broad decentralisation is the best way to decrease aggregate emissions. In Baltimore - Washington area, and use changes had minimal impact on emissions (14 year comparison).

Johnson J H (1988) Automotive Emissions in Watson A.Y., Bates R.R. & Kennedy D. (eds) 'Air Pollution, The Automobile, and Public Health' National Academy Press, Washington, D.C.

- Examines pollution from vehicles in great detail.
  14 Research recommendations:
  High Priority:
  i) Effect of tampering and misfuelling on emissions
  ii) Diesel particulate emissions and control
  iii) Formaldehyde measurements
  iv) Diesel fuel additives
  v) Kinetics of Nitro PAH formations
  vi) Particulate measurement variability
  vii) HC characterisation
  Medium Priority:
  viii) Evaporator Emission Model
  ix) Automotive Quality No. 2 Diesel Fuel (low 5, aromatics)
  x) Evaporative Emissions Control
  xi) Emissions Measurement Methods
  xii) PAH measurement
  xiii) Diesel odour
  xiv) Nitrous acid from older cars

Kasternan D, Skyllas-Kazacos M and Wagner P (1990) "The Vanadium Battery: Vehicle Power Source for the Future".

- Details many advantages of Vanadium batteries over conventional lead batteries (e.g. Change/Discharge Capacity, Electrolyte as fuel extending limited range, easy charging, long life, etc.). Thus if used in electric vehicles could extend their range (km) for travelling.

Kenworthy J R, and Newman P W G (1987) Learning from the Best and Worst: Transportation and Land Use Lessons from Thirty-Two International Cities with Implications for Gasoline Use and Emissions Transport Research Paper 7/87, School of Environmental and Life Sciences, Murdoch University, Western Australia.

- Study of gasoline use and emissions in 32 cities. Concluded that "traffic engineering approach" does not improve gasoline use and emissions. Proposes strategies:
  - i) Increasing density of population and jobs in all parts of city.
  - ii) Increasing importance of central area in concentration of population and jobs
  - iii) Decreasing automobile ownership
  - iv) Increasing P.T. use overall
  - v) Decreasing role of car to work, increasing P.T. to work
  - vi) Decreasing road availability per head population
  - vii) Decreasing parking
  - viii) Increasing intensity of road use
  - ix) Increasing P.T. provision

Kenworthy J R, Newman P W G, and Lyons T J, (1987) Does Free Flowing Traffic Save Energy and Lower Emissions in Cities? Transport Research Paper 6/87, School of Environmental and Life Sciences, Murdoch University, Western Australia.

- Free flowing traffic corridors do not reduce overall emissions on fuel consumption despite the advantages for individual cars due to travel distances. Planning will reduce this along with other forms of use and optimal vehicle usage (ie. >1 person).

Kenworthy J R, and Newman P W G (1984) Motor Vehicle Emissions Inventories: A review of methodology, applications and potential for Australian cities. Transport Research Paper 4/84, Environmental Science, Murdoch University, Western Australia.

- Use relative simple i.e. technique to show where stricter control can have most effect.
- Stress different driving patters in different capital cities

- With continued urban sprawl, improved emission control standards could be negated by increased fuel consumption.

Koushki P A (1989) Environmental Impact Analysis of Transportation in a Rapidly Developing Urban Area Transportation Research Record 1240, Transportation Research Board, National Research Council, Washington, D.C.

- Study in Riyadh. CO significantly exceeded limits. Correlation found between traffic volume, wind speed and traffic speed with CO.

Kroon M (1989) Mobile Source Control Strategies in the Netherlands., in EPA US-Dutch 3rd International Symposium 'Atmospheric Ozone: Its Policy Implications.' Elsevier Press.

- Dutch environmental policy towards road traffic is basically 3 steps:
  - source control through emission standards
  - reducing motor vehicle use ("automobility") promoting bicycle and PT
  - Traffic measures to control air quality in urban areas

Latham S, and Tonkin P R (1988) A Study of the Feasibility and Possible Impact of Reduced Emission Levels from Diesel Engined Vehicles Research Report 158, Transport and Road Research Laboratory, Berkshire UK.

- Establishes that technology exists for reduction of diesel emissions to v. low levels. Goes through means of reducing each pollutant. Particulate - changes in fuel (more volatile, reduced 5 and aromatic content), engine modification and exhaust after treatment (particulate filtering). Regular inspections would be necessary.

Leggett J (ed) (1990) Global Warming: The Greenpeace Report. Oxford University Press, Oxford.

- Chapter 12, p 260 "Motor Vehicles and Global Warming". Goes through OECD figures (ref Walsh & Moore 1989). Indirect greenhouse gases:- 1gm CO has greater global warming capacity than 1 gm CO_2, Ozone precursors, OH radicals etc. North America has 1/3 worlds cars and 2/5 worlds trucks. Suggests government control fuel consumption. CO_2 should be limited by regulations, policies. Minimise car growths.

Light Vehicles Energy Consumption Committee of the Society of Automotive Engineers - Australasia (1989) <u>Oxides of nitrogen Emissions from Motor Vehicles in Sydney</u> Clean Air 23(4): 146-148

- NO_x emissions not a problem in Sydney at moment but increasing. 3/4 Sydney NO_x from mobile but passenger vehicles and derivatives (most of |) decreasing of ADR37. These vehicles would probably be first targeted further limitations necessary due to existing technology.

Ly K H (1990) "Exhaust Emissions from Natural Gas Vehicles - A State of the Art Review". <u>Vehicles: Energy and Environmental Impacts</u> Seminar Report, 10 October 1990. Energy Research, Development and Information Centre, University of New South Wales.

- Technology is available for light and heavy duty vehicles to meet current emissions standards but more research development needed to meet tougher standards (e.g. Scandinavia).

Marks R (1990) "Carbon Taxes and Road Transport" - Vehicles: Energy and Environmental Impacts Seminar Report, 10 October 1990. Energy Research, Development and Information Centre, University of New South Wales.

- Exchange mechanisms in general, and fuel or carbon prices in particular, will play an important part in change the behaviour of economic actors in the market for road transport: the manufacturers and the drivers. If the price of a litre of fuel does not truly reflect the social costs associated with its combustion, then a tax can cost-effectively narrow this gap between social and private costs, and alter behaviour, so that less more-valuable fuel is used, and fewer emissions generated.

Milton B E (1990) "Engine Technology and Gaseous Fuels: Efficiency and Emission". Vehicles: energy and Environmental Impacts Seminar Report, 10 October 1990. Energy Research, Development and Information Centre, University of New South Wales.

- Current technology appropriate for local emissions. Reduction in consumption or alternative fuels offer solution for larger problem.

- Vehicle fuel economy continuing and improving.

- Alternative fuels being studied.

Nelson F F and Milne J W (1986) "Organic Particle Emissions From Motor Vehicles". Paper presented at 7th World IUAPPA Clean Air Congress, Sydney, August 1986. Vol 4 p 303.

- Measured particle exhaust from diesel vehicle and performed gas chromatography. Lubricating oil contributed significantly to this exhaust. Then measured petrol exhaust. Lube oil found to be significant here too.

Orski C K (1990) Can Management of Transportation Demand Help Solve Our Growing Traffic Congestion and Air Pollution Problems Transportation Quarterly 44(4): 483-498

- Assesses Transportation Demand Management as a method of reducing congestion and pollution.

  Conclusions:-

  i) need for general and objective study
  ii) problems in assessing effectiveness
  iii) Likely to be more effective in small areas which does not improve regional air quality
  iv) Take 1 car off the road, another will replace it
  v) Incentives ($) may be necessary to entice drivers off road
  vi) Congestion pricing doubtful

Pearman G I (ed) (1988) Greenhouse: Planning for climate change. CSIRO Australia.

- Numerous studies of greenhouse effects to illustrate sensitivity of Australian climate and environment. Atmospheric CO_2, CH_4 and N_2O risen by 23, 110 and 8% respectively since pre-industrial times. Over next 50 years these figures expected to increase to 45 - 115, 200 - 500, and 25 - 60%.

Pengilley M (1986) Trends in Australian motor vehicle emissions and fuel consumption paper presented at 7th World IUAPPA Clean Air Congress, Sydney, August 1986.

Renner M G (1988) 'Car Sick' in World Watch 1(6): 36-44

- Stresses need to reduce vehicle emissions. Health/environmental effects.
- Strategies
  - emission controls - not enough
  - different fuels
  - different transportation options eg. pooling,bus, rail, cycle, walk

Rombout PJA, Van Bree L, Heisterkamp SH and Marra M (1989) The Need For An Eight Hour Ozone Standard, in EPA US - Dutch' 3rd International Symposium 'Atmospheric Ozone: Lts Policy Implications' Elsevier Press.

- Notes daily exposure of many would be 8 - 12 hours just below 1 hour maximum. Current ozone standards based on health effects of 1 - 2 hour exposure. Health risk of exposure to ambient ozone appears to be more serious than first thought. These tests show 8 hour standard would be significantly lower than 1 hour standard.

Rotmans J (1989) A Scenario Study of the Greenhouse Effect, in EPA US-Dutch 3rd International Symposium 'Atmospheric Ozone: Its Policy Implications.' Elsevier Press.

- Developed IMAGE simulation model to produce long-term scenarios for greenhouse planning purposes. Primary use is to conduct policy experiments.

Rogers P L (1990) "Ethanol as a Transport Fuel" Vehicles: Energy and Environmental Impacts Seminar Report, 10 October 1990. Energy Research, Development and Information Centre, University of New South Wales.

- Breakeven point when crude oil is US $30.35 per barrel. NSW North Coast sugar fields can provide 12-15% of the regions liquid fuel requirements for high octane products. UNSW Biotech researching cost competitive and environmentally acceptable alternative.

Russell A G (1988) Mathematical Modelling of the Effect of Emission Sources on Atmospheric Pollutant Concentrations in Watson A.Y., Bates R.R. & Kennedy D. (eds) 'Air Pollution, The Automobile, and Public Health' National Academy Press, Washington, D.C.

- High Priority
  - i) Construction of an advanced chemical mechanism
  - ii) Model comparison and evaluation
  - iii) Aerosol process model development
  - iv) Indoor Air Quality Modelling

  Medium Priority
  - v) Pollutant deposition modelling
  - vi) Receptor modelling
  - vii) Pollutant dynamics in street canyons

  Low Priority
  - viii) Fog chemistry
  - ix) Reactive phase and sub grid scale modelling

Samson P J (1988) Atmospheric Transport and Dispersion of Air Pollutants Associated with Vehicular Emissions in Watson A.Y., Bates R.R. & Kennedy D. (eds) 'Air Pollution, The Automobile, and Public Health' National Academy Press, Washington, D.C.

- Summary of Research Recommendations

  High Priority
  - i) Open highway exposure (Vehicle disturbance)
  - ii) Transport and dispersion in street canyons

Medium Priority

iii) Plume buoyancy

iv) Physical modelling

v) Regional scale transport and dispersion

Low Priority

vi) Urban scale transport ⌉ monitoring

vii) Regional scale transport ⌋

Santini D J, and Rajan J B, (1990) Comparisons of Emissions of Transit Buses Using Methanol and Diesel Fuel Transportation Research Record 1255, Transportation Research Board, National Research Council, Washington, D.C.

- Compares emissions from methanol and diesel fuelled buses at different speeds. Methanol emissions varied greatly according to engine tests, speeds and emission controls. In low speed cases no great advantage of methanol as slight reduction in partic emissions offset by increases in CO, HC and formaldehyde.

Sexton K , and Ryan P B (1988) Assessment of Human Exposure to Air Pollution Methods, Measurements, and Models in Watson A.Y., Bates R.R. & Kennedy D. (eds) 'Air Pollution, The Automobile, and Public Health' National Academy Press, Washington, D.C.

- Health risk = Potency x Exposure x Exposed Population
  (morbidity/mortality) = (dose/response) x (concentration) x (No. of people exposed)

Research Recommendations:

High Priority

i) Tune activity patters

ii) Exposure monitoring

iii) Biological markers of exposure

Medium Priority

iv) Breathing patterns (mouth v nose, sitting, eating, talking etc).

Smith M R (1986) Pollution Control: Combustion Processes paper presented to Australian Institute of Energy, Newcastle Branch.

State Pollution Control Commission (1989) Quarterly Air Quality Monitoring Report. Vol 15(1). SPCC, Sydney.

Stewart A C (1987) Models for calculation of air pollution and noise emission from road traffic aspects of measurement accuracy, prediction accuracy and simplicity paper presented at Institute for Physics and Material Technology Seminar, Linkoping University, Sweden.

Stewart A C (1987) Australian motor vehicle emissions standards, paper presented to conference at Verein Deutscher Ingenieure, Nurenberg, West Germany.

Stewart A C , Pengilley M R, Brain R, Haley J J, and Mowle M.G. (1982) 'Motor Vehicle Emissions into Sydney's Atmosphere' in The Urban Atmosphere - Sydney, a Case Study (Carras and Johnson editors). CSIRO, Melbourne.

- After ADR 37,1986 introduced HC emissions will fall continuously to 2000.
  $HC:NO_x$ ratio will change significantly.
  Particulate emissions contribute to Sydney's brown haze. Will increase substantially to 2000, although moderated slightly by unleaded petrol.
  Lead emissions from vehicles will decrease to almost 0 by 2000.

Storey J W V (1990) "Electric Vehicles, and Vehicle Modifications for Efficiency" . Vehicles: energy and Environmental Impacts Seminar Report, 10 October 1990. Energy Research, Development and Information Centre, University of New South Wales.

- Argues that electrical vehicles don't need to be designed exactly like modern petrol cars. Commuter car: small, lightweight, seat 1 or 2 people, electric, range of approx. 100 km, max speed 80 km/hr and "traffic compatible performance". Quotes D.F. Gudsen "Electric Vehicles and the Greenhouse Effect", SUEE/EVRF 020990 as saying CO_2 reduction is achieved even if current power stations used and even if electric vehicles built like petrol vehicles.

Trimm D L (1990) "Catalytic Converters - Old Problems: Old Solutions, New Problems: Any Solution?" Vehicles: Energy and Environmental Impacts Seminar Report, 10 October 1990. Energy Research, Development and Information Centre, University of New South Wales.

- Technology on old converters increased and lifespan doubled; however new tech converters have a range of problems: 1 - High temp performance (more HC's, plug misfire), 2 - NO_x control, 3 - Diesel exhaust control, 4 - Aromatics in fuels and exhaust gases, 5 - Formaldehyde from methanol fuelled cars.

Veldt C (1989) Emission Inventories for Europe, in EPA US-Dutch 3rd International Symposium 'Atmospheric Ozone: Its Policy Implications.' Elsevier Press.

- Looked at differences in Emission Inventory procedures between different European cities and how this was gradually becoming standardised. Points out areas where differences still lay and importance of uniformity for more general studies and emissions to be performed.

Wainwright M S (1990) "Methanol as an Automotive Fuel" Vehicles: Energy and Environmental Impacts Seminar Report, 10 October 1990. Energy Research, Development and Information Centre, University of New South Wales.

- Advantages:
  - High octane no. (RON = 106 - 114)
  - Clean burn, no particulate, lead or sulfur emission
  - Reduced CO, NO_x, HC emission

- Disadvantages:
  - Lower energy/volume than gasoline
  - Aldehyde emissions

Walsh M P (1986) "Worldwide Developments in Motor Vehicle Pollution Control". Paper presented at 7th World IUAPPA Clean Air Congress, Sydney, August 1986. Vol 3 p 292.

- Three major problem areas for future: 1 - increasing NO_x emissions (ozone, acid deposition), 2 - Diesel particulate, 3 - Vehicle inspection and maintenance.

Walsh M P, and Moore C A (1989) Motor Vehicle Contribution to Global and Transported Air Pollution, in EPA US-Dutch 3rd International Symposium 'Atmospheric Ozone: Its Policy Implications.' Elsevier Press.

- Ozone Precursors:

  OECD total gaseous emissions (% for motor vehicles)

	(1000 tonnes)	
NO_x	36,019	(47.2)
HC	33,869	(39.1)
CO	119,148	(65.7)

Notes:

i) Motor vehicles major sources of above pollutants.

ii) Car numbers growing at very high rate.

iii) Also suggests removal or containment of CFC's from car air conditioning.

4.0 IMPACTS FROM ROAD CONSTRUCTION ON AIR QUALITY

4.1 Scope of Construction Activities

The following information has been supplied by Maunsell to facilitate determination of duration and concentration of the dust (particulate matter) emissions from road construction activities.

The rate of progress of construction will vary between the expressway option and the arterial upgrade. However, the difference in rate of progress may not be significant when the variables for each site are taken into account. For example, the expressway option will not have the same existing traffic encumbrance that the arterial upgrade option would have, i.e. modifying existing lane options to enable construction to proceed with minimal interruption to existing traffic pattern. Alternatively, the expressway option will have substantially more earthworks and sheer volume of material to be moved.

Hence, the comparative progress may be similar over the total distance of the route options. Thus it is difficult to generalise to the point of so many metres per day. However, to facilitate calculation of dust impacts, the construction timing presented in Section 4.1.1 has been calculated by Maunsell.

4.1.1 Construction Timing

The minimum construction period for both arterial and expressway options would be three years. Restrictions on funding may significantly extend the duration of construction.

Construction rates for the various options would be as follows:

- Expressway

-	Bridges	as per 4.1.2
-	Earthworks	10m/day
-	Drainage	100m/day
-	Pavement/Landscaping etc.	200m/day x 5 layers

- Carlingford/Epping Arterial

-	Bridges/structures	as per 4.1.2
-	Earthworks/drainage	50m/day
-	Drainage	100m/day
-	Pavement/Landscaping etc.	200m/day x 5 layers

- Expressway/Pennant Hills/Carlingford

Phase 1	Bridges/Pennant Hills Road and Carlingford Road	24 months
Phase 2	Earthworks/drainage	18 months
Phase 3	Pavement/Landscaping etc.	12 months

Phase 2 would commence 9 months after Phase 1 and Phase 3 would commence 15 months after Phase 2.

- F2 Reserve/North Rocks Road Arterial

Phase 1	Interchange/Pennant Hills Road and Carlingford Road	24 months
Phase 2	Windsor Road to Pennant Hills Road	24 months
Phase 3	Old Windsor Road to Windsor Road	18 months

Phase 2 and 3 could both commence 12 months after Phase 1.

- Tunnel - 3 months each for excavation, then portal construction

4.1.2 Construction Method

Structures (bridges, interchange, viaducts) will be built at:

(i) Viaduct in Devlins Creek (progress - 24 months)
(ii) Murray Farm overbridge - 6 months
(iii) Beecroft Interchange - 18 months
(iv) Railway Bridge - 15 months
(v) Terrys Creek - 21 months
(vi) Balaclava Road - 6 months
(vii) Lane Cove Road - 21 months
(viii) Dehli/Pittwater - 30 months

Roadworks will basically be by cut and fill techniques utilising standard forms of earthmoving machinery, e.g.

- Excavation, Pavement Construction and Drainage

  D5 and D9 bulldozers - ripping or blasting
  Scrapers (2 off)
  Wheeled loader ($2m^3$)
  $15m^3$ dump trucks
  Grader
  Backhoe and Excavator
  Sheepsfoot self-propelled roller
  Multi-wheeled roller
  Delivery trucks
  Crane
  Compactor
  Water cart
  Vibrating steel roller

Tunnel Construction

(i) Portals

Excavation -

D9

Wheeled loader

Back hoe

10 x 15 cubic metre trucks

Air compressor

Portal construction -

Excavator

Air compressor

Crane

Back hoe

1 x 15 cubic metre truck

Delivery trucks (2 per hour)

Concrete pump (20% of time)

(ii) General Tunnel Excavation

(per tube) (Progress: 50 metres per week)

Road header

Hydraulic drill jumbo

Ventilation plant

Conveyor belt system

3 x 15 cubic metre trucks

Delivery trucks (1 per hour)

Shotcrete pump

(iii) Fit-out

(per tube) (Progress: 50 metres per week)

Delivery trucks 1 per hour

Mobile erection gantry 2 N° (probably electric-powered)

Before any construction work commences, Maunsell advises that all measures required to maintain existing water quality downstream of the works and to avoid soil erosion would be put in place. This work would be overseen by the SPCC and the SCS.

The site would then be cleared of vegetation between the limits of the earthworks. The vegetation would be chipped for later use as landscape mulch.

In many locations, the extent of earthworks (and hence tree removal) will be limited by constructing retaining walls.

Topsoil would be stripped and stockpiled for respreading at the completion of the earthworks. The excavation of cuttings will generally be done by bulldozers using rippers. Some blasting would be required. A preblast inspection of all adjacent houses would be carried out and blasting would be closely monitored by the supervising engineers. Ripped material would be transported by scraper or truck and compacted in fills by various types of compacting rollers. Motor graders would shape the embankment surface. Pavement drainage would then be installed before the pavement is constructed.

The construction of the expressway would involve the excavation of approximately:

Expressway:	Total Cut	=	1,117,000 m^3
	Total Fill	=	981,000 m^3
Arterial:	Total Cut	=	292,000 m^3
	Total Fill	=	76,000 m^3

The remainder of the material would be used to flatten batters on the expressway or removed to nearby land fills, dumps or construction sites by trucks.

Construction requirements included in the specifications would include provision for the works to be kept clean and tidy as they proceed, dust suppression measures would be taken as required and sedimentation basins would be cleaned out regularly. All construction equipment would be required to conform with noise suppression regulations and disturbed areas would be revegetated immediately after completion of the earthworks.

4.1.3 Hours of Construction

To ensure that property owners in close proximity to the freeway would not be adversely affected by the construction process, construction activities would be limited to the following hours:

Monday to Saturday 7.00 a.m. to 5.00 p.m.

4.1.4 Construction Materials

All of the construction materials would be obtained either from the site as part of cut and fill operations required for road construction or from existing sources in the metropolitan area.

4.1.5 Construction Traffic

It is understood that all construction traffic carrying material that may emit dust in transit will be appropriately tarped and wheels washed.

It is expected that the existing roads most frequently used by construction traffic would be those trunk roads in the vicinity of the proposed works:

Pennant Hills Road
Carlingford Road
Beecroft Road
Epping Road
Lane Cove Road
Delhi Road

A large proportion of construction traffic associated with the project would consist of tip-trucks removing excess cut from the site and delivering aggregates and gravels to the site. In addition, a large number of semi-trailers would deliver materials such as steel reinforcement, drainage pipes and precast concrete units to the site.

The main sources of aggregates and gravels for the project would be quarries at Hornsby and Prospect and river gravel deposits at Penrith Lakes.

Material from Hornsby quarry would be trucked along Pennant Hills Road while material from Prospect quarry and the Penrith Lakes scheme would be trucked along the Great Western Highway and Pennant Hills Road and Carlingford Road to the vicinity of the project.

Finding suitable areas off site to dump excess material from the excavation would be the responsibility of the earthworks contractors. Suitable dump sites would be either other projects which have a deficiency of fill material or privately run dump sites. In any event, it is expected that the excess material can be spoiled reasonably close to the construction site and that the roads most affected by vehicle removing spoil from the site will be those listed above.

Traffic delivering miscellaneous items such as drainage pipes and steel reinforcement to the site will have a wide variety of origins. The roads most affected by this traffic will again therefore be the trunk roads close to the site.

Wherever practicable, minor roads in the vicinity of the site would not be used by construction traffic as access points onto the site will generally be from the existing major roads.

4.2 Probable Impacts on Air Quality from Construction

Construction activities will generate dust and exhaust emissions from heavy vehicles (mostly diesel exhaust) during the period for which construction work takes place. Hours for construction are planned to be 7 a.m. to 5 p.m. six days per week. The scale of the construction operation is discussed below. Diesel exhaust emissions are unlikely to cause any significant impact and dust is the area of most concern.

The construction work will depend on which options are selected. Each option is discussed below.

4.2.1 Arterial Option

Three major construction activities are identifiable: excavation, pavement construction and drainage works construction.

Excavation work is estimated to progress at the rate of 50 m per day. It will involve a D5 size dozer, a two cubic metre wheeled loader, a grader, a backhoe and 15 cubic metre rear dump trucks, three of which will be on site at any one time.

Pavement construction is estimated to progress at the rate of 200 m per day, but since there will be five layers of pavement laid, the operation will pass by each point five times. The equipment involved will be a grader, a water truck, material delivery trucks (three per hour), multi wheel roller and vibrating steel-wheel roller.

Drainage construction is estimated to progress at the rate of 100 metres per day. It will involve an excavator, backhoe and approximately three 15 cubic metre rear dump trucks.

Clearly the most likely period for impacts to occur will be during the first phase of heavy excavation, where substantial earth works will take place progressing at the relatively slow rate of 50 metres per day. The dust generated in any one day can be estimated from work undertaken in the United States (USEPA 1982) and in New South Wales by the National Energy Research and Development Council (NERDC 1988). The estimated amounts used as model input data were as follows:

- Dozer assuming ten-hours of operation per day generating dust at the rate of 2.75 kg/h - 27.5 kg.

- Grader assuming distance travelled in the day is 20 km and the dust generation rate is 0.75 kg/km - 15 kg.

- Dust from loading of material by excavator to trucks assuming dust is generated at the rate of 0.01 kg/t and that 50 x 15 cubic metre trucks' loads are removed in a ten-hour day, making a total of approximately 750 m^3 or approximately 1125 t of material removed per day - 11.25 kg.

- Dust from trucks travelling on the unsealed road surface assuming a 200 m one way trip distance, five movements per hour and 2 kg of dust/vehicle/km. This is the amount of dust generated after taking account of dust suppression by watering of the trafficked areas. The total amount of dust generated during a ten-hour working shift would be 40 kg.

- Dust from wind erosion from an exposed area of 200 m long by 30 m wide. (The exposed area will be greater than this but the area which could contribute significant amounts of dust to a particular residence would be unlikely to be larger). Wind erosion dust would be generated at the rate of 0.4 kg/ha/hour - 2.4 kg in ten hours.

Thus the total dust generated in a ten-hour working day would be expected to be 96 kg. On a hot dry windy day the amount of dust from wind erosion could be higher, but should still be easily controlled using water sprays.

The impacts from this dust can be estimated using a Gaussian dispersion model to predict dust fall out and dust concentrations in the vicinity of the construction area. However, to relate these to impacts on people is not a simple matter. Research by Dean et al (1988) has established acceptable long-term goals for dust concentrations in urban areas.

However, these are not appropriate for assessing potential impacts from an activity such as road construction, where the dust generation is a "rapidly" moving source which only affects any given point along the route for two or three days at a time, five times during the construction. The most appropriate approach to impact assessment is to use short term goals of which there are two that can be considered relevant.

These are the USEPA 24-hour primary and secondary goals which are 260 and 150 $\mu g/m^3$ [1] respectively. In an attempt to relate the significance of the estimated dust emission rate in terms of the possibility of causing adverse effects on people or property, the emissions have been used with a dispersion model and set of arbitrarily selected, but "typical" dispersion conditions to estimate a buffer distance beyond which it is unlikely that the 150 $\mu g/m^3$ (24 hour) concentration will be exceeded. The meteorological conditions assumed to apply were neutral stability (Pasquill-Gifford Class D), and 3 m/s wind blowing from the same direction for the entire day. To add an element of conservatism to the calculation it was assumed that emissions of dust occurred for 24-hours continuously. It should be noted however, that the maximum period construction would be in progress would be 10-12 hours. The distance that dust will travel before settling out depends on the range of dust particle sizes.

For this assessment the size distribution was taken from measurements made in the Hunter Valley open cut mines during overburden stripping. A single size distribution has been elected as follows:

Fine particles	(0 to 2.5 μm)	5%
Inhalable particles	(2.5 to 15 μm)	55%
Coarse particles	(15 μm and above)	40%

The results of the model run are presented in Figure 5. This shows the predicted concentration of dust as a function of downwind distance from the centre of the construction site.

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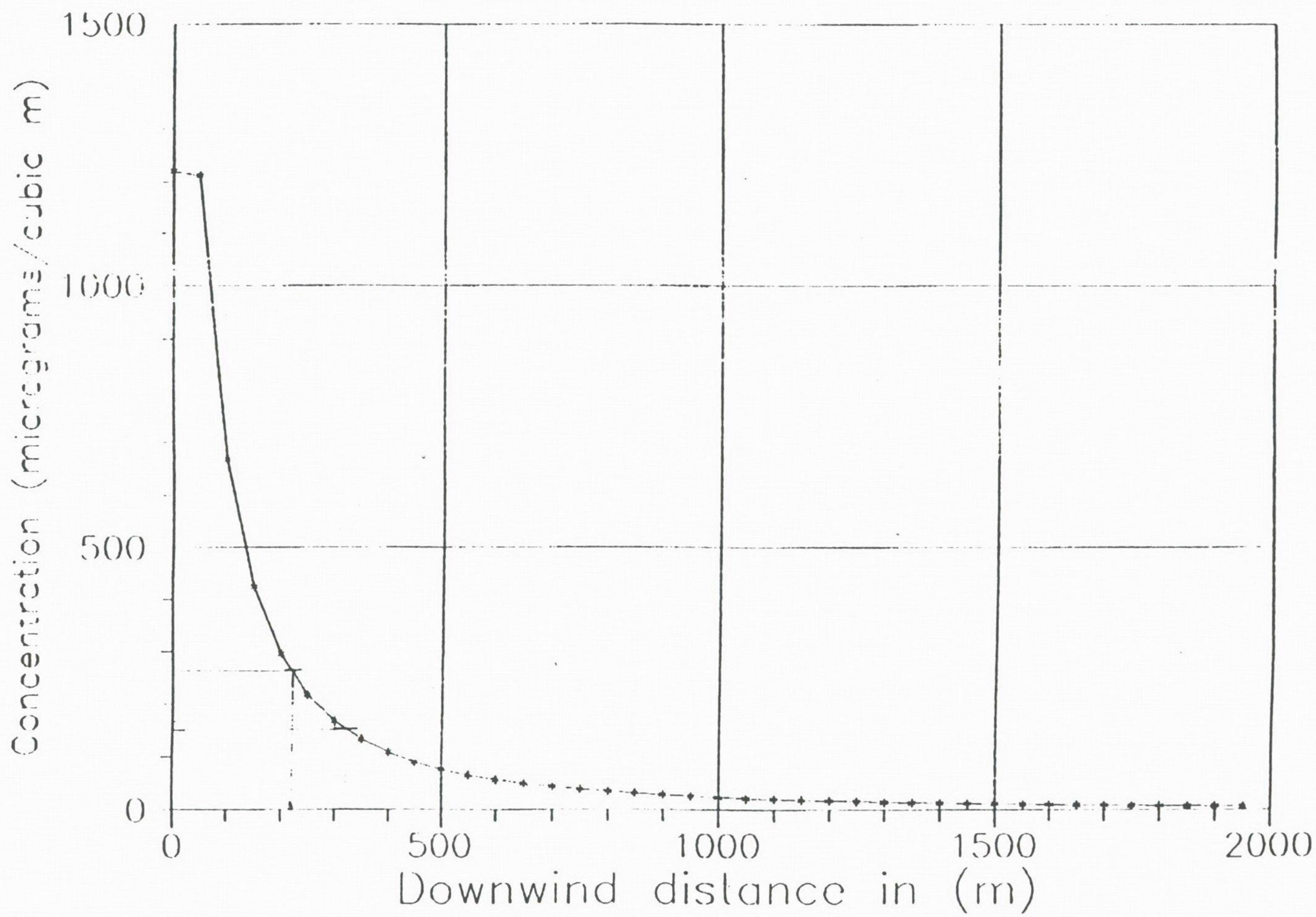
1 The USEPA primary ambient standards define levels of air quality which the EP Administration judges are necessary, with an adequate margin of safety, to protect the public health. USEPA secondary ambient air quality standards define levels of air quality, which the Administrator judges are necessary to protect the public welfare from any known, or anticipated, adverse effects of a pollutant.

FIGURE 5

PREDICTED DUST CONCENTRATION
DOWNWIND FROM CENTRE OF CONSTRUCTION AREA



From Figure 5 it can be seen that 24 hour dust concentrations would be expected to be below 260 $\mu g/m^3$ beyond approximately 200 m from the centre of construction and below the 150 $\mu g/m^3$ level beyond approximately 300 m from the centre. These distances are "worst case" estimates with the wind blowing from one direction only. They assume that the wind blows continuously from one direction for 24 hours and that a high level of activity is taking place for 24 hours. In practice construction operations will occur for 10-12 hours and hence the impact area, that is where the 260 $\mu g/m^3$ (24 hour) average level is likely to be exceeded, will probably be less than 50m.

Given that the impacts are temporary and major earthworks will be limited in duration at any particular location, it is considered that they will be accepted by the public in the same way that temporary inconveniences are accepted in other circumstances, many of which are related to construction of one type or another.

4.2.2 Expressway

Temporary air quality impacts during the construction of the expressway option are almost identical except that excavation work will involve additional dust from two scrapers, an additional D9 dozer and an additional excavator.

More importantly the rate of progress of the expressway work is estimated to be 10 m per day rather than 50 m per day. Thus impacts are expected to last for five times as long. the estimated dust emissions used as model input data were as follows (USEPA 1982, NERDC 1988):

- Two dozers assuming ten hours of operation each per day generating dust at the rate of 2.75 kg/h - 55 kg.

- Grader assuming distance travelled in the day is 20 km and the dust generation rate is 0.75 kg/km - 15 kg.

- Dust from loading of material by excavators (two) to trucks assuming dust is generated at the rate of 0.01 kg/t and that 100 x 15 cubic metre trucks' loads are removed in a ten hour day, making a total of approximately 1500 m^3 or approximately 2250 t of material removed per day - 22.5 kg.

- Dust from trucks travelling on the unsealed road surface assuming a 200 m one way trip distance, ten movements per hour and 2 kg of dust/vehicle/km. This is the amount of dust generated after taking account of dust suppression by watering of the trafficked areas. The total amount of dust generated during a ten hour working shift would be 80 kg.

- Dust from two scrapers working for ten hours per day and generating dusts at the rate of 2.7 kg/km. Assuming that the scrapers each travel 50 km/ten hour day then the total dust in the ten hour period is 270 kg.

- Dust from wind erosion from an exposed area of 200 m long by 30 wide. (The exposed area will be greater than this but the area which would contribute significant amounts of dust to a particular residence would be unlikely to be larger). Wind erosion dust would be generated at the rate of 0.4 kg/ha/hour - 2.4 kg in ten hours.

Thus the total dust generated in a ten hour working day would be expected to be 445 kg. This is substantially (4.6 times) more dust than from the arterial work.

Using Figure 5 and adjusting for the increased dust emissions, the distance to the 260 $\mu g/m^3$ 24 hour average will be approximately 600 m under the conservatively estimated "worst case" and approximately 300 m under "typical" conditions. Dust concentrations would exceed the State Pollution Control Commission's 260 $\mu g/m^3$ out to distances of approximately 300 m from the centre of the construction zone and which would affect any given residence for approximately 60 working days assuming a rate of progress of 10 m/day and that the location being assessed was on the route.

4.2.3 Construction of Structures

Structures required for specific parts of the project and the times for completion are listed below:

1.	Viaduct at Devlins Creek	24 months
2.	Overbridge at Murray Farm	18 months
3.	Beecroft Road interchange	18 months
4.	Railway Bridge	15 months

All other construction work could be undertaken without exceeding the 260 $\mu g/m^3$ goal as described above.

5.0 METHODS USED TO PREDICT AIR QUALITY IMPACTS

5.1 Estimated Emissions

The major emissions from motor vehicles are carbon monoxide, oxides of nitrogen, hydrocarbons, and particulate matter. Estimation of these emission have been made using work undertaken by Pengilley (1989) and US EPA emission factors (US EPA 1985). Traffic flow data were provided by Denis Johnson & Associates for the different section of the proposed route. Appendix 6 details the methods used to calculate these emissions based on the breakdown into light and heavy vehicles and different fuels. The 2006 estimations for the western section of the three major options are presented in Table 5 and are expressed in kg/hour/kilometre. Estimations for 1996 and 2016 are presented in Appendix 7.

Values are for morning peak hour and are assumed to represent the "worst-case". Calculation of vehicle emissions at multiple points along the route showed that the route could be divided into sections over which the emission rate was constant and these are indicated in the table.

The relationships between vehicle speed and emission rates for the various pollutants are presented in graphical form in Appendix 3, Figures 2 to 4. Carbon monoxide and hydrocarbon emissions decrease with increasing speed whether or not the vehicle is fitted with catalytic converters. For oxides of nitrogen emissions the picture is a little more complicated. For vehicles not fitted with catalytic converters, oxides of nitrogen increase with speed. For vehicles fitted with converters, emissions decrease initially up to a speed of about 60 km/h and then start to increase at speeds above 80 km/h. It should be noted that the equations used to calculate these emission rates are only valid up to 90 km/h

TABLE 5

ESTIMATED VEHICLE EMISSIONS IN 2006

(Dispersion Model Output Data)
(kg/km/hour}

Roadway Section	OPTIONS				
	Expw'y (Toll)	Expw'y (No Toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Rd intersection to Beecroft Rd intersection, Epping					
CO	11.9	14.4	25.5	27.0	15.0
HC	1.5	1.8	3.3	3.5	1.9
NO_x	5.8	6.7	6.0	6.1	3.2
PM	0.26	0.30	0.34	0.35	0.19
Beecroft Rd intersection to Lane Cove Rd intersection, North Ryde					
CO	15.6	23.5	28.4	29.6	24.7
HC	1.9	2.9	3.6	3.7	3.2
NO_x	6.2	7.4	8.5	8.9	6.4
PM	0.29	0.38	0.44	0.46	0.34
Lane Cove Rd intersection to Epping Rd/Delhi Rd, East Ryde					
CO	12.3	12.2	41.8	41.5	54.3
HC	1.5	1.5	5.4	5.4	7.3
NO_x	5.9	5.7	10.1	9.9	9.9
PM	0.27	0.26	0.56	0.55	0.56

5.2 The AUSPLUME Model - Operational Phase

AUSPLUME is an advanced Gaussian dispersion model developed on behalf of the Victorian EPA (VEPA 1986). It is based on the United States Environmental Protection Agency's Industrial Source Complex (ISC) model. It has been improved to include the recommendations of the American Meteorological Society's expert panel on dispersion modelling which are outlined in a paper by Hanna et al (1977). It is widely used throughout Australia and is regarded as a "state of the art" regulatory model.

A full technical description of the model is provided in the user manual for the AUSPLUME (VEPA 1986). Some of its features include:

- allowance for effects of terrain on dispersion
- use of hourly meteorological data
- calculation of concentrations averaged over several time intervals,including minutes, hours, days, months and the entire period of the meteorological data.

In its present application AUSPLUME has been used to predict ground level concentrations of vehicle emissions up to one kilometre from the roadside.

5.3 The General Motors Dispersion Model - Operational Phase

A dispersion model has been used to estimate the concentration of carbon monoxide, oxides of nitrogen, hydrocarbons and particulate matter that are likely to be produced in the vicinity of the various route options during operation.

The dispersion model is referred to as the "General Motors Model" and was developed at the General Motors Research Laboratories and is fully described by Chock (1977). For completeness a mathematical description of the model is presented in Appendix 8.

Validation information presented by Chock indicates that the model, which was used to predict carbon monoxide concentrations, is capable of predicting to within plus or minus 20 % of measured values in slightly over 60 % of cases for distance from the road of up to 50 m, and to within a factor of two for 87 % of predictions.

The largest disagreement between predicted and measured concentrations involved an over-prediction by a factor of 9.2. The second largest disagreement involved an over-prediction by a factor of 5.0 and the third largest involved an over-prediction by a factor of 4.5.

The model has been used to predict CO concentrations in Sydney on at least one occasion (see Watson, 1983). In the study described by Watson it was reported that the model provided predictions that were within a factor of two on 92 percent of occasions. However, Watson claimed that if anything the model may have a tendency to under-predict for the middle-range of predicted concentrations, in his case in the range 7 to 20 mg/m^3.

The model has been used in this report to predict roadside concentrations of the pollutants associated with motor vehicles and has also been validated by comparing predicted concentrations based on traffic flow measurements with measured concentrations at designated sites along the route.

5.4 The DUSTGLC Model - Construction Phase

DUSTGLC is a Gaussian dispersion model used to predict the dispersion and deposition of dust emissions from mining and other earth-moving operations. It has been widely used in the Hunter Valley and has been validated in two studies (Dames & Moore, 1984).

5.5 Estimating Concentrations in Valleys and Gullies

Valleys and Gullies

One of the potential air pollution problems associated with the project is the build-up of pollutant concentrations in valleys under poor dispersion conditions, such as would occur at night or in the early morning. The eastern section of the proposed expressway passes through two valleys, one at Devlins Creek and the other at Terrys Creek. Pseudo-three dimensional representations of the topography in the region of these valleys are shown in Figure 6 and 7 respectively.

The area and topography used for the volume estimates are shown in Figures 8 and 9. The volume of the Devlins Creek valley is estimated to be 14,942,000 m^3. The volume of the Terrys Creek valley is estimated to be 16,390,000 m^3.

Measurements of very low wind speeds were made in the Terrys Creek Valley using a sonic anemometer. A description of the equipment used and the methods of making the measurements are presented in Appendix 9. The cumulative frequency distribution of wind speeds over one representative 24-hour period is shown in Figure 10. Approximately 73 % of winds were below 1 m/s.

FIGURE 6 THREE DIMENSIONAL REPRESENTATION OF THE STUDY AREA - DEVLINS CREEK

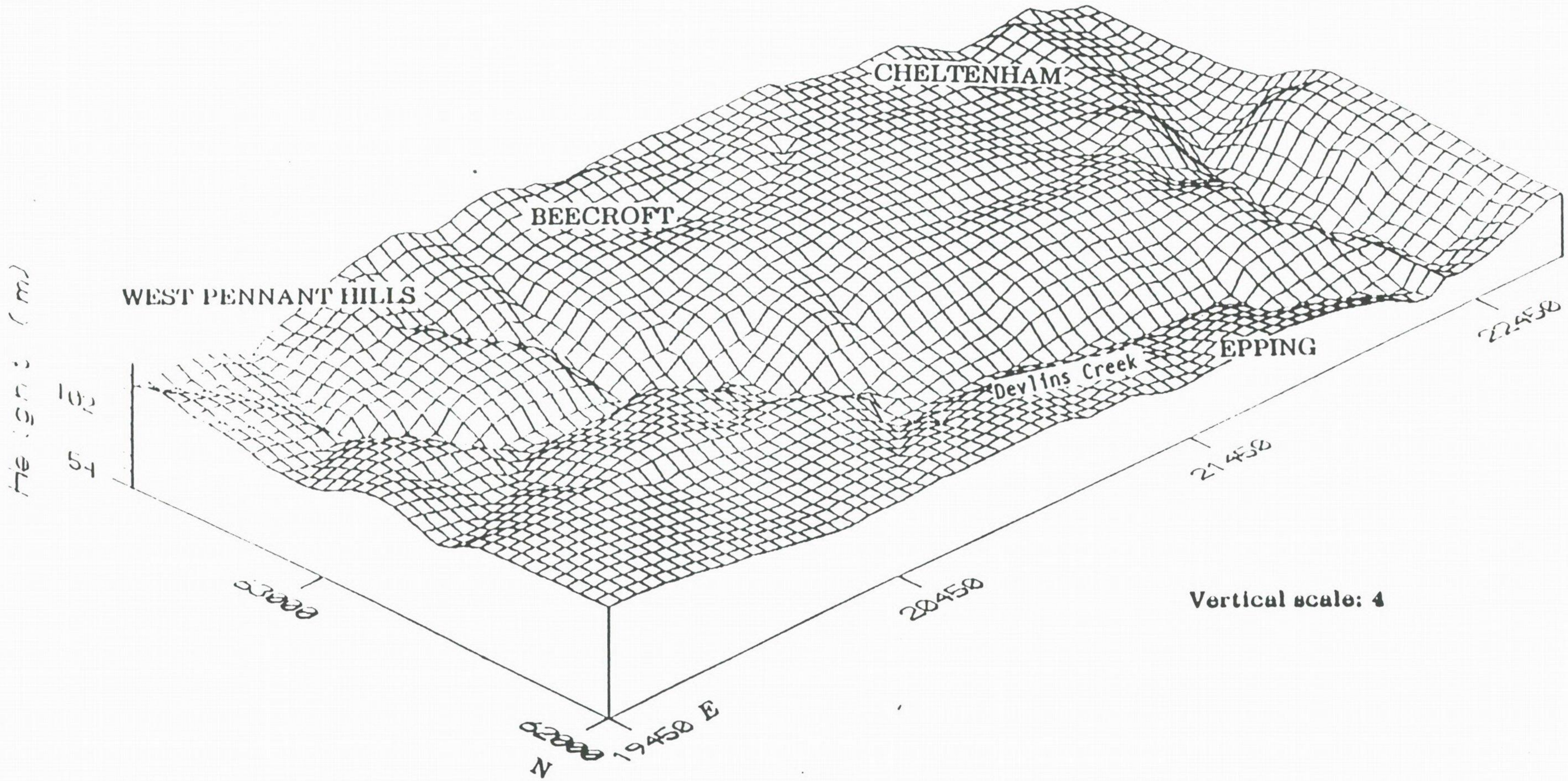


FIGURE 7 THREE DIMENSIONAL REPRESENTATION OF THE STUDY AREA - TERRYS CREEK

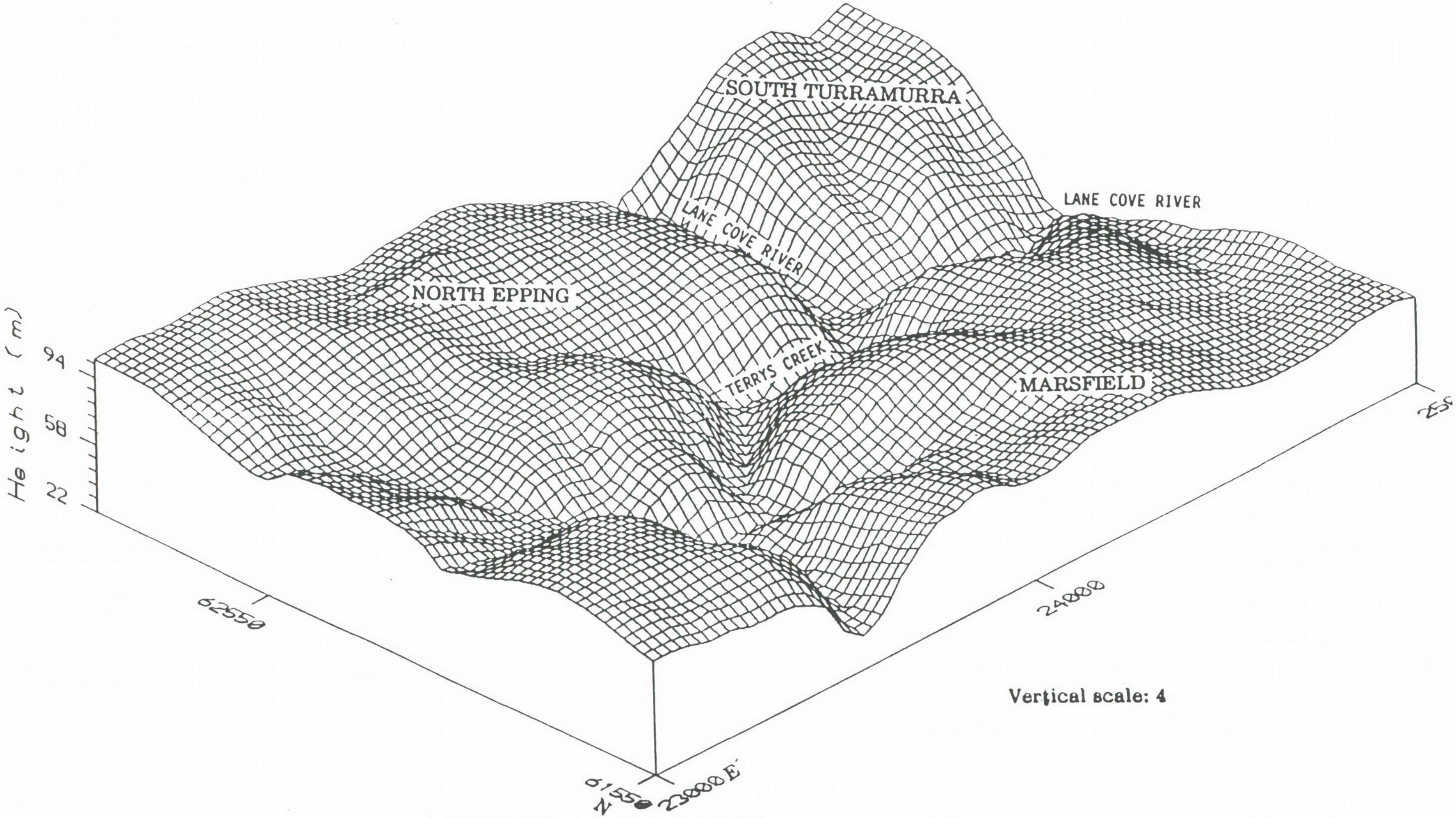


FIGURE 8 AREA AND TOPOGRAPHY USED FOR VOLUME ESTIMATES - DEVLINS CREEK

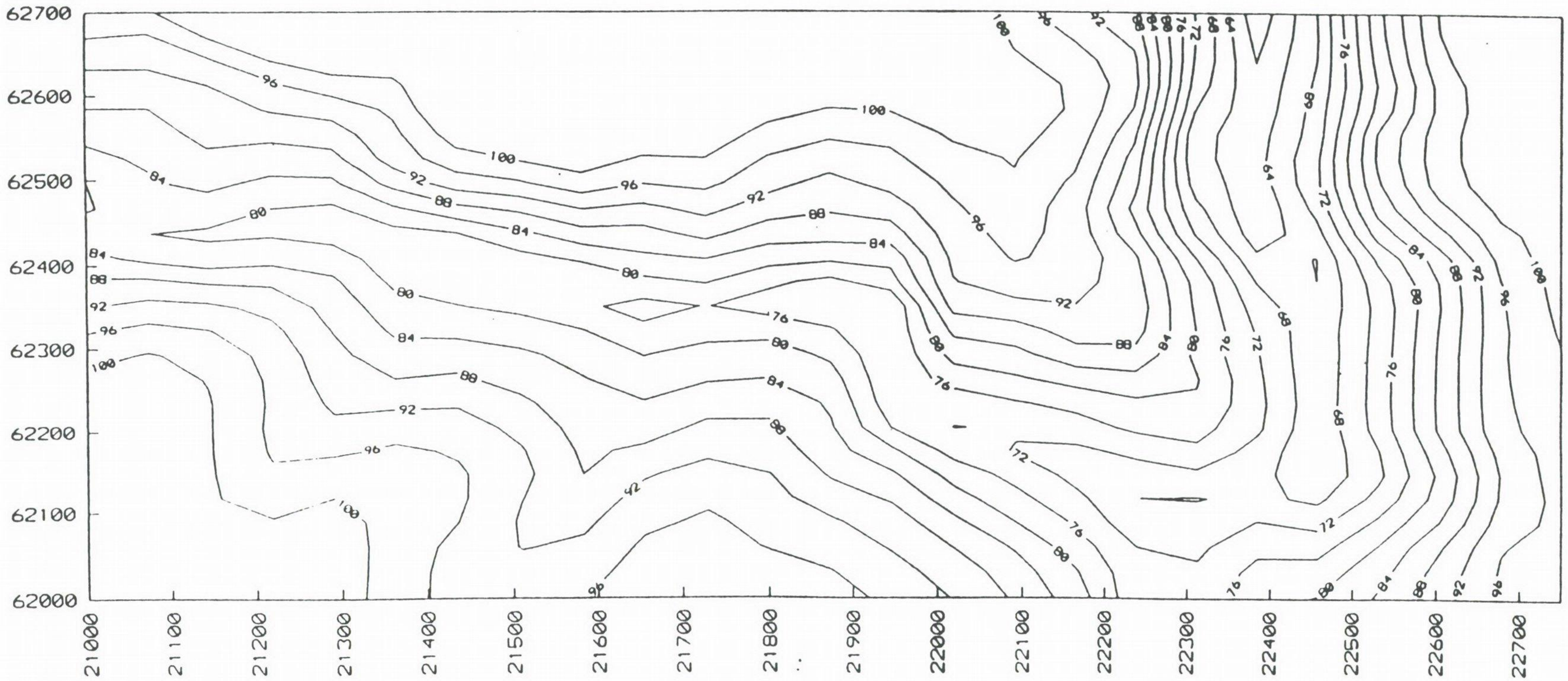


FIGURE 9 **AREA AND TOPOGRAPHY USED FOR VOLUME ESTIMATES - TERRYS CREEK**

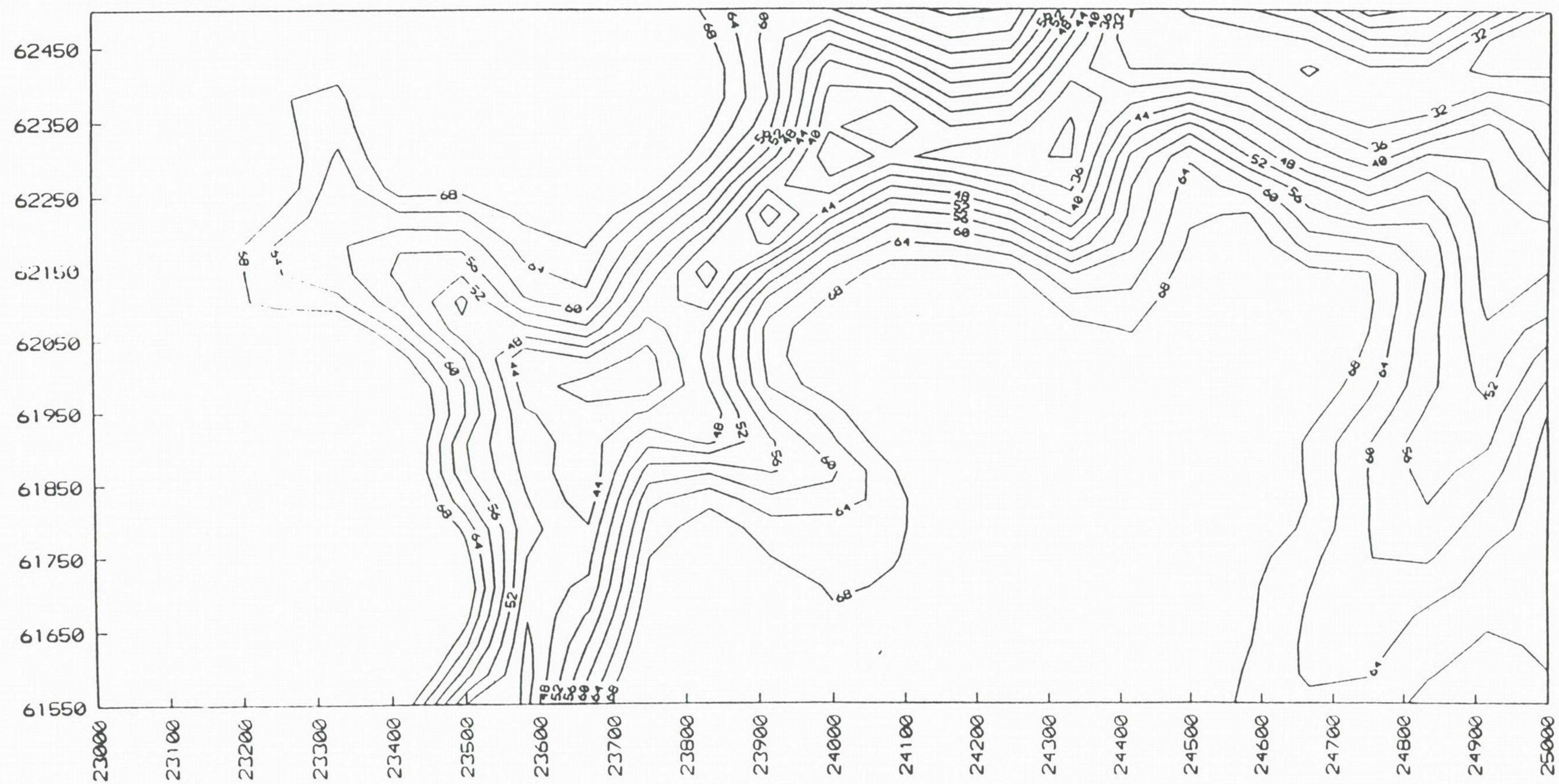
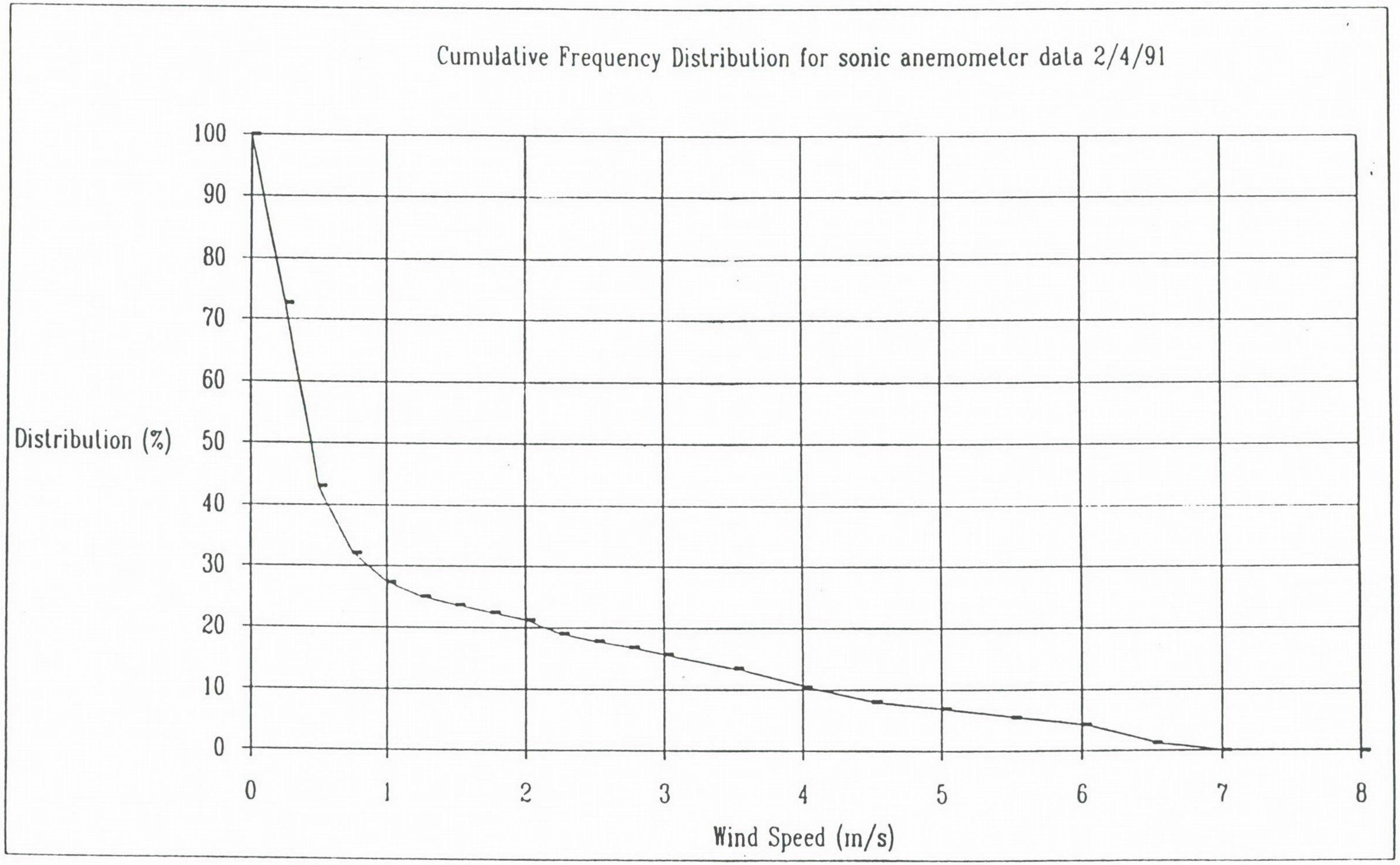


FIGURE 10



Cumulative Frequency Distribution for sonic anemometer data 2/4/91
Distribution (%)
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
Wind Speed (m/s)

The sonic anemometer studies indicate that on many occasions there is virtually no exchange of air in the valley overnight. During the day however, normal atmospheric turbulence would flush the pollutants out of the valley.

It is almost impossible to be precise about the build-up of pollutants overnight in these valleys, however a reasonable estimate can be made based on several conservative assumptions. Examination of traffic flow data shows that each hour of peak traffic constitutes approximately one twelfth of the total daily volume. If we assume that the overnight period encompasses the equivalent of six hours of peak traffic (about half the daily volume) and that there is about 20 % "leakage" of pollutants from the top of the valleys, then we can estimate the total emissions overnight emissions into the valleys. As only the expressway option passes through these valleys the expressway option emission rates for CO and NO_x along the relevant sections of the route (see Table 5) were used. Devlins Creek Valley is located in the first section of the route, that is between Pennant Hills road intersection and Beecroft Road intersection, Epping. Terrys Creek lies on the second section of the eastern expressway route, that is between the Beecroft Road intersection and Lane Cove Road intersection, North Ryde. The expressway route (with and without the 70 cent toll) were considered. Estimates of the concentrations in the two valleys are summarised in Table 6. The values at the end of the 12-hour period would represent the worst 1-hour average concentration. In the case of carbon monoxide which also has an 8-hour air quality goal, the average value over the last eight hours of the build-up period was estimated, assuming a linear increase in concentration over that time. It has been assumed that the percentage of NO_2 in the oxides of nitrogen mix is 35%.

TABLE 6 SUMMARY OF EMISSION CHARACTERISTICS IN VALLEY LOCATIONS

	DEVLINS CREEK		TERRYS CREEK	
Length of valley (km)	1.7		2.0	
Volume of valley (m^3)	14,492,000		16,392,000	
	$0.70 toll	no toll	$0.70 toll	no toll
Total CO emissions (kg)	97	118	150	226
Total NO_x emissions (kg)	47	55	60	71
Estimated CO concentration:				
at end of 12 hours	6.7	8.1	9.1	13.8
average over worst 8 hours (mg/m^{-3})	4.5	5.4	6.1	9.2
Estimated NO_x concentration:				
at end of 12 hours ($ug.m^{-3}$)	324	380	366	433
Estimated NO_2 concentration:				
at end of 12 hours (ug/m^{-3})	113	133	281	152

The two valleys are similar in terms of volumes and lengths, however Terrys Creek carries more traffic and consequently has higher predicted build-up of pollutants. For carbon monoxide the predicted values are well below the 1-hour average air quality goal of 31 mg/m^3 and do not exceed, albeit marginally in one case, the 8-hour average of 10 mg/m^3. However no allowance has been made for background concentration of carbon monoxide in these calculations. The use of the background is intended to account for pollutants in the air from other sources and provides an additional margin of safety to the assessment. Estimated background levels are discussed later in Section 6.0 and if the average measured background concentration of 4.8 mg/m^3 is added to the 8-hour average concentrations estimated in the valleys, the values would be close to the 8-hour goal in Devlins Creek and would exceed the goal in Terrys Creek. However it is unlikely that there would be any existing residences adversely affected by this air quality and motorists using the route would not be exposed for prolonged periods.

All predicted concentrations of nitrogen dioxide are well below the air quality goal of 300 $\mu g/m^3$.

Tunnels

There are two proposed tunnels in the eastern section, the longest of which connects the expressway option west of Epping through to Epping Road. An assessment of the build-up of carbon monoxide in this tunnel is taken as the worst case. It has been assumed that the tunnel is 1 km long 4 metres high and 10 metres wide. The volume is therefore estimated to be 40,000 cubic metres. Carbon monoxide emissions on this section of the route are estimated to be 28.4 kg/km/hour. Therefore the emission into the tunnel itself would be 28.4 kg/hour.

Therefore to maintain the concentration of CO in the tunnel at less than 31 mg/m^3 (1-hour goal) it will be necessary to have 17.5 changes of air per hour. This would require a ventilation velocity of 4.8 m/s at the portals assuming no other ventilation through the roof of the tunnel.

5.6 Evaluation of Performance of Models

As discussed in Section 5.1 the performance of the General Motors Model was evaluated by comparing predicted pollutant concentrations with measured values at selected sites along the route.

Measurements of ambient CO and NO_x were made at twelve sites as well as contemporaneous estimates of wind speed, wind direction and traffic statistics.

These data which are summarised in Appendix 4 were used as input into the General Motors model. Table 7 compares the predicted CO concentrations with the measured values and present other steps in the calculations of parameters required as input to the model.

TABLE 7

MODEL VALIDATION RESULTS

SITE	2N 12 Dec 1990	2S 12 Dec 1990	12E 12 Feb 1991	12E 12 Feb 1991	2N 11 Dec 1990	2S 11 Dec 1990	4E 13 Dec 1990	4W 13 Dec 1990
Cars (vehicles/hour)	1678	2968	3567	1326	1398	738	1344	900
Heavy Petrol (vehicles/hour)	36	77	63	71	156	93	125	174
Heavy Diesel (vehicles/hour)	21	21	45	24	3	3	18	47
Speed (km/h)	39	29	61	42	61	71	7.5	43
Wind speed (m/s)	1.2 SW	1.2 SW	calm 0.5	calm 0.5	1.5 variable	1.5 variable	0.27 E-SE	0.27 E-SW
Wind direction (degrees relative to road)	90	90	90	90	taken as 90	taken as 90	20	20
Assumed stability	Class 3 stable	Class 3 stable	Class 3 stable	Class 3 stable	Class 3 stable	Class 3 stable	Class 3 stable	Class 3 stable
CO emission rate (g/m/s)	0.006372	0.013820	0.010790	0.00503	0.002356	0.0002265	0.01360213	0.0025547
CO Predicted (measured) (mg/m^3)	9.8 (9.5)	wind SW 0.0 (10.3)	6.7 (0.1)	6.7 (7.7)	1.2 (8.3)	1.2 (8.1)	0.0 13.2	11.4 15.8

6.0 PREDICTED IMPACTS ON AIR QUALITY OF THE TRANSPORT OPTIONS

The results of the dispersion modelling runs for the three major transport options are summarised in Tables 8 to 12. The tables present the estimated maximum ground-level concentrations of carbon monoxide, hydrocarbons, oxides of nitrogen, nitrogen dioxide and particulate matter at a distance of 10 m from the roadside at selected points along the route. These calculations were carried out using the values in the emissions inventory (Table 5). It was assumed that 35 % of the oxides of nitrogen were in the form of NO_2.

Carbon Monoxide

The modelling results indicate that there is unlikely to be an adverse impact from carbon monoxide for any of the options being considered. All predicted roadside values are well below the 1-hour air quality goal of 31 mg/m^3 even when the estimated background level of 6.3 mg/m^3 is taken into account. It is interesting to note that the concentrations predicted for the expressway option are lower than measured values on equivalent roadways however the predicted levels do not take background levels into account and they are based on the assumption that all vehicles are fitted with catalytic converters. This substantially reduces carbon monoxide emissions; approximately by a factor of four.

The options with the worst air quality impact with respect to carbon monoxide concentrations are the arterial upgrade (East and West) and arterial upgrade (East only), particularly in the final section of the route from Lane Cove Road to Delhi Road.

There are two factors contributing to this effect.

TABLE 8 ESTIMATED MAXIMUM 1-HOUR CARBON MONOXIDE CONCENTRATION INCREASE - 2006 AT 10 m FROM ROAD SIDE FOR RANGE OF UPGRADE OPTIONS - (mg/m^{-3})

Roadway Section	Expw'y ($0.70 toll)	Expw'y (No toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Road intersection to Beecroft Road intersection, Epping	1.4	1.7	3.0	3.2	1.8
Beecroft Road intersection to Lane Cove Road intersection, North Ryde	1.9	2.8	3.4	3.6	3.0
Lane Cove Road to Epping Road/Delhi Road East Ryde	1.5	1.5	5.0	5.0	6.5

Expw'y ($0.70 toll)	Expressway ($0.70 toll) with public transport
Expw'y ($0.70 toll)	Expressway (No toll) with public transport
U.A.R. (East and West)	Upgraded arterial routes in both East and West
U.A.R. (East only)	Expressway in West to Pennant Hills Road and upgraded arterial route (Carlingford and Epping Roads) East of Pennant Hills Road
Base Case	No change to existing route system

TABLE 9 ESTIMATED MAXIMUM 1-HOUR HYDROCARBON CONCENTRATION INCREASE - 2006 AT 10 m FROM ROAD SIDE FOR RANGE OF UPGRADE OPTIONS - (mg/m-3)

Roadway Section	Expw'y ($0.70 toll)	Expw'y (No toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Road intersection to Beecroft Road intersection, Epping	0.18	0.21	0.40	0.42	0.23
Beecroft Road intersection to Lane Cove Road intersection, North Ryde	0.23	0.35	0.43	0.44	0.38
Lane Cove Road to Epping Road/Delhi Road East Ryde	0.18	0.18	0.65	0.65	0.88

Expw'y ($0.70 toll)	Expressway ($0.70 toll) with public transport
Expw'y ($0.70 toll)	Expressway (No toll) with public transport
U.A.R. (East & West)	Upgraded arterial routes
U.A.R. (East only)	Expressway in West to Pennant Hills Road and upgraded arterial route (Carlingford and Epping Roads) East of Pennant Hills Road
Base Case	No change to existing route system

TABLE 10 ESTIMATED MAXIMUM 1-HOUR OXIDES OF NITROGEN CONCENTRATION INCREASE - 2006 AT 10 m FROM ROAD SIDE FOR RANGE OF UPGRADE OPTIONS - (ug/m^{-3})

Roadway Section	Expw'y ($0.70 toll)	Expw'y (No toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Road intersection to Beecroft Road intersection, Epping	697	804	720	733	384
Beecroft Road intersection to Lane Cove Road intersection, North Ryde	745	888	1020	1068	768
Lane Cove Road to Epping Road/Delhi Road East Ryde	709	684	1212	1188	1188

Expw'y ($0.70 toll)	Expressway ($0.70 toll) with public transport
Expw'y ($0.70 toll)	Expressway (No toll) with public transport
U.A.R. (East & West)	Upgraded arterial routes for East and West
U.A.R. (East only)	Expressway in West to Pennant Hills Road and upgraded arterial route (Carlingford and Epping Roads) East of Pennant Hills Road
Base Case	No changes to existing route system

TABLE 11 ESTIMATED MAXIMUM 1-HOUR NITROGEN DIOXIDE CONCENTRATION INCREASE - 2006 AT 10 m FROM ROAD SIDE FOR RANGE OF UPGRADE OPTIONS - (ug/m_{-}^{3})

Roadway Section	Expw'y ($0.70 toll)	Expw'y (No toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Road intersection to Beecroft Road intersection, Epping	244	281	252	257	134
Beecroft Road intersection to Lane Cove Road intersection, North Ryde	261	311	357	374	269
Lane Cove Road to Epping Road/Delhi Road East Ryde	248	239	424	416	416

Expw'y ($0.70 toll)	Expressway ($0.70 toll) with public transport
Expw'y ($0.70 toll)	Expressway (No toll) with public transport
U.A.R. (East and West)	Upgraded arterial routes for East and West
U.A.R. (East only)	Expressway in West to Pennant Hills Road and upgraded arterial route (Carlingford and Epping Roads) East of Pennant Hills Road
Base Case	No changes to existing route system

TABLE 12 ESTIMATED MAXIMUM 1-HOUR PARTICULATE CONCENTRATION INCREASE - 2006 AT 10 m FROM ROAD SIDE FOR RANGE OF UPGRADE OPTIONS - (ug/m^{-3})

Roadway Section	Expw'y ($0.70 toll)	Expw'y (No toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Road intersection to Beecroft Road intersection, Epping	31	36	41	42	23
Beecroft Road intersection to Lane Cove Road intersection, North Ryde	35	46	53	55	41
Lane Cove Road to Epping Road/Delhi Road East Ryde	32	31	67	66	67

Expw'y ($0.70 toll)	Expressway ($0.70 toll) with public transport
Expw'y ($0.70 toll)	Expressway (No toll) with public transport
U.A.R. (East only)	Upgraded arterial routes for East and West
U.A.R. (East & West)	Expressway in West to Pennant Hills Road and upgraded arterial route (Carlingford and Epping Roads) East of Pennant Hills Road
Base Case	No changes to existing route system

Firstly the expressway option splits the traffic between the expressway and the major arterial routes resulting in lower traffic volumes on each road. The arterial upgrade options carry most of the traffic on the arterial roads resulting in higher emissions compared to the expressway options. The secondary effect of greater vehicle numbers is to slow the traffic down on the arterial routes relative to the expressway. As indicated in section 3.0 this results in higher emissions of carbon monoxide, particularly by the time that the traffic has reached the end of the eastern section of the arterial roads. This is most marked for the base case where the predicted carbon monoxide concentration is more than four times that predicted for the expressway.

The second section of the route shows a marked difference between the concentrations on the expressway depending on whether or not there is a toll. The increased carbon monoxide concentrations on the route with no toll arise from a combination of a greater number of vehicles and slower speed.

Hydrocarbons

As discussed in Section 2.2, the US EPA air quality goal for non-methane hydrocarbons has been discontinued because of its lack of specificity for the reactive species which contribute to photochemical smog. However hydrocarbon emissions and predicted concentrations have been considered in this report, as they are relevant to the air quality issues being considered.

Values exceeding the former US EPA limit were predicted for all options, however the Expressway with a 70 cent toll had substantially lower predicted concentrations than either of the arterial options, East and West being the worst.

Monitoring data from the Sydney Region (see section 2.3) indicate that ambient hydrocarbon concentrations are quite high.

The trends in hydrocarbon concentrations closely resemble the pattern of carbon monoxide distributions, reflecting the similarity in the effect of speed on emission rates.

Oxides of nitrogen

As discussed earlier there are no air quality standards for total NO_x, therefore it has been necessary to estimate the proportion of NO_2 in the nitrogen oxide emissions. This proportion increases with time and in general, measurements made close to the source show a low percentage of NO_2, of the order of 5-20%. As the emissions disperse, the total oxides of nitrogen concentration decreases while the proportion of NO_2 increases and can be as high as 70%, although an average value, based on Sydney Region monitoring data would be between 30 and 40 %.

In the situation considered in this report, the predicted concentrations are reasonably close to the source, and it has been assumed that the proportion of NO_2 is 35%. This is a reasonably conservative assumption. Nevertheless, the predicted levels of NO_2 are close to the 1-hour goal and are indicative of the long-term air quality problems in the Sydney Region. The estimated background level of approximately 36 $\mu g/m^3$ for NO_x and hence approximately 13 $\mu g/m^3$ for NO_2 does not make a very substantial difference to the predicted values. The expressway option with a 70 cent toll is predicted to have the lowest impact and the upgraded arterial routes the worst depending on the section of the road.

This again is a consequence of the fact that the expressway option splits the traffic between the expressway and the arterial roads.

For the arterial upgrade options the greater traffic volume relative to the expressway results in higher roadside concentrations for the arterial routes particularly in the final section.

Particulate Matter

Table 12 presents the maximum predicted 1-hour average concentrations of particulate matter arising from motor vehicle emissions. Values for all sections of each option are well below the 24-hour goal and it concluded that there will be no adverse air quality impact from particulate matter.

6.1 Dispersion of Pollutants

Figures 11 and 12 present contour plots of the predicted one-hour average increases in carbon monoxide and nitrogen dioxide concentrations in the vicinity of the expressway route (no toll) assuming unfavourable dispersion conditions, namely a wind speed of 0.5 m/s and stable atmospheric conditions. While these plots are helpful in illustrating the dispersion of pollutants, they do not provide useful information on the maximum predicted roadside concentrations. These have been presented in tabular form and the results of modelling runs for the three major transport options and the base case are summarised in Tables 8 to 12.

The tables present the maximum predicted increase in ground-level concentrations of carbon monoxide, hydrocarbons, oxides of nitrogen, nitrogen dioxide and particulate matter at a distance of 10 m from the roadside at selected points along the route. These calculations were carried out using the emission rates given in Table 1. It was conservatively assumed that 35 % of the oxides of nitrogen were in the form of NO_2.

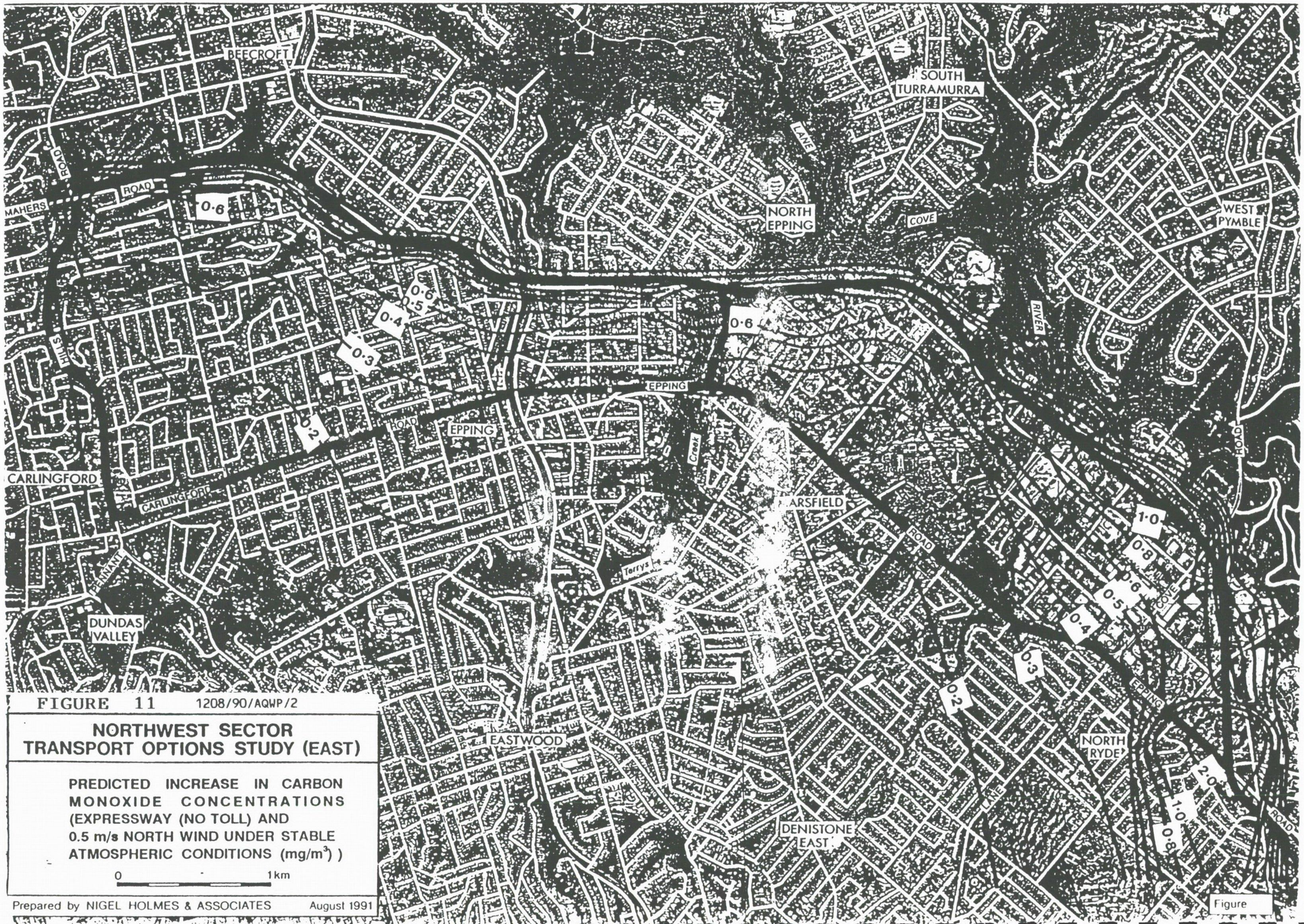


FIGURE 11 1208/90/AQWP/2

NORTHWEST SECTOR TRANSPORT OPTIONS STUDY (EAST)

PREDICTED INCREASE IN CARBON MONOXIDE CONCENTRATIONS (EXPRESSWAY (NO TOLL) AND 0.5 m/s NORTH WIND UNDER STABLE ATMOSPHERIC CONDITIONS (mg/m^3))

0 1km

Prepared by NIGEL HOLMES & ASSOCIATES August 1991

Figure

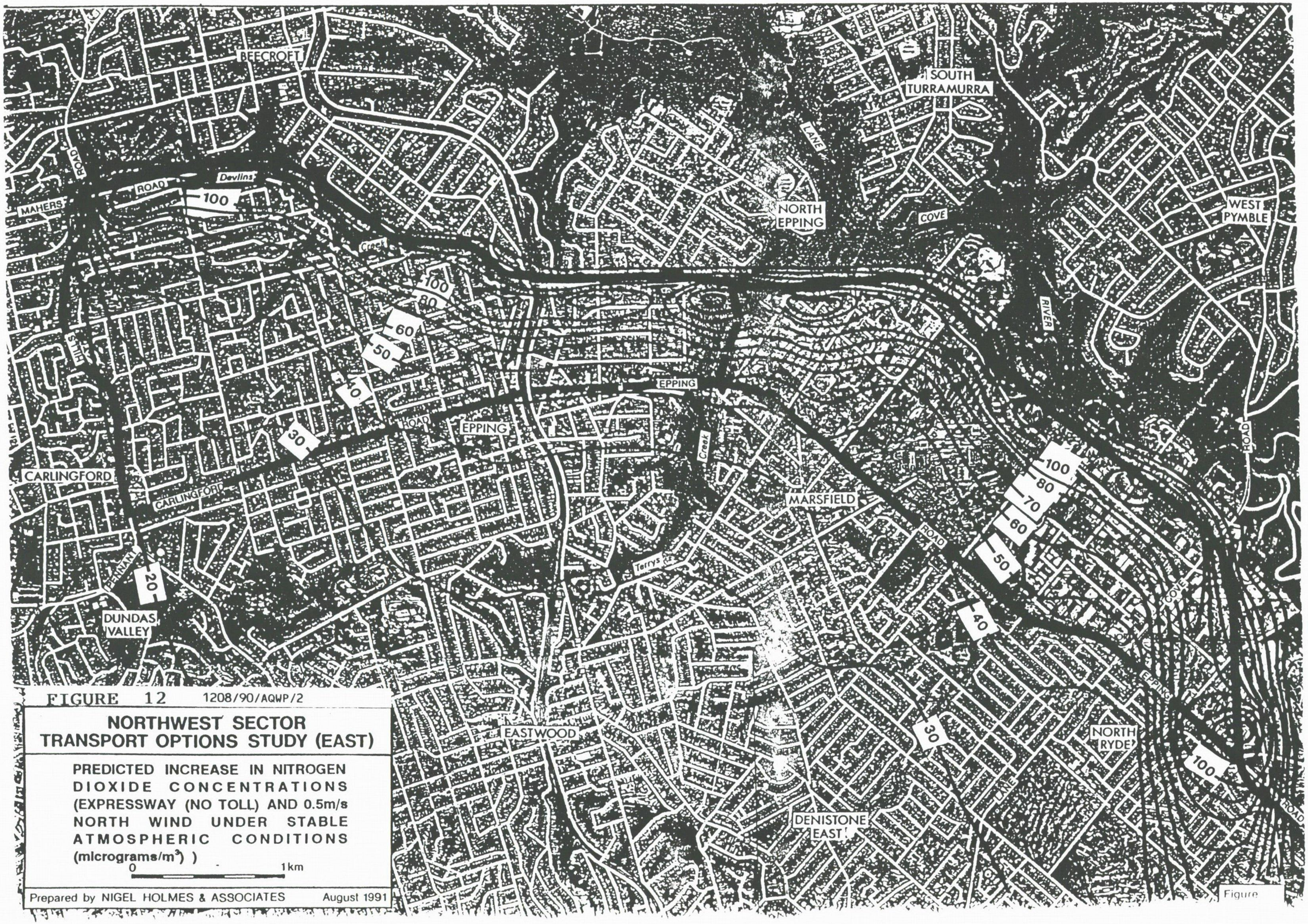
FIGURE 12 1208/90/AQWP/2

NORTHWEST SECTOR TRANSPORT OPTIONS STUDY (EAST)

PREDICTED INCREASE IN NITROGEN DIOXIDE CONCENTRATIONS (EXPRESSWAY (NO TOLL) AND 0.5m/s NORTH WIND UNDER STABLE ATMOSPHERIC CONDITIONS (micrograms/m^3))

0 1km

Prepared by NIGEL HOLMES & ASSOCIATES August 1991



It should be noted that the values in the tables represent increases in concentrations above background levels. The major source of background carbon monoxide would be from vehicles on other roads while background oxides of nitrogen, hydrocarbons and particulate matter would come from a range of sources including vehicles on other roadways and industrial emissions. Measurements of carbon monoxide and oxides of nitrogen concentrations were made specifically to address this issue at a selected site (site 6) well removed from major roadways or industrial sources (Appendix 4 and 5). The mean and standard deviation of six measurements of carbon monoxide was 4.8 $\pm$ 1.5 mg/m^3 and of oxides of nitrogen was 23 $\pm$ 13 μg/m^3. If a Gaussian distribution is assumed then two thirds of values will lie within one standard deviation on either side of the mean. A conservative value for the average background concentrations would then be 6.3 mg/m^3 for carbon monoxide and 36 μg/m^3 for nitrogen dioxide.

6.2 Assessment of Air Pollution Impact from Toll Plazas

6.2.1 Introduction

This sub-section assesses air pollution impacts from the Toll Plazas that is proposed to be located between Colloden and Balaclava Roads near the Macquarie University Graduate School of Management of the proposed expressway development between Pennant Hills Road and Delhi Road. The assessment considers the following points:-

1. The emissions expected from vehicles paying the toll;
2. The dispersion meteorology of the areas proposed for toll plazas, and;
3. The expected ground-level concentration of emissions.

The assessment is based on "worst-case" assumptions, which assume that all vehicles pay the toll at the same area and that maximum traffic flow rates apply. The assessment also assumes very unfavourable dispersion conditions.

6.2.2 Estimates of Emissions in Toll Plaza Areas

Emissions from vehicles using the Toll Plaza will be different from those from vehicles using the free flowing portions of the expressway. The difference arises from the slower speeds that vehicles will travel at in the vicinity of the toll booths. Unfortunately there are no data that can be used to calculate emissions in the acceleration/deceleration phase of vehicle usage. The US EPA (1985) emission factor formula for motor vehicle are for a standard driving cycle and relate to an "average" pattern of use, which includes speed changes, but does not provide data solely for the acceleration phase.

It is a research recommendation made at a recent meeting of the Air and Waste Management Association that these data be collected (see Wilson and Ripberger, 1990), but to date no data dealing with this specific aspect of the driving cycle are available.

In the absence of detailed information on emissions in the acceleration/deceleration mode the assessment approach has been to make use of the emission factors published by Pengilley (1989). These have been used in other parts of the assessment to estimate emissions under cruise conditions. They allow emissions to be estimated for various cruise speeds using formulae which are set out in Appendix 6.

Thus for the estimates to be realistic it will be necessary that any underestimates in emissions that might occur in the acceleration phase will be compensated for by overestimates in the deceleration phase. This is not unreasonable since the emission factors relate to vehicle usage that includes acceleration and deceleration.
In the assessment it has been assumed that vehicles approach the toll booths and commence deceleration approximately 200 m before the booth is reached. The vehicle is assumed to decelerate uniformly from 80 km/h to 0 km/h. The vehicle is then assumed to accelerate uniformly from the toll booth and to reach a speed of 80 km/h at 300 m from the booth.

Estimates of the emission rates of carbon monoxide from light duty petrol vehicles, heavy duty petrol vehicles and heavy duty diesel vehicles have been calculated assuming the above scenario at 20 m increments in the section of road from 200 m before the toll booths to 300 m after the booths. The total estimated carbon monoxide emission from traffic in the 500 m road section affected by the tolling activity (assuming the peak hour traffic flow of 11,069 EB and 1546 WB vehicles for the "worst-case" Expressway Option) would be 33.3 kg over two hours or 0.0093 g/s/m.

6.2.3 CONCLUSION: Worst-Case Meteorological Conditions and Expected Roadside Concentrations

No site specific meteorological data are available for the proposed toll plaza areas. However the areas are reasonably well exposed and it is unlikely that winds would average less than 0.2 m/s for more than an hour or so at the times of peak hour traffic flow at these sites.

Thus a reasonable "worst-case" dispersion condition would be 0.2 m/s winds with stable air. Under these unfavourable dispersion conditions, stable air with 0.2 m/s wind blowing across the road/toll area, the estimated emission rate of 0.0093 g/s/m could be expected to give rise to carbon monoxide ground-level concentrations at the kerbside of approximately 6.6 mg/m^3, which is below the NSW EPA's criterion of 31.3 mg/m^3 (25 ppm) 1-hour average and also below the 8-hour limit of 11.2 mg/m^3 (9 ppm). Concen-trations within the toll booth area would be expected to be marginally higher than these.

If an estimated background of 6.3 mg/m^3 is added to these predicted concentrations then kerbside concentrations would be 12.9 mg/m^3 (1-hour average), which again is below the NSW EPA's 1-hour goal. No data have been provided for 8-hour traffic flows through the toll areas, but with predicted 1-hour average carbon monoxide concentrations being less than the 8-hour criterion it is unlikely that the 8-hour goal would be exceeded. Indeed the background level would have to be almost as high as the predicted 1-hour "worst-case" concentration before the NSW EPA's 8-hour goal would be exceeded.

7.0 SAFEGUARDS TO MINIMISE IMPACTS ON AIR QUALITY

Once a preferred transport option has been established, an ongoing monitoring programme could be undertaken to ensure pollutant levels correlate to those predicted by this study. This monitoring programme could involve one or two fixed monitoring stations located within the study region. The precise location of these sites would have to be established by the relevant interested parties, probably the SPCC, the soon to be formed NSW Environment Protection Agency (EPA), local government and community groups.

7.1 Technological Changes

This study has been based on the premise that average individual vehicle emissions will significantly decrease while overall vehicle numbers increase to the year 2006. Thus the total mass emission rate from the transport options will not increase in direct proportion to the increase in vehicle numbers as this will be balanced by a decrease in individual vehicle emissions. Refer discussion in Section 1.4.

By the year 2006, almost all light vehicles will be fuelled by unleaded petrol, further reducing lead emission levels. Also, most vehicles will have three way catalysts as a design feature which will significantly reduce NO_x emissions. These reductions are almost certain and have been incorporated into this study according to current trends. Additional emission reductions could be possible with the development of alternative fuel sources such as dual fuel bases (e.g. diesel/ electric), ethanol, electricity or Hydrogen, or with stricter government emission regulations. Due to the current unpredictable progress of these developments, it was not practical to account for them in the predictions for this study.

Therefore in terms of absolute air quality an increase in vehicle numbers will probably be countered by the reduction in vehicle emission. Based on current predictions of vehicle numbers and mix in 2006, this factor has been incorporated into the modelling component of this study to a degree. However it could reasonably be expected that further emission reductions may be implemented which would further reduce overall vehicle emissions, and consequently roadside pollutant concentrations.

7.2 Construction Safeguards

The following safeguards are proposed to minimise dust emissions during the construction phase of this project:-

- Construction requirements in the specifications would include provision for the works to be kept clean and tidy as they proceed and dust suppression measures would be taken as required.

- Dust suppression will incorporate methods of best practice in the construction industry which will include watering of all haul roads and unsealed trafficked areas - water sprays during dozing, final grading and, where appropriate, excavation.
  - Increased volume water sprays during scraper operations.
  - Direct spraying of bitumen on unsealed surfaces to limit dust emissions.

- A wheel wash will operate for trucks leaving the construction zone. All loaded tip trucks will be tarped.

- The major earthworks construction zone will be a moving dust source which will only affect any given location along the route for a limited time during construction of the upgraded arterial road but for a period up to 60 working days during construction of the expressway.

- Given that the major dust impacts are temporary, it is considered that the dust emissions will be accepted by the public in the same way that temporary inconveniences are accepted in other circumstances, many of which are related to construction of one type or another.

- If the meteorological conditions are total unsatisfactory, then the appropriate safeguard will be to cease operations until conditions improve.

- Diesel exhaust emissions are unlikely to cause any significant impact during construction.

- All disturbed areas would be revegetated immediately after completion of the earthworks.

8.0 CONCLUSIONS

This air quality working paper has been concerned with the air quality impacts of the proposed changes to the transport system in the North West Sector of Sydney. It specifically addresses impacts in the eastern section of the proposed route, but where appropriate impacts in the western section have been taken into consideration. Three computer-based models have been used to assess the dispersion of pollutants associated with the project. The Gaussian dispersion model DUSTGLC was used to determine dust impacts during the construction phase. The General Motors model was used to predict roadside ground-level concentrations of carbon monoxide, hydrocarbons, oxides of nitrogen and particulate matter arising from traffic using the roads. AUSPLUME was used to predict concentrations up to one kilometre from the roadside.

It is concluded that during construction the dust impacts will typically be limited to a distance of 200 to 300 metres from the centre of the construction area. This effect will of course be temporary in nature. Some impacts, under worst case conditions, may be observed up to 600 metres from the centre of the construction area. The SPCC 24 hour (average) limit of 260 $\mu g/m^3$ would be exceeded in these circumstances. However, in practice, the area in which this limit is likely to be exceeded will probably be less than 50m.

Fundamental to the understanding of the analysis presented in this report are the six curves presented in Appendix 3, Figures 2 to 4. These show how the emission rates of carbon monoxide, hydrocarbons and oxides of nitrogen vary with speed for vehicles fitted with different emission controls. As discussed in Section 5.1, both hydrocarbon and carbon monoxide emissions decrease with increasing speed while oxides of nitrogen emissions gradually increase.

Therefore any change in the road system which facilitates an increase in traffic speed will reduce the total emissions of carbon monoxide and hydrocarbons but may increase oxides of nitrogen emissions. This of course assumes, perhaps unrealistically, that the change in traffic route options does not induce more traffic. In addition, the replacement of a distributed road network with a single high capacity road such as an upgraded arterial route or an expressway will concentrate the emissions along a single route and this may lead to a worsening of local air quality while still reducing overall emissions into the Sydney Basin regional airshed.

The results of the modelling runs to predict traffic exhaust impacts indicate that the expressway option will result in the least adverse local air quality impact. In addition, because of improved traffic flow, total emissions of carbon monoxide and hydrocarbons should be less. This is a consequence of the fact that the presence of an expressway provides two main routes to disperse the traffic. This contrasts with the situation in the west where the presence of an upgraded road system either arterial or expressway, tends to concentrate the traffic.

Roadside carbon monoxide emissions are predicted to be well below air quality goals; however, they are significantly lower for the expressway option. Nitrogen dioxide levels are predicted to exceed air quality goals for the arterial upgrade options particularly towards the end of the route.

This is also the case if no changes were made to the existing road system. Concentrations of hydrocarbons are predicted to exceed the former USEPA air quality goal which is still published by the SPCC as an air quality objective but, as discussed in Section 2.2, may no longer be applicable.

However, it is relevant to consider which option results in the lowest hydrocarbon concentrations and again this is the expressway.

Predicted concentrations of particulate matter are well below air quality goals and there are unlikely to be adverse impacts from particulate matter arising from vehicle exhaust emissions.

The potential build-up of pollutants in gullies and valleys under poor dispersion conditions was also assessed. It was concluded that although there could be a significant increase in concentrations of carbon monoxide and oxides of nitrogen overnight there was unlikely to be any adverse effects at residences or on motorists using the roads at these times.

It is clear from a local ambient air quality point of view that an expressway with no increase in motor vehicles in the region is the most desirable option. In addition, total emissions of carbon monoxide and hydrocarbons into the Sydney airshed will be decreased due to improved traffic flow but this may be offset by some increase in oxides of nitrogen emissions. However, all of the above comments must be considered against the fact that an upgraded road system will have the capacity to carry more traffic and may in time become saturated with low resultant traffic speeds and this initial benefit may be lost. The ideal approach is to preserve the road network in an uncongested state and this requires a matching of road systems to the community's needs for transport. The location of people's residences close to their place of work and viable public transport options are clearly important factors to be considered in the overall plan to upgrade the transport system.

8.1 Summary of Conclusions

Hence, in summary the overall conclusions of this air quality study are:

- This transport link will have minimal, if any, increased impact on regional air quality. Refer Figures 7 and 8.

- The incorporation of a public transport component in the link may facilitate in reducing the number of mobile emission sources in the Sydney Basin air pollution region.

- The impact of dust emissions during construction would typically be limited to a distance of 200 to 300 metres from the centre of the construction area. This effect will be of a temporary nature and in practice the area of impact of dust deposition will most likely be less than 50m.

- The major impacts on air quality would be expected as local impacts, that is within tens of metres from the road kerbside. These local impacts are outlined in Tables 8 to 12 and summarised in Table 13.

- The predicted kerbside particulate matter and carbon monoxide emission concentrations within 10 m of kerbside in the year 2006 are expected to comply readily with existing ambient air quality criteria.

- The predicted hydrocarbon concentrations within 10 m of the kerbside in the ambient atmosphere are expected to exceed the photochemical smog air quality standard. It should be noted that this is an indicative standard and not a health standard.

TABLE 13 SUMMARY OF PREDICTED POLLUTANT CONCENTRATIONS IN 2006

* - mg/m^3 + - $\mu g/m^3$

Roadway Section	OPTIONS				
	Expw'y (Toll)	Expw'y (No Toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Rd intersection to Beecroft Rd intersection, Epping					
CO *	1.4	1.7	3.0	3.2	1.8
HC *	0.18	0.21	0.40	0.42	0.23
NO_x +	697	804	720	733	384
NO_2 +	244	281	252	257	134
PM^+	31	36	41	42	23
Beecroft Rd intersection to Lane Cove Rd intersection, North Ryde					
CO *	1.9	2.8	3.4	3.6	3.0
HC *	0.23	0.35	0.43	0.44	0.38
NO_x +	745	888	1020	1068	768
NO_2 +	261	311	357	374	269
PM^+	35	46	53	55	41
Lane Cove Rd intersection to Epping Rd/Delhi Rd, East Ryde					
CO *	1.5	1.5	5.0	5.0	6.5
HC *	0.18	0.18	0.65	0.65	0.88
NO_x +	709	684	1212	1188	1188
NO_2 +	248	239	424	416	416
PM^+	32	31	67	66	67

- The predicted nitrogen dioxide concentration within 10 m of kerbside however will tend to increase to be marginally below the existing ambient air quality standard. These predicted NO_2 levels are based on the conservative estimation that 35% of the total NO_x is NO_2. In fact, the proportion of NO_2 at kerbside may be substantially lower.

- In terms of route alternatives, the difference in air quality impact terms would be marginal. However, the results of the modelling runs to predict traffic exhaust impacts indicate that the expressway option will result in the least adverse local air quality impact, that is, impact on local residents. In addition, because of improved traffic flow, total emissions of carbon monoxide and hydrocarbons should be less. This is a consequence of the fact that the presence of an expressway provides an additional arterial route to facilitate initial dispersion of the traffic density.

- Although there could be an increase in concentrations of carbon monoxide and oxides of nitrogen overnight, under poor dispersion conditions, there was unlikely to be any adverse effects on residents, or on motorists using the roads at these times.

- Construction impacts will mainly be dust emissions from movement of vehicles on unsealed surfaces and associated earthmoving equipment. Best practice dust suppression will be practised on all haul roads and unsealed access roads. Water sprays will be used during dozing and final grading and, where practicable, excavation and scraper operation. Surface spraying of bitumen on unsealed surfaces and haul roads may also be practiced. If meteorological conditions are totally unfavourable, then construction work would cease until conditions improved.

Typically the dust impacted area will be 200-300 metres from the construction zone emission point and each area will generally only be for a limited time during each phase of the road construction. In terms of expressway construction this period of major earthworks may extend to 60 working days at any specific locations.

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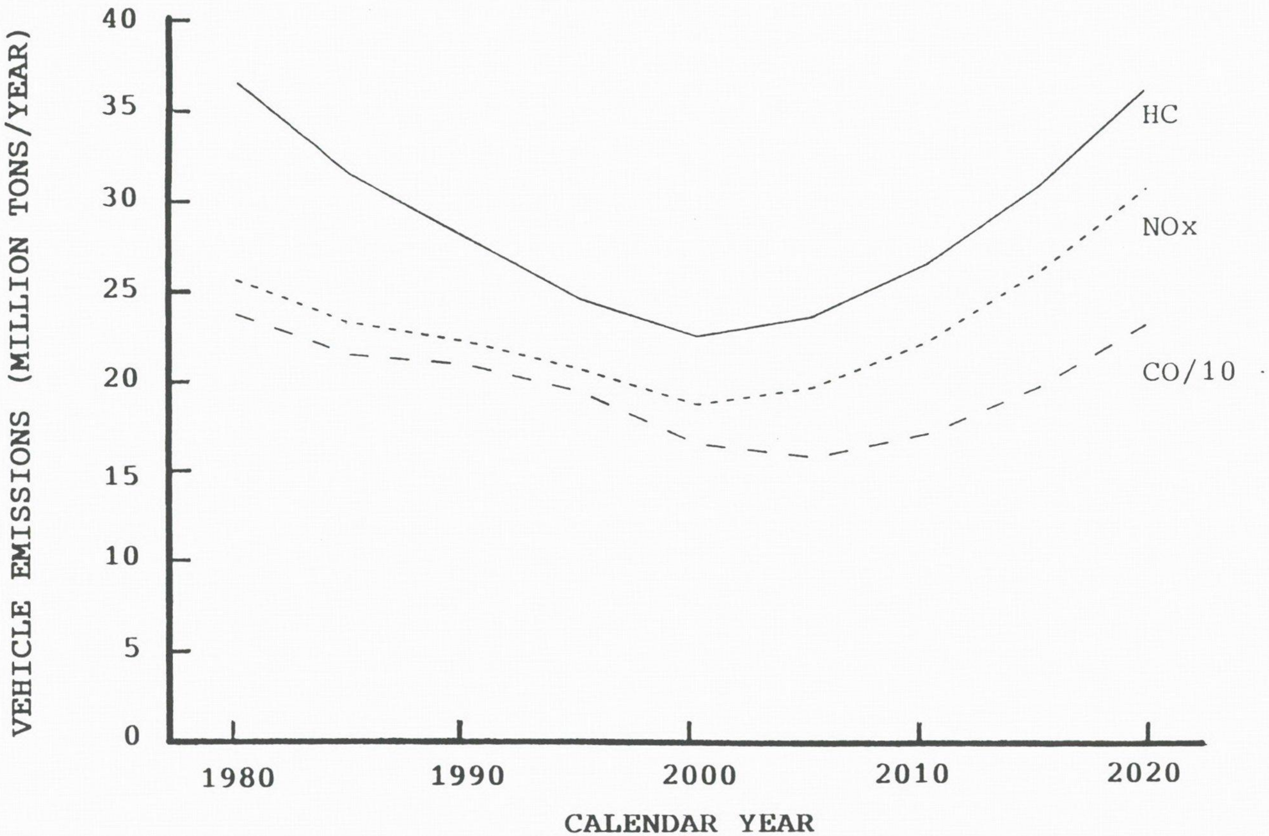
APPENDIX O

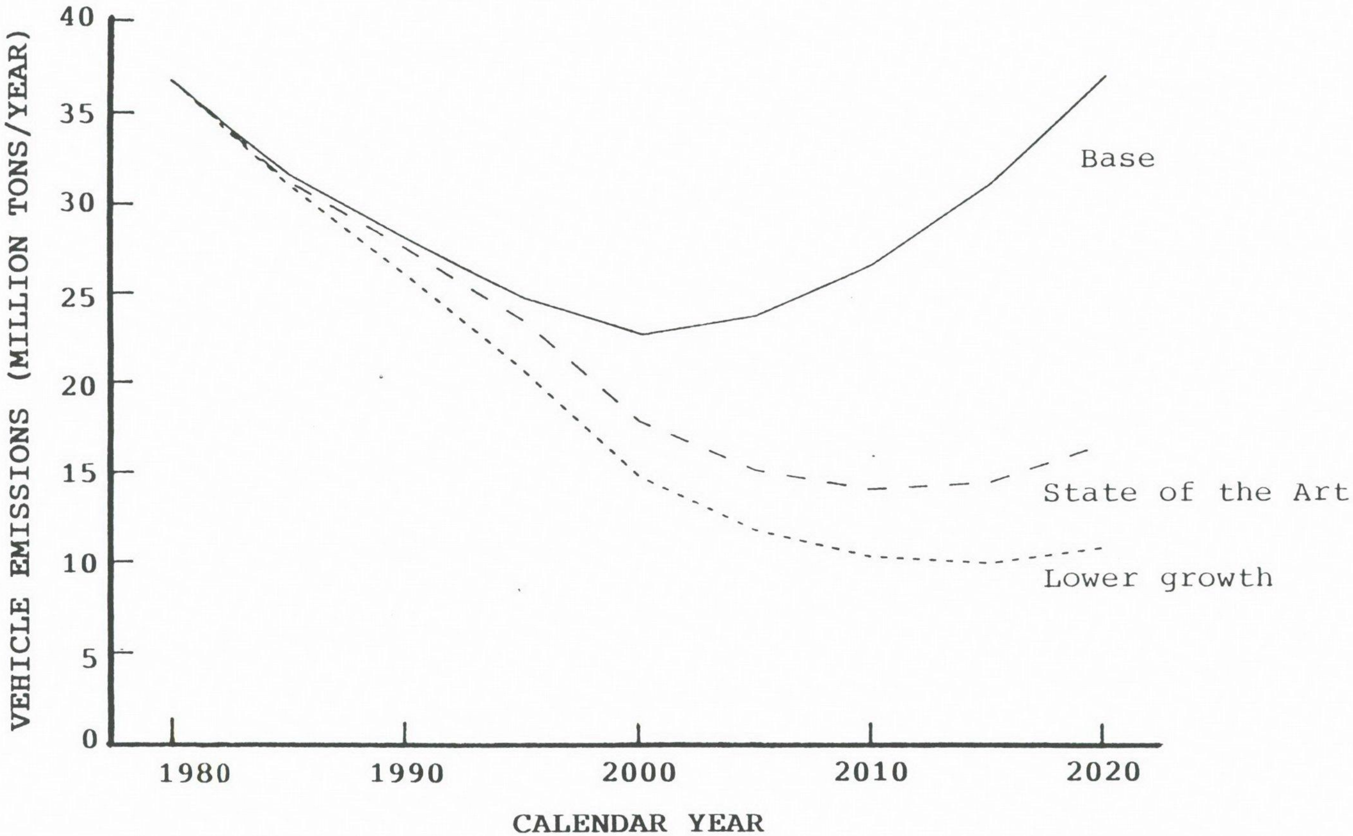
Greenhouse Data

FIGURE 1 **TRENDS IN VEHICLE EMISSIONS OF HC, CO, AND NO_x AS A RESULT OF THE PROJECTION OF CURRENTLY ADOPTED REQUIREMENTS (for CO, multiply vertical scale by 10)**



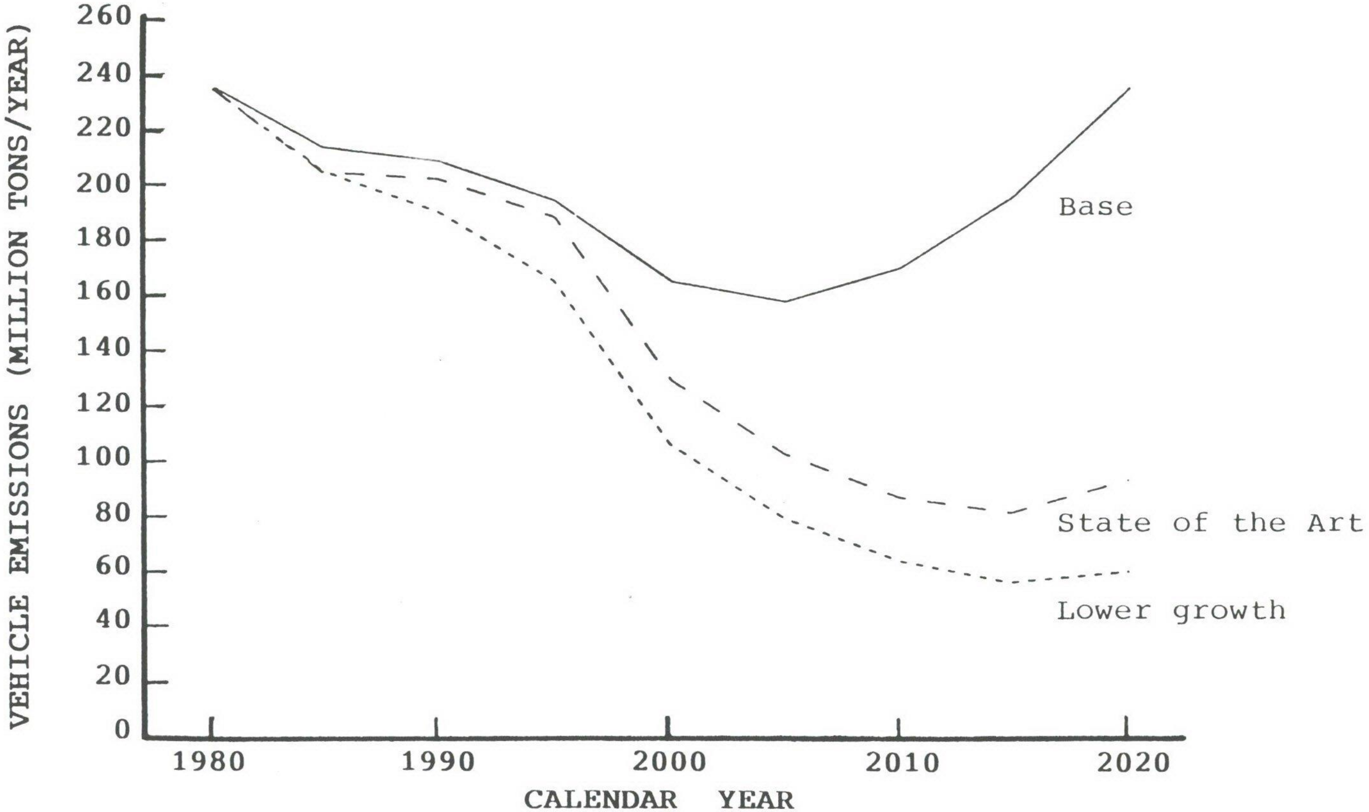
SOURCE: Leggett J (ed) (1990)
GLOBAL WARMING: THE GREENPEACE REPORT
Oxford University Press - ISBN 019 286119 0

FIGURE 2 **TRENDS IN VEHICLE HC EMISSIONS IF ALL VEHICLES AROUND THE WORLD USED STATE-OF-THE-ART EMISSION CONTROLS**



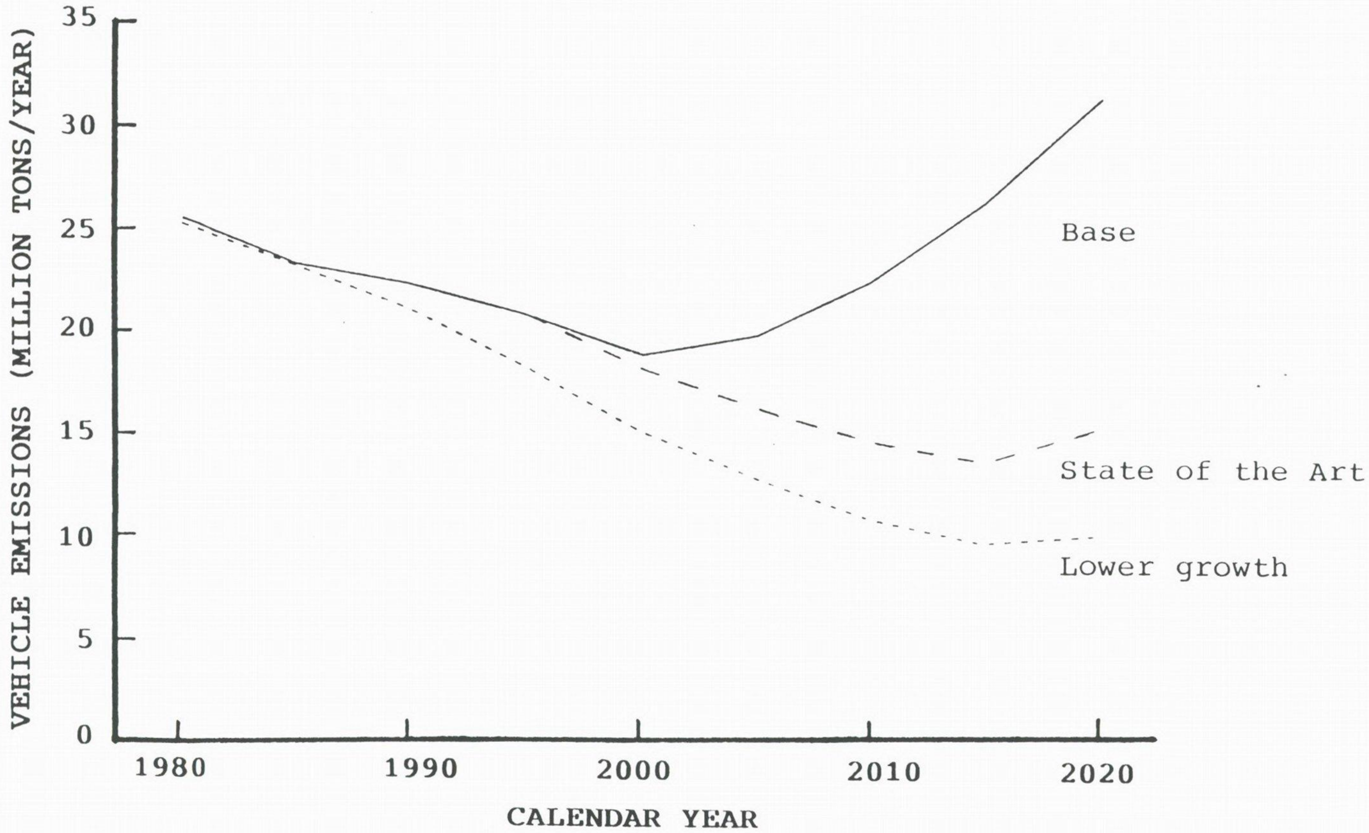
SOURCE: Leggett J (ed) (1990)
GLOBAL WARMING: THE GREENPEACE REPORT
Oxford University Press - ISBN 019 286119 0

FIGURE 3 **TRENDS IN VEHICLE CO EMISSIONS IF ALL VEHICLES AROUND THE WORLD USED STATE-OF-THE-ART EMISSION CONTROLS**



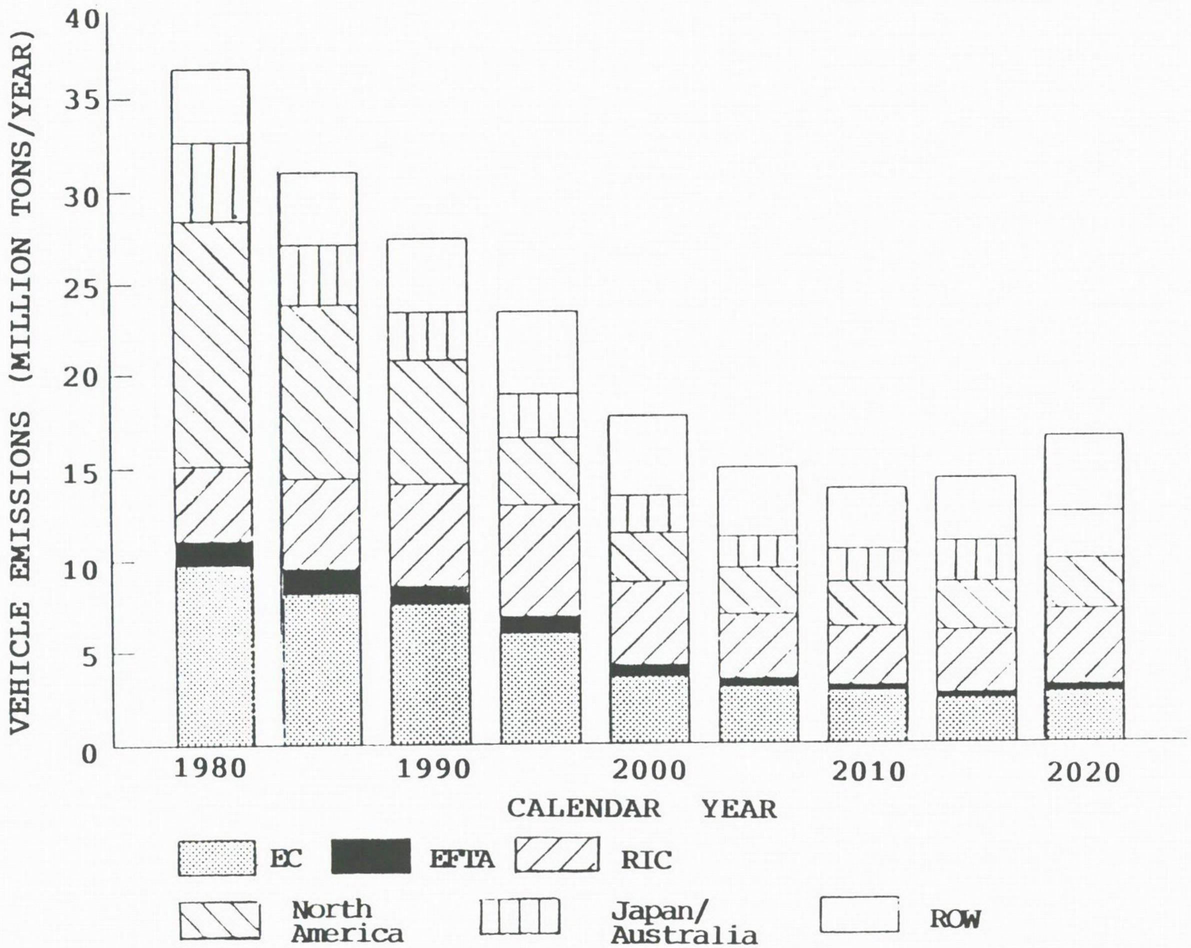
SOURCE: Leggett J (ed) (1990)
GLOBAL WARMING: THE GREENPEACE REPORT
Oxford University Press - ISBN 019 286119 0

FIGURE 4 **TRENDS IN VEHICLE NO_x EMISSIONS IF ALL VEHICLES AROUND THE WORLD USED STATE-OF-THE-ART EMISSION CONTROLS**



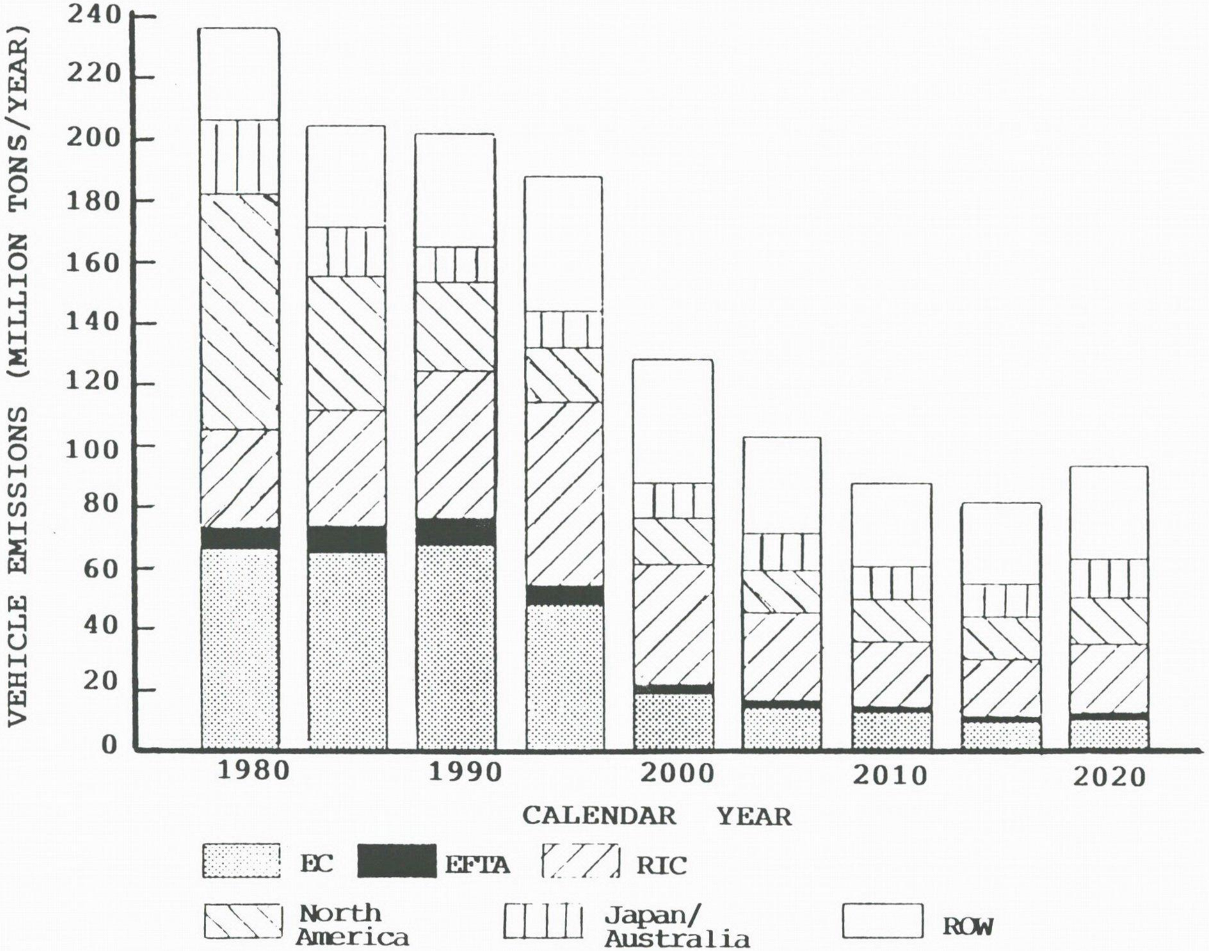
SOURCE: Leggett J (ed) (1990)
GLOBAL WARMING: THE GREENPEACE REPORT
Oxford University Press - ISBN 019 286119 0

FIGURE 5 TRENDS IN VEHICLE HC EMISSIONS BY REGION, IF ALL VEHICLES AROUND THE WORLD USED STATE-OF-THE-ART EMISSION CONTROLS



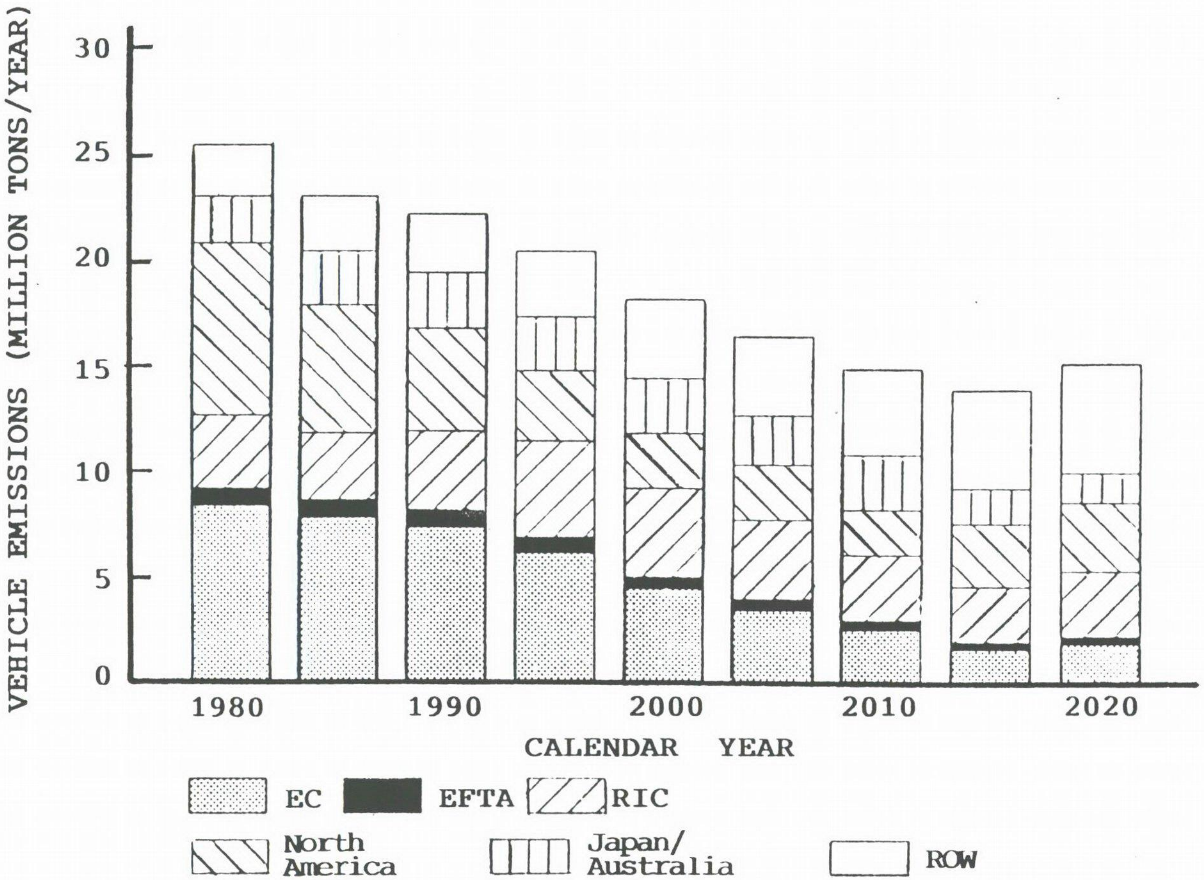
SOURCE: Leggett J (ed) (1990)
GLOBAL WARMING: THE GREENPEACE REPORT
Oxford University Press - ISBN 019 286119 0

FIGURE 6 **TRENDS IN VEHICLE CO EMISSIONS IF ALL VEHICLES AROUND THE WORLD USED STATE-OF-THE-ART EMISSION CONTROLS**



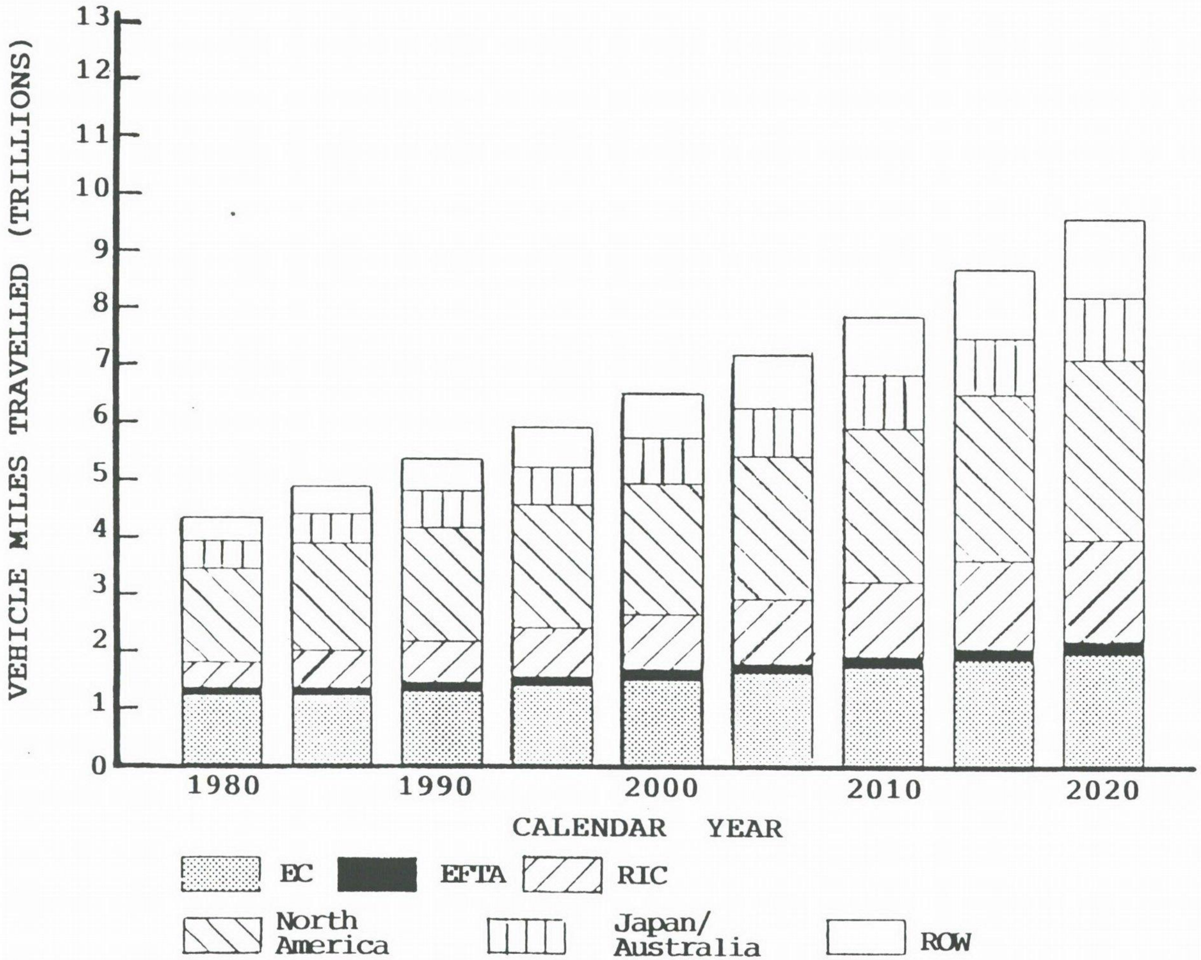
SOURCE: Leggett J (ed) (1990)
GLOBAL WARMING: THE GREENPEACE REPORT
Oxford University Press - ISBN 019 286119 0

FIGURE 7 **TRENDS IN VEHICLE NO_x EMISSIONS BY REGION IF ALL VEHICLES AROUND THE WORLD USED STATE-OF-THE-ART EMISSIONS CONTROLS**



SOURCE: Leggett J (ed) (1990)
GLOBAL WARMING: THE GREENPEACE REPORT
Oxford University Press - ISBN 019 286119 0

FIGURE 8 **TRENDS IN VEHICLE-MILES TRAVELLED, BY REGION, IF ALL VEHICLES AROUND THE WORLD USED STATE-OF-THE-ART EMISSIONS CONTROLS**



SOURCE: Leggett J (ed) (1990)
GLOBAL WARMING: THE GREENPEACE REPORT
Oxford University Press - ISBN 019 286119 0

APPENDIX 1

State Pollution Control Commission
Air Pollution Monitoring Data 1978-1988

TABLE A 1.1

ACID GAS CONCENTRATIONS (AS SULFUR DIOXIDE)
MICROGRAMS PER CUBIC METRE AT 0°C
SYDNEY MONITORING STATIONS, 1979 - 1988, 24 HOUR SAMPLING

Station		1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
SYDNEY	monthly average	45.0	40.0	48.6	48.6	38.1	33.8	29.3	25.9	16.0	NOT REPORTED
QVB George St.	max 24hr ave	245.0	130.0	175.0	126.0	295.0	112.0	90.0	90.0	75.0	
SYDNEY	monthly average	-	-	-	-	50.0	52.2	63.0	33.6	32.2	
Waterloo T.H.	max 24hr ave	-	-	-	-	160.0	390.0	180.0	135.0	80.0	
Elizabeth St.											
SYDNEY	monthly average	-	-	-	-	22.5	19.5	16.5	15.4	8.6	
Erskineville	max 24hr ave	-	-	-	-	128.0	210.0	115.0	140.0	35.0	
Rockford St.											
KURNELL	monthly average	60.0	40.0	30.4	17.7	13.5	8.9	5.4	-	-	
Customs Bldg.	max 24hr ave	215.0	175.0	125.0	80.0	40.0	30.0	25.0	-	-	
Prince Charles Pde.											
LANE COVE	monthly average	25.0	35.0	23.2	19.6	17.2	12.7	15.4	-	-	
Town Hall	max 24hr ave	125.0	85.0	115.0	100.0	65.0	70.0	80.0	-	-	-
Longueville Rd.											
MATRAVILLE	monthly average	20.0	25.0	12.8	7.6	5.2	4.8	-	-	-	-
Carnegie Circt.	max 24hr ave	105.0	105.0	185.0	35.0	30.0	20.0	-	-	-	-
NORTH SYDNEY	monthly average	40.0	50.0	38.7	28.3	22.6	16.5	22.6	-	-	-
P.O.	max 24hr ave	115.0	200.0	165.0	85.0	115.0	60.0	105.0	-	-	-
Mount St. & Pacific Hwy.											
PADDINGTON	monthly average	50.0	50.0	57.9	50.4	84.5	18.4	16.4	9.7	6.9	-
T.H. Oxford St.	max 24hr ave	210.0	135.0	214.0	149.0	337.0	139.0	85.0	80.0	30.0	-
PYRMONT	monthly average	50.0	55.0	50.5	44.2	41.7	42.3	40.2	27.2	12.7	-
John St.	max 24hr ave	205.0	220.0	349.0	126.0	178.0	308.0	265.0	160.0	100.0	-
RANDWICK	monthly average	20.0	30.0	17.7	15.1	9.9	5.5	4.3	-	-	-
P of Wales Hosp	max 24hr ave	100.0	105.0	70.0	70.0	80.0	40.0	15.0	-	-	-
Barker St.											
ROZELLE	monthly average	35.0	25.0	22.7	11.2	9.5	9.3	5.0	-	-	-
Rozelle Hosp	max 24hr ave	555.0	145.0	135.0	40.0	30.0	45.0	30.0	-	-	-
Balmain Road											
RYDALMERE	monthly average	30.0	45.0	31.2	26.2	18.7	11.1	15.5	-	-	-
Rydalmere Hosp.	max 24hr ave	165.0	225.0	175.0	140.0	110.0	90.0	105.0	-	-	-
Victoria Rd.											
SURRY HILLS	monthly average	40.0	25.0	27.9	27.6	21.3	19.4	16.9	12.2	11.5	-
Chalmers St.	max 24hr ave	245.0	100.0	110.0	60.0	100.0	80.0	60.0	60.0	40.0	-
SYDNEY	monthly average	45.0	60.0	54.7	49.3	34.3	27.0	20.7	-	-	-
Geo & Mkt Sts	max 24hr ave	115.0	255.0	175.0	130.0	95.0	90.0	55.0	-	-	-
PENRITH	monthly average	2.0	2.0	11.0	13.3	11.2	8.5	10.5	-	-	-
Cncl.Chambers	max 24hr ave	105	70	35.0	55.0	45.0	25.0	75.0	-	-	-

TABLE A 1.2 **NITROGEN DIOXIDE CONCENTRATIONS**
PARTS PER HUNDRED MILLION
SYDNEY MONITORING STATIONS, 1981 - 1988 , ONE HOUR SAMPLES

Station	Parameter	1981	1982	1983	1984	1985	1986	1987	1988
BONDI JCTN	% sampling time	-	-	66.7	85.9	85.2	80.4	85.6	-
	daily 1 hr maxima								
EASTERN	monthly average	-	-	5.7	4.2	3.2	5.3	3.7	-
SUBURBS	max 1 hour val	-	-	22.0	10.6	11.4	31.6	10.6	-
HOSPITAL	max 24 hour ave	-	-	9.0	5.0	6.0	9.1	4.1	-
	NHMRC 1 hr goal days exceeded	-	-	-	0	0	15.0	0	-
EARLWOOD	% sampling time	94.8	75.2	96.7	94.0	75.6	74.4	93.1	64.0
	daily 1 hr maxima								
BEAMAN	monthly average	4.7	3.9	3.5	3.8	2.3	3.1	4.9	5.0
PARK	max 1 hour val	23.0	27.0	11.0	28.0	9.3	21.0	20.3	23.0
	max 24 hour ave	10.0	6.0	6.0	11.0	5.0	4.7	8.3	4.0
	NHMRC 1 hr goal days exceeded	0	2	-	7	0	2	3	5
LIDCOMBE	% sampling time	96.2	86.3	90.1	93.8	85.9	74.0	76.9	81.0
	daily 1 hr maxima								
SPCC	monthly average	3.4	4.2	4.2	4.1	3.2	2.0	3.6	5.0
LABORATORIES	max 1 hour val	10.0	15.0	18.0	15.0	13.1	5.6	17.0	2.1
JOSEPH ST.	max 24 hour ave	4.0	6.0	10.0	5.1	8.4	2.7	4.6	5.0
	NHMRC 1 hr goal days exceeded	0	0	-	0	0	0	1	4
ROZELLE	% sampling time	95.9	77.6	83.9	89.9	86.9	64.9	90.4	73.0
	daily 1 hr maxima								
ROZELLE	monthly average	3.8	2.5	3.3	3.3	2.8	3.4	3.2	4.0
HOSPITAL	max 1 hour val	12.0	9.0	12.0	18.6	9.3	18.0	15.5	22.0
BALMAIN RD.	max 24 hour ave	5.0	3.0	6.0	6.0	4.7	5.9	5.2	4.0
	NHMRC 1 hr goal days exceeded	0	0	-	1	0	1	0	1

TABLE A 1.3 NITRIC OXIDE CONCENTRATIONS
PARTS PER HUNDRED MILLION
SYDNEY MONITORING STATIONS, 1981 - 1988, ONE HOUR SAMPLES

		1981	1982	1983	1984	1985	1986	1987	1988
BONDI JCTN	% sampling time	-	-	66.9	89.7	85.2	80.4	85.6	-
	daily 1 hr maxima								
EASTERN	monthly average	-	-	10.0	13.9	8.5	10.9	9.0	-
SUBURBS	max 1 hour val	-	-	41.0	42.0	43.4	57.3	36.9	-
HOSPITAL	max 24 hour ave	-	-	16.0	16.6	16.6	25.2	8.5	-
EARLWOOD	% sampling time	96.4	75.2	96.7	94.0	75.6	74.4	93.3	56.0
	daily 1 hr maxima								
BEAMAN	monthly average	13.7	13.6	16.5	18.3	10.3	14.8	16.8	15.0
PARK	max 1 hour val	45.0	50.0	79.0	100.0	59.6	64.0	77.0	40.0
	max 24 hour ave	26.0	35.0	34.0	32.2	18.2	20.4	23.4	12.0
LIDCOMBE	% sampling time	96.7	86.3	90.2	94.0	86.0	74.0	77.4	78.0
	daily 1 hr maxima								
SPCC	monthly average	11.8	10.4	11.1	12.1	11.3	5.0	11.3	11.0
LABORATORIES	max 1 hour val	44.0	42.0	50.0	46.6	43.6	29.0	42.2	62.0
JOSEPH ST.	max 24 hour ave	14.0	15.0	16.0	25.1	13.7	6.4	15.8	8.0
ROZELLE	% sampling time	96.3	77.6	84.0	90.0	88.6	64.9	92.1	73.0
	daily 1 hr maxima								
ROZELLE	monthly average	6.9	7.2	8.0	10.7	8.2	11.9	10.7	11.0
HOSPITAL	max 1 hour val	43.0	37.0	46.0	57.9	46.7	48.0	45.9	74.0
BALMAIN RD	max 24 hour val	10.0	12.0	12.0	18.3	17.1	18.2	15.1	9.0

TABLE A 1.4 **SUSPENDED MATTER CONCENTRATIONS**
MICROGRAMS PER CUBIC METRE AT 0°C
SYDNEY MONITORING STATIONS, 1978 - 1988, 24 HOUR SAMPLES

		1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
PADDINGTON	per month	12.0	13.0	11.0	10.3	10.9	7.9	7.0	10.3	9.7	9.2	
	max 24hr ave	56.0	70.0	50.0	52.0	54.0	52.0	43.0	67.0	52.0	59.0	
PYRMONT	per month	19.0	17.0	16.0	20.7	12.7	11.2	11.5	11.4	10.3	11.0	
	max 24hr ave	70.0	63.0	60.0	76.7	47.0	54.0	53.0	54.0	44.0	44.6	
SURRY HILLS	per month	12.0	12.0	11.0	8.7	-	-	-	-	9.9	11.0	
	max 24 hr ave	45.0	46.0	42.0	48.0	-	-	-	-	56.0	47.0	
SYDNEY George St	per month	23.0	24.0	25.0	20.2	-	-	-	-	16.7	17.6	
	max 24hr ave	34.0	84.0	73.0	84.0	-	-	-	-	47.0	225.0	
SYDNEY Elizabeth St	per month	-	-	-	-	-	-	-	-	11.8	9.8	
	max 24hr ave	-	-	-	-	-	-	-	-	72.0	69.0	
SYDNEY Rockford St	per month	-	-	-	-	-	-	-	-	8.4	7.1	
	max 24hr ave	-	-	-	-	-	-	-	-	47.0	37.0	
KURNELL	per month	-	-	4.0	3.7	3.4	4.3	4.1	5.1	-	-	
	max 24hr ave	-	-	20.0	22.0	20.0	20.0	20.3	30.4	-	-	
LANE COVE	per month	-	-	8.0	8.1	8.6	12.7	11.6	15.1	-	-	
	max 24hr ave	-	-	33.0	74.0	40.0	64.0	39.3	65.3	-	-	
NORTH SYDNEY	per month	-	-	15.0	14.0	12.8	12.2	10.9	14.8	-	-	
	max 24hr ave	-	-	42.0	34.0	29.0	30.0	30.8	34.4	-	-	
MATRAVILLE	per month	-	-	5.0	4.7	4.5	5.6	-	-	-	-	
	max 24hr ave	-	-	24.0	25.0	25.0	24.0	-	-	-	-	
RANDWICK	per month	10.0	7.0	-	4.5	4.5	5.7	-	-	-	-	
	max 24hr ave	57.0	38.0	30.0	22.0	26.0	27.0	-	-	-	-	
COLLAROY	per month	-	-	-	2.6	-	-	-	-	-	-	
	max 24hr ave	-	-	-	12.0	-	-	-	-	-	-	
ROZELLE	per month	9.0	10.0	8.0	7.5	-	-	-	-	-	-	
	max 24hr ave	40.0	49.0	37.0	33.0	-	-	-	-	-	-	
RYDALMERE	per month	11.0	12.0	10.0	9.3	-	-	-	-	-	-	
	max 24hr ave	35.0	58.0	38.0	60.0	-	-	-	-	-	-	
PENRITH	per month	-	-	10.0	6.3	-	-	-	-	-	-	
	max 24hr ave	-	-	47.0	25.0	-	-	-	-	-	-	
SYDNEY Geo.&Mkt.Sts	per month	36.0	46.0	36.0	26.7	-	-	-	-	-	-	
	max 24hr ave	94.0	87.0	126.0	109.0	-	-	-	-	-	-	
RYDE NORTH	per month	6.0	6.0	-	-	-	-	-	-	-	-	
	max 24hr ave	22.0	34.0	-	-	-	-	-	-	-	-	

TABLE A 1.5 CONCENTRATIONS OF TOTAL SUSPENDED PARTICULATES (TSP)
MICROGRAMS PER CUBIC METRE AT 0°C
SYDNEY MONITORING STATIONS, 1979 - 1988, 24 HOUR SAMPLES
YEARLY AVERAGE - 6 DAY CYCLE

		1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
EARLWOOD Beaman Park	yearly ave.	-	117	88.6	94.3	88	65	63	73	72	61
LANE COVE Town Hall Longueville Road	yearly ave.	63	62	51.7	51.1	55	45	49	52	55	-
RANDWICK P of Wales Hospital Barker St.	yearly ave.	81	75	-	-	-	-	-	-	-	-
ROZELLE Rozelle Hospital Balmain Rd.	yearly ave.	72	64	55.7	57.2	54	43	44	46	45	40
RYDALMERE Rydalmere Hospital Victoria Rd.	yearly ave.	86	85	68.5	76.7	68	55	53	-	-	-
SYDNEY George & & Market Streets	yearly ave.	100	118	97.3	100.1	88	110	137	113	113	-

TABLE A 1.6

TOTAL SUSPENDED PARTICLE CONCENTRATIONS
MICROGRAMS PER CUBIC METRE AT 0°C
SYDNEY MONITORING STATIONS, 1979 - 1988, 24 HOUR SAMPLES
HIGHEST MONTHLY AVERAGE - 6 DAY CYCLE

		1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
EARLWOOD Beaman Park	monthly ave	-	221	126	194	189	88	110	107	92	158
LANE COVE Town Hall Longueville Road	monthly ave	113	140	81	81	111	59	74	65	62	-
ROZELLE Rozelle Hospital Balmain Road	monthly ave	168	132	80	81	103	60	52	62	56	56
SYDNEY George & Market Sts.	monthly ave	316	462	112	126	140	197	190	141	155	-
RYDALMERE Rydalmere Hospital Victoria Road	monthly ave	162	182	103	108	128	73	72	-	-	-
RANDWICK Prince of Wales Hosp. Barker Street	monthly ave	192	116	-	-	-	-	-	-	-	-

TABLE A 1.7

LEAD CONCENTRATIONS
MICROGRAMS PER CUBIC METRE AT 0°C
SYDNEY MONITORING STATIONS, 1979 - 1988, 24 HOUR SAMPLES (6 DAY CYCLE)

		1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
EARLWOOD	monthly ave	-	1.3	1.3	1.4	1.1	1.2	0.9	0.9	0.9	0.8
Beaman Park	90 day ave	-	-	1.3	1.4	1.1	1.2	0.9	0.9	0.9	0.8
LANE COVE	monthly ave	1.8	1.2	1.7	1.5	1.5	1.5	1.4	1.3	0.5	-
Town Hall	90 day ave	-	-	1.6	1.6	1.6	1.5	1.4	1.3	0.7	-
Longueville Road											
ROZELLE	monthly ave	1.3	1.2	0.8	0.9	0.8	0.7	0.6	0.6	0.5	0.5
Rozelle Hosp	90 day ave	-	-	0.8	0.9	0.8	0.7	0.6	0.6	0.5	0.5
Balmain Road											
SYDNEY	monthly ave	2.6	2.4	2.6	2.6	2.1	1.9	1.6	1.5	1.3	-
Geo & Mkt Sts	90 day ave	-	-	2.5	2.7	2.2	1.9	1.6	1.5	1.3	-
RYDALMERE	monthly ave	1.3	1.2	1.3	1.4	1.2	1.1	-	-	-	-
Rydalmere Hosp	90 day ave	-	-	1.3	1.4	1.2	1.2	-	-	-	-
Victoria Road											
RANDWICK	monthly ave	1.4	1.1	-	-	-	-	-	-	-	-
P of Wales H	90 day ave	-	-	-	-	-	-	-	-	-	-

TABLE A 1.8 **NON METHANE HYDROCARBONS CONCENTRATIONS**
PARTS PER MILLION
SYDNEY MONITORING STATIONS, 1981 - 1988, ONE HOUR SAMPLES

		1981	1982	1983	1984	1985	1986	1987	1988
LIDCOMBE	% sampling time	92.6	95.4	69.9	83.3	81.1	58.7	87.7	90.2
SPCC LABS.	monthly average	1.1	1.3	0.5	0.7	0.4	0.7	0.6	1.2
JOSEPH ST.									
ROZELLE	% sampling time	94.4	82.2	74.0	72.7	81.8	43.2	63.7	62.5
ROZELLE HOSP.	monthly average	0.3	0.4	1.7	0.9	0.6	1.0	0.9	1.1
BALMAIN RD.									

TABLE A 1.9 CARBON MONOXIDE CONCENTRATIONS
PARTS PER MILLION
SYDNEY CITY MONITORING STATIONS, 1978 - 1988, ONE HOUR SAMPLES

SYDNEY CITY GEORGE & MARKET STREETS	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
% sampling time	91	85	-	-	-	-	90.7	-	72.2	79.3	80.8
daily 1-hour maxima											
monthly average	6	5	-	-	-	-	11.4	-	9.3	8.9	9.5
max 1-hour val	-	-	-	-	-	-	26.3	-	50.0	20.2	20.0
US EPA 8-hour goal											
DAYS EXCEEDED	104	56	-	-	-	-	87	-	18	47	69

TABLE A 1.10 OZONE CONCENTRATIONS
PARTS PER HUNDRED MILLION
SYDNEY MONITORING STATIONS, 1981 - 1988, ONE HOUR SAMPLES

		1981	1982	1983	1984	1985	1986	1987	1988
BONDI JCTN.	% sampling time	-	83.7	84.3	95.0	90.4	72.6	78.7	-
EASTERN	daily 1 hr maxima								
SUBURBS	monthly average	-	2.5	2.6	2.9	2.7	2.7	2.3	-
HOSPITAL	maximum 1 hr val	-	7.0	12.0	12.3	11.9	12.3	10.1	-
	NHMRC 1 hour goal days exceeded	-	0.0	1.0	2.0	0.0	1.0	0.0	-
CAMPBELLTOWN	% sampling time	92.7	85.9	74.1	92.2	85.1	67.9	76.8	86.9
	daily 1 hr maxima								
OFF FARROW ROAD	monthly average	3.9	3.9	4.0	3.7	4.1	4.2	3.8	3.7
	maximum 1 hr val	14.0	15.0	15.0	13.1	15.7	12.5	13.0	14.0
	NHMRC 1 hour goal days exceeded	2.0	3.0	5.0	1.0	2.0	2.0	2.0	6.0
LANSVALE	% sampling time	-	-	91.1	80.3	80.7	62.7	66.2	-
	daily 1 hr maxima								
HOLLYWOOD	monthly average	-	-	3.7	4.0	3.1	3.6	3.6	-
CRESCENT	maximum 1 hr val	-	-	18.0	14.3	14.8	11.3	7.6	-
	NHMRC 1 hour goal days exceeded	-	-	4.0	2.0	1.0	0.0	0.0	-
LIDCOMBE	% sampling time	97.7	95.2	98.0	91.8	97.6	83.6	93.4	99.2
	daily 1 hr maxima								
SPCC	monthly average	3.3	3.6	3.6	2.8	2.9	3.1	2.9	2.8
LABORATORIES	maximum 1 hr val	12.0	13.0	23.0	11.9	14.2	10.5	13.5	11.0
JOSEPH ST.	NHMRC 1 hour goal days exceeded	0.0	4.0	4.0	0.0	-	-	1.0	0.0
WESTMEAD	% sampling time	-	-	93.6	94.3	97.5	87.2	93.9	94.4
	daily 1 hr maxima								
WESTMEAD HOSP	monthly average	-	-	3.0	3.2	2.9	2.5	2.3	2.1
HAINSWORTH	maximum 1 hr val	-	-	16.0	10.7	14.0	8.3	12.1	11.0
STREET	NHMRC 1 hour goal days exceeded	-	-	1.0	0.0	2.0	0.0	1.0	0.0
WOOLOWARE	% sampling time	-	-	89.8	97.0	94.5	77.7	96.5	81.0
	daily 1 hr maxima								
CARONIA RD.	monthly average	-	-	3.0	3.2	3.4	3.2	3.8	2.5
	maximum 1 hr val	-	-	13.0	13.5	11.1	14.9	11.6	13.0
	NHMRC 1 hour goal days exceeded	-	-	1.0	3.0	0.0	3.0	0.0	1.0
ROZELLE	% sampling time	93.7	94.8	-	-	-	-	-	-
	daily 1 hr maxima								
	monthly average	3.3	3.4	-	-	-	-	-	-
	maximum 1 hr val	10.0	11.0	-	-	-	-	-	-
	NHMRC 1 hour goal days exceeded	0.0	0.0	-	-	-	-	-	-
WARWICK	% sampling time	95.2	96.5	-	-	-	-	-	-
FARM	daily 1 hr maxima								
RACECOURSE	monthly average	4.0	4.0	-	-	-	-	-	-
	maximum 1 hr val	11.0	12.0	-	-	-	-	-	-
	NHMRC 1 hour goal days exceeded	0.0	0.0	-	-	-	-	-	-

TABLE A 1.10 (continued)

OZONE CONCENTRATIONS
PARTS PER HUNDRED MILLION
SYDNEY MONITORING STATIONS, 1981 - 1988, ONE HOUR AVERAGES

		1981	1982	1983	1984	1985	1986	1987	1988
EARLWOOD	% sampling time	97.9	79.3	86.3	99.4	92.6	79.2	96.3	90.7
	daily 1 hr maxima								
BEAMAN	monthly average	3.3	2.7	3.2	3.3	3.1	2.8	3.1	2.1
PARK	maximum 1 hr val	11.0	14.0	19.0	12.1	13.1	10.8	12.2	8.0
	NHMRC 1 hour goal								
	days exceeded	0	1	2	1	1	0	1	0

TABLE A 1.11 **SULFUR DIOXIDE CONCENTRATIONS**

MICROGRAMS PER CUBIC METRE AT 0°C

SYDNEY MONITORING STATIONS, 1979 - 1988

YEARLY AVERAGE

		1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
	*	ug/m3	ug/m3	pphm	pphm	pphm	pphm				
LIDCOMBE	monthly av.	15	15	0.3	0.3	0.3	0.6	-	-	-	-
SPCC Labs Joseph St.	max 24 hr av.	50	90	1.7	1.6	2.7	2.6	-	-	-	-
ROZELLE	monthly av.	-	7	0.3	0.3	0.6	0.9	-	-	-	-
	max 24 hr av.	-	35	3.5	0.8	1.5	4.4	-	-	-	-

* ug/m3 = 24 hour average

pphm = 1 hour average

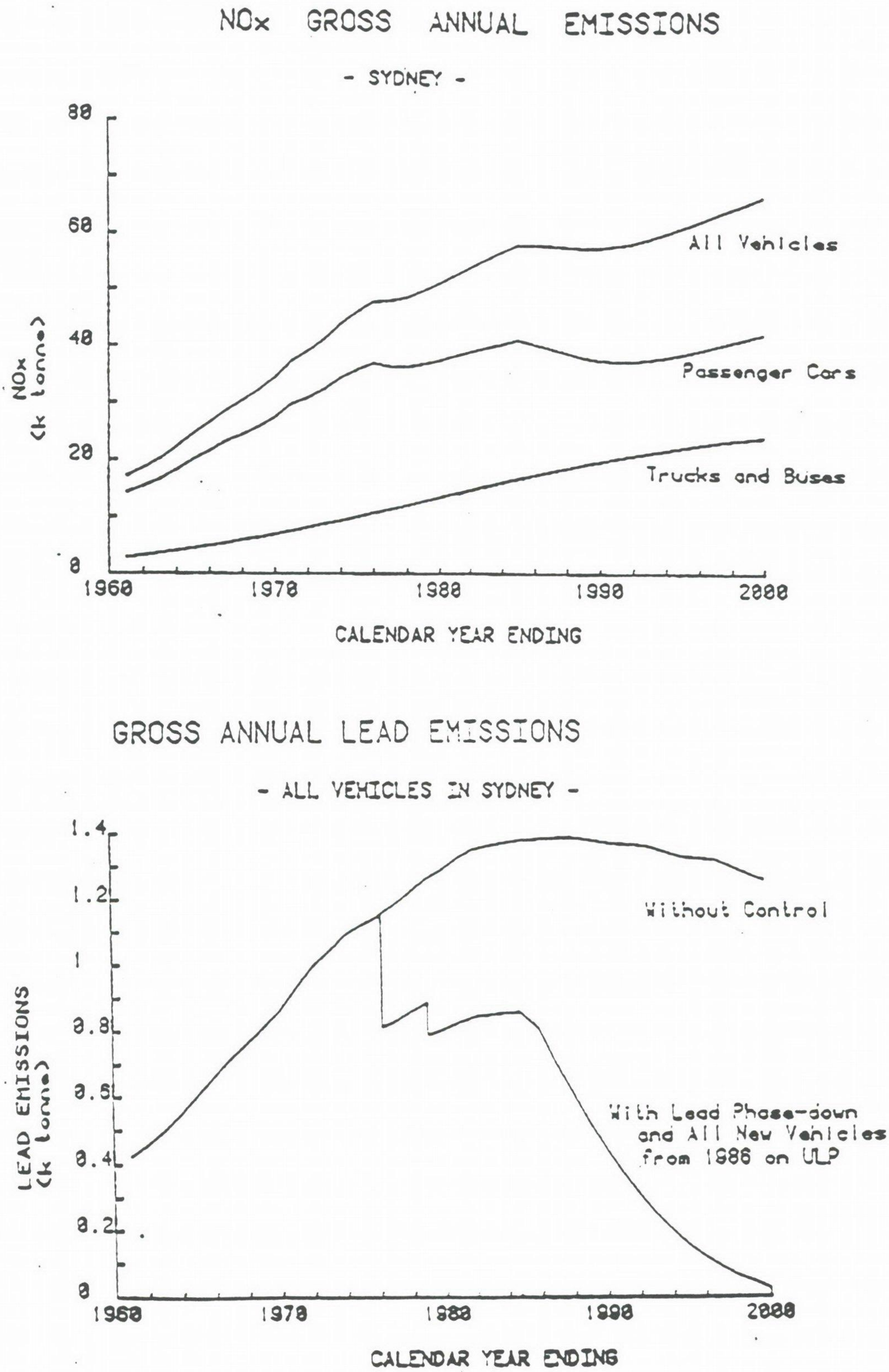
TABLE A 1.12 AVERAGES OF THE DAILY ONE-HOUR MAXIMA FOR NITROGEN DIOXIDE (pphm)

	1980	1981	1982	1983	1984	1985	1986	1987	1988
EARLWOOD BEAMAN PARK	42.0	17.4	16.2	19.1	21.7	12.2	17.0	21.4	20.1
LIDCOMBE SPCC LABS JOSEPH ST.	35.0	14.4	14.0	14.5	15.7	14.1	6.9*	14.1	15.4
ROZELLE ROZELLE HOSPITAL BALMAIN	34.0	10.0	9.3	10.6	13.8	10.5	14.1	13.3	13.7

* Note: Winter data missing

FIGURE A 1.13

GROSS ANNUAL EMISSIONS
FOR NITROGEN OXIDES AND LEAD
SYDNEY VEHICULAR TRAFFIC: 1960 - 2000



APPENDIX 2

Meteorological Data
North Parramatta

BUREAU OF METEOROLOGY - CLIMATIC DATA APPENDIX 2 TABLE A 2.1

Station Name PARRAMATTA NORTH Commenced 1965 NEW SOUTH WALES

Number 066124 Latitude 33 Deg 48 Min S Longitude 151 Deg 1 Min E Elevation 60.0 M

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
9 am Mean Temperatures (C) and Mean Relative Humidity (%)												22 Years of Record	
Dry Bulb	22.5	22.2	21.0	18.2	14.5	11.6	10.7	12.5	15.6	18.5	19.9	21.9	17.4
Wet Bulb	19.0	19.3	18.2	15.4	12.4	9.7	8.4	9.8	11.8	14.4	16.1	17.9	14.4
Dew Point	17	18	16	13	11	8	6	7	8	11	13	15	12
Humidity	70	75	75	73	77	77	71	69	61	61	65	66	70
3 pm Mean Temperatures (C) and Mean Relative Humidity (%)												22 Years of Record	
Dry Bulb	26.2	26.1	24.6	22.3	19.0	16.2	15.9	17.4	19.3	21.5	23.3	25.5	21.4
Wet Bulb	20.3	20.6	19.4	17.0	14.4	12.2	11.0	12.1	13.3	15.7	17.5	19.2	16.1
Dew Point	17	17	16	13	10	8	6	7	8	11	13	15	12
Humidity	56	58	59	56	58	60	51	50	47	51	53	52	54
Daily Maximum Temperature (C)												21 Years of Record	
Mean	28.0	27.6	26.2	23.9	20.3	17.4	17.1	18.7	21.1	23.4	25.1	27.4	23.0
86 Percentile	33.2	32.2	30.3	27.6	23.4	19.9	19.5	21.6	25.6	28.5	30.6	33.0	
14 Percentile	23.1	22.8	22.2	20.1	17.5	15.2	14.5	15.6	16.8	18.5	20.1	22.0	
Daily Minimum Temperature (C)												22 Years of Record	
Mean	17.5	17.6	16.1	13.1	10.1	7.6	6.2	7.3	9.3	12.1	14.1	16.2	12.3
86 Percentile	20.1	20.0	18.7	16.0	13.4	10.8	9.2	10.7	12.5	15.0	17.0	19.0	
14 Percentile	15.0	15.0	13.5	10.0	7.0	4.6	3.5	4.4	6.0	8.9	11.0	13.3	
Rainfall (mm)												24 Years of Record	
Mean	116	99	128	86	69	81	44	60	52	81	90	67	973
Median	103	84	121	43	69	68	32	24	43	54	67	56	992
Raindays (No)												24 Years of Record	
Mean	11	11	11	8	9	9	7	8	8	11	11	9	113

BUREAU OF METEOROLOGY - SURFACE WIND ANALYSIS

PERCENTAGE OCCURRENCE OF SPEED VERSUS DIRECTION BASED ON 22 YEARS OF RECORDS

FIRST YEAR : 1967 LAST YEAR : 1988 NUMBER OF MISSING OBSERVATIONS (AS PERCENTAGE OF MAXIMUM POSSIBLE) : 4.66 %

STATION : 066124 PARRAMATTA NORTH 33 48 S, 151 01 E 60.0 M ELEV

JANUARY 0900 HOURS LST

SPEED (KM/HR), CALM: 14

DIRN	1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	4	2	1					7
NE	4	3	2	1				11
E	4	4	2	•				10
SE	5	6	6	2	•			19
S	4	5	4	1	1			14
SW	4	2	1	•	•			8
W	3	2	1	•				6
NW	5	3	2	1				11
ALL	34	26	20	5	1			

NO. OF OBS. 62?

FEBRUARY 0900 HOURS LST

SPEED (KM/HR), CALM: 17

DIRN	1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	3	1	2	•				6
NE	4	3	2	•				9
E	3	3	1	1				8
SE	6	6	4	2	1			18
S	5	4	3	1	•			13
SW	5	3	1	1				9
W	6	1	•					8
NW	6	4	2	•				12
ALL	58	23	14	6	1			

NO. OF OBS. 585

MARCH 0900 HOURS LST

SPEED (KM/HR), CALM: 20

DIRN	1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	2	1	1	•				4
NE	4	2	1	•	•	•		7
E	4	1	1	•			•	7
SE	7	4	3	1	•		•	15
S	4	4	3	2	•	•		13
SW	5	3	1	1	•			11
W	6	3	1	•	•			9
NW	7	4	1	•	•			14
ALL	39	23	12	5	1	•	•	

NO. OF OBS. 649

APRIL 0900 HOURS LST

SPEED (KM/HR), CALM: 18

DIRN	1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	2	1	1	•				4
NE	1	1	•					2
E	1	1	•	•				3
SE	3	3	1	1				8
S	6	3	1	1	•	•		12
SW	7	6	3	1	•	•		18
W	9	5	3	1		•		17
NW	9	8	2	•	•			20
ALL	37	27	12	4	1	1		

NO. OF OBS. 620

JANUARY 1500 HOURS LST

SPEED (KM/HR), CALM: 2

DIRN	1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	1	2	1	•	•			5
NE	3	6	7	7	1	•		23
E	3	5	11	7	•	•		30
SE	3	6	8	4	1	•		25
S	•	1	1	1	•	•	•	4
SW	1	•	1	•		•		3
W	1	1	•	1	•	•		3
NW	2	1	2	1	•			5
ALL	13	28	30	21	4	1	•	

NO. OF OBS. 623

FEBRUARY 1500 HOURS LST

SPEED (KM/HR), CALM: 2

DIRN	1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	1	1	2	•				4
NE	4	6	7	4	•			22
E	[illegible]	8	12	5	•	•		29
SE	4	8	10	4	1	•	•	28
S	1	2	2	1	1	•		7
SW	•	1	•	•	•			2
W	1	1	•	•			•	2
NW	2	1	1	•			•	5
ALL	16	28	35	15	3	1	1	

NO. OF OBS. 578

MARCH 1500 HOURS LST

SPEED (KM/HR), CALM: 5

DIRN	1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	1	1	1	•				4
NE	5	6	7	3	1			22
E	4	8	8	2	•			22
SE	5	7	11	4	1	•	•	28
S	1	1	2	1	•	•	•	6
SW	1	1	1	•	•			4
W	1	1	1	1	•			3
NW	1	2	1	1	•	•		7
ALL	19	27	32	13	3	1	•	

NO. OF OBS. 639

APRIL 1500 HOURS LST

SPEED (KM/HR), CALM: 8

DIRN	1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	3	1	2	•	•			6
NE	4	4	3	1	•			12
E	5	6	6	2	•			19
SE	5	7	9	2	1	•		23
S	2	2	1	1	1		•	7
SW	2	2	2	1	1	•		7
W	2	1	3	1	•	•		8
NW	4	3	2	1	•			9
ALL	27	25	27	10	3	•	•	

NO. OF OBS. 613

BUREAU OF METEOROLOGY - SURFACE WIND ANALYSIS

PERCENTAGE OCCURRENCE OF SPEED VERSUS DIRECTION BASED ON 22 YEARS OF RECORDS

FIRST YEAR : 1967 LAST YEAR : 1988 NUMBER OF MISSING OBSERVATIONS (AS PERCENTAGE OF MAXIMUM POSSIBLE) : 4.66 %

STATION : 066124 PARRAMATTA NORTH 33 48 S. 151 01 E 60.0 M ELEV

MAY 0900 HOURS LST — SPEED (KM/HR) — CALM: 12

DIRN	1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	1	1	1	•				3
NE	•	•	•					1
E	1	•		•				2
SE	2	1	1	•		•		4
S	6	1	1	1	•	•	•	10
SW	7	4	4	•	•	•		16
W	13	6	3	1	•	•		23
NW	16	9	3	1	•			30
ALL	47	22	12	5	1	1	•	

NO. OF OBS. 610

JUNE 0900 HOURS LST — SPEED (KM/HR) — CALM: 15

DIRN	1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	2	1	1	•				4
NE	•	•	•					1
E	1	•	•	•	•		•	2
SE	2	1	1	•	•	•	•	3
S	2	2	1	1	•		•	7
SW	7	4	3	2	1	•		17
W	14	6	3	•				23
NW	15	8	3	2		•		28
ALL	42	23	13	6	2	•	•	

NO. OF OBS. 656

JULY 0900 HOURS LST — SPEED (KM/HR) — CALM: 12

DIRN	1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	2	1	1	•				4
NE	1	•	•					1
E	1	•	•	•				1
SE	1	•	1	•				2
S	3	1	1	1	•	•		6
SW	4	4	3	1	•	•		12
W	15	8	5	1	•	1	•	31
NW	13	9	7	2	•	•		31
ALL	40	24	17	5	1	2	•	

NO. OF OBS. 677

AUGUST 0900 HOURS LST — SPEED (KM/HR) — CALM: 12

DIRN	1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	2	1	1	•				4
NE	•	1	•		•			1
E	•		•					1
SE	2	1	1		•	•		4
S	2	1	1	1	•	•		6
SW	6	4	4	2	1	1	•	18
W	13	7	4	2	1	•	•	27
NW	11	8	5	2	1	•	•	27
ALL	38	22	15	8	3	1	•	

NO. OF OBS. 670

MAY 1500 HOURS LST — SPEED (KM/HR) — CALM: 11

DIRN	1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	4	2	•	•	•			6
NE	4	2	1					7
E	[illegible]	3	•	1	•			11
SE	6	4	5	2	•	•		16
S	4	5	2	1	1	•	•	13
SW	3	2	2	1	1	1		10
W	5	1	2	1	1	1		12
NW	6	4	3	1				14
ALL	56	21	16	8	4	2	•	

NO. OF OBS. 602

JUNE 1500 HOURS LST — SPEED (KM/HR) — CALM: 11

DIRN	1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	3	1	1	•		•		6
NE	3	1	1					5
E	2	2	1	•	•			6
SE	5	4	5	2	1	•	•	17
S	4	3	4	2	2	•	•	15
SW	4	2	3	4	1	•	•	15
W	5	2	1	2	1			11
NW	8	3	1	1	1	•		16
ALL	54	15	19	12	4	1	1	

NO. OF OBS. 652

JULY 1500 HOURS LST — SPEED (KM/HR) — CALM: 11

DIRN	1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	4	2	1					6
NE	2	1	1					3
E	2	3	1	•				5
SE	4	4	3	1	1	•		14
S	3	2	3	1	1	•		10
SW	3	4	4	3	2	•	•	17
W	5	3	5	2	1	1	•	16
NW	7	5	2	2	1	•		17
ALL	29	24	19	9	5	2	•	

NO. OF OBS. 669

AUGUST 1500 HOURS LST — SPEED (KM/HR) — CALM: 6

DIRN	1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	2	1	2	•				6
NE	3	3	2	1	•			10
E	3	2	3	1		•		9
SE	5	3	5	2	•	•	•	15
S	1	2	3	1	1	•		9
SW	4	4	5	3	2	1	•	18
W	3	3	4	1	2	1	1	16
NW	5	5	2	1	•	•	•	14
ALL	25	24	24	10	6	3	1	

NO. OF OBS. 664

BUREAU OF METEOROLOGY - SURFACE WIND ANALYSIS

PERCENTAGE OCCURRENCE OF SPEED VERSUS DIRECTION BASED ON 22 YEARS OF RECORDS

FIRST YEAR : 1967 LAST YEAR : 1988 NUMBER OF MISSING OBSERVATIONS (AS PERCENTAGE OF MAXIMUM POSSIBLE) : 4.66 %

STATION : 066124 PARRAMATTA NORTH 33 48 S, 151 01 E 60.0 M ELEV

SEPTEMBER 0900 HOURS LST — CALM: 10

DIRN	SPEED (KM/HR) 1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	2	1	1	•				5
NE	1	1	1					3
E	1	•	•	•				2
SE	3	1	1	•	1		•	7
S	5	3	2	1	1	•	•	12
SW	6	5	5	3	2	1	•	20
W	8	5	4	1	1	1		19
NW	7	9	4	1	1			22
ALL	32	25	19	7	5	2	•	

NO. OF OBS. 651

OCTOBER 0900 HOURS LST — CALM: 10

DIRN	SPEED (KM/HR) 1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	4	1	1	•		•		7
NE	3	1	1	•				5
E	3	2	1	•	•	•		6
SE	4	5	3	2	1		•	14
S	4	3	3	2	•	•		12
SW	4	4	4	1	1	•	•	14
W	3	4	4	1	•	1		12
NW	6	6	3	2	1	•		18
ALL	31	26	19	8	3	2	•	

NO. OF OBS. 667

NOVEMBER 0900 HOURS LST — CALM: 13

DIRN	SPEED (KM/HR) 1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	5	2	1	•		•		8
NE	4	2	2	•				8
E	2	2	1	•				6
SE	5	5	3	1	1			15
S	5	3	3	2	•			13
SW	5	3	3	2	1	•		14
W	3	3	1	1	•	•		8
NW	6	5	3	1	•	•		15
ALL	35	25	18	6	2	1		

NO. OF OBS. 648

DECEMBER 0900 HOURS LST — CALM: 12

DIRN	SPEED (KM/HR) 1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	4	1	1	•				7
NE	4	2	2	•				9
E	3	2	1	•				6
SE	7	4	4	2	•	•		17
S	4	4	3	1	1	1		13
SW	3	3	1	1	•			9
W	4	3	1	1	•			9
NW	9	5	3	1	•	•		18
ALL	32	25	17	6	1	1		

NO. OF OBS. 642

SEPTEMBER 1500 HOURS LST — CALM: 5

DIRN	SPEED (KM/HR) 1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	2	2	1	1	•			5
NE	[illegible]	[illegible]	[illegible]	[illegible]	•			[illegible]
E	4	4	6	1	•			14
SE	3	5	6	3	1		•	13
S	2	2	2	2	1	1		9
SW	2	2	2	3	2	1	•	[illegible]
W	2	3	2	3	2	1	•	12
NW	4	3	2	2	1			12
ALL	20	22	26	15	8	3	1	

NO. OF OBS. [illegible]

OCTOBER 1500 HOURS LST — CALM: 3

DIRN	SPEED (KM/HR) 1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	2	2	1	•		•		5
NE	2	4	6	2	•	•		15
E	3	5	6	[illegible]	•	•	•	20
SE	4	6	5	5	1	•	•	23
S	2	2	1	1	1	•		7
SW	2	2	2	2	1			[illegible]
W	1	2	2	2	1	•		8
NW	4	2	2	2	•	•	•	13
ALL	20	25	22	17	4	2	1	

NO. OF OBS. 661

NOVEMBER 1500 HOURS LST — CALM: 3

DIRN	SPEED (KM/HR) 1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	2	1	1	•	•			4
NE	2	5	7	4	•	•		21
E	3	8	5	4	•	•		20
SE	3	9	9	5	2	1		27
S	1	1	3	1	1	•		6
SW	•	1	1	1	1	•	•	6
W	1	1	1	1	1	•	•	7
NW	2	1	2	1	•	•		6
ALL	14	26	29	18	7	2	1	

NO. OF OBS. 640

DECEMBER 1500 HOURS LST — CALM: 2

DIRN	SPEED (KM/HR) 1 TO 5	6 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 & UP	ALL
N	1	2	1	1				5
NE	4	6	8	6	1			25
E	5	7	8	4	1		•	24
SE	4	5	7	4	3		•	23
S	1	1	1	1	1	•	•	4
SW	1	1	1	1	•	•		5
W	•	•	1	2	1	•		6
NW	3	1	2	1	•	•		8
ALL	18	23	27	20	8	1	•	

NO. OF OBS. 634

APPENDIX 3

Vehicle Emission Data

FIGURE 1 EMISSION RATES OF OXIDES OF NITROGEN, HYDROCARBONS AND LEAD RELATIVE TO CARBON MONOXIDE (from Hickman & Colwill, 1982)

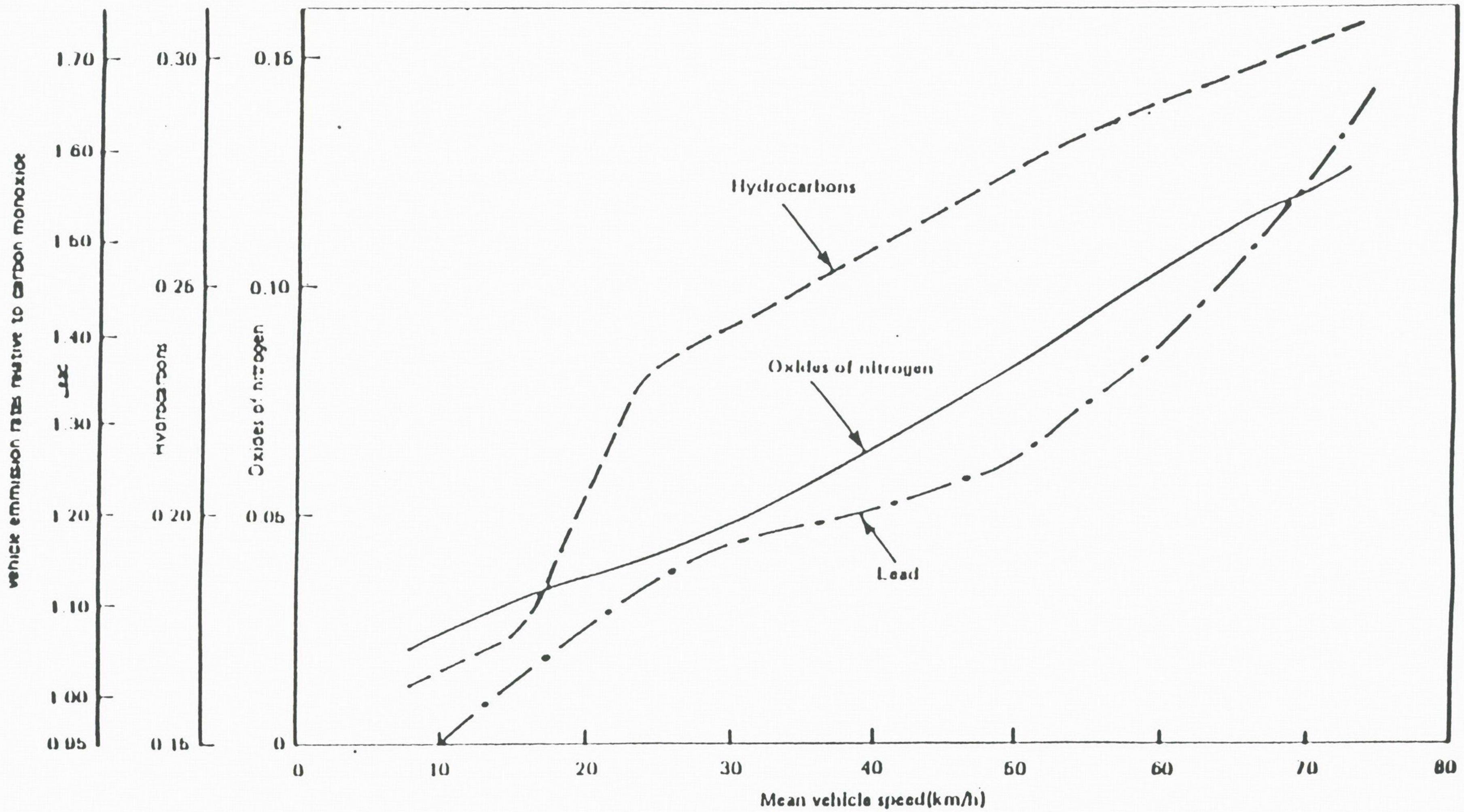
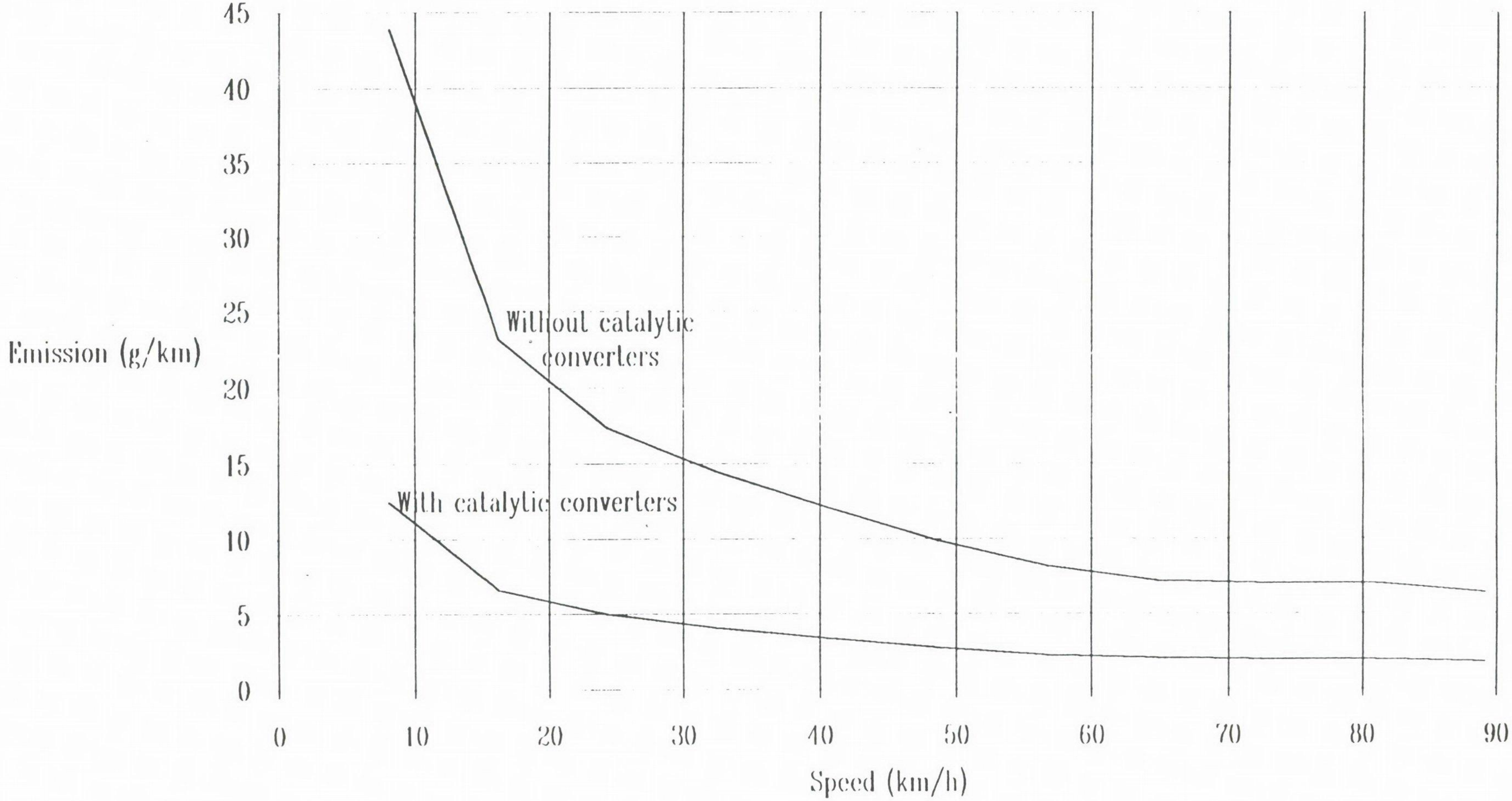
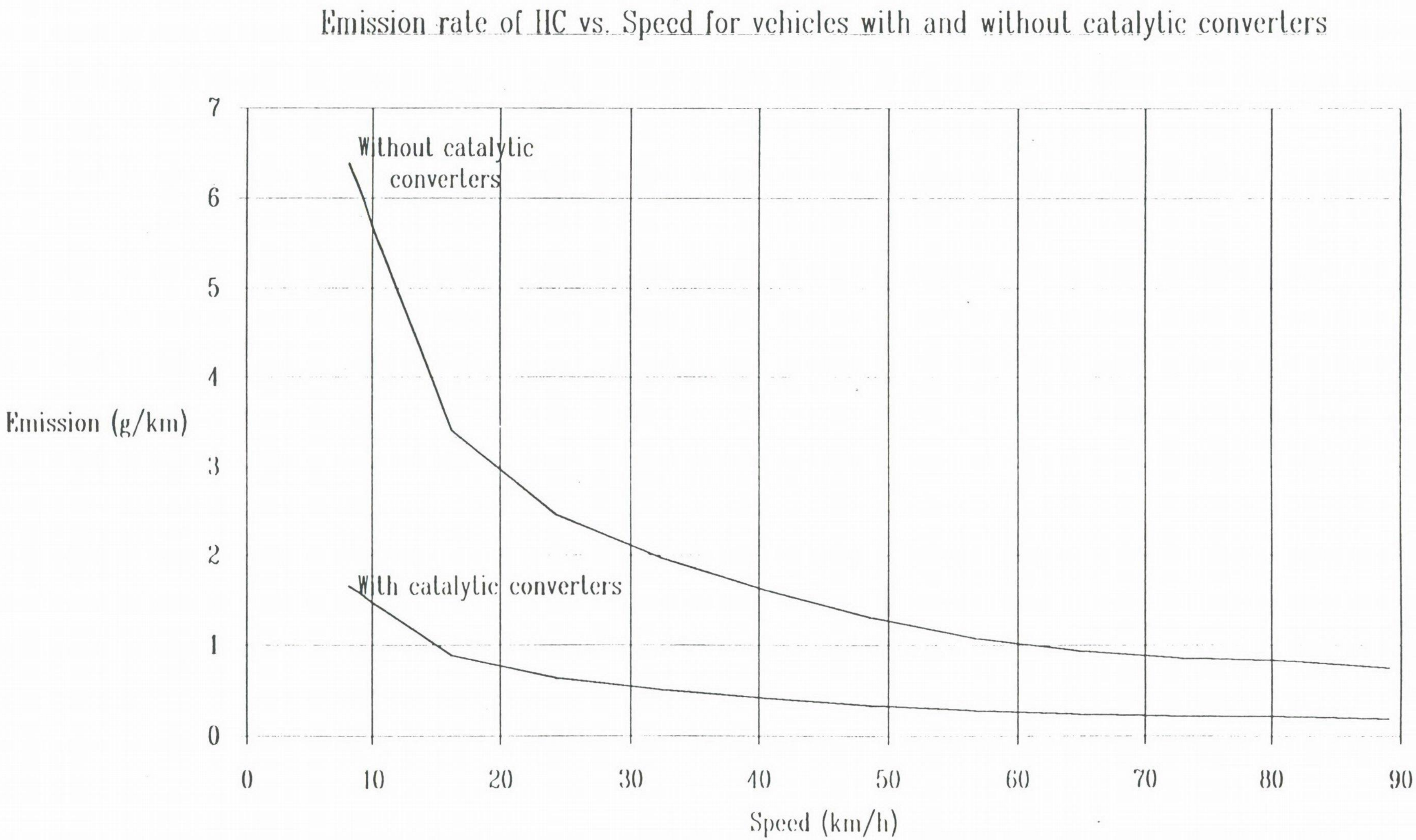


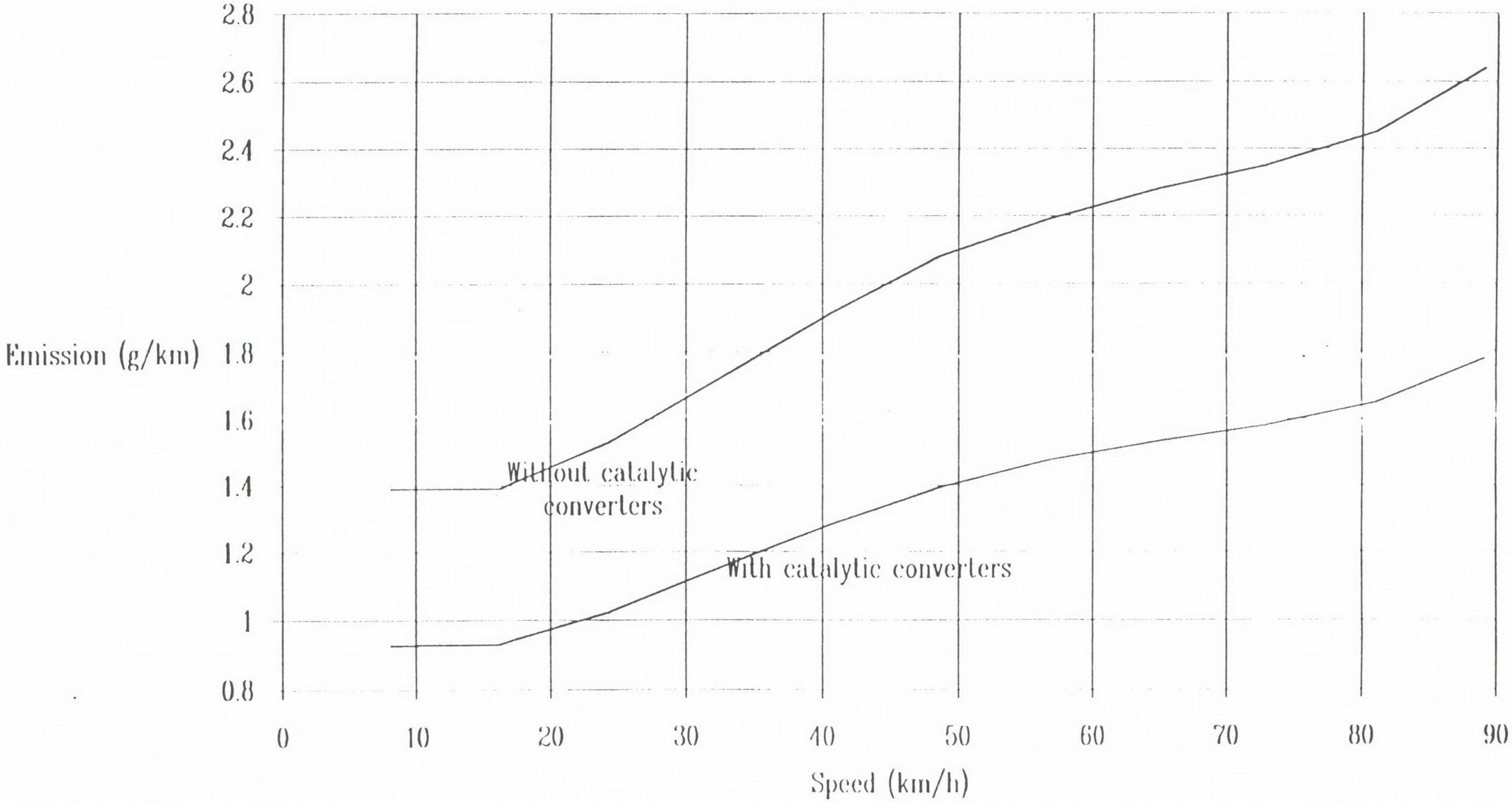
FIGURE 2 APPENDIX 3

Emission rate of CO vs. Speed for vehicles with and without catalytic converters




Emission rate of HC vs. Speed for vehicles with and without catalytic converters
Emission (g/km)
7
6
5
4
3
2
1
0
Without catalytic converters
With catalytic converters
0
10
20
30
40
50
60
70
80
90
Speed (km/h)

Emission rate of NOx vs. Speed for vehicles with and without catalytic converters



APPENDIX 4

Results of Existing Ambient Air Quality Monitoring
(Carbon Monoxide and Nitrogen Oxides)

APPENDIX 4 (i) **EXISTING AIR QUALITY MEASUREMENT RESULTS - TRAFFIC DATA EMISSION CONCENTRATIONS - P.M. 10/12/90 & 12/12/90**

Sampling Point	Date	Car	Heavy Petrol	Heavy Diesel	Carbon monoxide (ppm)	Nitrogen oxides (pphm)	Vehicle Speeds (km/h)	Temp-erature (°C)	Relative Humidity (%)	Wind Speed (m/s)
3 E	10/12	957	21	6	9.65	-	17-30	25.7	60	0-2 (NE)
3 W	10/12	1812	33	12	16.9	-	0-17-35	25.7	60	0.2 (NE)
4 E	10/12	0815	38	9	3.0	-	20-50	26.7	56.6	1.3-3.5(E)
4 W	10/12	1117	44	26	6.25	-	17-60	26.7	56.6	1.3-3.5(E)
5 E	10/12	826	14	6	4.9	-		27.0	56	0-1.5 (E)
5 W	10/12	1006	176	17	5.3	-		27.0	56	0-1.5(E)
6	10/12	-	-	-	2.6	-	-	-	-	-
7	10/12	-	-	-	2.35	-	-	-	-	-
1 E	12/12	1806	64	22	7.5	7.25*	17-40	3.15		1-2(SSE-NNW
1 W	12/12	3153	47	23	10.75	2.5	17-45	31.5		1-2(SSE-NNW
2 N	12/12	1678	36	8	8.25	2.625	33-44	30.5		0.96-1.44SW
2 S	12/12	2968	77	21	9.0	5.625	17-40	30.5		0.96-1.44SW
3 N	12/12	977	30	3	11.625	7.25	22-45	34.9		1-2.3 SW
3 S	12/12	1689	47	17	12.25	5.5	17-32	34.9		1-2.3 SW
4 N	12/12	917	18	6	10.75	4.125		-		
4 S	12/12	1197	54	17	10.75	7.25		-		
5 N	12/12	803	27	12	8.25	3.375	26-40	35.2		1-1.4:4.4NNW
5 S	12/12	1055	29	20	9.75	3.875	17-25	35.2		1-1.4:4.4NNW
6	12/12	-	-	-	3.25	1.75				
7	12/12	-	-	-	4.0	2.0				

* Run 1 - 12.5 Run 2 - 2.0

APPENDIX 4 (ii) EXISTING AIR QUALITY MEASUREMENT RESULTS - TRAFFIC DATA EMISSION CONCENTRATIONS - A.M. 11/12/90 & 12/12/90

Traffic Direction

Side of Road

Sampling Point	Date	Car	Heavy Petrol	Heavy Diesel	Carbon monoxide (ppm)	Nitrogen oxides (pphm)	Vehicle Speeds (km/h)	Temperature (°C)	Relative Humidity (%)	Wind Speed (m/s)
3 E	11/12	3312	88	19	9.5	2.75	26-45	19.1	37.6	1-3.7 (SW)
3 W	11/12	833	30	210	10.75	2.37	18-24	19.1	37.6	1-3.7 (SW)
4 E	11/12	1661	55	19	9.75	3.1	0-25	16.7	49.5	0.1-3 (SW)
4 W	11/12	1491	38	18	8.5	5.1	37-60	16.7	49.5	0.1-3 (SW)
5 E	11/12	1002	64	24	4.5	3.75	-	-	-	-
5 W	11/12	795	116	23	9.0	5.5	-	-	-	-
6	11/12	-	-	-	-	2.5	-	-	-	-
7	11/12	-	-	-	-	0.25	-	-	-	-
2 E	12/12	3310	97	34	9.75	3.5	15-52	18.4	58.5	1-2.6 (WSW)
2 W	12/12	1460	46	23	7.5	6.875	40-50	18.4	58.5	1-2.6 (WSW)
3 E	12/12	2385	38	29	13.0	9.875	20-50	21.5	38.9	Calm
3 W	12/12	992	35	18	14.0	5.75	0-20	21.5	38.9	Calm
4 E	12/12	1398	171	12	10.5	2.5	20-50	20.6	38.9	Calm
4 W	12/12	748	120	32	7.25	5.5	19-27	20.6	38.9	Calm
5 E	12/12	924	39	20	8.25	2.375	20-50		31	0-1
5 W	12/12	881	24	15	10.75	5.25	20-67	20.8	31	0-1
6	12/12	-	-	-	3.75	-	-	-	-	-
7	12/12	-	-	-	5.0	-	-	-	-	-

APPENDIX 4 (iii) EXISTING AIR QUALITY MEASUREMENT RESULTS - TRAFFIC DATA EMISSION CONCENTRATIONS - A.M. 13/12/90

Sampling Point	Date	Car	Heavy Petrol	Heavy Diesel	Carbon monoxide (ppm)	Nitrogen oxides (pphm)	Vehicle Speeds (km/h)	Temp-erature (°C)	Relative Humidity (%)	Wind Speed (m/s)
1 S	13/12	3816	75	38	7.50 E	2.00		21.6		0-1.3 (W)
1 N	13/12	1535	102	42	12.25 W	7.75				
2 E	13/12	3153	86	27	8.00 N	3.75		25.0		0.96-1.45 (W)
2 W	13/12	1436	61	26	6.25 S	6.00				
3 E	13/12	1853	39	14	12.25 N	7.25		26.9		0-1 (W)
3 S	13/12	822	35	24	10.00 S	4.50				
4 N	13/12	-	-	-	9.00	4.00				
4 S	13/12	-	-	-	11.00	6.75				
5 N	13/12	1028	44	12	4.75	2.88		21.0		1-1.7 (W)
5 S	13/12	752	38	20	9.50	5.00*				
6 N	13/12	-	-	-	2.25	0.62				
7 S	13/12	-	-	-	2.75	1.50				

* Run 1 - 7.5 Run 2 - 2.5

APPENDIX 4 (iv) EXISTING AIR QUALITY MEASUREMENT RESULTS - TRAFFIC DATA EMISSION CONCENTRATIONS - P.M. 13/12/90

Side of Road

Sampling Point	Date	Car	Heavy Petrol	Heavy Diesel	Carbon monoxide (ppm)	Nitrogen oxides (pphm)	Vehicle Speeds (km/h)	Temp-erature (°C)	Relative Humidity (%)	Wind Speed (m/s)
1 E	13/12	2202	105	14	14.5	1.75	20-45	29.4		0.4-1.5 (NE)
1 W	13/12	2738	51	14	7.75	3.0	17-30			
2 N	13/12	1794	35	8	8.0	0.25	30-65	27.1		1-3.5 (NE)
2 S	13/12	2964	79	21	5.5	4.75	30-55			
3 N	13/12	1167	26	11	15.0	1.0	32-40	29.4		2-3.5 (ENE)
3 S	13/12	1838	35	17	-	4.15	19-30			
4 N	13/12	-	-	-	11.75	3.5				
4 S	13/12	-	-	-	15.5	6.0				
5 N	13/12	1029	33	5	6.5	1.7	30-45	29.4		4-5.5 (NE)
5 S	13/12	987	48	8	-	2.3	25-40			
6	13/12	-	-	-	5.5	0.4				
7	13/12	-	-	-	3.0	0.3				

APPENDIX 4 (V) EXISTING AIR QUALITY MEASUREMENT RESULTS - TRAFFIC DATA EMISSION CONCENTRATIONS - A.M. 14/12/90

Side of Road

Sampling Point	Date	Car	Heavy Petrol	Heavy Diesel	Carbon monoxide (ppm)	Nitrogen oxides (pphm)	Vehicle Speeds (km/h)	Temp-erature (°C)	Relative Humidity (%)	Wind Speed (m/s)
1 E	14/12	3066	423	27	14.5	4.5	22-50	24.9		Calm
1 W	14/12	1385	419	53	7.75	7.0	20-51	24.9		Calm
2 N	14/12	3260	85	31	8.0	2.025	0-30	25.8		Calm
2 S	14/12	1445	64	24	5.5	5.75	40-68	25.8		Calm
3 N	14/12	2225	59	26	15.0	10.725	33-48	26.7		<0.3
3 S	14/12	900	33	26	-	7.35	0-20	26.7		<0.3
4 N	14/12	-	-	-	11.75	4.4				
4 S	14/12	-	-	-	15.5	7.6*				
5 N	14/12	974	71	20	6.5	3.125	35-50	21.7		Calm
5 S	14/12	837	35	21	-	6.375	19-47	21.7		Calm
6	14/12	-	-	-	5.5	2.0				
7	14/12	-	-	-	3.0	1.0				

* Run 1 - 13.7 Run 2 - 1.5

APPENDIX 4 (vi) EXISTING AIR QUALITY MEASUREMENT RESULTS - TRAFFIC DATA EMISSION CONCENTRATIONS - P.M. 14/12/90

Sampling Point	Date	Car	Heavy Petrol	Heavy Diesel	Carbon monoxide (ppm)	Nitrogen oxides (pphm)	Vehicle Speeds (km/h)	Temp-erature (°C)	Relative Humidity (%)	Wind Speed (m/s)
1	14/12	1716	413	14	12.0	7.45				
1	14/12	2933	381	24	9.65	5.9				
2	14/12	1711	29	8	4.65	3.0				
2	14/12	2858	76	11	4.95	6.0				
3	14/12	1188	27	2	10.75	5.3				
3	14/12	1980	41	5	8.25	5.15				
4	14/12	-	-	-	8.05	3.625*				
4	14/12	-	-	-	10.5	4.55				
5	14/12	923	18	8	6.6	2.45				
5	14/12	965	12	12	12.1	4.0				
6	14/12	-	-	-	4.75	1.4				
7	14/12	-	-	-	2.25	0.6				

- NO CLIMATIC OR SPEED DATA

Bureau of Meteorology data for North Parramatta at 3.00 p.m. on 14/12/90:-

Temperature: 31.5°C
Wet Bulb: 18.1°C
* Relative Humidity 28%
Wind (NW-SW) 9 km/h

* Run 1 - 0.75 Run 2 - 6.50

APPENDIX 4 (vii) EXISTING AIR QUALITY MEASUREMENT RESULTS - TRAFFIC DATA EMISSION CONCENTRATIONS - A.M. 18/12/90

Sampling Point (Side of Road)	Date	Car	Heavy Petrol	Heavy Diesel	Carbon monoxide (ppm)	Nitrogen oxides (pphm)	Vehicle Speeds (km/h)	Temp-erature (°C)	Relative Humidity (%)	Wind Speed (m/s)
1 E	18/12	2009	71	27	11.75	8.625	20-40	26.2		0-1.2 (NE)
1 W	18/12	3084	48	9	11.25	3.125	20-36	26.2		0-1.2 (NE)
2 N	18/12				7.0	1.75	35-84	28.0		0-2 (NE)
2 S	18/12				6.75	5.5	45-80	28.0		0-2 (NE)
3 N	18/12	824	27	5	15.5	11.125	30-60	27.5		Calm
3 S	18/12	1976	48	9	11.375	6.5	19-35	27.5		Calm
4 N	18/12	762	249	3	5.0	4.375	19-22	24.6		0-0.8 (NE)
4 S	18/12	1052	159	9	8.5	6.875	30-45	24.6		
5 N	18/12	746	14	3	7.125	3.25	20-56	28.6		0-2 (N)
5 S	18/12	884	36	5	7.75	6	20-52	28.6		0-2 (N)

APPENDIX 4 (viii) EXISTING AIR QUALITY MEASUREMENT RESULTS - TRAFFIC DATA EMISSION CONCENTRATIONS - P.M. 18/12/90

Sampling Point	Date	Car	Heavy Petrol	Heavy Diesel	Carbon monoxide (ppm)	Nitrogen oxides (pphm)	Vehicle Speeds (km/h)	Temp-erature (°C)	Relative Humidity (%)	Wind Speed (m/s)
1 E	18/12	3465	90	29	8.0	1.5	30-60	41.0		1-2 (NW)
1 W	18/12	1545	114	50	11.5	4.15	20-52			
2 N	18/12	-	-	-	9.75	2.6	40-64	39.9		0-1 (NW)
2 S	18/12	-	-	-	11.65	6.5	50-70	39.9		0-1 (NW)
3 N	18/12	2361	65	17	11.5	5.7	30-40	43		2-3 (NW)
3 S	18/12	906	36	18	5.25	2.75	0-30	43		2-3 (NW)
4 N	18/12	1418	231	24	8.0	2.5	21-25	40.3		1-1.6 (N)
4 S	18/12	672	101	15	8.5	2.9	20-53	40.3		1-1.6 (N)
5 N	18/12	1115	86	21	5.5	2.3	20-50	43.6		1-2.5 (NW)
5 S	18/12	876	44	14	13.25	4.6	20-23	43.6		1-2.5 (NW)

Side of Road:-
E = South bound traffic
W = North bound traffic
N = East bound traffic
S = West bound traffic

APPENDIX 4 (ix) EXISTING AIR QUALITY MEASUREMENT RESULTS - TRAFFIC DATA EMISSION CONCENTRATIONS - A.M. 12/02/91

Sampling Point	Date	Car	Heavy Petrol	Heavy Diesel	Carbon monoxide (ppm)	Nitrogen oxides (pphm)	Vehicle Speeds (km/h)	Temp-erature (°C)	Relative Humidity (%)	Wind Speed (m/s)
8 N	12/2	305	3	0	5.05	1.75	34-56			
8 S	12/2	765	9	0	-	1.875	42-59			
9 E	12/2	889	12	0	2.9	4.25	45-59			
9 W	12/2	301	10	1	2.2	2.75	28-34			
10 E	12/2	559	13	3	1.65	4	52-55			
10 W	12/2	494	9	2	1.25	1.93	58-64			
11C N	12/2				1.0	1.5				
11C S	12/2				0.95	1.575				
11K N	12/2	49	3	0	0.5	1.0		21.5	85	Calm
11K S	12/2	325	0	0	0.75	1.075	56			
12 E	12/2	3567	63	45	7.88 **	10.25	55-66			
12 W	12/2	1326	71	24	4.1	15.75	22-63			
13A E	12/2	2222	18	3	8.1	8.25 *	0-12			
13A W	12/2	1170	24	1	5.9	10.2	55-65			
13 E	12/2						54-64			
13B N	12/2	1272	93	25	4.95	11.45	25-35			
13B S	12/2	1124	35	18	4.0	4.9	0-50			
13C N	12/2				3.6	2.95				
13C S					1.25	2.625				

* Run 1 - 12 - 12.5
Run 2 - 4 - 4.5

** Run 1 - 14.25
Run 2 - 1.5

APPENDIX 4 (x) EXISTING AIR QUALITY MEASUREMENT RESULTS - TRAFFIC DATA EMISSION CONCENTRATIONS - P.M. 12/02/91

Sampling Point	Date	Car	Heavy Petrol	Heavy Diesel	Carbon monoxide (ppm)	Nitrogen oxides (pphm)	Vehicle Speeds (km/h)	Temp-erature (°C)	Relative Humidity (%)	Wind Speed (m/s)
8 E	12/2	351	3	0	1.475	2.525	53-61	28	56	1.79 (E-SE)
8 W	12/2	663	7	0	1.5	2.4	2-48-61	25.2	57	1.82 (SE-NE)
9 N	12/2	333	5	1	2.1	3.3	51-59			
9 S	12/2	767	3	0	-	5.1	42-54			
10 N	12/2	372	8	0	1.05	1.625	58-65			
10 S	12/2	632	11	2	1.7	3.25	58-68			
11C E	12/2				1.95	4.0				
11C W	12/2				2.55	2.5				
11K E	12/2	366	1	0	1.2	1.775	63-71			
11K W	12/2	647	2	1	2.15	2.15	59-68			
12 N	12/2	1461	36	9	4.65	9.5	68-77			
12 S	12/2	2613	59	11	2.0	6.925	0-63-68			
13A N	12/2	1255	9	1	3.2	3.05	68-81			0.73 (NW)
13A S	12/2	2244	20	3	5.45	5.475	71-78			
13B E	12/2						44-70			
13B W	12/2						45 - 70			

APPENDIX 4 (xi) EXISTING AIR QUALITY MEASUREMENT RESULTS - TRAFFIC DATA EMISSION CONCENTRATIONS - A.M. 14/02/91

Sampling Point	Date	Car	Heavy Petrol	Heavy Diesel	Carbon monoxide (ppm)	Nitrogen oxides (pphm)	Vehicle Speeds (km/h)	Temp-erature (°C)	Relative Humidity (%)	Wind Speed (m/s)
5 N	14/2	1083	53	18	3.7	4.75	32-60			
5 S	14/2	888	42	14	6	6.75	46-100			
8 E	14/2	771	6	1	3.9	4.45	0-39-55			
8 W	14/2	278	5	1	4.15	4	21-35			
9 N	14/2	932	9	1	1.65	1.625	34-42	29.2	63	
9 S	14/2	240	10	0	4.25	4.875	31-38	29.2		
10 N	14/2	731	21	0	1.85	1.5	38-56			
10 S	14/2	534	8	1	2.5	3.25	49-62			
11C N	14/2	943	0	0	1.5	1.625	0-22-37	27.0	85	0.66 (NW)
11C S	14/2	320	1	0	4.35	4.75	47-72	27.0		0.66 (NW)
11K N	14/2				1.65	1.275	61-69	27.0		0.3 (NW)
11K S	14/2				3.2	3.0	64-83	27.0		0.3 (NW)
12 N	14/2	3666	93	15	10.75	20.75				
12 S	14/2	1196	48	21	5.35	16.25				

APPENDIX 4 (xii) EXISTING AIR QUALITY MEASUREMENT RESULTS - TRAFFIC DATA EMISSION CONCENTRATIONS - P.M. 14/02/91

Sampling Point (Side of Road)	Date	Car	Heavy Petrol	Heavy Diesel	Carbon monoxide (ppm)	Nitrogen oxides (pphm)	Vehicle Speeds (km/h)	Temp-erature (°C)	Relative Humidity (%)	Wind Speed (m/s)
5 N	14/2	1136	29	5	3.15	1.5	47-58			
5 S	14/2	1262	42	8	5.55	3.85	42-64			
8 N	14/2	771	3	0	4.35	1.75	33-48			
8 S	14/2	269	4	1	5.45	3.0	39-49			
9 N	14/2	315	5	2	1.45	1.0	37-52			
9 S	14/2	755	5	1	4.9	4.05	29-35			
10 N	14/2	367	7	0	1.95	2.05	62-67	39.8	23	1.9 (NE)
10 S	14/2	685	7	0	1.3	0.7	57-67			
11C E	14/2				1.4	1.05				
11C W	14/2				2.75	1.65				
11K E	14/2	361	0	0	1.0	0.875	69-87			0.8 (NW)
11K W	14/2	604	0	0	2.05	1.2	56-75			
12 N	14/2	1596	42	1	15.35	11.95	59-68	39	32	0.55 (W)
12 S	14/2	2742	68	6	6.7	3.1	27-31			

APPENDIX 5

Tabulated Raw Data
(Carbon Monoxide & Nitrogen Oxides Roadside Concentrations)
Existing Environment

APPENDIX 5 (i) CARBON MONOXIDE ROADSIDE CONCENTRATIONS

Site*	Run 1 10/12 p.m.	Run 2 10/12 p.m.	Run 1 11/12 a.m.	Run 2 11/12 a.m.	Run 1 12/12 a.m.	Run 2 12/12 a.m.	Run 1 12/12 p.m.	Run 2 12/12 p.m.	Run 1 13/12 a.m.	Run 2 13/12 a.m.
1							7.50 16.00	- 5.50	5.50 13.00	9.50 11.50
2					10.50 -	9.00 7.50	7.50 10.50	9.00 7.50	9.50 7.00	6.50 5.50
3	10.30 15.60	9.00 18.20	9.50 13.00	- 8.50	16.00 13.00	10.00 15.00	13.25 9.50	11.00 10.50	15.50 10.50	15.00 9.50
4	- 7.00	3.00 5.50	9.00 9.00	10.50 8.00	9.50 8.50	11.50 6.00	10.00 15.50	8.50 15.00	9.50 10.50	8.50 11.50
5	4.60 5.30	5.20 -	4.50 9.50	3.50	9.50 14.50	7.00 7.00	9.50 12.50	8.00 12.00	3.00 10.50	6.50 8.50
6	3.00	2.20			4.50	3.00	3.50	1.00	2.00	2.50
7	2.70	2.00			6.50	3.50	4.50	1.00	2.50	3.00

* Refer Map 1 for site locations
All concentrations are measured in ppm (parts per million)

APPENDIX 5 (ii) CARBON MONOXIDE ROADSIDE CONCENTRATIONS

Site*	Run 1 14/12 a.m.	Run 2 14/12 a.m.	Run 1 14/12 p.m.	Run 2 14/12 p.m.	Run 1 18/12 a.m.	Run 2 18/12 a.m.	Run 1 18/12 p.m.	Run 2 18/12 p.m.
1	16.50 6.50	12.50 9.00	12.00 10.30	- 9.20	10.50 -	13.00 11.25	7.50 10.50	8.50 12.50
2	6.50 5.50	9.50 5.50	4.80 3.90	4.50 6.00	-	7.00 6.75	12.00 12.80	7.50 10.50
3	17.50 -	12.50 -	10.50 9.00	11.00 7.50	17.00 12.25	14.00 10.50	11.00 3.00	12.00 7.50
4	12.00 15.50	11.50 -	9.60 12.00	6.50 9.00	5.00 8.50	- -	10.50 8.00	5.50 9.00
5	- -	6.50 -	7.20 13.50	6.00 10.70	8.75 -	5.50 7.75	6.00 12.00	5.00 14.50
6	5.5	-	4.5	5.0				
7	3.0	-	3.0	1.5				

* Refer Map 1 for site locations
All concentrations are measured in ppm (parts per million)

APPENDIX 5 (iii) CARBON MONOXIDE ROADSIDE CONCENTRATIONS

Site†	Run 1 12/2 a.m.		Run 2 12/2 a.m.		Run 1 12/2 p.m.		Run 2 12/2 p.m.		Run 1 14/2 a.m.		Run 2 14/2 a.m.		Run 1 14/2 p.m.		Run 2 14/2 p.m.	
5									4.8	7.3	2.6	4.7	3.2	5.4	3.1	5.7
8	8.5	-	1.6	-	1.25	1.4	1.7	1.6	4.5	4.1	3.3	4.2	5.0	8.8	3.7	2.1
9	3.4	1.7	2.4	2.7	1.9	-	2.3	-	1.8	5.2	1.5	3.3	1.1	4.5	1.8	5.3
10	2.0	0.8	1.3	1.7	0.8	1.7	1.3	1.7	2.2	2.6	1.5	2.4	1.2	1.9	1.4	2.0
11 C	1.4	0.6	0.6	1.3	2.1	2.7	1.8	2.4	2.2	5.4	0.8	3.3	1.6	3.0	1.2	2.5
11 K	5.0	0.7	0.3	1.0	1.4	2.4	1.0	1.9	2.0	3.7	1.3	2.7	1.4	2.0	0.6	2.1
12	14.25	-	1.5	4.1	4.4	1.0	4.9	3.0	10.8	4.7	10.7	6.0	11.9	7.9	18.8	4.4
13 A	10.2	6.6	6.0	5.2	3.3	4.8	3.1	6.1								
13 B	6.5	4.2	3.4	3.6	1.3	2.8	3.7	2.3								
13 C	5.3	1.4	1.9	1.1	1.8	1.2	1.8	0.7								

† Refer Map 1 for site locations
All concentrations are measured in ppm (parts per million)

APPENDIX 5 (iv) NITROGEN OXIDES ROADSIDE CONCENTRATIONS

Site*	Run 1 11/12 a.m.	Run 2 11/12 a.m.	Run 1 12/12 a.m.	Run 2 12/12 a.m.	Run 1 12/12 p.m.	Run 2 12/12 p.m.	Run 1 13/12 a.m.	Run 2 13/12 a.m.	Run 1 13/12 p.m.	Run 2 13/12 p.m.
1	- -	- -	- -	- -	12.50 2.50	2.00 -	2.25 9.25	1.75 6.25	1.50 3.00	2.00 3.00
2	- -	- -	3.50 7.25*	3.50 6.50	3.50 5.00	1.75 6.25	3.75 5.25	3.75 6.75	0.20 5.00	0.30 4.50
3	- 2.25	2.75 2.50	12.25 5.75	7.50 5.75	7.75 6.00	6.75 5.00	7.25 4.25	7.25 4.75	1.00 3.80	1.00 4.50
4	4.25 6.25	2.00 4.00	2.50 6.25	2.50* 4.75	4.50 10.25	3.75 4.25	3.75 7.25	4.25 6.25	2.00 5.80	5.00 6.20
5	3.75 5.25	- 5.75	2.75 5.75	2.00 4.75	3.00 3.50	3.75 4.25	3.25 7.25	2.50 2.75	1.70 2.30	- -
6	2.50				2,00	1.50	1.00	0.25	0.30	0.50
7	0.25				1.75	2.25	1.25	1.75	0.30	0.30

* Refer Map 1 for site locations
All concentrations are measured in pphm (parts per hundred million)

APPENDIX 5 (v) **NITROGEN OXIDES ROADSIDE CONCENTRATIONS**

Site*	Run 1 14/12 a.m.	Run 2 14/12 a.m.	Run 1 14/12 p.m	Run 2 14/12 p.m.	Run 1 18/12 a.m.	Run 2 18/12 a.m.	Run 1 18/12 p.m.	Run 2 18/12 p.m.
1	2.00	7.00 7.00	7.40 5.60	7.50 6.20	7.25 1.50	10.00 4.75	1.00 3.00	2.00 5.30
2	2.25 5.75	1.80 5.75	3.00 5.00	3.00 7.00*	- -	1.75 5.50	3.20 5.00	2.00 8.00
3	11.20 9.50	10.25 5.20	4.00 6.30	6.60 4.00	12.50 5.25	9.75 7.75	- 2.50	5.70 3.00
4	4.30 13.70	4.50 1.50	0.75 5.30	6.50 3.80	3.75 11.25	5.00 2.50	3.00 2.50	2.00 3.30
5	4.25 7.25	2.00 5.50	2.50 2.00	2.40 6.00	4.75 7.25	1.75 4.75	- 4.20	2.30 5.00
6	2.00		2.30	0.50				
7	1.00		<0.2	1.0				

* Refer Map 1 for site locations
All concentrations are measured in pphm (parts per hundred million)

APPENDIX 5 (vi)

NITROGEN OXIDES ROADSIDE CONCENTRATIONS

Site¹	Run 1 12/2 a.m.		Run 2 12/2 a.m.		Run 1 12/2 p.m.		Run 2 12/2 p.m.		Run 1 14/2 a.m.		Run 2 14/2 a.m.		Run 1 14/2 p.m.		Run 2 14/2 p.m.	
5									6.25	8.75	3.25	4.75	1.5	3.8	1.5	3.9
8	2.25	2.5	1.25	1.25	2.3	2.8	2.75	2.0	5.75	3.75	3.15	4.25	1.5	2.3	2.0	3.7
9	4.25	3.25	–	2.25	2.5	–	4.1	5.1	1.25	5.75	1.15	4.0	0.8	4.1	1.2	4.0
10	4.0	1.25	–	2.6	2.25	3.5	1.0	3.0	1.75	2.75	1.25	3.75	0.6	2.0	0.8	2.1
11 C	1.75	1.65	1.25	1.5	4.2	2.7	3.8	2.3	1.75	5.25	2.0	4.25	1.1	1.6	1.0	1.7
11 K	1.0	1.25	0.75	1.15	1.8	1.8	1.75	2.5	1.25	3.25	0.5	2.75	1.0	1.0	0.75	1.4
12	14.25	18.25	6.25	10.25	8.0	7.25	11.0	6.6	21.25	19.75	20.25	12.75	9.7	3.7	14.2	2.5
13 A	12.25	12.25	4.25	8.15	3.1	3.2	3.0	7.75								
13 B	13.65	3.15	9.25	6.65	4.25	3.25	5.25	2.75								
13 C	2.25	3.1	3.65	2.15	1.25	0.5	1.75	1.3								

¹ Refer Map 1 for site locations
All concentrations are measured in pphm (parts per hundred million)

13 (A), (B), (C) - Refer Figure 1 for sampling site locations

APPENDIX 6

Vehicle Emission Factors

VEHICLE EMISSION FACTORS

The emissions from vehicles on Sydney's roads were assumed to all fit into three classes:

1. Light duty petrol vehicles (LDPV)
2. Heavy duty petrol vehicles (HDPV)
3. Heavy duty diesel vehicles (HDDV)

These classes of vehicles account for more than 99 % of all vehicle kilometres travelled on Sydney's roads (Pengilly 1989). The following assumptions were made regarding the vehicles in the year 2006:

* 100 % of petrol vehicles were using catalytic converters as emission control.

* 7 % of all vehicles on any particular stretch of road are considered to be cold start. This is assumed since the cold start conditions only apply for vehicles 2 km from the start up point.

* Of the heavy vehicles category on the route plans, 71 % are considered to be HDDV and 29 % area considered to be HDPV.

The emissions of CO and HC from vehicles can be determined from the following equation (Pengilly 1989, USEPA 1985):

$$E = P * \exp(A + B*S + C*S^2 + D*S^3 + E*S^4 + F*S^5) \quad (1)$$

NO_x emissions can be calculated using the following:

$$E = P * (A + B*S + C*S^2 + D*S^3 + E*S^4) \quad (2)$$

where,

E = speed corrected emission factor in $g.km^{-1}$ for the average vehicle (valid for the speed range of 8 $km.h^{-1}$ to 88 $km.h^{-1}$).

P = city cycle emission factor in $g.km^{-1}$ for the average vehicle.

S = average speed in $miles.h^{-1}$ for the section of road in question.

A,B,C,D,E and F = constants for each pollutant and each vehicle class.

The emission of particulate matter from vehicles is made up of lead salts, organic and sulphate components. The total emission factor is calculated from the average vehicle particulate emission factor plus the airborne brake wear particulate emission factor plus the airborne tire wear particulate emission factor (USEPA 1985). The equation is as follows:

$$E_p = E_{part} + E_{brakes} - E_{tires} \qquad (3)$$

For LDPV

CO: P = 14.3 $g.km^{-1}$ (cold)
P = 4.2 $g.km^{-1}$ (hot)

A = 0.248747 E+01
B = -0.391562 E+00
C = 0.270721 E-01
D = -0.976178 E-03
E = 0.165270 E-04
F = -0.104317 E-06

HC: P = 1.84 $g.km^{-1}$ (cold)
P = 0.52 $g.km^{-1}$ (hot)

A = 0.239540 E+01
B = -0.335781 E+00
C = 0.211609 E-01
D = -0.731550 E-03
E = 0.120715 E-04
F = -0.748566 E-07

NO_x: P = 1.69 $g.km^{-1}$ (cold)
P = 1.41 $g.km^{-1}$ (hot)

A = 0.942131 E+00
B = -0.423240 E-01
C = 0.386253 E-02
D = -0.939853 E-04
E = 0.753883 E-06

Particulates: $E_p = 0.0609\ g.km^{-1}$

For HDPV

CO: $P = 73.6\ g.km^{-1}$ (cold)
$P = 53.4\ g.km^{-1}$ (hot)

A = 1.5200
B = -0.0980
C = 0.0011
D = E = F = 0.0

HC: $P = 7.9\ g.km^{-1}$ (cold)
$P = 6.6\ g.km^{-1}$ (hot)

A = 1.60800
B = -0.09700
C = 0.00083
D = E = F = 0.0

NO_x: $P = 4.3\ g.km^{-1}$ (hot and cold)

A = 0.8240
B = 0.0088
C = D = E = 0.0

Particulates: $E_p = 0.1113\ g.km^{-1}$

For HDDV

CO: $P = 7.5\ g.km^{-1}$ (hot and cold)

A = 1.39600
B = -0.08800
C = 0.00091
D = E = F = 0.0

HC: $P = 2.56\ g.km^{-1}$ (hot and cold)

A = 0.92400
B = -0.05500
C = 0.00044
D = E = F = 0.0

NO_x: $P = 15.0\ g.km^{-1}$ (hot and cold)

$A = 0.67600$
$B = -0.04800$
$C = 0.00071$
$D = E = F = 0.0$
Note : the formula for this NO_x calculation is the exp formula.

Particulates: $E_p = 0.4375\ g.km^{-1}$

APPENDIX 7

Estimated Vehicle Emissions
and Roadside Pollutant Concentrations,
1996 and 2016

TABLE 1

ESTIMATED VEHICLE EMISSIONS IN 1996

(kg/km/hour)

Roadway Section 1996	OPTIONS				
	Expw'y ($0.70 toll)	Expw'y (No Toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Rd intersection to Beecroft Rd intersection, Epping					
CO	10.03	12.77	22.02	22.60	12.26
HC	1.22	1.56	2.67	2.84	1.56
NOx	5.17	6.32	5.61	5.96	3.09
PM	0.23	0.29	0.32	0.34	0.16
Beecroft Rd intersection to Lane Cove Rd intersection, North Ryde					
CO	13.16	13.16	25.03	23.57	20.81
HC	1.9	1.61	3.12	2.92	2.64
NOx	6.2	6.26	7.86	7.39	5.82
PM	0.29	0.29	0.39	0.39	0.30
Lane Cove Rd intersection to Epping Rd/Delhi Rd, East Ryde					
CO	9.53	12.03	36.3	36.26	57.84
HC	1.14	1.47	4.33	4.59	7.85
NOx	4.77	5.83	9.62	9.83	8.08
PM	0.21	0.26	0.51	0.53	0.50

TABLE 2

ESTIMATED VEHICLE EMISSIONS IN 2016

(kg/km/hour)

Roadway Section 2016	OPTIONS				
	Expw'y ($0.70 toll)	Expw'y (No Toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Rd intersection to Beecroft Rd intersection, Epping					
CO	17.86	18.75	33.56	36.33	20.85
HC	2.21	2.30	5.22	4.76	2.71
NOx	6.24	7.67	6.88	6.83	4.68
PM	0.31	0.36	0.42	0.44	0.26
Beecroft Rd intersection to Lane Cove Rd intersection, North Ryde					
CO	25.66	32.67	32.07	33.23	27.76
HC	3.17	4.17	4.05	4.22	3.59
NOx	6.23	8.11	8.71	8.63	6.41
PM	0.35	0.45	0.46	0.47	0.67
Lane Cove Rd intersection to Epping Rd/Delhi Rd, East Ryde					
CO	17.72	18.68	61.31	60.96	79.91
HC	2.20	2.30	8.17	8.13	10.86
NOx	5.77	6.81	10.96	10.70	9.94
PM	0.29	0.33	0.65	0.63	0.62

TABLE 3 1996 ESTIMATED MAXIMUM 1-HOUR CARBON MONOXIDE CONCENTRATION INCREASE AT 10 m FROM ROAD SIDE FOR RANGE OF UPGRADE OPTIONS - (mg/m^3)

Roadway Section	Expw'y ($0.70 toll)	Expw'y (No toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Road intersection to Beecroft Road intersection, Epping	1.2	1.5	2.6	2.7	1.5
Beecroft Road intersection to Lane Cove Road intersection, North Ryde	1.6	2.6	3.0	2.8	2.5
Lane Cove Road to Epping Road/Delhi Road East Ryde	1.1	1.4	4.4	4.4	6.9

Expw'y ($0.70 toll)	Expressway ($0.70 toll) with public transport
Expw'y ($0.70 toll)	Expressway (No toll) with public transport
U.A.R. (East and West)	Upgraded arterial routes in both East and West
U.A.R. (East only)	Expressway in West to Pennant Hills Road and upgraded arterial route (Carlingford and Epping Roads) East of Pennant Hills Road
Base Case	No change to existing route system

TABLE 4 1996 ESTIMATED MAXIMUM 1-HOUR HYDROCARBON CONCENTRATION INCREASE AT 10 m FROM ROAD SIDE FOR RANGE OF UPGRADE OPTIONS - (mg/m^3)

Roadway Section	Expw'y ($0.70 toll)	Expw'y (No toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Road intersection to Beecroft Road intersection, Epping	0.15	0.19	0.32	0.34	0.19
Beecroft Road intersection to Lane Cove Road intersection, North Ryde	0.19	0.32	0.37	0.35	0.32
Lane Cove Road to Epping Road/Delhi Road East Ryde	0.14	0.18	0.52	0.55	0.94

Expw'y ($0.70 toll)	Expressway ($0.70 toll) with public transport
Expw'y ($0.70 toll)	Expressway (No toll) with public transport
U.A.R. (East & West)	Upgraded arterial routes
U.A.R. (East only)	Expressway in West to Pennant Hills Road and upgraded arterial route (Carlingford and Epping Roads) East of Pennant Hills Road
Base Case	No change to existing route system

TABLE 5 1996 ESTIMATED MAXIMUM 1-HOUR NITROGEN OXIDES CONCENTRATION INCREASE AT 10 m FROM ROAD SIDE FOR RANGE OF UPGRADE OPTIONS - ($\mu g/m^3$)

Roadway Section	Expw'y ($0.70 toll)	Expw'y (No toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Road intersection to Beecroft Road intersection, Epping	620	758	673	715	371
Beecroft Road intersection to Lane Cove Road intersection, North Ryde	751	940	943	887	698
Lane Cove Road to Epping Road/Delhi Road East Ryde	572	700	1154	1180	970

Expw'y ($0.70 toll)	Expressway ($0.70 toll) with public transport
Expw'y ($0.70 toll)	Expressway (No toll) with public transport
U.A.R. (East & West)	Upgraded arterial routes for East and West
U.A.R. (East only)	Expressway in West to Pennant Hills Road and upgraded arterial route (Carlingford and Epping Roads) East of Pennant Hills Road
Base Case	No changes to existing route system

TABLE 6 1996 ESTIMATED MAXIMUM 1-HOUR NITROGEN DIOXIDE CONCENTRATION INCREASE AT 10 m FROM ROAD SIDE FOR RANGE OF UPGRADE OPTIONS - ($\mu g/m^3$)

Roadway Section	Expw'y ($0.70 toll)	Expw'y (No toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Road intersection to Beecroft Road intersection, Epping	217	265	236	250	130
Beecroft Road intersection to Lane Cove Road intersection, North Ryde	263	329	330	310	244
Lane Cove Road to Epping Road/Delhi Road East Ryde	200	245	404	413	340

Expw'y ($0.70 toll)	Expressway ($0.70 toll) with public transport
Expw'y ($0.70 toll)	Expressway (No toll) with public transport
U.A.R. (East and West)	Upgraded arterial routes for East and West
U.A.R. (East only)	Expressway in West to Pennant Hills Road and upgraded arterial route (Carlingford and Epping Roads) East of Pennant Hills Road
Base Case	No changes to existing route system

TABLE 7 1996 ESTIMATED MAXIMUM 1-HOUR PARTICULATE CONCENTRATION INCREASE AT 10 m FROM ROAD SIDE FOR RANGE OF UPGRADE OPTIONS - ($\mu g/m^3$)

Roadway Section	Expw'y ($0.70 toll)	Expw'y (No toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Road intersection to Beecroft Road intersection, Epping	28	35	38	41	19
Beecroft Road intersection to Lane Cove Road intersection, North Ryde	35	46	47	47	36
Lane Cove Road to Epping Road/Delhi Road East Ryde	25	31	61	64	60

Expw'y ($0.70 toll)	Expressway ($0.70 toll) with public transport
Expw'y ($0.70 toll)	Expressway (No toll) with public transport
U.A.R. (East only)	Upgraded arterial routes for East and West
U.A.R. (East & West)	Expressway in West to Pennant Hills Road and upgraded arterial route (Carlingford and Epping Roads) East of Pennant Hills Road
Base Case	No changes to existing route system

TABLE 8 2016 ESTIMATED MAXIMUM 1-HOUR CARBON MONOXIDE CONCENTRATION INCREASE AT 10 m FROM ROAD SIDE FOR RANGE OF UPGRADE OPTIONS - (mg/m^3)

Roadway Section	Expw'y ($0.70 toll)	Expw'y (No toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Road intersection to Beecroft Road intersection, Epping	2.1	2.3	4.0	4.4	2.5
Beecroft Road intersection to Lane Cove Road intersection, North Ryde	3.1	3.9	3.8	4.0	3.3
Lane Cove Road to Epping Road/Delhi Road East Ryde	2.1	2.2	7.4	7.3	9.6

Expw'y ($0.70 toll)	Expressway ($0.70 toll) with public transport
Expw'y ($0.70 toll)	Expressway (No toll) with public transport
U.A.R. (East and West)	Upgraded arterial routes in both East and West
U.A.R. (East only)	Expressway in West to Pennant Hills Road and upgraded arterial route (Carlingford and Epping Roads) East of Pennant Hills Road
Base Case	No change to existing route system

TABLE 9 2016 ESTIMATED MAXIMUM 1-HOUR HYDROCARBON CONCENTRATION INCREASE AT 10 m FROM ROAD SIDE FOR RANGE OF UPGRADE OPTIONS - (mg/m^3)

Roadway Section	Expw'y ($0.70 toll)	Expw'y (No toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Road intersection to Beecroft Road intersection, Epping	0.27	0.28	0.63	0.57	0.33
Beecroft Road intersection to Lane Cove Road intersection, North Ryde	0.38	0.50	0.49	0.51	0.43
Lane Cove Road to Epping Road/Delhi Road East Ryde	0.26	0.28	0.98	0.98	1.30

Expw'y ($0.70 toll)	Expressway ($0.70 toll) with public transport
Expw'y ($0.70 toll)	Expressway (No toll) with public transport
U.A.R. (East & West)	Upgraded arterial routes
U.A.R. (East only)	Expressway in West to Pennant Hills Road and upgraded arterial route (Carlingford and Epping Roads) East of Pennant Hills Road
Base Case	No change to existing route system

TABLE 10 2016 ESTIMATED MAXIMUM 1-HOUR NITROGEN OXIDES CONCENTRATION INCREASE AT 10 m FROM ROAD SIDE FOR RANGE OF UPGRADE OPTIONS - ($\mu g/m^3$)

Roadway Section	Expw'y ($0.70 toll)	Expw'y (No toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Road intersection to Beecroft Road intersection, Epping	749	920	826	820	562
Beecroft Road intersection to Lane Cove Road intersection, North Ryde	748	973	1045	1036	769
Lane Cove Road to Epping Road/Delhi Road East Ryde	692	817	1315	1284	1193

Expw'y ($0.70 toll)	Expressway ($0.70 toll) with public transport
Expw'y ($0.70 toll)	Expressway (No toll) with public transport
U.A.R. (East & West)	Upgraded arterial routes for East and West
U.A.R. (East only)	Expressway in West to Pennant Hills Road and upgraded arterial route (Carlingford and Epping Roads) East of Pennant Hills Road
Base Case	No changes to existing route system

TABLE 11 2016 ESTIMATED MAXIMUM 1-HOUR NITROGEN DIOXIDE CONCENTRATION INCREASE AT 10 m FROM ROAD SIDE FOR RANGE OF UPGRADE OPTIONS - ($\mu g/m^3$)

Roadway Section	Expw'y ($0.70 toll)	Expw'y (No toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Road intersection to Beecroft Road intersection, Epping	262	322	289	287	197
Beecroft Road intersection to Lane Cove Road intersection, North Ryde	262	341	366	363	269
Lane Cove Road to Epping Road/Delhi Road East Ryde	242	286	460	449	418

Expw'y ($0.70 toll)	Expressway ($0.70 toll) with public transport
Expw'y ($0.70 toll)	Expressway (No toll) with public transport
U.A.R. (East and West)	Upgraded arterial routes for East and West
U.A.R. (East only)	Expressway in West to Pennant Hills Road and upgraded arterial route (Carlingford and Epping Roads) East of Pennant Hills Road
Base Case	No changes to existing route system

TABLE 12 2016 ESTIMATED MAXIMUM 1-HOUR PARTICULATE CONCENTRATION INCREASE AT 10 m FROM ROAD SIDE FOR RANGE OF UPGRADE OPTIONS - ($\mu g/m^3$)

Roadway Section	Expw'y ($0.70 toll)	Expw'y (No toll)	U.A.R. (East & West)	U.A.R. (East only)	Base Case
Pennant Hills Road intersection to Beecroft Road intersection, Epping	37	43	50	53	31
Beecroft Road intersection to Lane Cove Road intersection, North Ryde	42	54	55	56	80
Lane Cove Road to Epping Road/Delhi Road East Ryde	35	40	78	76	74

Expw'y ($0.70 toll)	Expressway ($0.70 toll) with public transport
Expw'y ($0.70 toll)	Expressway (No toll) with public transport
U.A.R. (East only)	Upgraded arterial routes for East and West
U.A.R. (East & West)	Expressway in West to Pennant Hills Road and upgraded arterial route (Carlingford and Epping Roads) East of Pennant Hills Road
Base Case	No changes to existing route system

APPENDIX 8

Dispersion Modelling Approach

APPENDIX 8 DISPERSION MODELLING APPROACH

Ground-level concentrations of motor vehicle exhaust emissions have been calculated in a number of ways depending on the circumstances of the emissions. Two approaches have had to be adopted. The first is for simple situations in when the road is level, or approximately level, with the local ground surface and the surrounding land is either flat or gently undulating. The second is for cases where the road runs through steeply sided valleys in which case a simple box model is used. In the case of flat or undulating terrain the approach has been to use the dispersion model known as the General Motors (GM) model as developed by Chock (1977).

The model is based on the Gaussian line-source equation which can be written as follows:

$$C(x,z) = \frac{q}{\sqrt{2\pi u \sigma_z}}[\exp[-\frac{1}{2}\frac{(z+h_o)^2}{\sigma_z^2}] + \exp[-\frac{1}{2}\frac{(z-h_o)^2}{\sigma_z^2}]] \quad (1)$$

Where,

$C(x,z)$ = concentration at downwind distance x and height z above the ground,

U = effective crossroad wind speed (see later) at the effective height of the plume,

σ_z = the vertical dispersion parameter, and

h_o = the height of the source above the ground.

Equation (1) is the standard line-source equation for winds perpendicular to the line. Chock makes two modifications to the equation to enable it to be used for winds which are not parallel to the road and provides a set of vertical plume-spread σ_z parameters which take account of traffic induced turbulence.

The equation for σ_z is as follows:

$$\sigma_z = (a + bx)^c \qquad \textbf{(2)}$$

The values for a and b are dependent on meteorological conditions and are listed below.

	Stable	**Neutral**	**Unstable**
a (in $m^{1/c}$)	1.49	1.14	1.14
b (in $m^{-1+1/c}$)	0.15	0.10	0.05
c	0.77	0.97	1.33

The model also requires that σ_z is modified as the direction of the wind varies relative to the road. The equations are as follows:

$$\sigma_z = (a + b.f(\theta).x)^c \qquad \textbf{(3)}$$

$$f(\theta) = 1 + \beta \left| \frac{\theta - 90^o}{90^o} \right|^{\gamma} \qquad \textbf{(4)}$$

Where,

θ = the angle, in degrees, of the wind relative to the road.

Gamma (γ) is an experimentally determined variable, which varies with stability as follows:

	Stable	Neutral	Unstable
γ	3.57	3.50	3.50

When wind speed and direction are input to the model it is the crossroad wind speed U_a (that is the component of wind perpendicular to the road) plus a correction factor U_o that is used. In addition, a term U_1 is also used at low wind speeds to account for the additional effective wind caused by the traffic flow. The values for U_o and U_1 are again dependent on stability as shown below.

	Stable	Neutral	Unstable
U_1 (m/s)	0.18	0.27	
U_o (m/s)	0.23	0.38	0.63

Warm motor vehicle emissions will undergo plume rise appropriate for a line source. The procedure used in the current use of the GM model is that set out by Chock (1977) which is based on the Briggs (1969) and (1975) plume rise equations.

REFERENCES

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"Plume rise", US Atomic Energy Commission, Division of Technical Information Extension, Oak Ridge, Tennessee, Library of Congress Number 72-603261.

Briggs, G. A. (1975)
"Plume rise predictions". In "Lectures in Air Pollution and Environmental Impact Analyses". Editors D. A. Haugen, American Meteorological Society, Boston.

Chock, D. P. (1978)
"A simplified line-source model for dispersion near roadways", Atmospheric Environment, Volume 12, 823-829.

APPENDIX 9

Sonic Anemometer

SONIC ANEMOMETER

1.0 Introduction

To measure low velocity winds, a sonic anemometer was built. The principle of the anemometer is that an acoustic signal is transmitted at a known frequency, in this case - 40 kHz, and this signal is then received and amplified. The phases of the transmitted and received signals are then compared.

In still conditions, if the two signals are in phase initially, then they should remain in phase. Any wind movement causes the velocity of the sound wave to increase and hence the signals move out of phase. The velocity of this air movement is then calculated from this phase shift with an appropriate correction being made for air temperature, which also affects the phase shift.

2.0 Instrumentation

The sonic anemometer was designed to detect winds in the x-y plane. Two pairs of ultrasonic transducers were used at 90 degrees to each other to detect these winds. Each pair of ultrasonic transducers consisted of a transmitter and a receiver. Independent circuitry was then built for each pair of transducers such that no interference from one pair could affect the other pair.

The circuitry consisted of the following components:

2.1 Regulated power supply

The batteries used were 2 x 12 volt gel cell batteries connected to supply +12V, OV and -12V. The voltage was then regulated to +6V, 0V and -6V using standard voltage regulators.

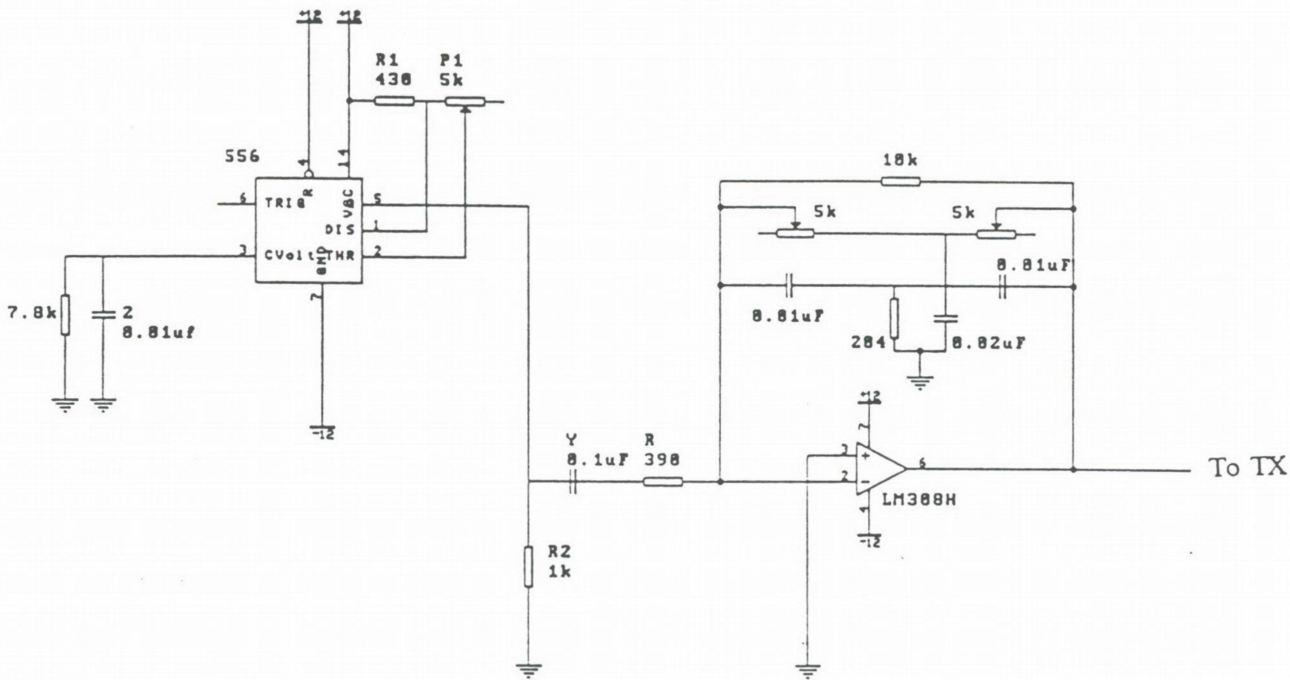
This provided a constant voltage within the circuit until the supply voltage (from batteries) dropped below 7 V, thus providing up to 36 hours of operation from the sonic anemometer.

2.2 40 kHz Oscillator

This circuit was used to drive the transmitters of each pair of ultrasonic transducers. A LM556 timer was used to generate a square wave with period of 20 µs and an amplitude of 6 volts. An active band pass filter was designed to filter the square wave so that the output to the circuit was a smooth sinusoid. This consisted of a 308 operational amplifier in parallel with a twin T filter. Potentiometers were used in the filter to allow fine tuning of the output.

The circuit used is as shown in Figure 1.

Figure 1
Oscillator Circuit



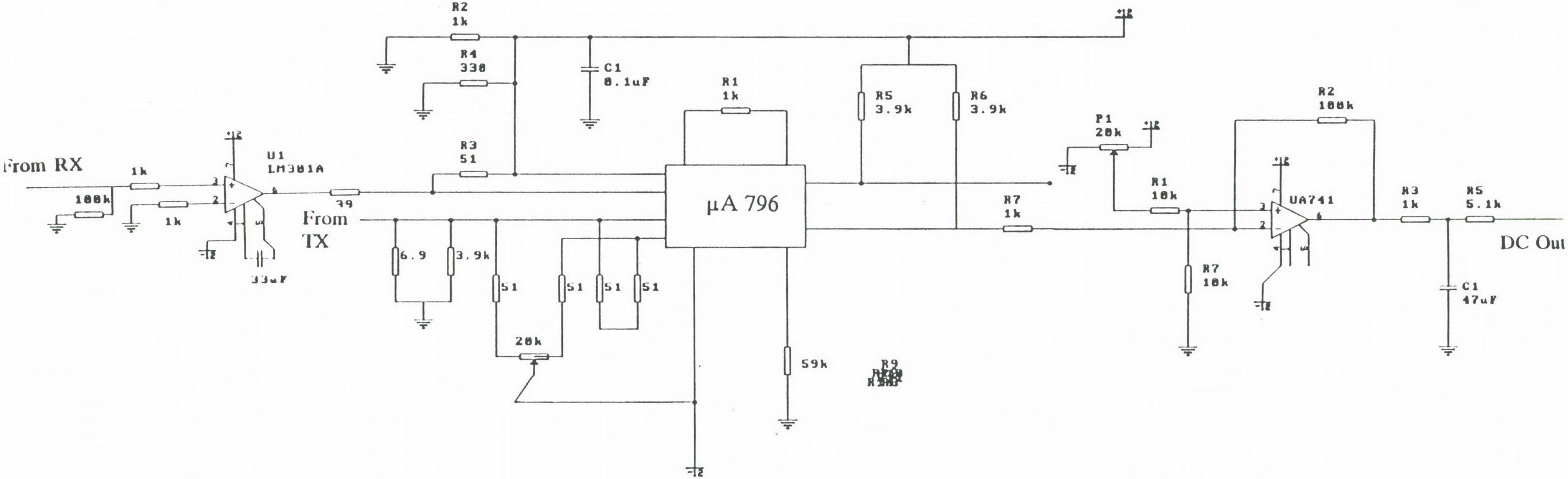
2.3 Phase Shift detector

The output from the receiver was amplified via a LM301 operation amplifier. Both the amplified receiver signal and the transmitter signal were put into a phase comparator. This consisted of a FAIRCHILD μA 796 operational amplifier connected in such a way as to act as a phase comparator. Both the input signals are sinusoidal. The output signal from the phase comparator is a DC voltage which reflects the phase difference between the two sinusoidal signals.

The output from the phase comparator is filtered and amplified to produce a clean voltage which can be detected by a standard datalogger.

The circuit used is shown in Figure 2.

Figure 2
Phase Detector Circuit



2.4 Ultrasonic Transducers

The two pairs of ultrasonic transducers were mounted approximately 31 cm apart and at 90 degrees to each other. The heights of each pair of transducers was displaced by 14 cm. This orientation provided minimum interference. The mountings allowed for slight movement of one transducer from each pair to enable fine tuning of the anemometer on site. The mountings could then be tightened to ensure no further movement.

The transducers were then connected to the anemometer circuitry via shielded coaxial cables.

3.0 Operation of Sonic Anemometer

The response of each pair of transducers to phase was measured by plotting the change in output voltage with change in separation of the transmitter and the receiver. This relationship is shown in Figures 3 and 4 for both pairs. The relationship in both cases is sinusoidal.

To detect wind in all directions in the x-y plain, it is important that the phase shift in both the positive and negative directions along any one axis (either the x or the y axis) be recorded. To ensure that this is the case, the separation of the transducers was always set at the midpoint of the curves shown in Figures 3 and 4 (Note points A and B on each of the Figures).

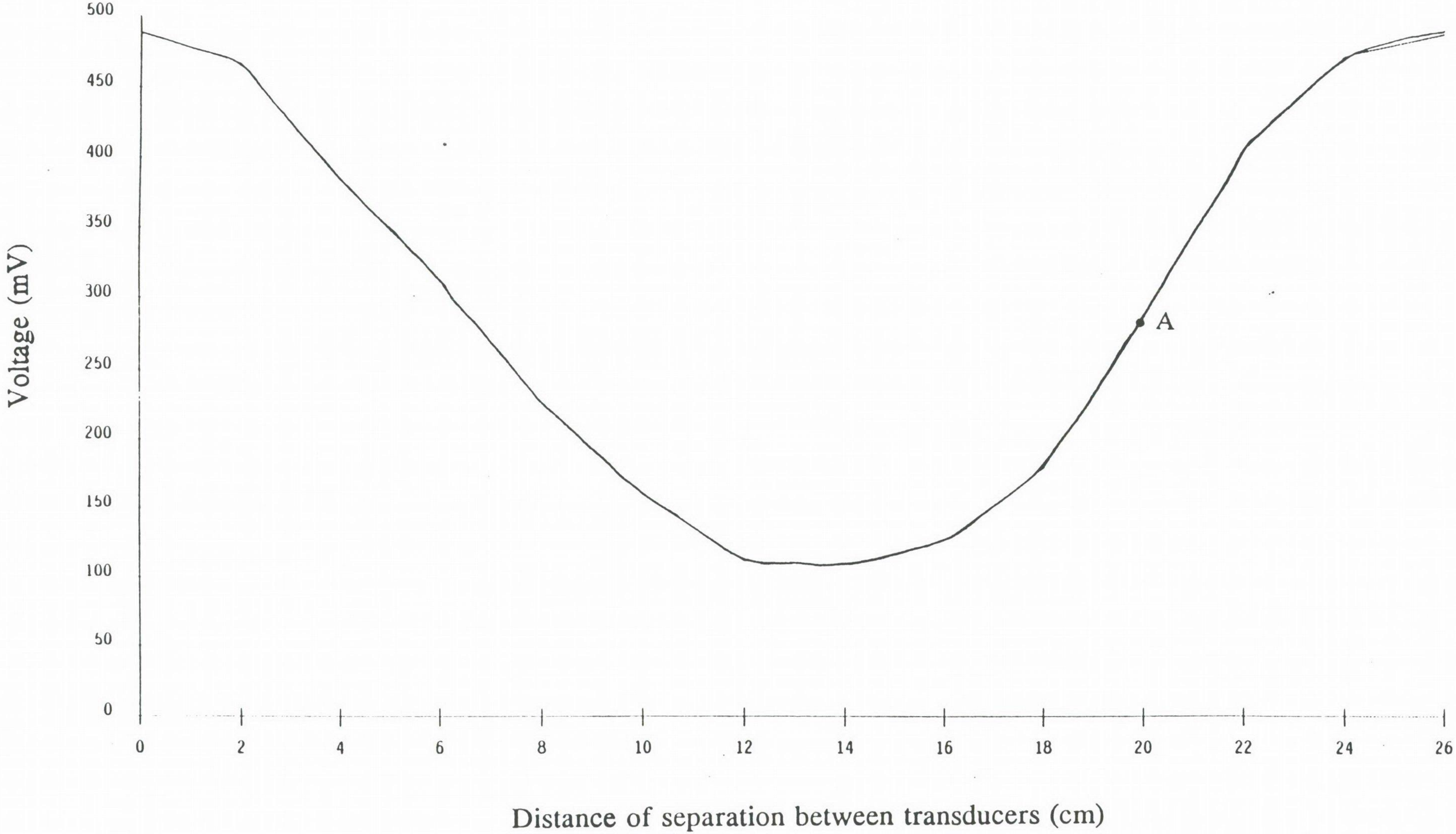
This point was always confirmed in the field. The output from the sonic anemometer was logged by a Unidata datalogger every 5 seconds. The DC voltage from the x axis transducers and the y axis transducers was logged. These voltages were then processed by a computer program which corrected the voltage for atmospheric temperature drifts as well as converting the voltage readings in the x and y plane to wind speed and wind direction.

This conversion was done by theory and by direct calibration with a standard anemometer. Figures 5 and 6 show a typical section of results from the direct comparison of the sonic anemometer with a standard anemometer and wind vane. Figure 5 shows the wind direction from each instrument at the same place and time. The two curves closely follow each other. The slight variation in the two is expected as the sonic anemometer is much more sensitive to rapid changes in wind direction than a standard wind vane.

Figure 6 show the wind speed comparison. It should be noted that the standard

Figure 3

Phase Shift for Transducer A



1208/90/AQWP/2

Figure 4

Phase Shift for Transducer B

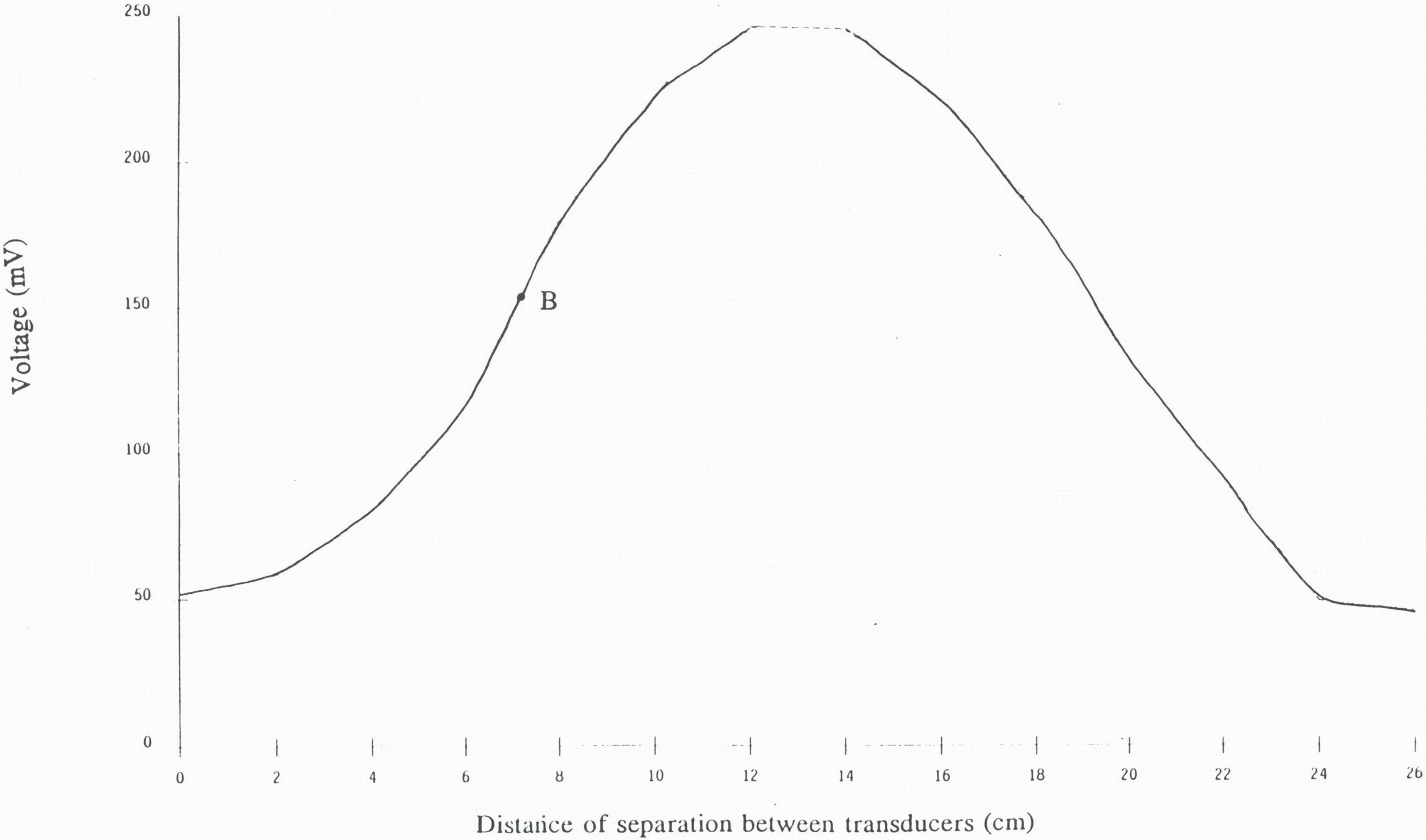
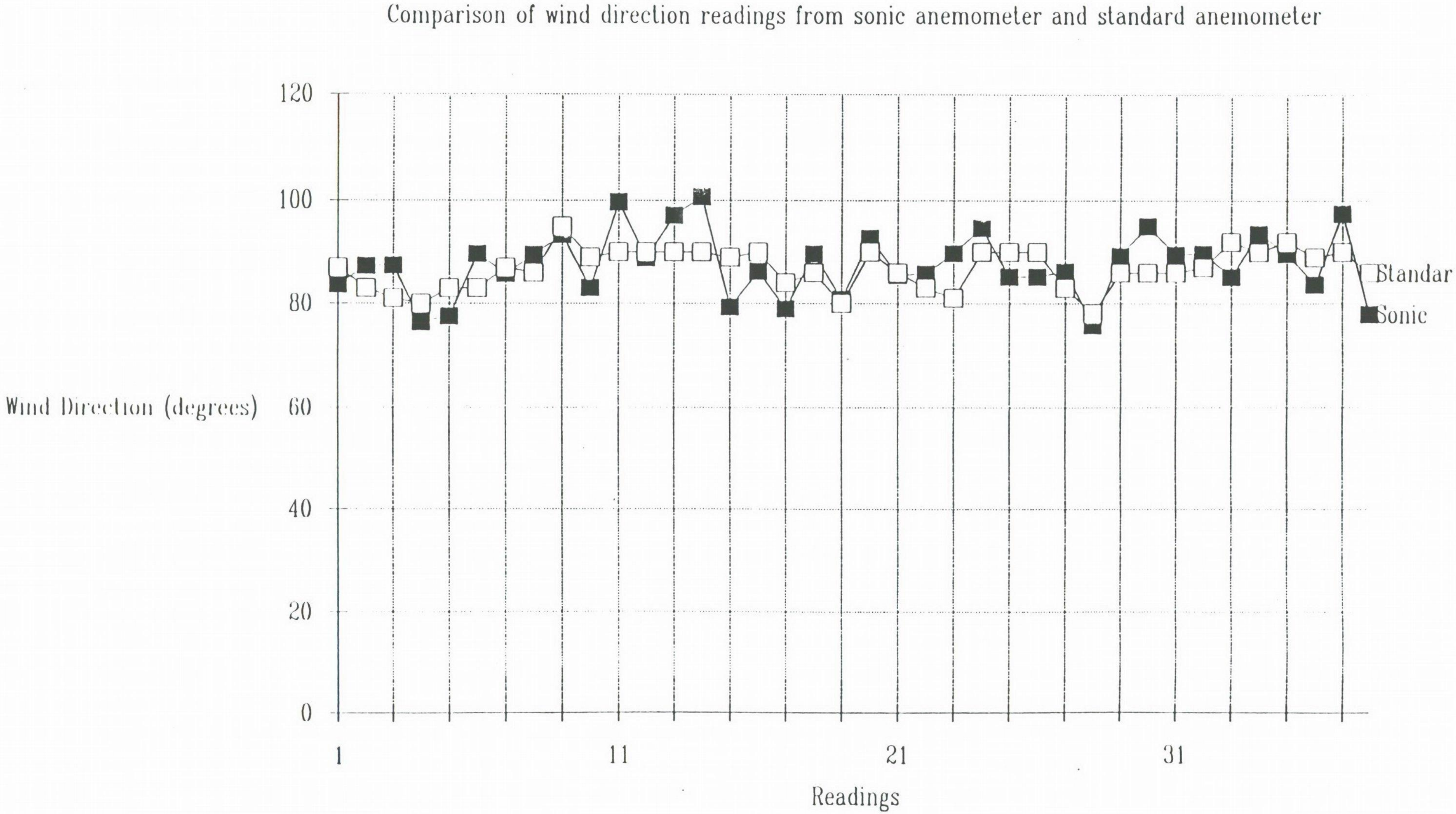


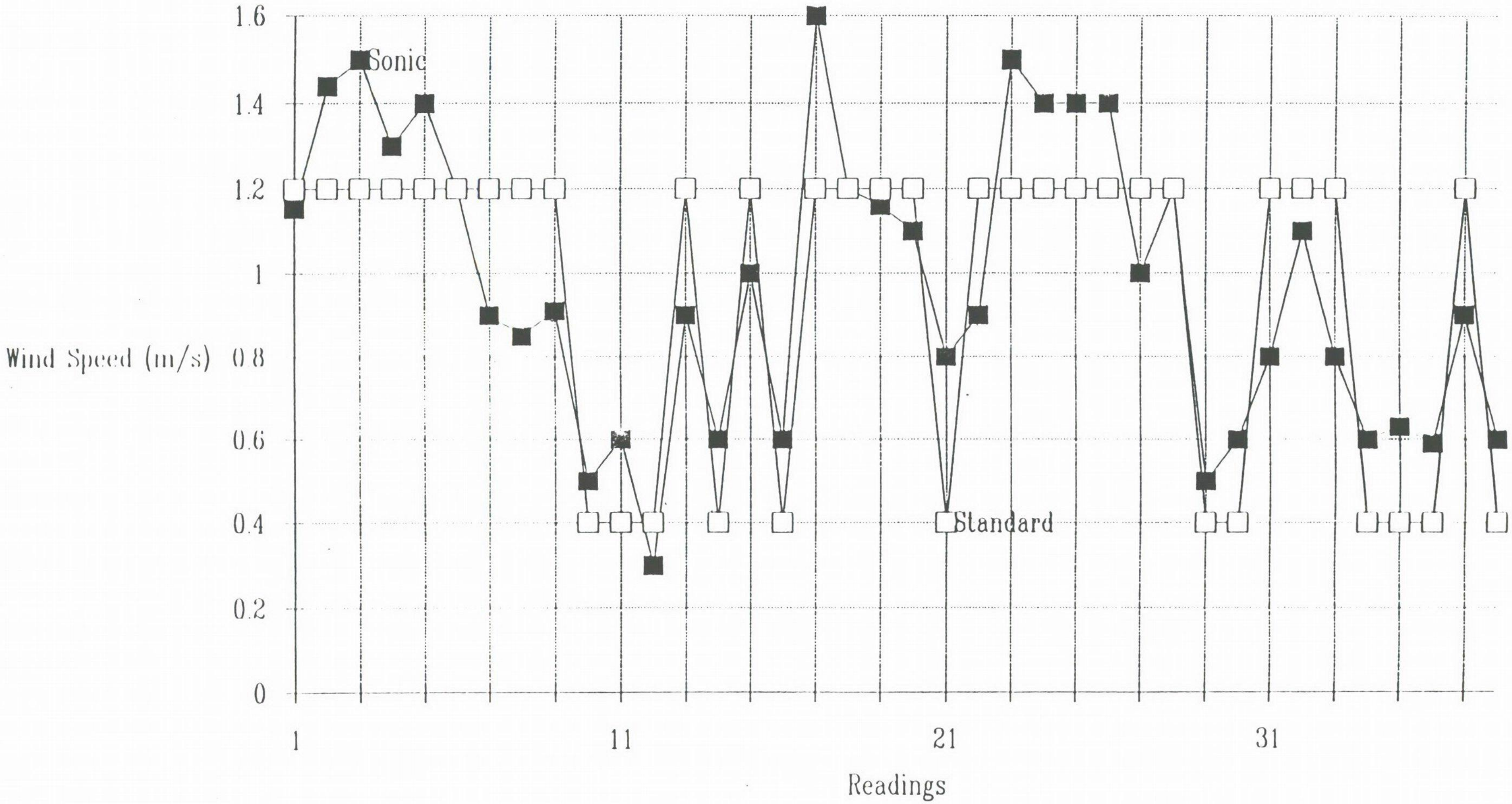
Figure 5



Comparison of wind direction readings from sonic anemometer and standard anemometer
120
100
80
60
40
20
0
Wind Direction (degrees)
1
11
21
31
Readings
Standar
Sonic

Figure 6

Comparison of wind speed measurements from sonic anemometer and standard anemometer



anemometer stalls at 0.4 $m.s^{-1}$. The wind speeds are very similar, following the same patterns. Again a slight disagreement between the two results is expected as the sonic anemometer takes an instantaneous picture of the wind speed whereas the standard anemometer is a rotating cup anemometer which digitally records the wind speed as the number of turns of the cups in a sampling time. The two figures show a good correlation between the two types of instruments.

APPENDIX 10

Ecologically Sustainable Development

ECOLOGICALLY SUSTAINABLE DEVELOPMENT

The observations and conclusions of the Ecologically Sustainable Development Working Groups (ESDWG) have been taken into consideration during the preparation of this Air Quality Working Paper. In particular, Energy Production, Energy Use and Transport Working Groups (AGPS, 1991 x 3).

The relevant areas of interest for this Working Paper were emissions to atmosphere from transport, their impacts on the environment both short term (local and regional impact) and long term (greenhouse impacts) and their interrelationship with the principles and practice of Ecologically Sustainable Development (ESD).

Recommendation 31 of ESDWG Final Report - Energy Production proposed "that there should be an increase in government support for Research, Development and Demonstration (R,D&D) funding, especially for renewable energy technologies, and that the following should be (selected) priority areas for Australian energy R,D&D:-

- **renewable energy systems for electricity generation and storage and thermal energy generation and storage;**

- **coal technologies for increased thermal efficiencies and reduced emissions of greenhouse gases and other pollutants (in particular, electricity generation required for electric powered public and private road transport);**

- **Reduction of greenhouse gas emissions from coal, oil and gas products.**

Recommendation 32 - **that governments facilitate the early introduction, for demonstration and commercialisation purposes, of some near-economic technologies by the manufacturing and energy production industries.**

Although Australia has enormous potential for producing synthetic liquid fuel from oil shale or coal, the environmental impacts of such industries, especially their contributions to global warming, could be considerable, relative to the conventional production of liquid fuels from petroleum using currently available technologies.

Recommendation 33 - **that the effect on overall greenhouse gas emissions should be an important factor in determining the level of government support, if any, that is made available for synfuels R,D&D.**

These recommendations, if implemented, would facilitate further research and development of more ecologically sustainable modes of people movement whether it be by road or a public mass transit system.

The ESD Transport Working Group presents a pair of Tables which refer to energy consumption and the transport energy efficiency for transport tasks, 1987-88 (Table 2.3 AGPS, 1991) and Carbon dioxide emissions from urban passenger transport 1987-88 (Table 2.4 AGPS, 1991).

The ESD Transport Working Group Final Report observes:-

> The specific energy consumption figures shown in Table 2.3 are the outcome of actual operational conditions; that is, they encompass the overall

national average loadings of each transport task and mode during 1987-88. In many tanks, the vehicles concerned often operate at well below their maximum capacity. This is almost universally true of passenger cars, the occupancy of which has been estimated to be around 1.7 on average for the urban passenger task; for journey to work, occupancy is about 1.2 per vehicle compared with about 2.0 for other urban trips. This, and degraded fuel efficiency in urban driving, are reflected in the car's specific energy consumption. It applies also to urban bus and rail transport, the capacity of which is determined by peak requirements. For example, average urban rail and bus load levels in 1987-88 were only 18-19 per cent of each system's full capacity, at first sight quite a low figure. This low average load factor reflects capacity use in peak periods, but very low occupancy rates at other times. This is a problem faced by mass transit systems across the world, even in cities of significantly higher population densities than those in Australia.

The specific energy consumption data in Table 2.3 can assist in analysing the likely effects on emissions that might be brought about by shifts in passenger or freight tasks between modes.

For example, Table 2.4 shows estimates of specific carbon dioxide emissions for various modes used in urban passenger transport. In interpreting these data, three considerations need to be borne in mind.

The first relates to the question of load factor, as discussed above. A particular mode can realise the advantage implied in Table 2.3 only if the load factor of the specific task is similar to the average load factor that has generated the data in the table. As a corollary to this, greater efficiencies than those shown are potentially achievable if higher load factors could be obtained.

The second consideration is relevant only when considering urban rail, which in most Australian cities draws its energy from the electricity grid. In that case, the substantially constant relationship previously noted between energy usage and carbon dioxide emissions of petroleum fuels does not apply. When comparing electric urban rail with petroleum-powered modes, the presentation of Table 2.4 must be taken one step further to compare carbon dioxide emissions per unit of passenger-kilometre. Calculation of such emission intensities depends on a range of assumptions, and any construction of estimates (to provide a consistent basis for comparison between modes) presents methodological problems.

These difficulties are particularly acute in the case of urban rail. Different assumptions as to urban context, load factors, power generation characteristics and or estimates of energy consumption in ancillary services, lead to different estimates of emission intensity.

Table 2.4 presents estimates for the major modes prepared by the BTCE. It should be noted that all these figures are subject to a margin of error on account of the factors noted above and alternative sources provide estimates that differ somewhat from those shown in the table. In particular, Newman & Kenworthy (1989) have estimated the carbon dioxide emission intensity for urban rail as 120 grams/ passenger kilometre, excluding energy consumed by ancillary services.

Third, the specific energy and carbon dioxide intensities given in Tables 2.3 and 2.4 are averages for the particular vehicle or task for 1987-88. The specific energy intensities applying to future shifts of a portion of one transport task from one mode to another may therefore differ considerably from their averages, since incremental energy and carbon dioxide intensities may be different to average intensities, and technological change in the future may also change the 1987-88 values.

The possibilities for greenhouse emission reductions through measures that might lead to shifts between modes in both passenger and freight tasks in both urban and interurban contexts are explored in later chapters of this report."

TABLE 2.3 ENERGY CONSUMPTION AND THE TRANSPORT ENERGY EFFICIENCY FOR TRANSPORT TASKS, 1987-88

	Urban		Non-Urban		
Transport task	Energy consumption	Specific energy consumption	Energy consumption	Specific energy consumption	Total energy consumption
Passenger	(Petajoules)	(Megajoules/pass km)	(Petajoules)	(Megajoules/pass-km)	(Petajoules)
Road					
Car	384	2.9	143	2.6	527
LCV	26	3.8	19	3.6	45
Bus	7	1.6	9	0.8	16
Rail	11	1.6	4	1.6	15
Air	..	..	50	3.6	50
Sub-total passenger	433	..	232	..	655
Freight	(Petajoules)	(Megajoules/tonne km)	(Petajoules)	(Megajoules/tonne km)	(Petajoules)
Road					
LCV	44	16.4	32	20.2	76
Truck (rigid)	52	4.0	27	3.3	79
Truck (articulated)	24	1.6	63	1.4	87
Rail - bulk					
Govt	na	na	15	0.4	15
Private			4	0.1	4
- non-bulk	na	na	11	0.8	11
Sea - bulk	..	..	16	0.2	16
- non bulk	..	..	3	0.7	3
Air	..	..	9	44.5	9
Sub-total freight	120	..	180	..	300
Total all transport	553	..	412	..	965

Notes: Totals may not add, since they include all transport vehicle types, for example, ferries. These make very small contributions to total emissions. Energy figures relate to the full fuel cycle.

Source: BTCE (1991)

TABLE 2.4 CARBON DIOXIDE EMISSIONS FROM URBAN PASSENGER TRANSPORT, 1987-88

	Passenger task (billion-passenger-km)	Specific energy consumption (megajoule/passenger-km)	Specific carbon dioxide emission intensity (grams/passenger-km)	Total carbon dioxode emissions (Megatonnes)
Road				
Car	131.3	2.9	210	27.3
LCV	6.8	3.6	270	1.8
Bus	4.5	1.6	120	0.5
Rail	7.0	1.6	150	1.0
Total	151.5	..	..	30.6

Note: Totals may not add, since they include all transport vehicle types, for example ferries. These make very small contributions to total emissions. Energy figures relate to full fuel cycles.
Source: BTCE (1991)