



COMMONWEALTH DEPARTMENT OF  
**TRANSPORT AND REGIONAL  
DEVELOPMENT**

# 6

## **Air Quality**

Proposal for a Second Sydney Airport  
at Badgerys Creek or Holsworthy Military Area

**Technical Paper**

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COMMONWEALTH DEPARTMENT OF  
**TRANSPORT AND REGIONAL  
DEVELOPMENT**

GPO Box 594  
Canberra ACT 2601

# Air Quality

Proposal for a Second Sydney Airport  
at Badgerys Creek or Holsworthy Military Area

# 6

## Technical Paper

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## **Explanatory Statement**

This technical paper is not part of the Draft Environmental Impact Statement (EIS) referred to in paragraph 6 of the Administrative Procedures made under the Environment Protection (Impact of Proposals) Act 1974.

The Commonwealth Government is proposing to construct and operate a second major airport for Sydney at Badgerys Creek. This technical paper contains information relating to the Badgerys Creek airport options which was used to assist the preparation of the Draft EIS.

The technical paper also assesses the impacts of developing a major airport at the Holsworthy Military Area. On 3 September 1997, the Government eliminated the Holsworthy Military Area as a potential site for Sydney's second major airport. As a consequence, information in this technical paper relating to the Holsworthy Military Area is presented for information purposes only.

## **Limitations Statement**

This technical paper has been prepared in accordance with the scope of work set out in the contract between Rust PPK Pty Ltd and the Commonwealth Department of Transport and Regional Development (DoTRD) and completed by PPK Environment and Infrastructure Pty Ltd (PPK). In preparing this technical paper, PPK has relied upon data, surveys, analyses, designs, plans and other information provided by DoTRD and other individuals and organisations, most of which are referenced in this technical paper. Except as otherwise stated in this technical paper, PPK has not verified the accuracy or completeness of such data, surveys, analyses, designs, plans and other information.

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## **Acknowledgments**

Data used to develop the figures contained in this document have been obtained and reproduced by permission of the Australian Bureau of Statistics, NSW Department of Land and Water Conservation, NSW National Parks and Wildlife Service (issued 14 January 1997), NSW Department of Urban Affairs and Planning and Sydney Water. The document is predominantly based on 1996 and 1997 data.

To ensure clarity on some of the figures, names of some suburbs have been deleted from inner western, eastern, south-eastern and north-eastern areas of Sydney. On other figures, only 'Primary' and 'Secondary' centres identified by the Department of Urban Affairs and Planning's Metropolitan Strategy, in addition to Camden, Fairfield and Sutherland, have been shown.

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# Part A

## Introduction

# CHAPTER 1 INTRODUCTION

## 1.1 INTRODUCTION

*This technical paper addresses the potential air quality impacts identified as part of the previously proposed development of the Second Sydney Airport at either Badgerys Creek or the Holsworthy Military Area. It contains information used to prepare the Draft Environmental Impact Statement (EIS) which addresses the overall environmental impacts of the Badgerys Creek airport options.*

## 1.2 A BRIEF HISTORY

The question of where, when and how a second major airport may be developed for Sydney has been the subject of investigation for more than 50 years. The investigations and the associated decisions are closely related to the history of the development of Sydney's existing major airport, located at Mascot.

The site of Sydney Airport was first used for aviation in 1919. It was acquired by the Commonwealth Government in 1921, and was declared an International Aerodrome in 1935. In 1940 the first terminal building and control tower were opened.

In 1945 the airport had three relatively short runways. A major expansion began in 1947, and by 1954 the current east-west runway was opened. The north-south runway was first opened in 1954 and was extended to its current length in 1972. The present international terminal was opened in 1970.

Planning and investigations for a site for a second Sydney airport first started in 1946. A large number of possible sites both within and outside the Sydney Basin have been investigated.

The *Second Sydney Airport Site Selection Program Draft Environmental Impact Statement* (Kinhill Stearns, 1985) re-examined all possible locations for the second airport and chose 10 for preliminary evaluation. Two sites, Badgerys Creek and Wilton, were examined in detail and an EIS was prepared. In February 1986 the then Commonwealth Government announced that Badgerys Creek had been selected as the site for Sydney's second major airport.

The Badgerys Creek site, which is about 46 kilometres west of Sydney's Central Business District and is 1,700 hectares in area, was acquired by the

Commonwealth between 1986 and 1991. A total of \$155 million has been spent on property acquisition and preparatory works.

Since 1986, planning for Sydney's second airport has been closely linked to the development of the third runway at Sydney Airport. In 1989 the Government announced its intention to construct a third runway. An EIS was undertaken and the decision to construct the runway was made in December 1991.

At the same time as investigations were being carried out on the third runway, detailed planning proceeded for the staged development of the second airport at Badgerys Creek. In 1991 it was announced that initial development at Badgerys Creek would be as a general aviation airport with an 1,800 metre runway.

The third runway at Sydney Airport was opened in November 1994. In March 1995, in response to public concern over the high levels of aircraft noise, the Commonwealth Senate established a committee in March 1995 to examine the problems of noise generated by aircraft using Sydney Airport and explore possible solutions. The committee's report, *Falling on Deaf Ears?*, containing several recommendations, was tabled in parliament in November 1995 (Senate Select Committee on Aircraft Noise, 1995).

During 1994 and 1995 the Government announced details of its proposed development of Badgerys Creek, and of funding commitments designed to ensure the new airport would be operational in time for the 2000 Olympics. This development included a 2,900 metre runway for use by major aircraft.

The decision to accelerate the development of the new airport triggered the environmental assessment procedures in the *Environment Protection (Impact of Proposals) Act 1974*. In January 1996 it was announced that an EIS would be prepared for the construction and operation of the new airport.

In May 1996, the present Commonwealth Government decided to broaden the environmental assessment process. It put forward a new proposal involving the consideration of 'the construction and operation of a second major international/domestic airport for Sydney at either Badgerys Creek or Holsworthy on a site large enough for future expansion of the airport if required' (Department of Transport and Regional Development, 1996). A major airport was defined as one 'capable of handling up to about 360,000 aircraft movements and 30 million passengers per year' (Department of Transport and Regional Development, 1996).

The Government also indicated that 'Badgerys Creek at this time remains the preferred site for Sydney's second major airport, subject to the favourable outcome of the EIS, while Holsworthy is an option to be considered as an



alternative' (Minister for Transport and Regional Development, 1996). The two sites considered in this technical paper are shown in *Figure 1.1*.

Following the substantial completion of a Draft EIS on the Badgerys Creek and Holsworthy airport options, the Government eliminated the Holsworthy Military Area as a potential site for Sydney's second major airport. The environmental assessment showed that the Badgerys Creek site was significantly superior to the Holsworthy Military Area. As a result a Draft EIS was prepared which examines only the Badgerys Creek site. While this technical paper examines both the Badgerys Creek and Holsworthy airport options, only the parts of the assessment relating to the Badgerys Creek airport options were used to assist the preparation of the Draft EIS.

### 1.3 THE PROPOSAL

The Commonwealth Government proposes the development of a second major airport for Sydney capable of handling up to 30 million domestic and international passengers a year. By comparison, Sydney Airport will handle about 20 million passengers in 1997. The *Second Sydney Airport Site Selection Program Draft Environmental Impact Statement* anticipated the airport would accommodate about 13 million passengers each year (Kinhill Stearns, 1985).

A stated objective of the Government is the building of a second major airport in the Sydney region to a full international standard, subject to the results of an EIS. In the Government's view, Sydney needs a second major airport to handle the growing demand for air travel and to control the level of noise experienced by Sydney residents (Coalition of Liberal and National Parties, 1996).

Government policy (Coalition of Liberal and National Parties, 1996) indicates:

- that Sydney's second airport will be more than just an overflow airport and will, in time, play a major role in serving Sydney's air transport needs; and
- a goal of reducing the noise and pollution generated by Sydney Airport as much as possible and that the Government would take steps to ensure that the noise burden around Sydney Airport is shared in a safe and equitable way.

The assumptions made on how the Second Sydney Airport would operate and the master plans which set out the broad framework for future physical development of the airport are based on an operational limit of 30 million passengers a year. The main features include parallel runways, a cross wind

runway and the provision of the majority of facilities between the parallel runways.

Consideration has also been given to how the airport may be expanded in the future and the subsequent environmental implications. Such an expansion could not proceed, however, unless a further detailed environmental assessment and decision making process were undertaken by the Government.

Five airport options are considered, as well as the implications of not proceeding with the proposal. Three of the airport options are located at Badgerys Creek and two are located within the Holsworthy Military Area. Generally, the airport options are:

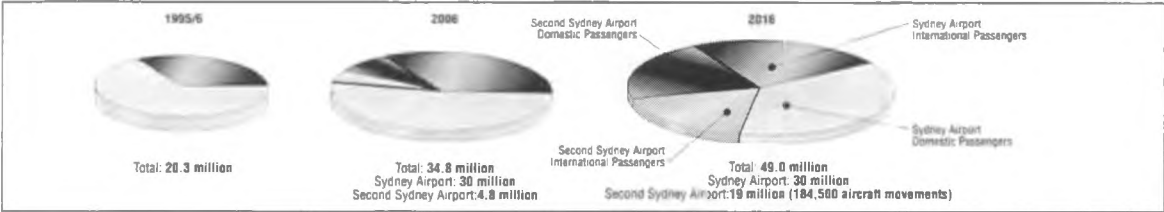
- Badgerys Creek Option A which has been developed to be generally consistent with the planning for this site undertaken since 1986. The airport would be developed within land presently owned by the Commonwealth with two parallel runways constructed on an approximate north-east to south-west alignment;
- Badgerys Creek Option B would adopt an identical runway alignment to Option A, but provides an expanded land area and also a cross wind runway;
- Badgerys Creek Option C would provide two main parallel runways on an approximate north to south alignment in addition to a cross wind runway. Again the land area required would be significantly expanded from that which is presently owned by the Commonwealth;
- Holsworthy Option A would be located centrally within the Holsworthy Military Area and would have two main parallel runways on an approximate north to south alignment and a cross wind runway; and
- Holsworthy Option B would be located in the south of the Holsworthy Military Area and would have two main parallel runways on an approximate south-east to north-west alignment and a cross wind runway.

To ensure that the likely range of possible impacts of the airport options are identified a number of different assumptions about how the airport options would be developed and operate have been adopted. These different assumptions relate to the number and types of aircraft that may operate from the airport, the flight paths used and the direction of take offs and landings.

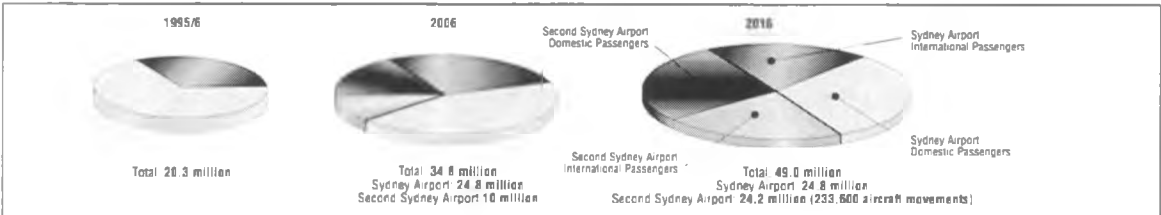
The number of flights into and out of the proposed Second Sydney Airport would depend on a number of factors including the types of aircraft that would use the airport and the associated numbers of passengers in each aircraft. The



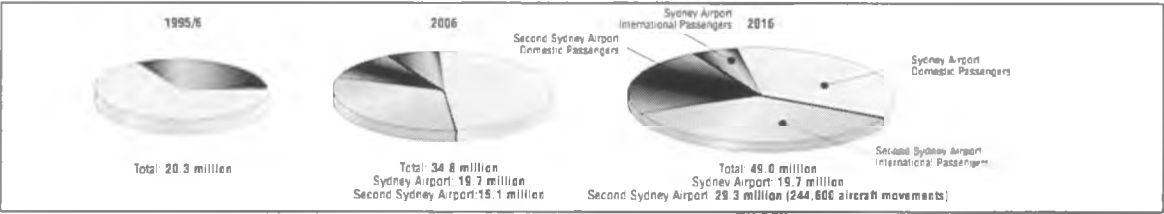
Figure 1.1  
Potential Airport Sites Considered in the Draft EIS



Assumptions about Passenger Movements for Air Traffic Forecast 1



Assumptions about Passenger Movements for Air Traffic Forecast 2



Assumptions about Passenger Movements for Air Traffic Forecast 3

Figure 1.2  
Summary of Passenger Movement Forecasts Used for Environmental Assessment

proposal put forward by the Government anticipates a major airport handling 30 million passengers and up to 360,000 aircraft movements per year.

Air traffic forecasts have been developed based on an examination of the number and type of aircrafts that would use the airport as it approaches an operating level of 30 million passengers per year. This examination has shown that if the airport accommodated about 245,000 aircraft movements each year, the number of air passengers would approach 30 million. This assumes a relatively high percentage of international flights being directed to the Second Sydney Airport. Therefore it is appropriate for this Draft EIS to assess the airport operating at a level of 245,000 aircraft movements per year, rather than the 360,000 originally anticipated by the Government. It has been assumed that this level of operation could be reached by about 2016.

## 1.4 AIR TRAFFIC FORECASTS

Cities around the world which have developed second major airports have responded to their particular needs in different ways. For example, the original airport in Dallas, United States, is now used for short range traffic that does not connect with other flights. Second airports in New York and Washington serve as hubs for particular airlines. In Taipei, Taiwan, smaller domestic aircraft use the downtown airport and larger international flights use a newer airport 40 kilometres from the city.

It is clear that each metropolitan area around the world has unique characteristics and the development of multi-airport systems respond to particular local circumstances. The precise role and consequential staging of development of the Second Sydney Airport would be the subject of future Government decisions. To assist in developing a realistic assessment of the potential impacts of the Second Sydney Airport, three sets of air traffic forecasts for the airport were developed. Each forecast assumes a major airport would be developed, however, this may be achieved at different rates of growth.

The three potential air traffic scenarios considered for the Second Sydney Airport are shown in *Figure 1.2*. They are:

- *Air Traffic Forecast 1* where the Second Sydney Airport would provide only for demand which cannot be met by Sydney Airport. This is an overflow forecast, but would nevertheless result in a significant amount of air traffic at the Second Sydney Airport. The proportion of international and domestic air traffic is assumed to be similar at both airports;
- *Air Traffic Forecast 2* where the Second Sydney Airport would be developed to cater for 10 million passengers a year by 2006, with all

further growth after this being directed to the second airport rather than Sydney Airport. The proportion of international and domestic traffic is also assumed to be similar at both airports; and

- *Air Traffic Forecast 3* which is similar to Forecast 2 but with more international flights being directed to the Second Sydney Airport. This would result in the larger and comparatively noisier aircraft being directed to the second airport. It would accommodate about 29.3 million passengers by 2016.

## 1.5 OPERATION OF THE AIRPORT OPTIONS

At any airport, aircraft operations are allocated to runways (which implies both the physical runway and the direction in which it is used) according to a combination of wind conditions and airport operating policy. The allocation is normally performed by Air Traffic Control personnel.

Standard airport operating procedures indicate that a runway may not be selected for either approach or departure if the wind has a downwind component greater than five knots, or a cross wind component greater than 25 knots. If the runway is wet, it would not normally be selected if there is any downwind component. This applies to all aircraft types, although larger aircraft would be capable of tolerating relatively higher wind speeds. Wind conditions at the airport site therefore limit the times when particular runways may be selected. However, there would be a substantial proportion of the time, under low wind conditions, when the choice of runways would be determined by airport operating policy.

For the environmental assessment, the maximum and minimum likely usage for each runway and runway direction was estimated and the noise impact of each case calculated. The actual impact would then lie between these values and would depend on the operating policy which is applicable at the time.

The three airport operation scenarios were adopted for the environmental assessment, namely:

- *Airport Operation 1* shown in *Figure 1.3*. Aircraft movements would occur on the parallel runways in one specified direction (arbitrarily chosen to be the direction closest to north), unless this is not possible due to meteorological conditions. That is, take offs would occur to the north from the parallel runways and aircraft landing would approach from the south, travelling in a northerly direction. Second priority is given to operations in the other direction on the parallel runways, with operations on the cross wind runway occurring only when required because of meteorological conditions;

- *Airport Operation 2* shown in *Figure 1.4*. As for Operation 1, but with the preferred direction of movements on the parallel runways reversed, that is to the south; and
- *Airport Operation 3*. Deliberate implementation of a *noise sharing* policy under which seven percent of movements are directed to occur on the cross wind runway (equal numbers in each direction) with the remainder distributed equally between the two parallel runway directions.

Since a cross wind runway is not proposed at Badgerys Creek Option A, only Operations 1 and 2 were considered for that option.

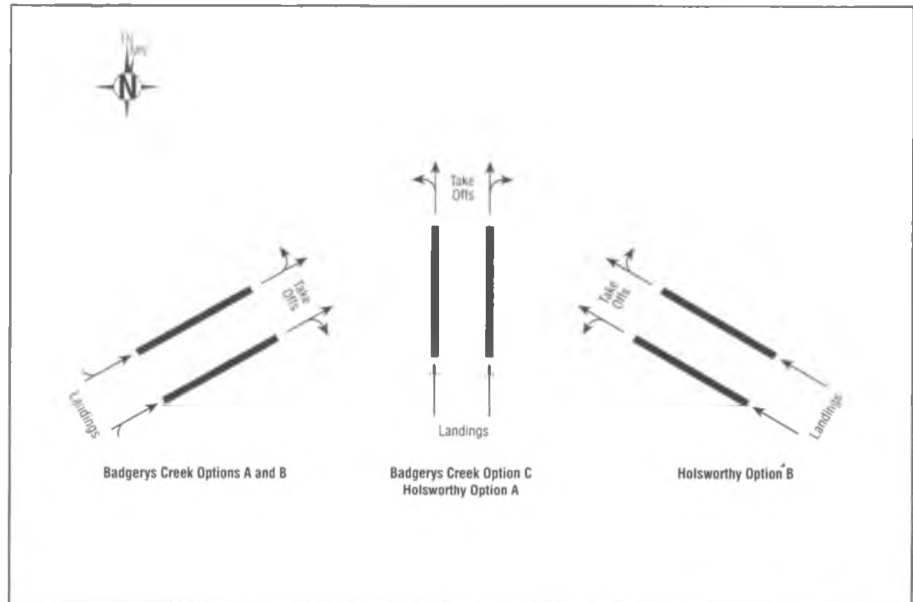


Figure 1.3  
**Predominant Directions of Movement of Aircraft  
 for Airport Operation 1**  
 Note: Cross wind runway used only when required  
 because of meteorological conditions

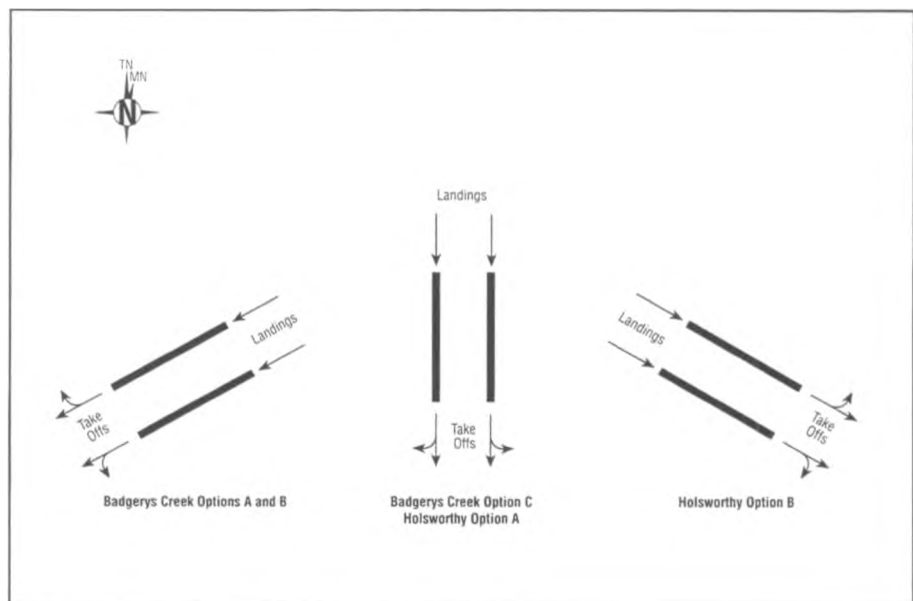


Figure 1.4  
**Predominant Directions of Movement of Aircraft  
 for Airport Operation 2**  
 Note: Cross wind runway used only when required  
 because of meteorological conditions

## CHAPTER 2 CONSULTATION

Preparation of this technical paper involved consultation with the community, other stakeholders, Commonwealth, State and local Governments and Government agencies.

### 2.1 COMMUNITY CONSULTATION

The primary role of the consultation process during the preparation of the Draft EIS was to provide accurate, up to date information on the proposals being considered and the assessment process being undertaken. From October 1996 to May 1997, ten separate information documents were released and over 400,000 copies distributed to the community. Four types of display posters were produced and 700 copies distributed. Over 140 advertisements were placed in metropolitan and local newspapers. Non English language documents were produced in 14 languages and over 20,000 copies distributed. Advertisements in seven languages were placed on ethnic radio.

Opportunities for direct contact and two way exchange of information with the community occurred through meetings, information days, displays at shopping centres, telephone conversations and by responding to written submissions. Through these activities over 20,000 members of the community directly participated in the consultation activities.

Written and telephone submissions received were incorporated into a database which grouped the issues in the same way as the chapters of the Draft EIS. The issues raised were progressively provided to the EIS study team to ensure that community input was an integral part of the assessment process.

Further details of consultation with the community and other stakeholders and its outcomes are contained in *Technical Paper No. 1 - Consultation*. Comments received from community submissions were taken into account in the preparation of this report.

### 2.2 OTHER CONSULTATION

Various Government departments and agencies were consulted during the preparation of the Draft EIS. These included the following:

- NSW Environment Protection Authority - consulted to obtain access to the *Sydney Metropolitan Air Quality Study* (Environment Protection



Authority, 1997a) findings. Access to the following material was provided by NSW Environment Protection Authority:

- emissions inventory data and findings relating to airports;
- data sets containing meteorological simulations;
- discussions of air chemistry and meteorology contained in the final reports;
- Australian Nuclear Science and Technology Organisation provided meteorological data for Lucas Heights and reports of air quality studies relating to its facility at Lucas Heights;
- Federal Airports Corporation provided:
  - access to Sydney Kingsford Smith Airport for the purpose of collection of air quality samples; and
  - reports of air quality and meteorological monitoring at Sydney Kingsford Smith Airport;
- Airservices Australia provided:
  - advice in relation to fuel dumping and fuel venting from aircraft.

## CHAPTER 3 METHODOLOGY

### 3.1 AIMS AND SCOPE OF WORK

The aims of the air quality study are to meet the objectives of the Draft EIS set out in the study brief provided by the Department of Transport and Regional Planning, and to respond to issues identified in the Guidelines issued by Environment Australia (formerly Commonwealth Environment Protection Agency).

The broad objectives of the study are to:

- provide an assessment of existing air quality at the sites of each of the five airport options considered;
- assess air quality impacts of airport operation under each of the five airport options considered; and
- discuss possible measures for mitigating air quality impacts.

The following items set out in the Environment Australia Guidelines have been addressed:

- identification of the existing air quality in the airport sub-region for each airport option including: a description of each site's relationship to Sydney's air drainage basin, diurnal and seasonal variations in air pollution levels and the influence of short term weather conditions;
- analysis of potential for dust fall-out during the construction stage and discussion of mitigation measures to control dust generation;
- identification of emission sources, the nature and levels of emissions, including oxides of nitrogen, hydrocarbons (including benzene, kerosene and benzo-pyrenes), reactive organic compounds, sulphur dioxide, carbon monoxide, lead, particulates, odours and air toxics;
- analysis and description of the contribution and impacts of the operation of the proposed Second Sydney Airport on air quality, at the local, regional and Sydney basin scale, having regard to the results of the *Sydney Metropolitan Air Quality Study* carried out on behalf of New South Wales Environment Protection Authority;
- changes to air quality and identification of affected populations in the study area, taking into account spatial and temporal variations and the

contribution of other sources, including airport-induced vehicle traffic and airport related commercial/industrial development;

- effect of the increase in ozone-producing compounds on areas downwind of the development and on the Sydney airshed in general;
- emergency fuel dumping procedures, including designated areas for such contingencies, effects of fuel dumping;
- potential impact on fabric of buildings;
- changes in odour arising from aviation fuel emissions and possible sewage treatment, including provisions for recording nuisance caused by ambient odours;
- “greenhouse” gas emissions, including design and procedural measures to reduce such emissions;
- possible management measures for all significant emission sources, including those for aircraft operations, aircraft fuelling systems and fuel storage, ground transport, power generating units and auxiliary power units;
- possible air quality monitoring programmes; and
- impacts of changes to air quality on the health of potentially affected populations, including long and short term effects, impacts on especially sensitive groups (for example, children, the elderly, sufferers of respiratory illnesses such as asthma).

Effects of aircraft emissions on water catchment areas and domestic rain water tanks supplying household water are addressed in *Technical Paper No. 7 - Geology, Soils and Water*.

Relevant weather conditions including winds, fogs, temperature inversions and effects of topographic features which may affect dispersion of air pollutants are addressed in *Technical Paper No. 5 - Meteorology*.

## 3.2 BASIS FOR METHODOLOGY

### 3.2.1 POTENTIAL AIR QUALITY IMPACTS OF A MAJOR AIRPORT

Emissions inventories for Sydney and other metropolitan areas for Australia show that major airports contribute key pollutants to the regional air-shed (such as nitrogen oxides, volatile organic compounds and carbon monoxide).

Emissions result from a wide variety of activities, resulting in a strong diurnal variation and a complex distribution of emissions with height. These emissions occur within an urban area which itself experiences complex spatial and temporal variations in emission rates of the same pollutants from industrial and other sources including motor vehicles.

The impact of an existing or proposed airport on regional air quality depends critically on the location of the airport within the region, the dominant transport mechanisms within this air-shed and the frequency of occurrence of conditions under which high rates of photochemical pollutants may occur.

Air pollutants associated with airport operation originate from the following emissions sources:

- aircraft engines;
- evaporation of fuel during refuelling and storage;
- motor vehicle engines and evaporative fuel losses from motor vehicles; and
- a range of minor sources including evaporation of solvents from maintenance operations, evaporation from paints and thinners, losses from asphalt repairs, boilers and heaters in terminal buildings and workshops, and use of auxiliary power units on stationary aircraft.

The following air pollutants would be emitted from Sydney Second Airport:

- hydrocarbons, oxides of nitrogen, carbon monoxide, oxides of sulphur and particulates emitted from aircraft engines, engines of support vehicles and passenger motor vehicles;
- hydrocarbon emissions include a range of compounds such as benzene, butadiene, acetaldehyde and formaldehyde which are toxic if prolonged exposure to elevated concentrations occur;
- particulate emissions also contain air toxic compounds such as lead and polycyclic aromatic hydrocarbons; and
- greenhouse gases (carbon dioxide, methane and nitrous oxide).

In addition to the above pollutants, secondary pollutants can be formed as a result of chemical reaction between primary air pollutants within the atmosphere. Photochemical smog is formed by a combination of oxides of nitrogen and hydrocarbons under the action of sunlight.

Principal concerns for regional air quality identified from past studies in Australia and overseas, recent Sydney air-shed work and comments offered during the public consultation stage of the current study relate to:

- possible levels of primary pollutants (such as carbon monoxide, oxides of nitrogen, fine particulates and odour) in the near (0 to 10 kilometre) and mid (5 to 20 kilometre) field regions downwind of the airport;
- potential impacts of airport emissions on the levels of ozone and nitrogen dioxide on days with high background photochemical levels;
- potential impacts of liquid releases from aircraft in flight on water storages, washing and external surfaces of buildings and cars; and
- potential impacts on health.

Near-field characteristics can be dealt with adequately by relatively conventional methodologies. Photochemical impacts are much more difficult to analyse as they require a full understanding of the various processes that occur within the air-shed.

A literature survey of previous airport air quality studies has demonstrated that, although some monitoring of photochemical variables has occurred close to airports in various countries, there has been little systematic investigation of the photochemical impacts of airport operations, except for the more generic and global studies of the impacts of increased air traffic on stratospheric ozone. Therefore the current study has included:

- a survey of past air quality studies for the Sydney air-shed; and
- application of recent and innovative air quality assessment techniques to determine the likely maximum photochemical impact of airport operations.

### **3.2.2 OVERVIEW OF CHEMICAL, TRANSPORT AND DISPERSION PROCESSES**

Air emissions from within a large airport vary according to the time of day. Activity levels are low late at night and in the small hours of the morning but rise quickly in the morning and tend to be relatively steady during the day until mid evening. The nature and strength of emission also varies with location. Emissions from aircraft occur in the terminal area, on the taxiways and along the runways. Emissions from the service vehicles occur largely from the tarmac in the terminal area. Motor vehicle emissions occur along the access roads.

Pollutant emissions are transported by winds passing over the airport resulting in mixing as the pollutants move down wind. As the distance downwind increases, the pollutant ground level concentrations tend to reduce and become more evenly distributed as a result of this mixing. The rate and direction of transport of pollutants depends upon wind speed and direction. The rate of mixing depends upon wind speed and the temperature structure within the atmosphere. During winter, conditions tend not to favour mixing so ground level concentrations of pollutants tend to be higher in winter than in summer.

Chemical reactions take place between oxides of nitrogen and hydrocarbons leading to production of photochemical smog. These chemical reactions take of the order of hours to occur so that by the time photochemical smog is generated, air would have moved many kilometres down wind from the airport. Photochemical smog reactions require light and take place more rapidly as temperature increases. As a result, photochemical impacts of the airport would be more severe during summer than winter.

### 3.3 APPROACH

The air quality study team comprised:

- Coffey Partners International Pty Ltd (team leader, air emissions studies and local scale dispersion modelling);
- CSIRO Division of Coal and Energy Technology (ozone chemistry specialists, analysis of regional impacts);
- CSIRO Division of Atmospheric Research (numerical modelling of regional transport of airport emissions and regional ozone impacts); and
- Katestone Scientific Pty Ltd (trajectory analysis of emissions from the airport using measured wind data).

The team included organisations and individuals who had contributed to the recent Sydney *Metropolitan Air Quality Study* on behalf of New South Wales Environment Protection Authority. The air quality team interacted with Macquarie Research, which was engaged under separate commission to contribute to meteorological studies for the EIS.

The air quality study program involved a number of components.

- An assessment of existing air quality was made based on a review of available monitoring data and air quality studies including the Sydney *Metropolitan Air Quality Study* (Environment Protection Authority,

1997a) which presented a detailed emissions inventory for the Sydney region and provided the results of numerical analysis of regional air quality for selected periods of poor air quality.

- An emissions inventory was developed to quantify expected rates of production of air pollutants for each of the second airport options. The emissions inventory included assessment of emissions from the airport and from aircraft within 1,000 metres of the ground. Emissions of hydrocarbons, oxides of nitrogen, carbon monoxide, sulphur dioxide and particulates were considered. An assessment was made of air toxic compounds, including benzene and 1,3 butadiene within the hydrocarbon emissions. Estimates of greenhouse emissions from the airport were included in the emissions inventory. Emissions inventories were developed for construction, initial operation of an airport in 2006 and under design operating conditions at 2016.
- Local scale dispersion modelling was carried out using AUSPLUME, a Gaussian dispersion model widely used within Australia for prediction of ground level concentration of air pollutants. This modelling work was used to assess air quality impacts within 10 kilometres of the airport boundaries.
- Numerical trajectory modelling using LADM (Lagrangian Atmospheric Dispersion Model) was carried out to assess the regional impacts of airport operation under two historical meteorological events which are known to have resulted in poor air quality in Western Sydney. This work was primarily directed to address photochemical smog impacts from the airport. In the model, chemical data gathered by NSW Environment Protection Authority (from two historical events that resulted in high ozone levels and formation of photochemical smog in Western Sydney) was combined with wind directions generated internally by the model and predicted emissions from the airport options.
- A second approach termed as footprint analysis was used to check the results of trajectory analysis. One year of meteorological and air quality data (July 1994 to June 1995) from monitoring stations over the Sydney Basin was purchased from NSW Environment Protection Authority to enable assessment of regional impacts of airport operation. This work was largely completed, but during meteorological appraisal, inconsistencies were identified in parts of the meteorological data set. Uncertainties about the data were not able to be satisfactorily resolved in time for the modelling to be repeated using a corrected dataset. Therefore the footprint analysis was undertaken using a much smaller set of records, from Sydney Water, Federal Airports Corporation, Bureau

of Meteorology and Australian Nuclear Science and Technology Organisation.

- Air quality impacts of airport operation including the impacts associated with traffic and population shifts attributed to the presence of the airport were assessed at a regional scale using a box modelling approach.

### 3.4 INFORMATION SOURCES

The following information sources were used as input to air quality studies:

- material from Second Sydney Airport Planners (1997a) consisting of plans and reports showing the layout, usage projections, construction details and infrastructure connections was used in development of the air emissions inventory for the range of operational conditions considered and for construction;
- NSW Environment Protection Authority monitoring records of air quality and meteorology were obtained in summary form from published Quarterly Reports (NSW Environment Protection Authority, 1997b) and in digital form from the Environment Protection Authority database (the digital data from the period July 1994 to June 1995 was not used for analysis);
- data from an air quality monitoring site at Campbelltown operated by Pilkington Australia was used to assess existing air quality in the Campbelltown area;
- results presented in the final reports of the *Metropolitan Air Quality Study* (NSW Environment Protection Authority, 1997a) were used to assist in the interpretation of meteorological factors influencing air quality and for background emissions inventory;
- wind monitoring records from the Australian Nuclear Scientific and Technical Organisation site at Lucas Heights were used as input to dispersion modelling of air emissions for the Holsworthy Options;
- wind monitoring data measured by Macquarie University at the Badgerys Creek site was used for dispersion modelling of air emissions for the Badgerys Creek options;
- air quality monitoring data relating to fine particulates collected by the Australian Nuclear Scientific and Technical Organisation over the Sydney basin was used in the assessment of existing air quality;



- material presented in EIS documents relating to the Western Sydney Orbital (Rust PPK, 1996c) and Elizabeth Drive Upgrade (Rust PPK, 1995), and the Third Runway for Sydney Kingsford Smith Airport (Kinhill, 1990) was reviewed; and
- monitoring data compiled on behalf of the Federal Airports Corporation for Sydney Airport was used to provide local experience of air quality impacts of airport operations.

## 3.5 REVIEW OF PREVIOUS WORK

### 3.5.1 NORTH AMERICAN STUDIES

The United States Federal Aviation Administration has sponsored several studies of the emissions and consequent local air quality impact (including odour) for several major airports (Wayson, 1996). Regional analysis has centred mainly on emission inventories, as the use of urban air-shed models was considered “beyond the scope of most projects”.

Emission controls are thought likely to reduce volatile organic hydrocarbon impact, although oxides of nitrogen emissions may still present problems. There is no direct research or measurement programme which has been undertaken to investigate the photochemical impact of a major airport on a regional air-shed.

The Airports Group of Canada has conducted multi-parameter monitoring studies at various airports since 1980 (Taylor, 1996). This monitoring has usually been at sites on or close to the airport. Ozone levels at these sites were generally decreased by the presence of combustion gases from airport activities. It was concluded that “airports did not appear to be the local source of this pollutant”. None of the recommended actions from a review of existing knowledge was concerned with regional impacts.

North American experience has therefore provided little guidance to the present study.

Vigyan (1993) carried out a study on behalf of US Environment Protection Agency to estimate and evaluate cancer risks attributed to air pollution in South-west Chicago. The study involved development of an inventory of air emissions from the area from sources including Midway Airport, motor vehicle traffic and industry. Dispersion modelling was carried out to predict average concentrations to which the population were exposed. Cancer risk factors for air toxic compounds were to use predict the number of cancer cases attributable to air pollution. The cancer risk from air toxic pollution was assessed to be two chances in 10,000. For the population considered this

translated to approximately one case every three and a half years. This was compared with the statistic that about one in three Americans will contract cancer over the course of an average lifetime.

The study found that the most significant contributors to cancer risk from air pollution were car, buses, trucks and trains. These accounted for 25 percent of the predicted number of cancer cases. Background concentrations of formaldehyde and carbon tetrachloride provided the second highest contribution. The third major contributor was a chrome plating operation which was associated with 16 percent of the total cancer cases. Aircraft emissions from Midway airport were identified as a significant contributor, accounting for approximately 11 percent of cancer cases due to air pollution.

### 3.5.2 EUROPEAN STUDIES

Recent British studies (Her Majesty's Scientific Office 1994, Stephenson, 1996) have emphasised the evaluation of local air quality at several British airports. Nitrogen dioxide has been considered the major problem area and attributed mainly to local motor vehicle emissions. On a regional scale, airport emissions are considered to be small compared to those of urban and industrial sources usually found next to airports. Ozone impacts considered have been mainly those identified by the Stratospheric Ozone Review Group.

Monitoring close to Gatwick Airport has facilitated the estimation of source contributions to modelled ground-level concentrations of oxides of nitrogen. Outside the airport boundary, the airport is thought to contribute up to 10-13 percent of the total ground-level concentrations. Aircraft are considered to be "a relatively small contributor to ambient nitrogen oxide concentrations outside of the airport boundary, compared to regional and background sources."

Recent German studies (for example, Ebel and Perry 1995) have used a mesoscale model to look at the impact of aircraft emissions on ozone concentrations at the tropopause. However, the available results are ambiguous.

The literature search did not identify any good examples of assessment of the impact of airport operations on regional photochemistry.

Moussiopoulos et al (1996) reported a study of nitrogen dioxide and ozone impacts due to Athens Airport. Athens Airport is to be relocated from Hellenikon, which is within the Athens Basin to Sparta, which is outside the Athens Basin. Photochemical airshed modelling was carried out for seven different meteorological conditions to assess impacts of the new airport. Athens currently suffers for regular exceedences of their nitrogen dioxide guidelines.

Under unfavourable meteorological conditions, emissions from the existing airport are recirculated within the Athens Basin. This leads to elevated concentrations of nitrogen dioxide. Increases in nitrogen dioxide concentration of up to two parts per hundred million were attributed to the airport. Operation of the airport at Sparta was predicted to have no impact on air quality within the Athens Basin due to isolation by a pronounced mountain ridge. Ozone was predicted to be reduced in the vicinity of the airport due to reaction of ozone with nitric oxide emissions. The study concluded that the airport would produce significant air quality impacts at the new site but these would not lead to exceedences of the prevailing air quality standards and that air quality within the Athens Basin would be improved as a result of the airport relocation.

### 3.5.3 AUSTRALIAN STUDIES

#### *Sydney Airport*

A number of documents relate to the operation of Sydney's (Kingsford Smith) Airport. These include the Third Runway EIS and the *Draft Air Quality Management Plan for Sydney (Kingsford Smith) Airport*, prepared by Mitchell McCotter, 1994. The EIS prepared to assess environmental impacts of the implementation of the Third Runway (Kinchill, 1990) includes a substantial discussion of air quality impacts. This EIS was investigated by the Senate Select Committee on Aircraft Noise in Sydney. A chapter of that Committee's report addressed air quality issues.

The Senate Select Committee (1995) report on submissions described kerosene odours, black particles in the air, and sooty oily deposition on cars and windows, all of which were attributed to aircraft emissions.

Complaints were predominantly from areas beneath aircraft flight paths. Evidence was taken from medical specialists that there was a cancer risk associated with emissions from aircraft and in particular from particulate matter which falls beneath the flight paths.

The Committee recommended that:

- monitoring of air quality around Sydney Airport be supervised by the Commonwealth Environment Protection Agency;
- airport and background monitoring be undertaken in conjunction with the New South Wales Environment Protection Authority, with reports to be published monthly and made publicly available with an analysis of the data and its application to airport operations;

- at least one permanent or mobile background monitoring station be established in the residential areas to the north of the airport and along the flight path;
- the suitability and effectiveness of the system in operation at Zurich Airport for the monitoring of air emissions at source be investigated for Kingsford Smith Airport; and
- dispersion modelling be undertaken under the supervision of the Commonwealth Environment Protection Agency to establish the current pattern of emissions.

The Draft EIS for the Third Runway (Kinhill, 1990) estimated that Sydney Airport would contribute approximately one percent of total emissions of air pollutants in the Sydney Basin in the year 2010. Some 15 percent of vehicle traffic on roads to the north and south of Kingsford Smith Airport was predicted to be related to the airport. These estimates of air emissions from Kingsford Smith Airport have been compared with predicted emissions for the Second Sydney Airport, later in this technical paper.

Monitoring at Sydney Airport over the period December, 1993 to May 1995 showed no exceedences of nitrogen dioxide concentrations above the National Health and Medical Research Council maximum one hour guideline of 16 parts per hundred million (Environment Protection Authority 1997b). Dispersion modelling carried out for the Third Runway Draft EIS indicated that the one hour guideline level for nitrogen dioxide (16 parts per hundred million) would be exceeded on occasions for projected operational conditions in 2010.

The *Sydney Kingsford Smith Airport Draft Air Quality Management Plan* (Mitchell McCotter, 1994) includes an air emissions inventory for Sydney Airport. The inventory addresses emissions of carbon monoxide, oxides of nitrogen, hydrocarbons, sulphur dioxide and particulate matter. Particulate emissions from aircraft are presented as a range of smoke number values indicating the range of regulatory limits for aircraft for each operating mode. No estimate of particulate emissions for the airport was made due to difficulties in obtaining particle emission data for aircraft engines.

### *Other Airports*

Emission inventories recently developed for various Australian cities have included the contributions of airports. Regional air-shed modelling for most of the cities has included these sources but has rarely identified explicitly the individual impact of airport operations. The simulations of high ozone days have emphasised the importance of seabreeze circulations, temperature and biogenic emissions on levels of photochemical pollutants.

One of the sensitivity runs for the *Sydney Metropolitan Air Quality Study* airshed estimated that Sydney Airport emissions in 1993 were likely to increase the peak ozone level in the region by an insignificant amount (less than one percent and below the model resolution). Local ozone levels could be changed by  $\pm$  five percent, dependent on location and conditions.

These are likely to be underestimates (mainly because of the model resolution and technical difficulties in treating seabreeze conditions). The location of Sydney Airport within the industrial area of Botany Bay and close to urban areas diminishes the applicability of these results to the Second Sydney Airport air quality study.

Recent impact assessments for Brisbane, Mascot and Melbourne airports have predicted local air quality impact but have not considered regional matters.

Air quality monitoring is currently taking place at Sydney Airport (two sites) and, to a lesser extent, near Brisbane Airport. Continuous monitoring of oxides of nitrogen, ozone and particulate matter smaller than 10 micrometres concentrations at these sites provides potential for evaluating the impact of airport operations in future. Formal assessments have not yet been published.

#### 3.5.4 REGIONAL SCALE STUDIES

Regional-scale studies have not been identified in the scientific literature for any other airports.

##### *Sydney West Airport Sub-Region Strategic Plan*

A State Government Task Force on Planning for the Sydney West Sub-Region has assessed the impacts of an airport at the Badgerys Creek site on urban development and employment and the consequential environmental effects of this development including air quality impacts. Findings of the task force presented in a Stage 1 Investigations report (Task Force on Planning for the Sub-Region Surrounding Sydney West Airport, 1995) were that:

- the Sydney West Sub-Region (the area in the vicinity of the Badgerys Creek site) is a receptor area for air pollutant emissions from the eastern half of the Sydney Metropolitan Area;
- air quality within the Sub-Region was found to be within current health guidelines but that summer ozone levels regularly approached the health goal prevailing at that time. A more stringent ozone health goal was anticipated which would mean that air quality in the region would exceed the health goal more frequently; and

- air quality was considered a primary constraint on the development of the Sub-Region. Development of the Sub-Region should be limited in the event that air quality standards would not be met.

In a subsequent report prepared for the Task Force, Symonds Travers Morgan (1996) presented the results of an analysis of air quality impacts of increased motor vehicle travel as a result of employment and urban development associated with the proposed airport. A 2.4 million increase in the number of daily vehicle kilometres travelled was predicted for the year 2016 within an area of 18 kilometres by 27 kilometres (Australian Map Grid coordinates 285 kilometres east to 303 kilometres east and 6,234 kilometres north to 6,261 kilometres north). This represents some 58 percent increase in the assessment of motor vehicle traffic for the area reported in the *Air Emissions Inventory Report*, which is contained in *Appendix C*. Increased emissions due to increase residential population were included in the analysis. It is not clear if additional traffic flow due to airport passengers was included in this assessment. No point source industrial emissions were considered.

The impacts of the increased air pollutant emissions due to this rise in traffic volume were modelled by NSW Environment Protection Authority using a photochemical airshed model developed during the Sydney Metropolitan Air Quality Study. The model was run for meteorological conditions corresponding to a photochemical smog event which occurred on 8, 9 and 10 February, 1994. Emissions from the airport itself were not included in the analysis. This analysis showed almost imperceptible changes in air pollutant concentrations as a result of the development.

Concern was expressed however, that given the grid size adopted for analysis, the results sought were at the limit of the resolution of the model. Ozone levels decreased slightly in the vicinity of the area of development and increased slightly downwind from the development to the south west. In the report, it was mentioned that NSW Environment Protection Authority had interpreted the modelling to suggest that goals for oxides of nitrogen may be exceeded as a result of the development. Plotted results showed changes smaller than five parts per billion of ozone concentration (reductions in the vicinity of the development).

### *Other Studies*

The impact of other types of sources of precursor emissions on regional photochemistry have also been assessed. These studies have usually involved point source emissions of nitrogen oxides (such as power stations) or various generic types of emissions (motor vehicles, all industrial emissions, biogenic sources). The results are not directly applicable to the Second Sydney Airport study.

Power station or cogeneration plant sources of strength 10-100 grams per second nitrogen oxides (and 1-5 grams per second volatile organic compounds) have been forecast to give rise to 2-15 parts per billion of additional ozone for some hours of high photochemical activity in Brisbane and Sydney. Motor vehicle sources are predicted to contribute 35-70 percent of ozone on such days. Biogenic sources may not increase maximum ozone levels but will increase the air-shed dosage (Environment Protection Authority, 1997). The recent Perth photochemistry study emphasised the importance of volatile organic compounds emissions from the Kwinana oil refineries.

These considerations are of particular interest to locations such as Mascot where industrial and urban emissions are high. For fringe urban areas such as Badgerys Creek and Holsworthy, recent simulations for the methane recovery and combustion plants at Tower and Appin are of more relevance (Katestone Scientific, 1995).

During these simulations, sources of strength 20-35 grams per second nitrogen oxides emitted at effective heights of 100 metres above ground-level were predicted by two different approaches to give an ozone impact of 5-15 parts per billion ozone for those few hours per year when high ozone levels and photochemically old air from Sydney and Campbelltown pass over these sources. Maximum ozone increments were predicted for 5-15 kilometres downwind, depending on conditions.

### 3.5.5 STUDIES AT LUCAS HEIGHTS

Studies relating to air quality carried out for the nuclear facility at Lucas Heights are relevant to the Holsworthy site, as the Australian Nuclear Science and Technology Organisation site is within five kilometres of Holsworthy Option A. Meteorological data recorded at Lucas Heights has been used for interpretation of meteorological conditions for Holsworthy Options A and B.

The Australian Atomic Energy Commission (1986) carried out a study of transport and dispersion of airborne pollutants in the vicinity of the Lucas Heights Research Laboratories. This study assessed the potential impact of short term inadvertent atmospheric releases using a Gaussian puff model of localised releases. Assessment was made of the dilution of short term releases.

Analysis was carried out assuming flat terrain and the question of the level of conservatism of this approach was discussed. The authors noted that complex terrain effects were likely to increase the levels of dispersion beyond those obtained using the assumption of flat terrain but experimental observations were needed to assess the effects of complex terrain. The authors presented the results of an analysis of transport in the Woronora Valley to assess potential for accumulation of pollutants in valleys under stable conditions.

Greater dilutions (and hence lower concentrations) were assessed for valley flow than were obtained assuming Gaussian dispersion in flat terrain. Despite these results the authors indicated a need to carry out experimental studies to test this result.

The Australian Nuclear Science and Technology Organisation (1990) carried out a study to assess the consequences of a severe accident of the nuclear reactor at Lucas Heights. Analysis of a sustained release was carried out using a Gaussian plume model. This study differed from an earlier study (Australian Atomic Energy Commission, 1986) in that airborne emissions from the site were considered to be continuous rather than of short duration. As for the earlier study, a horizontal ground surface was assumed for dispersion modelling. Population exposures were assessed for the case of an accident occurring under adverse meteorological conditions.

Australian Nuclear Science and Technology Organisation has advised that further field and numerical studies are being carried out but that reporting of the studies has not been completed. These studies include complex wind field and dispersion modelling and atmospheric tracer dispersion studies.

## 3.6 FIELD SURVEYS

Sampling of air directly affected by emissions from aircraft at Sydney Airport was carried out in November 1996. A total of eight samples were collected which included samples in the exhaust wake of large commercial jets. This work is reported in *Appendix G*.

Testing of each of these samples was undertaken to measure odour strength and speciated organic content including several air toxic compounds. These results were correlated with the results of the emissions inventory work and used to provide input to assessment of odour impacts.

## 3.7 AIR QUALITY MODELLING

### 3.7.1 EMISSIONS INVENTORY

The spatial allocation of airport related air emissions is discussed in *Section 7* of the *Air Emissions Inventory Report* which is contained in *Appendix C*. For each airport option, thirteen zones covering ground level and elevated emissions to 1000 metres in height were modelled. A description of these zones appears in *Table 3.1* and they are described in more detail in the *Air Emissions Inventory Report*.



TABLE 3.1 DESCRIPTION OF EMISSION ZONES AT SECOND SYDNEY AIRPORT

Emission Zone	Description	Height (metres above ground level)
A1	Terminal/apron area during early operational phase 2006	0
A1 + A2	Terminal/apron area during fully operational phase 2016	0
B	Airport access road	
C1	Maintenance area during early operational phase 2006	0
C1 + C2	Maintenance area during fully operational phase 2016	0
D	Fuel storage area	0
E	Fire training area	0
F1	1st Runway aircraft emissions, consisting of: Taxi, idle Takeoff	7' 7-200
F2	2nd Runway aircraft emissions, consisting of: Taxing, idle Takeoff	7 7-200
G1	1st Runway aircraft climbout emissions	200-1,000
G2	2nd Runway aircraft climbout emissions	200-1,000
H1	1st Runway aircraft approach emissions	7-1,000
H2	2nd Runway aircraft approach emissions	7-1,000

Notes: 1. Height of emission from aircraft engine while aircraft is on the ground, taking into account the heat of the exhaust (V&C Environment Consultants, 1995).

The location of airport emission zones was estimated using site plans and other information supplied by Second Sydney Airport Planners (1997a). Emission zones have been modelled as follows:

- Zone A - terminal/apron areas comprising emissions from boilers, aircraft refuelling, ground service vehicles, auxiliary power units and surface coatings were modelled as one or more area sources of equal side length;
- Zone B - access roads have been modelled as a series of eight area sources of side length 300 metres. The area sources are spaced 100 metres apart to avoid modelling artefacts such as plume 'peaks' occurring from the imposition of one area source plume upon another. The selection of 300 metres as the side length was based upon a configuration of double lanes separated by a median strip;

- Zone C - maintenance areas comprising emissions from ground running of aircraft engines and evaporation of solvents were modelled as one or more area sources of equal side length;
- Zone D - fuel storage areas comprising emissions from tank breathing and filling were modelled as one or more area sources of equal side length;
- Zone E - fire training burn-off area. As noted in the *Emissions Inventory Report (Appendix C)*, this source is not considered large enough to warrant inclusion in the inventory;
- Zone F - Runway emissions comprising aircraft taxi/idle and takeoff modes have been modelled as a series of 300 metres square area sources, spaced at 400 metre centres. Taxi/idle and ground level takeoff emissions are assumed to occur over the southern most two kilometres of each main runway. Elevated takeoff emissions are modelled as three additional area sources at elevations of 60 metres, 120 metres and 180 metres for a further one kilometre of horizontal travel. These assumptions are based on a consideration of typical takeoff trajectories for commercial jets supplied by Qantas (Mr W. Burke, personal communication, 1996). It should be noted that crosswind runway operation has not been considered and that a uniform emissions distribution with distance is used for the allocation of takeoff emissions;
- Zone G - Aircraft climbout emissions modelled as a series of 3 kilometre square area sources at varying heights covering a horizontal distance of 10 kilometres and a vertical distance of 1000 metres. This configuration is an approximation of the broad climb out corridors outlined by Second Sydney Airport Planners (1997a);
- Zone H - Aircraft approach emissions have been modelled as a series of 400 metre square area sources spaced at 600 metre centres. Approach lines (one for each runway) consist of 38 separate area sources rising from 25 metres to 950 metres over a horizontal distance of approximately 19 kilometres. Approach corridors are assumed to be relatively straight and narrow.

### 3.7.2 NITROGEN DIOXIDE CONVERSION

Interpretation of modelling of the impact of the airport on nitrogen dioxide concentrations requires an assumption of the proportion of nitrogen oxide which is converted to nitrogen dioxide. The emissions inventory has assumed that 10 percent of the oxides of nitrogen are in the form of nitrogen dioxide

with the remainder as nitrogen dioxide. Nitrogen oxide is rapidly converted to nitrogen dioxide in the presence of ozone and sunlight.

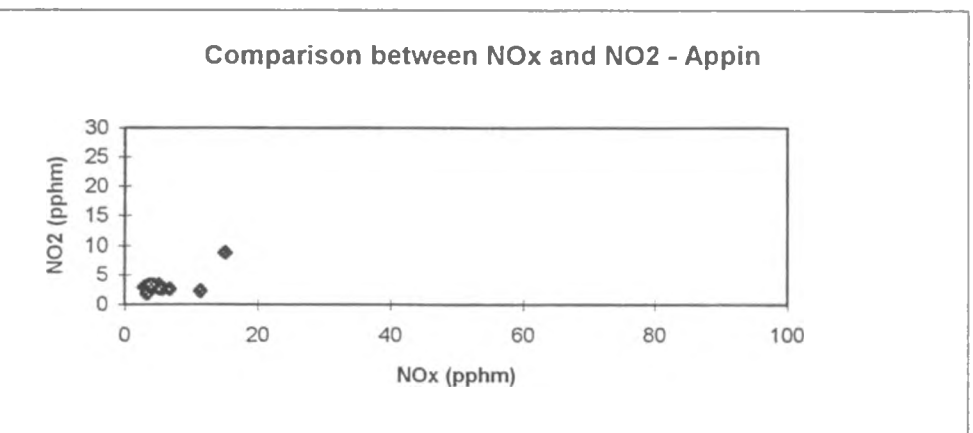
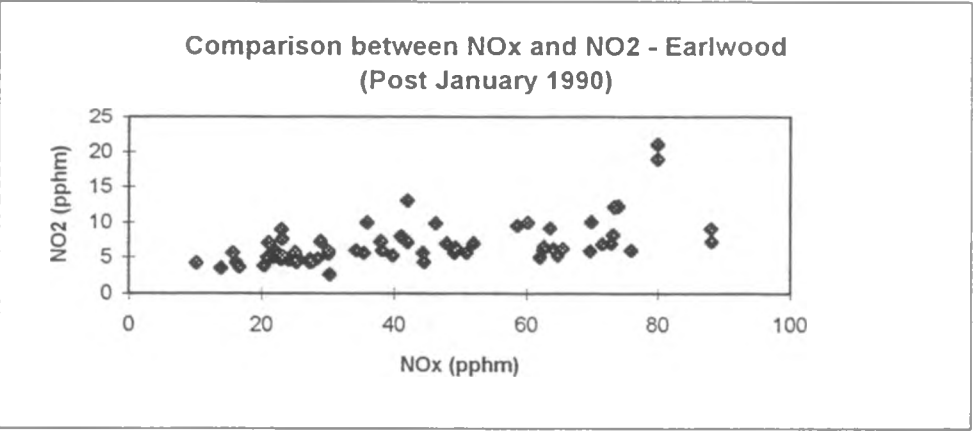
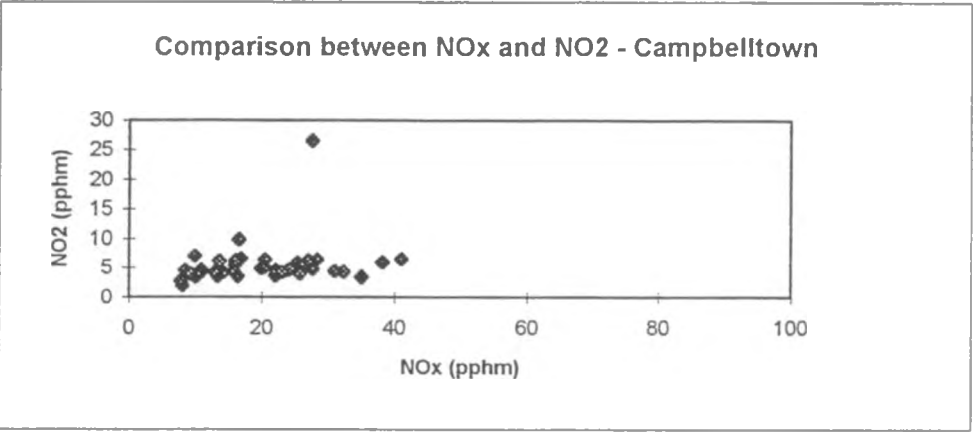
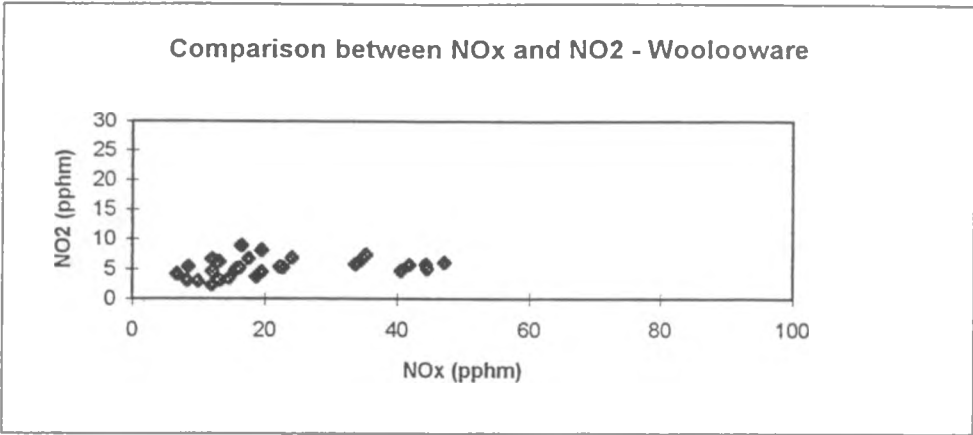
*Figures 3.1 and 3.2* present the correlation between maximum monthly nitrogen dioxide concentration and maximum monthly concentration of total oxides of nitrogen from the monthly monitoring data presented in the NSW EPA quarterly reports for eight monitoring stations surrounding the proposed airport site (Bringelly, Blacktown, St Marys, Liverpool, Woollooware, Campbelltown, Earlwood and Appin). These plots illustrate that the nitrogen dioxide concentration tends to increase with increasing total oxides of nitrogen. Linear correlations were fitted to each of the plots shown in *Figures 3.1 and 3.2* and the results tabulated in *Table 3.2*.

TABLE 3.2 CORRELATION BETWEEN MAXIMUM MONTHLY CONCENTRATIONS OF TOTAL OXIDES OF NITROGEN VERSUS NITROGEN DIOXIDE

Monitoring Station	Slope (Nitrogen Dioxide/ Oxides of Nitrogen)
Appin	0.350
Blacktown	0.086
Bringelly	0.162
Campbelltown	0.095
Earlwood	0.083
Liverpool	0.037
St Marys	0.059
Woollooware	0.038

Based on this correlation, an increase in maximum monthly concentration of total oxides of nitrogen would be expected to lead to an increase in maximum nitrogen dioxide concentrations for the month between 3.7 percent and 35 percent. The highest values of 16.2 percent and 35 percent were obtained for the monitoring stations at Bringelly and Appin where low concentrations of total oxides of nitrogen (less than 20 parts per hundred million) were recorded. A value of 10 percent increase in nitrogen dioxide is consistent with the value adopted in the emissions inventory speciation. Based on these results, nitrogen dioxide concentrations of 10 percent of the increase in concentration of total oxides of nitrogen are attributed to the operation of the airport.

The annual average concentration of nitrogen dioxide at monitoring stations reported in the 1995 NSW Environment Protection Authority Quarterly Air Quality Monitoring reports (NSW Environment Protection Authority, 1997b) are presented in *Table 3.3*.



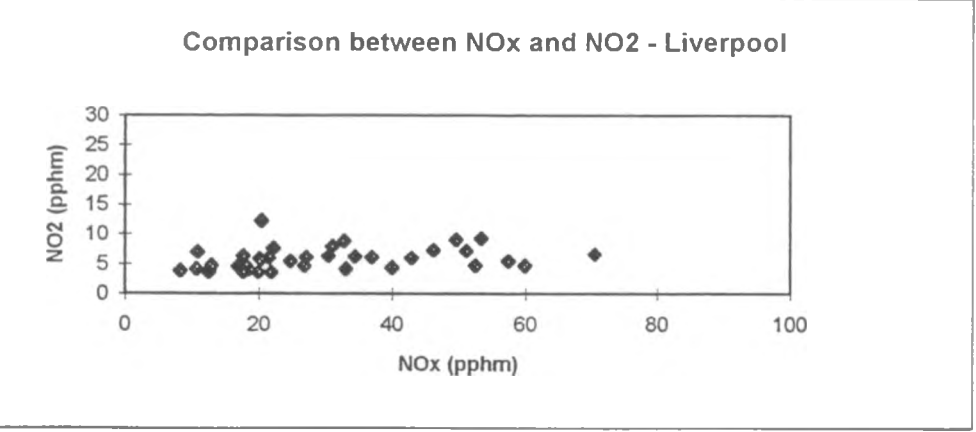
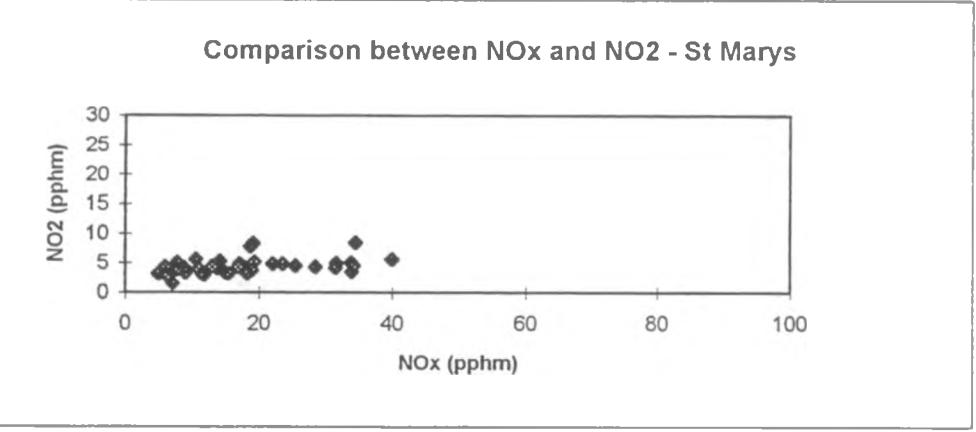
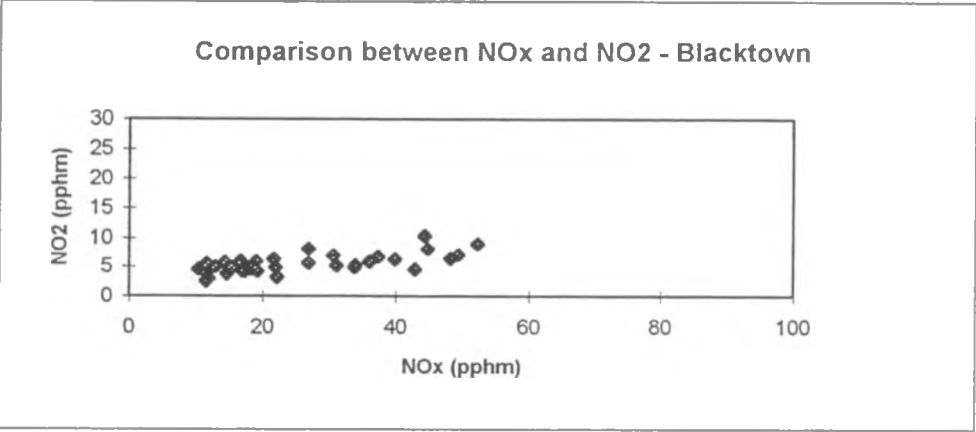
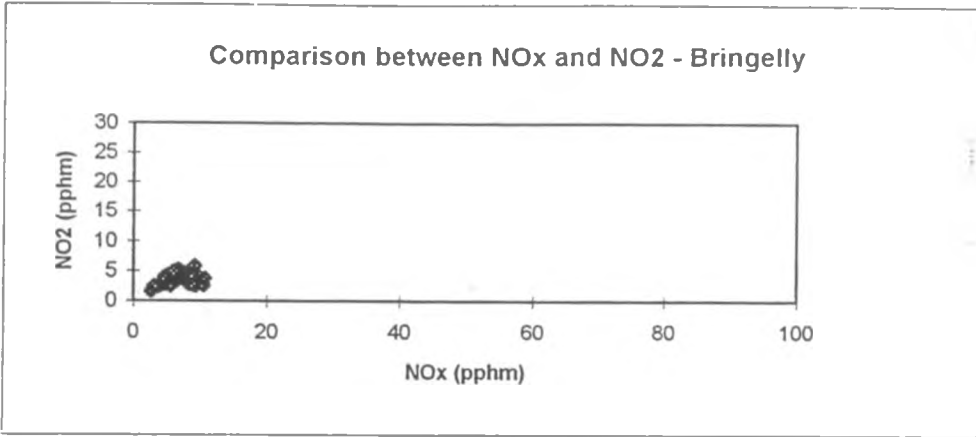


TABLE 3.3 BACKGROUND ANNUAL AVERAGE NITROGEN DIOXIDE CONCENTRATIONS

Location	1995 Average Concentration (pphm)
Appin	1.1
Blacktown	2.5
Bringelly	2.7
Campbelltown	2.0
Earlwood	2.9
Liverpool	1.6
St Marys	2.2
Woollooware	2.8

3.7.3 METEOROLOGICAL INPUTS INTO MODELLING

For the Badgerys Creek options, air quality impacts were modelled using hourly wind records obtained over period of two years covering the period 1 April 1990 to 31 March 1992. These wind records for this period were obtained by Macquarie University using a Lambrecht Woelfle mechanical wind recorder installed on a knoll at the northern end of the airport site where the elevation above seal level is 100 metres. A description of these records is contained in *Technical Paper No. 5 - Meteorology*. These data were also used for modelling of noise impacts.

The wind records for Badgerys Creek were processed to obtain meteorological records for input into the dispersion model. Development of the meteorological files for dispersion analysis was carried out by Katestone Scientific in a similar way to that used for the Holsworthy site described below except that seabreeze occurrence was based on local wind data and the effects of thermal internal boundary layer growth were considered to be negligible given that the site is some 50 kilometres from the coast. Mascot radiosonde and radiation data were used together with Richmond airport temperature information for processing of the Badgerys Creek wind data.

Dispersion modelling for the Holsworthy Options was carried out using meteorology data from the 10 metre mast at the Australian Nuclear Science and Technology Organisation facility at Lucas Heights as recommended by the meteorological consultant. This is the nearest wind monitoring site available. A two year period of records from January 1994 to December 1995 was used for modelling. This period is within the four year period November 1992 to October 1996 which was adopted for modelling of noise impacts. A two year period was adopted for consistency with the duration of wind monitoring records available at the Badgerys Creek site.

The Lucas Heights wind records were compiled as follows:

- Radiosond information for Mascot (6am and 3pm) was processed for 1994 to 1995 to retrieve the temperature and mixing ratio profiles and to assess the mixing height at these times. The afternoon flights for on-shore winds show good evidence of seabreeze flows (typically 1600 metres in depth) and occasionally thermal internal boundary layers (200 to 300 metres deep). The sea breeze depths were considered applicable to sites further inland but the thermal internal boundary layer will grow with distance from the coast. For this reason the afternoon information was not used directly but was used to check the conclusions of Clark (1982) on seabreeze depths at Lucas Heights and to forecast thermal internal boundary layer depths at 16 kilometres from the coast for the proposed second airport sites;
- the morning temperature profile was used in conjunction with the Lucas Heights wind temperature and net radiation data to forecast hourly mixing heights, using the energy budget method (Clarke 1991). For seabreeze and on-shore flows, the mixing heights (and corresponding convective velocities) were modified using the seasonal depths recommended by Clarke (1982) from acoustic sounder measurements at Lucas Heights, and a standard square root dependence of the thermal internal boundary layer height on overland distance. The seabreeze depths were assumed to decay with time (that is, incoming radiation) as found by Pitts and Brown (1992) at a similar site in Western Australia. Seabreeze occurrence was based on surface wind data taking account of the direction sector and speed history;
- stability estimates were based on the ratio of convective velocity to windspeed (for daytime) and windspeed and net radiation (at night). The stability distributions were checked with those obtained by Clark (1982) using a variety of other methods. For the 10 metre data the approach adopted for this work tends to produce more Class A (extremely unstable) and Class F (moderately stable) conditions than the standard Turner, Smith or United States Nuclear Regulatory Commission methods. This is because of the lower wind speeds at 10 metres height;
- a minimum wind speed of 0.5 metres per second was adopted to avoid numerical difficulties at very low wind speeds;
- the 2pm mixing heights forecast using the adopted methods are in good agreement with Mascot data (very good for off-shore flows, moderate to good for on-shore flows). Night time mixing heights are comparable to those obtained by Clark (1982) using an acoustic sounder and the various balloon profiles of others; and

- meteorological records were prepared for a full two year period from 1 January 1994 to 31 December 1995.

#### 3.7.4 LOCAL SCALE DISPERSION MODELLING

Gaussian dispersion modelling was carried out to simulate the air quality impacts of the Sydney Second Airport on the surrounding area. Modelling was carried out for each of the airport options for the following two of the proposed Sydney Second Airport operational scenarios:

- **Air Traffic Forecast 2, (2006 Equal Growth Scenario)** - this scenario assumes that 10 million passengers make use of the Sydney Second Airport in the year 2006. A mix of international, domestic and general aviation traffic is assumed. This scenario was taken as being representative of the scenarios applying to early operation of Sydney Second Airport;
- **Air Traffic Forecast 3, (2016 Additional Noise Scenario)** - this scenario assumes that Sydney Second Airport accommodates the majority of the wide body aircraft and all the international/domestic air traffic growth within the Sydney Basin after 2006. Of the scenarios considered in the *Air Emissions Inventory Report (Appendix C)* this would result in the greatest level of air pollutant emissions by 2016 and hence has the greatest potential impact on air quality.

The Gaussian plume dispersion model AUSPLUME was used to assess the impact of airport emissions on areas surrounding the proposed airport sites at Badgerys Creek and Holsworthy. In each case a two year meteorological record was used to obtain hour by hour increases in ground level concentration for the following air pollutants:

- carbon monoxide;
- particulates;
- total hydrocarbons;
- nitrogen dioxide;
- sulphur dioxide;
- odour; and
- air toxic compounds (benzene, 1,3 butadiene, toluene, xylenes, acetaldehyde and formaldehyde).



For each of the pollutants considered, model results were obtained for averaging periods which would allow comparison with air quality goals recognised by NSW Environment Protection Authority or for averaging periods relevant for assessment of health impacts.

AUSPLUME Version 3.3 was used for dispersion modelling. Assumptions concerning modelling are:

- terrain affects were ignored for the proposed airport sites. Both the Badgerys Creek and Holsworthy sites are elevated in comparison with the surrounding areas. In the case of Badgerys Creek the proposed runway level is approximately 90 metre AHD (Australian Height Datum) which is some 50 metres higher than the surrounding terrain. Runway levels of 150 to 190 metres AHD are proposed for the Holsworthy options compared with a level of about 50 metres AHD for the populated areas to the west of the Georges River. It is considered that the use of a flat terrain model provides a generally conservative assessment of air quality impacts. There is potential for transport of air pollutants within localised air flows within the valleys of the Holsworthy site. This mechanism cannot be modelled using conventional dispersion modelling. It is discussed in *Technical Paper No. 5 - Meteorology*.
- use of the cross wind runways was disregarded for air quality analysis. The cross wind runway is designed for use when wind conditions are unfavourable for take off and landing on the main runways. Relatively high wind speeds which would preclude use of the main runways would prevail during usage of the cross-wind runway. High wind speeds favour rapid dispersion of atmospheric pollutants and so analysis of cross-wind runway operations was not considered to be warranted;
- for the purposes of modelling it was assumed that the direction of take off would have a northerly component. It is understood that in normal operation, take off can routinely occur with a tailwind of up to 8 knots. Analysis of meteorological data revealed that take off toward the north could take place 84 percent of the time at Badgerys Creek and 92 percent of the time at Holsworthy. The distribution of ground level emissions are similar for either direction of take off and as ground level emissions tend to dominate ground level impacts at a local scale the assumption of northerly take off was considered reasonable. A check on the sensitivity of this assumption was made by carrying out analysis with direction of takeoff selected to give highest ground level concentration at receptor locations; and

- airport emissions sources were modelled using over 100 area sources. The simulation of area sources within the AUSPLUME software is achieved by orienting a line source perpendicular to the wind. This method of simulation can result in non-representative concentration adjacent to the source but it is considered an appropriate and reasonable method for assessment of ground level concentrations outside the airport boundary.

### 3.7.5 TRAJECTORY MODELLING OF OZONE IMPACTS

Numerical modelling was carried out by CSIRO Division of Atmospheric Research to predict impact of operation of the proposed airport on air quality at a regional scale due to operation or design level in 2016. This work was primarily directed at assessment of photochemical smog impacts. A report presenting the findings of the CSIRO smog study is included in *Appendix D* and a summary is presented below.

Three dimensional modelling of the windfield using the Lagrangian Atmospheric Dispersion Model (LADM) was carried out taking account of the surface topography, the synoptic conditions and the effects of surface warming and cooling. The LADM model is described by Physick et al (1994). Dispersion of pollutants by the windfield was simulated by tracking the paths of a series of particles released from areas of pollutant emissions. Ozone chemistry was modelled along these paths and as a result, predictions of photochemical smog impacts downwind of the airport were obtained.

This approach to regional modelling of air quality impacts has the advantage that it does not rely upon measurements of wind speed and direction and it results in a full three dimensional model of wind flow capturing the vertical structure of the wind. The alternative approach of assessing the path of pollutant migration based on monitoring relies upon interpolation of near ground level measurements of wind speed and direction at isolated locations. A disadvantage of LADM modelling is that significant computing resources are required for analysis of each meteorological condition and as a consequence, it is not practical to model large numbers of meteorological conditions.

For this work, two events which resulted in poor air quality and high ozone conditions in Western Sydney were selected for modelling namely:

- 9th February, 1994; and
- 4th February, 1991.

These were among the events subjected to windfield and photochemical smog modelling as part of the Sydney *Metropolitan Air Quality Study* (Environment Protection Authority, 1997a). The period 8th to 10th February 1994 was

selected for detailed analysis by the *Metropolitan Air Quality Study* as it corresponded to a period which resulted in widespread elevated ozone levels in Western Sydney and regional transport of air pollutants from Sydney to the Illawarra. This event was also adopted by NSW Environment Protection Authority (Symonds Travers Morgan, 1996) for modelling of the impact of air emissions associated with a Second Sydney Airport at Badgerys Creek.

Synoptic winds during the 9th February, 1994 were northerly. Before sunrise, predicted winds at the coast were moderate north-easterly. Inland winds were much lighter turning southerly at the foot of the Blue Mountains. Drainage flows occurred into the Sydney Basin from the surrounding slopes. After sunrise, warming of the land gave rise to sea breeze at the coast by 12 noon and by mid-afternoon (4pm) the sea breeze had travelled across the basin producing north-easterly winds at the coast and easterly winds inland.

The event of 4th February, 1991 was selected for analysis as poor dispersion occurred in Sydney leading to poor air quality and transport from Sydney to Wollongong.

Synoptic winds were north-north-westerly over the Sydney region on the 4th February 1991. Modelled overnight winds at the coast were northerly becoming north-westerly by sunrise with night time southerly drainage flows at Badgerys Creek and Holsworthy. In the morning drainage flows were replaced by upslope flows and sea-breeze began to form at the coast. In the afternoon north-easterly flows developed over the basin.

### 3.7.6 FOOTPRINT ANALYSIS OF OZONE IMPACTS

Analysis of chemical interaction of airport emissions within the Sydney Basin was carried out by Katestone Scientific. This work involved calculation of the trajectories of parcels of air passing over the proposed airport sites for a range of conditions identified from analysis of records for the period July 1994 to June 1995. The impact of airport emissions on the formation of photochemical smog and the areas which would be affected as a result were assessed for each airport site. A report describing this work is attached as *Appendix E*. The key findings of this work were:

- high smog levels and aged air are necessary for the airport emissions to have a significant impact on ozone levels. These conditions occur about five to fifteen times per year with a greater frequency in the western suburbs of Sydney. A coincidence of suitable synoptic conditions, delayed seabreeze and high levels of precursor emissions is necessary. This rarely occurs and on most days the photochemical impact of the airport will not be significant;

- if photochemical old air is incident on any of the candidate sites, the addition of volatile organic compounds will accelerate the chemical transformations leading to a nitrogen oxide limited state. The airport nitrogen oxide emissions can then give rise to additional ozone. The affected areas are predicted to be five kilometres to 20 kilometres downwind (depending on conditions); within the area covered by the airport emission plumes (typically three kilometres to five kilometres wide). Increases in maximum hourly ozone concentrations in the range 5 parts per billion to 15 parts per billion are predicted, with areas to the south-west of each site most frequently affected; and
- sensitivity studies indicated that the events chosen from the *Sydney Metropolitan Air Quality Study* (Environment Protection Authority, 1997a) are extreme events and such events would result in much higher impacts than on most historical days.

### 3.7.7 ASSOCIATED DEVELOPMENTS AND MOTOR VEHICLE EMISSIONS

Establishing a Second Sydney Airport could result in shifts in population and motor vehicle traffic within the Sydney Basin. These changes have the potential to cause air quality impacts. Therefore an assessment of ozone concentration changes due to the combination of these effects, together with the effects of airport emissions, was also undertaken, using a box model approach. Emissions predicted from associated developments and motor vehicle traffic are reported in *Section 6.2*, while impacts of these emissions are discussed in *Sections 7.3* and *8.3*, for the Badgerys Creek and Holsworthy options respectively.

### 3.7.8 POTENTIAL HEALTH EFFECTS OF AIR QUALITY

A review of the health effects of changes in air quality on respiratory health was undertaken. This involved a literature review of the human health impacts of exposure to the airborne pollutants of ozone, nitrogen dioxide and particulates. This report, prepared by the Institute of Respiratory Medicine at the Royal Prince Alfred Hospital, is contained in *Appendix F*.

Where evidence of an association between pollutant exposure and health outcomes existed, the magnitude of the health risk associated with a change in pollutant exposure was estimated. Health impacts of sulphur dioxide, carbon monoxide and lead were not examined in detail, because modelling indicated that increases in their concentrations due to the airport options would not result in levels which exceeded current health guideline values.

Chronic health impacts due to long term exposure to average increases in concentration of air toxic compounds arising from airport operation were assessed. Risks of contracting cancer, assuming a lifetime exposure to a

combination of air toxics predicted to be generated by the various airport options were also estimated.

This was done using a risk assessment methodology which assesses risks for a worst case scenario. A hypothetical individual who lives permanently outside the airport at the point of maximum level of each pollutant and is sensitive to each pollutant was allowed for in this analysis. If this hypothetical individual does not suffer ill health, members of the local population, who would be subjected to less extreme exposure would also be protected (Bridges et al, 1996).

# Part B

Existing Environment

## CHAPTER 4 EXISTING ENVIRONMENT

### 4.1 AIR QUALITY ISSUES FOR SYDNEY

#### 4.1.1 POTENTIAL EFFECTS OF AIR POLLUTANTS

Potential effects of air pollutants include increases in levels of greenhouse gases, reduced amenity due to "brown haze" effects and photochemical smog, possible degradation of the fabric of buildings, increased concentrations of pollutants in drinking water supplies, exacerbation of respiratory problems, and long term health impacts such as increased risks of contracting cancers.

Greenhouse gases such as carbon dioxide, methane and nitrous oxides in the atmosphere trap the heat radiated from the Earth providing a warming effect. While this phenomenon occurs naturally, and is essential for sustaining life, scientists now generally believe that global warming trends are linked to the accumulation in the atmosphere of increased amounts of greenhouse gases. This warming could lead to potentially significant changes in the Earth's climate, with consequences for ecosystems, people and infrastructure (NSW Environment Protection Authority, 1996a).

Acid rain is rain with a pH of less than 5.6. It is formed by the presence of acid gases (predominantly sulphur dioxide and oxides of nitrogen) which mix with water in the atmosphere to form acids. Acid rain has been associated with environmental problems including acidification of lakes, loss of aquatic life, contamination of drinking water and damage to buildings, monuments and motor vehicle paintwork. Acid rain is less of a problem in Australia than in Europe and North America because of the comparatively low emissions rate and wide geographic distribution of the Australian population.

Photochemical smog is a near ground mixture of ozone and other pollutants formed by a chemical reaction in the atmosphere. It occurs mainly in warm, stable air, particularly when there is strong sunlight. It is caused by oxides of nitrogen and reactive organic compounds being emitted from a variety of sources such as motor vehicles, industrial activities and domestic and commercial activities. Smog can be identified by the presence of ozone and is sometimes visible as a white haze during summer. While ozone occurs naturally in the atmosphere, and plays an essential role in absorbing harmful ultraviolet radiation, at lower levels it can have an adverse affect on human health, vegetation and materials.

The NSW Government's Green Paper *Developing a Smog Action Plan for Sydney, the Illawarra and Lower Hunter* (Environment Protection Authority, 1996b) identifies the following health impacts of photochemical smog:

'Ground-level ozone irritates the eyes and air passages and might interact with allergens to trigger asthma attacks. It might also increase susceptibility to infection. At exposure levels experienced in the Sydney region, health effects appear to be short-lived, although the long-term significance of exposure is not known.

Air pollution and photochemical smog in particular have been blamed for increasing the prevalence of asthma but, as yet, there is little scientific evidence to support this. The risk factors for asthma do, however, appear to be largely environmental, and include high allergen concentrations, exposure to environmental tobacco smoke, respiratory infections early in life and even diet. Some air pollutants, especially ozone, could, however play a role in exacerbating asthma. Air pollution has also been implicated in a range of other health problems.

The likelihood of an adverse response to an inhaled pollutant depends on the degree of exposure to the pollutant and the susceptibility of the exposed person. Those at greatest risk include children, the elderly, patients with lung disease such as asthma and chronic obstructive pulmonary disease, and smokers.' (Environment Protection Authority, 1996b, p.2).

Potential short term adverse effects of air pollutants include a decrease in the ability to perform tasks due to transient impairment of lung function. The spectrum of severity of possible health effects ranges from mild symptoms or disability, through to illness episodes severe enough to warrant medical attention or hospitalisation, to rare episodes resulting in premature death. However, healthy individuals with no history of respiratory disease are rarely affected by impairment of lung function or other symptoms.

Air toxics are a different class of pollutants from those which can cause exacerbation of respiratory problems as they can have toxic or carcinogenic (cancer causing) properties. Air toxics include benzene, formaldehyde, 1-3 butadiene and diesel soot (Roads and Traffic Authority, 1995). Nearly 200 air pollutants have been identified by the US Environment Protection Agency as being air toxics. These include benzene, dioxins, cadmium, organochlorines, halogenated ethylenes and PCBs. Sources of air toxics include chemical plants, motor vehicles, metal plating plants, dry cleaners, petrol stations, solid fuel home heaters, backyard burning and bushfires (Environment Protection Authority, 1996a).



#### 4.1.2 AIR QUALITY ISSUES IN SYDNEY

The main regional air pollutants in Greater Sydney (which includes Newcastle and Wollongong) are photochemical smog and brown haze (Roads and Traffic Authority, 1995).

##### *Photochemical Smog*

Photochemical smog, which sometimes appears as a white haze, is formed by chemical reactions between oxides of nitrogen and reactive organic compounds, in the presence of sunlight. The main constituent of photochemical smog is ozone. Although ozone is needed high in the atmosphere to absorb harmful ultraviolet radiation, it acts as a pollutant in the lower atmosphere. Heightened levels of photochemical smog can occur when calm, sunny weather conditions prevail for several consecutive days. Polluted air can be effectively trapped in the Sydney airshed on some occasions by the combined effect of sea breezes and elevated land to the north-west and south. Cool air containing pollutants, which drains down river valleys overnight and out to sea in the morning, can be blown back onto land by sea breezes (Roads and Traffic Authority, 1995).

As a result of such trapping of pollutants, heightened levels of ozone can be formed downwind of sources of pollution. Generally, ozone levels exceed ozone health goal levels of 12 parts per hundred million for less than 10 days per year.

Peak ozone concentrations in Sydney, in comparison with other cities in Australia and some international cities are shown in *Figure 4.1*. They indicate that peak levels in Sydney, in 1992, of approximately 15 parts per hundred million, were comparable with Melbourne at approximately 13 parts per hundred million and Perth at approximately 12 parts per hundred million. In contrast, peak levels in Los Angeles were of the order of 20 parts per hundred million (Western Power and Department of Environmental Protection, 1996).

The *Metropolitan Air Quality Study* (Environment Protection Authority, 1997a) was a major scientific study that identified the sources of photochemical smog precursors and the processes by which they form smog.

Some of the key findings of the *Metropolitan Air Quality Study* were that:

- concentrations of both oxides of nitrogen and reactive organic compounds need to be managed;
- reactive organic compound management, which past strategies have focussed upon, will continue to be important, however it will not ensure long-term achievement of air quality goals;

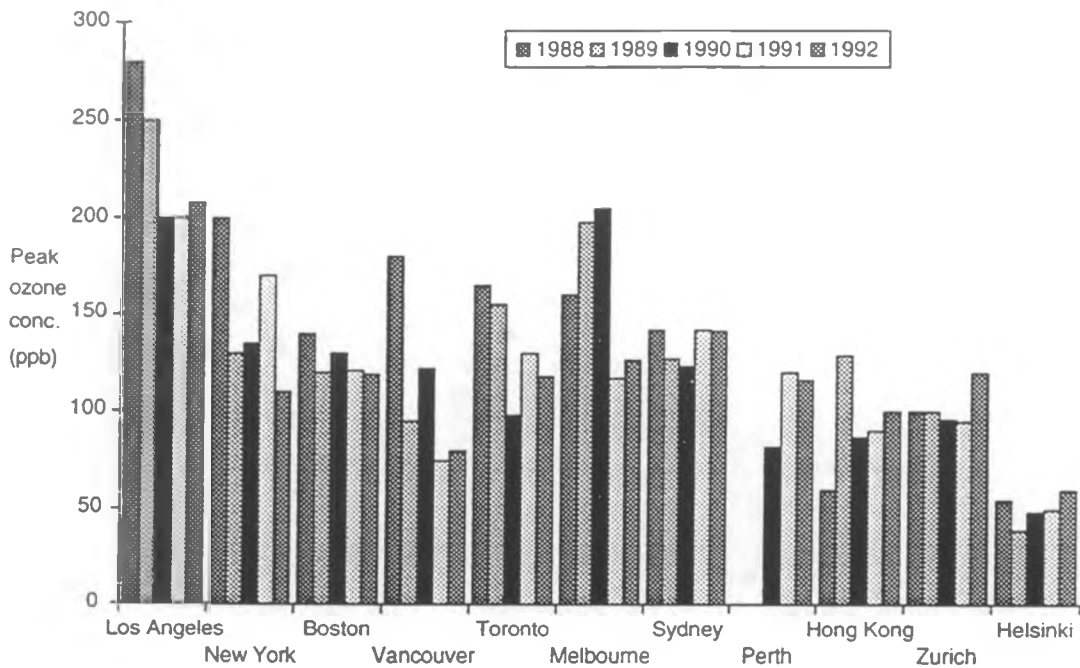
- the summer sea breezes frequently transport emissions from Sydney towards the west of the Sydney basin, therefore ozone levels in western Sydney cannot be reduced simply by managing emissions in the west;
- strategies to manage emissions throughout Sydney, particularly from cars and trucks are essential;
- concentrations of ozone in western Sydney are particularly sensitive to the addition of new sources of nitrogen oxides, which can lead to significantly higher concentrations of ozone downwind; and
- nitrogen dioxide (a component of nitrogen dioxide) is emerging as a pollutant of concern in the Sydney region in its own right, apart from the role it plays in the formation of ozone.

### *Brown haze*

"Brown haze" is caused by the presence of fine particles. Fine particles smaller than ten microns are very effective at scattering light. This can result in the phenomena called "brown haze" which can be seen on some winter mornings as a brownish layer which reduces visibility (Hyde et al, 1982a). A study of brown haze in Sydney was reported by Hyde et al (1982b) and a conference organised by CSIRO in 1982, *The Urban Atmosphere - Sydney, A Case Study*, included a series of papers describing findings in relation to brown haze. Contributions to brown haze include backyard incineration, motor vehicle emissions and industry.

The emissions inventory prepared as part of the *Metropolitan Air Quality Study* (Environment Protection Authority, 1997) indicates that in 1992, 46 percent of particulate emissions were from industry, 24 percent were from motor vehicles, 23 percent were from domestic solid and liquid fuel consumption with the remaining seven percent from commercial shipping. NSW Environment Protection Authority is currently developing a Brown Haze Action Plan. The NSW Government has gazetted a regulation under the *Clean Air Act, 1961* specifying emission standards for new solid fuel home heaters. Motor vehicle controls proposed under the NSW Smog Action Plan would result in reduced motor vehicle particulate emissions (Environment Protection Authority, 1996b).

While photochemical smog is generally more prevalent in summer, because of the stronger sunlight, brown haze can be observed mainly on calm winter days. Particulate matter from motor vehicles, industry, solid fuel home heating and bushfire hazard reduction burning (Roads and Traffic Authority, 1995), can be trapped by temperature inversions. A temperature inversion occurs when the temperature of the air in the atmosphere increases with height. Normally air temperature decreases with height, due to heating of the earth's surface by



Peak annual 1-hour average ozone values in selected world cities, 1988-1992.  
(Source: Kiely et al. 1995).

SOURCE: WESTERN POWER & DEPARTMENT OF ENVIRONMENTAL PROTECTION, 1996  
THE PERTH AIRSHED STUDY

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approved:	
date:	
scale:	

SECOND SYDNEY AIRPORT EIS  
OZONE CONCENTRATIONS  
INTERNATIONAL CITIES



FIGURE 4.1

job no. E2057/1-DA

the sun, and air pollutants rise into the atmosphere and are carried away by air currents. Inversions can cause air pollutants to become trapped in the lower atmosphere, and if the inversions are relatively stable, pollution levels can build up in the atmosphere over a number of days (Wark et al, 1985).

Over the past decade, the brown haze in Greater Sydney has been occurring with less intensity. This is partly due to Government policies prohibiting backyard burning and improved emission controls on industry and motor vehicles (Roads and Traffic Authority, 1995).

### *Motor Vehicle Emissions*

Motor vehicle emissions are a major influence on air quality in Sydney. The air emissions performance of individual motor vehicles has improved dramatically since 1976, due largely to better technology, however it is anticipated that in the next five to 10 years, increases in motor vehicles and their usage are likely to outweigh the gains made from lower emissions per vehicle, unless traffic growth is moderated (Roads and Traffic Authority, 1995).

Improvements in motor vehicle emissions technology have resulted in reduced emissions of hydrocarbons, oxides of nitrogen and carbon monoxide from cars manufactured since 1985. Significant improvements in overall motor vehicle emissions will occur as older vehicles are retired and post 1985 vehicles become more dominant. It is anticipated that by 2016, the motor vehicle fleet would be almost entirely made up of vehicles manufactured after 1985.

Motor vehicle emissions standards are strongly influenced by conditions in the United States. The Australian regulations (Australian Design Rules ADR37/01) become consistent with the prevailing United States emission limits in 1997. The US Environment Protection Agency has indicated its intention to introduce further restriction of air emissions from passenger vehicles and light trucks (including diesel powered vehicles). These would reduce emissions of oxides of nitrogen to less than half current levels per vehicle, while keeping total hydrocarbons and carbon monoxide emissions unchanged (Anyon, P, et al, 1992).

### *Acid Rain*

Acid rain is not a major air quality issue in Sydney. Emissions of potential acid forming gases in Sydney are modest by comparison with industrial and mining centres and coal burning industries. In the Sydney region in 1992, total emissions were estimated to be 26,000 tonnes of sulphur dioxide and 100,000 tonnes of oxides of nitrogen (Environment Protection Authority, 1997a). In comparison, combined sulphur dioxide emissions for Kalgoorlie and Mt Isa in 1990 were estimated to be 1,300,000 tonnes. Since 1992, further reductions in nitrogen dioxide emissions will have occurred due to the increased

representation of motor vehicles with improved motor vehicle emissions control technology.

### *Health Effects*

There is a high level of community concern about the health effects of air pollution in Sydney. Air pollution is widely perceived to have increased the prevalence of asthma and respiratory diseases in western Sydney. Pollutants such as ozone and particulates have been blamed for respiratory problems.

A survey undertaken by NSW Health Department indicated that asthma is no more common among adults in western, south-western or southern Sydney, than in other parts of Sydney or NSW. Central west NSW, south-western NSW and the Central Coast all had higher rates of asthma (NSW Health Department, 1994). A detailed discussion of respiratory health in NSW is contained in *Appendix F*.

A survey conducted in 1995 by the South Western Sydney Area Health Service (1995) indicated that the rates of diagnosis of asthma (which includes all people who have ever been diagnosed with asthma, not just those who still have asthma) are lower than the area average for Fairfield and Bankstown local government areas. Rates of diagnosis were higher than the area average for Campbelltown, Liverpool and the combined Camden, Wollondilly and Wingecarribee local government areas.

These rates are influenced by the inclination of doctors to diagnose asthma and the likelihood that patients will recall this diagnosis (Burney, 1992). Regional variation in these attributes may be as large as the variation in the actual prevalence of asthma, making the results of surveys based upon doctors' diagnosis of asthma difficult to interpret.

Hospitalisation data and local death rates provide other indicators of the prevalence of asthma, respiratory and heart disease in certain areas. This data provides information on a combination of factors including the frequency of severe or fatal exacerbations, the inclination of doctors to hospitalise patients and the standard of medical care available. Hospitalisation data indicates that within southern and south-western Sydney, only Blacktown local government area had admission rates which were higher than the State average, and rates in Auburn, Bankstown and Campbelltown were higher than the average for metropolitan Sydney. Among children, hospitalisation rates for asthma were significantly higher than the Sydney average in Blacktown and Bankstown.

Death rates due to diseases of the respiratory system were higher than the State and metropolitan Sydney average in Auburn, Bankstown, Hurstville and Parramatta, although the rate for the Blue Mountains was also slightly higher than the rate for metropolitan Sydney, but below the State average. Deaths

due to asthma are too rare to make meaningful comparisons between local government areas.

Air toxics have been identified as a priority issue by the NSW Government and nationally. Air toxic compounds are identified as being or likely to be a cause of cancer in humans. They include benzene, 1,3 butadiene, formaldehyde, acetaldehyde and benzo(a)pyrene.

It has previously been estimated that about 16 cancer cases per year are associated with motor vehicle air pollution in Melbourne (Hearne, 1994). This estimate was based on addition of risk from exposure to individual air quality pollutants due to motor vehicle emissions. The observed incidence of acute myeloid leukaemia was reported as significant but could not be correlated with the predicted contribution from motor vehicles.

Particulates such as from diesel fumes could potentially contain air toxics such as polycyclic aromatic hydrocarbons. They could therefore contribute to cancer risks, as well as cause respiratory problems, if inhaled. Deposition of such particles on roofs and in water storages such as rainwater tanks and reservoirs could result in ingestion of particulates, which would potentially pose other health risks. This issue is discussed in *Technical Paper No.7 - Water*.

Lead is an air pollutant which has been identified as causing major health problems in children. Since the introduction of leaded petrol in 1985, ambient lead levels in Sydney (in areas other than those affected by point source emissions) have decreased to levels below the National Health and Medical Research Council goal of 1.5 micrograms per cubic metre (Environment Protection Authority, 1993). As the proportion of cars using unleaded petrol continues to increase, further improvements in atmospheric lead levels may be achieved.

## 4.2 STATUTORY CONTEXT

### *NSW Standards*

The New South Wales Environment Protection Authority is responsible for implementation of State legislation relating to air quality. The following NSW legislation applies to air quality:

- the *Clean Air Act, 1961* imposes limits on emissions from all premises and motor vehicles and imposes controls on the storage and handling of motor vehicle fuel. The Act sets limits on the sulphur content of fuels used in the Sydney Metropolitan Area;

- the *Environmental Offences and Penalties Act, 1989* provides for issue of Infringement Notices covering a wide range of offences; and
- the *New South Wales Ozone Protection Act 1989* relates to control of use of ozone-depleting substances. The use of chlorofluorocarbons in new products was phased out in 1994.

It is understood that the *Clean Air Act, 1961* will be amalgamated with other Pollution Control Acts in the Protection of the Environment (Operations) Bill.

In addition to the above legislation, NSW Environment Protection Authority (1997b) has set goals for urban air quality which are consistent with national health-based goals for international agencies. The current goals are tabulated below.

TABLE 4.1 NEW SOUTH WALES AIR QUALITY GOALS

Pollutant	Goal	Averaging Time	Agency <sup>(1)</sup>
Total suspended particulates	90 micro grams per cubic metre	12 months	NHMRC
Particulate matter smaller than 10 micrometres	50 micro grams per cubic metre	12 months	US EPA
	150 micro grams per cubic metre	24 hours	US EPA
Lead	1.5 micro grams per cubic metre	3 months	NHMRC
Carbon monoxide	87 parts per million	15 minutes	WHO
	25 parts per million	1 hour	WHO
	9 parts per million	8 hours	NHMRC
Nitrogen dioxide	16 parts per hundred million	1 hour	NHMRC
	5.3 parts per hundred million	12 months	US EPA
Ozone	10 parts per hundred million	1 hour	NHMRC
	8 parts per hundred million	4 hour	NHMRC
Sulphur dioxide	50 parts per hundred million	10 minute	NHMRC
	25 parts per hundred million	1 hour	NHMRC
	2 parts per hundred million	12 hours	NHMRC
	17.5 parts per hundred million	10 minutes	WHO
	12.5 parts per hundred million	1 hour	WHO

Note: 1. Agencies responsible for developing adopted goals are abbreviated as follows:  
 NHMRC National Health and Medical Research Council.  
 US EPA United States Environment Protection Agency.  
 WHO World Health Organisation.

There is pressure for some of the above air quality goals to be reduced. NSW Environment Protection Authority (1996a) has indicated that it intends to adopt the World Health Organisation's ozone goal of 0.08 parts per million

(averaged over one hour) as a long term target for air quality in New South Wales. The National Environment Protection Council is currently reviewing National Air Quality Standards and a consultancy study is due to report in 1997.

Goals have not been established for air toxics. The NSW Environment Protection Authority considers that "although overseas goals do exist for a few air toxics, there is generally neither good information nor any standard process used in Australia for setting goals for air toxics. The general trend is to use risk analysis to assess whether any action needs to be taken on a particular air toxic" (Environment Protection Authority, 1996a).

The NSW Department of Health has recommended more stringent goals for particulates and nitrogen dioxide for assessment of air quality impacts associated with the Sydney Eastern Distributor road project (Rust PPK, 1996a). These are listed below:

- particulate matter smaller than 10 micrometres - 50 micro grams per cubic metre - 24 hour average (current UK goal); and
- nitrogen dioxide - 210 micro grams per cubic metre (11 parts per hundred million) - 1 hour average (current World Health Organisation goal).

### *National Standards*

National air pollution standards for emissions of air pollutants from stationary sources were issued by the Australian Environment Council (1989) and the National Health and Medical Research Council (1986). These guidelines specify limits for air emissions from a range of stationary sources and are recommended to statutory authorities in States and Territories for application to new plant.

The Commonwealth Government is responsible for setting emissions standards on motor vehicles and the State and Territory governments are responsible for policing of standards. The standards are set out in Australian Design Rule 37. They impose progressively more stringent limits on allowable emissions from new petrol engined vehicles over time.

The *Commonwealth Ozone Protection Act 1989* requires all states and territories to implement controls to limit manufacture and use of stratospheric ozone depleting substances to comply with international agreements.

The *Federal Airports Corporation Act 1986* empowers the Federal Airports Corporation to ensure, as far as practicable, the environment is protected from



the effects of and the effects associated with, the operation and use of aircraft (other than state aircraft) operating to and from Federal Airports.

The *Airports Act 1996* provides for a regulatory regime for leased Commonwealth airports. This act would apply to the Second Sydney Airport should the airport be leased to the private sector. The Act establishes a Commonwealth system of regulation for pollution and excessive noise.

### 4.3 METEOROLOGICAL CONTEXT

#### 4.3.1 BADGERYS CREEK

A description of meteorological factors relevant to air quality is presented in *Technical Paper No. 5 - Meteorology*. The following discussion presents a brief summary of that material.

The vertical dispersion of near surface air pollution is likely to be inhibited at Badgerys Creek on many nights per year, due to the high frequency of ground based inversions. These trapped emissions could be carried towards the Camden Basin, when winds are blowing from a north-easterly direction but it is likely that steep ground based inversions will decouple air within the Basin, from emissions carried towards it from Badgerys Creek. Alternatively these emissions could travel towards the Nepean River Valley and could become entrained in local and regional drainage flows and be carried northwards towards along the axis of the Hawkesbury Basin. This would occur at night. When local drainage flow along South Creek Valley is absent, near surface emissions could be carried east towards the Blacktown ridge and into the Liverpool Basin, when westerly coal air drainage flows or stable synoptic winds are present at Badgerys Creek.

Inversions as deep as 600 metres are often present at sunrise and it can take several hours before these inversions are eroded away. While the inversions remain, near-surface and elevated emissions will be carried towards the north until the drainage flow has dissipated. At that time emissions would be transported in the direction of the wind above.

In summer, if an elevated inversion was present above the Hawkesbury Basin, northerly winds would carry near surface and elevated emissions towards Camden and Campbelltown. Alternatively, near surface and elevated emissions could contribute to photochemical smog levels in air carried across Badgerys Creek within the sea breeze and contribute to ozone levels as the air moves inland into the lower Blue Mountains.

Elevated emissions during the day from aircraft in the vicinity of Lake Burragorang will be dispersed rapidly by vertical mixing due to winds and

convection. At night, it is unlikely that these elevated emissions would reach the surface because of the formation of a layer of stable air above the lake.

#### 4.3.2 HOLSWORTHY

A discussion of meteorology affecting the Lucas Heights area is presented by Australian Atomic Energy Commission (1986). This discussion is relevant to the Holsworthy airport options. Afternoon breezes tend to be north-easterly sea breezes accompanied by unstable conditions. Overnight light south to south-west winds (nocturnal drainage flows) occur accompanied by stable conditions. Sea breezes are weaker in winter than in summer but the nocturnal drainage flows are weaker in summer than in winter.

Near surface emissions from Holsworthy Option A would be trapped by stable layers during the evening and overnight. In summer, near surface emissions from Option A could be trapped within sea breezes and onshore synoptic winds during the evening and carried inland. However, they are unlikely to have an impact at the surface, instead becoming entrained within local and regional drainage flows. Near surface emissions may move north towards the Liverpool basin, but the formation of steep ground-based inversions within the basin after sunset would prevent such emissions reaching the surface and they would become entrained in cold air drainage flow and move east across Sydney. West and south-west stable drainage flows would carry near surface emissions towards the east and north-east and may impact on surface air quality in populated areas downwind.

The influence of urban related emissions on air quality in the vicinity of Holsworthy Option A in the cooler months of the year would be likely to be minimal, because these emissions would be trapped within ground based inversions or stable layers of air.

The impacts of near surface and elevated emissions on Holsworthy Option B would be similar to those for Option A. The increased elevation of the Holsworthy Option B site is likely to result in increased wind strengths and a possible decrease in the frequency of cold air drainage flows and near surface inversions at night. As inversions are likely to be more shallow at the Holsworthy Option B site, they may break down more quickly than at the Holsworthy Option A site, resulting in earlier dispersion and dilution of near surface and elevated emissions by the synoptic wind during the day.

It is considered unlikely that the emissions from Holsworthy Option B would reach the surface of Lake Woronora, because of the formation of a stable layer of air above the lake at nighttime. This would cause emissions to pass over the top of the catchment and be carried away by winds blowing across the plateau regions above the catchment.

Near surface emissions from Option B could be trapped within sea breezes and onshore synoptic winds during the late afternoon and evening and during the night within cold air drainage flows and stable synoptic winds. These emissions would be carried inland towards Wedderburn, Appin and Douglas Park. This would on occasions have an impact on nighttime air quality at Wedderburn.

Emissions from Holsworthy Option B would be carried towards the north by a shallow layer of northerly flowing air, at nighttime, or towards the east and north-east if regional drainage flows are present.

Because of the increased distance between Holsworthy Option A and residential areas of the Sydney basin, combined with the increase in elevation, and consequent enhanced dispersion, air quality in the vicinity of Holsworthy Option B would be better than in the vicinity of Holsworthy Option A.

## 4.4 ENVIRONMENTAL CONTEXT

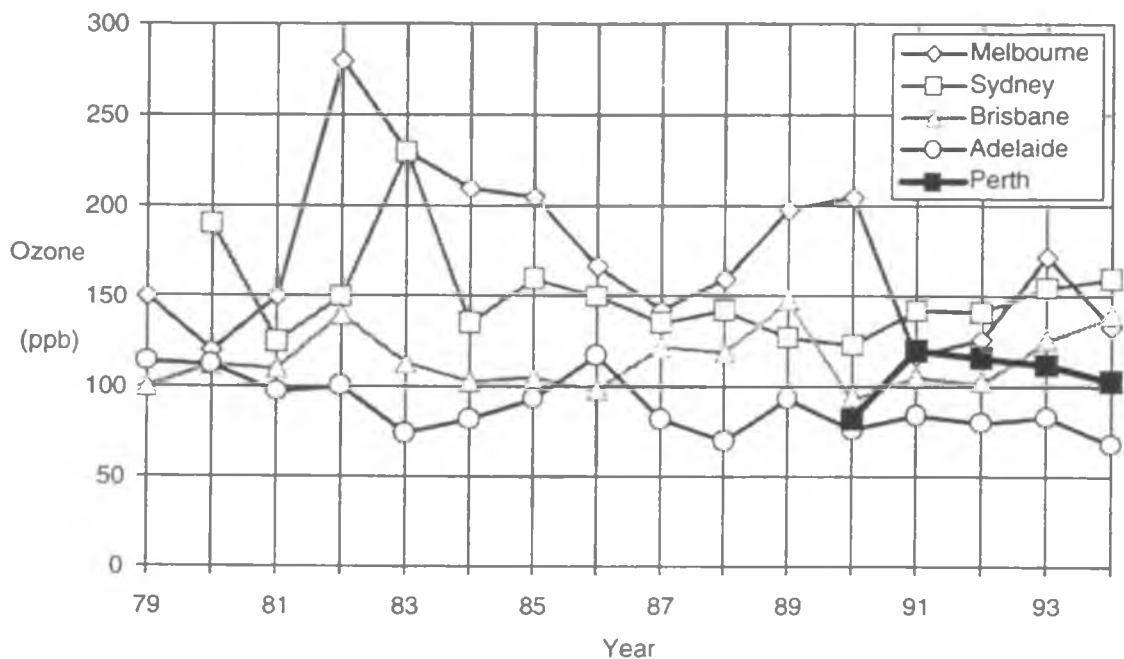
### 4.4.1 AIR QUALITY

A review of air quality in Australia is presented by *Australian Bureau of Statistics, 1996* and *Australia's State of Environment Report, 1996*. These reports discuss the major air pollutants within Australia. Ozone is noted to be of significance primarily in Sydney and Melbourne, with occasional breaches of guidelines.

The Western Power Corporation and the Western Australian Department of Environmental Protection (1996) presented a comparison of ozone levels recorded in Australian cities. *Figure 4.2* taken from that report presents peak hourly average ozone levels in Australian capital cities for years 1979 to 1994. This figure illustrates that Sydney and Melbourne tend to have the highest ozone levels of all Australian state capitals and shows that peak ozone levels in Melbourne have generally exceeded those in Sydney.

Monitoring of regional air quality is carried out at a series of monitoring stations within the Sydney region by NSW Environment Protection Authority. *Figure 4.3* shows the locations of the current monitoring network. This network includes stations at Campbelltown and Camden which are maintained and operated by private industry, with the data contributed to the Environment Protection Authority database. The results of monitoring are summarised in quarterly reports prepared by NSW Environment Protection Authority (Environment Protection Authority, 1997b).

*Table 4.2* shows the parameters monitored using this network as described in *Quarterly Air Quality Monitoring Report No. 4, 1995* (NSW Environment



Trends of peak hourly average ozone concentrations in Australian capital cities. (Source: annual reports of Australian state environment agencies, personal communications)

SOURCE: WESTERN POWER & DEPARTMENT OF ENVIRONMENTAL PROTECTION, 1996  
THE PERTH PHOTOCHEMICAL SMOG STUDY

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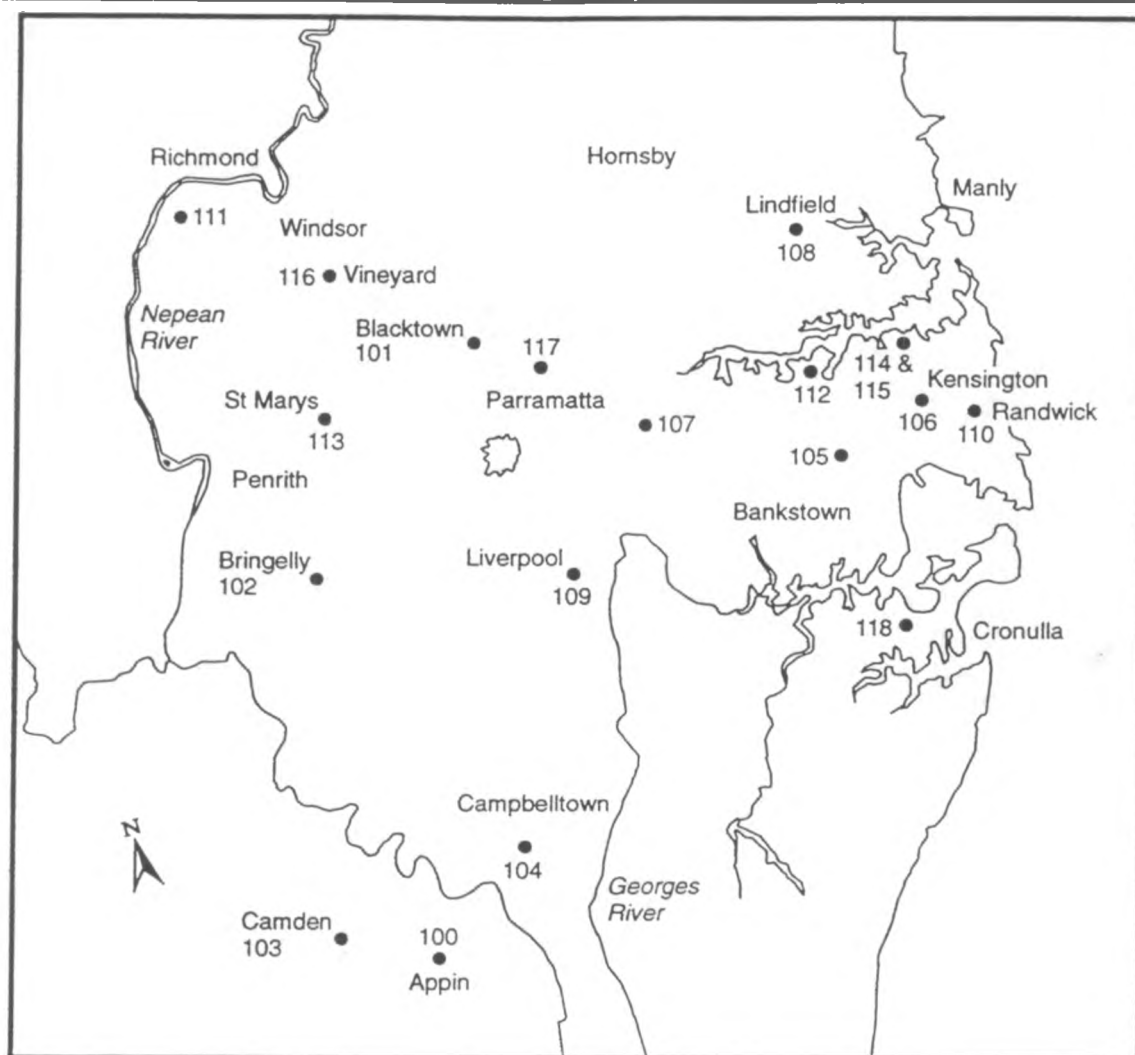
SECOND SYDNEY AIRPORT EIS

OZONE CONCENTRATIONS  
AUSTRALIAN CAPITAL CITIES



FIGURE 4.2

job no. E2057/1-DA



No.	MONITORING SITE		Neph	TSP	Lead	PM <sub>10</sub>	CO	Ozone	NO <sub>2</sub> NO <sub>x</sub> NO	SO <sub>2</sub>	TEOM
100	APPIN	Brooks Point Rd	@					@	@	@	
101	BLACKTOWN	Flushcombe Rd	⊕			⊕	⊕	⊕	⊕		⊕
102	BRINGELLY	Ramsay Rd	⊕					⊕	⊕		⊕
103	CAMDEN	Aerodrome						#	⊕		
104	CAMPBELLTOWN	Blaxland Rd						#	#		
105	EARLWOOD	Beaman Park		⊕	⊕	⊕		⊕	⊕		⊕
106	KENSINGTON	Prince of Wales Hospital	⊕				⊕	⊕	⊕		
107	LIDCOMBE	EPA Laboratories						⊕	⊕		⊕
108	LINDFIELD	Bradfield Rd				⊕		⊕	⊕		⊕
109	LIVERPOOL	Rose St	⊕				⊕	⊕	⊕		⊕
110	RANDWICK	Randwick Barracks	⊕					⊕	⊕		⊕
111	RICHMOND	Uni of Western Sydney	⊕			⊕		⊕	⊕		⊕
112	ROZELLE	Rozelle Hospital	⊕	⊕	⊕	⊕		⊕	⊕		
113	ST MARYS	Mamre Rd	⊕					⊕	⊕		⊕
114	SYDNEY (1)	George & Market Sts (Gowings)	⊕		⊕	⊕					
115	SYDNEY (2)	George & Market Sts (Grace Br.)		⊕	⊕	⊕					
116	VINEYARD	Bandon Rd	⊕					⊕	⊕	⊕	
117	WESTMEAD	Westmead Hospital	⊕					⊕	⊕		⊕
118	WOOLLOOWARE	Woollooware Rd	⊕					⊕	⊕	⊕	⊕

⊕ EPA monitoring site    # Industry self-monitoring site    @ Mobile site

(1) In George Street, 10m from Market St    (2) In George Street, 75m from Market Street

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**SECOND SYDNEY AIRPORT EIS**  
**EPA AIR POLLUTION MONITORING NETWORK**  
**SYDNEY**



**FIGURE 4.3**

job no E2057/1-DA

Protection Authority, 1995b). Not all air pollutants are monitored at all locations, and only mobile stations exist at some locations. Meteorological data on wind speeds and directions is collected at most stations.

TABLE 4.2 ENVIRONMENT PROTECTION AUTHORITY AIR QUALITY MONITORING NETWORK

Monitoring Site	Neph <sup>(1)</sup>	TSP <sup>(2)</sup>	Lead	PM <sub>10</sub> <sup>(3)</sup>	CO <sup>(4)</sup>	Ozone	Nitrogen Oxides	Sulphur Dioxide	TEOM <sup>(5)</sup>
100 Appin	@					@	@	+	
101 Blacktown	+			+	+	+	+		+
102 Bringelly	+					+	+		+
103 Camden						#	+		
104 Campbelltown						#	#		+
105 Earlwood		+	+	+		+	+		+
106 Lidcombe						+	+		+
107 Lindfield				+		+	+		+
108 Liverpool	+				+	+	+		+
109 Randwick	+					+	+		+
110 Richmond	+					+	+		+
111 Rozelle	+	+	+	+	+	+	+		
112 St Marys	+					+	+		
113 Sydney (1) <sup>(5)</sup>		+	+	+	+				
114 Sydney (2) <sup>(6)</sup>					+				
115 Vineyard	+					+	+	+	
116 Westmead	+					+	+		+
117 Woollooware	+					+	+	+	+

Notes:

1. 'Neph' is an abbreviation for nephelometer - a measure of light scattering.
2. 'TSP' is an abbreviation for Total Suspended Particulates.
3. 'PM<sub>10</sub>' is an abbreviation for particles less than 10 microns in size.
4. 'TEOM' is a device for continuous measurement of particles (used for measurement of PM<sub>10</sub>).
5. Site 'Sydney (1)' is in George Street, 10 metres from Market Street.
6. Site 'Sydney (2)' is in George Street, 75 metres from Market Street.
- '+' Indicates Environment Protection Authority monitoring site.
- '#' Indicates industry monitoring site.
- '@' Indicates mobile monitoring site.

The results of monitoring from this network are discussed in subsequent sections addressing individual pollutants.

#### 4.4.2 AIR EMISSIONS

An air emissions inventory of Sydney was commissioned by NSW Environment Protection Authority as part of the *Metropolitan Air Quality Study* (Environment Protection Authority, 1997a).

This inventory contained an assessment of air emissions from the Sydney region for the year of 1992. The inventory identified emissions from industry, motor vehicles and biological sources as well as emissions for a range of individually minor sources collected under the category of area based emissions.

An hour by hour assessment of emissions from a three kilometre by three kilometre grid was provided for typical days in summer and winter. Annual emissions from the Sydney region are summarised in *Table 4.3*.

The Sydney region, as defined for the emissions study, covered a rectangular region defined by Australian Map Grid co-ordinates 260,000 metres east to 360,000 metres east and 6,200,000 metres north and 6,300,000 metres north. This region includes the candidate airport sites considered in this study.

TABLE 4.3 1992 ANNUAL AIR EMISSIONS (TONNES/ANNUM) - SYDNEY REGION

Source	Pollutant				
	Volatile Organic Compounds	Oxides of Nitrogen	Carbon Monoxide	Sulphur Dioxide	Total Suspended Particulates
Mobile Sources	84,800	83,500	729,800	2,800	7,900
Domestic/Commercial	70,000	4,800	58,200	4,300	9,200
Industrial	16,800	13,400	13,500	12,700	8,300
Biogenic	46,500	1,100	0	0	0
<b>Total</b>	<b>218,100</b>	<b>102,800</b>	<b>801,500</b>	<b>19,800</b>	<b>25,500</b>

1992 air emissions from the Badgerys Creek and Holsworthy areas taken from the *Metropolitan Air Quality Study* (Environment Protection Authority, 1997) are presented in *Table 4.4*. These estimates are presented as average emissions per square kilometre and are based on the emissions from the nearest three kilometre by three kilometre grid squares from the 1992 inventory.

**TABLE 4.4** 1992 EMISSIONS (TONNES/SQUARE KILOMETRES/ANNUM) AT BADGERYS CREEK AND HOLSWORTHY

Source	Pollutant				
	Volatile Organic Compounds	Oxides of Nitrogen	Carbon Monoxide	Sulphur Dioxide	Total Suspended Particulates
Badgerys Creek	14.3	0.2	0	0	0.02
Holsworthy Option A <sup>(1)</sup>	14.9	0.01	0	0	0
Holsworthy Option B <sup>(1)</sup>	13.3	0.01	0	0	0
Sydney Region <sup>(2)</sup>	28.0	13.7	106.9	2.6	3.4

Note:

1. Bushfire emissions were not considered in the Metropolitan Air Quality Study.
2. Based on a land area of 7,500 square kilometres within the Sydney Region as defined in the Metropolitan Air Quality Study (NSW Environment Protection Authority, 1997a).

Lead and air toxic hydrocarbon emissions were not specifically included in the emissions inventory conducted as part of the *Metropolitan Air Quality Study* (Environment Protection Authority, 1997a), therefore these do not appear in *Tables 4.3* and *4.4*.

The sites of the airport options have low rates of air emissions compared with average emission rates for the Sydney region. At the Holsworthy sites, the only significant emissions are volatile organic compounds from the site vegetation. At the Badgerys Creek site some motor vehicle emissions exist but again the dominant emissions are volatile organic compounds from vegetation.

#### 4.4.3 AIR QUALITY TRENDS

Air quality is highly variable as it depends on the complex interaction between emissions of air pollutants and meteorological factors. Both air pollutant emissions and meteorology vary geographically and follow daily and seasonal cycles.

In the case of ozone there is a further complication as ozone is formed from chemical combination of hydrocarbons and oxides of nitrogen at a rate which depends on temperature and sunlight exposure.

Superimposed on this complex interaction between emissions and meteorology are gradual long term changes in the rate of air emissions. These long term changes are due to such influences as increasing population, changes to the distribution of population and motor vehicle usage, changes in emission control technology for industry and motor vehicles, changes in the



composition of paints and thinners, changes in motor vehicle fuels and changes to the mix of industrial operations carried out.

4.5 AIR POLLUTANTS

4.5.1 PARTICULATES

Sources

Particulate pollution of air is contributed to by:

- motor vehicle emissions;
- dust;
- industrial sources;
- bushfires; and
- domestic heating using wood or oil.

The Sydney Metropolitan Air Quality Study (Environment Protection Authority, 1997a) inventory of air emissions for the Sydney Basin estimated the breakdown of sources of particulate emissions. This is shown in Table 4.5.

TABLE 4.5      PERCENTAGE BREAKDOWN OF PARTICULATE EMISSIONS FOR SYDNEY IN 1992 (SYDNEY METROPOLITAN AIR QUALITY STUDY)

Source	Summer Weekday (Percent)	Winter Weekday (Percent)	Annual (Percent)
Mobile Sources <sup>(1)</sup>	36	25	31
Motor Vehicles	27.9	19.3	24.0
Marine	8.4	5.2	7.0
Rail	0.2	0.1	0.2
Domestic/Commercial	21	49	36
Domestic solid/liquid fuel combustion	0	36.4	22.7
Lawn mowing	0.3	0.1	0.6
Waste combustion	<0.1	<0.1	<0.1
Natural gas combustion	0.2	0.2	0.2
Other	20.8	12.8	12.5

Source	Summer Weekday (Percent)	Winter Weekday (Percent)	Annual (Percent)
<b>Industrial</b>	42	26	33
Non-metallic mineral processing	15.5	9.5	12.5
Food manufacture	8.4	5.2	6.4
Petroleum refining	5.0	3.1	4.2
Basic metal processing	4.4	2.7	2.8
Hospitals, incinerators and Harbour Tunnel	2.8	1.7	2.3
Quarrying	2.1	1.3	1.5
Other	3.8	2.5	3.3
<b>Total Particulate Emissions (Tonnes/day)</b>	<b>58</b>	<b>95</b>	<b>70</b>

Notes: 1. Aircraft, bushfire and windblown dust particulate emissions were not estimated in the Metropolitan Air Quality Study.

Of these sources, motor vehicles and industrial contributions are relatively consistent throughout the year but the contribution resulting from solid and liquid fuel combustion is substantially higher in winter resulting in a higher rate of emission of particulates in winter. The *Metropolitan Air Quality Study* (Environment Protection Authority, 1997a) estimated that some 95 percent of the emissions from domestic solid and liquid fuel combustion are from burning of wood in fireplaces and heaters. This did not include bushfire, dust or particulate emissions from aircraft.

### *Existing Air Monitoring*

Typical monitoring related to particulate content includes:

- measurements carried out using high volume sampling involving drawing air through a filter. This is the process used for measurement of total suspended particulates, particulate matter less than 10 micrometres (PM<sub>10</sub>), and particulate matter smaller than 2.5 micrometres (PM<sub>2.5</sub>). The increase in weight of the filter provides a measure of particulate concentration;
- continuous measurement of concentrations of particulate matter smaller than 10 micrometres, using a tapered element oscillating microbalance (TEOM, which has occurred in Sydney since 1993); and
- nephelometer records which provide a measure of the coefficient of light scattering and an indication of the concentration of suspended particulate matter.

Measurements of total suspended particulates are available for Earlwood, Rozelle and Sydney from 1983 to 1995 from Quarterly Air Monitoring Reports

(Environment Protection Authority, 1997b). The NSW Environment Protection Authority goal of 90 micro grams per cubic metre for annual average concentration is met for each site.

The maximum 24 hour concentration for each month is presented in *Figure A1* in *Appendix A*. At each site, there is a high level of variability with no clear seasonal pattern. There has been a minor reduction in average total suspended particulate concentration over the period of available records.

### *Particles Smaller than 10 Micrometres*

Records for total suspended solids and for particles less than 10 micrometres have been maintained by NSW Environment Protection Authority for eight stations in the Sydney area from as early as 1988. *Figures A2, A3 and A4* in *Appendix A* show the maximum 24 hour concentration of airborne particles smaller than 10 micrometres for each month of records for Blacktown, Bringelly, Campbelltown, Earlwood, Lindfield, Richmond, Rozelle and Sydney. Generally concentrations are less than one third of the New South Wales Environment Protection Authority goal of 150 micro grams per cubic metre (24 hour average).

The only exceedence of the goal value was recorded in January 1994 at Bringelly. The longest periods of record are for Sydney, Earlwood and Rozelle. These records do not show a long term trend for change and no clear seasonal pattern is apparent. Records for the other sites are too short to allow assessment of long term trends.

Nephelometer measurements of light scattering are available for twelve sites in the Sydney basin with records commencing from as early as 1981. Maximum one hour levels for each month of record are presented in *Figures A5 to A8* for monitoring sites within the Sydney Basin. The highest values tended to occur in the winter months though, as for other measurements related to particulate concentrations, there is a high level of variability with elevated levels well above average appearing at irregular intervals.

### *Particles Smaller than 2.5 Micrometres*

Australian Nuclear Science and Technology Organisation et al (1995) presented the results of a study to monitor fine particle concentrations in a network of 24 monitoring sites within a 200 kilometre radius of the Sydney central business district. This included sites in the vicinity of the proposed Second Sydney Airport sites, at Holsworthy and Badgerys Creek and sites at Mascot, Lucas Heights, Badgerys Creek and Campbelltown.

At each site, 24 hour filter samples of particulate content smaller than 2.5 micrometres were collected twice a week (on Sundays and Wednesdays). The filters were weighed to provide a measure of the average concentration of particulates in air. Each of the samples was tested using ion beam techniques to obtain a measure of the elemental composition of each filter sample.

Elements measured were hydrogen, carbon, nitrogen, oxygen, sodium, aluminium, silicon, phosphorus, sulphur, chlorine, potassium, calcium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, bromine and lead. The report presented monitoring data for the period January 1993 to June 1994.

This report provides a valuable record of the distribution fine particles in the vicinity of Sydney. *Figure 4.4* shows the locations of the monitoring network used for the study. Concentrations of fine particles were highest for the sites in the Sydney central business district, however they tended to reduce with distance from the central business district. Concentrations tended to be significantly higher in winter than in summer.

Monthly average concentrations of particulate content less than 2.5 micrometres for the period January 1992 to June 1993 are shown in *Figure 4.5*, for Mascot, Lidcombe, Campbelltown, Lucas Heights, Badgerys Creek and Wilton. These are the monitoring sites closest to the candidate airport sites.

Fine particle concentrations at all sites are highest during the winter months. Mascot, Lidcombe and Campbelltown tend to have the highest concentrations, which is consistent with their urban setting. Lower concentrations occur at the sites of Lucas Heights, Badgerys Creek and Wilton which are within rural settings.

*Figure 4.6* shows the monthly average lead content in fine particles (smaller than 2.5 micrometres) and *Figure A9* in *Appendix A* shows monthly average lead content in particulate matter smaller than 10 micrometres. Lead content is attributed to motor vehicle emissions. Seasonal trends are more clearly defined for lead with higher values occurring during the winter months.

Motor vehicle emissions are the main contributor of lead to atmospheric pollution in the Sydney area (Environment Protection Authority, 1996a). As motor vehicle emissions are comparatively consistent throughout the year, the seasonal pattern of higher lead concentrations during the winter months is attributed to the poor dispersion conditions which prevail in winter.

The long term records for Earlwood, Rozelle and Sydney show substantial reduction in lead concentrations from 1981 to 1995. Since 1990, measurements of atmospheric lead levels have been within the NSW

Environment Protection Authority goal of 1.5 micro grams per cubic metre for three monthly average concentrations.

Cohen (1996) presented a study showing the changes in airborne lead concentration in Sydney over the period 1992 to 1996. This work represented a continuation of the work presented by Australian Nuclear Science and Technology et al (1995).

Average concentration of airborne lead in fine particles (less than 2.5 micrometres) at Mascot reduced from 335 nano grams per cubic metre during 1992 to 128 nano grams per cubic metre during 1995. During this period total fine particle concentration at Mascot remained relatively stable varying between 10.8 micro grams per cubic metre during 1992 and 12.7 micro grams per cubic metre during 1994.

The reduction in airborne lead was attributed to reducing sales of leaded motor vehicle fuel (Sydney sales reduced from 10,234 megalitres in 1992 to 7,240 megalitres in 1995) and reducing lead content of leaded fuel from 0.4 grams per litre in 1992 to 0.2 grams per litre in 1995.

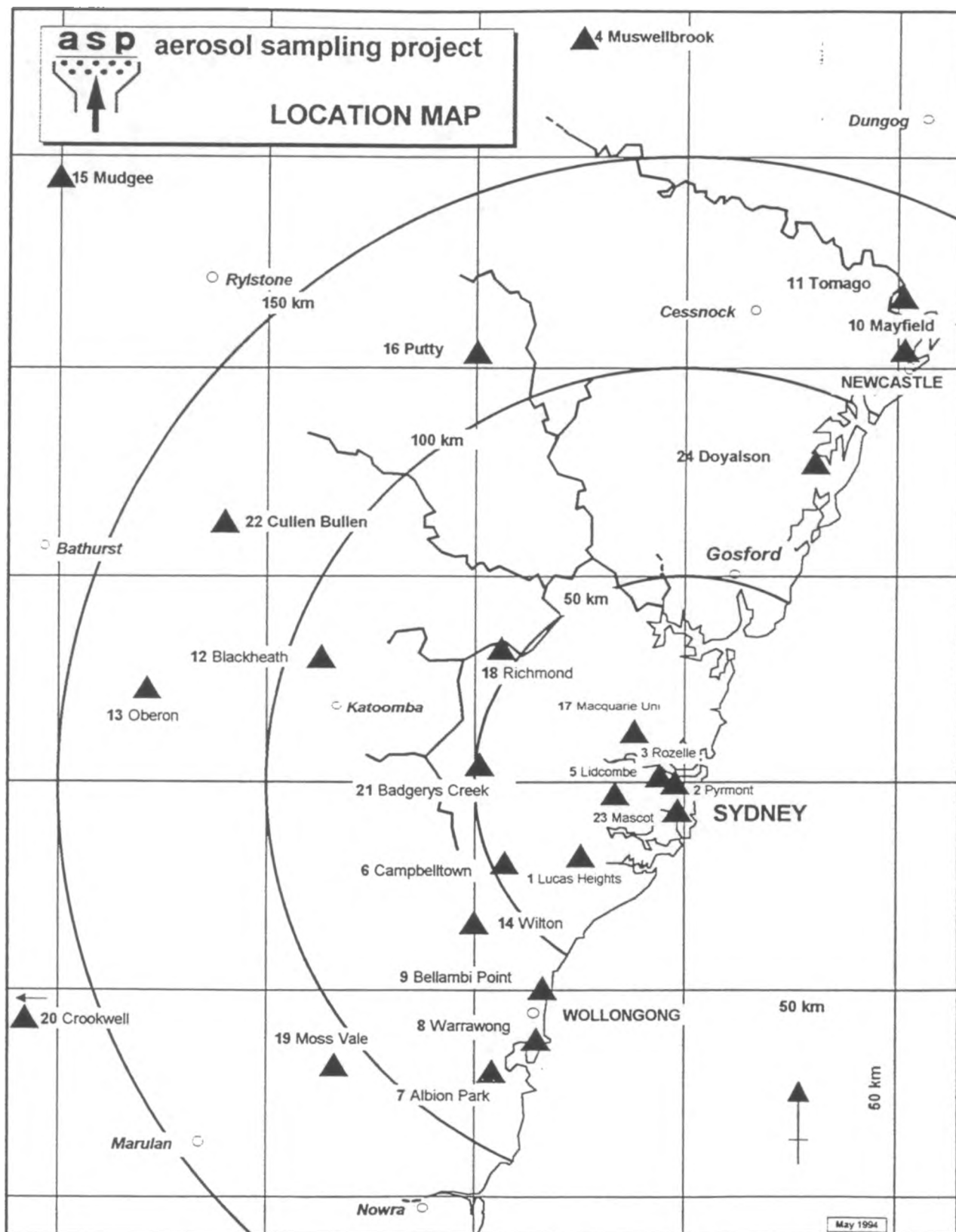
#### 4.5.2 CARBON MONOXIDE

Carbon monoxide is produced as a result of incomplete combustion. Sources include motor vehicle exhaust, emissions from domestic fuel burning heaters and industrial boilers. Of these sources, motor vehicles account for some 89 percent of carbon monoxide emissions in the Sydney Region in 1992 (Environment Protection Authority, 1997a).

Carbon monoxide is an asphyxiant which reduces the oxygen carrying capacity of blood. Exposure to concentrations over 1,000 parts per million can be fatal.

*Figures A10, A11 and A12 in Appendix A present measured maximum hourly carbon monoxide concentrations for the air quality stations at Appin, Blacktown, Kensington, Liverpool, Richmond, Rozelle, St Marys, Vineyard and Sydney. With the exception of the monitoring station in the Sydney central business district, monitored carbon monoxide concentrations are well below the NSW Environment Protection Authority goals of 25 parts per million for one hour average and 9 parts per million for eight hour average.*

Monitoring records for Sydney central business district show a gradual reduction in carbon monoxide concentrations over the past ten years. The *Sydney Metropolitan Air Quality Study Air Emissions Inventory* (Coffey Partners, 1996) carried out attributes 89 percent of carbon monoxide emissions to motor vehicles.



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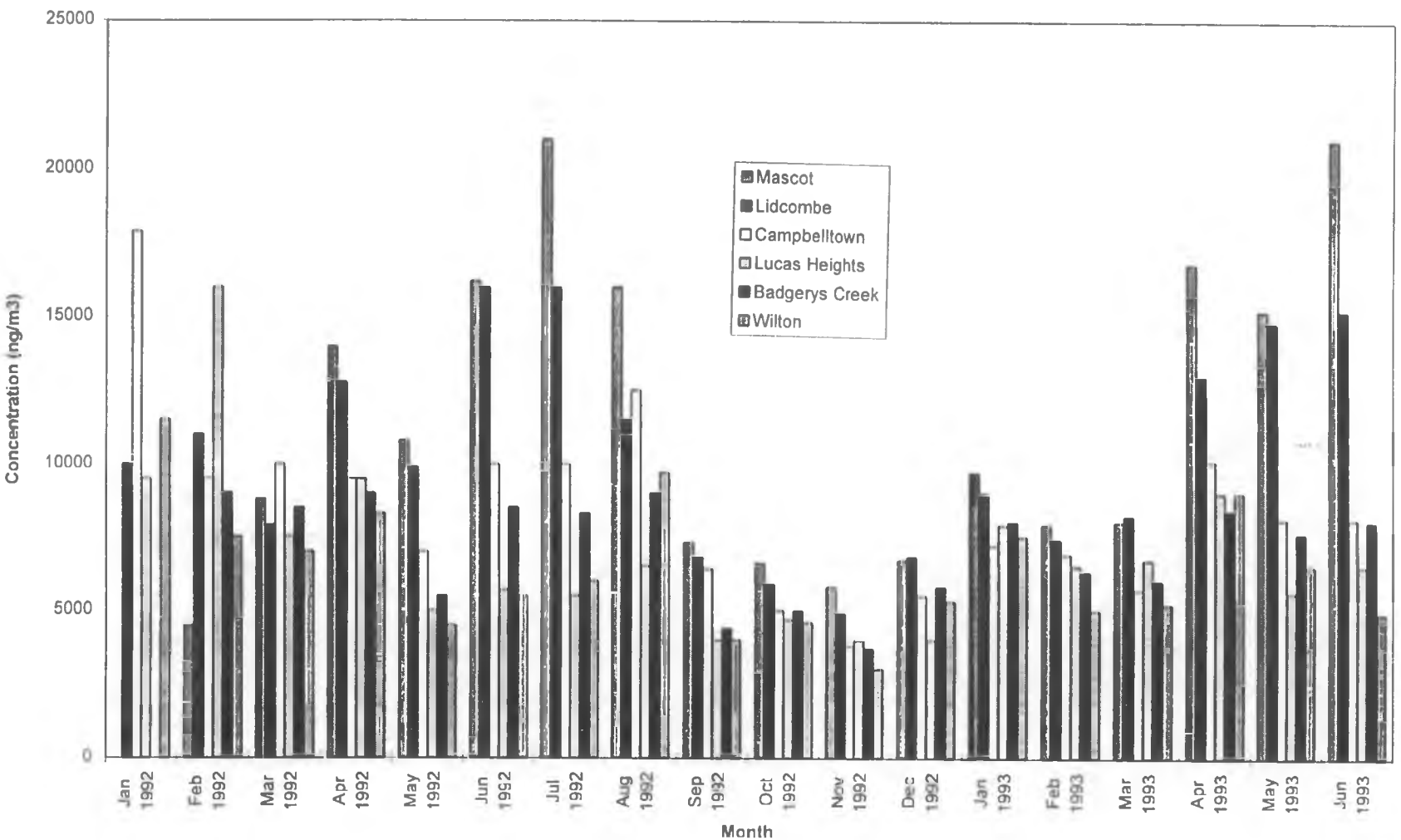
SECOND SYDNEY AIRPORT EIS  
AEROSOL SAMPLING LOCATIONS



FIGURE 4.4

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# Particles Smaller than 2.5 micron



SOURCE: ERDC, 1995

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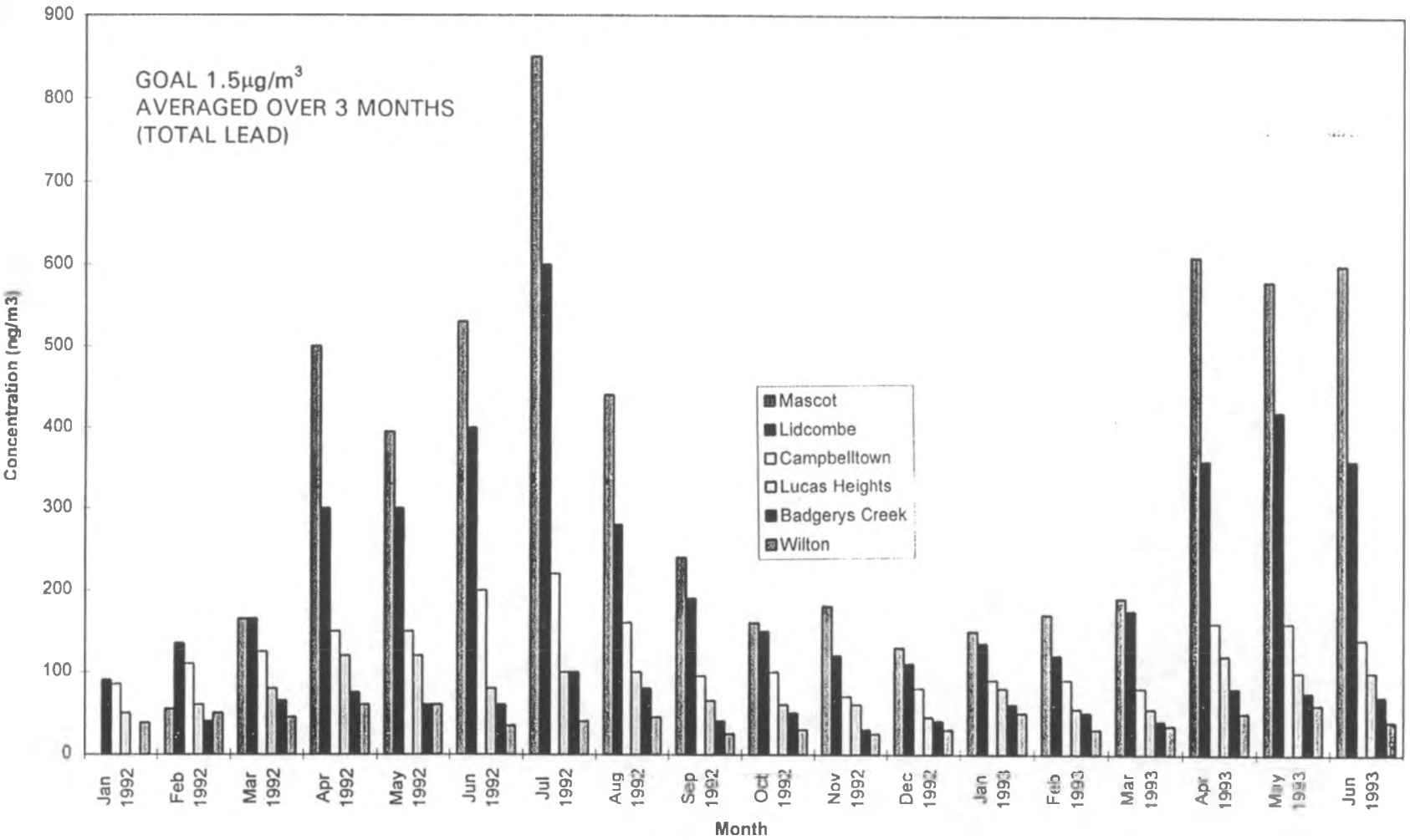
MONTHLY AVERAGE  
FINE PARTICLE CONCENTRATIONS



FIGURE 4.5

job no. E2057/1-DA

# Lead Content of Particles Smaller than 2.5 micron



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scale

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MONTHLY AVERAGE  
LEAD IN FINE PARTICLE CONCENTRATIONS



FIGURE 4.6

job no E2057/1-DA



Motor vehicle emission controls have resulted in reductions in carbon monoxide emissions. Data presented in the *Metropolitan Air Quality Study* (Environment Protection Authority, 1997a) shows that, in 1992, carbon monoxide emissions for vehicle equipped with three way catalytic converters have less than one quarter of the carbon monoxide emissions of pre-1976 vehicles.

#### 4.5.3 OZONE

Ozone is a secondary air pollutant which is an indicator of photochemical smog. It is formed by chemical reaction involving oxides of nitrogen and reactive organic compounds under the action of sunlight. The maximum ozone concentration which can be produced within a parcel of air is proportional to the concentration of oxides of nitrogen. The time to reach this maximum ozone concentration depends upon temperature, sunlight exposure and the concentration of reactive organic compounds.

During summer the time for a parcel of air to reach maximum ozone concentration is measured in hours. In winter, the rate of production of ozone is markedly lower than in summer due to lower temperatures and reduced sunlight exposure. Ozone generation ceases at night. As the formation of ozone takes significant time to occur, ozone impacts due to air pollutant emissions are felt at considerable distances downwind.

*Figures A13 to A18 in Appendix A* present the maximum hourly ozone concentration recorded for each month of monitoring at stations within the New South Wales Environment Protection Authority air quality monitoring network.

At all sites, ozone concentrations show a strong seasonal pattern, with the highest values invariably occurring during the summer months. The current New South Wales Environment Protection Authority air quality goal for ozone of 10 parts per hundred million has frequently been exceeded over the period of monitoring. Of the stations monitored, only Randwick and Lindfield have remained below the current air quality goal for ozone. These sites have only eighteen months of monitoring records available.

*Figure 4.7* shows the number of days during which ozone concentrations have exceeded the current goal of 10 parts per hundred million, the former goal of 12 parts per hundred million and the planned future goal level of 8 parts per hundred million (Environment Protection Authority, 1996a). This figure covers the period 1979 to 1994. In considering this data, it is important to recognise that the number of stations at which ozone is monitored increased substantially over the period of monitoring.

In 1981, there were six stations where ozone monitoring was carried out, the number increased to eight in 1988 and 17 stations monitored ozone in 1995. In 1995 no monitoring site recorded an ozone concentration in excess of 10 parts per hundred million. The highest measured hourly ozone concentration in the Sydney region was 9.2 parts per hundred million. This was measured at the Appin site during December, 1995.

Monthly maximum ozone levels prior to 1990 tend to be lower than those measured during and after 1990 at the stations where long term records are available (Campbelltown, Earlwood, Lidcombe, Rozelle, Westmead and Woollooware). Based on the above observations, it is clear that the incidence of high ozone events has reduced.

The reason for the reduction is attributed to management strategies put in place during the 1980s which include controls on motor vehicle exhaust and industrial emissions (Environment Protection Authority, 1996b).

#### 4.5.4 OXIDES OF NITROGEN

Oxides of nitrogen are emitted by a range of combustion sources. The *Sydney Metropolitan Air Quality Study* (Environment Protection Authority, 1997a) attributed over 80 percent of emission of oxides of nitrogen to motor vehicle exhaust.

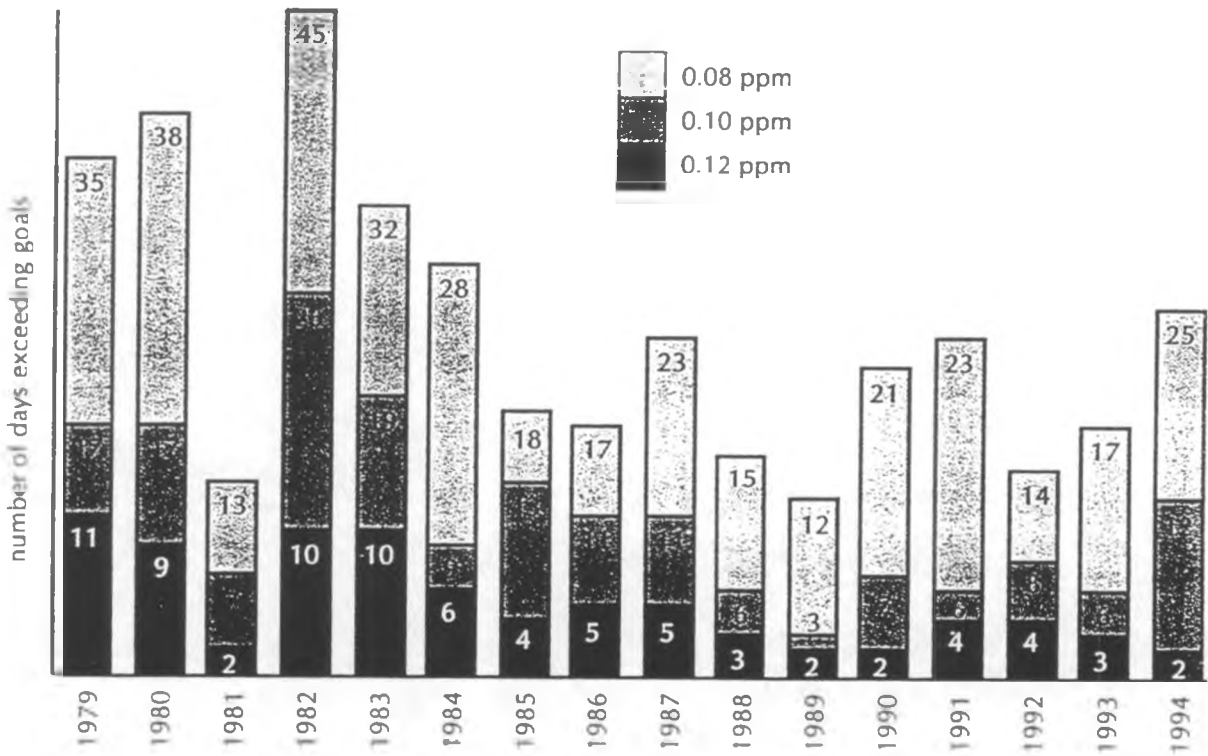
Emissions of oxides of nitrogen tend to be composed of approximately 90 percent nitric oxide and 10 percent nitrogen dioxide. Nitric oxide is oxidised to nitrogen dioxide over time.

If ozone is present in air receiving nitric oxide emissions, oxidation to nitrogen dioxide is rapid, and ozone is conserved in the process. As a result, nitric oxide and ozone do not occur simultaneously and emissions of nitric oxide tend to suppress ozone levels. Once all nitric oxide is oxidised to nitrogen dioxide, the process of ozone formation can occur, with the potential ultimate level of ozone proportional to the concentration of nitrogen dioxide.

Nitrogen dioxide is a respiratory irritant. The current NSW Environment Protection Authority goal for nitrogen dioxide is 16 parts per hundred million. *Figures A19 to A24 in Appendix A* show the maximum hourly concentration of nitrogen dioxide recorded for each month of records. Exceedences of the goal value were frequent prior to 1991, but since 1991 exceedences have been recorded for only two months.

Only one exceedence of the nitrogen dioxide goal of 16 parts per hundred million (one hour average) has been recorded in Sydney since 1990. Monitoring results have shown a gradual decline in the peak monthly levels of nitrogen dioxide (Environment Protection Authority, 1996a). This

Number of days on which ozone concentrations in Sydney have exceeded three goals: the old NHMRC goal of 0.12 ppm, the current NHMRC goal of 0.10 ppm and WHO's goal of 0.08 ppm (all averaged over one hour). (Data for the first quarter of 1981 are missing. Data for 1994 exclude the bushfires.)



SOURCE: NSW GOVERNMENT GREEN PAPER, 1996  
DEVELOPING SMOG ACTION PLAN FOR SYDNEY, THE ILLAWARRA & THE LOWER HUNTER

Coffey Partners International Pty Ltd

Consulting Engineers, Managers and Scientists  
Environment • Geotechnics • Mining • Water Resources ACN 003 682 019

drawn:	RJB/SW
approved:	
date:	
scale:	

SECOND SYDNEY AIRPORT EIS  
EXCEEDENCES OF OZONE GOALS 1979 TO 1994



FIGURE 4.7

job no E2057/1-DA

improvement is considered to be largely due to improved emissions control technology in current motor vehicles.

In August 1993, a maximum one hour concentration of 18.1 parts per hundred million was measured at Rozelle and in September, 1995 a maximum one hour concentration of 26.6 parts per hundred million was measured at Campbelltown. Given the isolated nature of these events it seems likely that they relate to local point source emissions, rather than average ambient conditions.

#### 4.5.5 SULPHUR DIOXIDE

Sulphur dioxide is a respiratory irritant. In the Sydney region, sulphur dioxide is produced largely as a result of combustion of fuels. Sulphur contents of fuels are controlled under the *Clean Air Act, 1961*.

The NSW Environment Protection Authority recognises the National Health and Medical Research Council one hour goal of 25 parts per hundred million and the World Health Organisation one hour goal of 12 parts per hundred million.

*Figures A25, A26 and A27 in Appendix A* present the results of monitoring of sulphur dioxide at NSW Environment Protection Authority stations in the Sydney region. No exceedences of the World Health Organisation goal have been measured since 1981. Concentrations of sulphur dioxide measured since 1992 have not exceeded 6 parts per hundred million (less than half the goal). On this basis, sulphur dioxide is not considered a significant pollutant at a regional level.

#### 4.5.6 AIR TOXICS

Air toxics are air pollutants which can lead to health effects as a result of long term exposure. Air toxic compounds considered for this study are listed in *Table 4.5*. This list includes substances referenced in the Guidelines for the EIS and substances referenced by the Senate Select Committee (1995). A reference produced by the Toxics Committee of the California Air Pollution Control Officers Association (1993) on risk assessment guidelines for air toxics was also used in the selection of air toxic compounds to be considered.

Of the substances listed in *Table 4.6* lead and polycyclic aromatic hydrocarbons are contained in particulate matter. The remaining substances are contained within organic gas emissions.

TABLE 4.6 AIR TOXIC SUBSTANCES CONSIDERED

Substance	Reason for Inclusion		
	Referenced in Guidelines <sup>1</sup>	Referenced in Falling on Deaf Ears <sup>2</sup>	Referenced in CAPCOA <sup>3</sup>
Acetaldehyde	no	no	yes
Benzene	yes	yes	yes
1,3 Butadiene	no	yes	yes
Formaldehyde	no	yes	yes
Lead Compounds	yes	no	yes
Polycyclic aromatic compounds including benzo(a)pyrene	yes	yes	yes
Phenol	no	no	yes
Toluene	no	no	yes
Xylenes	no	no	yes

- Notes:
1. Guidelines for an Environmental Impact Statement on the Proposal to Consider the Construction and Operation of a Second Major Airport for Sydney at Badgerys Creek or Holsworthy prepared by Environment Australia, November 1996.
  2. Report of the Senate Select Committee on Aircraft Noise in Sydney, 1995.
  3. California Air Pollution Control Officers Association's Air Toxics "Hot Spots" Program Revised 1992, Risk Assessment Guidelines published in October 1993.

*Air Toxics Within Particulate Emissions*

Lead and polycyclic aromatic hydrocarbons form part of the particulate emissions. Air emissions of lead originate predominantly from exhaust of motor vehicles fuelled by leaded petrol. Polycyclic aromatic hydrocarbons are contained in the particulate emission from petrol and diesel fuelled motor vehicles and are also contained in particulate emissions from aircraft engines.

Lead is a pollutant which has the potential to affect behaviour and mental development of children. Lead was not included in the emissions inventory as lead emissions associated with airport operation would be limited to the very small proportion of the motor vehicle fleet continuing to operate on leaded fuels. As this only applies to motor vehicles manufactured prior to 1986 it is considered that lead emissions would not be significant. A discussion of trends in monitored lead levels is included in *Section 4.1.2*. These results illustrate that lead concentrations have fallen substantially since the introduction of unleaded petrol in 1986. By 2006 ambient lead levels will also be low compared with the Environment Protection Authority goal value of 1.5 micrograms per cubic metre because virtually all motor vehicles will operate using unleaded fuels. For these reasons lead air pollution resulting from airport operation would not be significant.

Polycyclic aromatic hydrocarbons are associated with cancer risk. Measurements of polycyclic aromatic hydrocarbon content in ambient air are not generally carried out and no measurements of this kind were found for the Sydney area. The assessment of long term health impacts of exposure to polycyclic aromatic compounds in particulate matter can be approached by use of risk factors developed for particulate matter derived from individual sources. Vigyan (1993) presents a compilation of cancer risk factors for particulate matter derived from the following sources:

- heating oil usage;
- diesel vehicle emissions;
- petrol vehicle emissions;
- piston aircraft engines; and
- turbine aircraft engines.

These risk factors take account of the presence of polycyclic aromatic hydrocarbons including benzo(a)pyrene. Adoption of these parameters for assessment of human health due to long term exposure to particulate matter is described in the section on community health impacts.

### *Air Toxic Gases*

Air toxic gases are mainly formed during partial combustion of fuel and are contained in emissions from aircraft and motor vehicles though release of air toxic gases also occurs through evaporation loss of fuels and solvents. Limited measurement data is available for these compounds in the Sydney area. Monitoring results for air toxic gases in ambient air obtained from literature tend to be restricted to benzene and 1,3 butadiene as these compounds are associated with greater potential for risk to human health than the other air toxic gases considered (acetaldehyde, formaldehyde, phenol, ethylbenzene, toluene and xylenes).

Nelson (1994) reports results of monitoring of air toxic compounds at five sites in the Sydney area over the period November, 1992 to February, 1993. Samples were collected in early morning and the selected sites were generally in the vicinity of large sources of hydrocarbon emissions. Samples were collected over short time intervals and can be considered to represent conditions at a point in time rather than average conditions. Results were compared with earlier measurements of contaminant concentrations in 140 samples of Sydney's air carried out by Nelson and Quigley (1982).

Dawson et al (1994) carried out measurement of benzene and toluene concentration in George Street in the Sydney central business district. Measurements were carried out using a differential optical absorption spectrometer which allowed measurement of average concentration of a range of compounds along a path traced by a beam of light. Measurements were taken every three minutes during a one month period in summer and a second one month period in winter in 1994.

The results from these studies which relate to compounds represented in the *Emissions Inventory Report (Appendix C)* are presented in *Table 4.7*.

TABLE 4.7 AIR TOXIC COMPOUNDS CONCENTRATIONS MEASURED IN SYDNEY (PARTS PER BILLION)

Compound	Nelson 1994 <sup>1</sup>	Nelson and Quigley 1982 <sup>2</sup>	Dawson et al 1994 <sup>3</sup>
Benzene	2.5	2.6	4.1 (summer) 7.6 (winter)
Toluene	6.9	8.9	16.4 (summer) 27.2 (winter)
Xylenes	6.6	3.9	
1,2,4 trimethylbenzene	4.3	1.3	

- Notes:
1. Nelson, PF (1994), Measurements of Toxic Organic Compounds in Sydney's Atmosphere, 1994 Air Toxics Conference Proceedings, Clean Air Society of Australia and New Zealand and CSIRO Centre for Pollution Assessment and Control, Sydney, August, 1994.
  2. Nelson, PF and Quigley, SM (1982) Non-Methane Hydrocarbons in the Atmosphere of Sydney, Australia, Environment Science and Technology, Volume 16, pp650-655, 1982.
  3. Dawson, M, Young, BR and Child, N (1994) Continuous Monitoring of Ambient Toxic Air Pollutants Contributing to Photochemical Smog in Sydney's CBD, 1994 Air Toxics Conference Proceedings, Clean Air Society of Australia and New Zealand and CSIRO Centre for Pollution Assessment and Control, Sydney, August, 1994.

Exposure to air toxic compounds occurs in the cabins of motor vehicle during travel. Duffy and Nelson (1996) reports the results of monitoring of air quality in motor vehicles during peak-hour commuting and freeway driving in the Sydney area. Concentrations of benzene and 1,3 butadiene were measured in vehicles which had catalytic converters and vehicles without catalytic converters. Ambient air quality was measured in parkland at least 1 kilometre from major roads. The results summarised in *Table 4.8* show the in-vehicle exposure levels well above ambient concentrations of benzene and butadiene with post 1986 vehicles having the higher concentrations.

TABLE 4.8 IN VEHICLE CONCENTRATIONS OF AIR TOXICS

Vehicle type	Benzene Concentrations (parts per billion)		1,3 butadiene Concentrations (parts per billion)	
	In-Vehicle	Ambient	In-Vehicle	Ambient
<i>Commuter driving - Sydney (Manly to Randwick and Concord to Lane Cove)</i>				
Pre 1986 vehicles	48.1 ± 6.9	1.8 ± 1.1	11.5 ± 3.0	<0.1
Post 1986 vehicles	22.1 ± 4.1	2.0 ± 1.4	5.5 ± 2.1	<0.1
<i>Freeway driving - (Hornsby to Morisset)</i>				
Pre 196 vehicles	6.2	2.0	1.0	<0.1
Post 1986 vehicles	2.5	1.0	0.2	<0.1

Source: Duffy, BL and Nelson PF (1996). Exposure to Benzene, 1,3 - Butadiene and Carbon Monoxide in the Cabins of Moving Motor Vehicles, 13th International Clean Air and Environment Conference, Adelaide, September 1996, PP 195-200.

Given the limited available monitoring data, it is not possible to form a reliable assessment of existing concentrations of air toxic gases at the sites for the Sydney Second Airport options. As data presented in *Table 4.7* is based on measurements taken at sites where the air toxic concentrations were expected to be elevated, it is reasonable to assume existing concentrations of air toxic compounds at the Second Sydney Airport sites do not exceed the values reported in *Table 4.7*.



## CHAPTER 5 RESULTS OF SURVEYS

### 5.1 FIELD SURVEY RESULTS

Sampling of air directly affected by emissions from aircraft at Sydney Kingsford Smith Airport was carried out in November 1996. A total of eight samples were collected, including six samples taken in the exhaust wake of large commercial jets. A report on this work is contained in *Appendix G*.

These samples were collected from a vehicle driven by Federal Airports Corporation operational staff. Samples were selected at locations where air quality was expected to be significantly affected by ground level aircraft emissions. Locations for sampling were selected during the sampling program. Samples were taken downwind from turboprop aircraft, exhaust from the auxiliary power unit of a passenger jet and from the exhaust stream of several passenger jets. Air samples from the exhaust stream of passenger jets were obtained by following taxiing aircraft at a safe distance determined by the Federal Airports Corporation driver.

Odour testing of samples was carried out by Australian Water Technologies and chemical testing was carried out by CSIRO Division of Coal and Energy Technology. This work is described in *Appendix G* and results are summarised in *Table 5.1*. Engine types for each aircraft were obtained by enquiries of airlines and from field observations. Concentration of substances measured in laboratory testing are presented as a volumetric concentration in parts per billion (ppb) or as parts per million carbon (ppmC). Concentrations are also shown as mass per unit volume (in micrograms per cubic metre).

Odour level is based on assessment of the concentration at which only half an odour panel can detect an odour. This concentration corresponds to one odour unit. Twice this concentration would have an odour level of two odour units. A range of odour levels from 31 to 275 odour units were measured. The highest values being recorded in the exhaust of taxiing jets. The variability in odour level is attributed to the varying sampling conditions. Hydrocarbon concentrations varied from 0.5 parts per million carbon to 8.6 parts per million carbon with the kerosene fraction making up from 12.5 percent to 60 percent of the measured non-methane hydrocarbon content. For engine exhaust (as opposed to exhaust from the auxiliary power unit) the kerosene fraction generally accounted for more than 50 percent of non-methane hydrocarbons.

TABLE 5.1 RESULTS OF AIR QUALITY TESTING - KINGSFORD SMITH AIRPORT, 15TH OCTOBER, 1997

No.	Source	Engines	Time	Conditions	Odour Strength		Component						
					OU <sub>sod</sub>	OU <sub>sor</sub>	NMHC <sup>1</sup> (ppmC)	Kerosene (ppmC)	1,3butadiene (ppbV)	Benzene (ppbV)	Toluene (ppbV)	Ethylbenzene (ppbV)	Xylene (ppbV)
1	Ansett 737 auxiliary power unit exhaust - Bay 12	General Electric CFM 56	7:51am	wind light	32	25	1.6 [920] <sup>c</sup>	0.2 [110]	n/d <sup>2</sup> [0]	1.6 [5.1]	2.9 [11.0]	0.4 [1.7]	2.8 [12.2]
2	Ansett 737 taxiing to Bay 2	General Electric CFM 56	8:00am	wind light	31	22	2 [1150]	1.1 [630]	2.7 [6.0]	4.2 [13.4]	6.6 [24.9]	0.6 [2.6]	3 [13.1]
3	Ansett 737 taxiing to Bay 10	General Electric CFM 56	8:09am	wind light	33	22	0.5 [290]	0.3 [170]	3.8 [8.4]	3.8 [12.2]	3.2 [12.1]	0.4 [1.7]	2 [8.7]
4	Ansett 767 idling at Bay 16	General Electric CF6 (ST9D)	8:15am	wind light	23	22	2.2 [1260]	1.7 [980]	2.8 [6.2]	2.9 [9.3]	3.7 [14.0]	1.9 [8.3]	12.7 [55.2]
5	QANTAS Airbus300 taxiing to terminal	General Electric CF6	8:20am	wind light	43	26	8.6 [4950]	2.2 [1265]	11.4 [25.3]	7.7 [24.6]	5.9 [22.3]	1.6 [7.0]	11.2 [48.7]
6	Hazelton SAAB 220 idling prior to taxi for takeoff	SAAB 240 twin prop	8:30am	wind 360° 6kts Temp 18°	42	26	0.5 [290]	0.3 [170]	0.4 [0.9]	1.9 [6.1]	3.7 [14.0]	0.5 [2.2]	2.8 [12.2]
7	Nippon 747/300 taxing to terminal	Uncertain	8:45am	wind 010° 10 to 15kts	275	115	2 [1150]	1.1 [630]	37.4 [83.0]	17.6 [56.3]	7.8 [29.5]	2 [8.7]	9.6 [41.8]
8	JAL 747/300 taxiing to terminal	Rolls Royce RBT 211	9:05am	010° 10 to 15kts Temp 23°	95	37	2.1 [1210]	0.8 [460]	5.8 [12.9]	5.6 [17.9]	9.5 [35.9]	0.9 [3.9]	3.6 [15.7]

- Notes:
1. Odour strength is recorded as the factor by which odour exceeded the threshold of detection (OU<sub>sod</sub>) and the factor by which odour exceeded the threshold of recognition (OU<sub>sor</sub>).
  2. NMHC - Non-methane hydrocarbons.
  3. Values in square brackets indicate concentrations in micrograms per metre cubed.
  4. n/d - not detected.

A threshold hydrocarbon concentration at which odour becomes detectable (this is the concentration corresponding to one odour unit) was calculated for each of the samples containing engine emissions. These threshold values are presented in *Table 5.2*.

TABLE 5.2 CALCULATED ODOUR THRESHOLD CONCENTRATIONS - HYDROCARBON EMISSIONS

Sample	Odour Threshold Concentration (micrograms per cubic metre)
2	37
3	9
4	55
5	115
6	7
7	4
8	13
Average	34

Based on the results presented in *Table 5.2*, an odour threshold concentration for aircraft exhaust hydrocarbon emissions of 34 micrograms per cubic metre was adopted. This is taken as the concentration at which an average person could detect an odour.

The results of the test program provide a useful basis for comparison of aircraft engine emissions composition adopted in the emissions inventory study. This comparison is presented in *Table 5.3*. For the substances measured the percentage of total hydrocarbon concentration is presented together with the percentage adopted in the *Air Emissions Inventory Report* (contained in *Appendix C*).

TABLE 5.3 COMPARISON OF EMISSIONS INVENTORY SPECIATION WITH MONITORING RESULTS

Substance	Proportion of Hydrocarbon Content	
	Measured range (percent)	Emissions Inventory (percent) <sup>1</sup>
Benzene	0.5 to 4.9	2.15
1,3 Butadiene	0.32 to 7.22	0.23
Ethylbenzene	0.45 to 4.8	0.58
Toluene	0.14 to 0.76	0.19
Xylene	1.0 to 4.4	0.53

There is significant variation in the proportion of each substance as a percentage of total hydrocarbons. The proportion adopted in the emissions

inventory is generally within or just below the range of proportions measured. Given that the measured data correspond to a limited range of operating conditions the results are considered broadly consistent with the speciation profile adopted during emissions inventory studies. Should health studies indicate that air toxic compounds from the Second Sydney Airport could pose a significant risk to human health, it is recommended that additional speciated hydrocarbon testing be carried out at Sydney Kingsford Smith Airport to test the speciation profile adopted for analysis of the Second Airport.

## 5.2 ANALYSIS OF EXISTING DATA

The literature review described in *Section 3.5* demonstrates that there is little guidance from previous work elsewhere as to the regional significance of airport emissions. For nitrogen dioxide and carbon monoxide, local impacts have been assessed at several airports, with the major contributor being the airport and local motor vehicle fleets.

Little quantitative work has been done on the regional impact of these pollutants - these are expected to be much less than local effects and therefore of little concern. For ozone, there is some evidence of an overall reduction close to airports due to the reactions with airport nitrogen oxide emissions but little evidence of what happens on high smog days.

For fine particulates, there is little direct evidence for any significant impacts. Accurate emission estimates and dispersion estimates are usually relied on for evaluating the changes in regional air quality. Many community organisations have stated that airports are major contributors of urban air quality and that increases in regional levels of fine particulates (for example) are likely to give rise to significant health and economic impacts.

A report by the Natural Resources Advance Council (1996) asserted that many airports rank in one of the top ten air pollution sources in their studies and that planes at airports emitted about one percent of smog forming gases. Such statements concerning the ranking of industrial smog sources for various airports have been based on the emission rates, rather than the actual concentration impacts.

Considerable community concern has been expressed as to the growth of air transport and its resulting consequences on public health.

### 5.3 ASSESSMENT CRITERIA

Impacts for each airport option are assessed in this Technical Paper in the following ways:

- contours are prepared showing ground level increase in concentrations of air pollutants as a result of airport operations. These are compared with existing air quality and New South Wales Environment Protection Authority goals;
- zones relating to particular levels of air quality impact are defined;
- the number of people affected to various extents are estimated, based on population projections; and
- other impacts are discussed in qualitative terms.

# Part C

## Assessment of Impacts

## CHAPTER 6 AIRPORT AIR POLLUTANT EMISSIONS

### 6.1 PREDICTED EMISSIONS FROM THE AIRPORT

A study of the volume of emissions which would occur from Sydney Second Airport under a range of operating conditions was carried out by Coffey Partners International and a copy of a report describing this work is included as *Appendix C*. This study considered emissions of hydrocarbons, oxides of nitrogen, carbon monoxide, sulphur dioxide, fine particulates and greenhouse gases (carbon dioxide, methane and nitrous oxide).

Emissions from aircraft exhaust, motor vehicle operation within the airport, combustion of gaseous fuels in boilers, evaporative losses from fuel storage tanks, use of surface coatings (paints and thinners) and losses due to refuelling and maintenance operations were considered. The emissions of hydrocarbons were subdivided into the proportion represented by individual compounds for assessment of impacts of air toxic compounds and for use in modelling of chemical reactions leading to production of photochemical smog. The composition of the aircraft fleet was based on information provided by the airport master planners.

*Table 6.1* presents predictions of airport emissions during initial operation in 2006 for Air Traffic Forecast 2 and during design operation in 2016 for Air Traffic Forecast 3. The 2016 scenario results in the greatest emissions rates of the scenarios considered and this was therefore used for assessment of operational air quality impacts. A discussion of the possible operational scenarios is presented in *Appendix C*. In *Table 6.1* airport emissions are compared with typical motor vehicle emissions from an area of 20 kilometres squared in urban Sydney which is comparable to the area which would be occupied by the airport.

Typical daily motor vehicle emissions for an urban area of comparable size to the airport options (20 square kilometres) for Sydney (based on 1992 figures) are also shown in *Table 6.1*. This would be equivalent to about two thirds the size of Auburn local government area which has a population of about 50,000 people. This is one basis for assessing the relative impacts of the airport, in comparison with potential future urban development.

TABLE 6.1 ESTIMATE OF AIR POLLUTANT EMISSIONS DUE TO AIRPORT OPERATIONS

Pollutant	Year 2006 <sup>1</sup>			Year 2016 <sup>2</sup>			Typical Motor Vehicle Emission Rates Over a 20km <sup>2</sup> Area <sup>4</sup> of Urban Sydney
	Emissions (kilograms per day)						
	Ground	Elevated <sup>3</sup>	Total	Ground	Elevated	Total	
Hydrocarbons	914	71	985	2,280	190	2,470	2,600
Oxides of nitrogen	1,260	2,390	3,650	4,300	7,700	12,000	2,800
Fine particulates less than 10 micron	205	215	420	550	620	1,170	220
Carbon monoxide	3,260	190	3,450	8,030	440	8,470	20,000
Sulphur dioxide	71	106	177	262	325	587	80

- Note:
1. Based upon Air Traffic Forecast 2.
  2. Based upon Air Traffic Forecast 3.
  3. Elevated refers to emissions more than seven metres above ground level and includes aircraft takeoff, climbout and approach.
  4. Source for motor vehicle emissions - Sydney Metropolitan Air Quality Study report.

## 6.2 EMISSIONS FROM ASSOCIATED DEVELOPMENTS AND MOTOR VEHICLES

Development of the Second Sydney Airport would result in associated changes in urban development and changes to the volume and distribution of motor traffic. These changes would result in air pollutant emissions outside the airport boundary compared with conditions which would not occur if a Second Sydney Airport was not constructed. Predicted increases in air pollution emissions associated with changes in motor vehicle traffic and population distributions are summarised in *Table 6.2*, in comparison with the emissions from the airport for the year 2016 (based on Air Traffic Forecast 3).

The increases are primarily due to increased motor vehicle use, with non-vehicle population related increases making up less than 10 percent of the total predicted increase for hydrocarbons and less than one percent of the increase for oxides of nitrogen and carbon monoxide. Such increases would be diffused over a large land area. Increases in motor vehicle usage would occur along the length of main road links to the airport and as a result, plumes of emissions would be diluted into a large volume of air.



TABLE 6.2      ESTIMATE OF INCREASED AIR POLLUTANT EMISSIONS DUE TO ASSOCIATED DEVELOPMENT AND MOTOR VEHICLES

Pollutant	Year 2016 Emissions (Kilograms per Day)			
	Emissions Predicted for Airport Options Only <sup>1</sup>	Increased Regional Emissions Associated with Development and Motor Vehicles		
		Badgerys Creek	Holsworthy Option A	Holsworthy Option B
Hydrocarbons	2,470	10,300	8,900	13,000
Oxides of Nitrogen	12,000	9,600	8,400	12,400
Carbon Monoxide	8,470	48,000	42,000	63,000

Note:                    1.      Based upon Air Traffic Forecast 2.

The airshed dynamics of Sydney are complex but for simplicity the meteorology pertaining to daytime air pollution can be categorised as non-sea breeze and sea breeze airflows. For both cases, the current state of knowledge limits the usefulness and confidence that can be given to quantitatively model expected pollutant concentrations. However, the general pattern of the progress of the sea breeze front across the region and the associated transport of pollution from eastern districts of Sydney inland to the west and south-west is well established. As yet, there is no generally accepted explanation of the dynamics of pollution events that occur in the mornings or before the arrival of the sea breeze front. Therefore, it is not possible to make predictions of the impacts of the airport and associated developments on pre sea breeze ozone.

6.3    GREENHOUSE GAS EMISSIONS

Natural undisturbed forests are not considered to be a human induced source or sink for carbon dioxide and are not normally considered in calculations of greenhouse gas. Plants withdraw carbon dioxide from the atmosphere during photosynthesis. As plants grow, carbon from the carbon dioxide is converted to plant tissue. Carbon is also lost by respiration, respiration of animals which eat plant tissue and by decay of dead material. On average, the net movement of carbon dioxide is reasonably in balance in the absence of human activity (National Greenhouse Gas Inventory Committee, 1996).

Land clearing during airport construction would cause a one-off impact on greenhouse gases which would be spread over the construction period. This would be greater for the Holsworthy options than for the Badgerys Creek options because of the greater areas involved for the Holsworthy options and due to the higher density of vegetation in the forest within the Holsworthy sites compared with the rural setting at Badgerys Creek. Even in the case of the

Holsworthy options, average greenhouse emissions over the construction period would be substantially lower than those predicted during operation in 2016.

Annual greenhouse gas emissions from the airport alone in 2016 are predicted to be 633 gigagrams of carbon dioxide equivalent (comprised of emissions of carbon dioxide, methane and nitric oxide). This would be equivalent to 0.3 percent of the total NSW greenhouse gas emissions on the basis of current NSW projections extrapolated to 2016.

## CHAPTER 7      IMPACTS OF BADGERYS CREEK OPTIONS

### 7.1    CONSTRUCTION OF THE AIRPORT

An assessment of impacts due to airport construction for each of the options is presented in *Appendix H*. *Figure B1* in *Appendix B* shows the areas which would be affected by particulate matter and by dust deposition.

Atmospheric dust produced from the action of earthwork equipment and wind erosion of exposed surfaces would be the dominant air quality impact of construction. Other impacts such as those resulting from exhaust emissions of earthworks plant and gaseous emissions during detonation of explosives would be small by comparison. Estimates of emissions were made for each airport option taking account of the likely composition of the construction equipment fleet, the construction method and the areas subject to construction at a given time. Impacts of the construction on dust deposition and ground level concentrations of fine particles were modelled with the program Fugitive Dust Model using approximately two years of meteorological data recorded at Badgerys Creek. Only areas within one to two kilometres of the airport boundary would be affected by such levels.

It is also predicted that concentrations of airborne fine particulates would also be increased as a result of construction activity and that peak daily concentrations of particulates smaller than ten microns could be increased by 100 micrograms per cubic metre or more, up to five kilometres from the airport boundary. This would only occur under worst case conditions, such as when earthmoving activities are occurring close to the airport boundary. Generally impacts would not generally be as severe as shown in *Figure B2* in *Appendix B*. A particulate concentration increase of 100 micrograms or more would potentially result in concentrations higher than the NSW Environment Protection Authority goal of 150 micrograms per cubic metre.

Dust emissions during construction could potentially result in deposition of dust on washing being dried and into swimming pools and rainwater tanks. The amount of dust deposited would depend upon the effectiveness of dust control measures.

### 7.2    OPERATION OF THE AIRPORT

*Table 7.1* presents the estimated maximum increases in ground level concentrations at the airport boundary.

**TABLE 7.1**      **PREDICTED INCREASES IN GROUND LEVEL CONCENTRATIONS OF AIR POLLUTANTS DUE TO OPERATION OF BADGERYS CREEK OPTIONS**

Parameter	Goal	Maximum Background <sup>1</sup>	Predicted Maximum Increase 2016 <sup>2</sup>		
			Option A	Option B	Option C
One-hour Ozone (parts per hundred million)	10	10	2.4	2.4	2.4
One-hour Nitrogen Dioxide (parts per hundred million)	16	5	10	8	8
Daily particulates below 10 micron (micrograms per cubic metre)	150	50	20	12	20
One-hour Carbon Monoxide (parts per million)	25	5	5	3	5
Eight-hour Carbon Monoxide (parts per million)	9	3	1	0.7	0.7
One-hour Sulphur Dioxide (parts per hundred million)	12.5	4	5	5	4

- Note:
1. Maximum background concentrations were assessed based on monitoring results from available monitoring data.
  2. Maximum increase predicted for areas outside the airport boundary.

If a conservative assumption was made that the maximum airport impact and maximum background concentration occurred simultaneously, concentrations of carbon monoxide, sulphur dioxide, nitrogen dioxide and particulates would not exceed the goal values. Ozone levels, however, would exceed goal values.

The results of local scale dispersion modelling are discussed in the following sections for each of the pollutants considered for the year 2016. Results are presented in the form of contours showing the modelled increase in ground level concentration for each pollutant considered. These are presented either as annual average increases or as contours of the peak increase in concentration. Where plots of contours of peak concentration increase are presented, the figures do not represent a snapshot in time but a compilation of the highest values from simulation of hourly meteorological conditions over a two year period. Peak values at different locations will be at different times depending on what is the most severe meteorological conditions for each particular receptor location. As the results relate to increases in pollutant concentrations due to the airport they must be added to the background

concentrations of the pollutants which would apply in the absence of the airport. Background concentrations were assessed based on monitoring data.

Simple addition of peak background concentrations with the maximum obtained from modelling is conservative as it assumes that peak background concentration occurs at the same time as the peak impact from the airport. In most cases these peaks would not coincide.

### 7.2.1 CARBON MONOXIDE

*Figure B3 in Appendix B* presents the modelled highest hourly average carbon monoxide concentration in the vicinity of the airport for each of the options considered in the year 2016. An assessment of background carbon monoxide concentration in the absence of the airport at Badgerys Creek was made based on monitoring results from:

- EPA monitoring stations at Saint Marys and Blacktown. Plots showing peak monthly carbon monoxide measurements at these stations are presented in Section 4 of this report. Monthly maximum of hourly average carbon monoxide levels at Blacktown ranged from 1.6 parts per million to 8.7 parts per million for the period October, 1992 to December, 1995. Highest concentrations occurred during the autumn and winter months. Carbon monoxide concentrations at Saint Marys were available from February 1992 to January 1993. Peak monthly values of hourly averaged concentration ranged from 0.7 parts per million to 5.8 parts per million;
- TC Forensic (1995) monitoring carried out at Badgerys Creek and Kemps Creek from 2 June 1995 to 23 June 1995. Continuous records of carbon monoxide concentration were recorded over a three week period at each site. The average concentration at Kemps Creek was 0.85 parts per million and the average concentration at Badgerys Creek was 0.36 parts per million. Peak hourly average concentration was 1.8 parts per million at Badgerys Creek and 2.9 parts per million at Kemps Creek. Peak levels tended to occur during the times of morning and afternoon peak traffic; and
- monitoring carried out on behalf of the Roads and Traffic Authority for the Western Orbital at Horsley Park from 15 November 1994 to 8 December 1994 by Stephenson and Associates as reported by Coffey Partners (1995) showed peak hourly carbon monoxide concentration up to 4.7 parts per million along Wallgrove Road.

Based on the above results a background level of 5 parts per million was adopted for hourly carbon monoxide in the vicinity of Badgerys Creek. This value is within the range of peak monthly carbon monoxide concentrations

recorded at the nearest Environment Protection Authority air quality monitoring sites at Vineyard and Blacktown and allows for an increase from the concentrations recorded at Badgerys Creek and Kemps Creek as a result of non airport influences.

The longest record of carbon monoxide measurements in the Sydney Basin is for the Gowings building at the corner of George and Market Streets. This shows a relatively stable level of maximum monthly carbon monoxide concentration from 1989 to 1995 with a maximum monthly value of one hour average concentration typically in the range 10 parts per million to 15 parts per million. Given that this range of carbon monoxide values is recorded at the Environment Protection Authority air quality monitoring station which records the highest carbon monoxide values, the values of 10 parts per million and 5 parts per million adopted for background concentrations in the vicinity of Holsworthy and Badgerys Creek respectively, are considered reasonable.

*Figure B4 in Appendix B* presents the predicted maximum increase in hourly average carbon monoxide concentration for aircraft takeoff direction selected to maximise peak increase in carbon monoxide concentration for Badgerys Creek Option A. It is clear by comparison of *Figures B3 and B4* that peak ground level increase in carbon monoxide concentration has only modest sensitivity to direction of takeoff. Consequently, only takeoff with a northerly component was considered for subsequent analysis.

*Figure B3 in Appendix B* presents the maximum increase in hourly average ground level carbon monoxide concentration calculated for the two year period modelled. For all airport options the calculated increase in carbon monoxide concentration is well below the NSW Environment Protection Authority goal of 25 parts per million for a one hour average. If the calculated maximum increases are added to the background values of 5 parts per million for Badgerys Creek the resulting concentrations are still well within the goal of 25 parts per million.

*Figure B5 in Appendix B* presents the maximum increase in eight hour average ground level carbon monoxide concentration calculated for the two year period modelled. Similar concentration impacts are assessed for each of the airport options. These increases are typically less than 0.5 parts per million. This increase is much less than the goal of 9 parts per million. Assessment of background peak eight hour carbon monoxide concentration is uncertain.

Measurement of eight hour concentration of carbon monoxide was carried out using grab samples along the proposed Western Sydney Orbital (Coffey Partners, 1995) in November and December 1994 which gave eight hour carbon monoxide concentrations ranging between 1.5 and 7.6 parts per million at ten locations adjacent to major roads. In each case concentrations on both sides of a road were measured.

There was typically a factor of two contrast between measurements taken on either side of the road indicating that local impacts of road emissions made a significant contribution to the measurements. Eight hour average carbon monoxide levels based on continuous monitoring at Horsley Park over a three week period from 15 November, 1994 did not exceed 1 part per million.

Continuous monitoring carried out by TC Forensic (1995) over a three week period in June and July 1995 at Badgerys Creek and Kemps Creek gave a maximum eight hour average of 2.2 parts per million for Kemps Creek and 1.1 parts per million for Badgerys Creek.

Based on these results a peak background of 3 parts per million was adopted for eight hour average carbon monoxide in the vicinity of Badgerys Creek.

The maximum increase in eight hour carbon monoxide over the two year period modelled was 1 part per million for Badgerys Creek Option A. It is considered unlikely that the airport would result in exceedences of the eight hour carbon monoxide goal of 9 parts per million because at Badgerys Creek, background peak one hour concentrations (assessed as 3 parts per million in the absence of the airport) are well below the goal and would remain well below the goal of 9 parts per million under the modelled maximum increase of 1 part per million.

*Figure B6 in Appendix B* shows the modelled increase in one hour carbon monoxide concentration due for initial airport operation in 2006. Predicted increases in concentration are of the order of half those predicted for design level operation in 2016.

### 7.2.2 NITROGEN DIOXIDE

Background monitoring results from the NSW Environment Protection Authority air quality monitoring station at Bringelly from October 1992 to December 1995 gave a range of peak monthly one hour nitrogen dioxide concentrations ranging from 1.6 parts per hundred million to 5.8 parts per hundred million with an average of 4 parts per hundred million. Based on this record a background peak one hour nitrogen dioxide concentration of 5 parts per hundred million was adopted for Badgerys Creek.

The calculated increases in average long term nitrogen dioxide concentration which would occur as a result of airport operation are presented in *Figure B7 in Appendix B*. Calculated increases are well below the goal of 5 parts per hundred million and it is assessed as unlikely that airport operation would result in an increase of average nitrogen dioxide concentration above the NSW Environment Protection Authority goal.

*Figure B8 in Appendix B* show increases in peak hourly nitrogen dioxide concentrations which are predicted to result from airport operations in 2016. The maximum predicted increase in nitrogen dioxide concentrations is 10 parts per hundred million, for Option A. *Table 7.1* shows that even if a conservative assumption is made that this maximum increase of nitrogen dioxide concentrations occurs in an area with maximum background levels, the current nitrogen dioxide goal would not be exceeded.

*Figure B9 in Appendix B* shows the modelled increases in peak one hour nitrogen dioxide concentration due to initial airport operation. Predicted increases are about half those predicted for 2016.

Assessment of the increase in ground level nitrogen dioxide concentration was based on 10 percent of the oxides of nitrogen emitted from the airport occurring as nitrogen dioxide as outlined in *Section 3.7.2*. Rapid conversion of nitric oxide to nitrogen dioxide takes place in air containing ozone.

The value of 10 percent adopted for the Draft EIS was based on comparison of measured peak monthly concentrations of nitrogen dioxide and total oxides of nitrogen from quarterly air quality monitoring reports (Environment Protection Authority, 1997b), for eight monitoring stations surrounding the proposed airport sites (Bringelly, Blacktown, St Marys, Liverpool, Woollooware, Campbelltown, Earlwood and Appin). These results show that increases in peak monthly concentration of total oxides of nitrogen are roughly ten times the accompanying increase in peak monthly nitrogen dioxide concentration.

### 7.2.3 OZONE

Ozone impacts were assessed using two methods of analysis, trajectory modelling as described in *Section 3.7.5* and footprint analysis as described in *Section 3.7.6*.

#### *Trajectory Modelling*

Two meteorological events resulting in high ozone levels in western Sydney were modelled to assess the ozone impacts which would arise from the Second Sydney Airport.

The modelled ozone impact due to emissions from an airport at Badgerys Creek were similar in distribution for both events modelled. In each case increased ozone concentrations were predicted to the west and south west of the airport commencing some 10 kilometres downwind from the airport and persisting for downwind distances in excess of 50 kilometres. Impacts for the event of 9 February 1994 were more severe than for the event of 4 February 1991. Ozone concentration increases for the 9 February 1994 of up to 20



parts per billion were modelled with increases greater than 10 parts per billion within a band with a cross wind dimension of 9 kilometres. For the 4 February 1991 event, increases in ozone concentration of 5 parts per billion or greater were modelled over a cross-wind distance of about 2 kilometres.

### *Footprint Analysis*

One-hour ozone impacts of airport operation were predicted to result in increased concentrations of from 0.6 to 2.4 parts per hundred million during otherwise high ozone events. Work by Katestone Scientific (*Appendix E*) shows that the amount of increase in ozone concentration due to the airport is sensitive to the air chemistry reaching the airport. These increases would be likely to result in increased incidence of ozone levels in excess of the goal of 10 parts per hundred million. *Figure 7.1* shows the predicted area which would be affected by an increased ozone concentration of at least one part per hundred million about six times per year. The number of people living in these areas in 2016 is estimated to be approximately 8,000 for all three Badgerys Creek airport options.

#### **7.2.4 AIR TOXICS**

The increase in average ground level concentrations of the following air toxic compounds was modelled:

- Acetaldehyde;
- Benzene;
- 1,3 butadiene;
- Formaldehyde;
- Toluene;
- Phenol; and
- Xylenes.

Based on modelling, *Figure B10* in *Appendix B* shows the increase in average ground level concentration of benzene which would occur as a result of airport operation in 2116. It is predicted that average benzene concentrations would increase by less than 0.1 parts per billion which are much lower than background concentrations currently existing within the Sydney Basin. Health impacts associated with increases in concentrations of air toxics are discussed in *Section 9.1.4*.

### 7.2.5 ODOUR

Odour impacts of the airport were assessed based upon calculated ground level hydrocarbon concentrations. The odour associated with a nominated ground level concentration was calculated by applying a factor developed based on sampling of air emissions from aircraft exhaust. The occurrence of kerosene type odours was predicted by dividing the modelled hydrocarbon concentration by 34 micrograms per cubic metre to obtain odour units. This factor was assessed based on field measurements of odour and hydrocarbon concentration described in *Section 5*.

Odour strengths and hydrocarbon concentrations for eight samples were measured at Sydney Airport and used to assess a factor for prediction of odour level based on hydrocarbon concentration. NSW Environment Protection Authority recommends that odour concentration calculated as a three minute average should not exceed two odour detection units with a frequency of more than 0.5 percent.

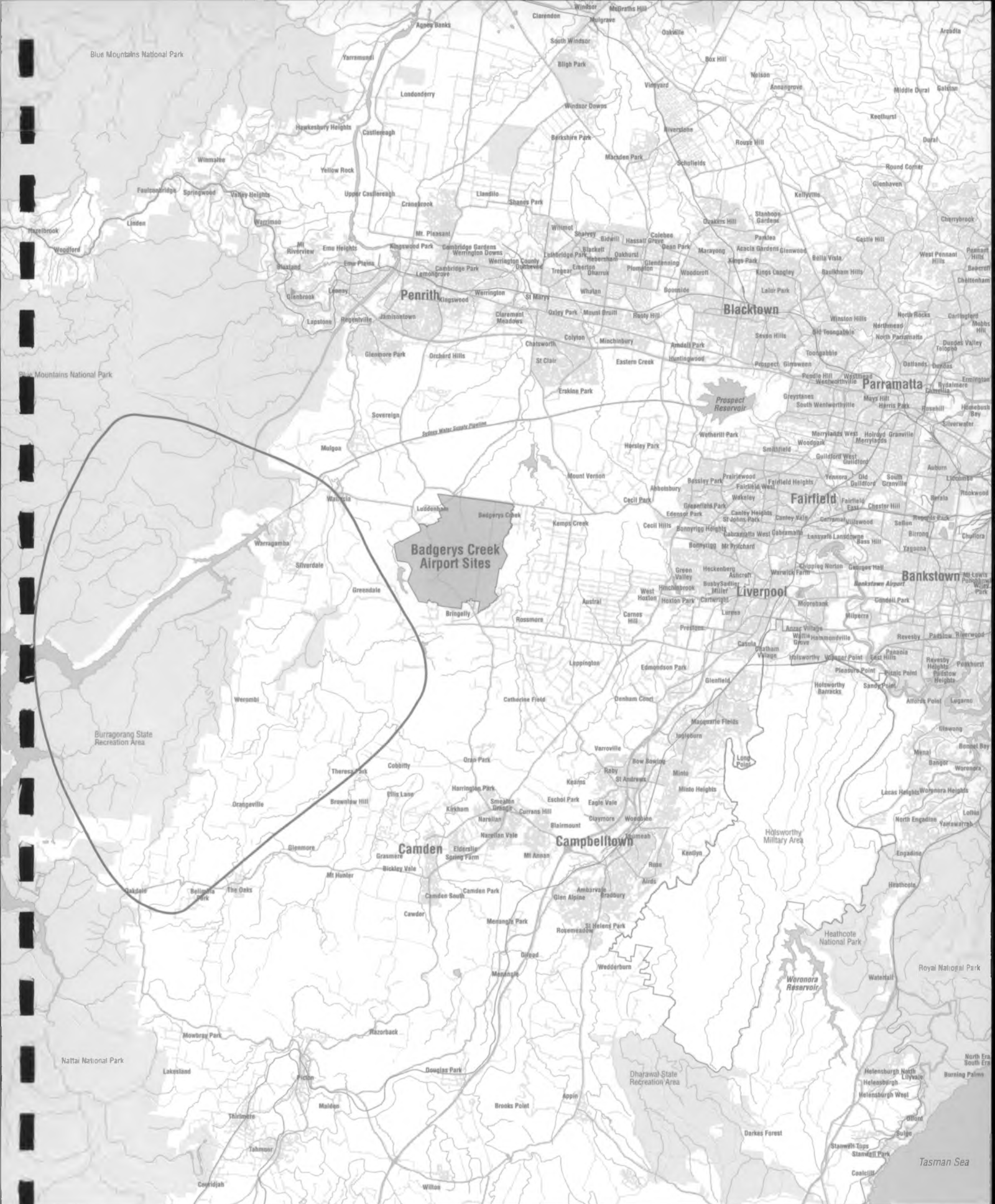
Based on this analysis it is predicted that kerosene type odours would be detected at distances of up to three kilometres from the airport boundary 0.5 percent of the time. This is shown in *Figure B11* in *Appendix B*. This represents detectable odour levels during 44 hours in a year, in 2016, by between 1,000 and 1,500 people.

A sewage treatment plant is proposed to be constructed to service the airport. This would have the capacity to meet the demands of an equivalent population of 84,000 people. Dispersion modelling of odour impacts (*Appendix I*) predicts that odours from the sewage treatment plant would be able to be detected for 44 hours or more per year at distances of up to 500 metres from the airport boundary, in the vicinity of the plant.

### 7.2.6 PARTICULATES

An assessment of background concentrations of particulate matter smaller than 10 microns was developed for the Badgerys Creek vicinity based on the following monitoring data:

- monitoring at the NSW Environment Protection Authority air quality monitoring station at Bringelly over the period from October 1991 to January 1994. The peak daily average concentration measured during this period was 191 micrograms per cubic metre measured in January, 1994. This value is well in excess of the NSW Environment Protection Authority goal of 150 micrograms per cubic metre and is attributed to the effects of severe bushfires which occurred at that time. The range of peak monthly values of daily average concentration over the remainder of the monitored period was 18 micrograms per cubic metre



Area predicted to be affected by at least one part per hundred million increase in peak one hour ozone concentrations due to airport operations in 2016

Urban Areas (indicated by local roads)

Figure 7.1  
**Predicted Ozone Increases for  
 Badgerys Creek Options A, B and C**  
 Note: Assumes Air Traffic Forecast 3 Level of Operation in 2016



to 45 micrograms per cubic metre. The highest values occurred during the winter months when poor dispersion conditions occur and use of solid fuel heaters takes place;

- monitoring of the concentration of particulate matter smaller than ten micron was carried out by TC Forensic (1995) at Bringelly and Kemps Creek for a period of one month at each site during the winter of 1995. The highest daily average concentration recorded was 14 micrograms per cubic metre at Badgerys Creek (June 1995) and 26 micrograms per cubic metre at Kemps Creek (July 1995); and
- peak daily concentrations of particulate matter smaller than ten microns ranging between 30 and 35 micrograms per cubic metre were recorded at during monitoring at Hoxton Park and Horsley Park (16 November to 31 December 1994).

Based on the above results a background concentration of particulate matter less than ten microns of 50 micrograms per cubic metre were adopted in the vicinity of the Badgerys Creek area.

*Figure B12 in Appendix B* presents the calculated peak increase in daily  $PM_{10}$  concentration due to operation of the airport for each of the airport options. As peak background concentrations are assessed to be 50 micrograms per cubic metre, these increases would not result in increase of particulate concentrations above the NSW Environment Protection Authority goal of 150 micrograms per cubic metre.

*Figure B13 in Appendix B* presents the calculated average increase in  $PM_{10}$  ground level concentration due to airport operation. The increase is small by comparison with the annual goal of 50 micrograms per cubic metre and would not be expected to increase average  $PM_{10}$  concentrations above the goal.

*Figure B14 in Appendix B* shows the modelled increased in peak 24 hour  $PM_{10}$  concentrations due to initial airport operation in 2006. Predicted increases follow a similar form to that predicted for 2016 but with only about half the predicted increase.

#### 7.2.7 SULPHUR DIOXIDE

Existing background levels of sulphur dioxide are well within the World Health Organisation goal of 12 parts per hundred million for the one hour concentration. The highest value recorded in the Sydney basin in 1995 was 4 parts per hundred million at Woollooware in January. *Figure B15 in Appendix B* shows the calculated increase in maximum hourly ground level sulphur dioxide concentrations as a result of airport operation in 2116. The

calculated increases are well below the goal level and would not be expected to result in the goal level being exceeded.

### 7.3 ASSOCIATED DEVELOPMENTS AND MOTOR VEHICLES

Changes in urban development and the volume and distribution of motor vehicle traffic resulting from operation of the Second Sydney Airport would result in increases in air pollutant emissions over and above those generated by aircraft and other sources within the airport boundaries. Increases are primarily due to increased motor vehicle use with non-vehicle related increases (due to population changes) comprising less than 10 percent of the total predicted increase for hydrocarbons and less than one percent of the increase for oxides of nitrogen and carbon monoxide.

In particular, increases in motor vehicle usage would occur along the main road links to the airport sites, but the resulting emissions would likely be spread over a wide area. An assessment of air quality impacts due to these additional emissions was carried out by CSIRO Division of Coal and Energy Technology and is presented in *Appendix J*.

For the Badgerys Creek options, motor vehicle emissions would be significantly increased to the north along the main access road connecting to the M4 Motorway. These emissions would tend to reinforce ozone impacts due to emissions from the airport itself during conditions leading to increased ozone. It is predicted that airport associated emissions of nitrogen dioxide would result in a combined impact 20 to 30 percent greater than due to the airport alone.

The effect of airport associated emissions would be greatest for north-easterly winds when motor vehicle emissions from roads to the north of the airport would be carried over the airport reinforcing emissions from the airport itself. In addition to the impact along trajectories passing through the airport, there would be more widespread impacts of lower magnitude due to the broad distribution of airport associated emissions.

The influence of airport associated emissions is complex. Emissions of nitric oxide are oxidised to nitrogen dioxide consuming ozone in the process. Once the nitric oxide is converted to nitrogen dioxide, the production of ozone resumes. The nitrogen dioxide then contributes to chemical reactions resulting in the formation of ozone and if these reactions proceed to equilibrium the ultimate ozone concentration is proportional to the total amount of oxides of nitrogen emitted into a particular parcel of air. Thus the emissions of nitrogen dioxides result in a localised reduction in ozone concentration but increased ozone concentration downwind. The rate of the chemical reactions leading to ozone formation increases with increasing concentration of hydrocarbons.

Thus airport associated emissions of hydrocarbons would result in more rapid photochemical smog reactions.

In the area immediately downwind of the sources of emissions, the general effect of hydrocarbon emissions is to move the boundary of the onset of increased ozone impacts towards the source of the hydrocarbon emissions whereas the effect of nitrous oxides emissions is to extend downwind the zone of ozone suppression caused by the presence of nitric oxide. In summary, these near field effects due to hydrocarbon and nitrogen oxide emissions have opposite effects and, depending on the relative magnitudes of the quantities of hydrocarbon and nitrogen oxide emissions from a source region, can be self compensating. In the receptor areas further downwind the effects are different, with both hydrocarbons and nitrous oxides increases likely to increase ozone concentrations.

For the Badgerys Creek airport options, associated nitrous oxides and hydrocarbon emissions would tend to occur upwind of the airport for events leading to high ozone concentrations. Taking into account the opposing effects in the near field of hydrocarbons and oxides of nitrogen emissions from airport associated developments, this positioning would tend to result in no great change in the location of the upwind boundary for the onset of ozone increases due to emissions from the airport.

While this assessment of impacts of associated development and motor vehicle traffic is subject to certain limitations because of the modelling process and availability of data, it still provides a useful comparison of possible indirect impacts associated with each of the airport options.

## CHAPTER 8      IMPACTS OF HOLSWORTHY OPTIONS

### 8.1      CONSTRUCTION OF THE AIRPORT

Construction of Sydney Second Airport at Holsworthy would involve substantially more earthworks than for Badgerys Creek due to the greater relief in the terrain. Dispersion modelling of dust impacts indicates that there would be potential for increased dust deposition rates in excess of the generally allowable limit of two micrograms per square metre, at the airport boundaries, due to construction (see *Figure B1 in Appendix B*).

These levels of dust deposition would occur largely within the Holsworthy Military Area and would be unlikely to affect populated areas. Increases in concentrations of particulates smaller than ten microns are also predicted. Peak daily concentrations of particulates smaller than ten microns could be increased by more than 100 micrograms per cubic metre for distances of up to four kilometres from the airport boundary. This would only occur under worst case conditions, such as when earthmoving activities are occurring close to the airport boundary. Impacts would not generally be as severe as shown in *Figure B2 in Appendix B*. Increases of greater than 100 micrograms per cubic metre have the potential to raise the concentration of particulates above the NSW Environment Protection Authority goal of 150 micrograms per cubic metre.

Concerns have been expressed in relation to the possible presence of lead in the soils within the Holsworthy Military Area arising from artillery bombardment and the potential for dispersion of lead as part of dust emissions during construction. Preliminary assessment of soils from areas which have been subjected to heavy artillery bombardment has not indicated elevated lead levels (refer *Technical Paper No.10 - Hazards and Risks*). It is therefore considered unlikely that any lead introduced as a result of artillery bombardment would provide a significant source of lead in construction dust.

Dust emissions during construction could potentially result in deposition of dust on washing being dried and into swimming pools and rainwater tanks. The amount of dust deposited would depend upon the effectiveness of dust control measures.

### 8.2      OPERATION OF THE AIRPORT

*Table 8.1* presents the predicted maximum increases in ground level concentrations at the airport boundary for a range of pollutants.

**TABLE 8.1**      **PREDICTED INCREASES IN GROUND LEVEL CONCENTRATIONS OF AIR POLLUTANTS DUE TO OPERATION OF HOLSWORTHY OPTIONS**

Parameter	Goal	Maximum Background <sup>1</sup>	Predicted Maximum Increase 2016 <sup>2</sup>	
			Option A	Option B
One-hour Ozone (parts per hundred million)	10	10	2.1	2.2
One-hour Nitrogen Dioxide (parts per hundred million)	16	10	8	8
Daily particulates below 10 micron (micrograms per cubic metre)	150	50	20	25
One-hour Carbon Monoxide (parts per million)	25	10	4	5
Eight-hour Carbon Monoxide (parts per million)	9	3	0.6	1.0
One-hour Sulphur Dioxide (parts per hundred million)	12.5	4	5	5

- Notes:
1. Maximum background concentrations were assessed based on monitoring results from available monitoring data.
  2. Maximum increase predicted for areas outside the airport boundary.

The results in *Table 8.1* illustrate, for the conservative assumption that maximum airport impact and maximum background concentration might occur simultaneously, that the concentrations of carbon monoxide, sulphur dioxide, and particulates would not exceed the goal values. Ozone levels, however would exceed goal values.

### **8.2.1 CARBON MONOXIDE**

Background concentrations of carbon monoxide at Holsworthy were assessed using monitoring results from the Environment Protection Authority monitoring station at Liverpool which is the nearest Environment Protection Authority air quality monitoring site for which carbon monoxide monitoring data is available. Peak monthly, hourly, average carbon monoxide concentrations at Liverpool over the period February 1994 to December 1995 ranged from 1.7 parts per million to 9.3 parts per million. Highest concentrations were recorded during winter and this is attributed to poorer dispersion of pollutants during winter and the use of solid fuel heaters.



A background level of 10 parts per million was adopted for one hour carbon monoxide in the vicinity of the Holsworthy airport sites. This value is considered reasonable for the more heavily populated areas such as Campbelltown but is considered conservative for lightly populated areas.

There is not sufficient information for adoption of a background level for eight hour carbon monoxide concentration for Holsworthy expect to note that it would be less than the maximum one hour carbon monoxide concentration.

At Holsworthy, the background levels within the Military Area are likely to be significantly lower than in populated areas. The modelled maximum increase in 8 hour carbon monoxide levels in populated areas to the west of the airport site (such as Campbelltown, Wedderburn, St Helens Park, Minto and Glenfield Park) is less than 0.5 parts per million which is well below the goal value of 9 parts per million. Increases in these areas due to the airport would take place as a result of evening winds with an easterly component typically between 6pm and 9pm.

*Figure B4 in Appendix B* presents the predicted maximum increase in hourly average carbon monoxide concentration for aircraft takeoff direction selected to maximise peak increase in carbon monoxide concentration for Holsworthy Options A and B. It is clear by comparison of *Figures B3 and B4* that peak ground level increase in carbon monoxide concentration has only modest sensitivity to direction of takeoff. Consequently, only takeoff with a northerly component was considered for subsequent analysis.

*Figure B3 in Appendix B* presents the maximum increase in hourly average ground level carbon monoxide concentration calculated for the two year period modelled. For all airport options the calculated increase in carbon monoxide concentration is well below the NSW Environment Protection Authority goal of 25 parts per million for a one hour average. If the calculated maximum increases are added to the background values of 10 parts per million for Holsworthy the resulting concentrations are still well within the goal of 25 parts per million.

*Figure B5 in Appendix B* presents the maximum increase in eight hour average ground level carbon monoxide concentration calculated for the two year period modelled. Similar concentration impacts are assessed for each of the airport options. These increases are typically less than 0.5 parts per million. This increase is much less than the goal of 9 parts per million. Assessment of background peak eight hour carbon monoxide concentration is uncertain.

*Figure B6 in Appendix B* shows the modelled increase in one hour carbon monoxide concentration due for initial airport operation in 2006. Predicted increases in concentration are of the order of half those predicted for design level operation in 2016.

Given the uncertainty in carbon monoxide levels in the vicinity of the Holsworthy site it is recommended that monitoring be carried out at the candidate sites and at Campbelltown to provide background information, should airport development proceed for either of the Holsworthy options.

### 8.2.2 NITROGEN DIOXIDE

Background monitoring results from the industry air quality monitoring station at Campbelltown reported by NSW Environment Protection Authority from January 1992 to December 1995 recorded a range of monthly maximum values for hourly nitrogen dioxide of 2.1 parts per hundred million to 27 parts per hundred million. An isolated high value of 27 parts per hundred million was recorded for September 1995. The average concentration of nitrogen dioxide for this month was 2.2 parts per hundred million which is typical of monthly averages. The next highest hourly value of 9.9 parts per hundred million. Apart from a possible increase in levels following relocation of the monitoring station during early 1995 there is no apparent long term trend in monitoring data.

Background monitoring by NSW Environment Protection Authority at Liverpool from November 1992 to December 1995 recorded a range of monthly maximum values for hourly nitrogen dioxide of 3.7 parts per hundred million to 12 parts per hundred million with an average maximum of 6.0 parts per million. The highest hourly values tend to occur in winter.

Background monitoring by NSW Environment Protection Authority at Appin from January 1995 to December 1995 recorded a range for monthly maximum values for nitrogen dioxide from 1.8 to 8.9 parts per hundred million with an average monthly maximum of 3.0 parts per hundred million. The highest value of 8.9 parts per hundred million was recorded in January and was more than double the second highest monthly maximum. The results do not show seasonal trends and the record is too short to allow assessment of long term trends.

Based on these results a background value of 10 parts per hundred million was adopted for peak hourly nitrogen dioxide in the vicinity of the Holsworthy airport options.

The calculated increases in average long term nitrogen dioxide concentration which would occur as a result of airport operation are presented in *Figure B7* in *Appendix B*. Calculated increases are well below the goal of 5 parts per hundred million and it is assessed as unlikely that airport operation would result in an increase of average nitrogen dioxide concentration above the NSW Environment Protection Authority goal.

For modelling of the Holsworthy options, 10 per cent of oxides of nitrogen were assumed to be nitrogen dioxide. This assumption is based on measured data as outlined in Section 3.7.2.

*Figures B8 in Appendix B* show increases in peak hourly nitrogen dioxide concentrations which are predicted to result from airport operations in 2016. The maximum predicted increase in nitrogen dioxide concentrations is eight parts per hundred million. Apart from in a small zone within the Holsworthy Military Area, the predicted increases would not result in peak nitrogen dioxide concentrations exceeding the goal of 16 parts per hundred million, even if a conservative assumption is made that the maximum predicted increase occurs in an area with maximum background levels.

*Figure B9 in Appendix B* shows the modelled increase in peak one hour nitrogen dioxide concentration due to initial airport operation. Predicted increases are about half those predicted for 2016.

### 8.2.3 OZONE

Ozone impacts were assessed using two methods of analysis, trajectory modelling as described in Section 3.7.5 and footprint analysis as described in Section 3.7.6.

#### *Trajectory Modelling*

Two meteorological events resulting in high ozone levels in western Sydney were modelled to assess ozone impacts which would result from the Second Sydney Airport.

The modelled ozone impacts due to emissions from an airport at the Holsworthy Option A site were similar in distribution for both events modelled with higher concentrations predicted for the event of 9 February 1994. Increased ozone concentrations of up to 20 parts per billion were predicted as a result of airport operation. In the case of the event of 9 February, 1997, ozone impacts in excess of 10 parts per billion were predicted over a width of 9 kilometres. Increased ozone concentrations commenced about 10 kilometres downwind of the airport and continued in excess of 50 kilometres. Similar effects were noted for the event of 4 February, 1991.

For the case of Holsworthy Option B, increases in ozone concentration of up to 20 parts per billion were predicted for the event of 9 February, 1997 with increases of 10 parts per billion affecting a strip with a cross wind distance of 12 kilometres commencing about 10 kilometres downwind from airport and persisting for over 50 kilometres. For the event of 4 February, 1991, much lower increases in ozone concentration were predicted with impacts generally less than 10 parts per billion.

### *Footprint Analysis*

Airport operation is predicted to result in an increase in one-hour ozone concentration of up to 2.1 parts per hundred million during otherwise high ozone events. Analysis by Katestone Scientific (*Appendix E*) shows that ozone impacts of the airport would be sensitive to the chemistry of the incident air reaching the airport site. Increases for Holsworthy Option A from 0.6 to 2.1 parts per hundred million were predicted under a range of high background ozone conditions. This would be likely to result in an increased occurrence of ground level ozone concentrations in excess of the goal of 10 parts per hundred million. Similar impacts are predicted for Holsworthy Option B.

*Figures 8.1 and 8.2* show the areas which are predicted to be affected by increased ozone concentrations of at least one part per hundred million for Holsworthy Option A and Option B in the year 2016. It is estimated that 176,000 people (estimated 2016 population) could be affected by ozone increases of this magnitude, generated by about nine times per year for Holsworthy Option A. Approximately 28,000 people would be affected by ozone generated by Holsworthy Option B, again approximately nine times per year.

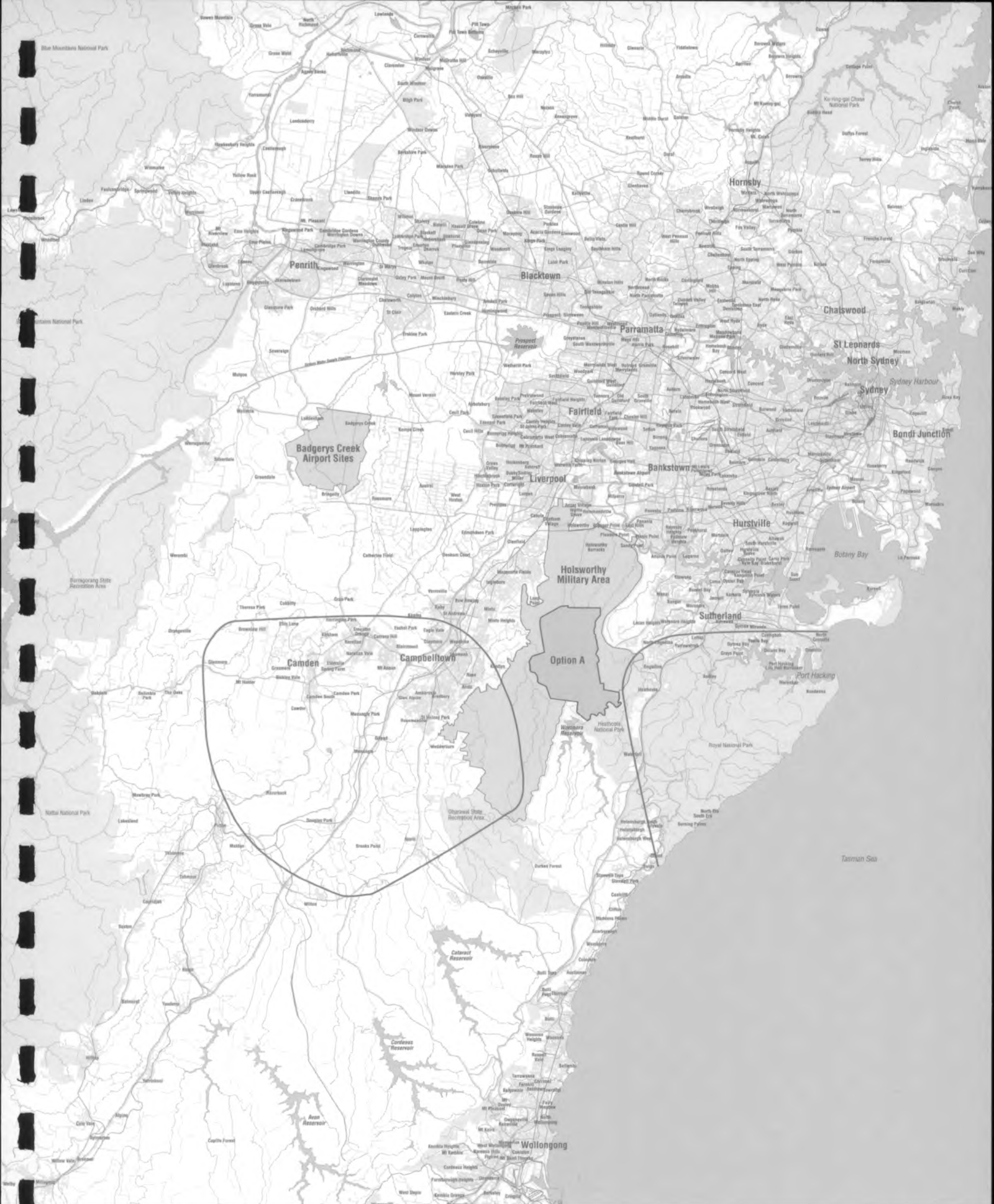
Ozone impacts of Holsworthy Option A would affect the greatest number of people because the area where peak ozone concentrations would occur includes large population centres in Campbelltown local government area.

#### **8.2.4 AIR TOXICS**

The increase in average ground level concentrations of the following air toxic compounds was modelled:

- Acetaldehyde;
- Benzene;
- 1,3 butadiene;
- Formaldehyde;
- Toluene;
- Phenol; and
- Xylenes.

Based on modelling, *Figure B10* in *Appendix B* shows the increase in average ground level concentration of benzene which would occur as a result of



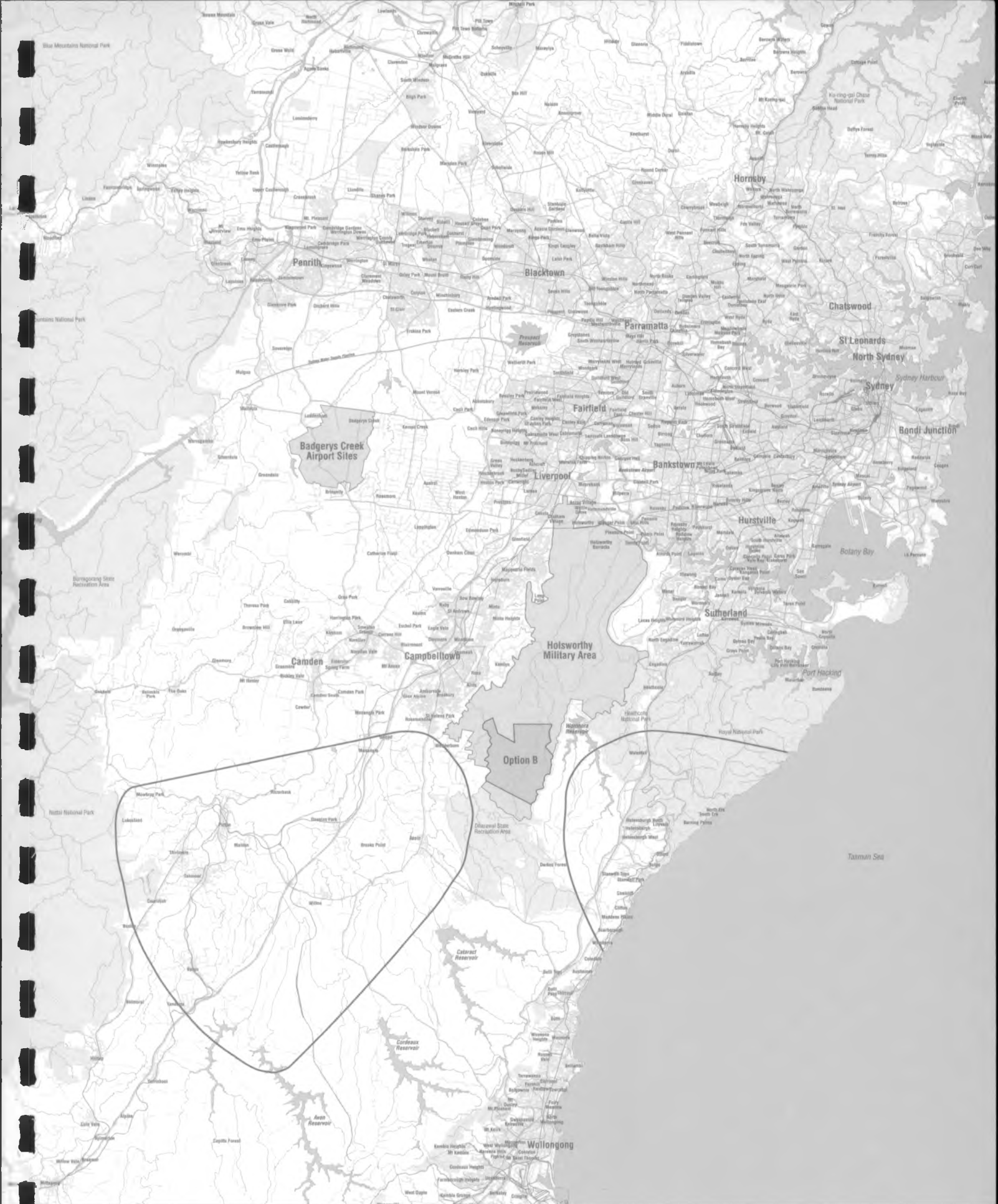
Area predicted to be affected by at least one part per hundred million increase in peak one hour ozone concentration due to airport operations (2016)

Urban Areas (indicated by local roads)

Figure 8.1  
**Predicted Ozone Increases for Holsworthy Option A**  
 Note: Assumes Air Traffic Forecast 3 Level of Operation in 2016



0km 10km 20km



Area predicted to be affected by at least one part per hundred million increase in peak one hour ozone concentration due to airport operations (2016)

Urban Areas (indicated by local roads)

Figure 8.2  
**Predicted Ozone Increases for  
 Holsworthy Option B**  
 Note: Assumes Air Traffic Forecast 3 Level of Operation in 2016



0Km 10Km 20Km

airport operation in 2116. It is predicted that average benzene concentrations would increase by less than 0.1 parts per billion which are much lower than background concentrations currently existing within the Sydney Basin. Health impacts associated with increases in concentrations of air toxics are discussed in *Section 9.1.4*.

#### **8.2.5 ODOUR**

Odour impacts of the airport were assessed based upon calculated ground level hydrocarbon concentrations. The odour associated with a nominated ground level concentration was calculated by applying a factor developed based on sampling of air emissions from aircraft exhaust. The occurrence of kerosene type odours was predicted by dividing the modelled hydrocarbon concentration by 34 micrograms per cubic metre to obtain odour units. This factor was assessed based on field measurements of odour and hydrocarbon concentrations described in *Section 5*.

Odour strengths and hydrocarbon concentrations for eight samples were measured at Sydney Airport and used to assess a factor for prediction of odour level based on hydrocarbon concentration.

Based on this analysis it is predicted that kerosene type odours would be detected at distances of up to three kilometres from the airport boundary 0.5 percent of the time. This represents detectable odour levels during 44 hours in a year, for less than 100 people for Options A and B in 2016.

A sewage treatment plant is proposed to be constructed to service the airport. This would have the capacity to meet the demands of an equivalent population of 84,000 people. For Holsworthy Option A, dispersion modelling of odour impacts (*Appendix I*) predicts that areas where odour would be able to be detected for 44 hours or more per year would be contained within the airport boundary or within the Holsworthy Military Area. For Holsworthy Option B, it is predicted that odour impacts would occur in an uninhabited area within 500 metres of the south-west corner of the airport boundary.

#### **8.2.6 PARTICULATES**

Background concentrations of PM<sub>10</sub> in the vicinity of the Holsworthy airport option sites were assessed based on the following data:

- Quarterly Air Quality Monitoring Reports (Environment Protection Authority, 1997b) show that the industry air quality monitoring site at Campbelltown recorded peak daily concentrations of 17, 13, 127 micrograms per cubic metre for the months of February, March and April in 1994;



- the NSW Environment Protection Authority monitoring station at Earlwood which is the nearest station for which an extended record of PM<sub>10</sub> monitoring is available, shows maximum daily concentration measured each month varying from 17 micrograms per cubic metre to 96 micrograms per cubic metre with an average of 38 micrograms per cubic metre; and
- measurement of fine particle (less than 2.5 microns) concentrations by Australian Nuclear Science and Technology Organisation et al (1995) showed similar monthly average concentrations of fine particles at Campbelltown, Lucas Heights and Wilton.

Based on these results the adopted peak background daily PM<sub>10</sub> concentration in the vicinity of the Holsworthy sites was taken as 50 micrograms per cubic metre.

*Figure B13 in Appendix B* presents the calculated peak increase in daily PM<sub>10</sub> concentration due to operation of the airport for each of the airport options. The maximum increase in PM<sub>10</sub> concentration outside the airport boundary due to operation of the airport is 20 micrograms per cubic metre for Holsworthy Option B. As peak background concentrations are assessed to be 50 micrograms per cubic metre, these increases would not result in increase of particulate concentrations above the NSW Environment Protection Authority goal of 150 micrograms per cubic metre.

*Figure B13 in Appendix B* presents the calculated average increase in PM<sub>10</sub> ground level concentration due to airport operation. The increase is small by comparison with the annual goal of 50 micrograms per cubic metre and would not be expected to increase average PM<sub>10</sub> concentrations above the goal.

*Figure B14 in Appendix B* shows the modelled increase in peak 24 hour PM<sub>10</sub> concentrations due to initial airport operation in 2006. Predicted increases follow a similar form to that predicted for 2016 but with only about half the predicted increase.

### 8.2.7 SULPHUR DIOXIDE

Existing background levels of sulphur dioxide are well within the World Health Organisation goal of 12 parts per hundred million for the one hour concentration. The highest value recorded in the Sydney Basin in 1995 was 4.0 parts per hundred million at Woollooware in January. *Figure B15 in Appendix B* shows the calculated increase in maximum hourly ground level sulphur dioxide concentrations as a result of airport operation in 2116. The calculated increases are well below the goal level and would not be expected to result in the goal level being exceeded.



### 8.3 ASSOCIATED DEVELOPMENTS AND MOTOR VEHICLES

Changes in urban development and the volume and distribution of motor vehicle traffic resulting from operation of the Second Sydney Airport would result in increases in air pollutant emissions over and above those generated by aircraft and other sources within the airport boundaries. Increases are primarily due to increased motor vehicle use with non-vehicle related increases (due to population changes) comprising less than 10 percent of the total predicted increase for hydrocarbons and less than one percent of the increase for oxides of nitrogen and carbon monoxide. An assessment of air quality impacts due to these additional emissions was carried out by CSIRO Division of Coal and Energy Technology and is presented in *Appendix J*.

For Holsworthy Option A, increased emissions due to associated development tend to be concentrated to the north of the airport along the main transport corridors. Under meteorological conditions where increases in ozone as a result of airport operation are predicted, the impacts of these associated emissions would tend to add to impacts of emissions from airport ground operations and aircraft during climb out. The increase in emissions due to airport associated developments (estimated to be along six kilometre wide trajectories through the airport) would amount to up to 34 percent increase over airport emissions alone. This would be expected to result in an increase in peak ozone impacts of similar percentage. Impacts of this magnitude would only apply in the zone of ozone impact to the south-east of the airport. There would be little impact to the south-west of the airport as for these cases airport associated emissions would be low in comparison with airport emissions for trajectories passing over the airport. The location of the zone of maximum ozone impact would not be greatly affected by airport associated emissions.

For Holsworthy Option B, it is predicted that the ozone impact would be increased by up to 28 percent by the effects of airport associated emissions compared with the impact due to airport emissions alone. These increases in ozone concentration would affect the regions to the south-east and south-west of the airport which would suffer increased ozone concentrations as a result of airport emissions. The location of the area impacted to the south-east of the airport would not be greatly affected as a result of airport associated emissions. The zone of impact to the south-west would tend to move downwind (further to the south-west) as a result of the airport associated emissions because of the concentration of airport associated emissions to the west of the airport.

While this assessment of impacts of associated development and motor vehicle traffic is subject to certain limitations, because of the modelling process and availability of data, it still provides a useful comparison of possible indirect impacts associated with each of the airport options.

## CHAPTER 9    POTENTIAL HEALTH IMPACTS

### 9.1 RESPIRATORY HEALTH IMPACTS

The Institute of Respiratory Medicine at the Royal Prince Alfred Hospital carried out a literature review of respiratory health impacts due to exposure to ozone, nitrogen dioxide and particulates. A copy of this review is presented as *Appendix F* and the main findings are summarised below.

#### 9.1.1 OZONE

Ozone is an insoluble gas which means it can exert effects throughout the airways from the mouth to the periphery of the lung. As a highly reactive chemical with potent oxidant activity, it produces direct and indirect toxic effects on cell constituents.

There are few domestic indoor sources of ozone. Furthermore, ozone which enters the house from outdoors is quickly inactivated by chemical reaction with household surfaces. Hence ozone is predominantly an outdoor pollutant.

The current Australian air quality goals for ozone are 10 parts per hundred million for one hour average and 8 parts per hundred million for four hour average.

Exposure of ozone causes a short-term reduction in lung function, the extent of which is related to the ozone concentration, the duration of exposure and the level of activity (such as exercise) being undertaken. In many cases, reduction in lung function is not accompanied by any symptoms, but some people (more commonly adults rather than children) experience chest discomfort or difficulty in taking a deep breath. Individuals vary in their sensitivity to ozone but the elderly and those with pre-existing respiratory diseases (including asthma) are more susceptible than others. Those whose work or recreation entails outdoor physical activity are most likely to be affected by ozone exposure.

The Technical Report on *Respiratory Health Effects (Appendix F)* identified three measures to quantify the lung function changes in response to ozone exposure. From the literature review it was estimated that a 0.1 part per hundred million increase in ozone concentration would result in:

- 1.7 percent reduction in lung capacity;
- 1.4 percent increase in the risk of hospitalisation; and

- 1.0 percent increase in the risk of death.

These impacts would only apply for the duration of the period of increase ozone concentration. For example if the risk of death on a particular day was 1 in 20,000 then this would increase to 1.01 in 20,000 or 1 in 19,800 for a day when ozone was increased by 0.1 parts per hundred million. It should be noted that there is significant variability in the results quoted in the literature and the level of impact of ozone concentration on health must be considered uncertain.

Table 9.1 summarises the predicted numbers of people who would be exposed to increases in ozone levels beyond one part per hundred million, during high ozone events.

TABLE 9.1 PREDICTED POPULATIONS IN 2016 AFFECTED BY OZONE IMPACTS AND NUMBER OF OZONE EVENTS

Predicted Impact	Badgerys Creek Option			Holsworthy Options	
	A	B	C	A	B
Number of people exposed to increased peak hourly ozone concentration by more than 1 part per hundred million during high ozone events	8,000	8,000	8,000	176,000	28,000
Number of high ozone events predicted per annum	6	6	6	9	9

Adverse health effects may occur on these days when peak ozone concentrations are significantly increased by airport operations. On the basis of the affected populations shown above it is estimated that two to three extra hospital admissions and one death could occur each 100 years as a result of the operation of the airport at Badgerys Creek airport options.

Adverse health effects may occur on the days when peak ozone concentrations are significantly increased by airport operations. On the basis of the affected populations shown above, it is estimated that 90 extra hospital admissions would occur each 100 years for Holsworthy Option A and 14 for Holsworthy Option B. The estimated number of additional deaths per 100 years due to high ozone concentrations is 34 for Option A, and five for Option B.

It should be noted that predicted numbers of hospital admissions and deaths due to ozone are likely to be over estimates, because some admissions and deaths would have occurred in any case. Airport related emissions would likely hasten these deaths rather than be the cause.

### 9.1.2 HEALTH EFFECTS DUE TO EXPOSURE TO NITROGEN DIOXIDE

Nitrogen dioxide is a poorly water soluble gas which reaches the small airways of the lung. It is a by-product of combustion of fossil fuels and is also generated in the atmosphere by reaction among other pollutant gases. The major outdoor source is the motor vehicle. Gas heaters and stoves are important indoor sources of nitrogen dioxide. Indoor concentrations of nitrogen dioxide in some homes are higher than those found in outdoor air.

The current National Health and Medical Research Council goal for nitrogen dioxide is a one hour maximum of 16 parts per hundred million.

Exposure to nitrogen dioxide at levels seen under ambient conditions does not cause any change in lung function in healthy people and probably only causes concern in people with asthma or other respiratory disease at levels above 25 parts per hundred million. The available data do not allow quantification of the relationship between nitrogen dioxide exposure and changes in lung function.

Evidence that variation in nitrogen dioxide is associated with risk of hospitalisation for respiratory disease is conflicting and there is evidence that nitrogen dioxide exposure is not linked with daily death rates. For both these outcomes it is not appropriate to attempt to quantify an association with nitrogen dioxide exposure levels.

### 9.1.3 HEALTH EFFECTS OF EXPOSURE TO PARTICULATES

Particulate pollution is a heterogeneous mixture of everything in the air which is not a gas. Only those particles which are small enough to enter the lungs are clinically important. Particles with a mass median aerodynamic diameter greater than ten microns are filtered out by the upper respiratory tract. Particles with a mass median aerodynamic diameter near five microns tend to deposit in the airways of the lower respiratory tract and particles less than two microns reach the alveoli. Some ultra fine particles, which reach the periphery of the lung, are capable of inducing an inflammatory reaction which may have effects within and beyond the lung.

There is no Australian National Health and Medical Research Council guideline for particulates at present. US Environment Protection Authority goals for particulate matter with a mass median aerodynamic diameters less than 10 microns (PM<sub>10</sub>) are an annual mean less than 50 micro grams per cubic metre and a 24 hour mean of 150 micro grams per cubic metre. The UK Department of Environment Expert Panel of Air Quality Standards for Particles has recommended a standard 50 micrograms per cubic metre as a 24 hour running average.

Increased exposure to particulates is associated with increased symptoms and decreased lung function. This has been most clearly shown in children and the effect is more marked in children with pre-existing respiratory disease such as asthma. This estimated that a 30 microgram per cubic metre increase in  $PM_{10}$  is associated with an eight percent increase in hospitalisation. Day to day variation in particulate levels also correlated with variation in daily death rates. The correlations are strongest for deaths in elderly and deaths due to cardiac and respiratory diseases. It is estimated that on a given day, a 30 microgram per cubic metre increase in particulate exposure (a large increase) is predicted to cause, on average, a two percent increase in the risk of dying on that day.

Only particles which are small enough to enter the lungs (less than 10 micrometres in diameter) are clinically important. Air quality modelling results shown in *Table 7.1* indicate that predicted increases of such particulates would not result in current goals being exceeded. The health implications of these increased concentrations on the affected populations at Badgerys Creek are that an increase of between 160 and 170 person days of reported cough is predicted to occur due to an increase in particulates concentrations of three micrograms per cubic metre. The number of additional people who would be hospitalised for respiratory disease is predicted to increase by approximately two to three per 100 years, due to episodes of increased particulates, while the projected numbers of additional deaths on a given day is predicted to increase by less than one per 100 years for the Badgerys Creek options.

Air quality modelling results in *Table 8.1* indicate that predicted increases of such particulates would not result in current goals being exceeded for the Holsworthy options. The health implications of these increased concentrations on the affected populations at Holsworthy are that an increase of between 190 and 270 person days of reported cough is predicted to occur due to an increase in particulate concentrations of three micrograms per cubic metre for Options A and B respectively. The number of additional people who would be hospitalised for respiratory disease is predicted to increase by approximately five per 100 years for Option A and seven per year for Option B due to episodes of increased particulates. The projected numbers of additional deaths on a given day is predicted to increase by one per 100 years for Options A and B.

It should be noted that predicted numbers of hospital admissions and deaths due to particulates are likely to be over estimates, because some admissions and deaths would have occurred in any case. Airport related emissions would likely hasten these deaths rather than be the cause.

#### **9.1.4 AIR TOXIC HEALTH IMPACTS**

California Air Pollution Control Officers Association (1993) provides a list of substances for which annual average concentrations should be calculated for

assessment of cancer and chronic non-cancer risks. Substances in that list which have also been identified in the air emissions inventory for the proposed airport (contained in *Appendix C*) are listed in *Table 9.2*.

TABLE 9.2 SUBSTANCES CONSIDERED FOR LONG TERM HEALTH RISK

Acetaldehyde
Benzene
1, 3 - Butadiene
Formaldehyde
Gasoline vapours
Lead Compounds <sup>1</sup>
Polycyclic aromatic hydrocarbons including benzo(a)pyrene
Phenol
Toluene
Xylenes

Notes: 1. Lead compounds were not included in the air emissions inventory because air emissions are substantially reduced due to the phase out of leaded petrol. They are discussed because lead is listed for consideration in the Guidelines for the EIS prepared by Environment Australia.

Non-Cancer Risk

Reference exposure levels for long term exposure to air pollutants have been tabulated by the California Air Pollution Control Officers Association (1993). These reference exposure levels are used as indicators of potential health effects which are not related to cancer. For average concentrations below these levels, no adverse health effects are anticipated. The potential for chronic health effects is assessed by comparing with the long-term exposure levels. The compounds listed by California Air Pollution Control Officers Association (1993) which are also identified in the *Air Emissions Inventory Report (Appendix C)* are listed in *Table 9.3*.

TABLE 9.3 NON-CANCER REFERENCE EXPOSURE LEVELS - AIR POLLUTANTS

Substance	Inhalation Reference Exposure Level (micrograms per cubic metre)	References (see below)
Acetaldehyde	9	IRIS
Benzene	71	TLV
Formaldehyde	3.6	IRIS
Lead	1.5	CAAQS
Nitrogen Dioxide	470	CAAQS

Substance	Inhalation Reference Exposure Level (micrograms per cubic metre)	References (see below)
Ozone	180	IRIS
Phenol	45	IRIS
Sulphur dioxide	660	DTSC
Toluene	200	TLV
Xylenes	300	SPHEM

Source: Table III-8 of California Air Pollution Control Officers Association's Air Toxics "Hot Spots" Program Revised 1992 Risk Assessment Guidelines published in October 1993.

Notes: The references listed below are those referred to in the above publication:

IRIS	Reference Doses from US Environment Protection Authority's Integrated Risk Information System.
TLV	Indicates that the number is derived from an ACGIH Threshold Limit Value (TLV) which has been divided by an uncertainty factor of 420. (4.2 (to extrapolate from a 40 hour week to a 168 hour full week) times 10 (to extrapolate from healthy workers to sensitive people) times 10 (since adverse health effects are often seen at the TLVs)).
SPHEM	the Superfund Public Health Evaluation Manual, 1986, pp. 149-156.
CAAQS	California Ambient Air Quality Standard.
DTSC	Department of Toxic Substances Control Applied Action Levels.

Lead is an air pollutant released from motor vehicles fuelled with leaded petrol. Poisoning occurs when blood levels of lead exceed 500 micrograms per litre. Levels as low as 100 micrograms per litre in blood have been linked with behavioural changes in children (Needleman et al 1979). By 2006, the proportion of the motor vehicle fleet which uses leaded fuels (petrol fuel vehicles manufactured prior to 1986) will be very low and as a result air emissions of lead will not be significant. By 2006 ambient lead levels will also be low compared with the Environment Protection Authority goal value of 1.5 micrograms per cubic metre. For these reasons lead air pollution resulting from airport operation will not be significant.

For each of the air toxic compounds listed in *Table 9.3*, with exception of lead and ozone, the long term increase in concentration due to operation of Sydney Second Airport was predicted using dispersion modelling. Lead was not included for the reasons discussed above and increase in long term average ozone concentration was not able to be assessed using dispersion modelling. Note that the inhalation reference dosage for ozone of 180 micrograms per cubic metre is approximately equal to nine parts per hundred million.

For each of the remaining air toxic compounds the predicted increase in average air toxic concentration was divided by the inhalation reference exposure. This gave an exposure index for each of the air toxic compounds considered. None of the individual predicted long term concentration increases exceeded the inhalation reference exposure levels for any of the

airport options. The combined exposure, calculated by summing the fractional exposure levels, was less than 0.3 (acceptable exposures are less than one) outside the airport boundary for all airport options indicating that the non-cancer impact due to these air toxic compounds was within acceptable limits. *Figure B16 in Appendix B* shows the modelled reference exposure dosage for each of the airport options. Similar increases in exposure are assessed in each case.

### Cancer Risk

This section describes the results of an assessment of health impacts due to carcinogenic air toxic compounds which would be emitted as a result of the operation of the Second Sydney Airport. Emissions from aircraft, ground service vehicles, maintenance operations and passenger motor vehicles are outlined in the *Emissions Inventory Report in Appendix C*. The pollutants which are addressed are:

- Acetaldehyde;
- Benzene;
- 1,3-butadiene;
- Formaldehyde; and
- Polycyclic aromatic hydrocarbons including benzo(a)pyrene.

*Table 9.4* presents the lifetime inhalation cancer unit risk factors for the above compounds obtained for a range of sources. The tabulated factors represent the theoretical risk of cancer over the course of an average lifetime due to a continuous inhalation exposure to a concentration of one microgram per cubic metre.

For example, in the case of benzene, the California Air Pollution Control Officers Association (1993) indicates a lifetime risk of 2.9 in one hundred thousand ( $2.9 \times 10^{-5}$ ). This means that, theoretically, if 100,000 people were exposed to benzene at a concentration of one microgram per metre cubed then 2.9 people would develop cancer over their lifetime as a result. A range of risk factors was identified in the literature indicating that the assessment of these cancer risks is changing with time.



TABLE 9.4 INHALATION CANCER UNIT RISK FACTORS (LIFETIME RISK FOR INHALATION AT ONE MICROGRAM PER CUBIC METRE)

Pollutant	Source				
	Falling on Deaf Ears <sup>a</sup>	Victorian EPA <sup>b</sup>	Katatani et al 1994 <sup>c</sup>	Vigyan Inc <sup>d</sup>	CAPCOA <sup>e</sup>
Acetaldehyde					2.7x10 <sup>-6</sup>
Benzene	8.3x10 <sup>-6</sup>	8.3x10 <sup>-6</sup>	1.3x10 <sup>-7</sup>	8.3x10 <sup>-6</sup>	2.9x10 <sup>-5</sup>
1,3 Butadiene	2.8x10 <sup>-4</sup>	2.8x10 <sup>-4</sup>		2.8x10 <sup>-4</sup>	1.7x10 <sup>-4</sup>
Formaldehyde	1.3x10 <sup>-5</sup>	1.3x10 <sup>-5</sup>		1.3x10 <sup>-5</sup>	6.0x10 <sup>-6</sup>
Benzo(a)pyrene		3.3x10 <sup>-3</sup>	3.3x10 <sup>-3</sup>	1.7x10 <sup>-3</sup>	1.7x10 <sup>-3</sup>
Particulate matter					
Petrol vehicles				5.1x10 <sup>-5</sup>	
Diesel vehicles				1.7x10 <sup>-5</sup>	
Aircraft				1.7x10 <sup>-5</sup>	

- Notes:
- Report of the Senate Select Committee on Aircraft Noise in Sydney November, 1995. Reference is to US Environment Protection Authority material.
  - Dennis Hearne, Motor Vehicle Emissions in Melbourne: Their Environmental Impact, Proceedings of The Clean Air Society of Australia and New Zealand Inc., 12th International Conference, October, 1994.
  - N. Katatani, N. Furushashi, S. Ogura, O. Nakasugi, A Case Study for the Estimation of Human Risk by Toxic Organic Compounds, Proceedings of The Clean Air Society of Australia and New Zealand Inc., 12th International Conference, October, 1994.
  - Vigyan Inc, Estimation and Evaluation of Cancer Risks Attributed to Air Pollution in Southwest Chicago, Report prepared for US EPA, April 1993.
  - California Air Pollution Control Officers Association's Air Toxics "Hot Spots" Program Revised 1992 Risk Assessment Guidelines, published in October 1993.

The combined cancer risk associated with airport emissions for each of the above air toxics was estimated for each of the airport options. For each air toxic compound, dispersion modelling was carried out to predict the average increases in concentrations. The highest of the risk factors for each air toxic compound from Table 9.4 was applied to the predicted average increase in concentration and the sum of the cancer risk for the combined exposure to the list of air toxic compounds was calculated. In the case of particulates, the risk factors reported by Vigyan (1993) were adopted. These risk factors address the presence of a number of carcinogenic compounds present in particulate emissions including polycyclic aromatic hydrocarbons such as benzo(a)pyrene. Different risk factors were applied to particulates emitted from petrol fuelled motor vehicles, diesel fuelled motor vehicles and from aircraft.

Figure B17 in Appendix B presents contours of the predicted increase in lifetime risk of cancer which would result from exposure to air toxic compounds from Sydney Second Airport. The level of risk is similar for each of the airport

options considered, with risk factors as high as one in one hundred thousand ( $1 \times 10^{-5}$ ) predicted at the airport boundary in each case.

These risks are for a worst case situation as they would apply to a person who spent 24 hours per day for their entire life (assumed 70 years) at a location near the airport.

TABLE 9.5 POPULATIONS EXPOSED TO CANCER RISKS IN 2016 FOR EACH OF THE AIRPORT OPTIONS

Airport Option	Risk Factor	Projected Population Estimates (2016)
Badgerys Creek Option A	1 to $2 \times 10^{-5}$	125,000
	2 to $5 \times 10^{-5}$	3,100
	greater than $5 \times 10^{-5}$	1,000
Badgerys Creek Option B	1 to $2 \times 10^{-5}$	122,000
	2 to $5 \times 10^{-5}$	4,000
	greater than $5 \times 10^{-5}$	900
Badgerys Creek Option C	1 to $2 \times 10^{-5}$	109,000
	2 to $5 \times 10^{-5}$	5,200
	greater than $5 \times 10^{-5}$	500
Holsworthy Option A	1 to $2 \times 10^{-5}$	282,000
	2 to $5 \times 10^{-5}$	32,000
	greater than $5 \times 10^{-5}$	0
Holsworthy Option B	1 to $2 \times 10^{-5}$	150,000
	2 to $5 \times 10^{-5}$	1,000
	greater than $5 \times 10^{-5}$	0

Integration of the modelled cancer risk with projected populations in the areas (shown in Table 9.5) surrounding the airport options gives a worst case range of three cases of cancer per 100 years for all three Badgerys Creek options (for 2016). A worst case range of eight cases per 100 years for Holsworthy Option A and three cases per 100 years for Holsworthy Option B (for 2016) is predicted. Risks on 2006 would be lower than this because of reduced emissions and lower projected populations.

The main contributors to cancer risk are 1,3 butadiene and particulate matter which was assumed as presenting a cancer risk, due to the presence of polycyclic aromatic compounds including benzo(a)pyrene. These two pollutants (1,3 butadiene and particulates) typically account for about 80 percent of the total cancer risk.

## CHAPTER 10 OTHER POTENTIAL AIR QUALITY IMPACTS

### 10.1 FUEL RELEASES

Two possible causes for fuel to be released from an aircraft during flight are fuel dumping and fuel venting. There are also a number of phenomena that are commonly mistaken for fuel releases.

#### 10.1.1 FUEL DUMPING

In some circumstances, it is necessary for an aeroplane to 'dump' fuel in order to reduce its weight in order to make landing either safer or possible. The release of fuel into the atmosphere is a potential hazard and, therefore, fuel dumping is governed by specific regulations.

The regulations for fuel jettison are outlined in the Australian Manual of Air Traffic Services (Airservices Australia, 1996). The regulations take into account:

- likelihood of humans or animals suffering toxic effects;
- possibility of damage to crops or built-up areas; and
- airspace likely to be affected by the fuel.

Investigations show that if fuel is dumped above 1,000 ft, it should evaporate before reaching the ground (Australian Manual of Air Traffic Services, 1996). Fuel dumping is only permitted at least 6,000 ft above ground level and therefore all fuel should evaporate. An additional safety requirement is that any fuel dumping (associated with Sydney Airport) must take place over the Tasman Sea. This requirement would also apply for Sydney's Second Airport and regulations would not be changed to permit National Parks or water catchments such as Lake Woronora or Lake Burrogorang to be used for this purpose.

The regulations recognise that there are emergencies where fuel dumping is necessary at lower altitudes and/or over land. This is only permitted when an aircraft is in danger of crashing. As commercial plane crashes are rare, the dumping of fuel outside of the designated region is also rare.

The Bureau of Air Safety Investigation (BASI) is responsible for recording fuel dumping events. However due to BASI's database structure the exact number of fuel dumping events cannot be retrieved. To find records of fuel dumping BASI must search through files of incidents that may cause fuel dumping (e.g., collision with birds, a passenger requiring medical attention, engine failure, or other equipment failure). If BASI does not search all the possible categories it is

possible that certain fuel dumping events may be overlooked. Between January 1987 and January 1997 there were 13 fuel dumping incidents (Bureau of Air Safety Investigation, 1997) that occurred within 30 kilometres of Kingsford Smith Airport. Anecdotal evidence from a former air traffic controller was consistent with the frequency of fuel dumping obtained from the BASI database.

Fuel dumping only occurred two or three times last year over water and there is no record of aircraft in emergency situations being forced to dump fuel at low altitude over built up areas (Airservices Australia, 1997).

#### **10.1.2 FUEL VENTING**

Accidental fuel venting has however been known to occur occasionally because of faults in an aircraft's fuel valve system. No records are kept of such events. Fuel dumping and venting is not considered to be a major emission in terms of affecting air quality.

Fuel venting can be a problem for large aircraft (e.g., 747, DC10) whilst taking off with a full load of fuel where fuel is accidentally released due to changing pressure in the fuel tanks. This could occur in the event of a fault in the aircraft's fuel valve system. As venting occurs during take-off and whilst gaining altitude, the fuel can be released at low altitudes and is therefore a potential hazard.

Fuel venting can be prevented by the installation of specific valves into the fuel supply system. It has been regulated that all aircraft manufactured after 1982, that operate in Australia, must have these fuel valves installed (International Civil Aviation Organisation, 1994). As a result, fuel venting is becoming increasingly rare. Certain airlines (for example, Qantas) have fitted these valves to all of their aircraft, even those manufactured before 1982. The most common cause of fuel venting is if the valve system malfunctions. Such events are rare, but have been known to happen.

#### **10.1.3 POSSIBLE MISCONCEPTIONS**

Both fuel dumping and fuel venting are rare events. However, there are frequent complaints by residents about fuel incidents. The main reasons for this disparity are two simple phenomena.

Vapour trails are caused when water vapour condenses to form water droplets after passing over the wings of aircraft. The appearance of a vapour trail behind the plane is often mistaken to be fuel and is the cause for a number of complaints. As vapour trails do not contain any fuel, they are not viewed as an air quality concern.

Complaints about fuel releases are also common when residents find a unexplained liquid on top of their cars. Liquids apart from rainwater are commonly assumed to be aircraft fuel. There are many other possible sources of such deposits. Certain specific occurrences of such liquid in suburbs have been tested and shown that the liquid is produced by a species of moth.

## **10.2 IMPACTS ON BUILDINGS**

Acid gases have the potential to result in damage to buildings by such mechanisms as erosion of mortar from brickwork and chemical attack of concrete. These effects are generally associated with high levels of sulphur dioxide which when combined with water forms sulphuric acid. Emissions of sulphur dioxide from the second airport would be comparable to the level of emissions from vehicle traffic associated with a similar area of urban development. It is assessed that the average increase in sulphur dioxide levels which would occur as a result of the operation of the Second Sydney Airport would be less than one part per billion. At this level it is considered unlikely that the fabric of buildings would be materially affected.

## **10.3 IMPACTS ON WATER QUALITY**

Effects of aircraft emissions and fuel discharges on water quality in reservoirs and domestic water tanks are discussed in *Technical Paper No. 7 - Geology, Soils and Water*.

# Part D

**Environmental Management**

## CHAPTER 11 MITIGATION OF IMPACTS

### 11.1 CONSTRUCTION IMPACTS

#### 11.1.1 MITIGATION AND CONTROL MEASURES

During construction, it would be necessary to control dust emissions of earthworks plant and to control dust erosion from exposed surfaces. This would be necessary to keep dust and particulate levels below allowable limits on days when wind conditions are unfavourable.

The following measures are recommended to control dust impacts:

- watering of working and unsealed haulage areas to suppress emissions of dust from haul trucks and scrapers;
- restriction of working areas to the minimum practicable to reduce potential for dust erosion;
- suspension of earthworks activity when wind conditions result in high dust emissions from earthworks handling;
- rapid sealing or revegetation of areas not under construction; and
- regular review of dust monitoring results to provide feedback on effectiveness of dust control measures.

#### 11.1.2 MONITORING

It is recommended that a network of directional dust deposition monitoring be established. This directional monitoring would provide a record of dust deposition originating from different directions so that dust deposition of construction dust from the airport could be distinguished from dust from other sources. A total of approximately 10 directional deposition gauges would be used for each site distributed outside the airport boundary.

It is recommended that four high volume samplers be installed to monitor increases in particulate pollution smaller than 10 micros resulting from airport construction. For the Badgerys Creek options the high volume samplers could be located to the northeast, southwest, southeast and northwest of the airport boundary at a distance of the order of 100 metres from the boundary. Suitable locations for the Holsworthy options would not be as easy to establish because of the terrain of the surrounding areas and uncertainties about wind conditions, especially at Holsworthy Option B.

Monitoring equipment should be in place at least three months prior to commencement of construction to provide a measure of background conditions.

It is recommended that a monthly report describing the results of monitoring be prepared and that every six months a review of monitoring results and the effectiveness of construction air quality control be carried out, with recommendations to cover the following six months.

## **11.2 OPERATIONAL IMPACTS**

### **11.2.1 MITIGATION AND CONTROL MEASURES**

Measures which can improve the environmental performance of operating airports are identified by US Civil Federal Aviation Administration (1997) and include:

- reduction in the number of aircraft engines in use during taxi and idle;
- take off under reduced engine power;
- reduced use of reverse thrust;
- turning of the auxiliary power unit while aircraft are docked; and
- improvement in emissions of the ground support fleet by use of low emissions engines such as those powered by electricity.

Adoption of the above measures would be contingent on meeting acceptable safety standards and the improvements would depend upon the proportion of the aircraft fleet able to adopt these measures. A number of the measures can result in cost savings as well as improvement to airport emissions.

In addition to the above measures, air traffic control practices which result in reduced queuing and taxi time would assist in minimising aircraft emissions. Procedures to ensure that aircraft using the airport comply with prevailing maintenance and control standards and efficient management of the passenger vehicle fleet to avoid congestion would also assist in minimising emissions from the airport.

### **11.2.2 MONITORING**

Continuing monitoring and management of air quality during operation of the airport would be addressed within an Environmental Management Plan which would be developed to address environmental issues associated with airport operations.



# Part E

## Summary of Impacts

# CHAPTER 12 SUMMARY OF AIR QUALITY IMPACTS

## 12.1 SUMMARY OF IMPACTS

Potential increases in dust and fine particulate levels beyond current accepted guideline levels are predicted to occur under worst case conditions as a result of airport construction, unless appropriate dust management measures are developed and strictly adhered to. Flexibility in work locations and programs may be necessary on days when wind conditions could lead to excessive levels of airborne dust and particulates.

Air quality studies have predicted that increased concentrations of nitrogen dioxide, fine particulates, carbon monoxide and sulphur dioxide due to airport operation would not result in concentrations of these pollutants in excess of goal values adopted by NSW Environment Protection Authority. Odour impacts are predicted due to airport operation and it is predicted that significant ozone impacts would result from operation of the airport.

Tables 12.1 and 12.2 present a summary of concentration impacts which are predicted due to airport operations. These results show that similar concentration impacts are predicted for each airport option. Background concentrations of air pollutants tend to be higher in the vicinity of Holsworthy than at Badgerys Creek due to the presence of population centres such as Campbelltown and Ingleburn.

TABLE 12.1 PREDICTED INCREASES IN AIR POLLUTANT CONCENTRATIONS - BADGERYS CREEK OPTIONS

Parameter	Goal	Background	Predicted Increase in Concentration due to Airport					
			Initial Operation 2006			Design Level Operation 2016		
			Option A	Option B	Option C	Option A	Option B	Option C
One hour ozone (parts per hundred million)	10	10	N/A	N/A	N/A	2.4	2.4	2.4
One hour nitrogen dioxide (parts per hundred million)	16	5	4	4	4	10	8	8
Daily particulates smaller than 10 micron (micrograms per cubic metre)	150	50	11	8	6	20	12	20

Parameter	Goal	Background	Predicted Increase in Concentration due to Airport					
			Initial Operation 2006			Design Level Operation 2016		
			Option A	Option B	Option C	Option A	Option B	Option C
One hour carbon monoxide (parts per million)	25	5	4	3	3	5	3	5
Eight hour carbon monoxide (parts per million)	9	3	N/A	N/A	N/A	1	0.7	0.7
One hour sulphur dioxide (parts per million)	12.5	4	N/A	N/A	N/A	5	5	4

Note: N/A Not Assessed.

TABLE 12.2 PREDICTED INCREASES IN AIR POLLUTANT CONCENTRATIONS - HOLSWORTHY OPTIONS

Parameter	Goal	Background	Predicted Increase in Concentration due to Airport			
			Initial Operation 2006			Design Level Operation 2016
			Option A	Option B	Option A	Option B
One hour ozone (parts per hundred million)	10	10	N/A	N/A	2.1	2.2
One hour nitrogen dioxide (parts per hundred million)	16	10	3	3	8	8
Daily particulates smaller than 10 micron (micrograms per cubic metre)	150	50	10	12	20	25
One hour carbon monoxide (parts per million)	25	10	2	3	4	5
Eight hour carbon monoxide (parts per million)	9	N/A	N/A	N/A		1.0
One hour sulphur dioxide (parts per million)	12.5	4	N/A	N/A		5

Note: N/A Not Assessed.

Greenhouse impacts of the airport would be similar for any of the options. As the Holsworthy options involve greater area, the one off greenhouse allocation for land clearing would be greatest for these sites. The land clearing contribution to greenhouse would be significantly less than operational impacts and would be distributed over the period of the construction program.

Table 12.3 presents predictions of the number of people who would be affected by ozone, odour and health impacts under design level operation in 2016 for each of the options considered.

The frequency of ozone Impacts would be higher for the Badgerys Creek site than for the Holsworthy sites due to the inland location and the greater prevalence of aged air. The main difference between impacts of the Holsworthy Option A and Option B is that the impacts of Option B would occur further to the south and impact on areas with lower population. Emissions from any of the three candidate sites would be likely to have more adverse smog consequences than the current emissions from the coastal airport at Mascot.

Predictions of ozone impacts are relatively sensitive to the adopted mixing depths for seabreeze conditions for which there is little information at inland sites in the Sydney region. The Holsworthy sites are in the transition zone between inland and coastal areas resulting in uncertainty in the thickness of the mixing layer during seabreeze conditions.

The results of the study suggest that regional photochemical smog would be a significant impact of the airport development and ozone impacts should be considered in airport site selection and environmental management.

Air quality studies have predicted that increased concentrations of nitrogen dioxide, fine particulates, carbon monoxide and sulphur dioxide due to airport operation would not result in concentrations of these pollutants in excess of goal values adopted by NSW Environment Protection Authority. Odour impacts would result from airport operations and it is predicted that significant ozone impacts would occur. Small health impacts are also predicted due to increased levels of air toxics.

TABLE 12.3      PREDICTED POPULATIONS IN 2016 AFFECTED BY AIR QUALITY IMPACTS OF SECOND SYDNEY AIRPORT

Predicted Impact	Badgerys Creek Option			Holsworthy Options	
	A	B	C	A	B
Number of people exposed to increased peak hourly ozone concentration by more than 1 part per hundred million during high ozone events	8,000	8,000	8,000	176,000	28,000
Increase in deaths due to ozone (persons per 100 years)	1	1	1	34	5

Predicted Impact	Badgerys Creek Option			Holsworthy Options	
	A	B	C	A	B
Increase in hospitalisation rates due to ozone (persons per 100 years)	2	2	3	90	14
Increase in hospitalisation rates due to particulates below 10 microns (persons per 100 years)	4	3	4	5	7
Increase in deaths due to particulates (persons per 100 years)	less than 1	less than 1	less than 1	1	1
Increase in number of cancer cases per 100 years due to exposure to airport air toxics	3	3	3	8	3
Number of people who would be able to detect kerosene odours for more than 44 hours per year	1,500	1,000	1,500	less than 100	less than 100

It is predicted that all of the airport options considered would result in increased peak ozone concentrations in areas which are currently subject to exceedences of the NSW Environment Protection Authority goal of 10 parts per hundred million. Increases in regional emissions due to associated development and motor vehicle traffic induced by the airport would be likely to amplify the impacts shown in *Tables 12.1* and *12.2*, and may increase the number of people affected, to greater than the figures shown in *Table 12.3*. The extent by which these impacts would increase was not able to be quantified, primarily because of the sophistication of the model used to analyse regional impacts and because of limited availability of data.

Of the five airport options considered, Holsworthy Option A would result in by far the largest population being exposed to significant increase in ozone concentrations. This conclusion is considered robust as it is supported by two alternate analysis methods. The studies carried out for this Draft EIS are considered to provide a reasonable basis for comparison of the airport options on the grounds of air quality. However, additional study is required to better define air quality impacts, because of limitations in the data available for use in the Draft EIS. These and other limitations of the study are outlined in *Chapter 13* of this Technical Paper.

## 12.2 LIMITATIONS OF STUDIES

The air quality study carried out for the Draft EIS is considered to provide a reasonable basis for comparison of the airport options. It is predicted that all airport options would result in increases in peak ozone concentrations in areas

which are currently subject to exceedance of the NSW Environment Protection Authority goal of 10 parts per hundred million. This conclusion is considered robust as it is supported by two alternate analysis methods. However as with all scientific studies, there were certain limitations associated with the work undertaken.

For example, detailed monitoring data from the NSW Environment Protection Authority air quality monitoring network was not able to be used for analysis of ozone impacts due to difficulties in resolving apparent orientation problems with wind monitoring data. This necessitated use of data from alternative sites which were not as well located. Ongoing review of monitoring data more recently collected by the NSW Environment Protection Authority air quality network may be appropriate. This may necessitate further footprint analysis of ozone impacts. The impacts may then be able to be assessed on the basis of several years of data from monitoring stations in the vicinity of the proposed airport sites.

Dispersion modelling carried out using Gaussian modelling is not able to capture the meteorological complexities of the sites, particularly the Holsworthy sites. It is expected that the simplifications involved will have resulted in over prediction of air quality impacts in the lower lying populated areas surrounding the airport sites.

Other methodological issues for the air quality study are listed below.

- It was planned to use the airshed model developed for the *Metropolitan Air Quality Study* (Environment Protection Authority, 1997a) for analysis of the regional impacts of the airport and the associated development. Access to this model was not made available by NSW Environment Protection Authority for the Draft EIS. Therefore it was necessary to carry out analysis of regional impacts and associated developments using less sophisticated methods. It is noted that the NSW Environment Protection Authority has carried out airshed modelling of the impact of increase motor vehicle traffic which would be associated with an airport at Badgerys Creek (Symonds Travers Morgan, 1996). This modelling did not take account of airport emissions and was carried out for meteorological conditions which were known to result in high ozone levels. Estimated increases in ozone concentrations due to airport induced motor vehicle traffic were small. It was noted in the report that the areas affected by increased traffic were comparable to the grid size of the model and this may have affected the results of the analysis;
- No air quality monitoring data exists for the sites for Holsworthy Option A and Holsworthy Option B. If these sites continue to be

considered, monitoring stations should be established to monitor wind speed and direction and air quality over a period of one year;

- Assessment of kerosene type odour impacts is based on limited field studies of odour strength taken from sampling of aircraft exhaust emissions at Sydney Airport. This limited program provides a basis for assessment of odour impacts but results should be considered uncertain. It would be beneficial for the odour impact in the vicinity of Sydney Airport be assessed in a similar way and the results of the modelling assessment compared with the odour complaint record. This would provide a means of calibration of the odour assessment for the Second Sydney Airport;
- Odour assessment for the sewage treatment works was made in the absence of detailed design of the facility. Odour strength was based on comparison with similar facilities elsewhere. When the design of the sewage treatment plant is carried out, it will be necessary to revise the odour impact assessment;
- Dispersion modelling of ground level concentrations of air pollutants was carried out assuming a horizontal ground surface. For each of the proposed airport sites receptors are located below the level proposed for the airport. As a result estimated concentrations are considered to be conservative. Additional analyses taking account of the complex terrain in the vicinity of the airport sites would provide more accurate dispersion modelling results;
- Assessment of health impacts of air toxic emissions was carried out based upon dispersion modelling results and published risk factors associated with individual air toxic compounds. These risk factors contain a high level of uncertainty as, in many cases, they are based on extrapolation of testing on animals; and
- Vertical profiling of the atmosphere has not been carried out over an extended period at any of the proposed airport sites. It was not practicable to carry this out as part of the Draft EIS studies given the need to obtain information for different seasons and the timeframe of the Draft EIS studies. A monitoring program to address the vertical profile at any airport sites which remain under consideration may be prudent.

The assessment of the impact of airport associated developments and motor vehicle emissions also contains some uncertainties.

- Ambient air chemistry for ozone interpretation is based on data from monitoring distant from the airport sites and may differ significantly from ambient air chemistry at the airport sites;
- Ambient data is based on monitoring data and does not take account of general development of Sydney and the changes this would induce in air chemistry; and
- The values for the rate coefficients for photochemical smog production used in the modelling are estimated values based on monitoring data for nitrogen oxides and ozone and inventory values for hydrocarbons/nitrogen oxides ratios of emissions in the Sydney region.

Also, a box model approach was employed which does not take account of variations in wind speed with height, does not take account of emissions outside of the six kilometre wide band modelled and contains uncertainty in the mixing depth.

It is recommended that airshed modelling be carried out to assess the effect of airport emissions. This would allow more thorough treatment of the broadly distributed airport associated emissions than is possible using the box model employed for the work carried out to date.

Uncertainties in the depth of mixing of air pollutant emissions affect the assessment of ozone impacts. It is recommended that boundary layer profiling be carried out over a summer season for each of the candidate airport sites to resolve this uncertainty.

No background monitoring of air quality at the sites of the Holsworthy Options has been carried out. It is strongly recommended, while these sites remain under consideration for Sydney Second Airport, that the following continuous air quality and meteorological monitoring be carried out:

- continuous monitoring of meteorology wind speed and direction;
- measurement of the vertical temperature and wind profile during winter and summer;
- continuous monitoring of ozone and nitrogen dioxide concentrations;
- monitoring of particulate concentration by establishment of high volume samples at each site; and
- monitoring of ozone chemistry using an specialist equipment such as the AIRTRAK device which measures oxides of nitrogen and particulates.



A number of these monitoring functions are served by the Environment Protection Authority monitoring station at Bringelly and wind speed monitoring carried out at Badgerys Creek by the Bureau of Meteorology., however there is significant uncertainty regarding the vertical temperature and wind profile during the year at Badgerys Creek.

As is an important factor in prediction of ozone impacts, it is recommended that a program for monitoring the upper wind profile using remote sensing equipment such as electromagnetic radar or radio-acoustic sounding systems be carried out over a twelve month period at Badgerys Creek, while the Badgerys Creek airport options remain under consideration.

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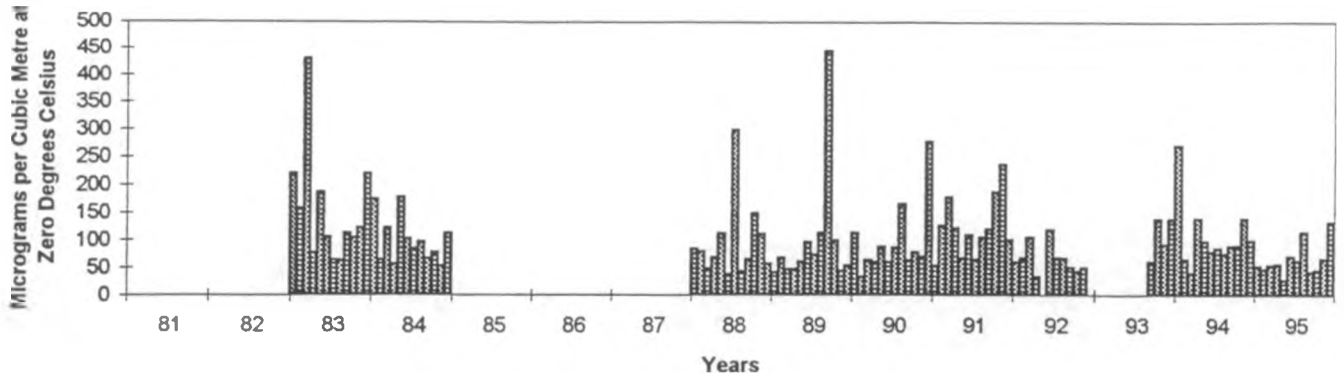
# Appendices

## **Appendix A**

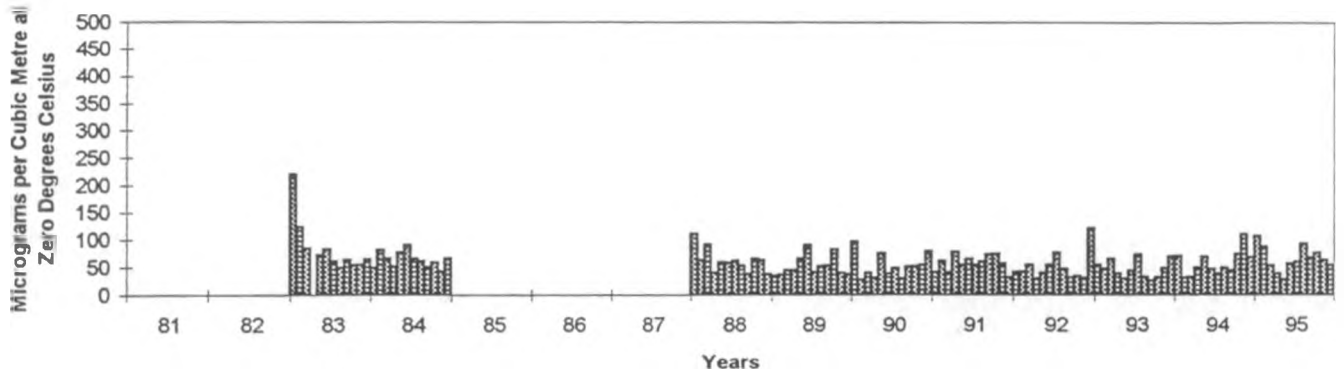
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Environment Protection Authority  
Sampling Results

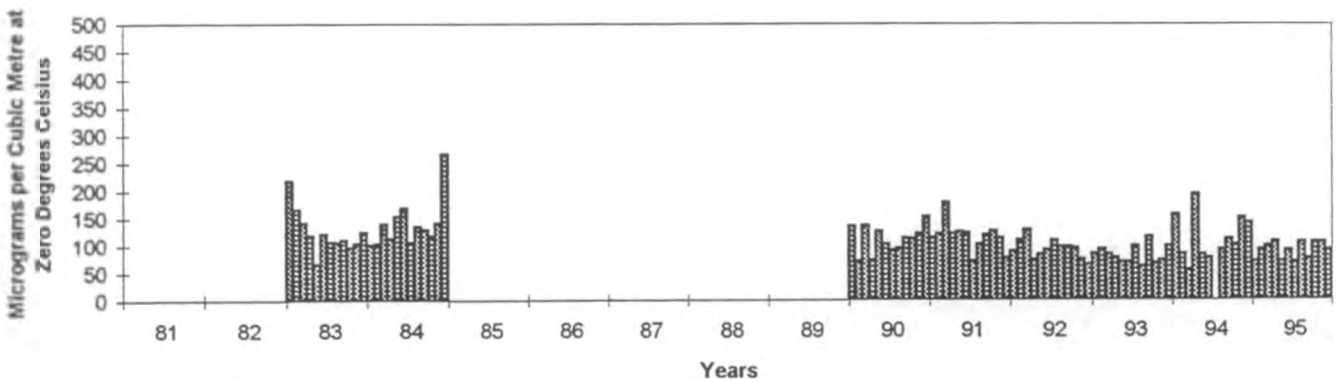
Earlwood TSP : Maximum 24 Hour TSP Level each Month



Rozelle TSP : Maximum 24 Hour TSP Level each Month



SYDNEY (1) TSP : Maximum 24 Hour TSP Level each Month



Source: NSW EPA, Quarterly Air Quality Monitoring Reports.

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Environment \* Geotechnics \* Mining \* Water Resources

A.C.J.I. 003 692 016

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approved	
date	29/01/97
scale	AS SHOWN

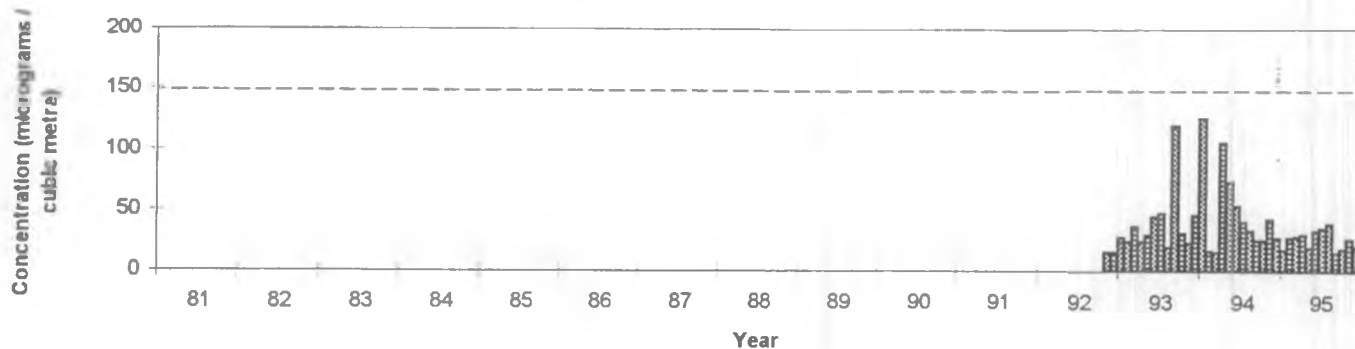
SECOND SYDNEY AIRPORT EIS  
TOTAL SUSPENDED PARTICULATES (TSP)  
MONTHLY MAXIMA OF 24 HOUR SAMPLES



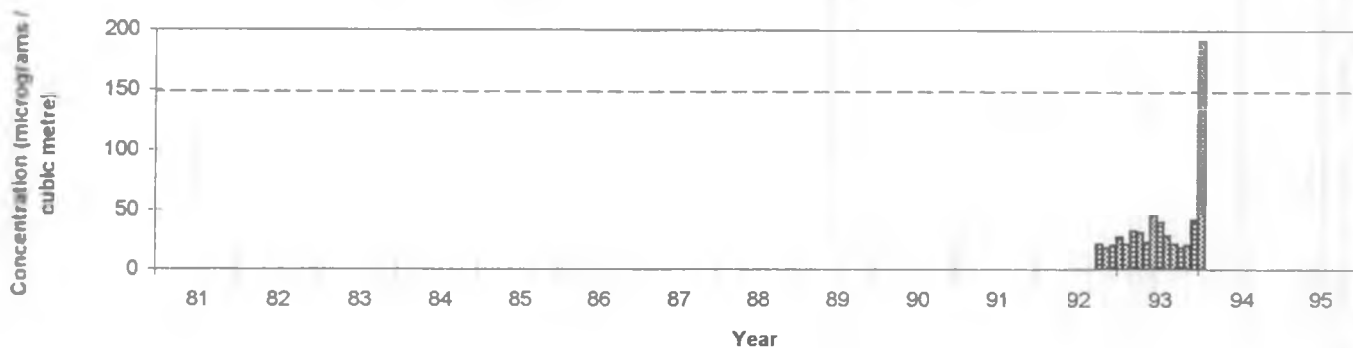
FIGURE A1

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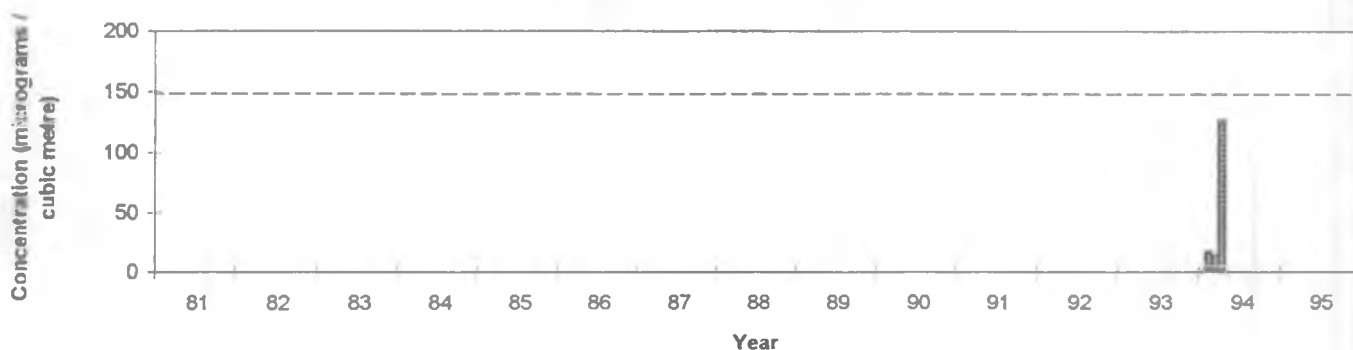
**Blacktown Particulate Matter < 10micrometres :  
Maximum 24 hour Level Each Month**



**Bringelly Particulate Matter < 10micrometres :  
Maximum 24 hour Level Each Month**



**Campbelltown Particulate Matter < 10micrometres :  
Maximum 24 hour Level Each Month**



----- Current EPA Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports.

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scale	AS SHOWN

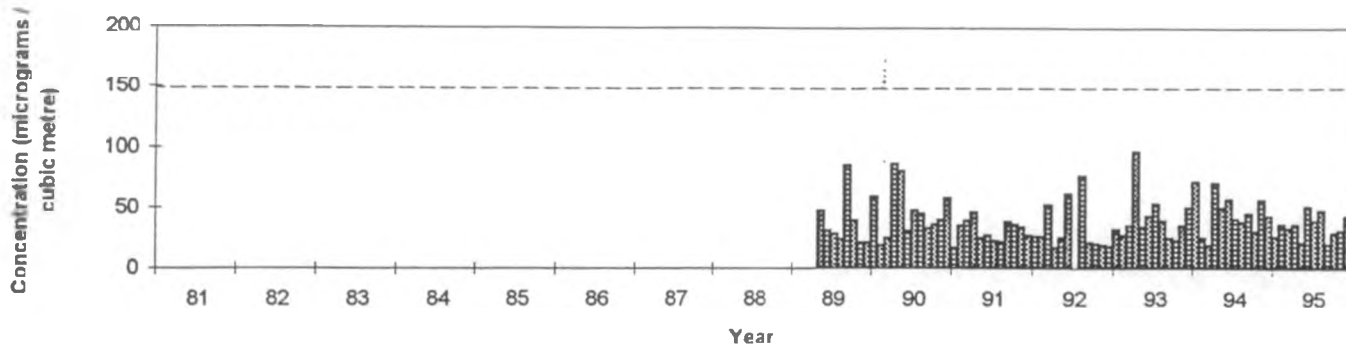
**SECOND SYDNEY AIRPORT EIS  
PARTICULATE MATTER LESS THAN 10 MICROMETRES  
MAXIMUM 24 HOUR LEVEL EACH MONTH**



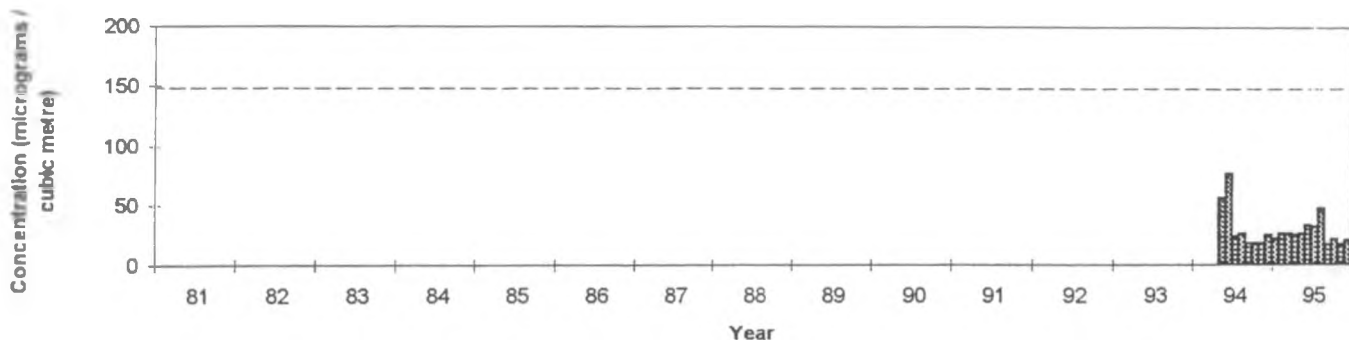
**FIGURE A2**

job no: E2057/1-D/A

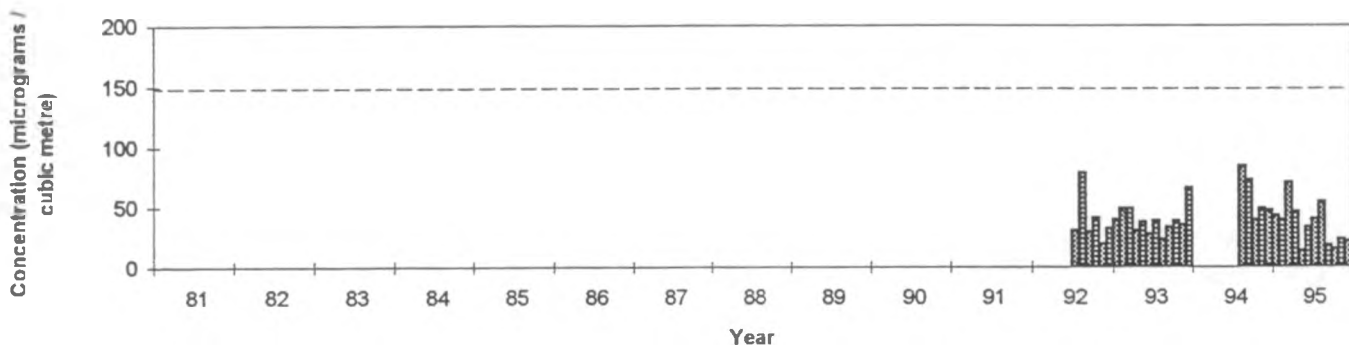
**Earlwood Particulate Matter < 10micrometres :  
Maximum 24 hour Level Each Month**



**Lindfield Particulate Matter < 10micrometres :  
Maximum 24 hour Level Each Month**



**Richmond Particulate Matter < 10micrometres :  
Maximum 24 hour Level Each Month**



----- Current EPA Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports.

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Environment • Geotechnics • Mining • Water Resources

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date	29/01/97
scale	AS SHOWN

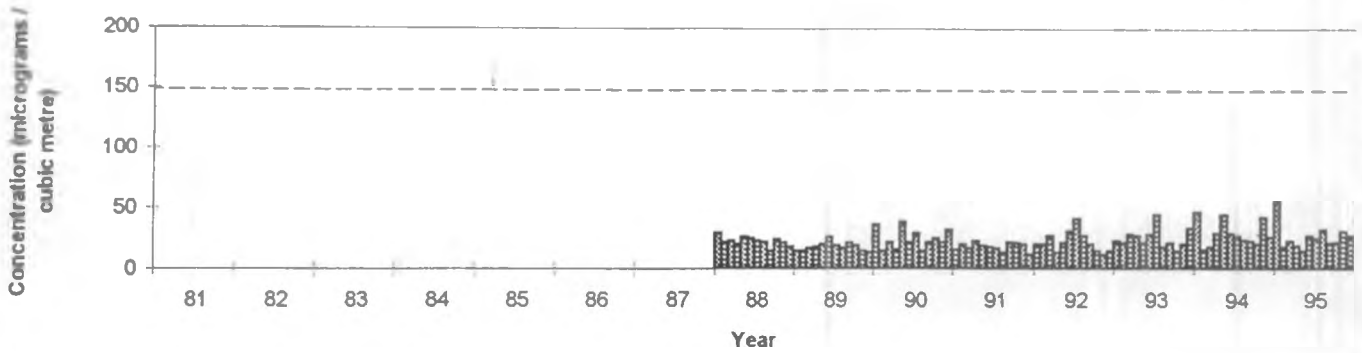
**SECOND SYDNEY AIRPORT EIS  
PARTICULATE MATTER LESS THAN 10 MICROMETRES  
MAXIMUM 24 HOUR LEVEL EACH MONTH**



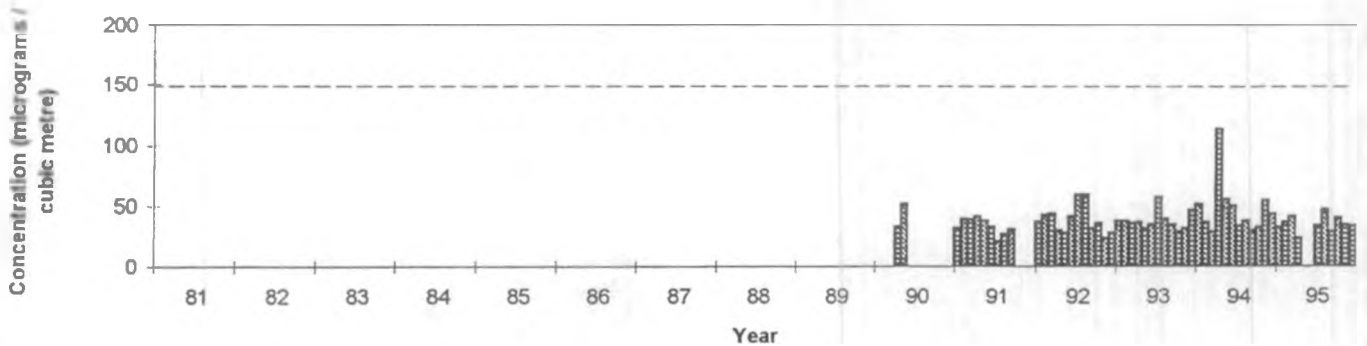
**FIGURE A3**

job no: E2057/1-DA

**Rozelle Particulate Matter < 10micrometres :  
Maximum 24 hour Level Each Month**



**Sydney (1) Particulate Matter < 10micrometres :  
Maximum 24 hour Level Each Month**



----- Current EPA Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports.

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scale	AS SHOWN

**SECOND SYDNEY AIRPORT EIS  
PARTICULATE MATTER LESS THAN 10 MICROMETRES  
MAXIMUM 24 HOUR LEVEL EACH MONTH**



**FIGURE A4**

job no: E2057/1-D4

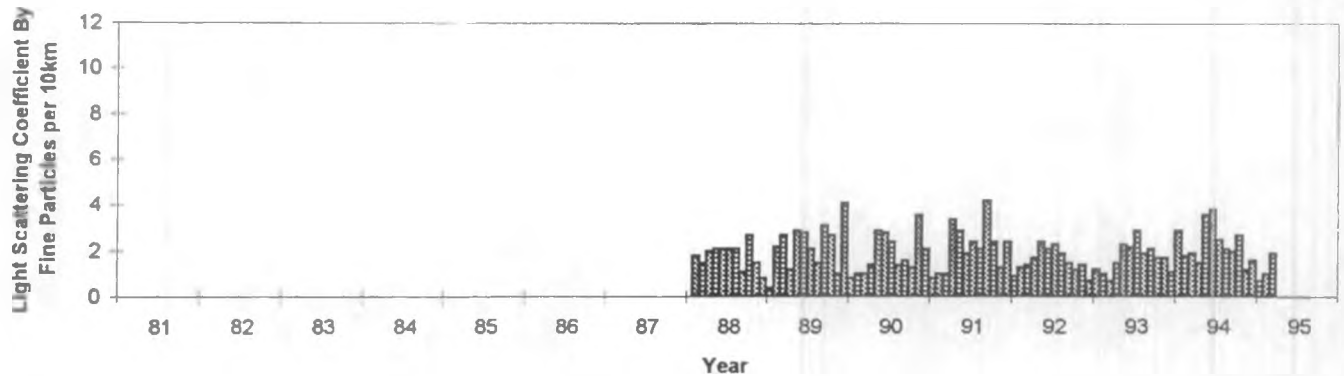
Year	Light Scattering Coefficient By Fine Particles per 10km
81	0
82	0
83	0
84	0
85	0
86	0
87	0
88	0
89	0
90	0
91	0
92	0
93	0
94	10
95	10

The bar chart displays the Light Scattering Coefficient by Fine Particles per 10km for each year from 1981 to 1995. The y-axis is labeled 'Light Scattering Coefficient By Fine Particles per 10km' and ranges from 0 to 12. The x-axis is labeled 'Year' and ranges from 81 to 95. Data is only present for the years 1992 through 1995. The values show a general upward trend with significant fluctuations, peaking in 1993 at approximately 9.6.

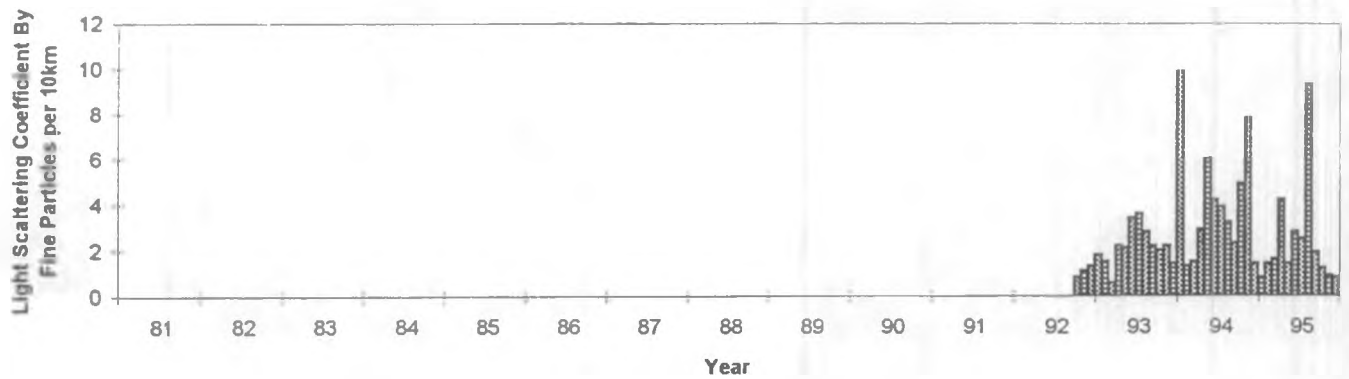
Year	Light Scattering Coefficient by Fine Particles per 10km
1992	1.5
1993	9.6
1994	7.2
1995	6.1

Year	Light Scattering Coefficient
1981	0.0
1982	0.0
1983	0.0
1984	0.0
1985	0.0
1986	0.0
1987	0.0
1988	0.0
1989	0.0
1990	0.0
1991	0.0
1992	0.5
1993	9.5
1994	2.5
1995	1.5

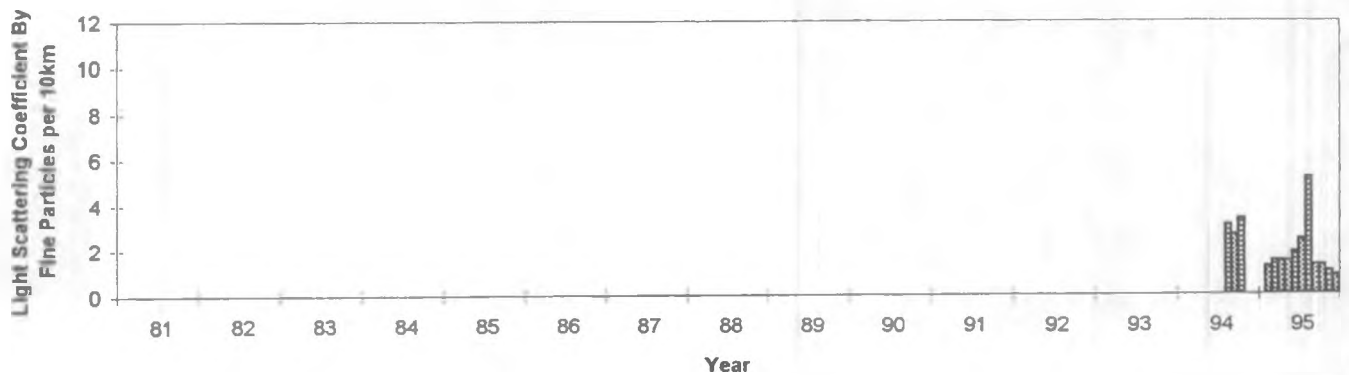
### Kensington Suspended Matter : Maximum One Hour Level each Month



### Liverpool Suspended Matter : Maximum One Hour Level each Month



### Randwick Suspended Matter : Maximum One Hour Level each Month



Source: NSW EPA, Quarterly Air Quality Monitoring Reports.

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date	29/01/97
scale	AS SHOWN

SECOND SYDNEY AIRPORT EIS  
SUSPENDED MATTER (NEPHELOMETER)  
MAXIMUM ONE HOUR LEVEL EACH MONTH

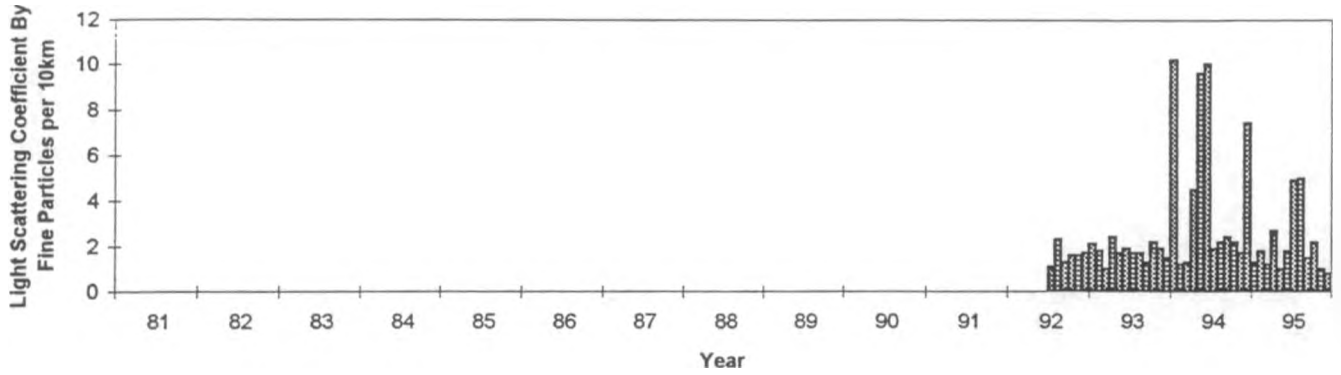


**FIGURE A6**

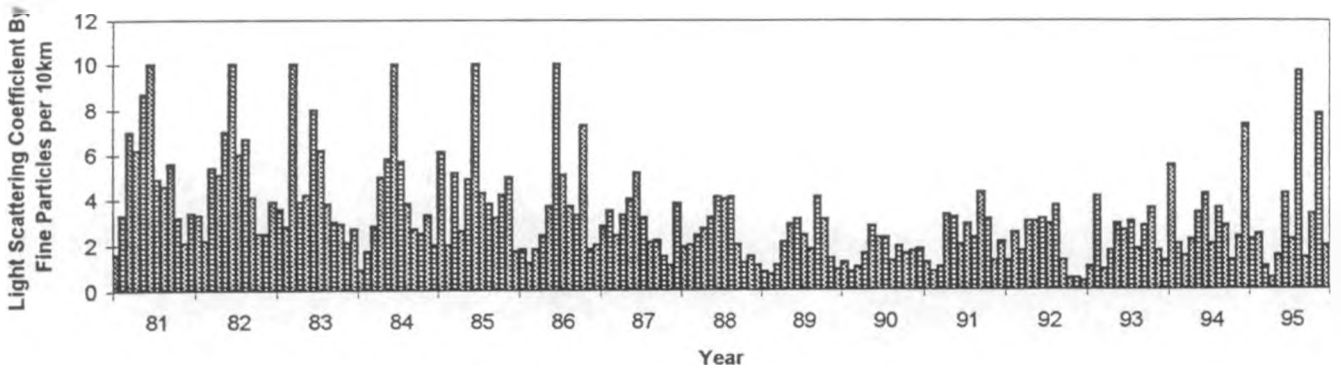
job no: E2057/1-D/



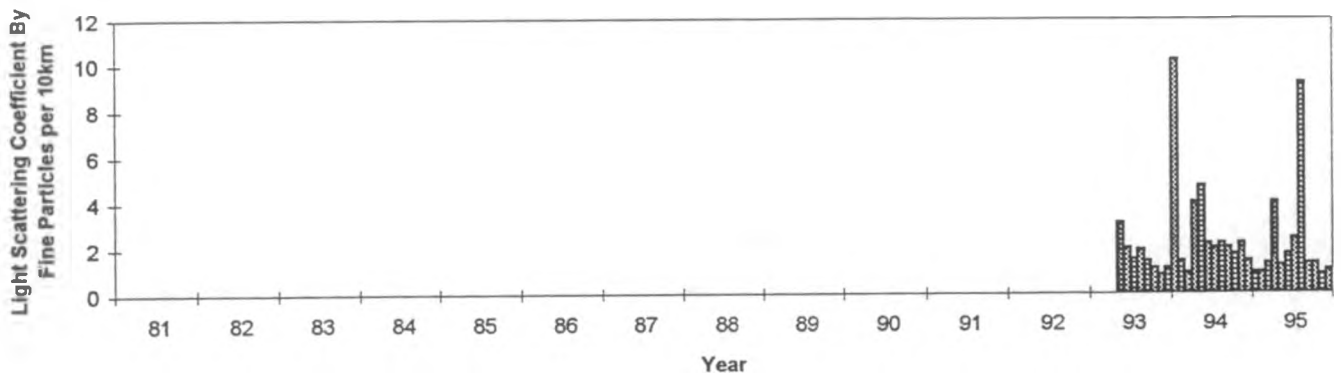
### Richmond Suspended Matter : Maximum One Hour Level each Month



### Rozelle Suspended Matter : Maximum One Hour Level each Month



### St Marys Suspended Matter : Maximum One Hour Level each Month



Source: NSW EPA, Quarterly Air Quality Monitoring Reports.

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date	29/01/97
scale	AS SHOWN

SECOND SYDNEY AIRPORT EIS  
SUSPENDED MATTER (NEPHELOMETER)  
MAXIMUM ONE HOUR LEVEL EACH MONTH



FIGURE A7

job no: E2057/1-DA

[illegible]

The bar chart illustrates the annual light scattering coefficient by fine particles per 10km from 1981 to 1995. The Y-axis, labeled 'Light Scattering Coefficient By Fine Particles per 10km', ranges from 0 to 12. The X-axis, labeled 'Year', shows years from 81 to 95. The data shows significant variability, with major peaks occurring around 1985 (reaching approximately 10), 1986 (reaching approximately 10), 1989 (reaching approximately 6.5), and 1993 (reaching approximately 10.5). There are also smaller peaks in 1983, 1984, 1987, 1988, 1990, 1991, 1992, 1994, and 1995. The lowest values are generally seen in the early 1980s and mid-1980s, often dropping to near zero.

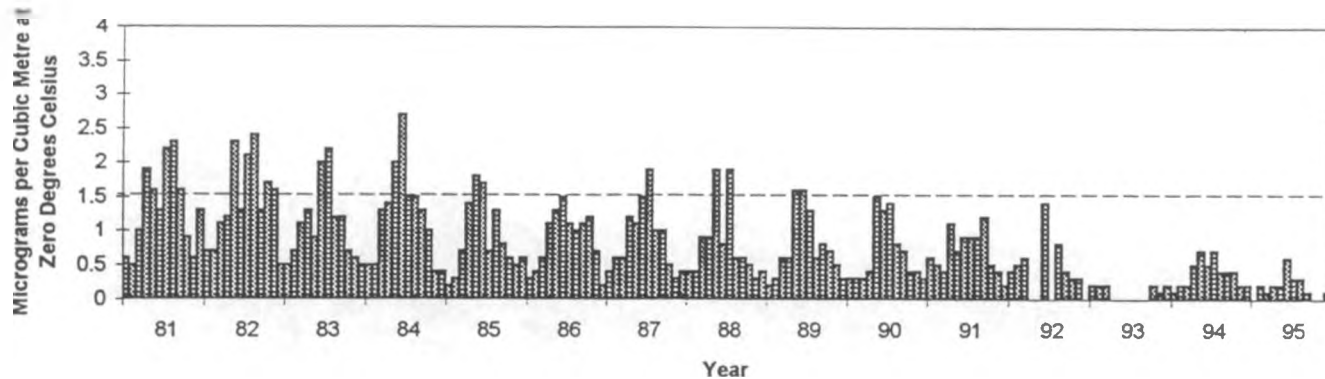
The bar chart illustrates the annual light scattering coefficient by fine particles per 10km from 1981 to 1995. The Y-axis, labeled 'Light Scattering Coefficient By Fine Particles per 10km', ranges from 0 to 12. The X-axis, labeled 'Year', shows years from 81 to 95. The data shows significant variability, with several years reaching values above 4, and a peak near 10 in 1985 and 1994. Error bars are present for each data point.

Year	Light Scattering Coefficient (approx.)
81	0.0
82	0.0
83	0.0
84	2.3
85	10.0
86	10.0
87	3.2
88	3.5
89	1.8
90	2.1
91	9.7
92	2.5
93	3.4
94	10.4
95	2.5

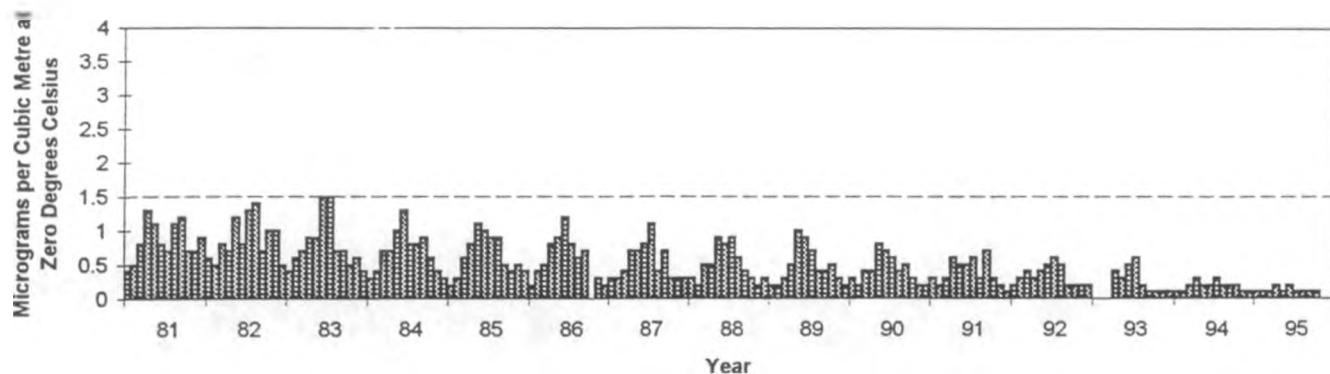
A.C.N 003 692 019

job no: E2057/1-DA

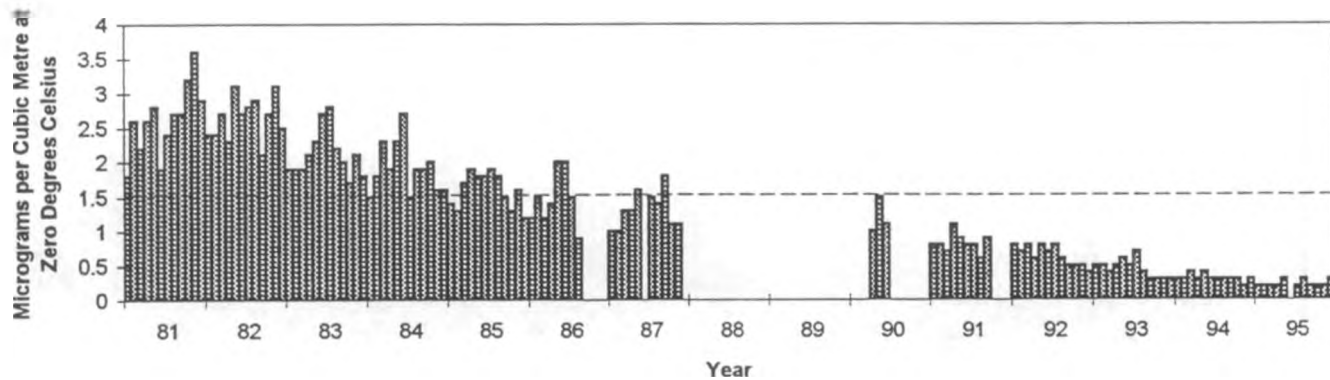
Earlwood Lead : Monthly Average of 24 Hour Samples



Rozelle Lead : Monthly Average of 24 Hour Samples



Sydney (1) Lead : Monthly Average of 24 Hour Samples



----- Current Epa Goal

Source: NSW EPA Quarterly Air Quality Monitoring Reports

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scale	AS SHOWN

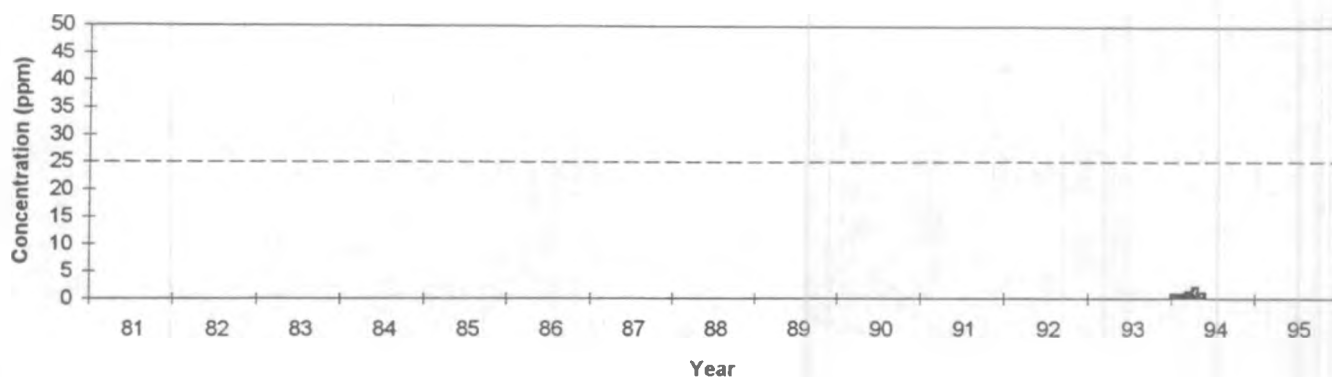
SECOND SYDNEY AIRPORT EIS  
LEAD LEVELS  
MONTHLY AVERAGE OF 24 HOUR LEAD LEVELS



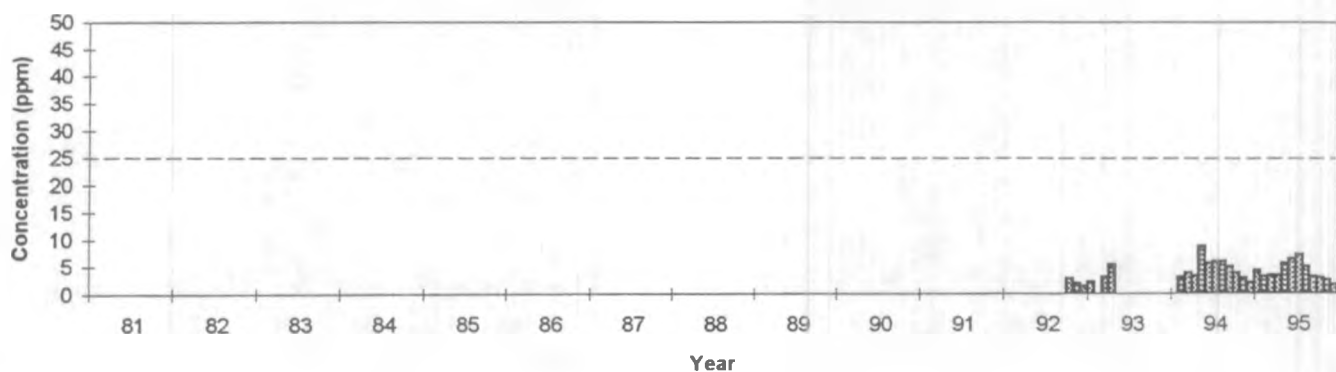
**FIGURE A9**

job no: E2057/1-DA

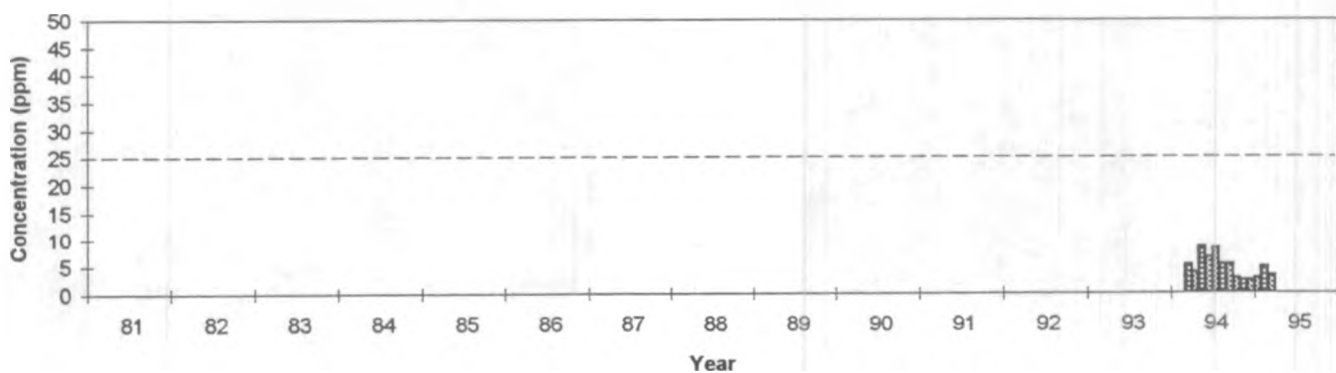
### Appin Carbon Monoxide : Maximum One Hour Level each Month



### Blacktown Carbon Monoxide : Maximum One Hour Level each Month



### Kensington Carbon Monoxide : Maximum One Hour Level each Month



----- World Health Organisation Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports

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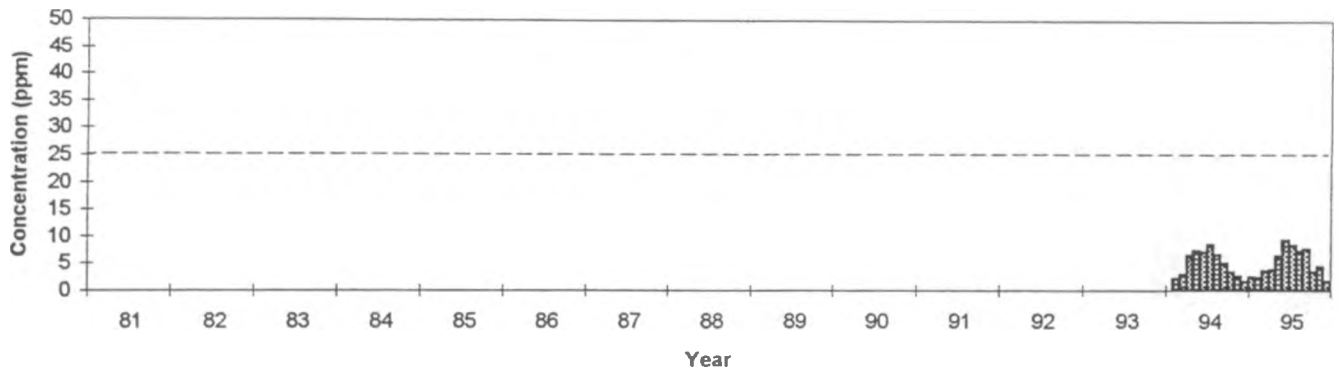
SECOND SYDNEY AIRPORT EIS  
CARBON MONOXIDE LEVELS  
MAXIMUM ONE HOUR LEVEL EACH MONTH



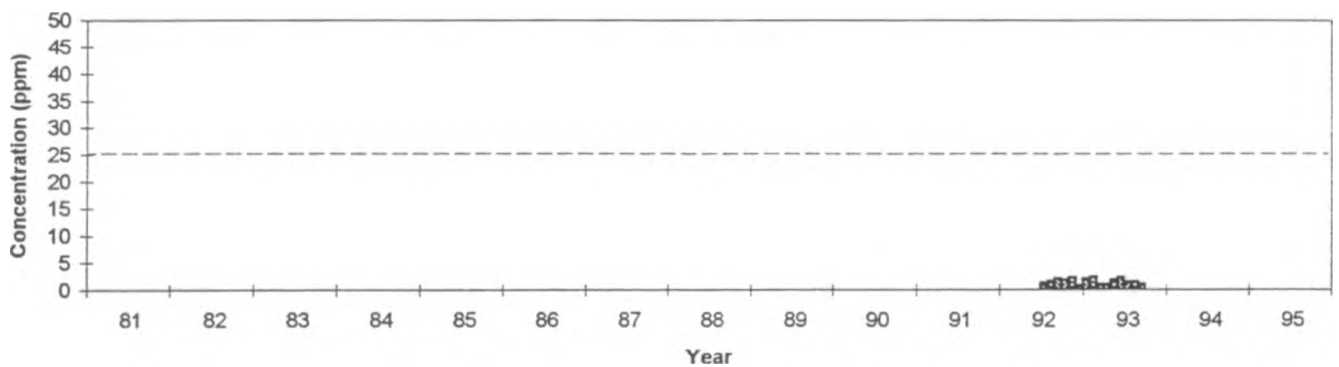
**FIGURE A10**

job no: E2057/1-DA

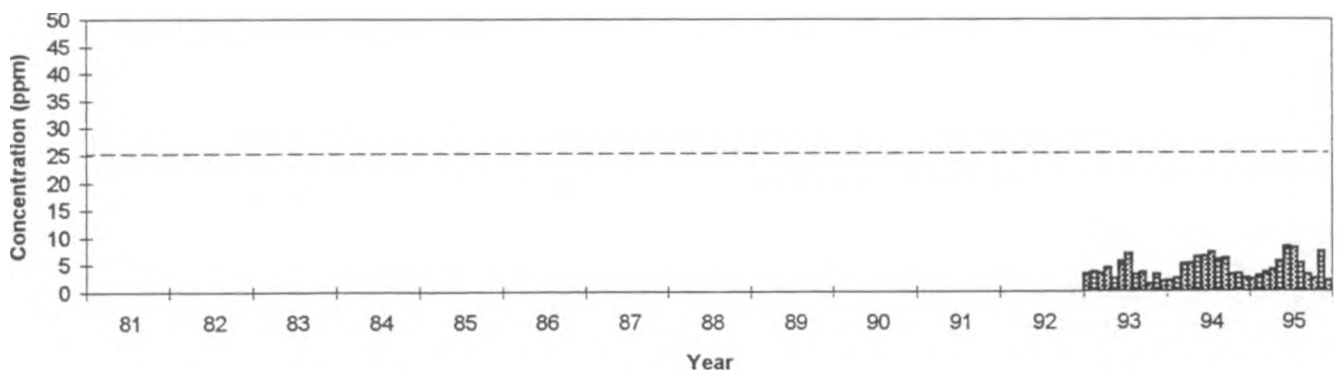
### Liverpool Carbon Monoxide : Maximum One Hour Level each Month



### Richmond Carbon Monoxide : Maximum One Hour Level each Month



### Rozelle Carbon Monoxide : Maximum One Hour Level each Month



World Health Organisation Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports

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date	29/01/97
scale	AS SHOWN

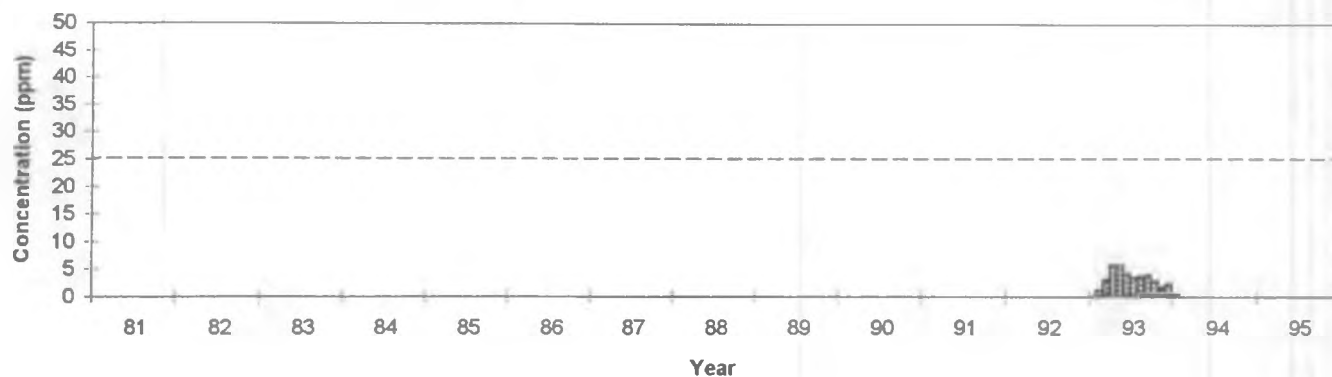
SECOND SYDNEY AIRPORT EIS  
CARBON MONOXIDE LEVELS  
MAXIMUM ONE HOUR LEVEL EACH MONTH



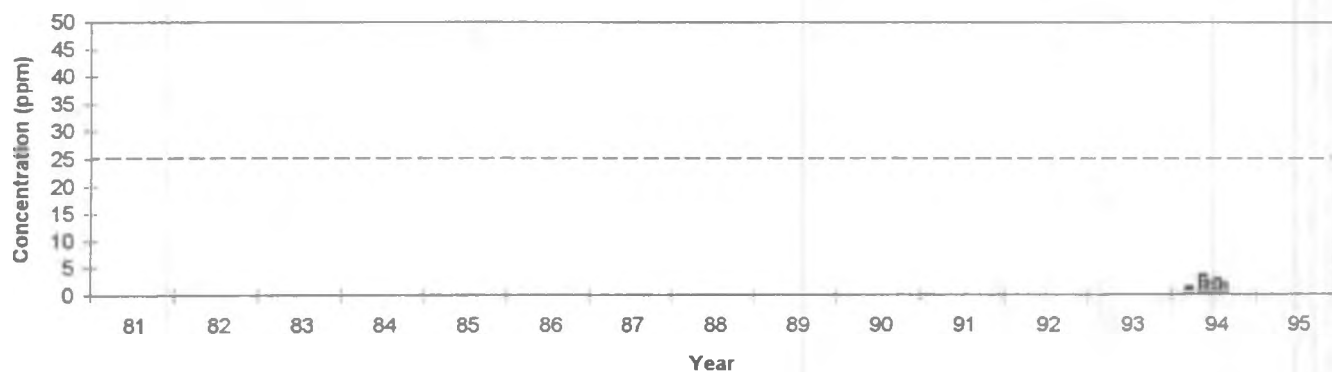
**FIGURE A11**

job no: E2057/1-DA

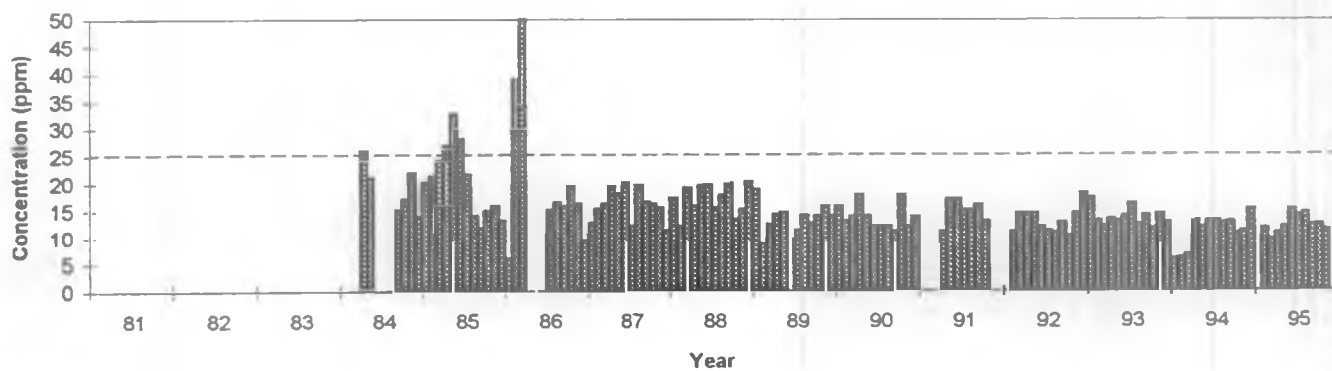
### St Marys Carbon Monoxide : Maximum One Hour Level each Month



### Vineyard Carbon Monoxide : Maximum One Hour Level each Month



### Sydney (1) Carbon Monoxide : Maximum One Hour Level each Month



----- World Health Organisation Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports

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scale	AS SHOWN

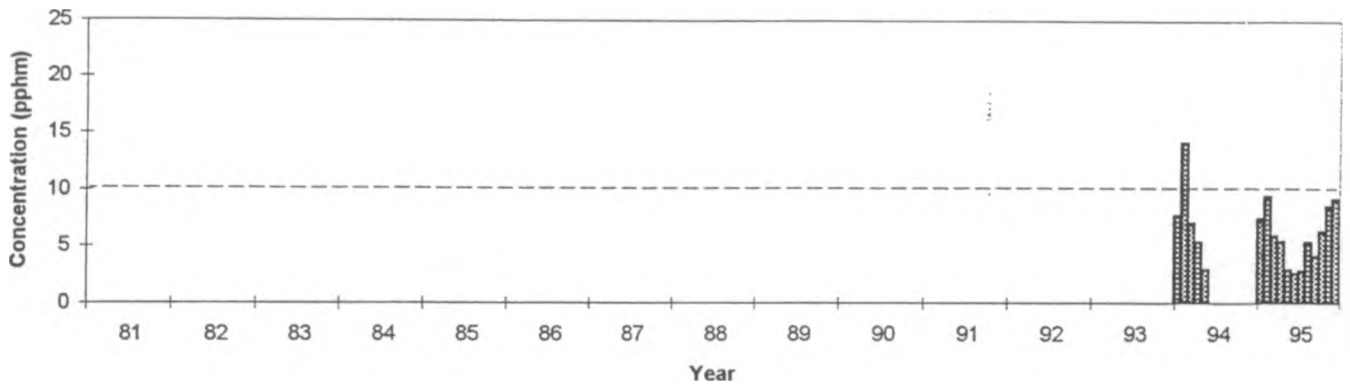
SECOND SYDNEY AIRPORT EIS  
CARBON MONOXIDE LEVELS  
MAXIMUM ONE HOUR LEVEL EACH MONTH



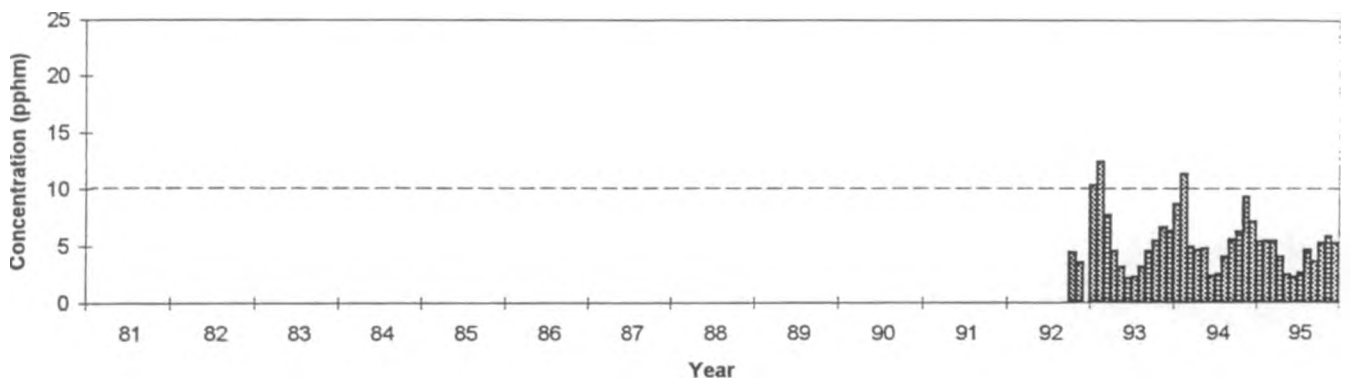
**FIGURE A12**

job no: E2057/1-DA

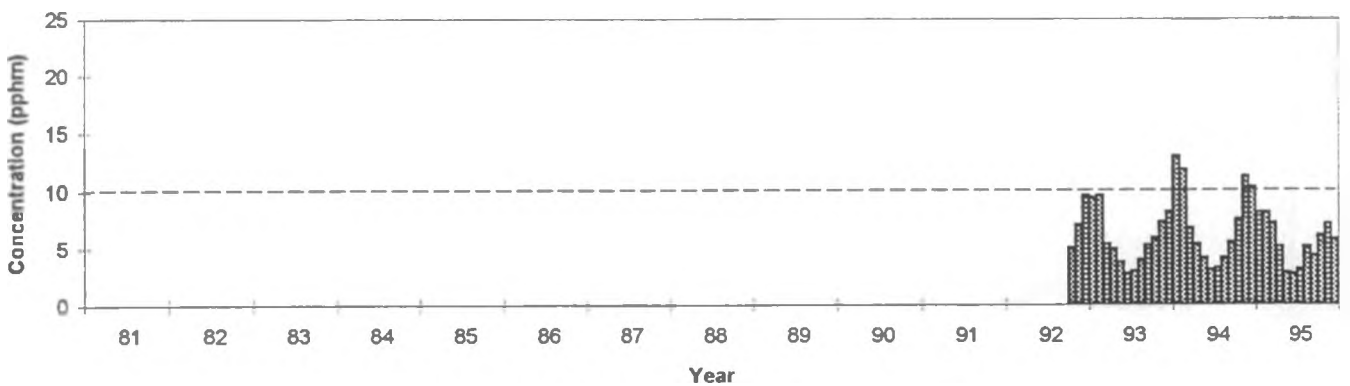
Appin Ozone : Maximum One Hour Ozone Level each Month



Blacktown Ozone : Maximum One Hour Ozone Level each Month



Bringelly Ozone : Maximum One Hour Ozone Level each Month



Current EPA Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports.

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scale	AS SHOWN

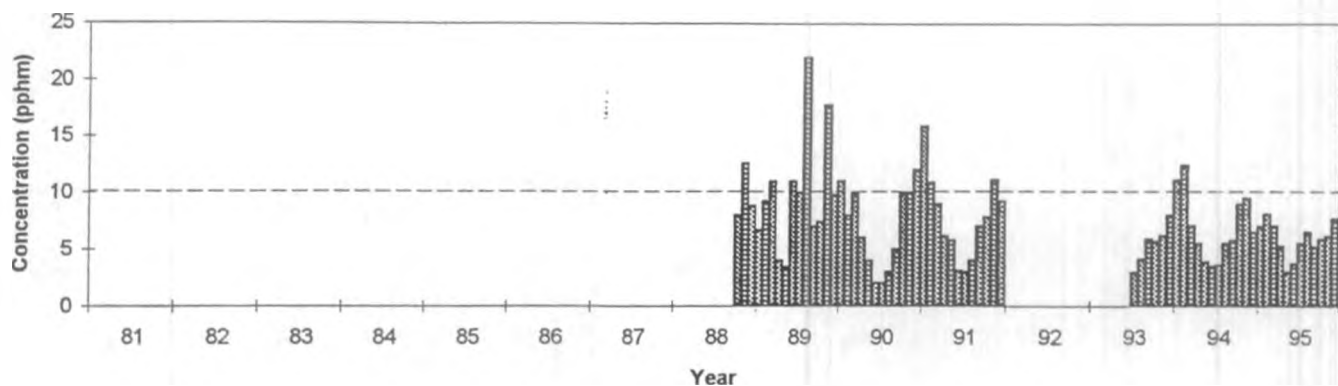
SECOND SYDNEY AIRPORT EIS  
OZONE LEVELS  
MAXIMUM ONE HOUR OZONE LEVEL EACH MONTH



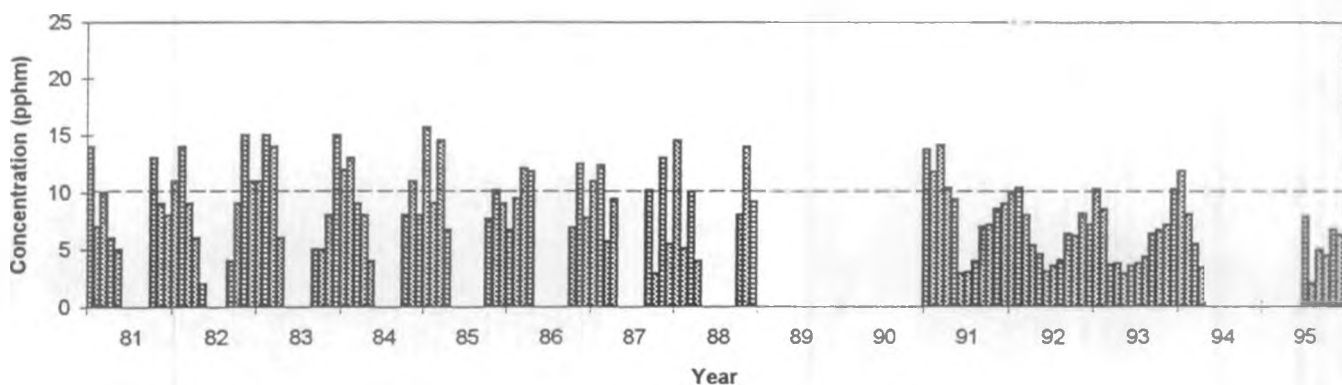
FIGURE A13

job no: E2057/1-DA

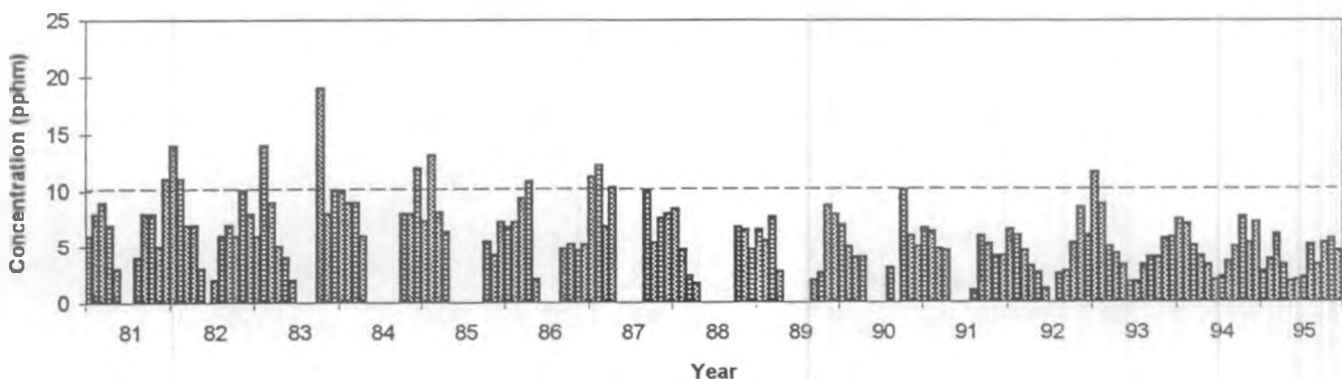
**Camden Ozone : Maximum One Hour Ozone Level each Month**



**Cambelltown Ozone : Maximum One Hour Ozone Level each Month**



**Earlwood Ozone : Maximum One Hour Ozone Level each Month**



----- Current EPA Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports.

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scale	AS SHOWN

SECOND SYDNEY AIRPORT EIS  
OZONE LEVELS

MAXIMUM ONE HOUR OZONE LEVEL EACH MONTH

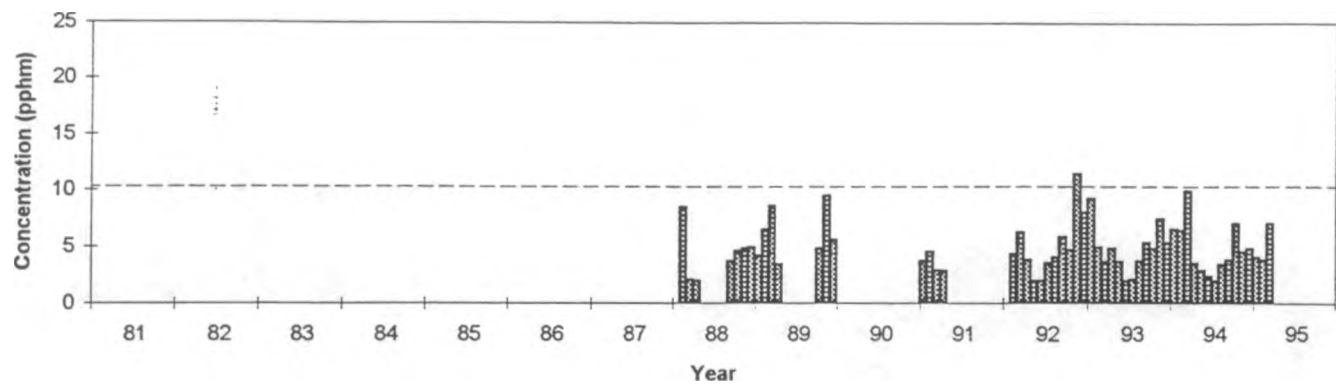


**FIGURE A14**

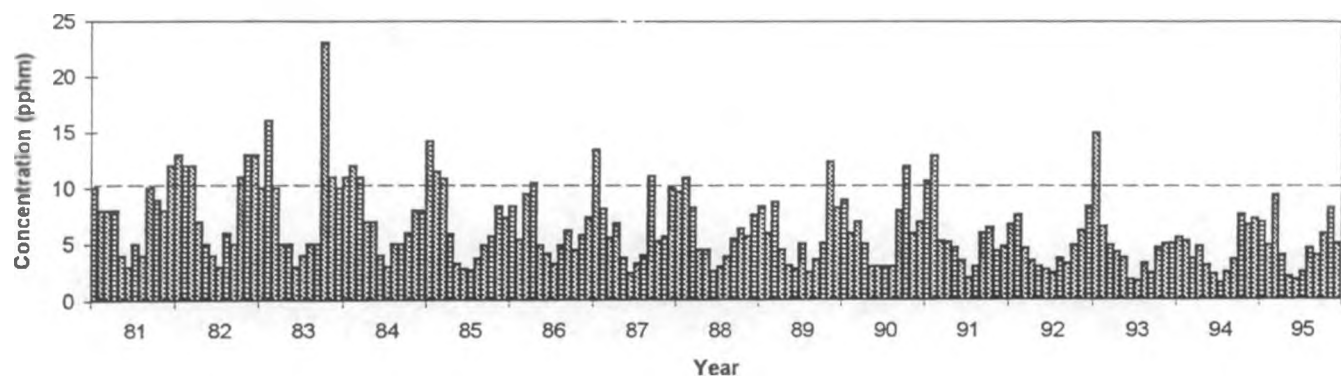
job no: E2057/1-DA



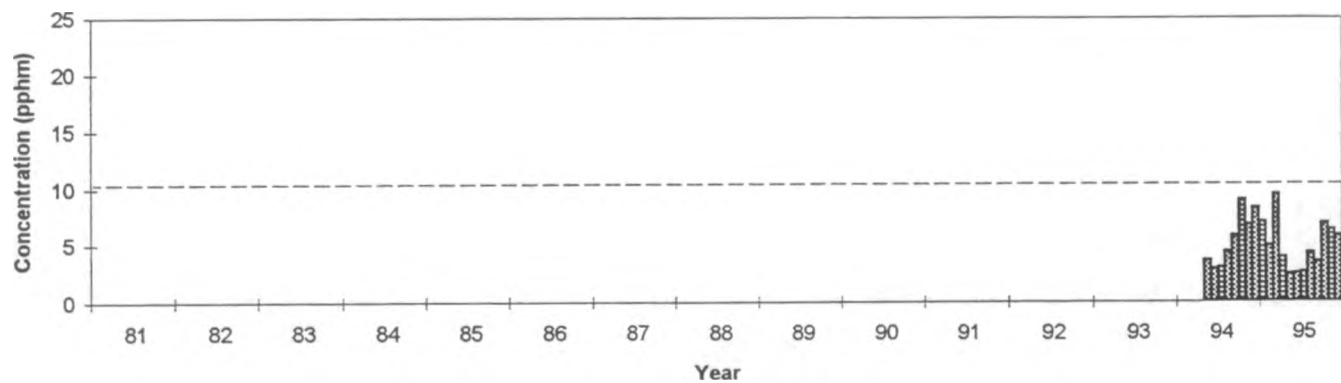
Kensington Ozone : Maximum One Hour Ozone Level each Month



Lidcombe Ozone : Maximum One Hour Ozone Level each Month



Lindfield Ozone : Maximum One Hour Ozone Level each Month



Current EPA Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports.

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date	28/01/97
scale	AS SHOWN

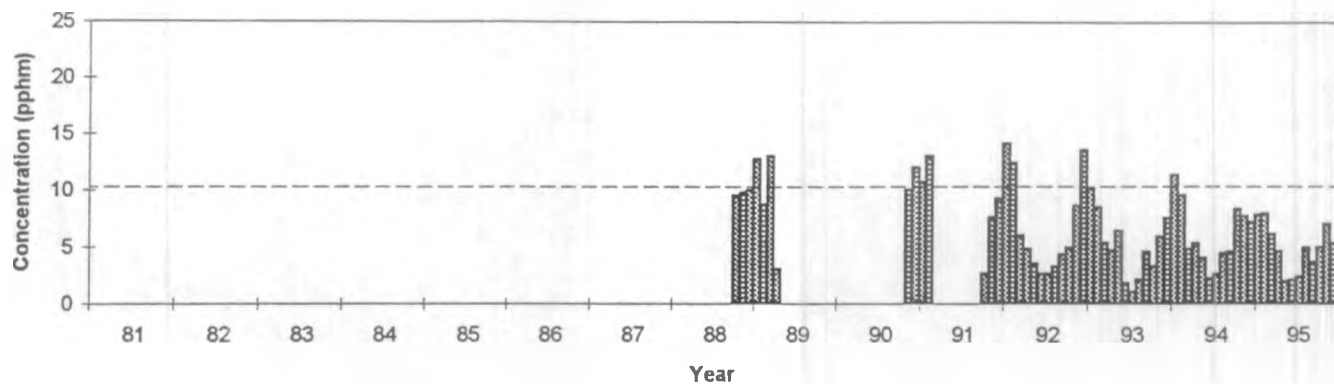
SECOND SYDNEY AIRPORT EIS  
OZONE LEVELS  
MAXIMUM ONE HOUR OZONE LEVEL EACH MONTH



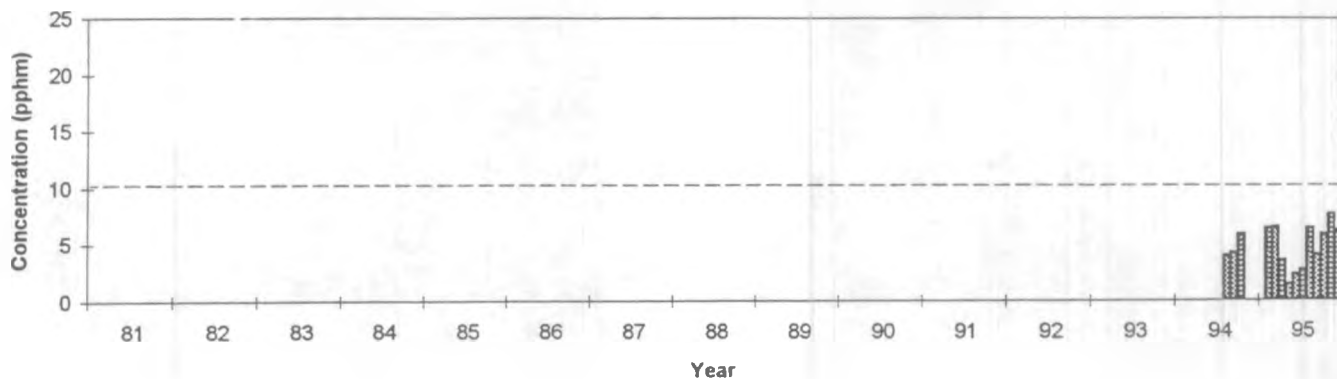
FIGURE A15

job no: E2057/1-DA

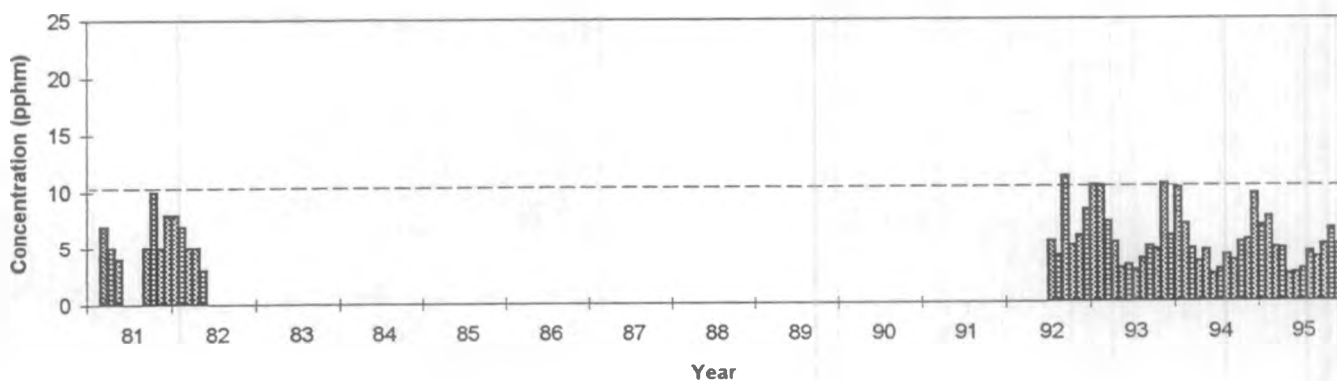
Liverpool Ozone : Maximum One Hour Ozone Level each Month



Randwick Ozone : Maximum One Hour Ozone Level each Month



Richmond Ozone : Maximum One Hour Ozone Level each Month



----- Current EPA Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports.

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scale	AS SHOWN

SECOND SYDNEY AIRPORT EIS  
OZONE LEVELS

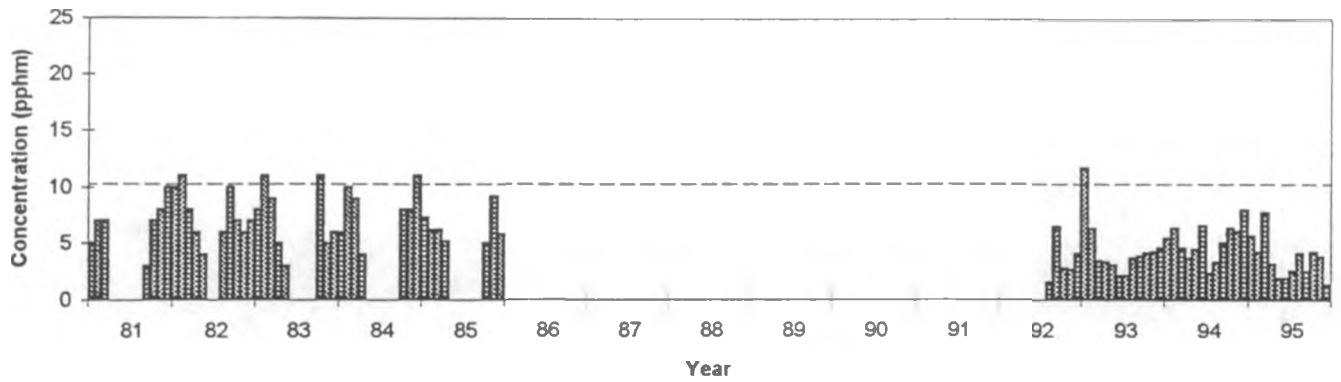
MAXIMUM ONE HOUR OZONE LEVEL EACH MONTH



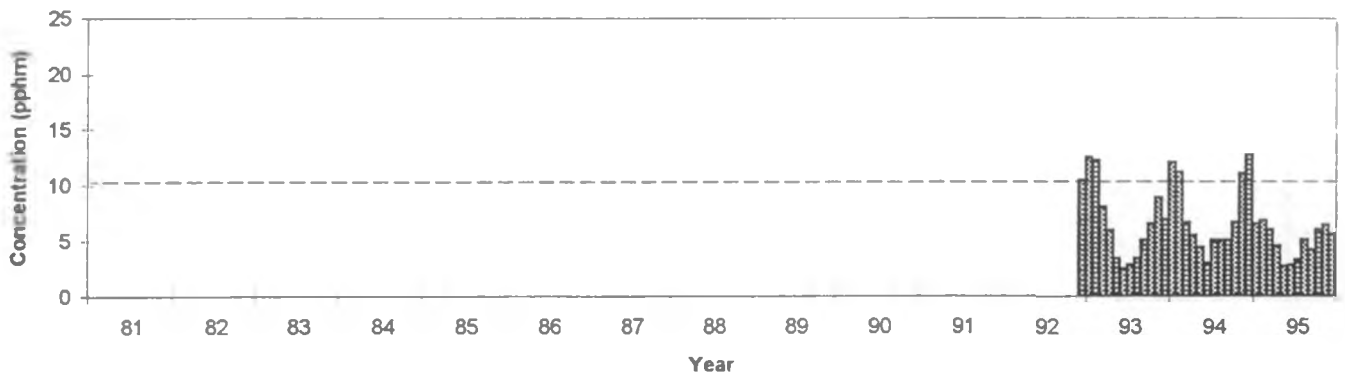
FIGURE A16

job no: E2057/1-D

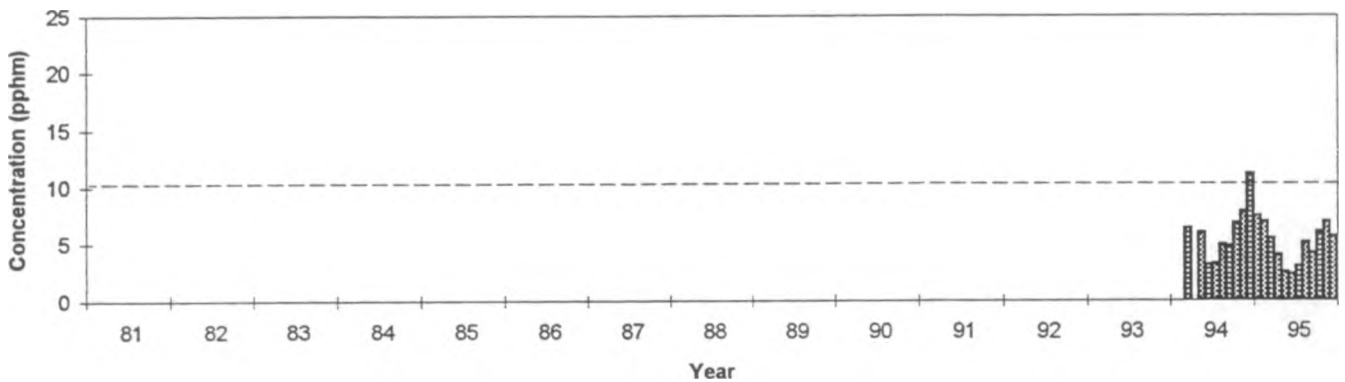
Rozelle Ozone : Maximum One Hour Ozone Level each Month



St Marys Ozone : Maximum One Hour Ozone Level each Month



Vineyard Ozone : Maximum One Hour Ozone Level each Month



----- Current EPA Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports.

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date	28/01/97
scale	AS SHOWN

SECOND SYDNEY AIRPORT EIS  
OZONE LEVELS

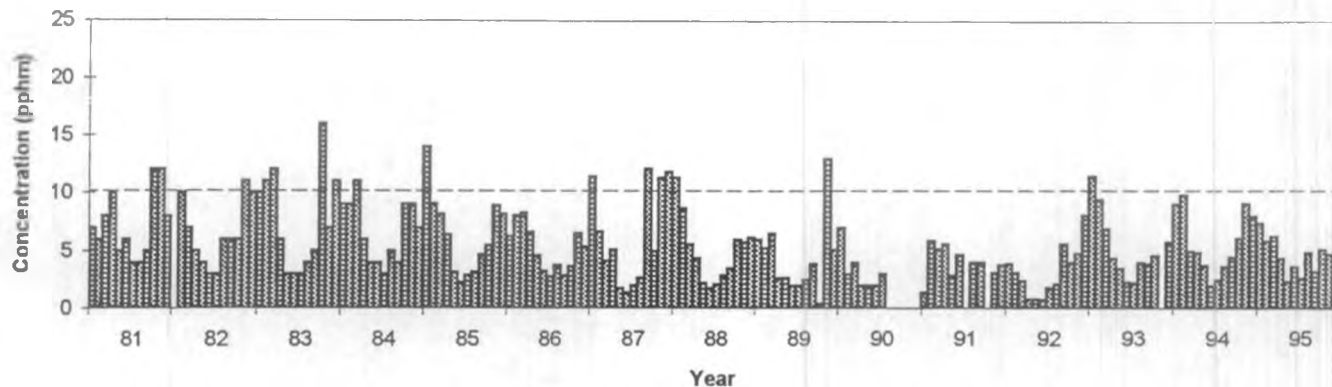
**MAXIMUM ONE HOUR OZONE LEVEL EACH MONTH**



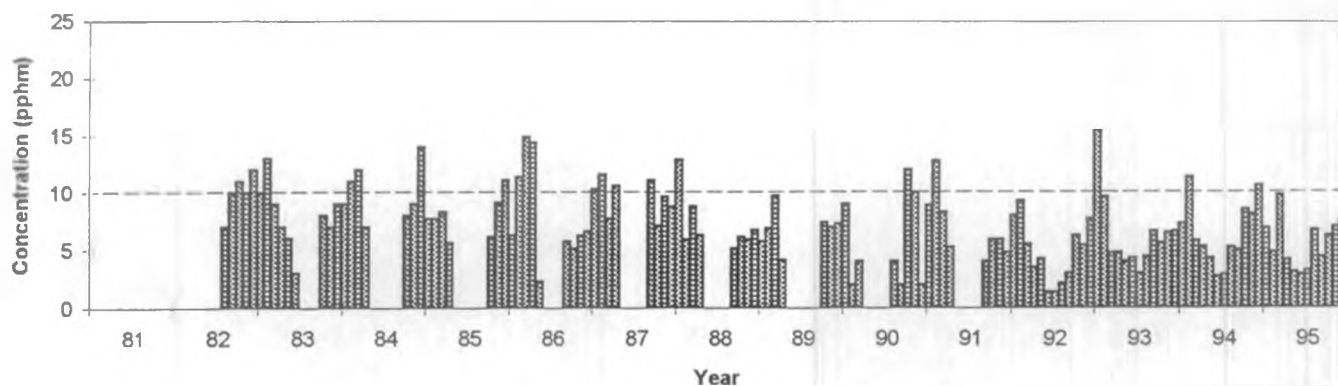
**FIGURE A17**

job no: E2057/1-DA

**Westmead Ozone : Maximum One Hour Ozone Level each Month**



**Woollooware Ozone : Maximum One Hour Ozone Level each Month**



----- Current EPA Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports.

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date	28/01/97
scale	AS SHOWN

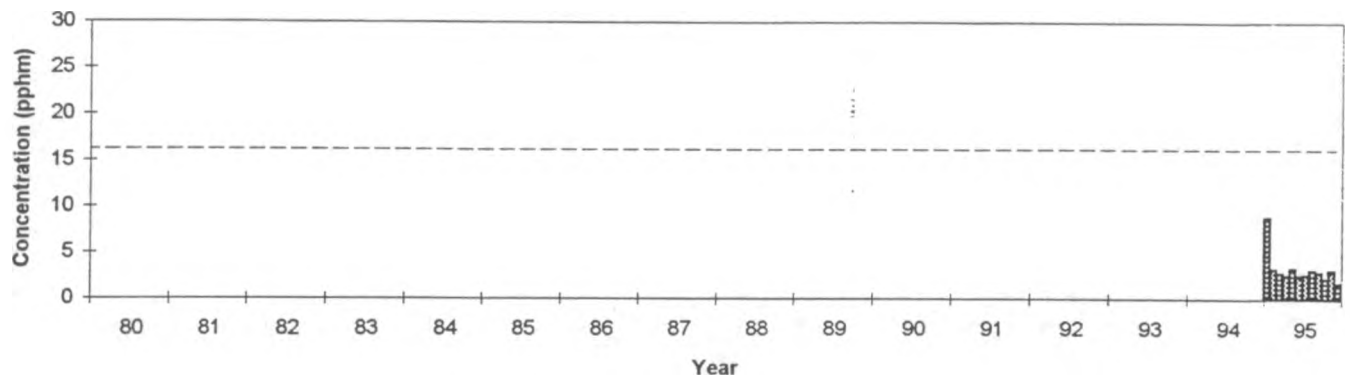
**SECOND SYDNEY AIRPORT EIS**  
**OZONE LEVELS**  
**MAXIMUM ONE HOUR OZONE LEVEL EACH MONTH**



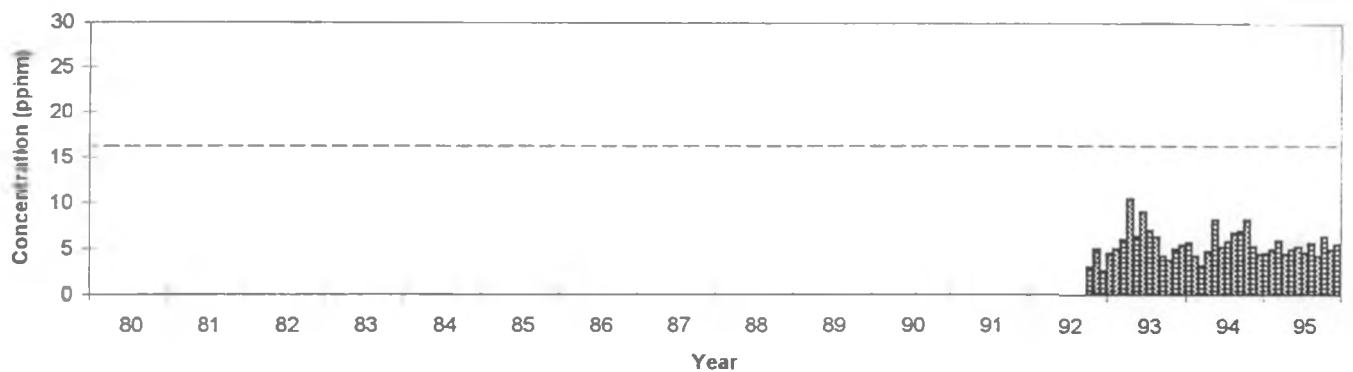
**FIGURE A18**

job no: E2057/1-DA

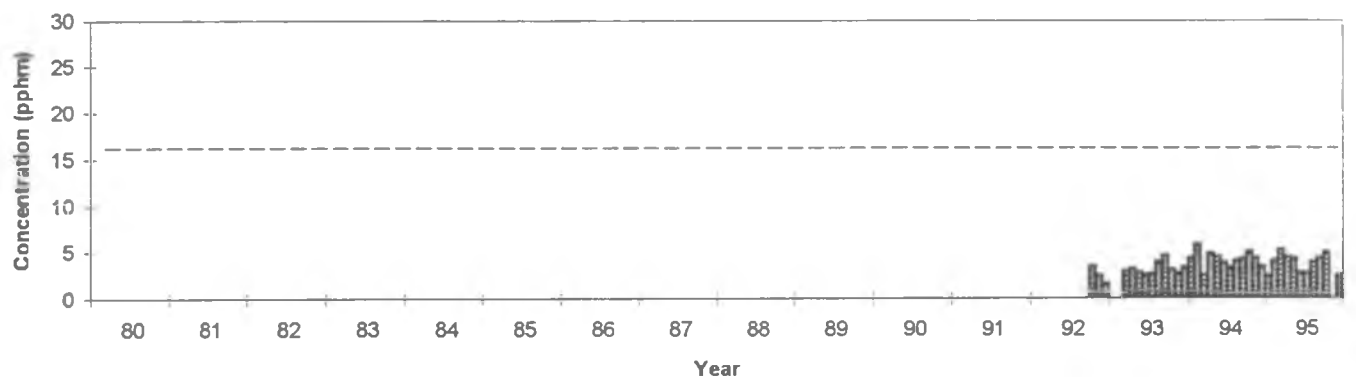
Appin NO2 : Maximum One Hour NO2 Level each Month



Blacktown NO2 : Maximum One Hour NO2 Level each Month



Bringelly NO2 : Maximum One Hour NO2 Level each Month



----- Current EPA Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports.

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date	29/01/97
scale	AS SHOWN

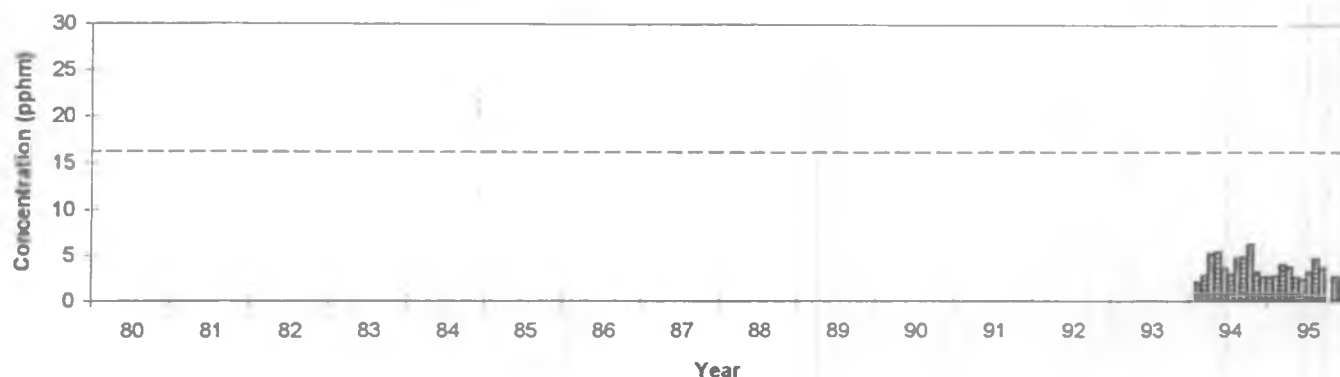
SECOND SYDNEY AIRPORT EIS  
NITROGEN DIOXIDE LEVELS  
MAXIMUM ONE HOUR LEVEL EACH MONTH



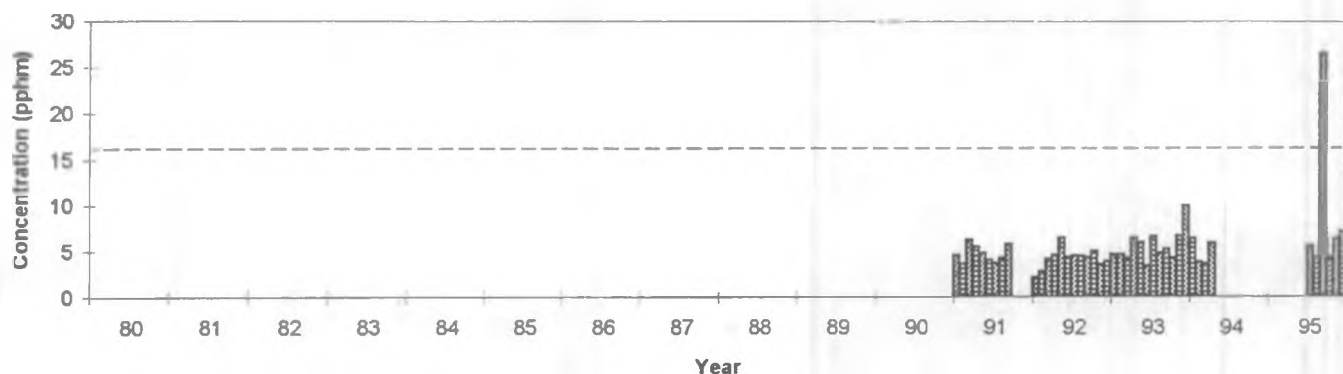
FIGURE A19

job no: E2057/1-DA

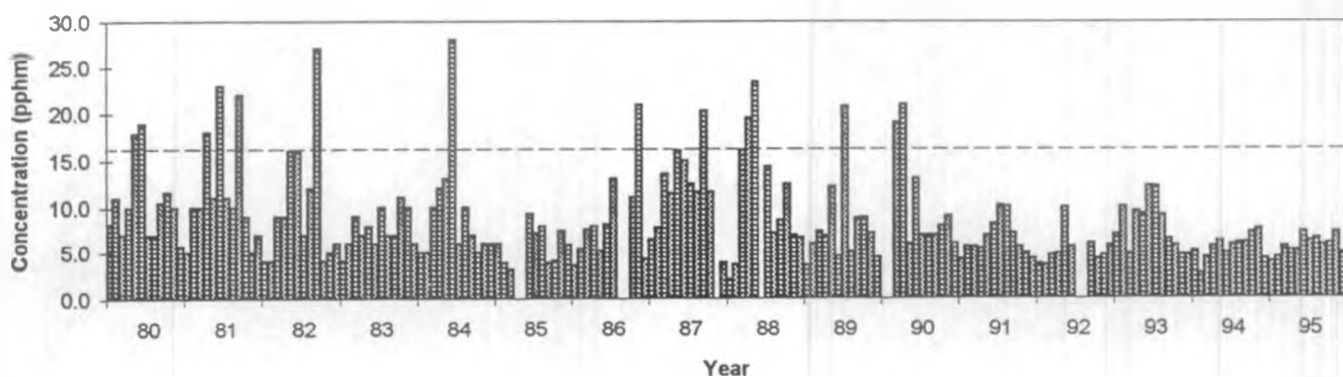
Camden NO2 : Maximum One Hour NO2 Level each Month



Campbelltown NO2 : Maximum One Hour NO2 Level each Month



Earlwood NO2 : Maximum One Hour NO2 Level each Month



----- Current EPA Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports.

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scale	AS SHOWN

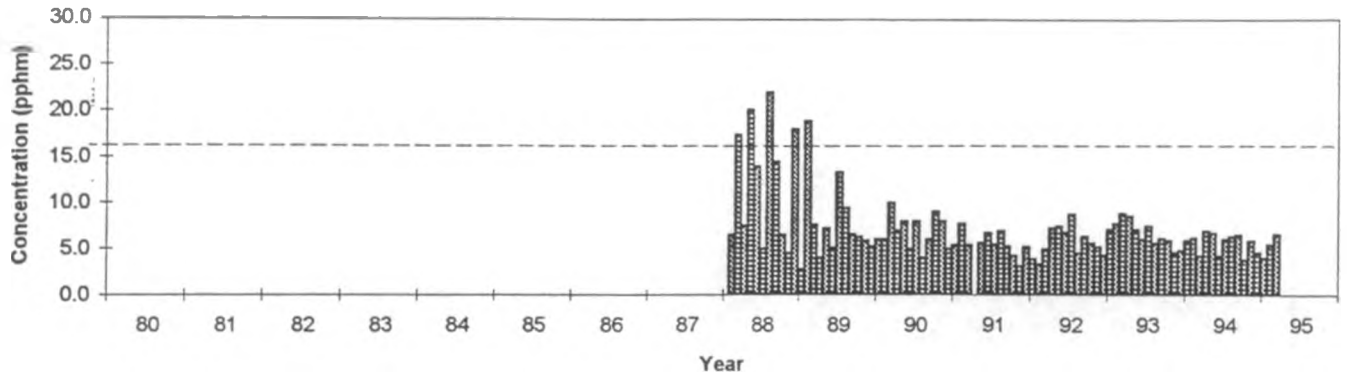
SECOND SYDNEY AIRPORT EIS  
NITROGEN DIOXIDE LEVELS  
MAXIMUM ONE HOUR LEVEL EACH MONTH



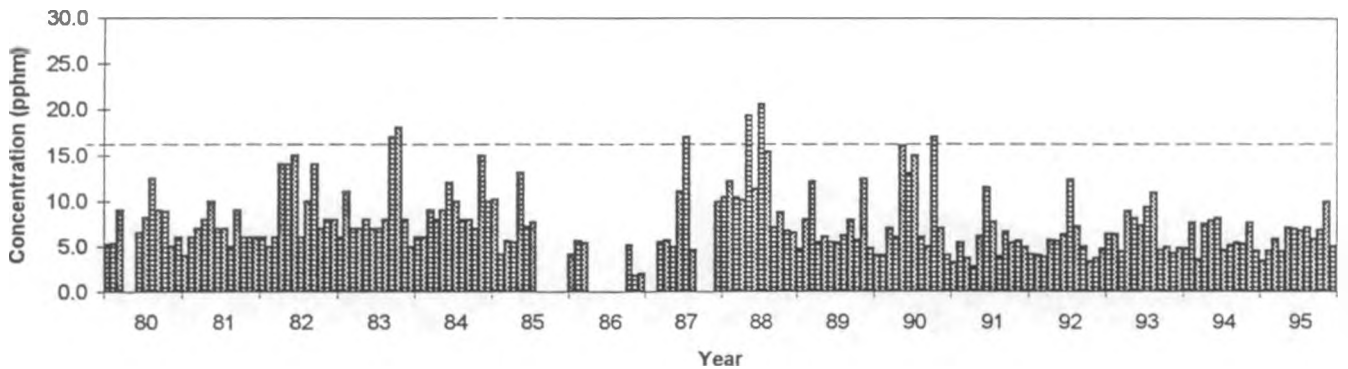
FIGURE A20

job no: E2057/1-DA

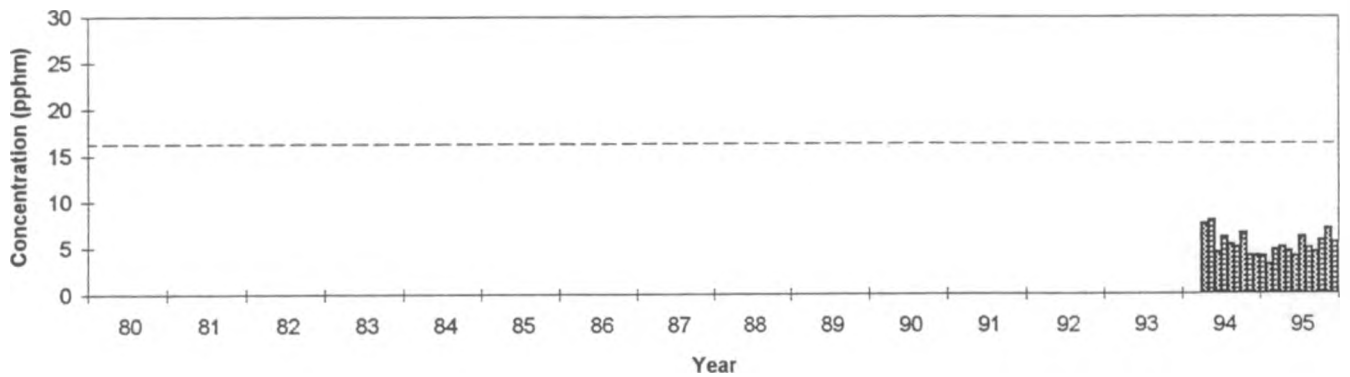
**Kensington NO2 : Maximum One Hour NO2 Level each Month**



**Lidcombe NO2 : Maximum One Hour NO2 Level each Month**



**Lindfield NO2 : Maximum One Hour NO2 Level each Month**



----- Current EPA Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports.

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approved	
date	29/01/97
scale	AS SHOWN

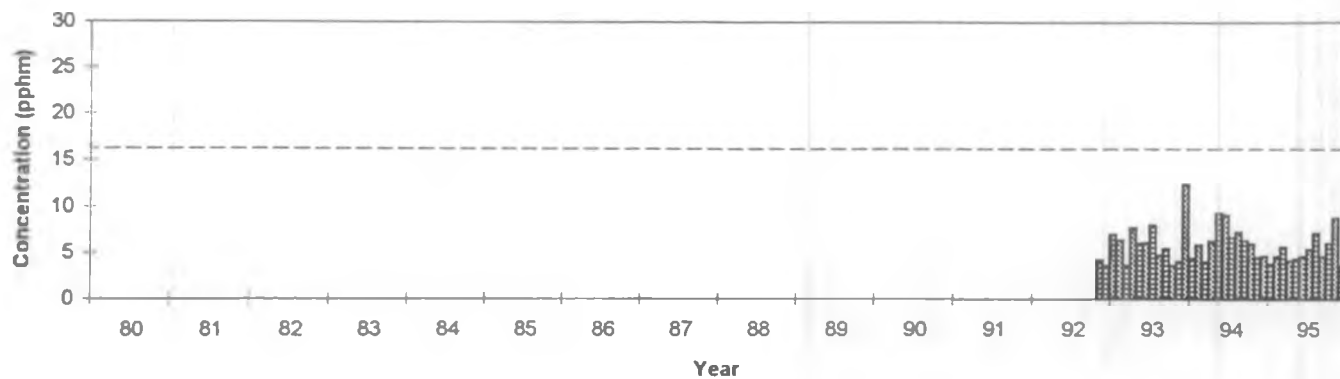
**SECOND SYDNEY AIRPORT EIS  
NITROGEN DIOXIDE LEVELS  
MAXIMUM ONE HOUR LEVEL EACH MONTH**



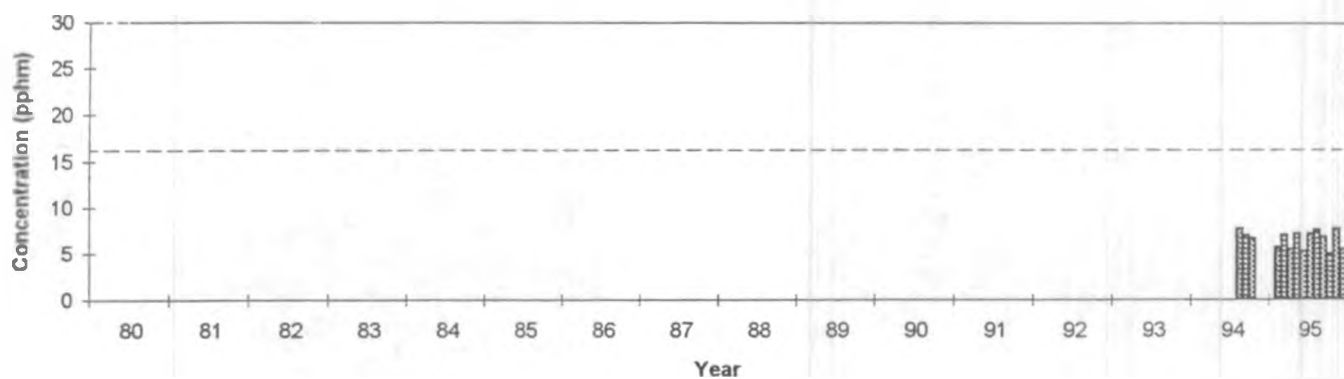
**FIGURE A21**

job no: E2057/1-DA

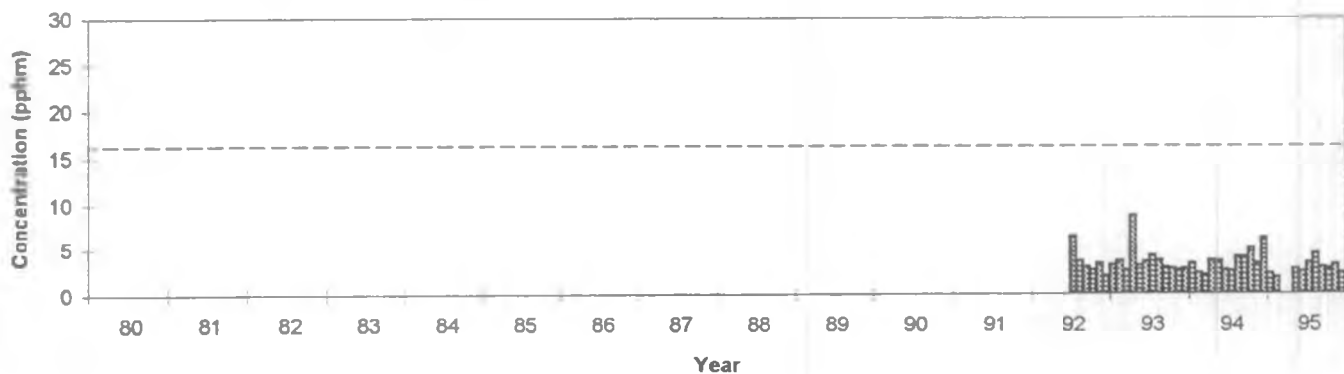
**Liverpool NO2 : Maximum One Hour NO2 Level each Month**



**Randwick NO2 : Maximum One Hour NO2 Level each Month**



**Richmond NO2 : Maximum One Hour NO2 Level each Month**



----- Current EPA Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports.

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drawn	JVDV
approved	
date	29/01/97
scale	AS SHOWN

**SECOND SYDNEY AIRPORT EIS  
NITROGEN DIOXIDE LEVELS  
MAXIMUM ONE HOUR LEVEL EACH MONTH**

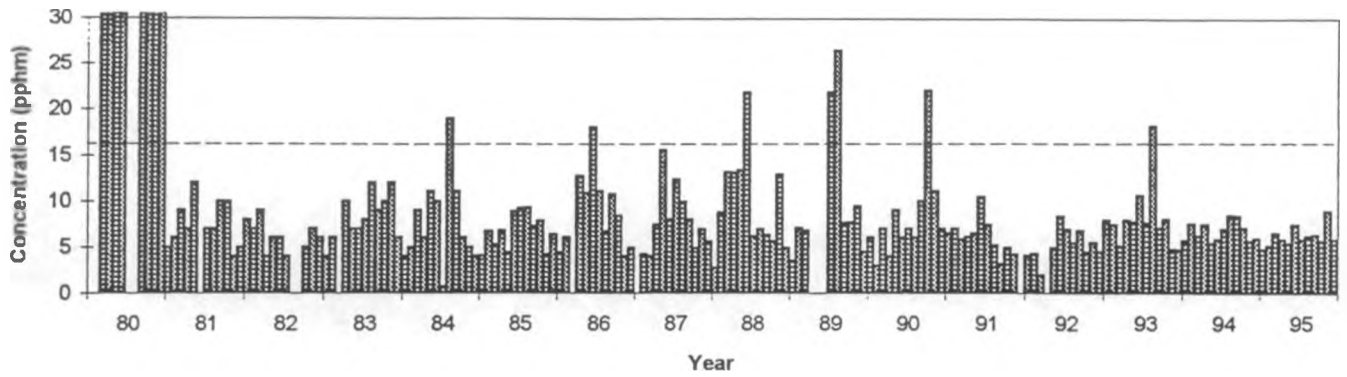


**FIGURE A22**

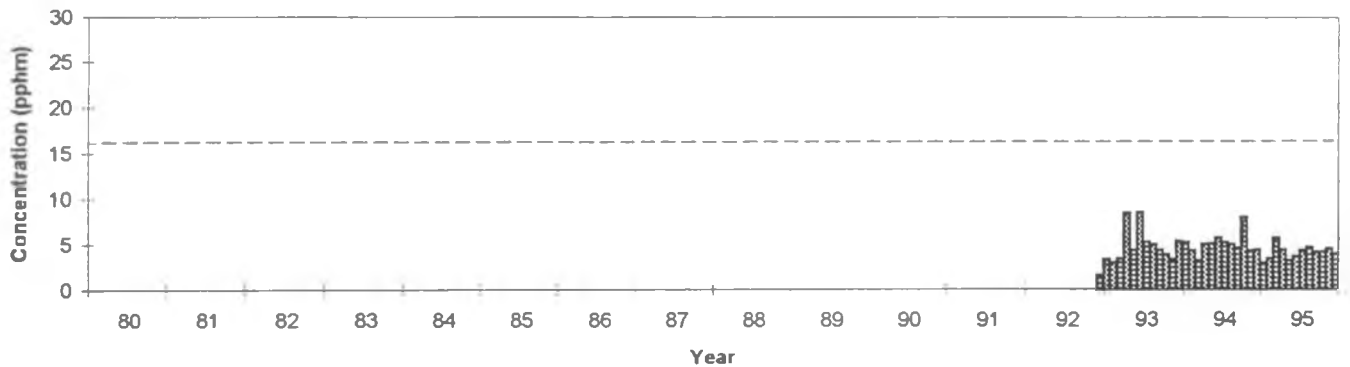
job no: E2057/1-DA



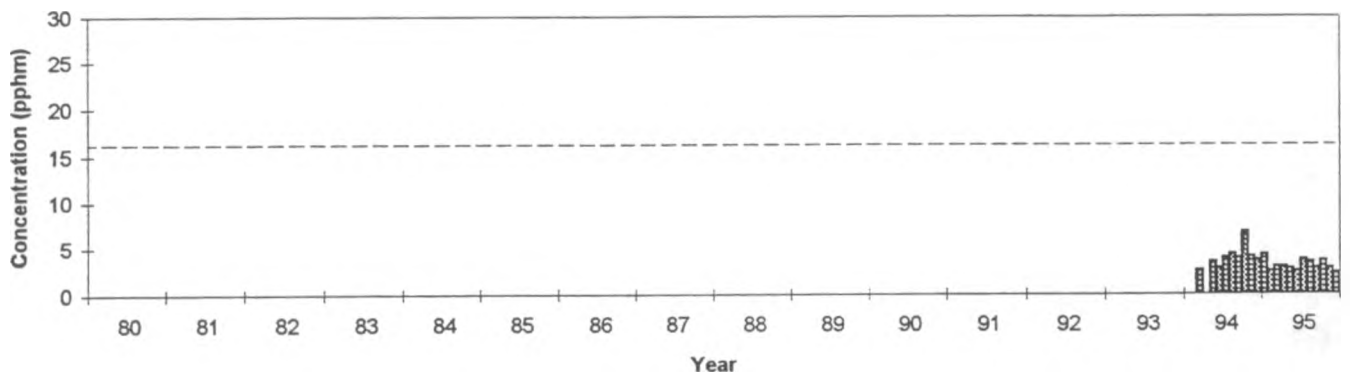
### Rozelle NO2 : Maximum One Hour NO2 Level each Month



### St Marys NO2 : Maximum One Hour NO2 Level each Month



### Vineyard NO2 : Maximum One Hour NO2 Level each Month



----- Current EPA Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports.

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NITROGEN DIOXIDE LEVELS  
MAXIMUM ONE HOUR LEVEL EACH MONTH



**FIGURE A23**

job no: E2057/1-DA

[illegible][illegible]

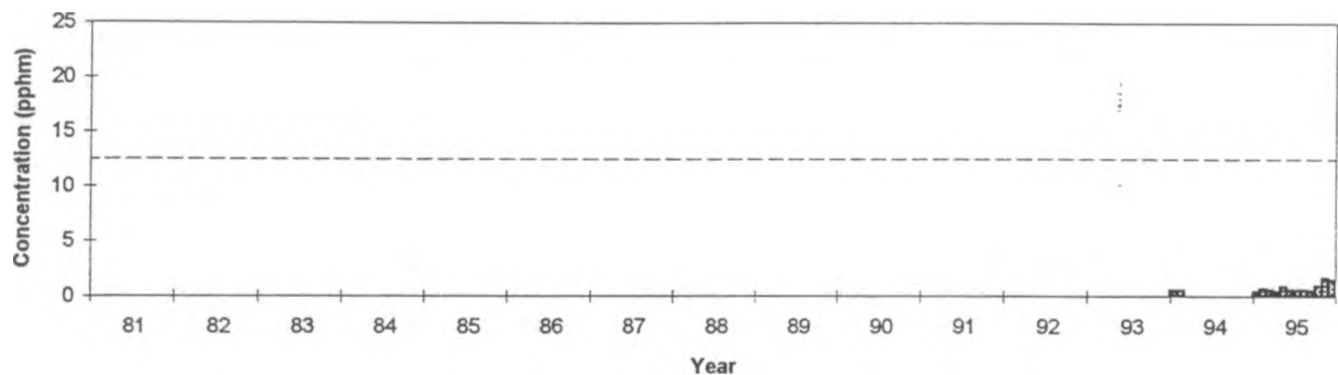
A C N. 003 692 019

drawn	JVDV
approved	
date	29/01/97
scale	AS SHOWN

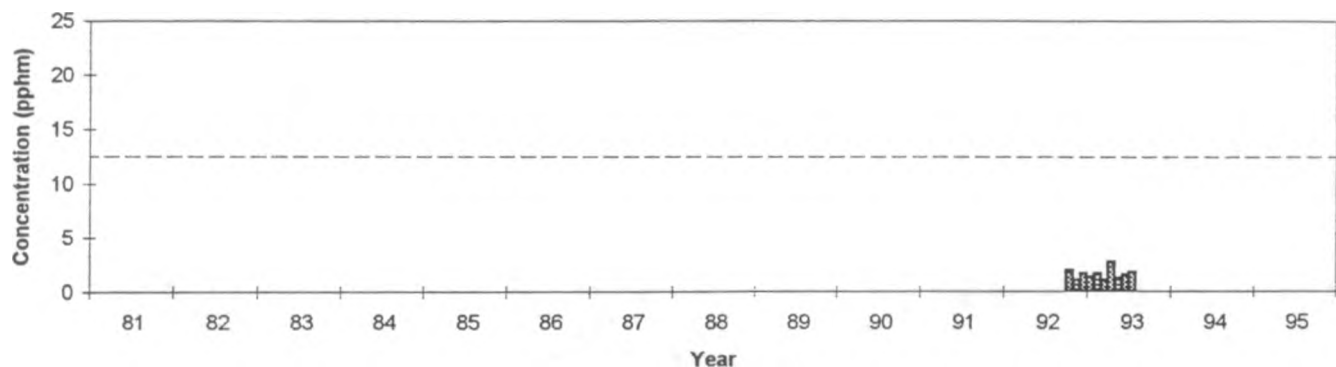
**COFFEY**  


job no: E2057/1-DA

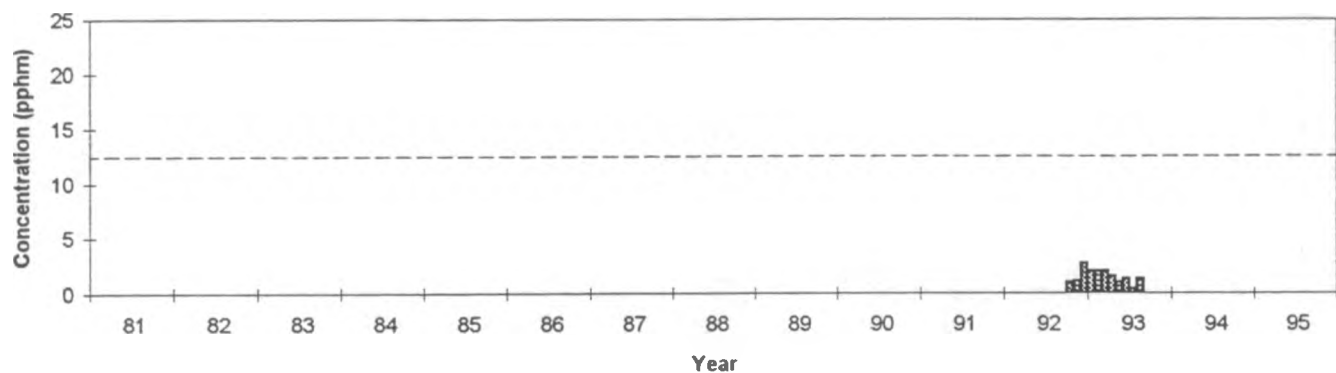
Appin Sulfur Dioxide : Maximum One Hour Level each Month



Blacktown Sulfur Dioxide : Maximum One Hour Level each Month



Bringelly Sulfur Dioxide : Maximum One Hour Level each Month



----- World Health Organization Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports

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scale	AS SHOWN

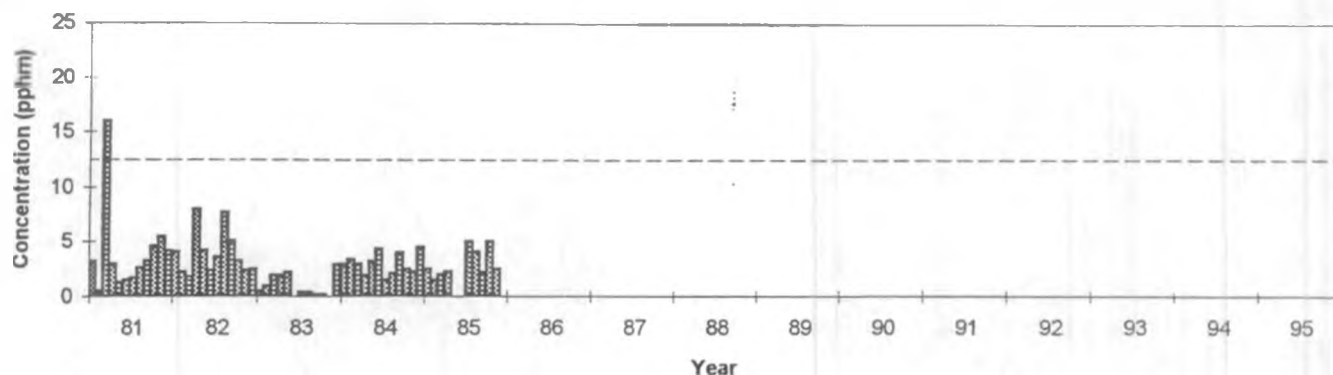
SECOND SYDNEY AIRPORT EIS  
SULFUR DIOXIDE  
MAXIMUM ONE HOUR LEVEL EACH MONTH



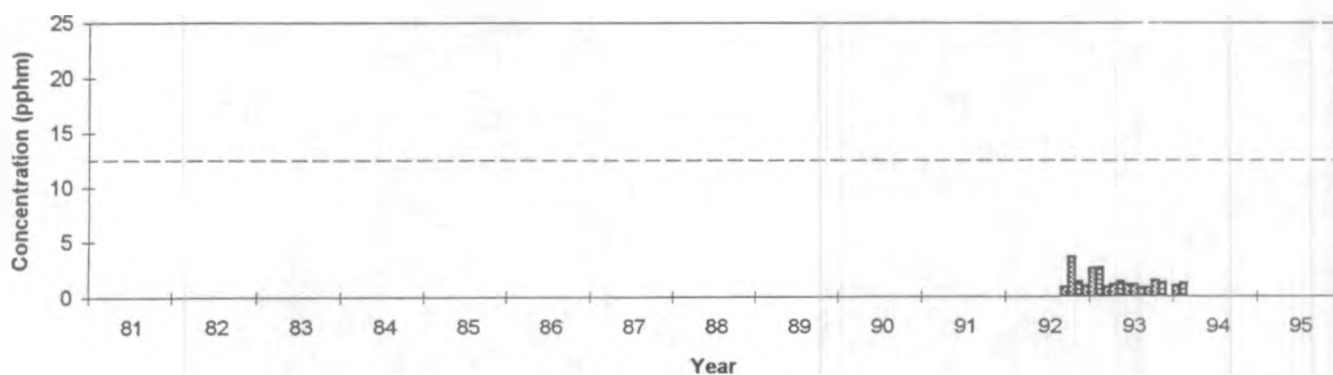
FIGURE A25

job no: E2057/1-DA

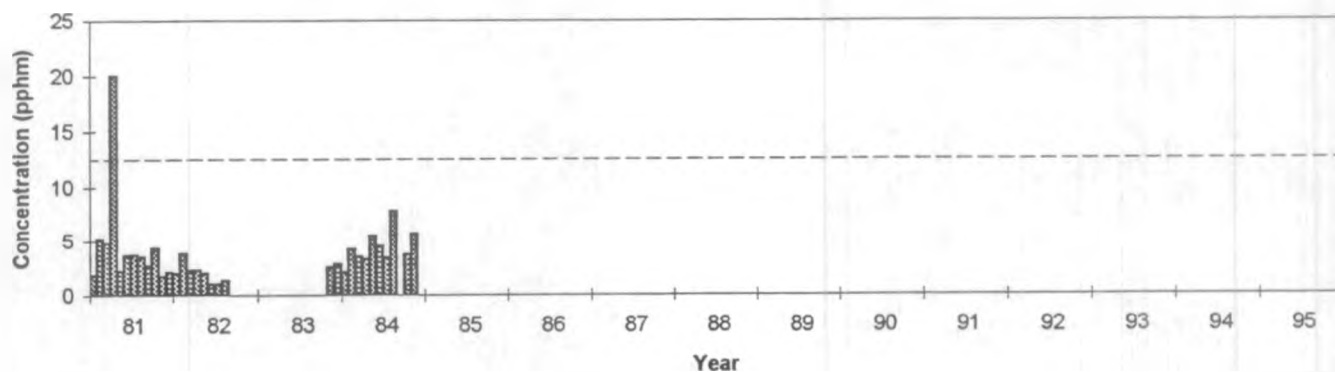
### Lidcombe Sulfur Dioxide : Maximum One Hour Level each Month



### Richmond Sulfur Dioxide : Maximum One Hour Level each Month



### Rozelle Sulfur Dioxide : Maximum One Hour Level each Month



World Health Organization Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports

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drawn	JVDV
approved	
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scale	AS SHOWN

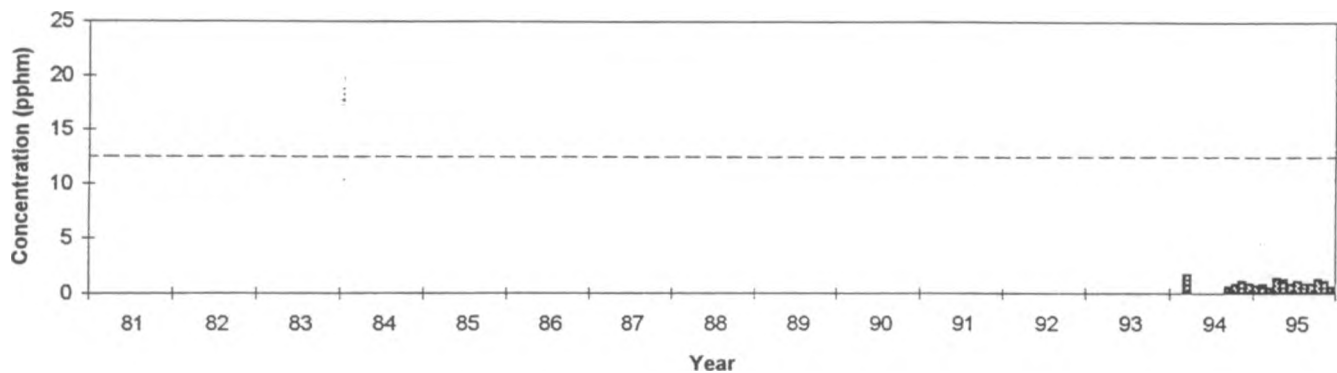
SECOND SYDNEY AIRPORT EIS  
SULFUR DIOXIDE  
MAXIMUM ONE HOUR LEVEL EACH MONTH



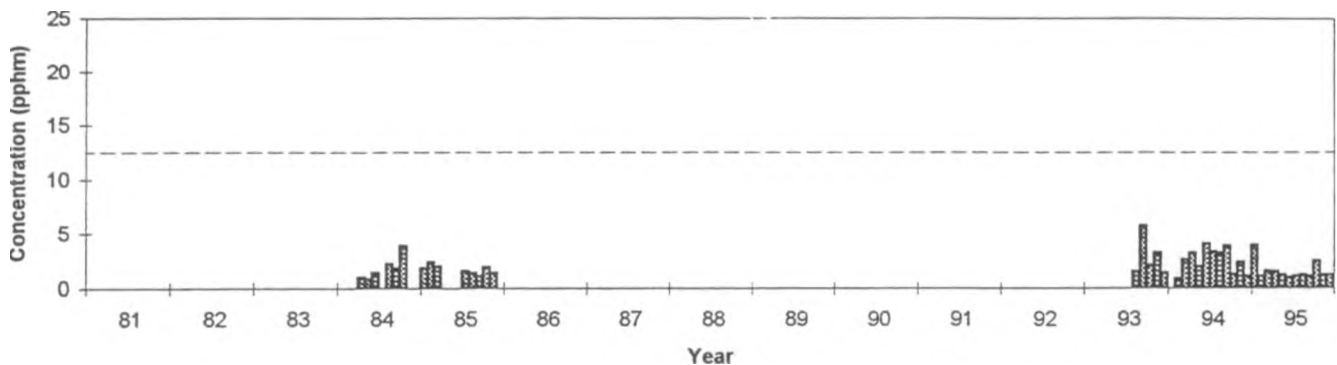
FIGURE A26

job no: E2057/1-DA

### Vineyard Sulfur Dioxide : Maximum One Hour Level each Month



### Woollooware Sulfur Dioxide : Maximum One Hour Level each Month



----- World Health Organization Goal

Source: NSW EPA, Quarterly Air Quality Monitoring Reports

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date	29/01/97
scale	AS SHOWN

SECOND SYDNEY AIRPORT EIS  
SULFUR DIOXIDE  
MAXIMUM ONE HOUR LEVEL EACH MONTH



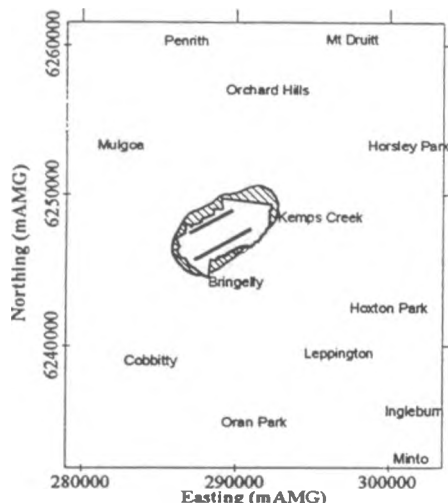
FIGURE A27

job no: E2057/1-DA

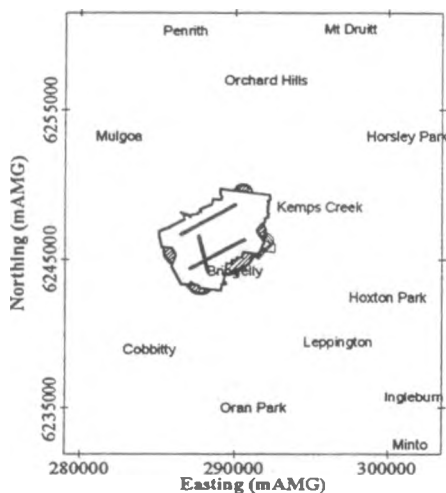
## **Appendix B**

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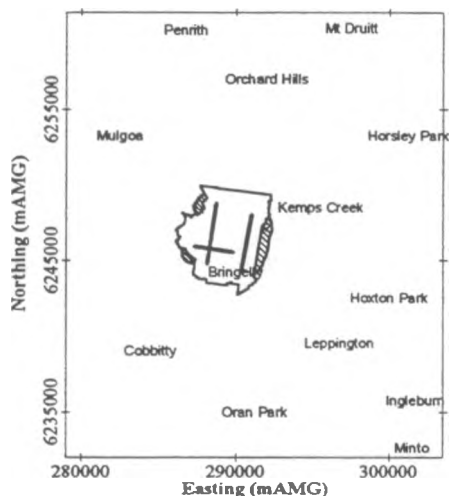
### Air Pollutants Contours



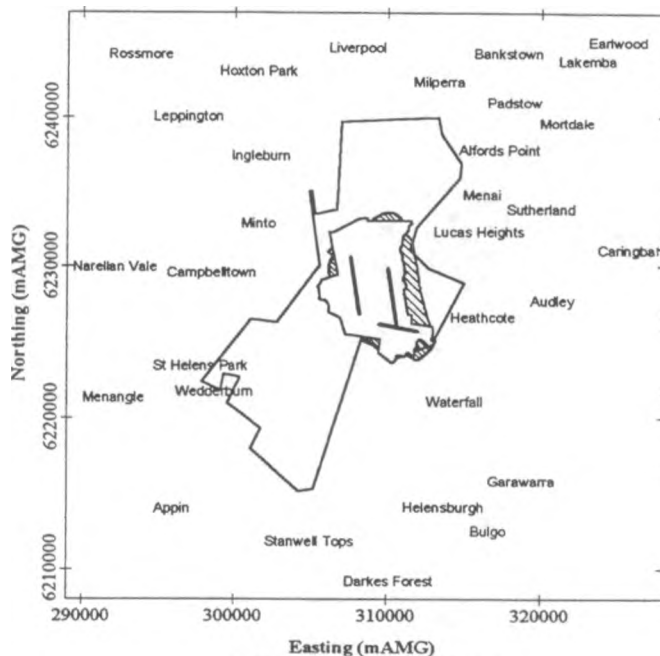
BADGERYS CREEK OPTION A



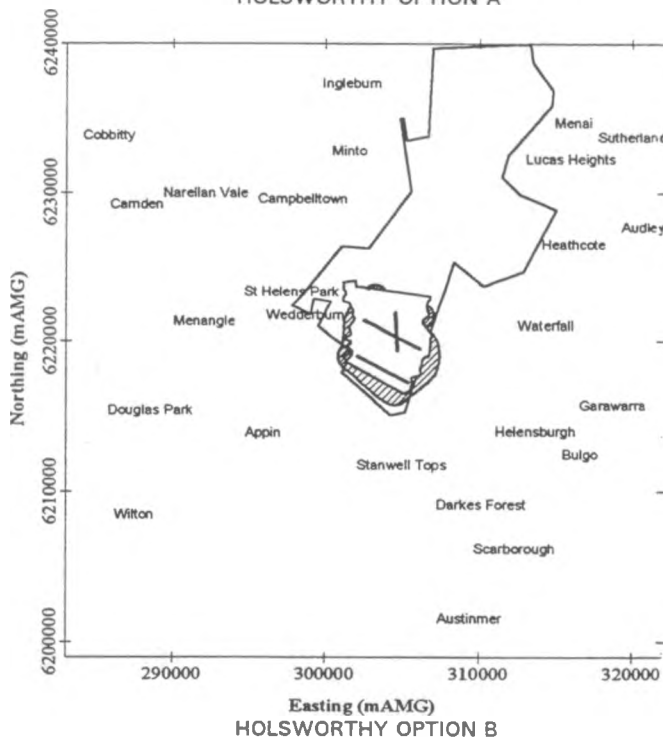
BADGERYS CREEK OPTION B



BADGERYS CREEK OPTION C



HOLSWORTHY OPTION A



HOLSWORTHY OPTION B

NOTES:

Shaded region shows maximum increase in dust deposition by more than 2 g/m<sup>2</sup>/mth.

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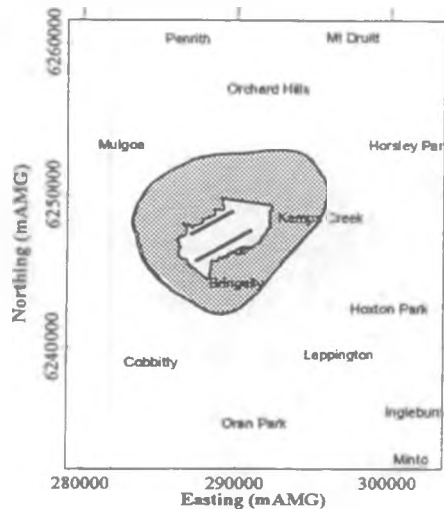
drawn	RJB
approved	<i>[Signature]</i>
date	23/5/97
scale	1:500,000

SYDNEY SECOND AIRPORT EIS  
AIR QUALITY STUDIES  
PREDICTED MAXIMUM CONSTRUCTION DUST IMPACT

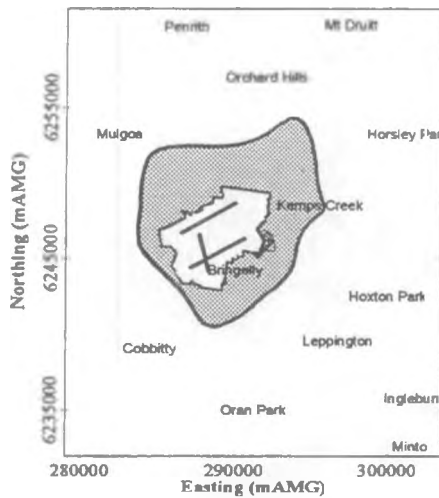


FIGURE B1

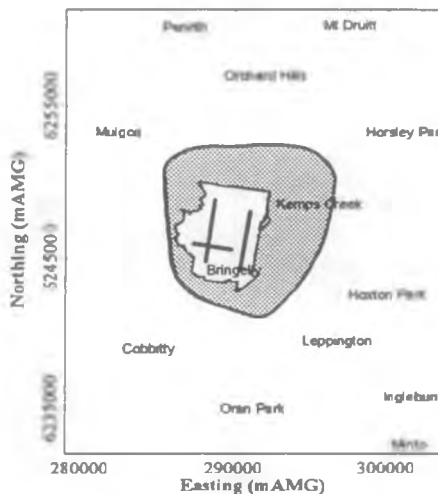
job no: E2057/1-DA



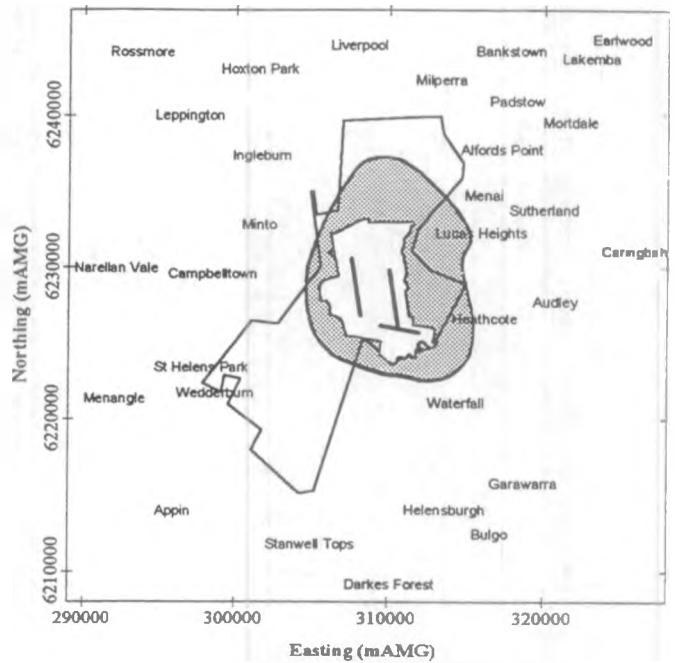
BADGERYS CREEK OPTION A



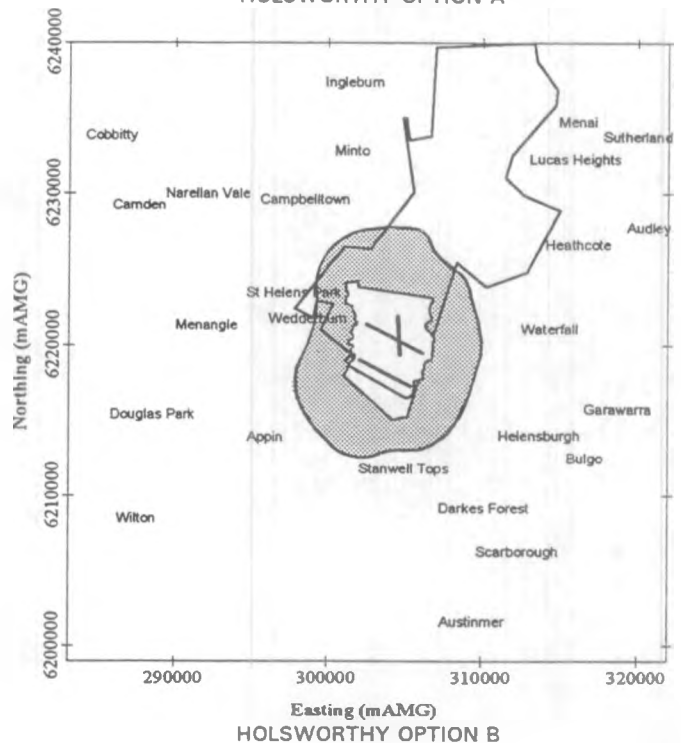
BADGERYS CREEK OPTION B



BADGERYS CREEK OPTION C



HOLSWORTHY OPTION A



HOLSWORTHY OPTION B

NOTES:

Shaded region shows predicted increase in PM<sub>10</sub> particulate concentration by more than 100ug/m<sup>3</sup>

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approved	<i>[Signature]</i>
date	23/5/97
scale	1:500,000

SYDNEY SECOND AIRPORT EIS  
AIR QUALITY STUDIES

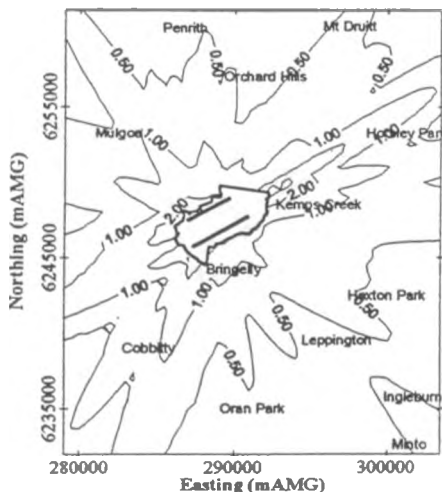
MAXIMUM PREDICTED CONSTRUCTION PM<sub>10</sub> IMPACT (ug/m<sup>3</sup>)



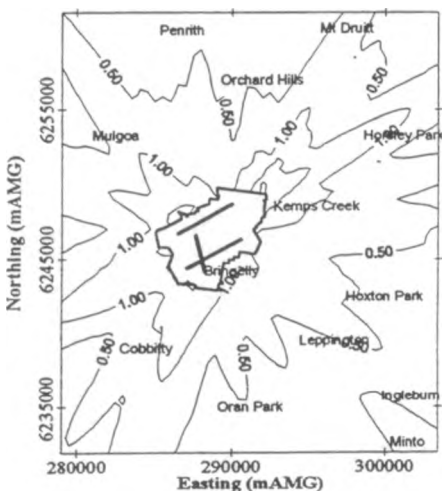
FIGURE B2

job no: E2057/1-DA

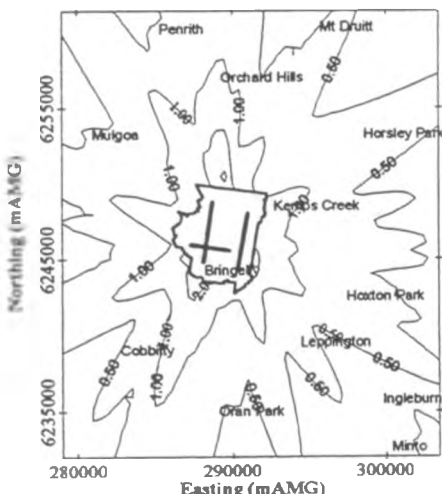




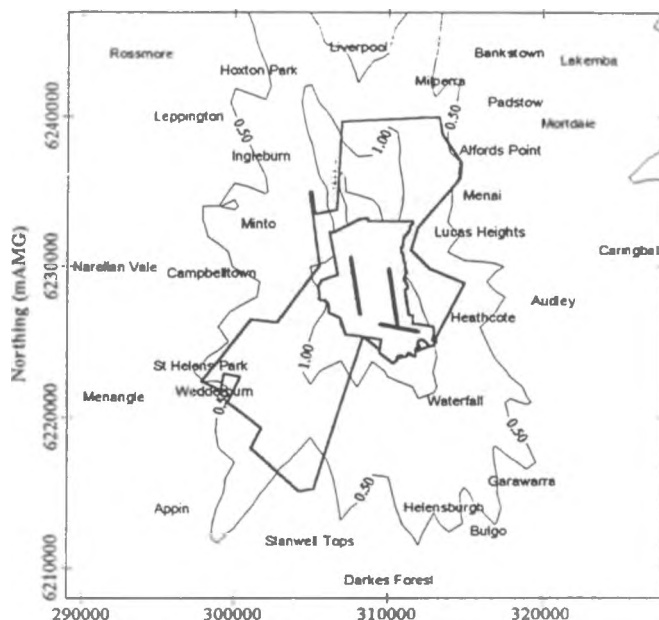
BADGERYS CREEK OPTION A



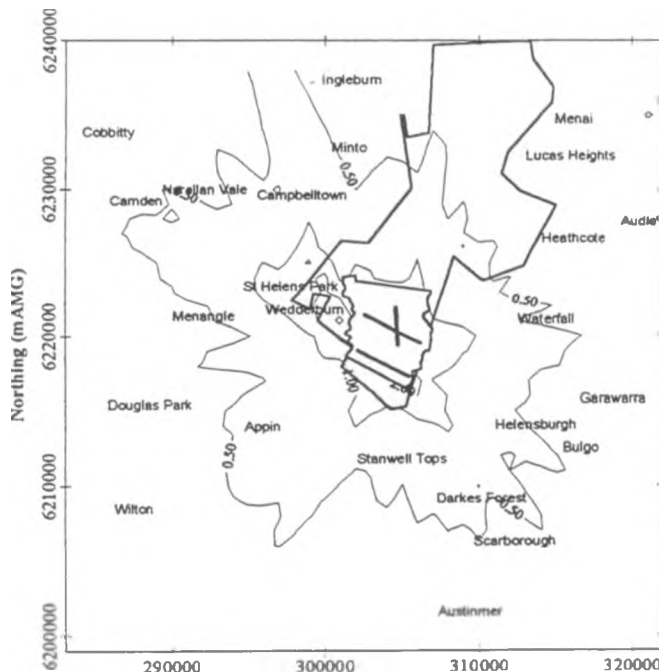
BADGERYS CREEK OPTION B



BADGERYS CREEK OPTION C



HOLSWORTHY OPTION A



HOLSWORTHY OPTION B

NOTES:

- NSW EPA Guideline for peak one hour carbon monoxide concentration 25ppm
- Background peak one hour carbon monoxide concentration
- Badgerys Creek: 5 parts per million
- Holsworthy: 10 parts per million

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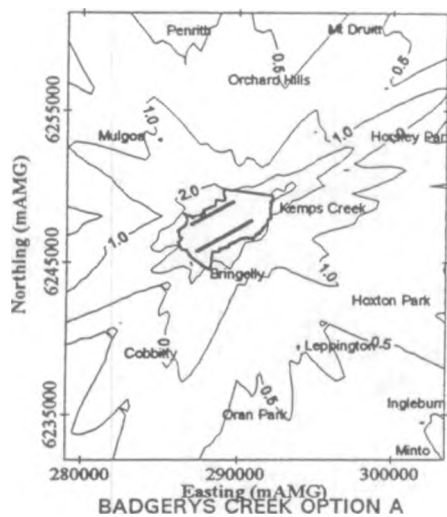
drawn	JVDV
approved	<i>[Signature]</i>
date	23/5/97
scale	AS SHOWN

SYDNEY SECOND AIRPORT EIS  
AIR QUALITY STUDIES  
PEAK INCREASE IN 1 HOUR CO CONCENTRATION (ppm)

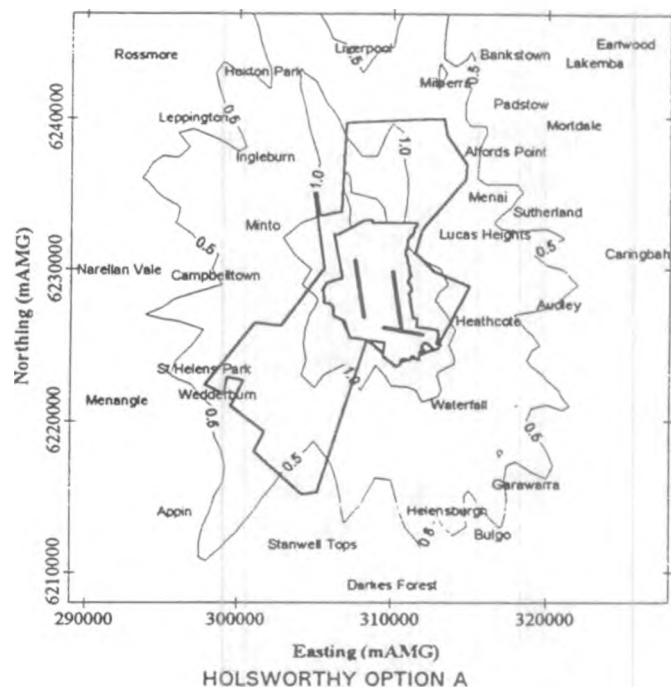


FIGURE B3

job no: E2057/1-DA

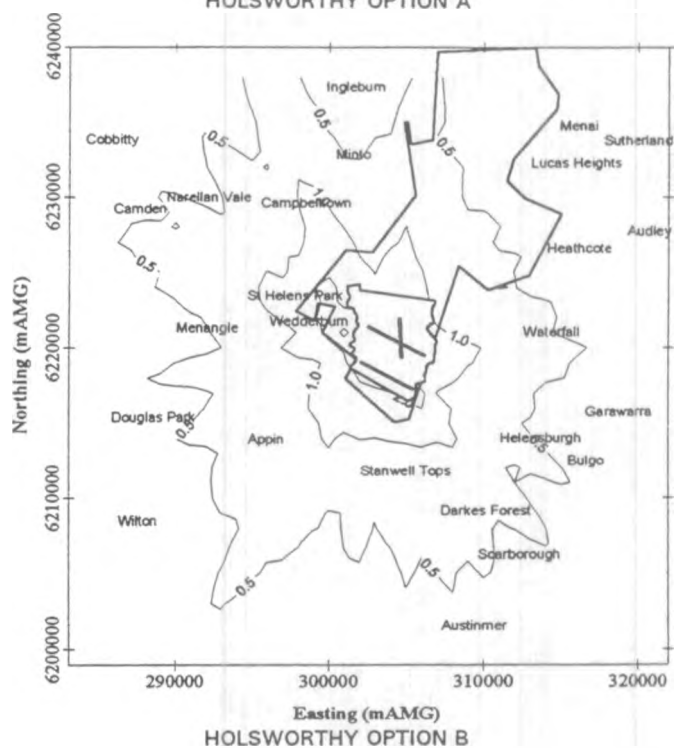


BADGERYS CREEK OPTION A



HOLSWORTHY OPTION A

BADGERYS CREEK OPTION B



HOLSWORTHY OPTION B

NOTES: Modelled using worst case direction of takeoff

NSW EPA Guideline for peak one hour carbon monoxide concentration 25ppm

Background peak one hour carbon monoxide concentration

Badgerys Creek: 5 parts per million

Holsworthy: 10 parts per million

BADGERYS CREEK OPTION C

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approved	<i>[Signature]</i>
date	23/5/97
scale	AS SHOWN

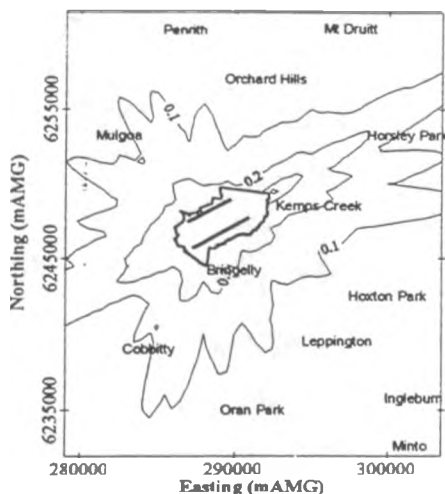
SYDNEY SECOND AIRPORT EIS  
AIR QUALITY STUDIES

PEAK 1HR CO INCREASE - WORST TAKEOFF DIRECTION

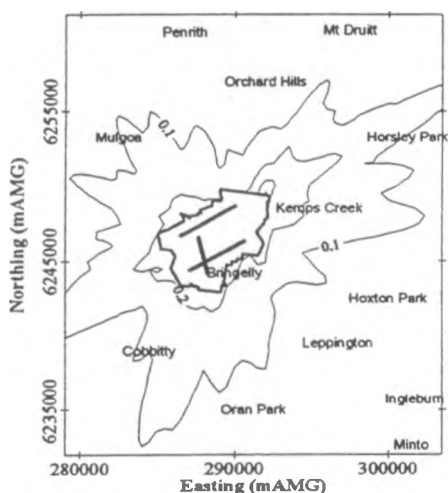


FIGURE B4

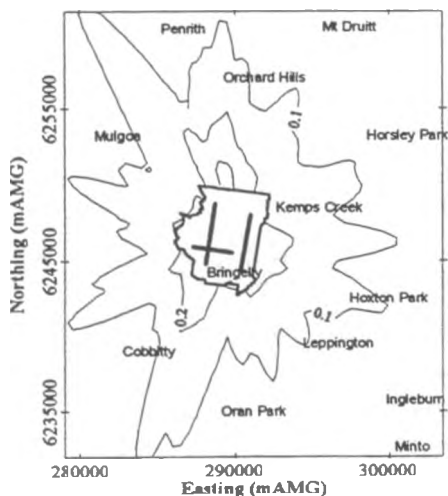
job no: E2057/1-DA



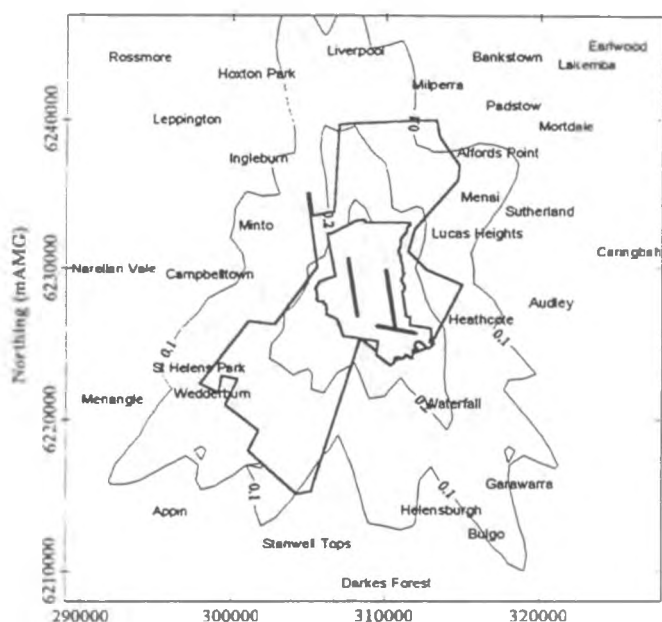
BADGERYS CREEK OPTION A



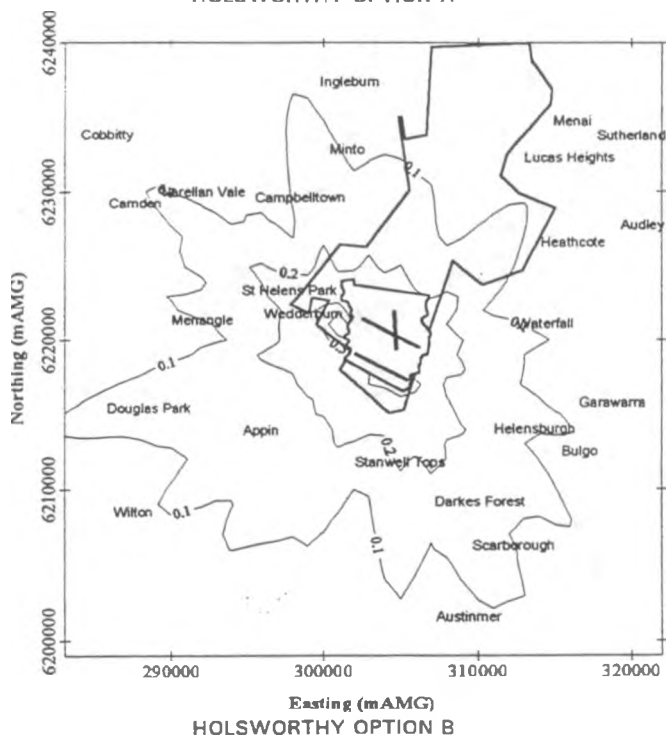
BADGERYS CREEK OPTION B



BADGERYS CREEK OPTION C



HOLSWORTHY OPTION A



HOLSWORTHY OPTION B

#### NOTES:

NSW EPA Guideline for peak eight hour carbon monoxide concentration 9ppm

Background peak one hour carbon monoxide concentration

Badgerys Creek: 3 parts per million

Holsworthy: not assessed

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SYDNEY SECOND AIRPORT EIS

AIR QUALITY STUDIES

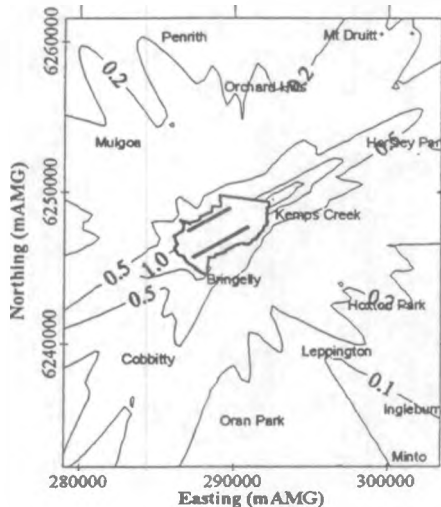
PEAK INCREASE IN 8 HOUR CO CONCENTRATION (ppm)



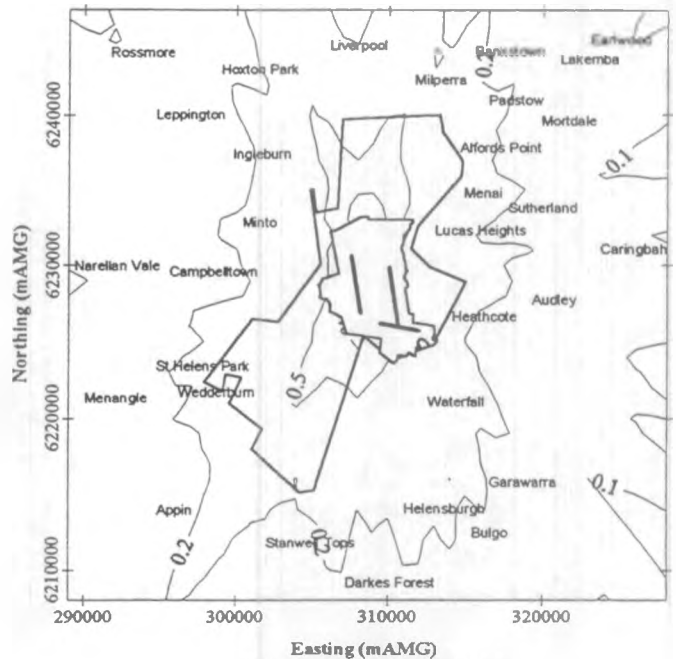
FIGURE B5

job no: E2057/1-DA

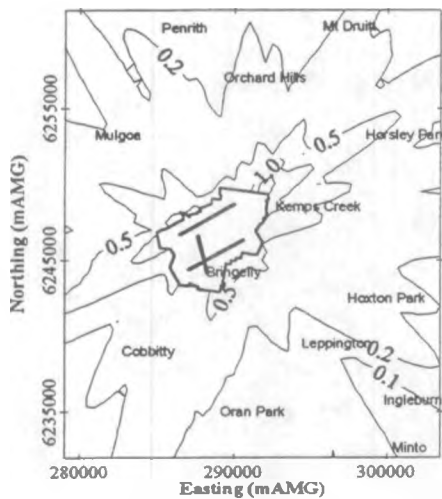
drawn	JVDV
approved	<i>[Signature]</i>
date	23/5/97
scale	AS SHOWN



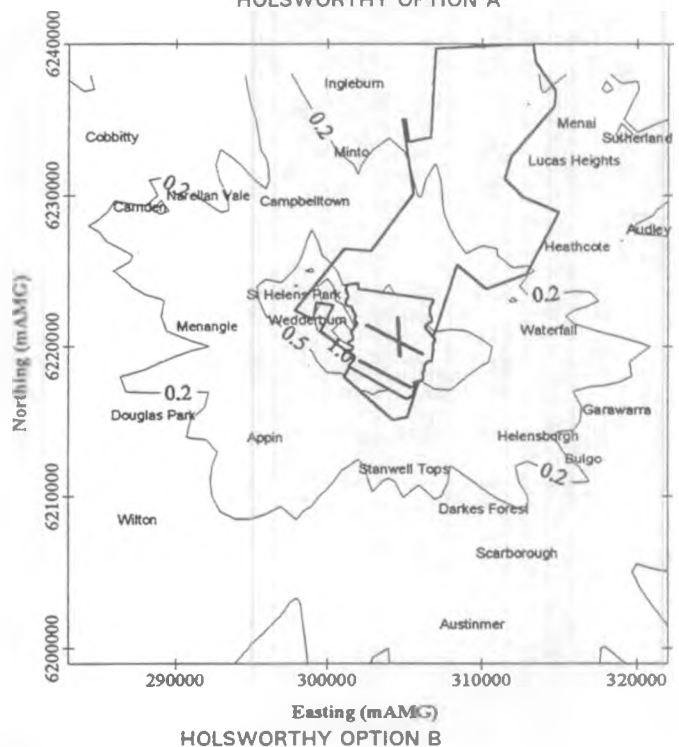
BADGERYS CREEK OPTION A



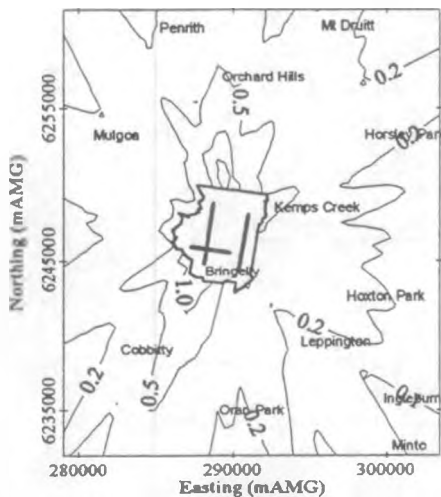
HOLSWORTHY OPTION A



BADGERYS CREEK OPTION B



HOLSWORTHY OPTION B



BADGERYS CREEK OPTION C

NOTES:

NSW EPA Guideline for peak one hour carbon monoxide concentration 25ppm

Background peak one hour carbon monoxide concentration

Badgerys Creek: 5 parts per million

Holsworthy: 10 parts per million

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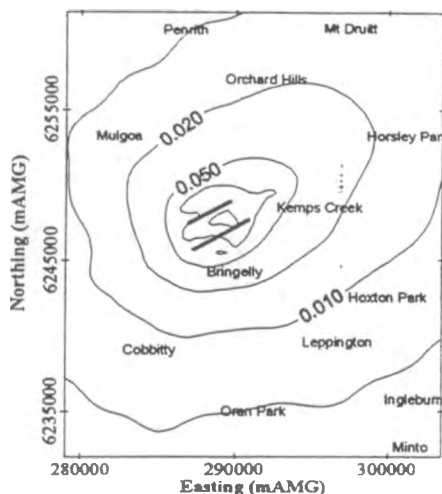
drawn	RJB
approved	<i>[Signature]</i>
date	23/5/97
scale	1:500,000

SYDNEY SECOND AIRPORT EIS  
AIR QUALITY STUDIES  
2006 PEAK INCREASE IN CO CONCENTRATION (ppm)

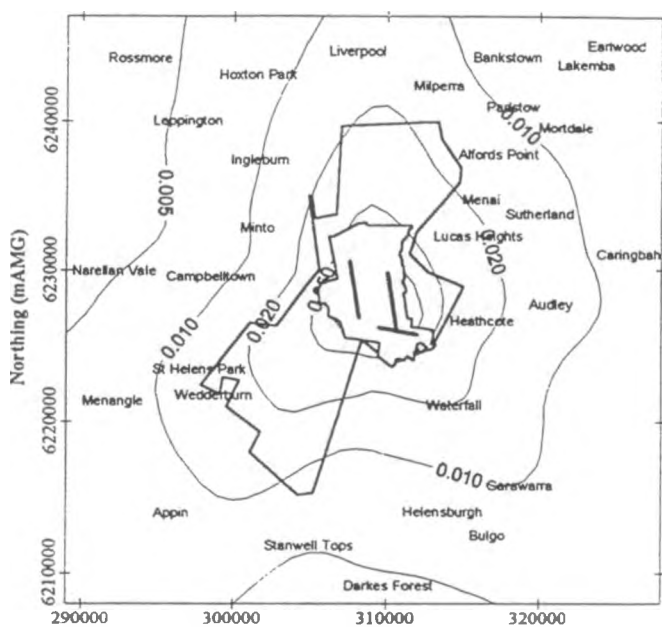


FIGURE B6

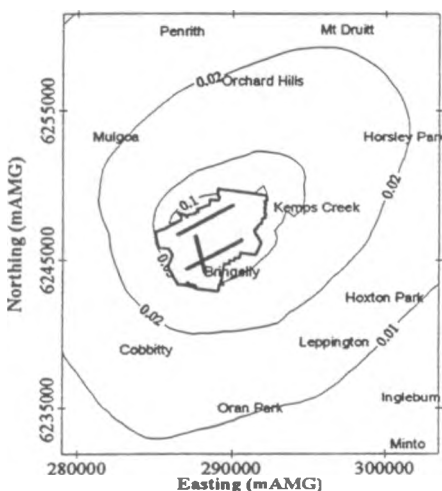
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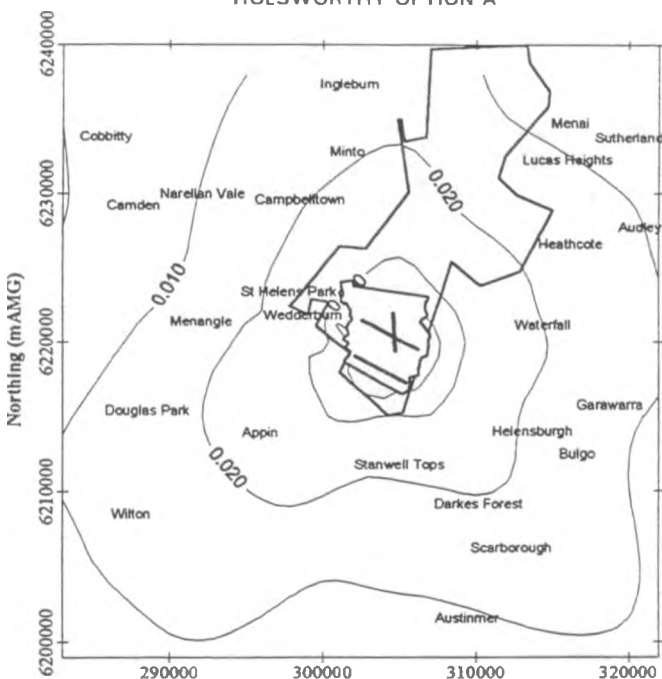
BADGERYS CREEK OPTION A



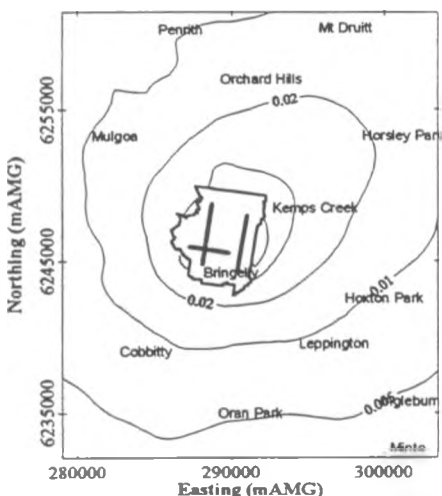
HOLSWORTHY OPTION A



BADGERYS CREEK OPTION B



HOLSWORTHY OPTION B



BADGERYS CREEK OPTION C

NOTES:

NSW EPA Guideline for average nitrogen dioxide concentration 5pphm

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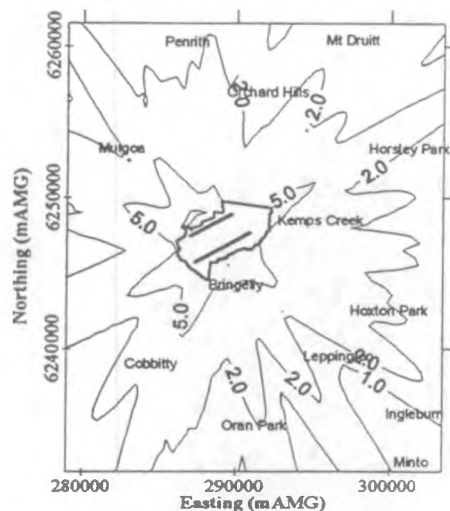
drawn	JVDV
approved	<i>MA</i>
date	23/5/97
scale	AS SHOWN

SYDNEY SECOND AIRPORT EIS  
AIR QUALITY STUDIES  
INCREASE IN AVERAGE NO<sub>2</sub> CONCENTRATION (pphm)

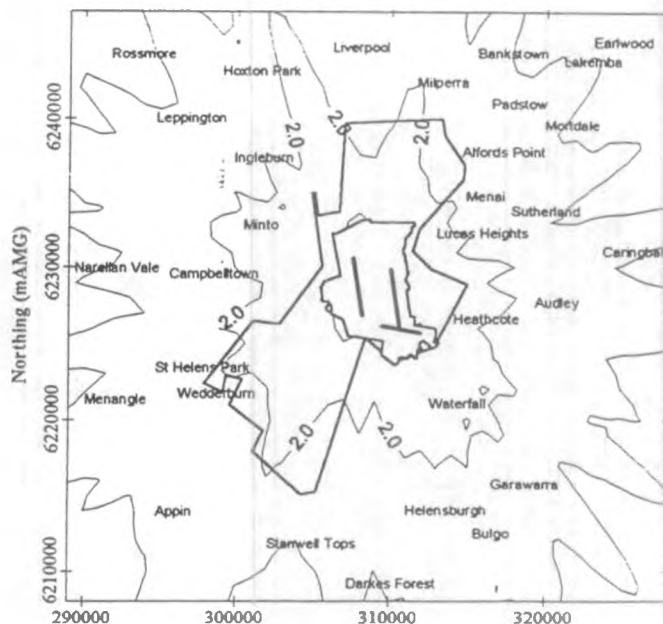


FIGURE B7

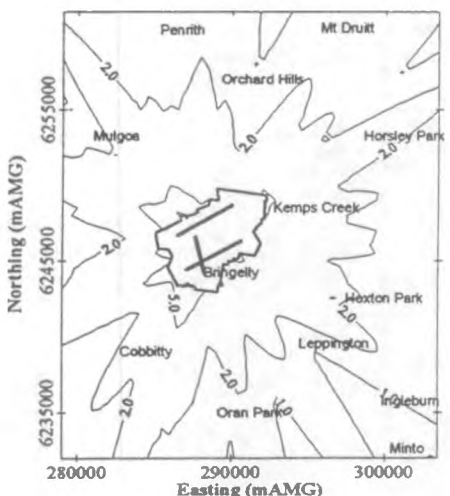
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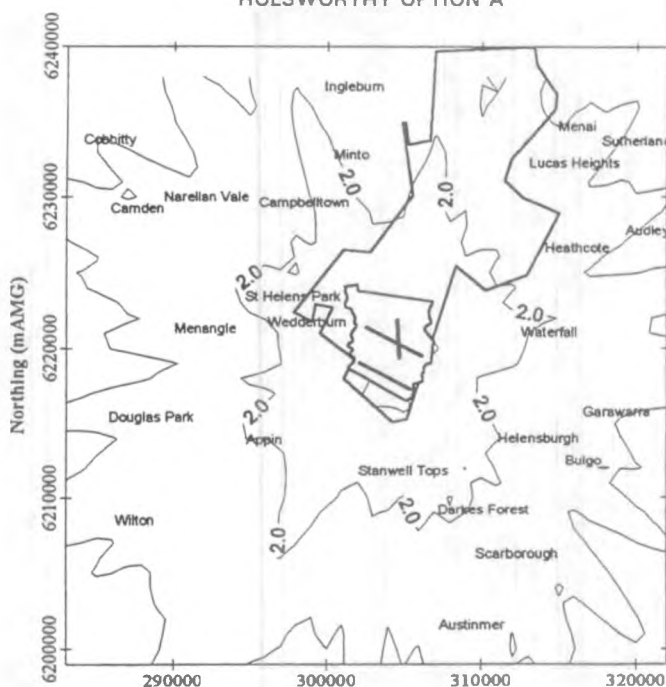
BADGERYS CREEK OPTION A



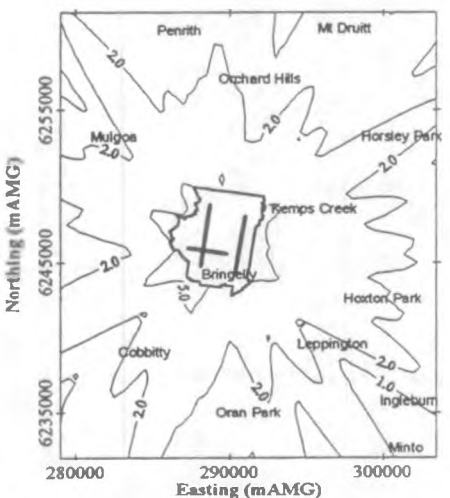
HOLSWORTHY OPTION A



BADGERYS CREEK OPTION B



HOLSWORTHY OPTION B



BADGERYS CREEK OPTION C

#### NOTES:

NSW EPA Guideline for peak one hour nitrogen dioxide concentration 16pphm

Background peak one hour carbon monoxide concentration

Badgerys Creek: 5 parts per hundred million

Holsworthy: 10 parts per hundred million

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drawn	JVDV
approved	<i>[Signature]</i>
date	23/5/97
scale	AS SHOWN

SYDNEY SECOND AIRPORT EIS  
AIR QUALITY STUDIES

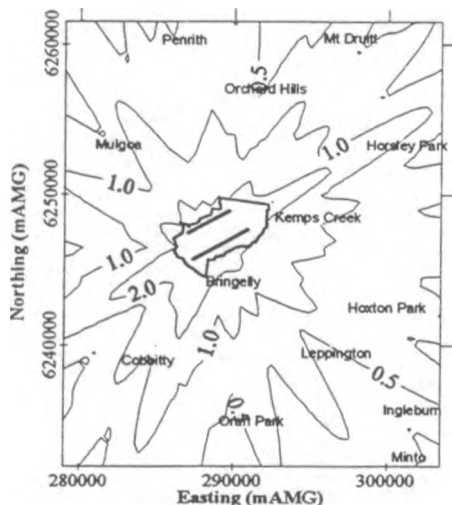
PEAK INCREASE IN 1 HOUR NO<sub>2</sub> CONCENTRATION (pphm)



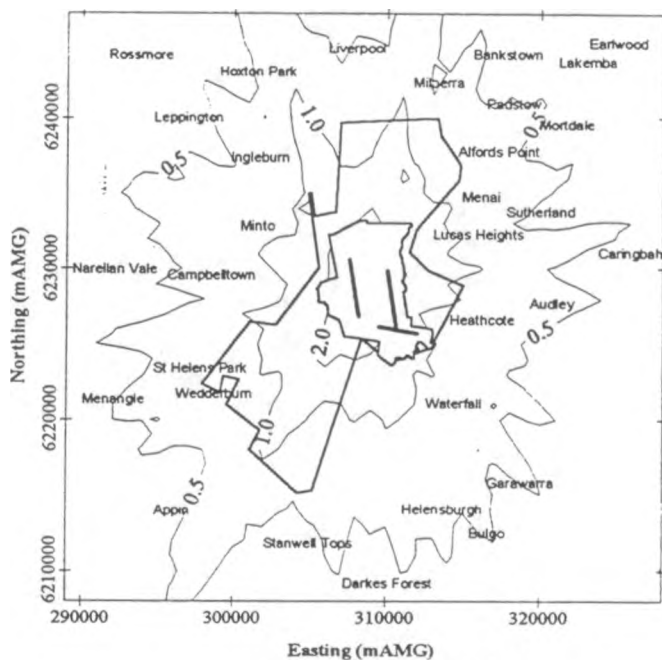
FIGURE B8

job no: E2057/1-DA

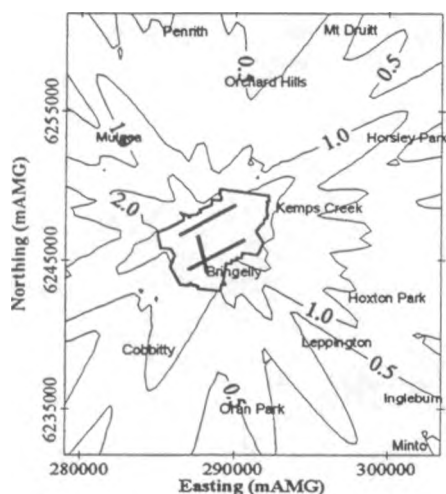




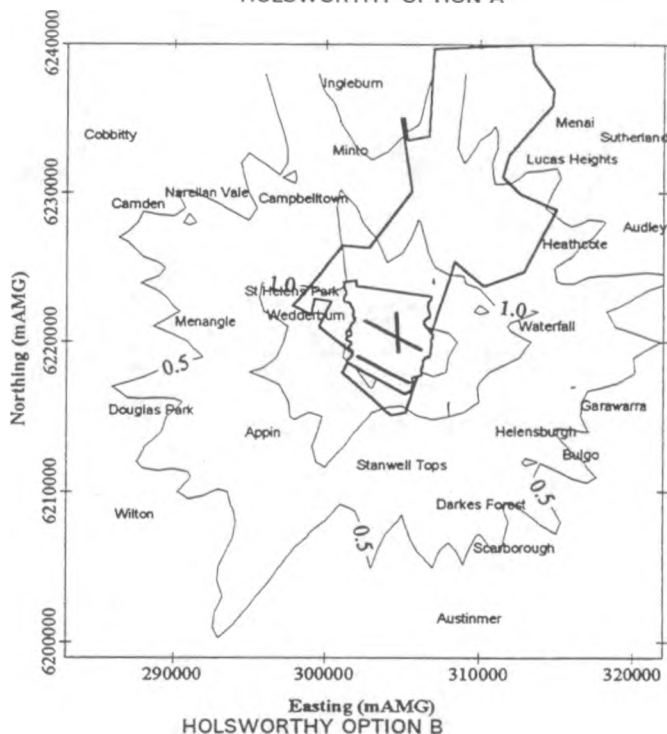
BADGERYS CREEK OPTION A



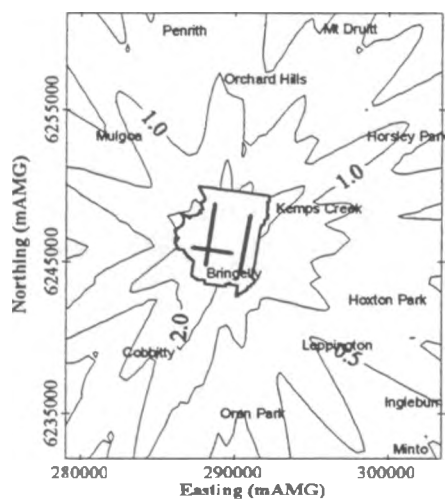
HOLSWORTHY OPTION A



BADGERYS CREEK OPTION B



HOLSWORTHY OPTION B



BADGERYS CREEK OPTION C

#### NOTES:

NSW EPA Guideline for peak one hour nitrogen dioxide concentration 16pphm  
 Background peak one hour carbon monoxide concentration  
 Badgerys Creek: 5 parts per hundred million  
 Holsworthy: 10 parts per hundred million

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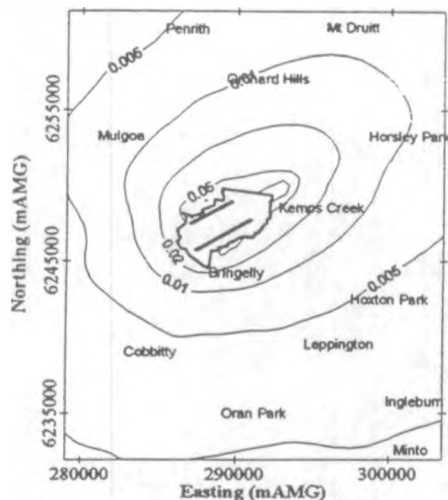
drawn	RJB
approved	<i>[Signature]</i>
date	23/5/97
scale	1:500,000

SYDNEY SECOND AIRPORT EIS  
 AIR QUALITY STUDIES  
 2006 PEAK INCREASE IN 1 HOUR NO<sub>2</sub> (pphm)

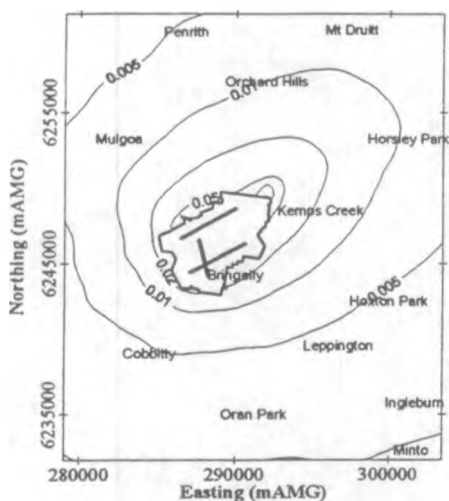


**FIGURE B9**

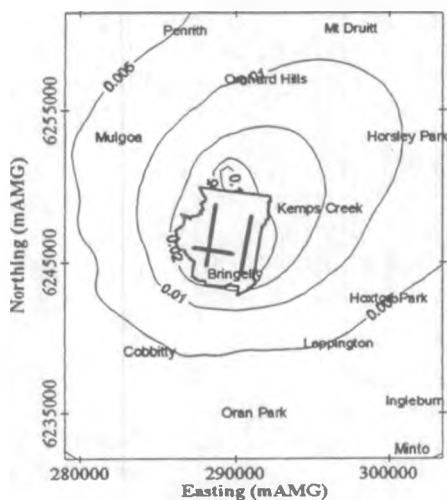
job no: E2057/1-CD



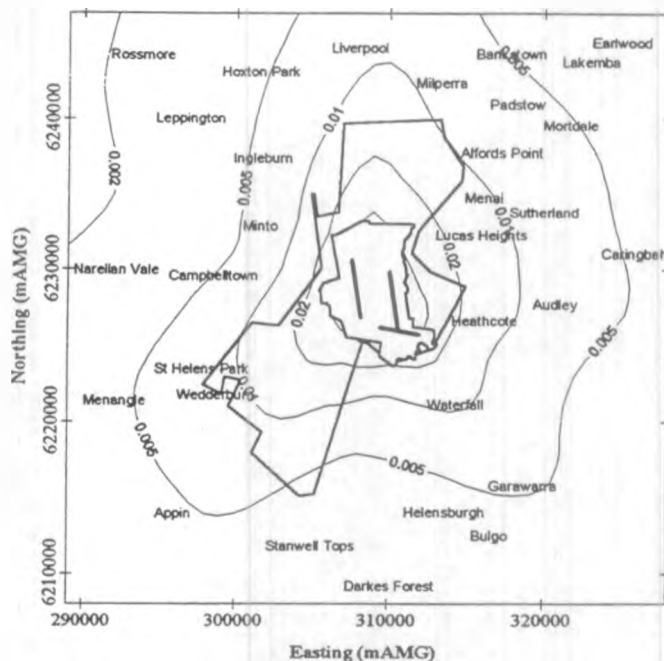
BADGERYS CREEK OPTION A



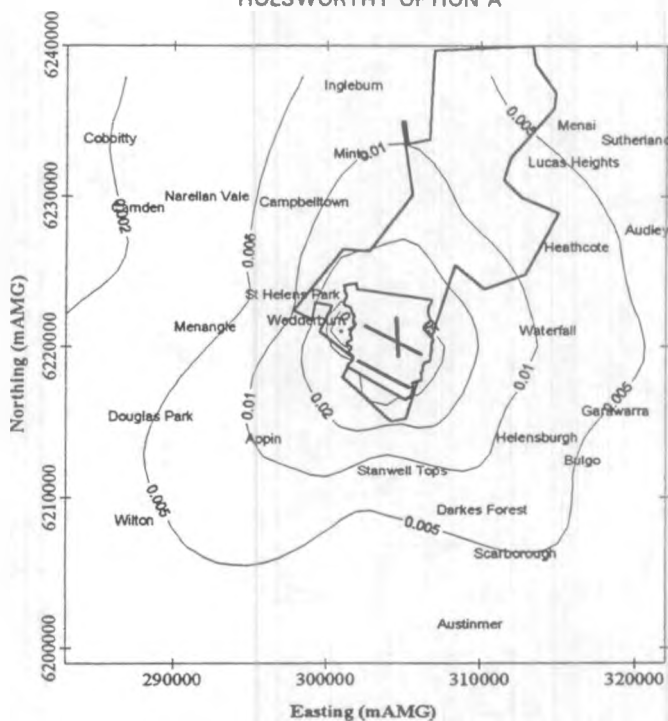
BADGERYS CREEK OPTION B



BADGERYS CREEK OPTION C



HOLSWORTHY OPTION A



HOLSWORTHY OPTION B

NOTES:

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drawn	JVDV
approved	
date	23/5/97
scale	AS SHOWN

SYDNEY SECOND AIRPORT EIS  
AIR QUALITY STUDIES

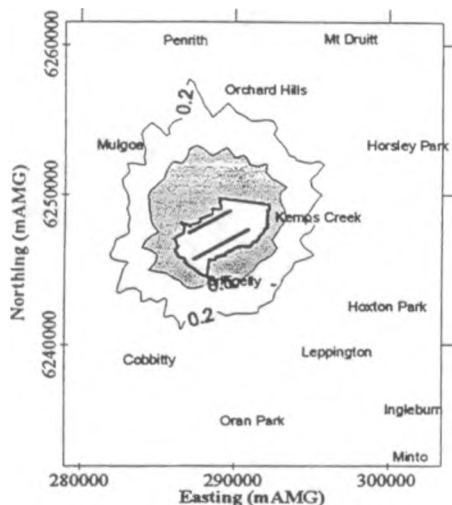
AVERAGE BENZENE CONCENTRATION INCREASE (ppb)



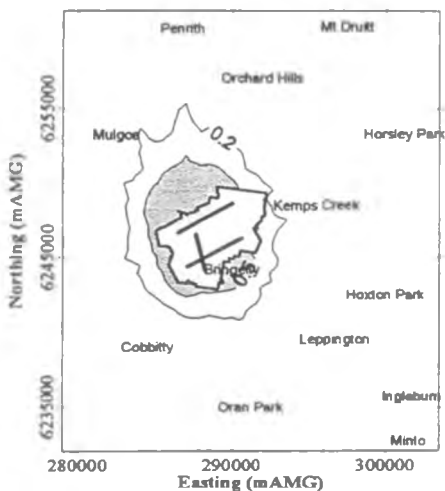
FIGURE B10

job no: E2057/1-DA

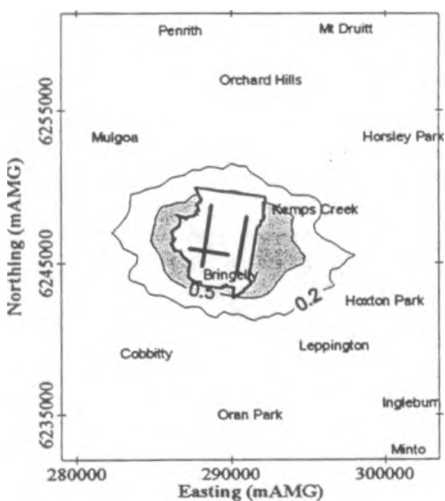




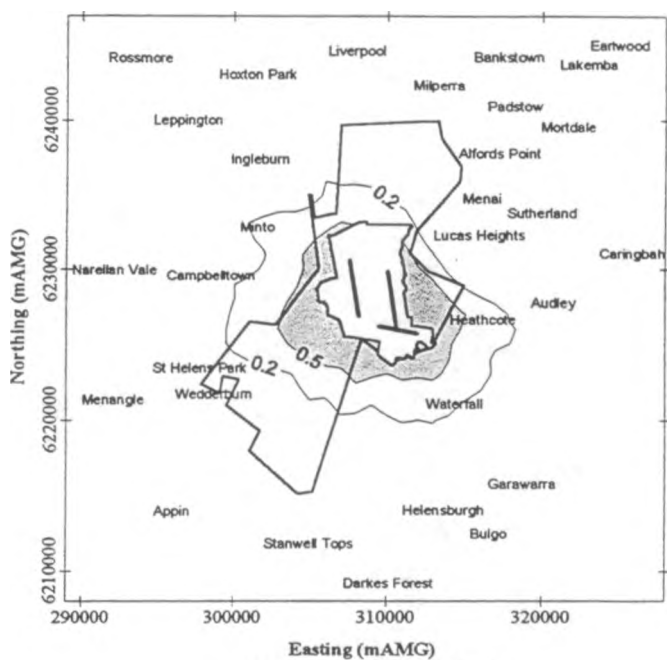
BADGERYS CREEK OPTION A



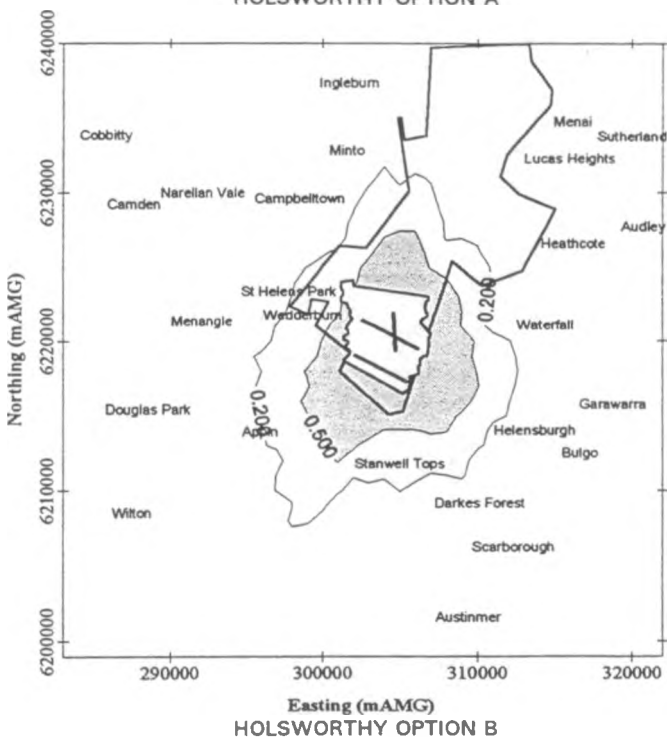
BADGERYS CREEK OPTION B



BADGERYS CREEK OPTION C



HOLSWORTHY OPTION A



HOLSWORTHY OPTION B

NOTES:

Exceedence of 2 odour detection units average over three minutes

Shaded areas indicate NSW EPA odour nuisance criterion

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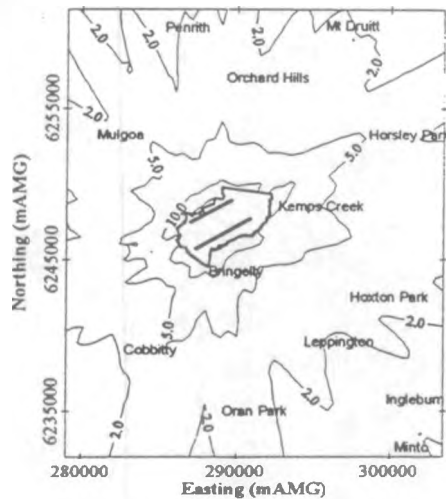
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date	23/5/97
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SYDNEY SECOND AIRPORT EIS  
AIR QUALITY STUDIES  
PERCENTAGE EXCEEDENCE OF 2 ODOUR UNITS

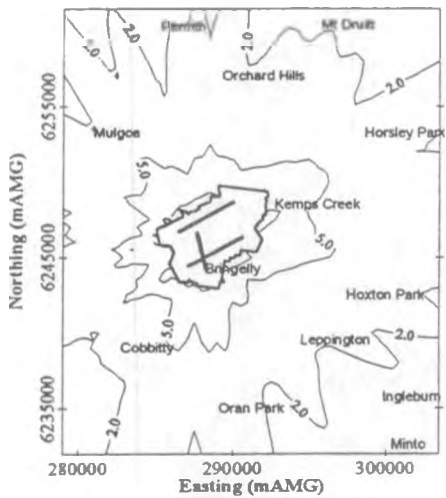


FIGURE B11

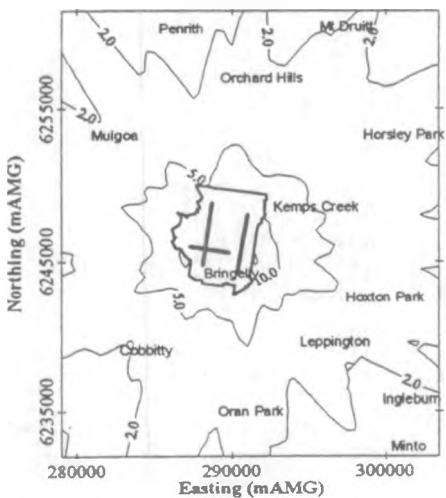
job no: E2057/1-DA



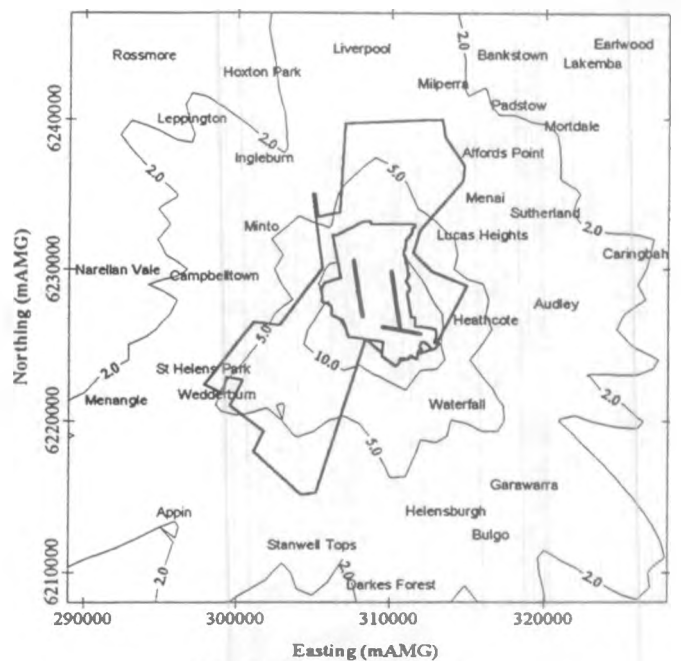
BADGERYS CREEK OPTION A



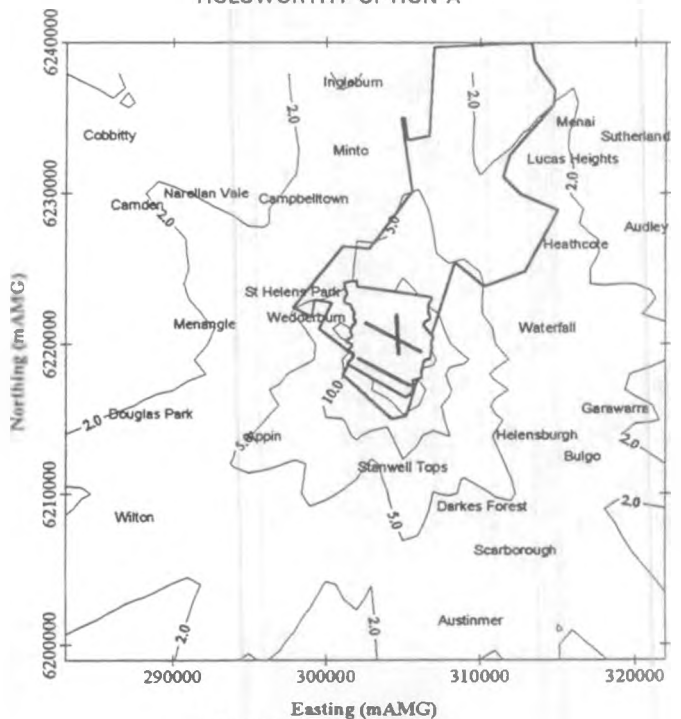
BADGERYS CREEK OPTION B



BADGERYS CREEK OPTION C



HOLSWORTHY OPTION A



HOLSWORTHY OPTION B

NOTES:

NSW EPA Guideline for peak 24 hour PM10 concentration 150 ug/m3

Background peak 24 hour PM10 concentration

Badgerys Creek: 50 ug/m3

Holsworthy: 50 ug/m3

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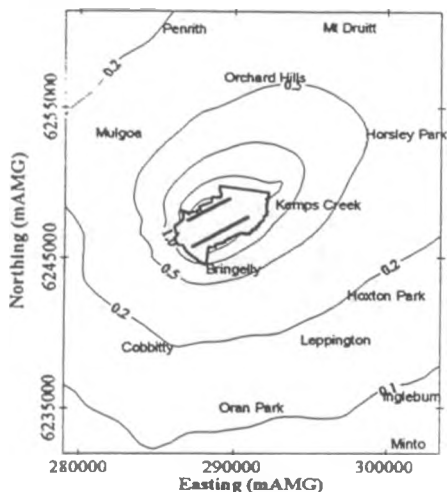
drawn	JVDV
approved	
date	23/5/97
scale	AS SHOWN

SYDNEY SECOND AIRPORT EIS  
AIR QUALITY STUDIES  
PEAK INCREASE IN 24 HOUR PM10 ( $\mu\text{g}/\text{m}^3$ )

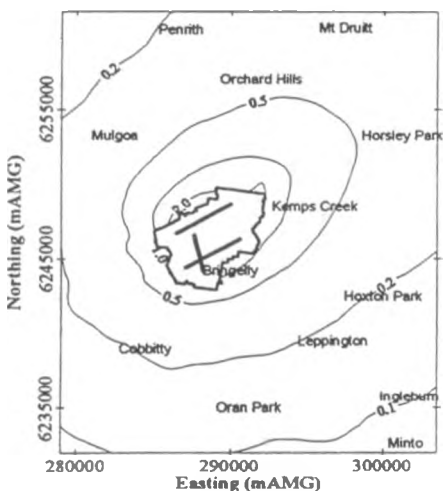


FIGURE B12

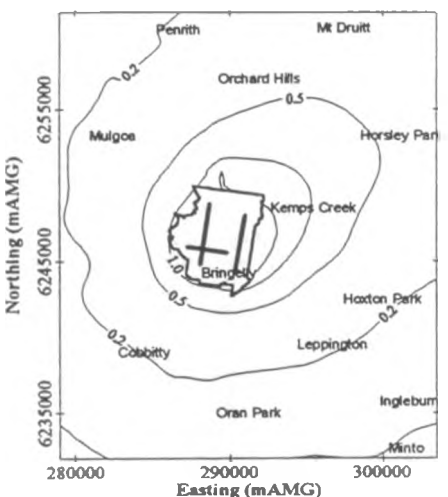
job no: E2057/1-DA



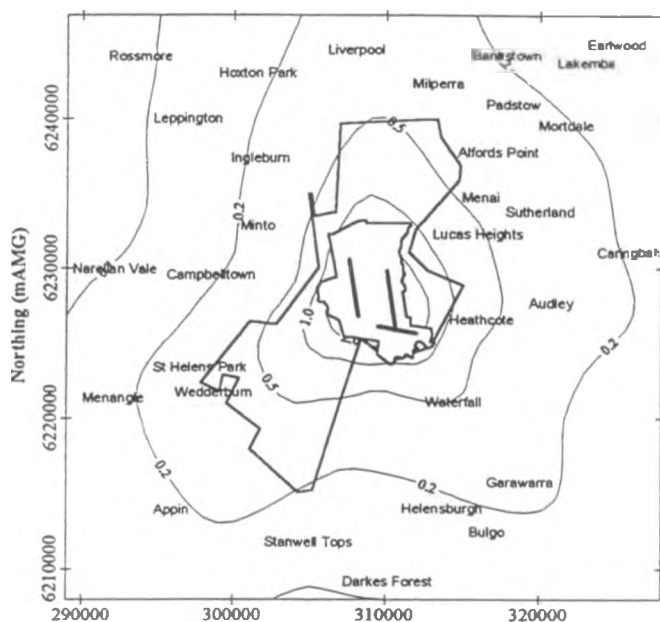
BADGERYS CREEK OPTION A



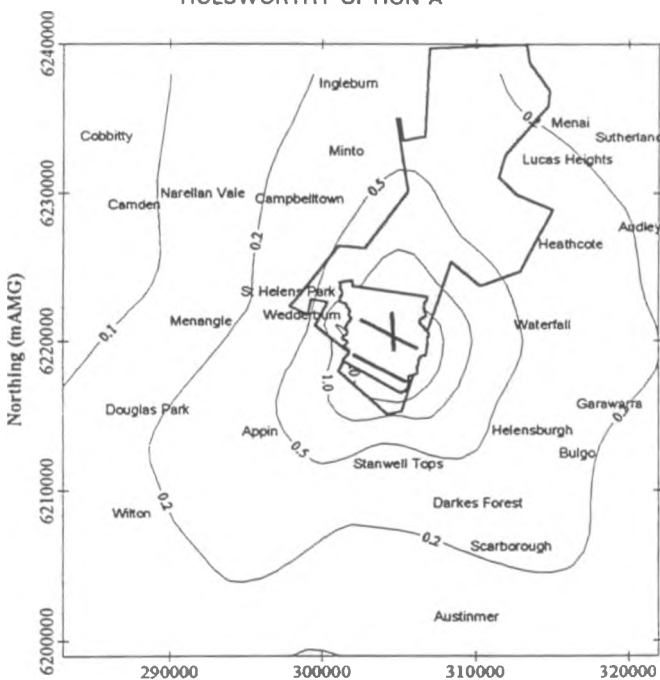
BADGERYS CREEK OPTION B



BADGERYS CREEK OPTION C



HOLSWORTHY OPTION A



HOLSWORTHY OPTION B

NOTES:

NSW EPA Guideline for peak 24 hour PM10 concentration 50 ug/m<sup>3</sup>

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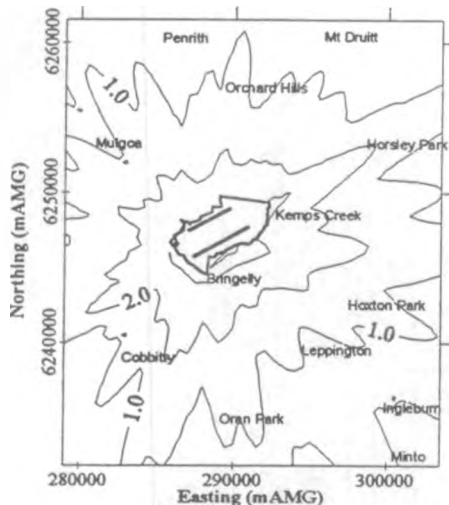
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approved	<i>[Signature]</i>
date	23/5/97
scale	AS SHOWN

SYDNEY SECOND AIRPORT EIS  
AIR QUALITY STUDIES  
INCREASE IN AVERAGE PM10 CONCENTRATION (ug/m<sup>3</sup>)

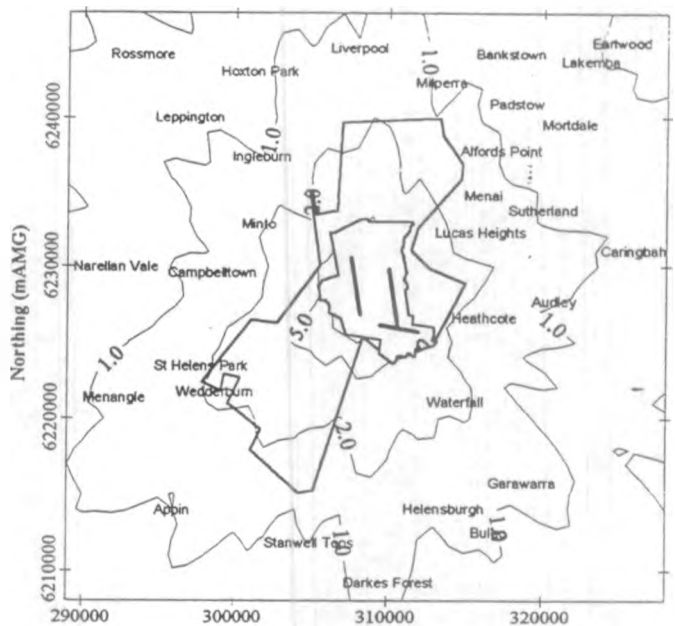


FIGURE B13

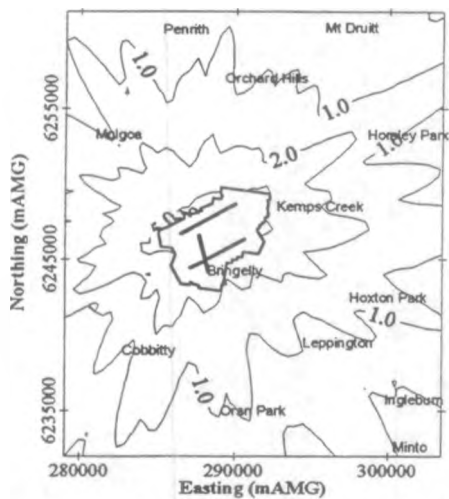
job no: E2057/1-DA



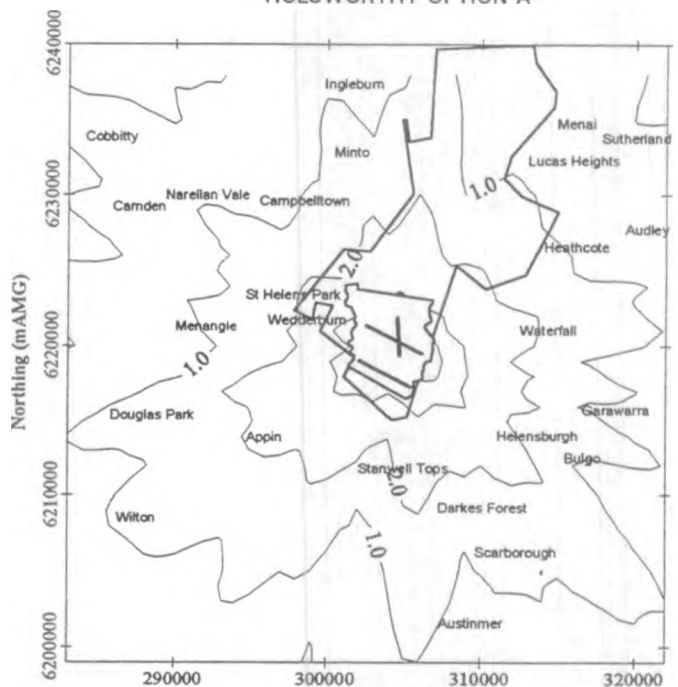
BADGERYS CREEK OPTION A



HOLSWORTHY OPTION A



BADGERYS CREEK OPTION B



HOLSWORTHY OPTION B

NOTES:

NSW EPA Guideline for peak 24 hour PM10 concentration 150 ug/m3

Background peak 24 hour PM10 concentration

Badgerys Creek: 50 ug/m3

Holsworthy: 50 ug/m3

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drawn	RJB
approved	<i>[Signature]</i>
date	23/5/97
scale	1:500,000

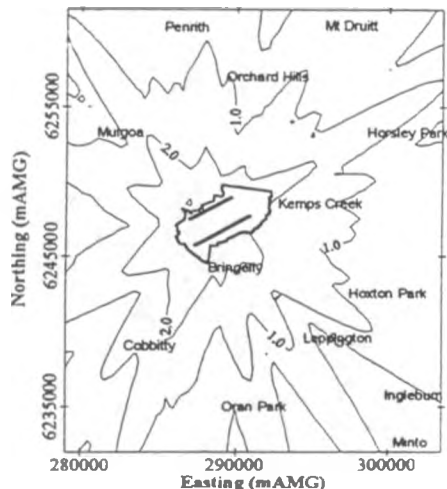
SYDNEY SECOND AIRPORT EIS  
AIR QUALITY STUDIES

2006 PEAK INCREASE IN 24 HOUR PM10 (ug/m<sup>3</sup>)

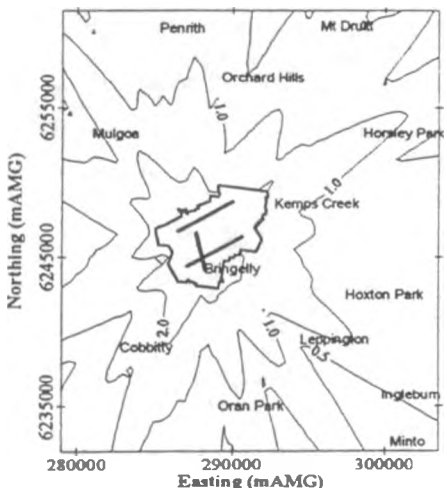


FIGURE B14

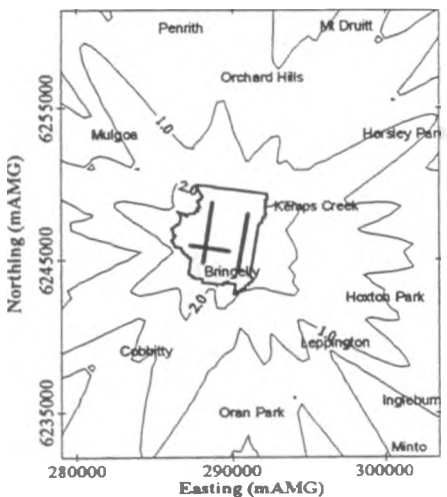
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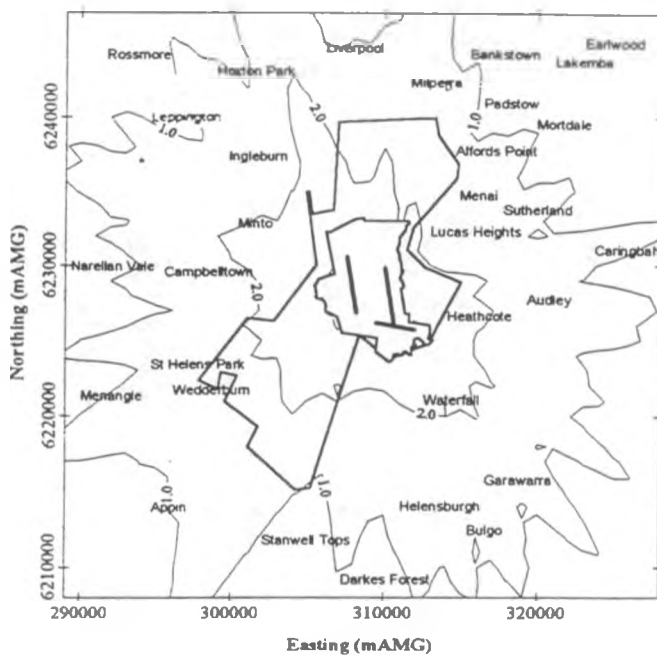
BADGERYS CREEK OPTION A



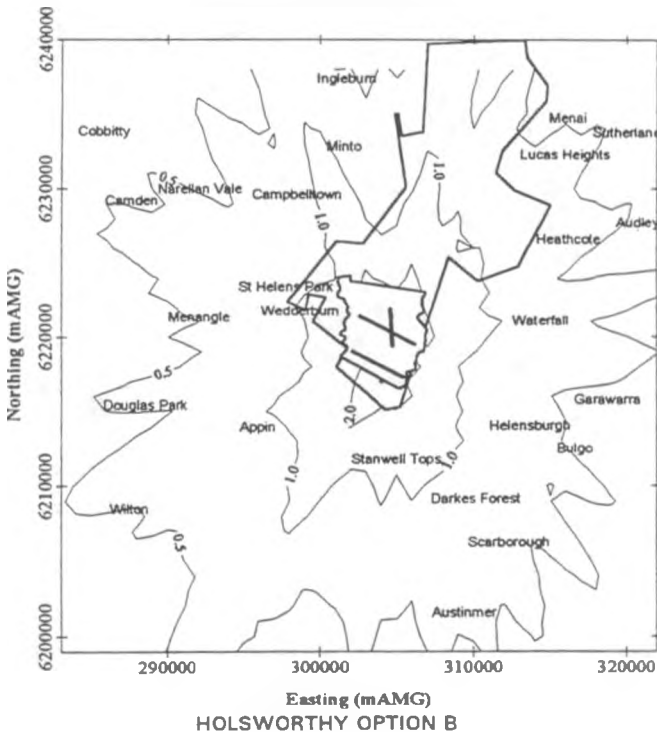
BADGERYS CREEK OPTION B



BADGERYS CREEK OPTION C



HOLSWORTHY OPTION A



HOLSWORTHY OPTION B

NOTES:

NSW EPA Guideline for peak one hoursulfur dioxide concentration 12pphm

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SYDNEY SECOND AIRPORT EIS  
AIR QUALITY STUDIES



FIGURE B15

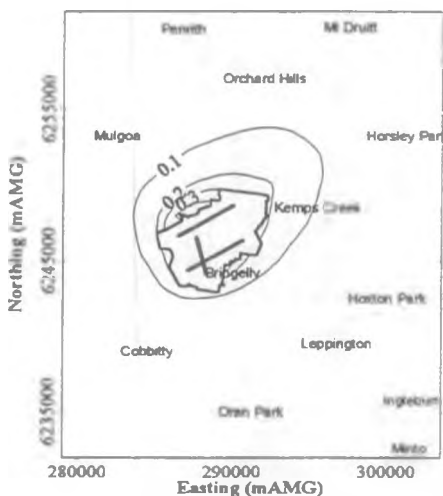
PEAK INCREASE IN 1 HOUR SO<sub>2</sub> CONCENTRATION (pphm)

job no: E2057/1-DA

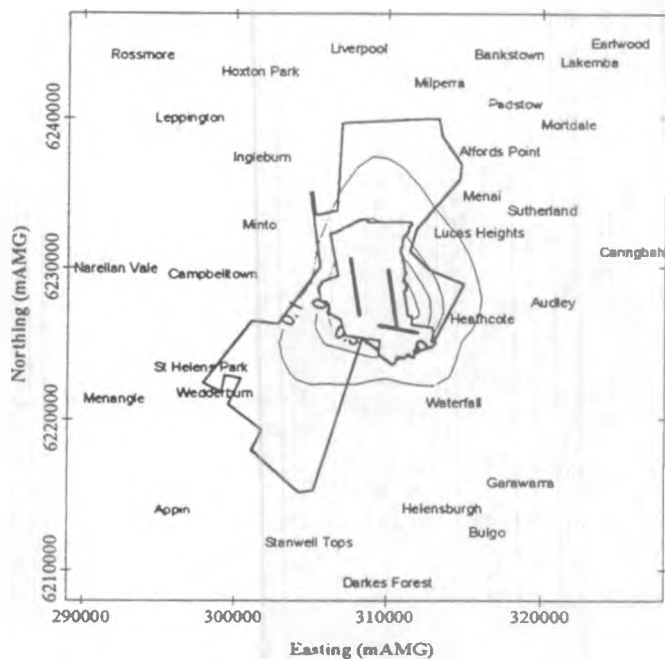
drawn	JVDV
approved	<i>[Signature]</i>
date	23/5/97
scale	AS SHOWN



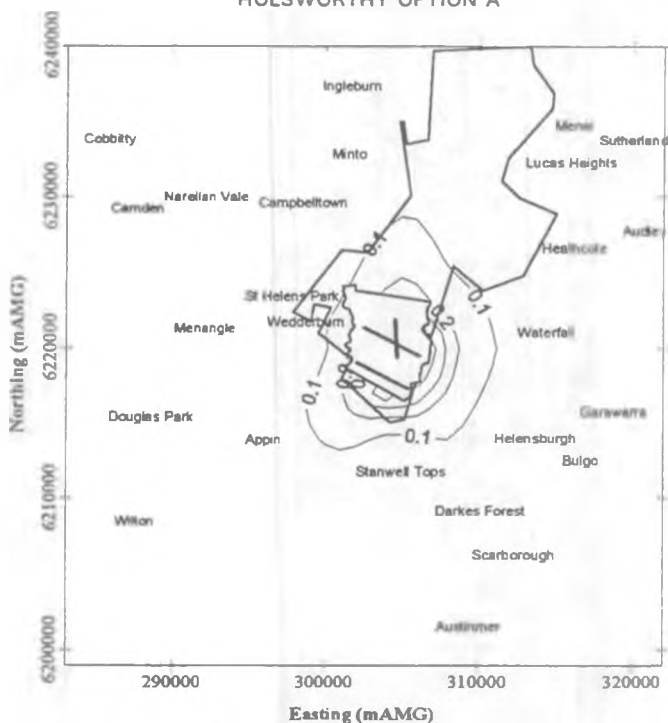
BADGERYS CREEK OPTION A



BADGERYS CREEK OPTION B



HOLSWORTHY OPTION A



HOLSWORTHY OPTION B

NOTES:

A combined air toxic reference dosage less than one indicates acceptable impact.

BADGERYS CREEK OPTION C

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approved	<i>MS</i>
date	23/5/97
scale	1:500,000

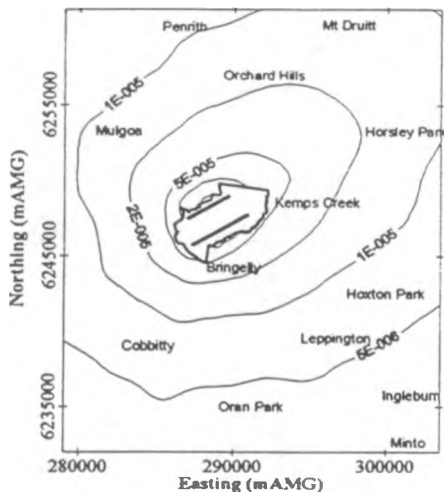
SYDNEY SECOND AIRPORT EIS  
AIR QUALITY STUDIES  
AIR TOXIC REFERENCE DOSAGE (2016)



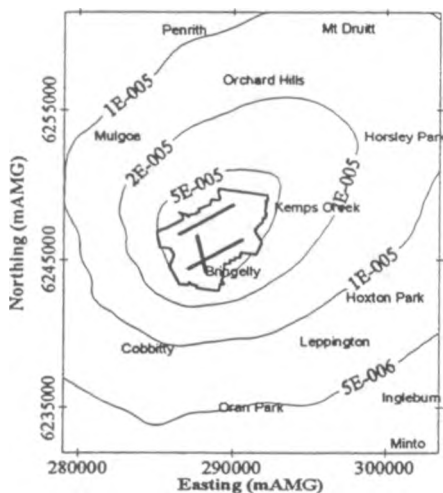
FIGURE B16

job no: E2057/1-CD

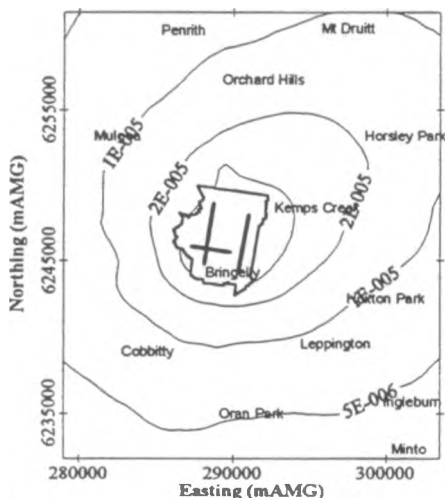




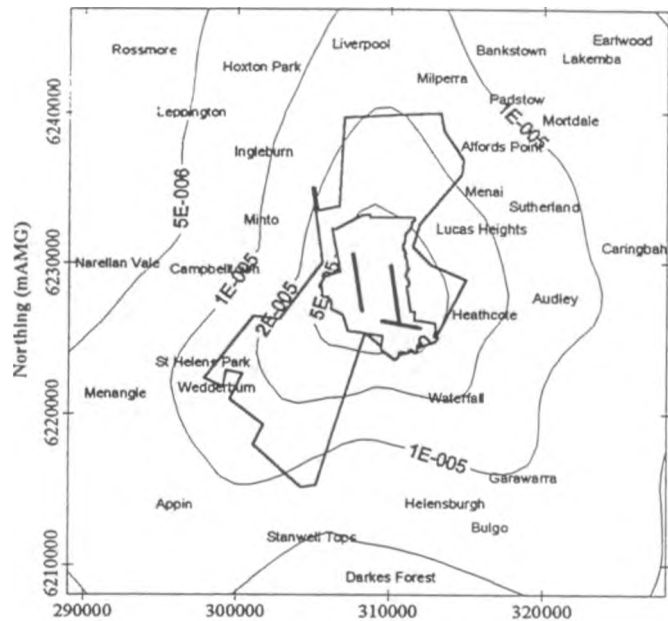
BADGERYS CREEK OPTION A



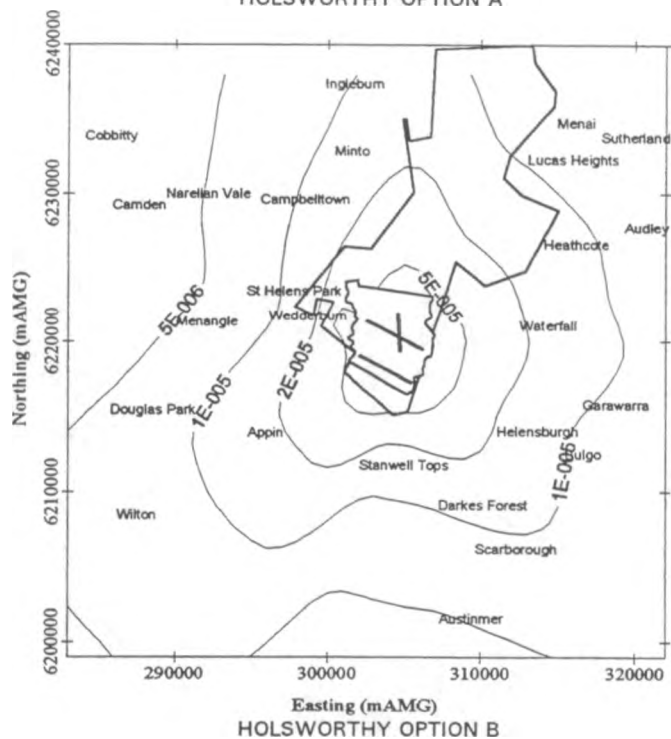
BADGERYS CREEK OPTION B



BADGERYS CREEK OPTION C



HOLSWORTHY OPTION A



HOLSWORTHY OPTION B

#### NOTES:

Risks are expressed in exponential notation. The notation 2E-005 means 2 people per 100,000 would theoretically develop cancer as a result of the airport over their lifetime.

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date	23/5/97
scale	1:500,000

SYDNEY SECOND AIRPORT EIS  
AIR QUALITY STUDIES  
INCREASED LIFETIME CANCER RISK (2016)



FIGURE B17

job no: E2057/1-CD

## **Appendix C**

---

### Air Emissions Inventory Report



Rust PPK

**SECOND SYDNEY AIRPORT  
ENVIRONMENTAL IMPACT STATEMENT  
AIR EMISSIONS INVENTORY**

Report No E2057/1-DA     June 1997

**Coffey Partners International Pty Ltd**

A.C.N. 003 692 019

Consulting Engineers, Managers and Scientists  
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## 1.0 INTRODUCTION

This report details the air emissions inventory for the Second Sydney Airport (SSA) Environment Impact Statement (EIS). The air emissions inventory represents one of the air quality assessment tasks of the EIS and has been undertaken by Coffey Partners International Pty Ltd (Coffey) on behalf of Rust PPK Pty Ltd.

The aim of the emissions inventory component of the project is to identify and quantify the major emission sources that would be associated with the operation of the second airport. The pollutants assessed include hydrocarbons (HC, total hydrocarbons including methane), oxides of nitrogen ( $\text{NO}_x$ ), carbon monoxide (CO), sulphur dioxide ( $\text{SO}_2$ ) and fine particulates ( $\text{PM}_{10}$ ). Emissions of a number of air toxics, namely benzene, toluene, ethyl benzene, xylene, 1,3-butadiene, formaldehyde and acetaldehyde have also been assessed. Estimates are also made of emissions of the greenhouse gases carbon dioxide ( $\text{CO}_2$ ), methane ( $\text{CH}_4$ ) and nitrous oxide ( $\text{N}_2\text{O}$ ).

The emissions of ozone-depleting substances such as chloroflourocarbons (CFCs), hydrochloroflourocarbons (HCFCs) and halons from airport operations have not been quantified in this study. The consumption of these substances is now controlled by international treaties and it is expected that the emissions of these substances will be minimal once the second airport is operating at design level in the next century.

The inventory was prepared in accordance with guidelines issued by the Commonwealth Environment Protection Agency and forms the input to subsequent assessments of air quality impacts of SSA on the surrounding environment. As the operational characteristics of SSA are expected to be similar for both of the proposed sites, the emissions scenarios presented are applicable to both the Badgerys Creek and Holsworthy sites.

Aircraft exhaust during normal aircraft operation is the largest emissions source within airport boundaries. Landside motor vehicle emissions from access roads and carparks (i.e. private/rental passenger vehicles, taxis, buses, delivery trucks, etc.) are typically the next largest source. Other airport sources include airside vehicles and plant, combustion of gaseous fuels (primarily natural gas) in boilers, evaporative losses from fuel storage tanks, use of surface coatings, refuelling operations and aircraft maintenance practices.

Given that aircraft exhaust and the landside motor vehicle fleet will account for the bulk of emissions at SSA, a greater emphasis has been placed on the assessment of pollution from these sources. The magnitude and distribution of emissions from the other, less significant airport sources will depend on detailed operational arrangements for SSA. Emissions from those sources for which operational details are yet to be finalised have been estimated from previous airport emissions



inventory studies recently undertaken for Tullamarine airport by VCEC (1995) and for Sydney's Kingsford Smith Airport (KSA) by Stephenson and Associates (1993). Emissions from all airport sources have been resolved temporally and spatially over the airport site according to the expected operational characteristics of the source.

## **2.0 EMISSIONS OF HC, NO<sub>x</sub>, CO<sub>2</sub>, SO<sub>2</sub> AND PM<sub>10</sub>**

### **2.1 Aircraft Exhaust Emissions**

#### **2.1.1 Methodology**

The methodology employed in this study is based on that recommended by the USEPA (1992) and involves the assessment of aircraft exhaust emissions from ground level to a height of 1000m. The conditions under which aircraft operate within this range are defined by the landing and takeoff (LTO) cycle. This cycle consists of the following operational modes:

- Approach;
- Taxi/idle-in;
- Taxi/idle-out;
- Takeoff; and
- Climbout.

Most aircraft go through a sequence similar to that above for a complete operating cycle. Some aircraft may have a slightly different sequence or combine some of the operational modes. For example, helicopters combine the takeoff and climbout modes.

The time spent in each mode of the LTO depends on a number of factors including aircraft type, congestion levels and airport layout. Time in Mode (TIM) estimates used in previous studies are shown in Table 1. These estimates have been sourced from previous emissions inventory work undertaken by V & C Environment Consultants for Melbourne's Tullamarine airport (VCEC, 1995) and by Coffey for Sydney's Kingsford Smith Airport (KSA) as part of the Metropolitan Air Quality Study (Carnovale et al., 1995). It should be noted that the TIM estimates adopted for the Tullamarine study were based on site specific measurements whereas takeoff, climbout and approach times adopted for the KSA study were based on USEPA data (1992a) which are considered to be applicable to large domestic/international airports.



**TABLE 1**  
**TIME IN MODE (TIM) ESTIMATES USED IN PREVIOUS STUDIES**

MODE	TIME (min)	
	Tullamarine (VCEC, 1995)	KSA (Carnovale, et al., 1995)
Takeoff	0.85	0.7
Taxi/idle <sup>a</sup>	8.33	26
Climbout	1.33	2.45
Approach	4.33	4.37

a. Taxi/idle mode time is the sum of taxi/idle-in and taxi/idle-out.

It can be seen from Table 1 that there are significant differences in the TIM estimates for taxi/idle and climbout. The difference in the taxi/idle times is due to a lower level of congestion at Tullamarine compared with larger airports such as KSA (VCEC, 1995). The reason for the contrast in the climbout times for the two studies is not clear but may be related to factors such as a greater proportion of heavy commercial jets represented in the USEPA (1992) data.

The TIM estimates for SSA are shown in Table 2. The taxi/idle times have been provided by Airplan (1997). The takeoff, climbout and approach TIM estimates of Carnovale et al. (1995) which are within the range of values specified by USEPA(1992) and are representative of a large and congested airport have been conservatively adopted for this study. It should be noted that these estimates are assumed to apply to all aircraft categories.

**TABLE 2**  
**TIME IN MODE (TIM) ESTIMATES FOR SSA**

MODE	TIME (min)	
	Stage 1 - 2006	Stage 2 - 2016
Takeoff	0.7	0.7
Taxi/idle <sup>a</sup>	16.5	20.2
Climbout	2.45	2.45
Approach	4.37	4.37

a. Taxi/idle mode time is the sum of taxi/idle-in and taxi/idle-out.

The LTO cycle provides the basis for calculating aircraft exhaust emissions. Each of the modes reflect different engine throttle settings, ranging from 100% during take-off to around 10% during idling. Total emissions are assessed from the number of LTO cycles for the airport, the types of engines fitted to the aircraft and the time spent in each mode.



### **2.1.2 Aircraft Movements**

The airport planning scenarios for SSA proposed by Airplan are as follows :

#### **Cases 1a and 1b - Overflow Scenario**

This scenario proposes that 10% of all Sydney basin traffic is moved to the Second Sydney Airport in the year 2006 (Case 1a). An equal mix of international, domestic and general aviation is assumed at each airport. After 2006, all growth in the Sydney basin would be accommodated at the Second Sydney Airport for the year 2016 scenario (Case 1b).

#### **Cases 2a and 2b - Equal Growth Scenario**

This scenario proposes that 10 million passengers from the Sydney basin are accommodated at the Second Sydney Airport in the year 2006 (Case 2a). An equal mix of international, domestic and general aviation traffic is assumed at each airport. After 2006, all growth in the Sydney basin would be accommodated at the Second Sydney Airport for the year 2016 scenario (Case 2b).

#### **Cases 3a and 3b - Additional Noise Scenario**

This scenario proposes that the majority of the Sydney basin wide body aircraft are located at the Second Sydney Airport from 2006 (Case 3a). After 2006, all growth in the Sydney basin (apart from general aviation) would be accommodated at the Second Sydney Airport for the year 2016 scenario (Case 3b).

Data on the aircraft types expected at SSA have been provided by Airplan (1997). These data are based on aircraft movement data for KSA compiled by Air Services Australia. Representative aircraft types and associated annual movements for SSA according to the various scenarios are shown in Table 3.





**TABLE 3**  
**ANNUAL AIRCRAFT MOVEMENTS FOR SSA**

AIRCRAFT CATEGORY	AIRCRAFT TYPE	SCENARIO					
		1a 2006	1b 2016	2a 2006	2b 2016	3a 2006	3b 2016
Heavy Jet	B-747s	6,071	24,412	12,472	30,211	33,945	47,568
	MD11	295	2,114	614	2,724	951	2,907
	DC10	143	575	294	710	773	1,137
	NLA	1,573	9,966	3,228	12,257	9,021	20,276
Widebody Jet	B-767s	6,873	21,413	14,353	27,509	18,501	30,387
	A310	1,835	5,992	3,851	7,807	3,395	7,270
Narrowbody Jet	B-737s	12,488	44,097	26,235	57,648	20,467	51,354
	A320	2,448	10,696	5,145	14,003	3,762	12,236
Regional Jet	BAe-143	1,309	3,647	2,761	4,786	1,902	4,113
Business Jet	500 Citation	1,595	2,043	1,773	2,111	1,951	2,281
Turboprop	DH8, SH6	20,987	50,970	38,947	64,404	28,335	57,114
Twin GA	LT1	5,664	6,492	5,673	6,457	5,585	6,391
Single GA	LT1	404	444	407	445	409	449
Helicopter	JRH	1,708	1,897	1,714	1,901	1,712	1,899
<b>TOTAL</b>		<b>63,392</b>	<b>184,758</b>	<b>117,466</b>	<b>232,973</b>	<b>130,710</b>	<b>245,383</b>

### 2.1.3 Emission Rates for HC, NO<sub>x</sub>, CO<sub>2</sub> and SO<sub>2</sub>

In the absence of Australian data, emission rates for HC, NO<sub>x</sub> and CO are based on experimental data according to engine operating mode and have been sourced from the United States Federal Aviation Administration Aircraft Engine Emission Database (FAEED, 1995). Emission rates of SO<sub>2</sub> have been estimated based on the sulphur content of aviation fuels. It should be noted that emissions of particulate matter are not well defined for aircraft engines, even though particulate emissions are regulated for newly manufactured engines through the use of a smoke number. A discussion of particulate matter emissions is presented in Section 2.1.5.



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6.

After discussions with industry representatives (Mr W Bourke, QANTAS, personal communication, 1996) the aircraft type specifications provided by Airplan have been matched with appropriate engine types so that the fleet is considered to be representative of the likely situation in 2006 and 2016. For example, in the widebody jet category, A300 and A310 aircraft are being phased out and the Boeing 767 is expected to be the major representative in this category. Another expected development is the introduction of the New Large Aircraft (NLA) which will carry significantly more passengers than do existing heavy jets such as the Boeing 747. The aircraft engine types considered in the inventory and the associated emission factors for HC, NO<sub>x</sub>, CO<sub>2</sub> and SO<sub>2</sub> appear in Tables 4 and 5 respectively.

**TABLE 4**  
**AIRCRAFT AND ENGINE TYPES FOR SSA**

<b>AIRCRAFT CATEGORY</b>	<b>AIRCRAFT TYPE</b>	<b>ENGINE NUMBER</b>	<b>ENGINE TYPES</b>
Heavy Jet	B-747s	4	RB211-524G
		4	RB211-524D4 Ph1
		4	PW4056/4156
		4	CF6-80C2B4
	MD11	3	CF6-80C2D1F
	DC10	3	CF6-6D
		3	CF6-50E/E2
	NLA	4	TRENT 890
Widebody Jet	B-767s	2	CF6-80C2B6
		2	JT9D-7R4E1
		2	CF6-80A
		2	PW4056/4156
	A310	2	JT9D-7R4E1
		2	PW4152
Narrowbody Jet	B-737s	2	CFM56-3B
		2	CFM56-3C
	A320	2	CFM56-5A1



TABLE 4 (ctd)  
AIRCRAFT AND ENGINE TYPES FOR SSA

AIRCRAFT CATEGORY	AIRCRAFT TYPE	ENGINE NUMBER	ENGINE TYPES
Regional Jet	BAe-143	4	ALF502R-5
Business Jet	500 Citation	2	JT15D-1A
		2	JT15D-1B
Turboprop	DH8, SH6	2	PT6A-27
		2	PT6A-41
Twin GA	LT1	2	O200
		2	O320
		2	PT61-41
Single GA	LT1	1	O200
		1	O320
		1	PT61-41
Helicopter	JRH	1	T53-L-11D

**TABLE 5: AIRCRAFT ENGINE EMISSION RATES (KG/MIN/ENGINE) FOR HC, CO, NO<sub>x</sub> AND SO<sub>2</sub> OVER LTO CYCLE (FAEED, 1995)**

ENGINE TYPE	TAKEOFF				CLIMBOUT				APPROACH				TAXI/IDLE			
	HC	CO	NO <sub>x</sub>	SO <sub>2</sub>	HC	CO	NO <sub>x</sub>	SO <sub>2</sub>	HC	CO	NO <sub>x</sub>	SO <sub>2</sub>	HC	CO	NO <sub>x</sub>	SO <sub>2</sub>
ALF502R-5	1.29E-03	6.45E-03	2.91E-01	2.15E-02	9.40E-04	4.43E-03	1.87E-01	1.77E-02	1.35E-03	4.40E-02	4.09E-02	6.21E-03	1.32E-02	1.00E-01	9.25E-03	2.45E-03
CF6-50E/E2	8.95E-02	7.46E-02	5.42E+00	1.46E-01	8.30E-02	5.93E-02	3.52E+00	1.15E-01	3.96E-02	1.70E-01	3.76E-01	3.99E-02	2.81E-01	7.97E-01	4.64E-02	1.01E-02
CF6-6D	3.12E-02	5.21E-02	4.17E+00	1.04E-01	2.58E-02	4.29E-02	2.80E+00	8.59E-02	2.03E-02	1.89E-01	3.31E-01	2.90E-02	2.18E-01	5.62E-01	4.67E-02	1.04E-02
CF6-80A	3.73E-02	1.29E-01	3.84E+00	1.29E-01	3.12E-02	1.18E-01	2.76E+00	1.08E-01	1.73E-02	1.14E-01	3.80E-01	3.69E-02	5.66E-02	2.54E-01	3.06E-02	9.00E-03
CF6-80C2B4	1.17E-02	8.16E-02	4.26E+00	1.46E-01	1.07E-02	6.42E-02	2.59E+00	1.19E-01	8.19E-03	9.09E-02	3.47E-01	3.90E-02	1.16E-01	5.24E-01	4.38E-02	1.19E-02
CF6-80C2B6	1.08E-02	8.05E-02	4.77E+00	1.55E-01	9.99E-03	6.49E-02	2.86E+00	1.25E-01	8.23E-03	7.94E-02	3.75E-01	4.12E-02	1.12E-01	5.17E-01	4.71E-02	1.24E-02
CFM56-3B	2.28E-03	5.70E-02	1.23E+00	6.84E-02	2.48E-03	4.74E-02	8.80E-01	5.58E-02	1.38E-03	6.41E-02	1.64E-01	2.16E-02	1.25E-02	2.15E-01	2.93E-02	7.80E-03
CFM56-3C	2.62E-03	4.71E-02	8.69E-01	7.08E-02	2.20E-03	4.39E-02	6.46E-01	5.82E-02	1.31E-03	6.88E-02	1.31E-01	2.04E-02	1.90E-02	2.54E-01	2.53E-02	7.20E-03
CFM56-5A1	1.45E-02	5.68E-02	1.55E+00	6.48E-02	1.19E-02	4.65E-02	1.01E+00	5.28E-02	6.98E-03	4.37E-02	1.40E-01	1.80E-02	8.49E-03	1.07E-01	2.43E-02	6.60E-03
O-200	7.12E-03	3.33E-01	1.67E-03	6.80E-05	7.12E-03	3.33E-01	1.67E-03	6.80E-05	6.38E-06	2.28E-01	2.19E-04	3.90E-05	1.74E-03	3.87E-02	9.48E-05	1.27E-05
O-320	7.92E-03	7.24E-01	1.47E-03	1.34E-04	6.24E-03	4.99E-01	2.00E-03	1.01E-04	6.81E-06	4.32E-01	3.36E-04	7.08E-05	2.66E-03	7.75E-02	3.74E-05	1.45E-05
PT6A-27	0.00E+00	3.21E-03	2.51E-02	3.21E-03	0.00E+00	3.63E-03	2.12E-02	3.03E-03	3.56E-03	3.79E-02	1.36E-02	1.62E-03	4.36E-02	5.57E-02	2.11E-03	8.71E-04
PT6A-41	6.75E-03	1.97E-02	3.08E-02	3.86E-03	7.26E-03	2.32E-02	2.71E-02	3.57E-03	4.69E-02	7.18E-02	9.60E-03	2.06E-03	1.13E-01	1.28E-01	2.19E-03	1.11E-03
PW4056/4156	1.23E-02	3.83E-02	4.36E+00	1.41E-01	1.07E-02	3.89E-02	2.79E+00	1.16E-01	7.42E-03	5.69E-02	4.54E-01	3.95E-02	1.57E-02	2.02E-01	5.82E-02	1.25E-02
RB211-524D4Ph1	0.00E+00	7.68E-02	8.57E+00	1.50E-01	5.07E-02	1.42E-01	4.94E+00	1.20E-01	2.13E-01	7.50E-01	4.28E-01	4.43E-02	8.36E-01	1.33E+00	7.40E-02	1.80E-02
RB211-524G	3.58E-01	9.27E-02	9.23E+00	1.57E-01	1.82E-01	5.37E-02	5.06E+00	1.25E-01	4.79E-02	4.24E-02	4.02E-01	4.19E-02	5.12E-02	2.14E-01	7.22E-02	1.56E-02
T53-L-11D	0.00E+00	0.00E+00	0.00E+00	5.22E-03	1.49E-03	1.54E-02	3.78E-02	5.18E-03	1.49E-03	1.54E-02	3.78E-02	4.88E-03	6.81E-02	3.18E-02	1.51E-03	1.10E-03
CF6-80C2D1F	1.09E-02	8.10E-02	5.09E+00	1.56E-01	9.91E-03	6.44E-02	2.98E+00	1.24E-01	7.88E-03	7.65E-02	3.61E-01	3.94E-02	1.06E-01	4.91E-01	4.47E-02	1.18E-02
JT9D-7R4E1	2.03E-02	7.24E-02	5.29E+00	1.27E-01	1.34E-02	5.48E-02	3.54E+00	1.03E-01	5.09E-03	4.82E-02	4.07E-01	3.92E-02	1.47E-02	1.10E-01	5.44E-02	1.33E-02
PW4152	1.70E-02	1.57E-02	3.51E+00	1.31E-01	1.71E-02	1.82E-02	2.43E+00	1.07E-01	5.34E-03	3.88E-02	3.95E-01	3.56E-02	7.86E-03	1.36E-01	5.20E-02	1.06E-02
JT8D-209	2.50E-02	7.15E-02	1.63E+00	7.15E-02	2.95E-02	8.26E-02	1.12E+00	5.90E-02	3.64E-02	9.48E-02	1.90E-01	2.16E-02	3.15E-02	1.10E-01	2.74E-02	7.82E-03
JT15D-1A & 1B	8.88E-05	2.35E-02	6.75E-02	8.88E-03	7.44E-05	2.60E-02	5.04E-02	7.44E-03	1.36E-02	1.24E-01	1.05E-02	3.06E-03	6.97E-02	1.82E-01	2.42E-03	1.38E-03
TRENT 890 <sup>a</sup>	2.32E-03	6.27E-02	1.05E+01	2.32E-01	0.00E+00	3.51E-02	6.12E+00	1.85E-01	0.00E+00	3.40E-02	7.09E-01	6.18E-02	1.33E-02	2.42E-01	9.47E-02	1.80E-02

a. TRENT 890 is assumed to be the representative engine of the New Large Aircraft (Mr W Bourke, QANTAS, personal communication, 1996).



#### 2.1.4 Emissions of HC, NO<sub>x</sub>, CO<sub>2</sub> and SO<sub>2</sub>

The following steps allow the calculation of total emissions from aircraft exhaust and are based on the number of aircraft movements, aircraft/engine types and modal emission rates as discussed in the previous sections.

Step 1. Calculate emissions for each aircraft/engine configuration according to the formula:

$$E_{ij} = \text{Sum}[TIM_k \times ER_{ijk} \times N_j]$$

where:

$E_{ij}$  = total emissions of pollutant i produced by aircraft/engine configuration j per LTO cycle.

$TIM_k$  = time in mode for mode k.

$ER_{ijk}$  = emission rate for pollutant i, mode k and aircraft/engine configuration j.

$N_j$  = number of engines on aircraft/engine configuration j.

Step 2. Calculate total emissions for all aircraft according to the formula:

$$ET_i = \text{Sum}[E_{ij} \times LTO_j]$$

where:

$ET_i$  = total emissions of pollutant i produced by aircraft fleet.

$LTO_j$  = the number of LTO cycles for aircraft/engine configuration j.

Estimates of annual and daily aircraft exhaust emissions are presented in Table 6.



**TABLE 6**  
**EMISSIONS OF HC, NO<sub>x</sub>, CO<sub>2</sub> AND SO<sub>2</sub> FROM AIRCRAFT EXHAUST AT SSA**

Scenario (units)	HC	NO <sub>x</sub>	CO	SO <sub>2</sub>
Case 1a - Overflow Scenario 2006 (t/yr)	99	500	289	28
Case 1a - Overflow Scenario 2006 (kg/day)	271	1,369	791	77
Case 1b - Overflow Scenario 2016 (t/yr)	363	2,124	1,173	119
Case 1b - Overflow Scenario 2016 (kg/day)	995	5,820	3,214	327
Case 2a - Equal Growth Scenario 2006 (t/yr)	188	1,032	561	58
Case 2a - Equal Growth Scenario 2006 (kg/day)	515	2,828	1,538	158
Case 2b - Equal Growth Scenario 2016 (t/yr)	454	2,662	1,476	150
Case 2b - Equal Growth Scenario 2016 (kg/day)	1,243	7,293	4,043	412
Case 3a - Additional Noise Scenario 2006 (t/yr)	300	2,176	890	107
Case 3a - Additional Noise Scenario 2006 (kg/day)	821	5,961	2,439	294
Case 3b - Additional Noise Scenario 2016 (t/yr)	563	3,761	1,820	200
Case 3b - Additional Noise Scenario 2016 (kg/day)	1,542	10,305	4,985	547

A comparison of these results with those of previous airport emission studies undertaken in Australia and the United States is presented in Section 2.5.

#### 2.1.5 Emissions of Particulate Matter

Particulate matter forms as a result of incomplete combustion of fuel. Particulate emissions are highest during the takeoff and climbout phases of the LTO cycle when fuel use is at a maximum. Particulate emission rates for aircraft engines are difficult to determine and are generally not available. An approximate methodology for the estimation of particulate emissions has been adopted for this study as discussed below.

Profile 34001 (SDS, 1993) is a general composition profile that was developed from a study of engine-related particulate matter and is applied to turbines fuelled by kerosene, diesel and natural gas. Emissions of PM<sub>10</sub>, consisting of organic and elemental carbon are documented to be approximately 2.7 g/kg fuel burnt. With annual consumption of aviation fuel in the vicinity of 148,000 t for SSA at design level in 2016 (see Section 7.0), an annual emission of approximately 392 tonnes of PM<sub>10</sub> is estimated. Emissions for the other scenarios are calculated by scaling according to the number of annual aircraft movements. A summary of PM<sub>10</sub> emission estimates is shown in Table 7.



**TABLE 7**  
**EMISSIONS OF PM<sub>10</sub> FROM AIRCRAFT EXHAUST AT SSA**

<b>Scenario</b>	<b>PM<sub>10</sub> (t/yr)</b>	<b>PM<sub>10</sub> (kg/day)</b>
Case 1a - Overflow Scenario 2006 (t/yr)	66	182
Case 1b - Overflow Scenario 2016 (t/yr)	243	666
Case 2a - Equal Growth Scenario 2006 (t/yr)	137	375
Case 2b - Equal Growth Scenario 2016 (t/yr)	308	843
Case 3a - Additional Noise Scenario 2006 (t/yr)	245	672
Case 3b - Additional Noise Scenario 2016 (t/yr)	392	1075

It should be noted that USEPA has assigned a data quality rating of D/E to the above emission factor, meaning that there is a low level of confidence in its use (the scale adopted by the USEPA ranges from "A" to "E", where "A" signifies a high level of confidence in the accuracy of the emission factor). The estimates derived should only be considered to represent order of magnitude indicators of emission levels.

## **2.2 Landside Motor Vehicle Emissions**

Road traffic carrying passengers, airport employees and freight to and from the airport is a significant source of airport related emissions. Emissions from motor vehicles within airport boundaries at KSA were assessed to be the second largest single source of emissions by Stephenson and Associates (1993). In a similar study for Tullamarine airport, V&C Environment Consultants (1995) estimated that road traffic within the airport was in fact the largest source of HC and CO on a typical day.

As no detail was available regarding traffic projections for SSA, an approximate methodology for the estimation of motor vehicle emissions assumed to apply to both the Badgerys Creek and Holsworthy proposed airport sites has been adopted. The essential features of the methodology are as follows:

- a single access road for the airport with a round trip length of 6 km;



- daily traffic volumes based on work previously undertaken for Tullamarine Airport by V & C Environment Consultants (1995). Estimates of traffic volumes at KSA are available (Masson and Wilson, 1996), but are not considered to be directly applicable to the proposed second airport given the differences in ground access requirements. For example, there is a large component of ground traffic at KSA generated by airport related industry that may not be a feature of the second airport (Mr F. Gennaoui, Rust PPK, personal communication, 1996);
- emission factors developed by Coffey for the 2006 and 2016 motor vehicle fleets on a hot summer day and mild winter day were adopted assuming typical urban-type traffic flow at the airport. Airport carparks have not been explicitly modelled, however, the nature of the traffic flow assumed (ADR drive cycle) incorporates elements of congestion and low speed travel similar to conditions expected within airport carparks.

It should be noted that the possible effects of a rail link on traffic volumes at the second airport have not been considered in this study due to a lack of available data.

Emission factors for the 2006 and 2016 motor vehicle fleets are shown in Table 8. The following formula was used to calculate emissions:

$$ET_{ij} = vpd_j \times D \times EF_{ij}$$

where:

$ET_{ij}$  = total emissions of pollutant i for scenario (season/year) j.

$vpd_j$  = the number of vehicles per day (vpd) for scenario j.

$D$  = the average distance travelled within the airport by each vehicle.

$EF_{ij}$  = motor vehicle fleet emission factor for pollutant i and scenario (season/year) j.

Estimates of landside motor vehicle emissions for the various scenarios on a hot summer day are presented in Table 9 and have been calculated on the assumption that daily traffic volumes will range from approximately 14,600 vehicles per day (vpd) for Case 1a to 34,400 vpd for Case 3b respectively. Estimates for the winter day scenarios appear in Section 8.





**TABLE 8**  
**EMISSION FACTORS FOR 2006 AND 2016 MOTOR VEHICLE FLEETS**

Compound	2006 (g/km)		2016 (g/km)	
	Summer	Winter	Summer	Winter
HC	2.41	1.92	2.16	1.74
NO <sub>x</sub>	1.54	1.66	1.16	1.24
CO	12.25	18.64	9.75	16.76
SO <sub>2</sub>	0.065	0.065	0.065	0.065
PM <sub>10</sub>	0.12	0.14	0.12	0.14

**TABLE 9**  
**ESTIMATES OF EMISSIONS FROM LANDSIDE MOTOR VEHICLES AT**  
**SSA, HOT SUMMER DAY**

Scenario	HC kg/day	NO <sub>x</sub> kg/day	CO kg/day	SO <sub>2</sub> kg/day	PM <sub>10</sub> kg/day
Case 1a - Overflow Scenario 2006	128	82	653	3	6
Case 1b - Overflow Scenario 2016	335	180	1,514	10	19
Case 2a - Equal Growth Scenario 2006	238	152	1,210	6	12
Case 2b - Equal Growth Scenario 2016	422	226	1,910	13	24
Case 3a - Additional Noise Scenario 2006	264	170	1,346	7	13
Case 3b - Additional Noise Scenario 2016	445	239	2,011	13	25

### 2.3 Airside Vehicles And Plant

There is a wide variety of equipment comprising the airside vehicle fleet and plant which performs essential services while the aircraft is on the ground during an LTO cycle. Examples of this ground service equipment (GSE) include large capacity tractors for aircraft pushback, fuel trucks, air conditioning units and baggage conveyors. Units may be powered by petrol, diesel or electricity. At Australian airports, such equipment is generally diesel-fuelled (C. Jarvis, Airplan, personal communication, 1997).

Annual GSE movements for each of the proposed SSA scenarios have been estimated from data provided by Airplan. Emission factors and TIM estimates have been sourced from the Emissions and Dispersion Modelling System (EDMS, 1993).

A summary of emissions from GSE for the proposed scenarios is presented in Table 10. Further details of the calculations are presented in Appendix A.



**TABLE 10**  
**EMISSIONS FROM AIRSIDE VEHICLE FLEET AND PLANT AT SSA**

SCENARIO	HC kg/day	NO <sub>x</sub> kg/day	CO kg/day	SO <sub>2</sub> kg/day	PM kg/day
Case 1a - Overflow Scenario 2006	47	247	236	6	18
Case 1b - Overflow Scenario 2016	137	719	688	18	53
Case 2a - Equal Growth Scenario 2006	87	457	437	11	34
Case 2b - Equal Growth Scenario 2016	173	907	867	22	67
Case 3a - Additional Noise Scenario 2006	97	509	487	12	38
Case 3b - Additional Noise Scenario 2016	182	955	913	23	70

#### 2.4 Other Airport Sources

Other sources considered in this study comprise the following:

- aircraft maintenance;
- aircraft refuelling and fuel storage;
- use of Auxiliary Power Units (APUs);
- use of solvents such as surface coatings and engine degreasers; and
- boilers/heaters in terminal buildings and workshops.

As discussed, detailed information relating to these sources was not available at the time of writing. The results of a study of emissions at KSA undertaken by Stephenson and Associates (1993) on behalf of the FAC have been scaled according to the level of activity expected at the second airport and supplemented with additional information where possible. This approach provides an approximate assessment of emissions, but is considered to be reasonable given that the sources involved make a relatively minor contribution to total emissions. Estimates of emissions for 2016 at design capacity appear in Table 11. Emissions from these sources for the SSA scenarios are presented in Section 8.0.

**TABLE 11: EMISSIONS FROM OTHER SOURCES FOR SSA , SCENARIO 3B**

SOURCE	kg/day				
	HC	NO <sub>x</sub>	CO	SO <sub>2</sub>	PM <sub>10</sub>
Maintenance	9	126	63	3	n/e
Refueling / Storage	29	0	0	0	0
Surf coat	20	0	0	0	0
Solvent use	226	0	0	0	0
APU	17	278	481	n/e	n/e
Boiler	2	47	11	0.2	1
TOTAL	303	452	555	3	1

note : n/e indicates parameter not estimated.

## 2.5 Comparison of Emissions Estimates with Those of Other Studies

Estimates of emissions made in this study for SSA in 2016 at design capacity have been compared with those of previous inventory studies undertaken for KSA (Stephenson and Associates, 1993; Carnovale et al., 1995) and Tullamarine airport (V & C Environment Consultants, 1995). Inventory results have also been compared with modelled results derived for the Washington National Airport in the United States using the Emissions and Dispersion Modelling System (EDMS, 1993). Note that emissions of particulate matter were not assessed in these previous studies.

Results of studies for different airports are not directly comparable given differences in parameters such as aircraft fleet mix, motor vehicle emission control technology, level of airport activity, time in mode, airport design and study year. Such comparisons are, however, useful for first order assessment of total and relative emissions for the various sources.

The comparison of inventory results appears in Table 12. To the extent that the inventories can be meaningfully compared with one another, it can be seen that the results of this study are broadly similar to previous studies in terms of the relative magnitudes of the various sources of emission at airports. For example, the contribution of aircraft exhaust to total NO<sub>x</sub> shows close agreement for all studies, ranging from 86% to 89%. Aircraft exhaust emissions of HC display much wider variability, ranging from approximately 24% (V & C Environment Consultants, 1995) to 81% (EDMS, 1993) with results for SSA derived for this study being somewhere near the midpoint of this range at 62%. Again, it must be stressed that comparisons of this nature must be considered with caution in the light of fundamental differences in airport layout. For example, the contrast in relative HC emissions for the two previous studies mentioned above is due partly to differences in the length of roadways considered in the studies. In addition, the emission control technology found on US vehicles is generally further advanced than that of comparable model year Australian vehicles.

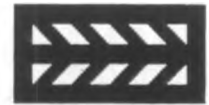
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**TABLE 12**  
**COMPARISON OF EMISSIONS FROM PREVIOUS STUDIES**  
**WITH ESTIMATED EMISSIONS FOR SSA, SCENARIO 3B**

Author, Study Year	HC	NO <sub>x</sub>	CO	SO <sub>2</sub>	HC	NO <sub>x</sub>	CO	SO <sub>2</sub>
Airport, Annual	kg/day	kg/day	kg/day	kg/day	%	%	%	%
Movements								
<b>Stephenson, 2010</b>								
<b>KSA, 303000</b>								
Aircraft Exhaust	1220	7824	9668	612	65%	89%	73%	99%
Motor Vehicles	220	250	1970		12%	3%	15%	0%
Other	435	678	1556	4	23%	8%	12%	1%
TOTAL	1875	8752	13194	616	100%	100%	100%	100%
<b>VCEC, 1995</b>								
<b>Tullamarine, 144000</b>								
Aircraft Exhaust	172	1963	1377	441	24%	86%	39%	98%
Motor Vehicles	344	88	1806		48%	4%	52%	0%
Other	199	222	309	9	28%	10%	9%	2%
TOTAL	715	2273	3492	450	100%	100%	100%	100%
<b>Carnovale, 1992</b>								
<b>KSA, 230000</b>								
Aircraft Exhaust	1970	4480	5410	290	79%	87%	69%	99%
Motor Vehicles	113	156	1228		5%	3%	16%	0%
Other	396	516	1232	3	16%	10%	16%	1%
TOTAL	2479	5152	7870	293	100%	100%	100%	100%
<b>EDMS, 1990</b>								
<b>Washington, 190000</b>								
Aircraft Exhaust	1547	4778	6496	321	81%	89%	74%	15%
Motor Vehicles	34	29	469	0	2%	1%	5%	0%
Other	338	587	1797	1879	18%	11%	21%	85%
TOTAL	1919	5394	8762	2200	100%	100%	100%	100%
<b>Coffey, 2016</b>								
<b>SSA, 245000</b>								
Aircraft Exhaust	1542	10305	4985	547	62%	86%	59%	93%
Motor Vehicles	445	239	2011	13	18%	2%	24%	2%
Other	485	1407	1469	26	20%	12%	17%	4%
TOTAL	2472	11951	8465	587	100%	100%	100%	100%



The aircraft exhaust results for the 2016 (Case 3b) scenario have been compared with those of Carnovale et al. (1995) for Kingsford Smith airport in 1992, scaled according to the number of annual movements expected at SSA when operating at design capacity in 2016. Results from this study for HC, NO<sub>x</sub> and CO are substantially different from the estimates of Carnovale et al. (1995), being 27% lower, 116% higher and 13% lower respectively. This variation is due primarily to the much larger proportion of heavy jets in the SSA fleet compared to the fleet mix adopted for the KSA work. These observations are also consistent with studies which have reported that improvements in aircraft engine technology have led to lower HC and CO emissions whereas NO<sub>x</sub> emissions have stayed the same or increased (Grieb & Simon, 1990).

The projection work of Stephenson and Associates (1993) for KSA in 2010 has also been compared with the results of this study. These projections were based on 303,000 aircraft movements per year and have been scaled according to the SSA 2016 design level of approximately 245,000 movements annually. Aircraft exhaust HC, NO<sub>x</sub> and CO emissions estimates of Stephenson and Associates (1993) are significantly different to those of this study, being approximately 56% lower, 63% higher and 36% lower respectively. The TIM estimates and details of the engine mix adopted by Stephenson and Associates (1993) for the projections were not available so comment cannot be made as to the reasons for this discrepancy. Differences of this magnitude, however, can be expected given the variation in emission rates for the engines that can be chosen to represent modern aircraft fleets.

### 3.0 EMISSIONS OF AIR TOXICS

Air toxics refer to those compounds with known or suspected carcinogenic, mutagenic, teratogenic or other toxic effects. Emissions of the following air toxics have been assessed:

- Benzene;
- Toluene;
- Ethyl Benzene;
- Xylene;
- Formaldehyde;
- Acetaldehyde; and
- 1,3 - Butadiene.

Benzene and 1,3-butadiene are of concern primarily because of their potential carcinogenic effects on humans. Benzene has been classified by the International Agency for Research on Cancer (IARC, 1989) as a known (Group 1) human carcinogen while 1,3-Butadiene is classified as a probable (Group 2A) human carcinogen.



Toluene, xylene and ethyl benzene are not classifiable as human carcinogens, however, their toxic effects include irritation of the eyes and respiratory system. Chronic (long term) exposure to these substances can lead to lung and liver damage (IRIS, 1996). Carbonyl compounds such as formaldehyde and acetaldehyde, in addition to their toxic effects, are of environmental interest due to their high reactivity in the atmosphere and the role they play in the formation of photochemical smog.

Emissions of these toxic compounds have been estimated from a consideration of volatile organic compound (VOC) speciation profiles for each source. Note that VOC is generally defined as being equivalent to hydrocarbon (HC) emissions with the exclusion of methane and the inclusion of substituted hydrocarbon compounds such as carbonyls.

The speciation profile for aircraft exhaust is a weighted average for a typical U.S. commercial aviation LTO cycle (Profile 1098, SDS, 1993). This profile is assumed to apply to maintenance and APU operation.

For the landside motor vehicle fleet, the benzene content of exhaust HC has been estimated using an equation established by the USEPA (1993) for petrol-fuelled catalyst equipped vehicles as follows:

$$\% \text{ Benzene} = 1.077 + 0.7732 \times (\text{Vol. \% benzene}) + 0.0987 \times (\text{Vol. \% aromatics} - \text{Vol \% benzene})$$

The benzene and total aromatic percentages (2% and 29% respectively) used in the above equation have been estimated for regular unleaded fuel produced in Sydney (Associated Octel Petrol Survey, W.T. Perreau, personal communication, 1996). Toluene, xylene, ethyl benzene and carbonyl profiles for motor vehicles have been conservatively based on the 1992 NSW motor vehicle fleet as reported by Carnovale et al. (1995).

For the predominantly diesel airside vehicle and plant fleet, the aldehyde content of diesel exhaust has been sourced from the USEPA (Profile 1201, SDS, 1993). The benzene content of diesel exhaust is taken to be 1.9% as reported by Environment Canada (1990).

The profile for surface coatings is also based on the work of Carnovale et al. (1995). The VOC profile for solvents used at airports is difficult to estimate due to the range of compounds used and has been approximated by an urban solvent mix adopted in previous inventory work undertaken by Coffey (Morell et al., 1995). For natural gas combustion, the profile for commercial natural gas boilers as reported by the USEPA has been adopted (Profile 0003, SDS, 1993). Aviation fuel contains negligible amounts of the air toxics considered in this study and for this reason no contribution to air toxics is included for evaporative fuel losses which would occur during aircraft



refueling. Air toxics emitted in exhaust from aircraft engines are discussed above and presented in Table 13.

The air toxics speciation profiles adopted for airport sources are presented in Table 13. Note that aircraft exhaust VOC is calculated by multiplying the HC emission values by 1.0947 as recommended by the USEPA (1992). Landside and airside motor vehicle and plant VOC emissions have been assumed to be equivalent to 92% of HC (F. Carnovale, personal communication, 1996). For surface coatings, other solvents and natural gas combustion, VOC emissions have been assumed to be equivalent to HC emissions.

**TABLE 13**  
**ESTIMATES OF AIR TOXICS SPECIATION PROFILES**

Species	Aircraft Exhaust (% VOC)	Landside Vehicles (% VOC)	Airside Veh./Plant (% VOC)	Surface Coatings (% VOC)	Solvent Usage (% VOC)	Boiler (% VOC)
Benzene	1.94	4.34	1.9	0	0	4
Toluene	0.52	5.75	0	25	14	2
Ethyl Benzene	0.17	0.86	0	0	0	0
Xylene	0.48	5.79	0	18	12	0
Formaldehyde	15.01	1.07	9.1	0	0	2
Acetaldehyde	4.65	0.21	3.1	0	0	0
1,3-Butadiene	1.80	0.37	0	0	0	0

Air toxic emissions are calculated using the following formula:

$$ET_{ijk} = EF_j \times VOC_{jk}$$

where:

$ET_{ij}$  = total emissions of air toxic i for source j and scenario (season/year) k.

$EF_{ij}$  = emission factor (% of VOC) for air toxic i and source j.

$VOC_{jk}$  = emission of VOC for source j and scenario k.

Estimates of daily emissions of air toxics for SSA at design level in 2016 scenario are presented in Table 14. Emissions estimates for the alternative scenarios appear in Section 8.



**TABLE 14**  
**ESTIMATES OF AIR TOXICS EMISSIONS FROM SSA. SCENARIO 3B**

Species	Aircraft Exhaust (kg/day)	Landside Vehicles (kg/day)	Airside Veh./Plant (kg/day)	Surface Coatings (kg/day)	Solvent Usage (kg/day)	Boiler (kg/day)	TOTAL (kg/day)
Benzene	33	12	3	0	0	0.1	49
Toluene	9	23	0	5	32	0.04	68
Ethyl Benzene	3	3	0	0	0	0	6
Xylene	8	23	0	4	27	0	62
Formaldehyde	258	3	17	0	0	0.2	277
Acetaldehyde	80	1	6	0	0	0	87
1,3-Butadiene	31	1	0	0	0	0	31

#### 4.0 EMISSIONS OF GREENHOUSE GASES

Greenhouse gas emissions at airports consist primarily of carbon dioxide (CO<sub>2</sub>) which is formed by the oxidation of fuel carbon during fuel combustion. Other greenhouse gases such as CH<sub>4</sub> and N<sub>2</sub>O are emitted from the incomplete combustion of fuel and from reactions between fuel constituents and air during and after the combustion process. Pollutants such as CO and NO<sub>x</sub> are not greenhouse gases as such but are indirect contributors to the greenhouse effect by influencing the rate of formation and destruction of the greenhouse gases.

Emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O from airport related sources have been estimated for SSA at design capacity in 2016 using the Australian methodology specified by the National Greenhouse Gas Inventory Committee (NGGIC, 1996a/1996b). This method, endorsed by the Intergovernmental Panel on Climate Change (IPCC) involves the estimation of fuel consumption by each source and application of emission factors that relate the emission of greenhouse gas to the energy content of the fuel consumed. As for aircraft exhaust, emissions of these greenhouse gases have been assessed from ground level up to a height of 1000 metres.

Emission factors for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O for the fuel types considered in this analysis are shown in Table 15. Note that the total carbon content of the fuel consumed is assigned to CO<sub>2</sub> emissions and solid products such as soot. Under actual engine operating conditions, however, a small proportion of the fuel carbon is released as CH<sub>4</sub>, CO and other organic gases.





**TABLE 15**  
**GREENHOUSE GAS EMISSION RATES AND FUEL ENERGY DENSITIES**

<b>Fuel Type</b>	<b>Energy Density (units)</b>	<b>CO<sub>2</sub> (g/MJ)</b>	<b>CH<sub>4</sub> (units)</b>	<b>N<sub>2</sub>O (g/MJ)</b>
Aviation Turbine Fuel	36.8 (g/MJ)	69.70	0.0094 (g/MJ)	0.002
Automotive Gasoline	34.2 (g/MJ)	66	0.2512 <sup>b</sup> (g/km)	0.122
Natural Gas	38.8 (MJ/m <sup>3</sup> )	51.4	0.0011 (g/MJ)	0.0001

a. NGGIC (1996a, 1996b)

b. Deterioration of CH<sub>4</sub> emission rate calculated on accumulated VKT of 220,000 km.

The amount of fuel consumed by the SSA aircraft fleet has been estimated from the TIM and aircraft movement data used in the exhaust analysis together with fuel flow rates associated with the modes of the LTO cycle. Fuel flow rates sourced from FAEED (1995) and fuel consumption estimates for the engine types considered in the inventory are shown in Table 16. Greenhouse gas emissions are calculated by applying the emission factors contained in Table 15 to these fuel consumption estimates. Similarly, greenhouse emissions from aircraft engine maintenance have been estimated from the fuel flows for a small number of representative engine types and typical maintenance periods as reported by Stephenson and Associates (1993). The following steps enable the calculation of greenhouse gas emissions from aircraft engines during normal operation and maintenance:

Step 1. Calculate emissions for each aircraft/engine configuration according to the formula:

$$E_{ij} = \text{Sum}[\text{TIM}_k \times \text{FR}_{ijk} \times D \times \text{ER}_i \times N_j]$$

where:

$E_{ij}$  = total emissions of greenhouse gas  $i$  emitted by aircraft/engine configuration  $j$  per LTO cycle.

$\text{TIM}_k$  = time in mode for mode  $k$ .

$\text{FR}_{jk}$  = fuel flow rate for aircraft/engine configuration  $j$  and mode  $k$ .

$D$  = energy density of fuel. Note that the simplifying assumption has been made that all fuel consumed is aviation turbine fuel.

$\text{ER}_i$  = emission rate for greenhouse gas  $i$ .

$N_j$  = number of engines on aircraft/engine configuration  $j$ .



Step 2. Calculate total greenhouse emissions for all aircraft according to the formula:

$$ET_i = \text{Sum}[E_{ij} \times LTO_j]$$

where:

$ET_i$  = total emissions of greenhouse gas  $i$  produced by aircraft fleet.

$LTO_j$  = the number of LTO cycles for aircraft/engine configuration  $j$ .

Annual greenhouse gas emissions from aircraft exhaust are estimated to be approximately 478000 tonnes of  $\text{CO}_2$ , 4500 tonnes of  $\text{CH}_4$  and 9 tonnes of  $\text{N}_2\text{O}$ .

TABLE 16: FUEL FLOW RATES AND FUEL CONSUMPTION FOR SSA , SCENARIO 3B

AIRCRAFT TYPE	ENGINE TYPE	NO. OF ENGINES	NO. OF MOVEMENTS	TKO (kg/min)	CLBO (kg/min)	APP (kg/min)	TAX/ID (kg/min)	TKO (t/yr)	CLBO (t/yr)	APP (t/yr)	TAX/ID (t/yr)
B-747s	RB211-524G	4	2.71E+04	1.57E+02	1.25E+02	4.19E+01	1.56E+01	5.95E+03	1.65E+04	9.93E+03	2.19E+04
	RB211-524D4 Ph1	4	4.76E+03	1.50E+02	1.20E+02	4.43E+01	1.80E+01	1.00E+03	2.81E+03	1.84E+03	4.44E+03
	PW4056/4156	4	8.09E+03	1.41E+02	1.16E+02	3.95E+01	1.25E+01	1.59E+03	4.59E+03	2.79E+03	5.25E+03
	CF6-80C2B4	4	7.61E+03	1.46E+02	1.19E+02	3.90E+01	1.19E+01	1.55E+03	4.43E+03	2.59E+03	4.72E+03
MD11	CF6-80C2D1F	3	2.91E+03	2.60E+00	2.07E+00	6.57E-01	1.96E-01	7.92E+00	2.21E+01	1.25E+01	2.22E+01
DC10	CF6-6D	3	5.69E+02	1.04E+02	8.59E+01	2.90E+01	1.04E+01	6.22E+01	1.79E+02	1.08E+02	2.30E+02
	CF6-50E/E2	3	5.69E+02	1.46E+02	1.15E+02	3.99E+01	1.01E+01	8.70E+01	2.41E+02	1.49E+02	2.24E+02
NLA	TRENT 768	4	2.03E+04	3.87E+00	3.08E+00	1.03E+00	3.00E-01	1.10E+02	3.06E+02	1.83E+02	3.16E+02
B-767s	CF6-80C2B6	2	1.49E+04	1.55E+02	1.25E+02	4.12E+01	1.24E+01	1.61E+03	4.55E+03	2.68E+03	4.81E+03
	JT9D-7R4E1	2	7.90E+03	2.12E+00	1.72E+00	6.53E-01	2.21E-01	1.17E+01	3.34E+01	2.25E+01	4.54E+01
	CF6-80A	2	6.38E+03	1.29E+02	1.08E+02	3.69E+01	9.00E+00	5.75E+02	1.68E+03	1.03E+03	1.49E+03
	PW4056/4156	2	1.22E+03	1.41E+02	1.16E+02	3.95E+01	1.25E+01	1.20E+02	3.45E+02	2.10E+02	3.94E+02
A310	JT9D-7R4E1	2	3.63E+03	2.12E+00	1.72E+00	6.53E-01	2.21E-01	5.39E+00	1.54E+01	1.04E+01	2.09E+01
B-737s	CFM56-3B	2	3.42E+04	6.84E+01	5.58E+01	2.16E+01	7.80E+00	1.64E+03	4.68E+03	3.23E+03	6.94E+03
	CFM56-3C	2	1.71E+04	7.08E+01	5.82E+01	2.04E+01	7.20E+00	8.48E+02	2.44E+03	1.53E+03	3.20E+03
A320	CFM56-5A1	2	1.22E+04	6.48E+01	5.28E+01	1.80E+01	6.60E+00	5.55E+02	1.58E+03	9.62E+02	2.10E+03
BAe-143	ALF502R-5	4	4.11E+03	2.15E+01	1.77E+01	6.21E+00	2.45E+00	1.24E+02	3.57E+02	2.23E+02	5.24E+02

TABLE 16 (ctd): FUEL FLOW RATES AND FUEL CONSUMPTION FOR SSA, SCENARIO 3B

AIRCRAFT TYPE	ENGINE TYPE	NO. OF ENGINES	NO. OF MOVEMENTS	TKO (kg/min)	CLBO (kg/min)	APP (kg/min)	TAX/ID (kg/min)	TKO (t/yr)	CLBO (t/yr)	APP (t/yr)	TAX/ID (t/yr)
500 Citation	JT15D-1A	2	1.14E+03	1.48E-01	1.24E-01	5.10E-02	2.30E-02	1.18E-01	3.46E-01	2.54E-01	6.82E-01
	JT15D-1B	2	1.14E+03	1.48E-01	1.24E-01	5.10E-02	2.30E-02	1.18E-01	3.46E-01	2.54E-01	6.82E-01
DH8	PW120 (PT6A-41)	2	4.57E+04	3.86E+00	3.57E+00	2.06E+00	1.11E+00	1.23E+02	4.00E+02	4.12E+02	1.32E+03
SH6	PT6A-27	2	5.71E+03	3.21E+00	3.03E+00	1.62E+00	8.71E-01	1.28E+01	4.23E+01	4.05E+01	1.29E+02
	PT6A-41	2	5.71E+03	3.86E+00	3.57E+00	2.06E+00	1.11E+00	1.54E+01	5.00E+01	5.15E+01	1.65E+02
LT1	O200	2	2.13E+03	3.40E-01	3.40E-01	1.95E-01	6.35E-02	5.07E-01	1.78E+00	1.82E+00	3.52E+00
	O320	2	2.13E+03	6.71E-01	5.03E-01	3.54E-01	7.26E-02	1.00E+00	2.63E+00	3.29E+00	4.02E+00
	PT6A-41	2	2.13E+03	3.86E+00	3.57E+00	2.06E+00	1.11E+00	5.75E+00	1.87E+01	1.92E+01	6.16E+01
LT1	O200	1	1.50E+02	3.40E-01	3.40E-01	1.95E-01	6.35E-02	1.78E-02	6.24E-02	6.38E-02	1.24E-01
	O320	1	1.50E+02	6.71E-01	5.03E-01	3.54E-01	7.26E-02	3.52E-02	9.23E-02	1.16E-01	1.41E-01
	PT6A-41	1	1.50E+02	3.86E+00	3.57E+00	2.06E+00	1.11E+00	2.02E-01	6.55E-01	6.75E-01	2.16E+00
JRH	T53-L-11D	1	1.90E+03	5.22E+00	5.18E+00	4.88E+00	1.10E+00	3.47E+00	1.21E+01	2.02E+01	2.71E+01
TOTAL			2.45E+05	TOTAL				1.60E+04	4.54E+04	2.81E+04	5.84E+04



In the absence of detailed information relating to vehicle fleet projections at SSA, an approximate methodology has been adopted for the analysis of greenhouse gas emissions from landside motor vehicles at SSA as detailed below.

It is assumed that the 2016 landside motor vehicle fleet at the second airport is represented by a petrol-fuelled post-1985 vehicle with a 3-way exhaust catalyst. While it is recognised that other vehicle and fuel types may have significantly different greenhouse gas emission profiles, the approach adopted is considered to be reasonable given that petrol fuelled passenger vehicles have been reported to account for approximately 85% of the motor vehicle fleet at airports (V & C Environment Consultants, 1955).

The average fuel consumption rate for post 1985 petrol fuelled motor vehicles is reported to be 0.115 L/km (NGGIC, 1996a). Assuming this rate of consumption for the 2016 fleet and considering the daily traffic volumes and trip length data as discussed in Section 3, annual fuel consumption is estimated to be approximately 375 TJ. An annual CO<sub>2</sub> emission of 19,500 tonnes is then derived using the recommended emission factor of 66 g/MJ as shown in Table 15.

The total distance travelled within SSA by landside motor vehicles in 2016 is estimated to be 75 million km (see Section 3). This figure has been applied to the CH<sub>4</sub> and N<sub>2</sub>O emission factors in Table 15 to yield an annual emission of approximately 19 and 9 tonnes respectively.

Greenhouse emissions from airside service vehicles have been approximated by scaling landside vehicle greenhouse estimates according to the relative magnitudes of CO emissions from landside and airside vehicles respectively. This yields an annual emission of 8,900 tonnes of CO<sub>2</sub>, 9 tonnes of CH<sub>4</sub> and 4 tonnes of N<sub>2</sub>O.

Greenhouse emissions from the combustion of natural gas in boilers are based on 1992 fuel consumption estimates presented in Stephenson and Associates (1993), scaled according to the expected level of activity at SSA at design capacity in 2016. A consumption estimate of  $4 \times 10^5$  GJ was applied to the emission factors in Table 15 to yield an annual emission of 20,400 tonnes of CO<sub>2</sub>, 0.4 tonnes of CH<sub>4</sub> and negligible emissions of N<sub>2</sub>O. It has been assumed that the composition of natural gas presently consumed in NSW will be the equivalent to that in 2016.

A summary of greenhouse gas emissions for the second airport operating at design capacity in 2016 appears in Table 17. The estimates are presented as mass emissions and as CO<sub>2</sub> equivalents which allows more meaningful comparison to be made between the greenhouse gases in relation to their relative effect on global warming. The global warming potential (GWP) of CH<sub>4</sub> and N<sub>2</sub>O, expressed as CO<sub>2</sub> equivalents, is reported to be 21 and 290 respectively (NGGIC, 1996a/1996b). This means that, for example, one tonne of CH<sub>4</sub> has the same effect on global warming as 21 tonnes



of CO<sub>2</sub>. It should be noted that CO<sub>2</sub> equivalent factors are dependant on the time scale assumed as carbon emitted as CH<sub>4</sub> and other gases eventually convert to CO<sub>2</sub> in the atmosphere.

**TABLE 17**  
**ESTIMATE OF GREENHOUSE GAS EMISSIONS (0 - 1000m) FROM SSA, SCENARIO 3B**

Compound	tonnes/year	CO <sub>2</sub> Equiv. (Gg)
CO <sub>2</sub>	530,000	530
CH <sub>4</sub>	4,500	96
N <sub>2</sub> O	22	7

Inventories of NSW greenhouse gas emissions have been established for 1995 and 2000 (EPANSW, 1995). A linear extrapolation of trends based on the 1995 and 2000 inventories yields an estimate of 213,000 Gg in CO<sub>2</sub> equivalents by 2016. This analysis indicates that emissions from the proposed second airport account for approximately 0.3% of state greenhouse emissions.

## **5.0 EMISSIONS OF OZONE DEPLETING SUBSTANCES**

Halogenated compounds containing chlorine or bromine, such as chloroflouorocarbons (CFCs), hydrochloroflouorocarbons (HCFCs) and halons are used as refrigerants, foam blowing agents, cleaning solvents and fire retardants. In the atmosphere, these compounds are broken down by sunlight at high altitudes and the resulting products react with and destroy ozone. The depletion of the stratospheric ozone layer has increased the amount of damaging UV radiation reaching the Earth's surface (ANZECC, 1994).

Australia is a signatory to the *Montreal Protocol on Substances that Deplete the Ozone Layer* which is an international treaty that sets a timetable for the phasing out of these substances. For example, the production and sale of CFCs and halons is now prohibited for non-essential uses. The use of HCFCs is still permitted as a substitute for CFCs, however, the consumption level has been frozen with a total phase-out planned for 2030. It should be noted that HCFCs have a lower ozone depleting potential than CFCs.

The major sources of emission of these and other ozone depleting substances at airports are motor vehicle air conditioners, air conditioning/refrigeration systems in terminal buildings and solvents used for cleaning and degreasing in terminal workshops. Other sources include the use of fire extinguishers used in the event of fires and for training purposes.

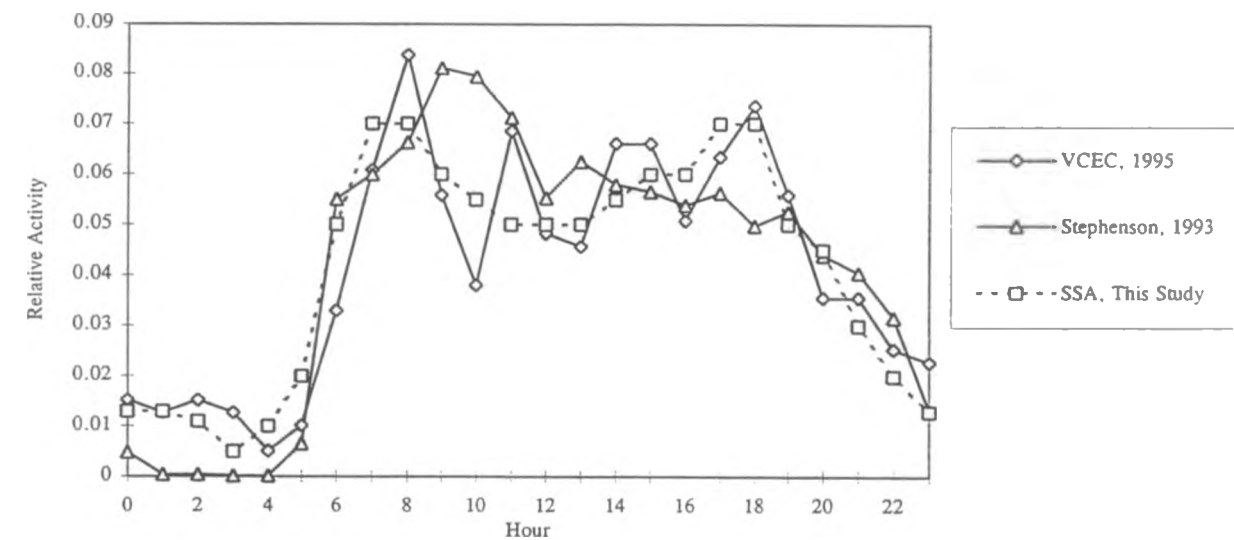


Due to the controls measures described above and the advent of ozone benign technologies, emissions of ozone depleting substances related to SSA operating at design level in 2016 are expected to be minimal (F. Kernabone, EPANSW, personal communication, 1996). An inventory of the release of these substances has not been undertaken for this reason.

6.0 TEMPORAL RESOLUTION OF EMISSIONS

The temporal emission profile for the proposed second airport has been based on hourly activity profiles reported in recent studies for Tullamarine Airport (V & C Environment Consultants, 1995) and KSA (Stephenson and Associates, 1993). The profile, shown in Table 18, has been derived from a consideration of hour by hour landings and takeoffs for the major aircraft categories. The temporal profiles considered are presented in Figure 1.

The temporal profile adopted for this study represents a 24 hour airport operation. Although no decision has been made regarding whether or not SSA should operate 24 hours a day, the use of a non-curfew profile is considered to be a reasonable approximation of an airport with a curfew given the low level of activity between midnight and 5:00 am.



**FIGURE 1: TEMPORAL PROFILES FOR AIRPORT OPERATIONS**



**TABLE 18**  
**SSA TEMPORAL EMISSIONS PROFILE**

<b>Hour ending (Eastern Standard Time)</b>	<b>Percentage of daily emissions</b>
0100	1.3
0200	1.3
0300	1.1
0400	0.5
0500	1.0
0600	2.0
0700	5.0
0800	7.0
0900	7.0
1000	6.0
1100	5.5
1200	5.0
1300	5.0
1400	5.0
1500	5.5
1600	6.0
1700	6.0
1800	7.0
1900	7.0
2000	5.0
2100	4.5
2200	3.0
2300	2.0
2400	1.3





## 7.0 SPATIAL RESOLUTION OF EMISSIONS

The air emissions estimates have been distributed spatially over each of the proposed SSA sites to allow subsequent modelling and analysis. Each airport site has been divided up into thirteen areas covering ground level and elevated emissions to 1000m in height. Sketches contained in Appendix B indicate the location of each of the zones. A description of each of the zones appears in Table 19. Zones A1, B, C1, D, E F1, G1 and H1 apply to the early operational phase in 2006 while all zones apply for the fully operational conditions in 2016.

Note that these emission zones do not consider cross wind runway operation as it is likely that such operation would be limited to periods of high wind speed and would tend to apply to a limited proportion of the landings and takeoffs, predominantly for smaller craft.

**TABLE 19**  
**DESCRIPTION OF EMISSION ZONES AT SSA**

<b>Emission Zone</b>	<b>Description</b>	<b>Height (m AGL)</b>
A1	Terminal/apron area during early operational phase 2006 (Cases 1a, 2a, 3a)	0
A1 + A2	Terminal/apron area during fully operational phase 2016 (Cases 1b, 2b, 3b)	0
B	Airport access road	0
C1	Maintenance area during early operational phase 2006 (Cases 1a, 2a, 3a)	0
C1 + C2	Maintenance area during fully operational phase 2016 (Cases 1b, 2b, 3b)	0
D	Fuel storage area	0
E	Fire training area	0
F1	1st Runway aircraft emissions, consisting of : Taxi/idle Takeoff	7 <sup>a</sup> 7 - 200
F2	2nd Runway aircraft emissions, consisting of : Taxiing, idle Takeoff	7 7 - 200
G1	1st Runway aircraft climbout emissions	200 - 1000
G2	2nd Runway aircraft climbout emissions	200 - 1000
H1	1st Runway aircraft approach emissions	1000 - 7
H2	2nd Runway aircraft approach emissions	1000 - 7

a. Height of emission from aircraft engine while aircraft is on the ground, taking into account the heat of the exhaust (VCEC, 1995).

As the direction of takeoff and landing will change depending on wind direction, the sketches in Appendix B also indicate the aircraft emissions distribution according to takeoff direction. It has



been assumed that landings and takeoffs will be in the same direction. Assumptions concerning parallel runway usage according to wind direction are shown in Table 20.

**TABLE 20**  
**ASSUMED RUNWAY USAGE AT SSA**

<b>OPTION</b>	<b>Wind Direction (degrees)</b>	<b>Runway</b>
Badgerys Creek Option A	152 clockwise to 332	062
	332 clockwise to 152	242
Badgerys Creek Option B	152 clockwise to 332	062
	332 clockwise to 152	242
Badgerys Creek Option C	280 clockwise to 100	190
	100 clockwise to 280	010
Holsworthy - Northern Option	262 clockwise to 82	172
	82 clockwise to 262	352
Holsworthy - Southern Option	211 clockwise to 031	121
	031 clockwise to 211	301

With respect to the horizontal distribution of aircraft exhaust emissions, the following assumptions have been made:

- after discussions with industry representatives (Mr B. Bourke, QANTAS, personal communication, 1996) the rate of ascent has been taken as approximately 5.7 degrees for take off and climbout based on expected operation of commercial aircraft; and
- take off, landing and taxiing at ground level is expected to be predominantly over 3km of the upwind end of the runways.

For the early operational scenarios (2006), it has been assumed that only one runway will be open.

## **8.0 SUMMARY OF EMISSIONS**

Summaries of the inventory results for SSA for the airport planning scenarios (2006/2016, summer/winter) are presented in Tables 21 through 32.

**TABLE 21**  
**DAILY EMISSIONS FROM SSA, CASE 1A-OVERFLOW SCENARIO, 2006 (63,000 ANNUAL MOVEMENTS), SUMMER DAY**

Emission Source	Height <sup>a</sup> (in AGL)	NMHC (kg/day)	NO <sub>x</sub> (kg/day)	CO (kg/day)	SO <sub>2</sub> (kg/day)	PM <sub>10</sub> (kg/day)	Benzene (kg/day)	1,3- Butadiene (kg/day)	Form- aldehyde (kg/day)	Acet- aldehyde (kg/day)	Toluene (kg/day)	Xylene (kg/day)	Ethyl Benzene (kg/day)
A1 + A2 Terminal/Apron.	0	5.86E+01	3.31E+02	3.63E+02	6.10E+00	1.85E+01	1.71E-01	1.40E-01	5.52E+00	1.82E+00	1.34E+00	9.55E-01	1.32E-02
B Access Road	0	1.28E+02	8.23E+01	6.53E+02	3.46E+00	6.40E+00	3.65E+00	1.78E-01	8.43E-01	3.75E-01	6.80E+00	6.87E+00	8.43E-01
C1 + C2 Aircraft Maint.	0	6.07E+01	3.26E+01	1.63E+01	7.11E-01	0.00E+00	8.02E-02	7.44E-02	6.20E-01	1.92E-01	8.20E+00	7.03E+00	7.02E-03
D Fuel Storage	0	6.06E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F1 1st Runway													
Taxiing, idle	7	1.16E+02	4.57E+01	3.38E+02	1.11E+01	3.13E+01	2.47E+00	2.29E+00	1.91E+01	5.91E+00	6.61E-01	6.10E-01	2.16E-01
Takeoff	7 - 200	2.84E+00	1.80E+02	5.03E+00	4.85E+00	1.09E+01	6.02E-02	5.59E-02	4.66E-01	1.44E-01	1.61E-02	1.49E-02	5.28E-03
F2 2nd Runway													
Taxiing, idle	7	1.16E+02	4.57E+01	3.38E+02	1.11E+01	3.13E+01	2.47E+00	2.29E+00	1.91E+01	5.91E+00	6.61E-01	6.10E-01	2.16E-01
Takeoff	7 - 200	2.84E+00	1.80E+02	5.03E+00	4.85E+00	1.09E+01	6.02E-02	5.59E-02	4.66E-01	1.44E-01	1.61E-02	1.49E-02	5.28E-03
G1 1st Runway													
Climbout	200-1000	5.89E+00	3.79E+02	1.46E+01	1.38E+01	3.04E+01	1.25E-01	1.16E-01	9.68E-01	3.00E-01	3.35E-02	3.10E-02	1.10E-02
G2 2nd Runway													
Climbout	200-1000	5.89E+00	3.79E+02	1.46E+01	1.38E+01	3.04E+01	1.25E-01	1.16E-01	9.68E-01	3.00E-01	3.35E-02	3.10E-02	1.10E-02
H1 1st Runway													
Approach	1000 - 7	1.05E+01	8.03E+01	3.84E+01	8.63E+00	1.83E+01	2.22E-01	2.06E-01	1.72E+00	5.33E-01	5.96E-02	5.50E-02	5.89E-02
H2 2nd Runway													
Approach	1000 - 7	1.05E+01	8.03E+01	3.84E+01	8.63E+00	1.83E+01	2.22E-01	2.06E-01	1.72E+00	5.33E-01	5.96E-02	5.50E-02	5.89E-02
<b>TOTAL</b>		<b>5.24E+02</b>	<b>1.82E+03</b>	<b>1.82E+03</b>	<b>8.70E+01</b>	<b>2.07E+02</b>	<b>9.65E+00</b>	<b>5.73E+00</b>	<b>5.15E+01</b>	<b>1.62E+01</b>	<b>1.79E+01</b>	<b>1.63E+01</b>	<b>1.45E+00</b>

a. The height of aircraft exhaust emissions while the aircraft is on the ground is estimated to be 7m, allowing for the heat of the exhaust (VCEC, 1995).

TABLE 22

**DAILY EMISSIONS FROM SSA, CASE 1B-OVERFLOW SCENARIO, 2016 (185,500 ANNUAL MOVEMENTS), SUMMER DAY.**

Emission Source	Height <sup>a</sup> (m AGL)	NMHC (kg/day)	NO <sub>x</sub> (kg/day)	CO (kg/day)	SO <sub>2</sub> (kg/day)	PM <sub>10</sub> (kg/day)	Benzene (kg/day)	1,3- Butadiene (kg/day)	Form- aldehyde (kg/day)	Acet- aldehyde (kg/day)	Toluene (kg/day)	Xylene (kg/day)	Ethyl Benzene (kg/day)
A1 + A2 Terminal/Apron	0	1.71E+02	9.64E+02	1.06E+03	1.78E+01	5.39E+01	3.27E-01	2.49E-01	1.47E+01	4.89E+00	3.86E+00	2.74E+00	2.35E-02
B Access Road	0	3.35E+02	1.80E+02	1.51E+03	1.01E+01	1.86E+01	8.92E+00	4.13E-01	1.96E+00	8.69E-01	1.70E+01	1.74E+01	1.96E+00
C1 + C2 Aircraft Maint.	0	1.77E+02	9.51E+01	4.76E+01	2.07E+00	0.00E+00	1.42E-01	1.32E-01	1.10E+00	3.41E-01	2.39E+01	2.05E+01	1.25E-02
D Fuel Storage	0	1.77E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F1 1st Runway													
Taxiing, idle	7	4.33E+02	2.28E+02	1.45E+03	5.35E+01	1.15E+02	9.20E+00	8.53E+00	7.12E+01	2.20E+01	2.47E+00	2.28E+00	8.06E-01
Takeoff	7 - 200	1.10E+01	7.61E+02	1.34E+01	1.97E+01	4.01E+01	2.33E-01	2.16E-01	1.80E+00	5.59E-01	6.25E-02	5.77E-02	2.04E-02
F2 2nd Runway													
Taxiing, idle	7	4.33E+02	2.28E+02	1.45E+03	5.35E+01	1.15E+02	9.20E+00	8.53E+00	7.12E+01	2.20E+01	2.47E+00	2.28E+00	8.06E-01
Takeoff	7 - 200	1.10E+01	7.61E+02	1.34E+01	1.97E+01	4.01E+01	2.33E-01	2.16E-01	1.80E+00	5.59E-01	6.25E-02	5.77E-02	2.04E-02
G1 1st Runway													
Climbout	200-1000	2.22E+01	1.59E+03	3.82E+01	5.57E+01	1.11E+02	4.71E-01	4.37E-01	3.64E+00	1.13E+00	1.26E-01	1.17E-01	4.13E-02
G2 2nd Runway													
Climbout	200-1000	2.22E+01	1.59E+03	3.82E+01	5.57E+01	1.11E+02	4.71E-01	4.37E-01	3.64E+00	1.13E+00	1.26E-01	1.17E-01	4.13E-02
H1 1st Runway													
Approach	1000 - 7	3.13E+01	3.30E+02	1.08E+02	3.45E+01	6.68E+01	6.64E-01	6.16E-01	5.14E+00	1.59E+00	1.78E-01	1.64E-01	1.76E-01
H2 2nd Runway													
Approach	1000 - 7	3.13E+01	3.30E+02	1.08E+02	3.45E+01	6.68E+01	6.64E-01	6.16E-01	5.14E+00	1.59E+00	1.78E-01	1.64E-01	1.76E-01
<b>TOTAL</b>		<b>1.70E+03</b>	<b>7.06E+03</b>	<b>5.83E+03</b>	<b>3.57E+02</b>	<b>7.39E+02</b>	<b>3.05E+01</b>	<b>2.04E+01</b>	<b>1.81E+02</b>	<b>5.68E+01</b>	<b>5.04E+01</b>	<b>4.58E+01</b>	<b>4.08E+00</b>

a. The height of aircraft exhaust emissions while the aircraft is on the ground is estimated to be 7m, allowing for the heat of the exhaust (VCEC, 1995).

TABLE 23

**DAILY EMISSIONS FROM SSA, CASE 2A-EQUAL GROWTH SCENARIO, 2006 (117,000 ANNUAL MOVEMENTS). SUMMER DAY.**

Emission Source	Height (m AGL)	NMHC (kg/day)	NOx (kg/day)	CO (kg/day)	SO2 (kg/day)	PM (kg/day)	Benzene (kg/day)	1,3- Butadiene (kg/day)	Formaldehy de (kg/day)	Acetaldehy de (kg/day)	Toluene (kg/day)	Xylene (kg/day)	Ethyl Benzene (kg/day)
A1 + A2 Terminal/Apron	0	1.09E+02	6.13E+02	6.73E+02	1.13E+01	3.43E+01	2.08E-01	1.58E-01	9.38E+00	3.11E+00	2.46E+00	1.74E+00	1.49E-02
B Access Road	0	2.38E+02	1.52E+02	1.21E+03	6.42E+00	1.19E+01	6.77E+00	3.30E-01	1.56E+00	6.95E-01	1.26E+01	1.27E+01	1.56E+00
C1 + C2 Aircraft Maint.	0	1.13E+02	6.05E+01	3.02E+01	1.32E+00	0.00E+00	9.06E-02	8.40E-02	7.01E-01	2.17E-01	1.52E+01	1.30E+01	7.94E-03
D Fuel Storage	0	1.12E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F1 1st Runway													
Taxiing, idle	0	2.20E+02	9.44E+01	6.70E+02	2.28E+01	6.45E+01	4.67E+00	4.34E+00	3.62E+01	1.12E+01	1.25E+00	1.16E+00	4.10E-01
Takeoff	0 - 200	5.77E+00	3.71E+02	8.16E+00	1.00E+01	2.25E+01	1.22E-01	1.14E-01	9.48E-01	2.94E-01	3.28E-02	3.03E-02	1.07E-02
F2 2nd Runway													
Taxiing, idle	0	2.20E+02	9.44E+01	6.70E+02	2.28E+01	6.45E+01	4.67E+00	4.34E+00	3.62E+01	1.12E+01	1.25E+00	1.16E+00	4.10E-01
Takeoff	0 - 200	5.77E+00	3.71E+02	8.16E+00	1.00E+01	2.25E+01	1.22E-01	1.14E-01	9.48E-01	2.94E-01	3.28E-02	3.03E-02	1.07E-02
G1 1st Runway													
Climbout	200-1000	1.19E+01	7.83E+02	2.37E+01	2.84E+01	6.26E+01	2.53E-01	2.34E-01	1.95E+00	6.05E-01	6.77E-02	6.25E-02	2.21E-02
G2 2nd Runway													
Climbout	200-1000	1.19E+01	7.83E+02	2.37E+01	2.84E+01	6.26E+01	2.53E-01	2.34E-01	1.95E+00	6.05E-01	6.77E-02	6.25E-02	2.21E-02
H1 1st Runway													
Approach	1000 - 0	1.98E+01	1.66E+02	6.74E+01	1.78E+01	3.76E+01	4.20E-01	3.90E-01	3.25E+00	1.01E+00	1.13E-01	1.04E-01	1.11E-01
H2 2nd Runway													
Approach	1000 - 0	1.98E+01	1.66E+02	6.74E+01	1.78E+01	3.76E+01	4.20E-01	3.90E-01	3.25E+00	1.01E+00	1.13E-01	1.04E-01	1.11E-01
<b>TOTAL</b>		<b>9.85E+02</b>	<b>3.65E+03</b>	<b>3.45E+03</b>	<b>1.77E+02</b>	<b>4.21E+02</b>	<b>1.80E+01</b>	<b>1.07E+01</b>	<b>9.63E+01</b>	<b>3.02E+01</b>	<b>3.32E+01</b>	<b>3.02E+01</b>	<b>2.69E+00</b>

a. The height of aircraft exhaust emissions while the aircraft is on the ground is estimated to be 7m, allowing for the heat of the exhaust (VCEC, 1995).

**TABLE 24**  
**DAILY EMISSIONS FROM SSA. CASE 2B-EQUAL GROWTH SCENARIO. 2006 (233.000 ANNUAL MOVEMENTS). SUMMER**  
**DAY**

Emission Source	Height <sup>a</sup> (m AGL)	NMHC (kg/day)	NO <sub>x</sub> (kg/day)	CO (kg/day)	SO <sub>2</sub> (kg/day)	PM <sub>10</sub> (kg/day)	Benzene (kg/day)	1,3- Butadiene (kg/day)	Form- aldehyde (kg/day)	Acet- aldehyde (kg/day)	Toluene (kg/day)	Xylene (kg/day)	Ethyl Benzene (kg/day)
A1 + A2 Terminal/Apron	0	2.15E+02	1.22E+03	1.33E+03	2.24E+01	6.79E+01	4.12E-01	3.14E-01	1.86E+01	6.16E+00	4.87E+00	3.45E+00	2.96E-02
B Access Road	0	4.22E+02	2.26E+02	1.91E+03	1.27E+01	2.35E+01	1.13E+01	5.21E-01	2.47E+00	1.10E+00	2.14E+01	2.19E+01	2.47E+00
C1 + C2 Aircraft Maint.	0	2.23E+02	1.20E+02	6.00E+01	2.61E+00	0.00E+00	1.80E-01	1.67E-01	1.39E+00	4.31E-01	3.01E+01	2.58E+01	1.57E-02
D Fuel Storage	0	2.23E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F1 1st Runway													
Taxiing, idle	7	5.41E+02	2.87E+02	1.82E+03	6.75E+01	1.45E+02	1.15E+01	1.07E+01	8.89E+01	2.75E+01	3.08E+00	2.84E+00	1.01E+00
Takeoff	7 - 200	1.36E+01	9.51E+02	1.64E+01	2.48E+01	5.07E+01	2.89E-01	2.68E-01	2.24E+00	6.94E-01	7.76E-02	7.16E-02	2.54E-02
F2 2nd Runway													
Taxiing, idle	7	5.41E+02	2.87E+02	1.82E+03	6.75E+01	1.45E+02	1.15E+01	1.07E+01	8.89E+01	2.75E+01	3.08E+00	2.84E+00	1.01E+00
Takeoff	7 - 200	1.36E+01	9.51E+02	1.64E+01	2.48E+01	5.07E+01	2.89E-01	2.68E-01	2.24E+00	6.94E-01	7.76E-02	7.16E-02	2.54E-02
G1 1st Runway													
Climbout	200-1000	2.76E+01	1.99E+03	4.66E+01	7.02E+01	1.41E+02	5.86E-01	5.43E-01	4.53E+00	1.40E+00	1.57E-01	1.45E-01	5.13E-02
G2 2nd Runway													
Climbout	200-1000	2.76E+01	1.99E+03	4.66E+01	7.02E+01	1.41E+02	5.86E-01	5.43E-01	4.53E+00	1.40E+00	1.57E-01	1.45E-01	5.13E-02
H1 1st Runway													
Approach	1000 - 7	3.90E+01	4.15E+02	1.34E+02	4.35E+01	8.46E+01	8.28E-01	7.69E-01	6.41E+00	1.99E+00	2.22E-01	2.05E-01	2.19E-01
H2 2nd Runway													
Approach	1000 - 7	3.90E+01	4.15E+02	1.34E+02	4.35E+01	8.46E+01	8.28E-01	7.69E-01	6.41E+00	1.99E+00	2.22E-01	2.05E-01	2.19E-01
<b>TOTAL</b>		<b>2.13E+03</b>	<b>8.86E+03</b>	<b>7.35E+03</b>	<b>4.50E+02</b>	<b>9.34E+02</b>	<b>3.82E+01</b>	<b>2.55E+01</b>	<b>2.27E+02</b>	<b>7.09E+01</b>	<b>6.34E+01</b>	<b>5.77E+01</b>	<b>5.12E+00</b>

a. The height of aircraft exhaust emissions while the aircraft is on the ground is estimated to be 7m, allowing for the heat of the exhaust (VCEC, 1995).

**TABLE 25**  
**DAILY EMISSIONS FROM SSA, CASE 3A-ADDITIONAL NOISE SCENARIO, 2006 (131.000 ANNUAL MOVEMENTS).**  
**SUMMER DAY.**

Emission Source	Height (m AGL)	NMHC (kg/day)	NOx (kg/day)	CO (kg/day)	SO2 (kg/day)	PM (kg/day)	Benzene (kg/day)	1,3- Butadiene (kg/day)	Formaldehy de (kg/day)	Acetaldehy de (kg/day)	Toluene (kg/day)	Xylene (kg/day)	Ethyl Benzene (kg/day)
A1+A2 Terminal/Apron	0	1.21E+02	6.82E+02	7.49E+02	1.26E+01	3.81E+01	2.78E-01	2.20E-01	1.08E+01	3.57E+00	2.75E+00	1.95E+00	2.07E-02
B Access Road	0	2.64E+02	1.70E+02	1.35E+03	7.14E+00	1.32E+01	7.53E+00	3.68E-01	1.74E+00	7.73E-01	1.40E+01	1.42E+01	1.74E+00
C1+C2 Aircraft Maint.	0	1.25E+02	6.73E+01	3.36E+01	1.47E+00	0.00E+00	1.26E-01	1.17E-01	9.73E-01	3.01E-01	1.69E+01	1.45E+01	1.10E-02
D Fuel Storage	0	1.25E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F1 1st Runway													
Taxiing, idle	0	3.38E+02	1.82E+02	1.08E+03	4.16E+01	1.16E+02	7.17E+00	6.65E+00	5.55E+01	1.72E+01	1.92E+00	1.77E+00	6.28E-01
Takeoff	0 - 200	1.44E+01	8.11E+02	1.20E+01	1.90E+01	4.04E+01	3.06E-01	2.83E-01	2.36E+00	7.32E-01	8.19E-02	7.56E-02	2.68E-02
F2 2nd Runway													
Taxiing, idle	0	3.38E+02	1.82E+02	1.08E+03	4.16E+01	1.16E+02	7.17E+00	6.65E+00	5.55E+01	1.72E+01	1.92E+00	1.77E+00	6.28E-01
Takeoff	0 - 200	1.44E+01	8.11E+02	1.20E+01	1.90E+01	4.04E+01	3.06E-01	2.83E-01	2.36E+00	7.32E-01	8.19E-02	7.56E-02	2.68E-02
G1 1st Runway													
Climbout	200-1000	2.81E+01	1.66E+03	3.32E+01	5.35E+01	1.12E+02	5.97E-01	5.54E-01	4.62E+00	1.43E+00	1.60E-01	1.48E-01	5.23E-02
G2 2nd Runway													
Climbout	200-1000	2.81E+01	1.66E+03	3.32E+01	5.35E+01	1.12E+02	5.97E-01	5.54E-01	4.62E+00	1.43E+00	1.60E-01	1.48E-01	5.23E-02
H1 1st Runway													
Approach	1000 - 0	3.05E+01	3.23E+02	9.69E+01	3.28E+01	6.74E+01	6.47E-01	6.01E-01	5.01E+00	1.55E+00	1.74E-01	1.60E-01	1.72E-01
H2 2nd Runway													
Approach	1000 - 0	3.05E+01	3.23E+02	9.69E+01	3.28E+01	6.74E+01	6.47E-01	6.01E-01	5.01E+00	1.55E+00	1.74E-01	1.60E-01	1.72E-01
<b>TOTAL</b>		<b>1.34E+03</b>	<b>6.88E+03</b>	<b>4.57E+03</b>	<b>3.15E+02</b>	<b>7.23E+02</b>	<b>2.54E+01</b>	<b>1.69E+01</b>	<b>1.48E+02</b>	<b>4.65E+01</b>	<b>3.83E+01</b>	<b>3.49E+01</b>	<b>3.53E+00</b>

a. The height of aircraft exhaust emissions while the aircraft is on the ground is estimated to be 7m, allowing for the heat of the exhaust (VCEC, 1995).

**TABLE 26**  
**DAILY EMISSIONS FROM SSA, CASE 3B-ADDITIONAL NOISE SCENARIO, 2016 (245,000 ANNUAL MOVEMENTS).**  
**SUMMER DAY**

Emission Source	Height <sup>a</sup> (m AGL)	NMHC (kg/day)	NO <sub>x</sub> (kg/day)	CO (kg/day)	SO <sub>2</sub> (kg/day)	PM <sub>10</sub> (kg/day)	Benzene (kg/day)	1,3- Butadiene (kg/day)	Form- aldehyde (kg/day)	Acet- aldehyde (kg/day)	Toluene (kg/day)	Xylene (kg/day)	Ethyl Benzene (kg/day)
A1 + A2 Terminal/Apron	0	2.27E+02	1.28E+03	1.41E+03	2.36E+01	7.16E+01	3.90E+00	3.30E-01	1.96E+01	6.49E+00	5.13E+00	3.64E+00	3.12E-02
B Access Road	0	4.45E+02	2.39E+02	2.01E+03	1.34E+01	2.48E+01	1.18E+01	5.49E-01	2.60E+00	1.15E+00	2.25E+01	2.31E+01	2.60E+00
C1 + C2 Aircraft Maint.	0	2.35E+02	1.26E+02	6.32E+01	2.75E+00	0.00E+00	1.89E-01	1.76E-01	1.46E+00	4.53E-01	3.17E+01	2.72E+01	1.66E-02
D Fuel Storage	0	2.34E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F1 1st Runway													
Taxiing, idle	7	6.62E+02	3.89E+02	2.26E+03	8.87E+01	1.85E+02	1.41E+01	1.30E+01	1.09E+02	3.37E+01	3.77E+00	3.48E+00	1.23E+00
Takeoff	7 - 200	2.06E+01	1.37E+03	1.97E+01	3.33E+01	6.47E+01	4.37E-01	4.06E-01	3.38E+00	1.05E+00	1.17E-01	1.08E-01	3.83E-02
F2 2nd Runway													
Taxiing, idle	7	6.62E+02	3.89E+02	2.26E+03	8.87E+01	1.85E+02	1.41E+01	1.30E+01	1.09E+02	3.37E+01	3.77E+00	3.48E+00	1.23E+00
Takeoff	7 - 200	2.06E+01	1.37E+03	1.97E+01	3.33E+01	6.47E+01	4.37E-01	4.06E-01	3.38E+00	1.05E+00	1.17E-01	1.08E-01	3.83E-02
G1 1st Runway													
Climbout	200-1000	4.06E+01	2.83E+03	5.47E+01	9.39E+01	1.80E+02	8.63E-01	8.01E-01	6.68E+00	2.07E+00	2.31E-01	2.14E-01	7.56E-02
G2 2nd Runway													
Climbout	200-1000	4.06E+01	2.83E+03	5.47E+01	9.39E+01	1.80E+02	8.63E-01	8.01E-01	6.68E+00	2.07E+00	2.31E-01	2.14E-01	7.56E-02
H1 1st Runway													
Approach	1000 - 7	4.79E+01	5.67E+02	1.59E+02	5.77E+01	1.08E+02	1.02E+00	9.44E-01	7.88E+00	2.44E+00	2.73E-01	2.52E-01	2.70E-01
H2 2nd Runway													
Approach	1000 - 7	4.79E+01	5.67E+02	1.59E+02	5.77E+01	1.08E+02	1.02E+00	9.44E-01	7.88E+00	2.44E+00	2.73E-01	2.52E-01	2.70E-01
<b>TOTAL</b>		<b>2.47E+03</b>	<b>1.20E+04</b>	<b>8.47E+03</b>	<b>5.87E+02</b>	<b>1.17E+03</b>	<b>4.87E+01</b>	<b>3.14E+01</b>	<b>2.77E+02</b>	<b>8.66E+01</b>	<b>6.82E+01</b>	<b>6.20E+01</b>	<b>5.88E+00</b>

a. The height of aircraft exhaust emissions while the aircraft is on the ground is estimated to be 7m, allowing for the heat of the exhaust (VCEC, 1995).



TABLE 27

**DAILY EMISSIONS FROM SSA, CASE 1A-OVERFLOW SCENARIO, 2006 (63,000 ANNUAL MOVEMENTS), WINTER DAY.**

Emission Source	Height (m AGL)	NMHC (kg/day)	NOx (kg/day)	CO (kg/day)	SO2 (kg/day)	PM (kg/day)	Benzene (kg/day)	1,3- Butadiene (kg/day)	Formaldehy de (kg/day)	Acetaldehy de (kg/day)	Toluene (kg/day)	Xylene (kg/day)	Ethyl Benzene (kg/day)
A1+A2 Terminal/Apron	0	5.86E+01	3.31E+02	3.63E+02	6.10E+00	1.85E+01	1.71E-01	1.40E-01	5.52E+00	1.82E+00	1.34E+00	9.55E-01	1.32E-02
B Access Road	0	1.03E+02	8.83E+01	9.93E+02	3.46E+00	7.46E+00	3.65E+00	1.78E-01	8.43E-01	3.75E-01	6.80E+00	6.87E+00	8.43E-01
C1+C2 Aircraft Maint.	0	6.07E+01	3.26E+01	1.63E+01	7.11E-01	0.00E+00	8.02E-02	7.44E-02	6.20E-01	1.92E-01	8.20E+00	7.03E+00	7.02E-03
D Fuel Storage	0	6.06E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F1 1st Runway													
Taxiing, idle	0	1.16E+02	4.57E+01	3.38E+02	1.11E+01	3.13E+01	2.47E+00	2.29E+00	1.91E+01	5.91E+00	6.61E-01	6.10E-01	2.16E-01
Takeoff	0 - 200	2.84E+00	1.80E+02	5.03E+00	4.85E+00	1.09E+01	6.02E-02	5.59E-02	4.66E-01	1.44E-01	1.61E-02	1.49E-02	5.28E-03
F2 2nd Runway													
Taxiing, idle	0	1.16E+02	4.57E+01	3.38E+02	1.11E+01	3.13E+01	2.47E+00	2.29E+00	1.91E+01	5.91E+00	6.61E-01	6.10E-01	2.16E-01
Takeoff	0 - 200	2.84E+00	1.80E+02	5.03E+00	4.85E+00	1.09E+01	6.02E-02	5.59E-02	4.66E-01	1.44E-01	1.61E-02	1.49E-02	5.28E-03
G1 1st Runway													
Climbout	200-1000	5.89E+00	3.79E+02	1.46E+01	1.38E+01	3.04E+01	1.25E-01	1.16E-01	9.68E-01	3.00E-01	3.35E-02	3.10E-02	1.10E-02
G2 2nd Runway													
Climbout	200-1000	5.89E+00	3.79E+02	1.46E+01	1.38E+01	3.04E+01	1.25E-01	1.16E-01	9.68E-01	3.00E-01	3.35E-02	3.10E-02	1.10E-02
H1 1st Runway													
Approach	1000 - 0	1.05E+01	8.03E+01	3.84E+01	8.63E+00	1.83E+01	2.22E-01	2.06E-01	1.72E+00	5.33E-01	5.96E-02	5.50E-02	5.89E-02
H2 2nd Runway													
Approach	1000 - 0	1.05E+01	8.03E+01	3.84E+01	8.63E+00	1.83E+01	2.22E-01	2.06E-01	1.72E+00	5.33E-01	5.96E-02	5.50E-02	5.89E-02
<b>TOTAL</b>		<b>4.99E+02</b>	<b>1.82E+03</b>	<b>2.16E+03</b>	<b>8.70E+01</b>	<b>2.08E+02</b>	<b>9.65E+00</b>	<b>5.73E+00</b>	<b>5.15E+01</b>	<b>1.62E+01</b>	<b>1.79E+01</b>	<b>1.63E+01</b>	<b>1.45E+00</b>

a. The height of aircraft exhaust emissions while the aircraft is on the ground is estimated to be 7m, allowing for the heat of the exhaust (VCEC, 1995).

TABLE 28

DAILY EMISSIONS FROM SSA. CASE 1B-OVERFLOW SCENARIO. 2016 (185,000 ANNUAL MOVEMENTS). WINTER DAY.

Emission Source	Height (m AGL)	NMHC (kg/day)	NOx (kg/day)	CO (kg/day)	SO2 (kg/day)	PM (kg/day)	Benzene (kg/day)	1,3- Butadiene (kg/day)	Formaldehy de (kg/day)	Acetaldehy de (kg/day)	Toluene (kg/day)	Xylene (kg/day)	Ethyl Benzene (kg/day)
A1 + A2 Terminal/Apron	0	1.71E+02	9.64E+02	1.06E+03	1.78E+01	5.39E+01	3.27E-01	2.49E-01	1.47E+01	4.89E+00	3.86E+00	2.74E+00	2.35E-02
B Access Road	0	2.70E+02	1.93E+02	2.60E+03	1.01E+01	2.17E+01	1.00E+01	5.72E-01	2.70E+00	1.20E+00	1.72E+01	1.66E+01	2.70E+00
C1 + C2 Aircraft Maint.	0	1.77E+02	9.51E+01	4.76E+01	2.07E+00	0.00E+00	1.42E-01	1.32E-01	1.10E+00	3.41E-01	2.39E+01	2.05E+01	1.25E-02
D Fuel Storage	0	1.77E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F1 1st Runway													
Taxiing, idle	0	4.33E+02	2.28E+02	1.45E+03	5.35E+01	1.15E+02	9.20E+00	8.53E+00	7.12E+01	2.20E+01	2.47E+00	2.28E+00	8.06E-01
Takeoff	0 - 200	1.10E+01	7.61E+02	1.34E+01	1.97E+01	4.01E+01	2.33E-01	2.16E-01	1.80E+00	5.59E-01	6.25E-02	5.77E-02	2.04E-02
F2 2nd Runway													
Taxiing, idle	0	4.33E+02	2.28E+02	1.45E+03	5.35E+01	1.15E+02	9.20E+00	8.53E+00	7.12E+01	2.20E+01	2.47E+00	2.28E+00	8.06E-01
Takeoff	0 - 200	1.10E+01	7.61E+02	1.34E+01	1.97E+01	4.01E+01	2.33E-01	2.16E-01	1.80E+00	5.59E-01	6.25E-02	5.77E-02	2.04E-02
G1 1st Runway													
Climbout	200-1000	2.22E+01	1.59E+03	3.82E+01	5.57E+01	1.11E+02	4.71E-01	4.37E-01	3.64E+00	1.13E+00	1.26E-01	1.17E-01	4.13E-02
G2 2nd Runway													
Climbout	200-1000	2.22E+01	1.59E+03	3.82E+01	5.57E+01	1.11E+02	4.71E-01	4.37E-01	3.64E+00	1.13E+00	1.26E-01	1.17E-01	4.13E-02
H1 1st Runway													
Approach	1000 - 0	3.13E+01	3.30E+02	1.08E+02	3.45E+01	6.68E+01	6.64E-01	6.16E-01	5.14E+00	1.59E+00	1.78E-01	1.64E-01	1.76E-01
H2 2nd Runway													
Approach	1000 - 0	3.13E+01	3.30E+02	1.08E+02	3.45E+01	6.68E+01	6.64E-01	6.16E-01	5.14E+00	1.59E+00	1.78E-01	1.64E-01	1.76E-01
<b>TOTAL</b>		<b>1.63E+03</b>	<b>7.07E+03</b>	<b>6.92E+03</b>	<b>3.57E+02</b>	<b>7.42E+02</b>	<b>3.16E+01</b>	<b>2.06E+01</b>	<b>1.82E+02</b>	<b>5.71E+01</b>	<b>5.07E+01</b>	<b>4.50E+01</b>	<b>4.83E+00</b>

a. The height of aircraft exhaust emissions while the aircraft is on the ground is estimated to be 7m, allowing for the heat of the exhaust (VCEC, 1995).

**TABLE 29**  
**DAILY EMISSIONS FROM SSA, CASE 2A-EQUAL GROWTH SCENARIO, 2006 (117,000 ANNUAL MOVEMENTS). WINTER**  
**DAY**

Emission Source	Height (m AGL)	NMHC (kg/day)	NOx (kg/day)	CO (kg/day)	SO2 (kg/day)	PM (kg/day)	Benzene (kg/day)	1,3- Butadiene (kg/day)	Formaldehy de (kg/day)	Acetaldehy de (kg/day)	Toluene (kg/day)	Xylene (kg/day)	Ethyl Benzene (kg/day)
A1 + A2 Terminal/Apron	0	1.09E+02	6.13E+02	6.73E+02	1.13E+01	3.43E+01	2.08E-01	1.58E-01	9.38E+00	3.11E+00	2.46E+00	1.74E+00	1.49E-02
B Access Road	0	1.90E+02	1.64E+02	1.84E+03	6.42E+00	1.38E+01	7.27E+00	4.20E-01	1.99E+00	8.84E-01	1.24E+01	1.19E+01	1.99E+00
C1 + C2 Aircraft Maint.	0	1.13E+02	6.05E+01	3.02E+01	1.32E+00	0.00E+00	9.06E-02	8.40E-02	7.01E-01	2.17E-01	1.52E+01	1.30E+01	7.94E-03
D Fuel Storage	0	1.12E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F1 1st Runway													
Taxiing, idle	0	2.20E+02	9.44E+01	6.70E+02	2.28E+01	6.45E+01	4.67E+00	4.34E+00	3.62E+01	1.12E+01	1.25E+00	1.16E+00	4.10E-01
Takeoff	0 - 200	5.77E+00	3.71E+02	8.16E+00	1.00E+01	2.25E+01	1.22E-01	1.14E-01	9.48E-01	2.94E-01	3.28E-02	3.03E-02	1.07E-02
F2 2nd Runway													
Taxiing, idle	0	2.20E+02	9.44E+01	6.70E+02	2.28E+01	6.45E+01	4.67E+00	4.34E+00	3.62E+01	1.12E+01	1.25E+00	1.16E+00	4.10E-01
Takeoff	0 - 200	5.77E+00	3.71E+02	8.16E+00	1.00E+01	2.25E+01	1.22E-01	1.14E-01	9.48E-01	2.94E-01	3.28E-02	3.03E-02	1.07E-02
G1 1st Runway													
Climbout	200-1000	1.19E+01	7.83E+02	2.37E+01	2.84E+01	6.26E+01	2.53E-01	2.34E-01	1.95E+00	6.05E-01	6.77E-02	6.25E-02	2.21E-02
G2 2nd Runway													
Climbout	200-1000	1.19E+01	7.83E+02	2.37E+01	2.84E+01	6.26E+01	2.53E-01	2.34E-01	1.95E+00	6.05E-01	6.77E-02	6.25E-02	2.21E-02
H1 1st Runway													
Approach	1000 - 0	1.98E+01	1.66E+02	6.74E+01	1.78E+01	3.76E+01	4.20E-01	3.90E-01	3.25E+00	1.01E+00	1.13E-01	1.04E-01	1.11E-01
H2 2nd Runway													
Approach	1000 - 0	1.98E+01	1.66E+02	6.74E+01	1.78E+01	3.76E+01	4.20E-01	3.90E-01	3.25E+00	1.01E+00	1.13E-01	1.04E-01	1.11E-01
<b>TOTAL</b>		<b>9.37E+02</b>	<b>3.67E+03</b>	<b>4.08E+03</b>	<b>1.77E+02</b>	<b>4.23E+02</b>	<b>1.85E+01</b>	<b>1.08E+01</b>	<b>9.67E+01</b>	<b>3.04E+01</b>	<b>3.30E+01</b>	<b>2.93E+01</b>	<b>3.12E+00</b>

a. The height of aircraft exhaust emissions while the aircraft is on the ground is estimated to be 7m, allowing for the heat of the exhaust (VCEC, 1995).

**TABLE 30**  
**DAILY EMISSIONS FROM SSA. CASE 2B-EQUAL GROWTH SCENARIO. 2006 (233.000 ANNUAL MOVEMENTS). WINTER**  
**DAY**

Emission Source	Height (m AGL)	NMHC (kg/day)	NOx (kg/day)	CO (kg/day)	SO2 (kg/day)	PM (kg/day)	Benzene (kg/day)	1,3- Butadiene (kg/day)	Formaldehy de (kg/day)	Acetaldehy de (kg/day)	Toluene (kg/day)	Xylene (kg/day)	Ethyl Benzene (kg/day)
A1 + A2 Terminal/Apron	0	2.15E+02	1.22E+03	1.33E+03	2.24E+01	6.79E+01	4.12E-01	3.14E-01	1.86E+01	6.16E+00	4.87E+00	3.45E+00	2.96E-02
B Access Road	0	3.40E+02	2.44E+02	3.28E+03	1.27E+01	2.74E+01	1.26E+01	7.21E-01	3.41E+00	1.52E+00	2.17E+01	2.09E+01	3.41E+00
C1 + C2 Aircraft Maint.	0	2.23E+02	1.20E+02	6.00E+01	2.61E+00	0.00E+00	1.80E-01	1.67E-01	1.39E+00	4.31E-01	3.01E+01	2.58E+01	1.57E-02
D Fuel Storage	0	2.23E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F1 1st Runway													
Taxiing, idle	0	5.41E+02	2.87E+02	1.82E+03	6.75E+01	1.45E+02	1.15E+01	1.07E+01	8.89E+01	2.75E+01	3.08E+00	2.84E+00	1.01E+00
Takeoff	0 - 200	1.36E+01	9.51E+02	1.64E+01	2.48E+01	5.07E+01	2.89E-01	2.68E-01	2.24E+00	6.94E-01	7.76E-02	7.16E-02	2.54E-02
F2 2nd Runway													
Taxiing, idle	0	5.41E+02	2.87E+02	1.82E+03	6.75E+01	1.45E+02	1.15E+01	1.07E+01	8.89E+01	2.75E+01	3.08E+00	2.84E+00	1.01E+00
Takeoff	0 - 200	1.36E+01	9.51E+02	1.64E+01	2.48E+01	5.07E+01	2.89E-01	2.68E-01	2.24E+00	6.94E-01	7.76E-02	7.16E-02	2.54E-02
G1 1st Runway													
Climbout	200-1000	2.76E+01	1.99E+03	4.66E+01	7.02E+01	1.41E+02	5.86E-01	5.43E-01	4.53E+00	1.40E+00	1.57E-01	1.45E-01	5.13E-02
G2 2nd Runway													
Climbout	200-1000	2.76E+01	1.99E+03	4.66E+01	7.02E+01	1.41E+02	5.86E-01	5.43E-01	4.53E+00	1.40E+00	1.57E-01	1.45E-01	5.13E-02
H1 1st Runway													
Approach	1000 - 0	3.90E+01	4.15E+02	1.34E+02	4.35E+01	8.46E+01	8.28E-01	7.69E-01	6.41E+00	1.99E+00	2.22E-01	2.05E-01	2.19E-01
H2 2nd Runway													
Approach	1000 - 0	3.90E+01	4.15E+02	1.34E+02	4.35E+01	8.46E+01	8.28E-01	7.69E-01	6.41E+00	1.99E+00	2.22E-01	2.05E-01	2.19E-01
<b>TOTAL</b>		<b>2.04E+03</b>	<b>8.87E+03</b>	<b>8.72E+03</b>	<b>4.50E+02</b>	<b>9.38E+02</b>	<b>3.96E+01</b>	<b>2.57E+01</b>	<b>2.28E+02</b>	<b>7.14E+01</b>	<b>6.38E+01</b>	<b>5.67E+01</b>	<b>6.06E+00</b>

a. The height of aircraft exhaust emissions while the aircraft is on the ground is estimated to be 7m, allowing for the heat of the exhaust (VCEC, 1995).

**TABLE 31**  
**DAILY EMISSIONS FROM SSA, CASE 3A-ADDITIONAL NOISE SCENARIO, 2006 (131,000 ANNUAL MOVEMENTS).**  
**WINTER DAY**

Emission Source	Height (m AGL)	NMHC (kg/day)	NOx (kg/day)	CO (kg/day)	SO2 (kg/day)	PM (kg/day)	Benzene (kg/day)	1,3- Butadiene (kg/day)	Formaldehy de (kg/day)	Acetaldehy de (kg/day)	Toluene (kg/day)	Xylene (kg/day)	Ethyl Benzene (kg/day)
A1 + A2 Terminal/Apron	0	1.21E+02	6.82E+02	7.49E+02	1.26E+01	3.81E+01	2.78E-01	2.20E-01	1.08E+01	3.57E+00	2.75E+00	1.95E+00	2.07E-02
B Access Road	0	2.11E+02	1.82E+02	2.05E+03	7.14E+00	1.54E+01	7.09E+00	4.04E-01	1.91E+00	8.50E-01	1.22E+01	1.17E+01	1.91E+00
C1 + C2 Aircraft Maint.	0	1.25E+02	6.73E+01	3.36E+01	1.47E+00	0.00E+00	1.26E-01	1.17E-01	9.73E-01	3.01E-01	1.69E+01	1.45E+01	1.10E-02
D Fuel Storage	0	1.25E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F1 1st Runway													
Taxiing, idle	0	3.38E+02	1.82E+02	1.08E+03	4.16E+01	1.16E+02	7.17E+00	6.65E+00	5.55E+01	1.72E+01	1.92E+00	1.77E+00	6.28E-01
Takeoff	0 - 200	1.44E+01	8.11E+02	1.20E+01	1.90E+01	4.04E+01	3.06E-01	2.83E-01	2.36E+00	7.32E-01	8.19E-02	7.56E-02	2.68E-02
F2 2nd Runway													
Taxiing, idle	0	3.38E+02	1.82E+02	1.08E+03	4.16E+01	1.16E+02	7.17E+00	6.65E+00	5.55E+01	1.72E+01	1.92E+00	1.77E+00	6.28E-01
Takeoff	0 - 200	1.44E+01	8.11E+02	1.20E+01	1.90E+01	4.04E+01	3.06E-01	2.83E-01	2.36E+00	7.32E-01	8.19E-02	7.56E-02	2.68E-02
G1 1st Runway													
Climbout	200-1000	2.81E+01	1.66E+03	3.32E+01	5.35E+01	1.12E+02	5.97E-01	5.54E-01	4.62E+00	1.43E+00	1.60E-01	1.48E-01	5.23E-02
G2 2nd Runway													
Climbout	200-1000	2.81E+01	1.66E+03	3.32E+01	5.35E+01	1.12E+02	5.97E-01	5.54E-01	4.62E+00	1.43E+00	1.60E-01	1.48E-01	5.23E-02
H1 1st Runway													
Approach	1000 - 0	3.05E+01	3.23E+02	9.69E+01	3.28E+01	6.74E+01	6.47E-01	6.01E-01	5.01E+00	1.55E+00	1.74E-01	1.60E-01	1.72E-01
H2 2nd Runway													
Approach	1000 - 0	3.05E+01	3.23E+02	9.69E+01	3.28E+01	6.74E+01	6.47E-01	6.01E-01	5.01E+00	1.55E+00	1.74E-01	1.60E-01	1.72E-01
<b>TOTAL</b>		<b>1.29E+03</b>	<b>6.89E+03</b>	<b>5.27E+03</b>	<b>3.15E+02</b>	<b>7.25E+02</b>	<b>2.49E+01</b>	<b>1.69E+01</b>	<b>1.49E+02</b>	<b>4.65E+01</b>	<b>3.65E+01</b>	<b>3.25E+01</b>	<b>3.70E+00</b>

a. The height of aircraft exhaust emissions while the aircraft is on the ground is estimated to be 7m, allowing for the heat of the exhaust (VCEC, 1995).

**TABLE 32**  
**DAILY EMISSIONS FROM SSA, CASE 3B-ADDITIONAL NOISE SCENARIO, 2016 (245,000 ANNUAL MOVEMENTS).**  
**WINTER DAY**

Emission Source	Height (m AGL)	NMHC (kg/day)	NO <sub>x</sub> (kg/day)	CO (kg/day)	SO <sub>2</sub> (kg/day)	PM (kg/day)	Benzene (kg/day)	1,3- Butadiene (kg/day)	Formaldehy de (kg/day)	Acetaldehy de (kg/day)	Toluene (kg/day)	Xylene (kg/day)	Ethyl Benzene (kg/day)
A1 + A2 Terminal/Apron	0	2.27E+02	1.28E+03	1.41E+03	2.36E+01	7.16E+01	3.90E+00	3.30E-01	1.96E+01	6.49E+00	5.13E+00	3.64E+00	3.12E-02
B Access Road	0	3.58E+02	2.57E+02	3.46E+03	1.34E+01	2.89E+01	1.33E+01	7.59E-01	3.59E+00	1.60E+00	2.29E+01	2.20E+01	3.59E+00
C1 + C2 Aircraft Maint.	0	2.35E+02	1.26E+02	6.32E+01	2.75E+00	0.00E+00	1.89E-01	1.76E-01	1.46E+00	4.53E-01	3.17E+01	2.72E+01	1.66E-02
D Fuel Storage	0	2.34E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F1 1st Runway													
Taxiing, idle	0	6.62E+02	3.89E+02	2.26E+03	8.87E+01	1.85E+02	1.41E+01	1.30E+01	1.09E+02	3.37E+01	3.77E+00	3.48E+00	1.23E+00
Takeoff	0 - 200	2.06E+01	1.37E+03	1.97E+01	3.33E+01	6.47E+01	4.37E-01	4.06E-01	3.38E+00	1.05E+00	1.17E-01	1.08E-01	3.83E-02
F2 2nd Runway													
Taxiing, idle	0	6.62E+02	3.89E+02	2.26E+03	8.87E+01	1.85E+02	1.41E+01	1.30E+01	1.09E+02	3.37E+01	3.77E+00	3.48E+00	1.23E+00
Takeoff	0 - 200	2.06E+01	1.37E+03	1.97E+01	3.33E+01	6.47E+01	4.37E-01	4.06E-01	3.38E+00	1.05E+00	1.17E-01	1.08E-01	3.83E-02
G1 1st Runway													
Climbout	200-1000	4.06E+01	2.83E+03	5.47E+01	9.39E+01	1.80E+02	8.63E-01	8.01E-01	6.68E+00	2.07E+00	2.31E-01	2.14E-01	7.56E-02
G2 2nd Runway													
Climbout	200-1000	4.06E+01	2.83E+03	5.47E+01	9.39E+01	1.80E+02	8.63E-01	8.01E-01	6.68E+00	2.07E+00	2.31E-01	2.14E-01	7.56E-02
H1 1st Runway													
Approach	1000 - 0	4.79E+01	5.67E+02	1.59E+02	5.77E+01	1.08E+02	1.02E+00	9.44E-01	7.88E+00	2.44E+00	2.73E-01	2.52E-01	2.70E-01
H2 2nd Runway													
Approach	1000 - 0	4.79E+01	5.67E+02	1.59E+02	5.77E+01	1.08E+02	1.02E+00	9.44E-01	7.88E+00	2.44E+00	2.73E-01	2.52E-01	2.70E-01
<b>TOTAL</b>		<b>2.39E+03</b>	<b>1.20E+04</b>	<b>9.91E+03</b>	<b>5.87E+02</b>	<b>1.18E+03</b>	<b>5.02E+01</b>	<b>3.17E+01</b>	<b>2.78E+02</b>	<b>8.70E+01</b>	<b>6.85E+01</b>	<b>6.09E+01</b>	<b>6.87E+00</b>

a. The height of aircraft exhaust emissions while the aircraft is on the ground is estimated to be 7m, allowing for the heat of the exhaust (VCEC, 1995).



## 9.0 PHOTOCHEMISTRY SPECIATION

The formation of photochemical smog is a complex and non-linear process involving volatile organic compounds (VOC) and oxides of nitrogen ( $\text{NO}_x$ , comprising NO and  $\text{NO}_2$  in the presence of sunlight. Smog production, generally assessed by modelling ozone-forming reactions, requires the emissions of VOC and  $\text{NO}_x$  to be further resolved (speciated) into their component species. It has been assumed that all  $\text{NO}_x$  emissions consist of 90% NO and 10%  $\text{NO}_2$  where  $\text{NO}_x$  is expressed as  $\text{NO}_2$  weight equivalents. The profiles adopted for VOC emissions from the various airport sources are discussed below and are presented in Appendix C.

The VOC speciation profile for aircraft exhaust is based on a weighted average for a U.S. commercial aviation LTO cycle (Profile 1098, SDS, 1993). This profile is assumed to apply to maintenance and APU operation.

The landside motor vehicle fleet exhaust VOC speciation is based on results for unleaded fuelled, catalyst equipped vehicles over the ADR 27A cycle as reported originally by CSIRO (Galbally et al., 1991) and corrected for C5/C6 alkenes by Carnovale et al. (1991). Evaporative VOC is based on the profile for the NSW motor vehicle fleet as reported by Carnovale et al. (1995). The calculated profile as shown in Appendix C represents the weighted contributions of exhaust and evaporative VOC emissions with the incorporation of an exhaust carbonyl component of 2% (F. Carnovale, personal communication, 1996). For the predominantly diesel airside vehicle and plant fleet, the VOC profile adopted is that recommended by the USEPA (Profile 1201, SDS, 1993). 90).

The VOC speciation profile for evaporative loss from aviation fuel storage tanks has been documented by USEPA (Profile 100, SDS, 1993). The surface coatings VOC profile is based on the work of Carnovale et al. (1995). The VOC profile for solvents used at airports is difficult to estimate due to the range of compounds used and has been approximated by an urban solvent mix adopted in previous inventory work undertaken by Coffey (Morrell et al., 1995). For natural gas combustion, the profile for commercial natural gas boilers recommended by the USEPA has been adopted (Profile 0003, SDS, 1993).



## **10.0 FIRE TRAINING EMISSIONS**

Burn operations are undertaken at airports on a regular basis to train personnel in fire fighting procedures. This generally involves igniting jet fuel/kerosene in a defined area set aside for such activity away from the terminal and apron reserve. The frequency of such operations varies according to weather conditions and fire brigade activities.

The duration of a training burn is approximately 5 minutes and the amount of fuel consumed per burn has been reported to be in the vicinity of 300 litres (Stephenson and Associates, 1993). Using emission factors sourced from the Emissions and Dispersion Modelling System (EDMS, 1994) for the combustion of jet fuel, it is estimated that a single training burn will result in the emission of approximately 75 kg of HC, 1 kg of NO<sub>x</sub>, 130 kg of CO, 30 kg of SO<sub>2</sub> and 0.25 kg of particulate matter.

There is no set emission pattern associated with fire training due to the relatively short duration of burning and there are no defined times when burning will take place. Due to the random nature of the source and the fact that emissions are small when compared with other airport sources, fire training emissions have not been incorporated into the inventory.

## **11.0 CONCLUSIONS**

An air emissions inventory of airport related sources has been undertaken as part of the Environmental Impact Statement for the second Sydney airport. Aircraft exhaust emissions are estimated to be the largest source of air pollutants followed by emissions from the landside motor vehicle fleet. Emissions from other airport sources were estimated from available data or from a consideration of previous Australian airport emission studies. The emissions scenarios presented have been assumed to be applicable to both the Badgerys Creek and Holsworthy sites.

The limitations of this study are as follows :

- seasonal variations in airport activity have not been considered. Annual emissions from aircraft exhaust have been apportioned evenly across the year.
- emissions scenarios have been established for a typical day only. Episodic events such as major aviation fuel spills or have not been modelled.
- the estimates of particulate matter emissions from aircraft engines are based on a general emission factor from the USEPA that has a significant level of uncertainty.





The study recommendations are as follows :

- estimates of particulate matter emissions should be refined as more data becomes available.
- in the event of future airport planning and design work identifying major operational differences between the Badgerys Creek and Holsworthy sites, various aspects of the emissions inventory should be revised to reflect these differences.

## 12.0 REFERENCES

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**APPENDIX A**  
**ASSESSMENT OF EMISSIONS FROM GROUND SERVICE EQUIPMENT**



**EMISSION FACTORS FOR AIRSIDE MOTOR VEHICLE FLEET AND PLANT**  
**(EDMS, 1993)**

EQUIPMENT TYPE	HC kg/hr	NO <sub>x</sub> kg/hr	CO kg/hr	SO <sub>x</sub> kg/hr	PM <sub>10</sub> kg/hr
Tug	6.929E-02	3.629E-01	3.469E-01	8.884E-03	2.676E-02
Stairs	4.423E-02	2.316E-01	2.214E-01	5.670E-03	1.708E-02
Air conditioner unit	5.160E-02	2.702E-01	2.583E-01	6.615E-03	1.992E-02
Air start	2.418E-01	1.266E+00	1.210E+00	3.100E-02	9.336E-02
Fuel truck	5.012E-02	2.625E-01	2.509E-01	6.426E-03	1.936E-02
Cabin cleaning	4.423E-02	2.316E-01	2.214E-01	5.670E-03	1.708E-02
Lavatory truck	4.423E-02	2.316E-01	2.214E-01	5.670E-03	1.708E-02
Service galley	5.897E-02	3.088E-01	2.952E-01	7.561E-03	2.277E-02
Baggage loader	2.064E-02	1.081E-01	1.033E-01	2.646E-03	7.970E-03
Baggage mobile	5.307E-02	2.779E-01	2.657E-01	6.804E-03	2.049E-02
Water truck	4.423E-02	2.316E-01	2.214E-01	5.670E-03	1.708E-02
Electricity generating unit	2.093E-01	1.096E+00	1.048E+00	2.684E-02	8.084E-02
Bulk cargo loader	4.423E-02	2.316E-01	2.214E-01	5.670E-03	1.708E-02
Bulk cargo train	4.423E-02	2.316E-01	2.214E-01	5.670E-03	1.708E-02

**OPERATIONAL PARAMETERS FOR AIRSIDE MOTOR VEHICLE FLEET AND PLANT**  
**FOR SSA AT DESIGN CAPACITY 2016 (CASE 3B)**

EQUIPMENT TYPE	Operating time/LTO (min)	LTO/year	Total time (hr/yr)
Tug	8.18E+00	8.66E+04	1.18E+04
Stairs	1.57E+01	8.66E+04	2.27E+04
Air conditioner unit	6.00E+01	1.12E+05	1.12E+05
Air start	3.00E+00	1.14E+05	5.69E+03
Fuel truck	3.33E+01	1.25E+05	6.92E+04
Cabin cleaning	1.93E+01	1.12E+05	3.59E+04
Lavatory truck	1.93E+01	1.14E+05	3.66E+04
Service galley	4.43E+01	2.14E+05	1.58E+05
Baggage loader	4.15E+01	1.70E+05	1.18E+05
Baggage mobile	3.98E+01	2.00E+05	1.32E+05
Water truck	8.84E+00	1.12E+05	1.65E+04
Electricity generating unit	6.00E+01	1.14E+05	1.14E+05
Bulk cargo loader	9.00E+01	5.75E+04	8.63E+04
Bulk cargo train	9.10E+01	5.69E+04	8.63E+04

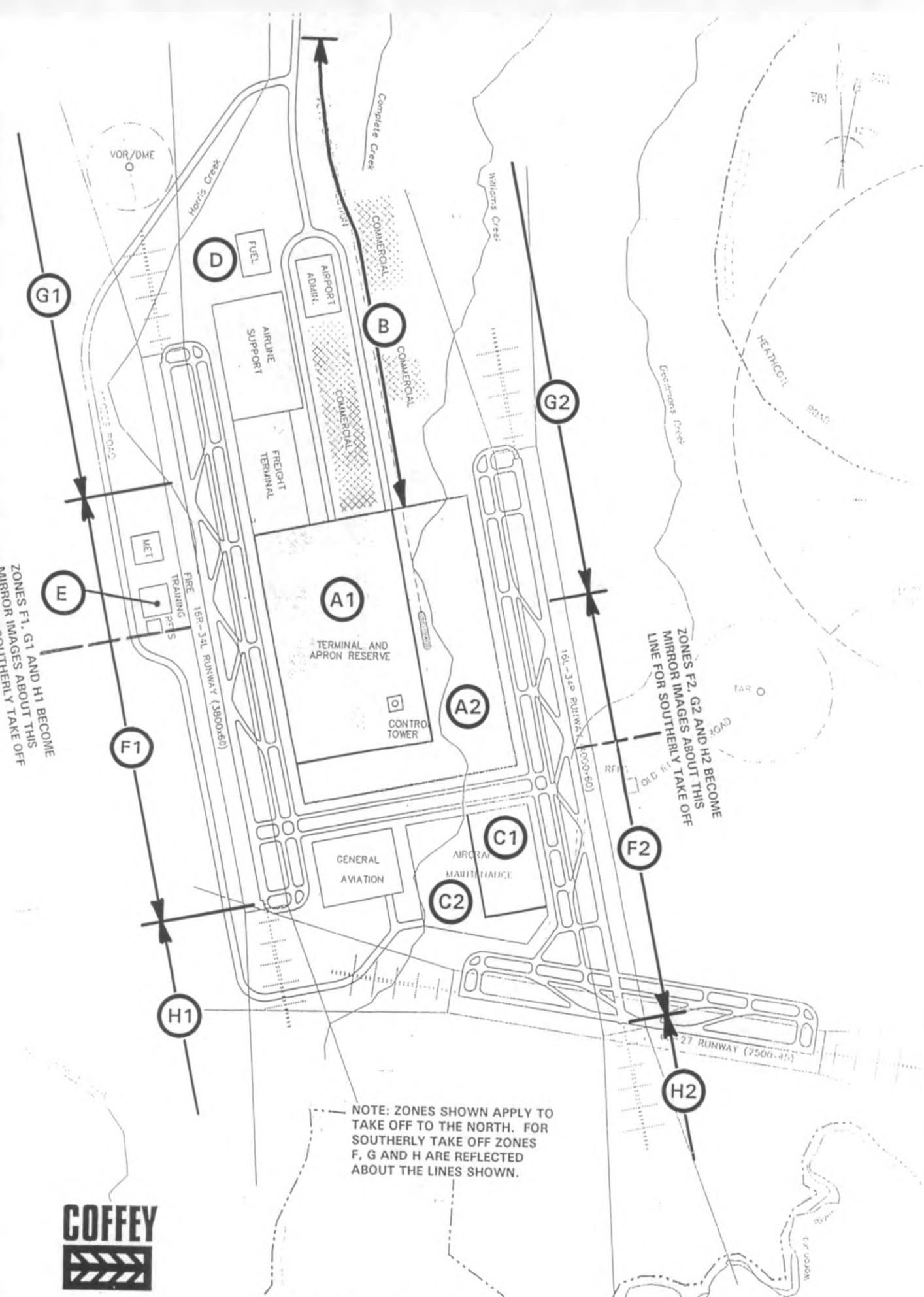


**ESTIMATION OF EMISSIONS FROM AIRSIDE MOTOR VEHICLE FLEET AND PLANT  
FOR SSA AT DESIGN CAPACITY 2016 (CASE 3B)**

EQUIPMENT TYPE	HC	NO <sub>x</sub>	CO	SO <sub>x</sub>	PM <sub>10</sub>
Tug	8.18E-01	4.28E+00	4.09E+00	1.05E-01	3.16E-01
Stairs	1.00E+00	5.26E+00	5.02E+00	1.29E-01	3.87E-01
Air conditioner unit	5.77E+00	3.02E+01	2.89E+01	7.39E-01	2.23E+00
Air start	1.38E+00	7.21E+00	6.89E+00	1.76E-01	5.31E-01
Fuel truck	3.47E+00	1.82E+01	1.74E+01	4.45E-01	1.34E+00
Cabin cleaning	1.59E+00	8.31E+00	7.94E+00	2.03E-01	6.13E-01
Lavatory truck	1.62E+00	8.48E+00	8.11E+00	2.08E-01	6.25E-01
Service galley	9.31E+00	4.87E+01	4.66E+01	1.19E+00	3.59E+00
Baggage loader	2.43E+00	1.27E+01	1.22E+01	3.12E-01	9.39E-01
Baggage mobile	7.03E+00	3.68E+01	3.52E+01	9.01E-01	2.71E+00
Water truck	7.28E-01	3.81E+00	3.64E+00	9.33E-02	2.81E-01
Electricity generating unit	2.38E+01	1.25E+02	1.19E+02	3.06E+00	9.20E+00
Bulk cargo loader	3.82E+00	2.00E+01	1.91E+01	4.89E-01	1.47E+00
Bulk cargo train	3.82E+00	2.00E+01	1.91E+01	4.89E-01	1.47E+00
<b>TOTAL (t/yr)</b>	<b>6.66E+01</b>	<b>3.49E+02</b>	<b>3.33E+02</b>	<b>8.54E+00</b>	<b>2.57E+01</b>
<b>TOTAL (kg/day)</b>	<b>1.82E+02</b>	<b>9.55E+02</b>	<b>9.13E+02</b>	<b>2.34E+01</b>	<b>7.05E+01</b>



APPENDIX B  
DISTRIBUTION OF AIR EMISSIONS

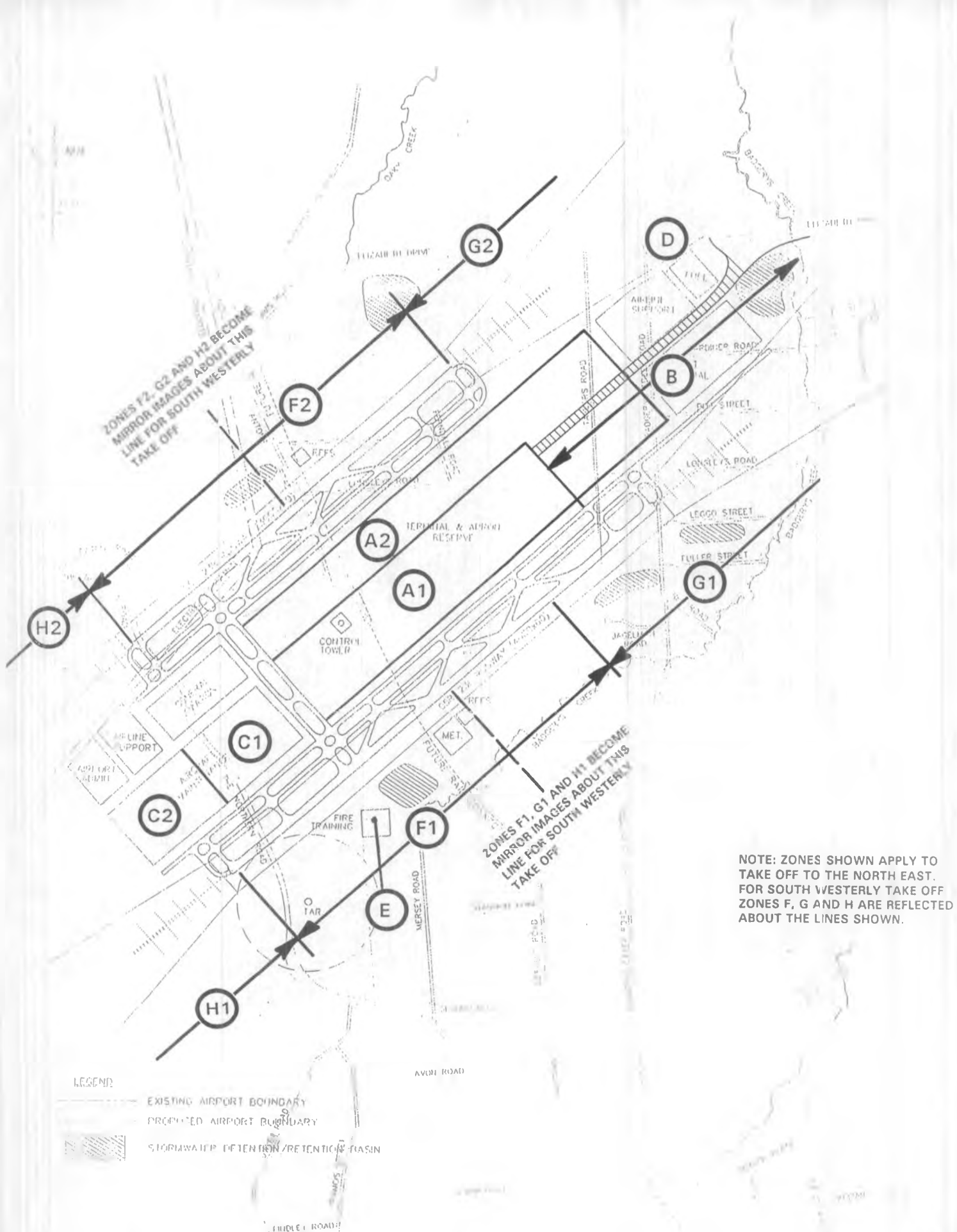


PLANNING AND DESIGN



Figure 3  
HOLSWORTHY  
OPTION A (NORTHERN)

AIR EMISSION ZONES



BADGERYS CREEK  
OPTION A  
ORIGINAL PROPOSAL  
AIR EMISSION ZONES





LITERATURE 119



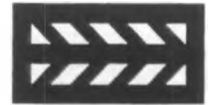
Figure 1

BADGERYS CREEK  
OPTION C  
NORTH/SOUTH ALIGNMENT  
AIR EMISSION ZONES





APPENDIX C  
VOC SPECIATION - PHOTOCHEMICAL ACTIVITY



**AIRCRAFT ENGINE EXHAUST VOC SPECIATION PROFILE**  
**SOURCE : PROFILE 1098. SDS (1993). CORRECTED FOR METHANE.**

SPECIES	% VOC (by weight)
ISOMERS OF DODECANE	0.20
ISOMERS OF TETRADECANE	0.21
ISOMERS OF PENTADECANE	0.19
ISOMERS OF PENTENE	0.81
C16 BRANCHED ALKANE	0.15
C7-C16 PARAFFINS	0.33
ETHANE	0.97
ETHYLENE	19.28
PROPANE	0.20
PROPENE	5.70
ACETYLENE	4.61
BUTENE	2.18
CIS-2-BUTENE	0.53
1,3 BUTADIENE	1.99
N-PENTANE	0.23
1-PENTENE	0.93
2-METHYL-2-BUTENE	0.22
2-METHYLPENTANE	0.43
HEPTANE	0.07
OCTANE	0.06
NONANE	0.14
N-DECANE	0.46
N-UNDECANE	0.59
1-HEXENE	0.91
N-DODECANE	1.18
N-TRIDENCANE	0.73
N-TETRADECANE	0.64
N-PENTADECANE	0.29
HEPTENE	0.60
OCTENE	0.31
1-NONENE	0.27
FORMALDEHYDE	16.60
ACETALDEHYDE	5.14
PROPIONALDEHYDE	1.05
ACROLEIN	2.51
BUTYRALDEHYDE	1.33
HEXANAL	0.23



**AIRCRAFT ENGINE EXHAUST VOC SPECIATION PROFILE (cont'd)**  
**SOURCE : PROFILE 1098. SDS (1993). CORRECTED FOR METHANE**

SPECIES	% VOC (by weight)
GLYOXAL	2.81
METHYL GLYOXAL	2.18
CROTONALDEHYDE	0.00
ACETONE	2.71
BENZENE	2.15
TOLUENE	0.58
ETHYLBENZENE	0.19
O-XYLENE	0.21
STYRENE	0.43
PENTYL BENZENE	0.21
BUTYL BENZENE	0.27
PHENOL	0.27
BENZALDEHYDE	0.61
NAPTHALENE	0.63
METHYL NAPHTHALENES	0.54
M-XYLENE AND P-XYLENE	0.32
1-DECENE	0.19
C6H1803SI3	10.08
C6H2404SI4	3.23
HEXADECANE	0.13
N-HEPTADECANE	0.01
<b>TOTAL</b>	<b>100</b>



**MOTOR VEHICLE VOC SPECIATION PROFILE**  
**SOURCE : CSIRO (Galbally, 1991) and Carnovale et al. (1991)**

	WEIGHTED PROF.					
	EVAP % VOC	EXH % VOC	SUMMER	SUMMER	WINTER	WINTER
			2006 % VOC	2016 % VOC	2006 % VOC	2016 % VOC
<b>ALKANES</b>						
ETHANE		4.8	1.9	1.7	3.0	2.9
PROPANE	1.2	0.3	0.8	0.9	0.6	0.7
BUTANE	23.7	4.5	16.1	16.9	11.6	12.1
PENTANE	32.0	15.0	25.2	26.0	21.3	21.7
C6+ALKANES	19.9	24.0	21.5	21.4	22.5	22.4
<b>SUBTOTAL</b>	<b>76.8</b>	<b>48.6</b>	<b>65.6</b>	<b>66.9</b>	<b>59.0</b>	<b>59.7</b>
<b>ALKENES</b>						
ETHYLENE		7.1	2.8	2.5	4.5	4.3
PROPENE		2.2	0.9	0.8	1.4	1.3
1-BUTENE	1.3	0.4	0.9	1.0	0.7	0.8
2-BUTENE	5.3	1.8	3.9	4.1	3.1	3.2
C5/C6	7.7	1.4	5.2	5.5	3.7	3.9
<b>SUBTOTAL</b>	<b>14.3</b>	<b>12.7</b>	<b>13.7</b>	<b>13.8</b>	<b>13.3</b>	<b>13.4</b>
<b>ALKYNES</b>						
ACETYLENE		1.7	0.7	0.6	1.1	1.0
<b>AROMATICS</b>						
BENZENE	1.3	6.6	3.4	3.2	4.6	4.5
TOLUENE	3.5	9.3	5.8	5.6	7.2	7.0
ETHYL BENZ		1.5	0.6	0.5	0.9	0.9
XYLENE	4.2	8.6	6.0	5.8	7.0	6.9
ETHYL		2.0	0.8	0.7	1.2	1.2
TOLUENE						
TRI-METHYL		3.3	1.3	1.2	2.1	2.0
BENZ						
OTHER		3.7	1.5	1.3	2.4	2.3
<b>SUB-TOTAL</b>	<b>9.0</b>	<b>35.0</b>	<b>19.3</b>	<b>18.2</b>	<b>25.4</b>	<b>24.7</b>



**MOTOR VEHICLE VOC SPECIATION PROFILE (ctd)**  
**SOURCE : CSIRO (Galbally, 1991) and Carnovale et al. (1991)**

<b>CARBONYLS</b>						
FORMALDEHYDE EQUIV		2.0	0.8	0.7	1.2	1.2
<b>TOTAL</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

	Summer 2006	Summer 2016	Winter 2006	Winter 2016
exhaust	0.96	0.76	1.22	1.05
evaporation	1.45	1.40	0.71	0.69
<b>total</b>	<b>2.40</b>	<b>2.17</b>	<b>1.92</b>	<b>1.74</b>





**AIRSIDE MOTOR VEHICLE FLEET AND PLANT VOC SPECIATION PROFILE**  
**SOURCE : PROFILE 1201, SDS (1993)**

SPECIES	% VOC
FORMALDEHYDE	9.14
ACETALDEHYDE	3.09
PROPIONALDEHYDE	1.88
ACROLEIN	0.00
HEXANAL	0.08
CROTONALDEHYDE	1.07
BENZALDEHYDE	0.58
C-2 COMPOUNDS	21.17
C-3 COMPOUNDS	5.53
C-4 COMPOUNDS	4.33
C-5 COMPOUNDS	2.51
C-6 COMPOUNDS	4.57
C-7 COMPOUNDS	3.07
C-8 COMPOUNDS	1.20
C-9 COMPOUNDS	0.80
C-10 COMPOUNDS	3.74
C-11 COMPOUNDS	3.80
C-12 COMPOUNDS	2.34
C-13 COMPOUNDS	3.64
C-14 COMPOUNDS	4.72
C-15 COMPOUNDS	4.62
C-16 COMPOUNDS	3.71
C-17 COMPOUNDS	3.25
C-18 COMPOUNDS	2.17
C-19 COMPOUNDS	1.66
C-20 COMPOUNDS	0.97
C-21 COMPOUNDS	0.80
C-22 COMPOUNDS	0.63
C-23 COMPOUNDS	0.51
C-24 COMPOUNDS	0.51
C-25 COMPOUNDS	0.57
C-26 COMPOUNDS	0.47
C-27 COMPOUNDS	0.23
C-28 COMPOUNDS	0.34
C-29 COMPOUNDS	0.15
C-30 COMPOUNDS	0.34
C-31 COMPOUNDS	0.31
C-32 COMPOUNDS	0.29
C-33 COMPOUNDS	0.23
C-34 COMPOUNDS	0.25
C-35 COMPOUNDS	0.17
C-36 COMPOUNDS	0.21
C-37 COMPOUNDS	0.08



**AIRSIDE MOTOR VEHICLE FLEET AND PLANT VOC SPECIATION PROFILE (ctd)**

**SOURCE : PROFILE 1201, SDS (1993)**

C-38 COMPOUNDS	0.05
C-39 COMPOUNDS	0.12
C-40 COMPOUNDS	0.02
C-41 COMPOUNDS	0.05
C-42 COMPOUNDS	0.02
C-43 COMPOUNDS	0.01
<b>TOTAL</b>	<b>1.0</b>

**AIRCRAFT REFUELLING AND FUEL STORAGE LOSS VOC SPECIATION PROFILE**

**SOURCE : PROFILE 100, SDS (1993)**

<b>SPECIES</b>	<b>% VOC</b>
HEPTANE	0.1
OCTANE	0.5
NONANE	4.7
N-DECANE	19.6
N-UNDECANE	20.3
N-DODECANE	18.2
N-TRIDECANE	17.7
N-TETRADECANE	11.7
N-PENTADECANE	7.2
<b>TOTAL</b>	<b>100</b>

**SURFACE COATINGS VOC SPECIATION PROFILE**

**SOURCE : Carnovale et al. (1995)**

<b>SPECIES</b>	<b>% VOC</b>
ALKANES	27
TOLUENE	25
XYLENE	18
BUTANOL	7
GLYCOL	6
ACETONE	4
BUTYL ACETATE	4
OTHER	9
<b>TOTAL</b>	<b>100</b>



**SOLVENT VOC SPECIATION PROFILE**

**SOURCE : Morrell et al. (1995)**

<b>SPECIES</b>	<b>% VOC</b>
ALKANES	18
ETHANOL EQUIV	16
BUTANE	15
TOLUENE EQUIV	14
XYLENES	12
OTHER	7
DICHLOROMETHANE EQUIV	4
PENTANE EQUIV	4
PERCHLOROETHYLENE	3
METHYL ETHYL KETONE	3
ACETATES	2
PROPANE	2
MISC ETHERS, SILICONES, ESTERS	1
BUTENES	0.3
<b>TOTAL</b>	<b>100</b>

**NATURAL GAS COMBUSTION VOC SPECIATION PROFILE**

**SOURCE : PROFILE 0003, SDS (1993)**

<b>SPECIES</b>	<b>% VOC</b>
ISOMERS OF HEXANE	2
ISOMERS OF PENTANE	20
PROPANE	9
N-BUTANE	20
N-PENTANE	14
CYCLOHEXANE	2
FORMALDEHYDE	18
BENZENE	9
TOLUENE	5
<b>TOTAL</b>	<b>100</b>

## **Appendix D**

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CSIRO Smog Modelling Report

**SECOND SYDNEY AIRPORT EIS  
SMOG MODELLING ON TWO SUMMER DAYS**

**P.J. Hurley and P.C. Manins**

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**A Report to Coffey Partners International**

## 1. Introduction

This report describes photochemical smog simulations of the afternoon impact on ozone levels of proposed emissions from three alternative sites for the Second Sydney Airport. The work was done under contract to Coffey Partners International (CPI) using the Lagrangian Atmospheric Dispersion Model (LADM) (see Physick *et al.*, 1994). Meteorological modelling was performed for two summer days based on two of the high smog days identified by Hyde *et al.* (1996) for the Metropolitan Air Quality Study (MAQS). Photochemical dispersion modelling used the predicted meteorological fields and background air representative of existing conditions on these days.

## 2. Meteorological Modelling

Meteorological modelling using LADM has been undertaken previously for the MAQS study for a variety of high pollution days (see Hyde *et al.*, 1996). Here we have based our simulations on two of the same summer high smog days considered by MAQS (9 February 1994 and 4 February 1991). These days are representative of worst-case smog days for the southwest region of the Sydney Basin. They both have clear skies and northerly component synoptic winds over the region: the first is representative of north-northeasterly conditions, leading to daytime easterly sea breezes throughout the Basin; the second is characterised by north-northwesterlies leading to daytime northeasterly sea breezes. In this study, the simulations were done with an improved version of LADM (version 2) for 40, 20, 10, 5, and 2.5 km spaced grids on a 40x40 horizontal grid, centred on the Australian Map Grid (x, y) coordinate (280 km, 6220 km). Figure 1 shows the two inner grids used in this study.

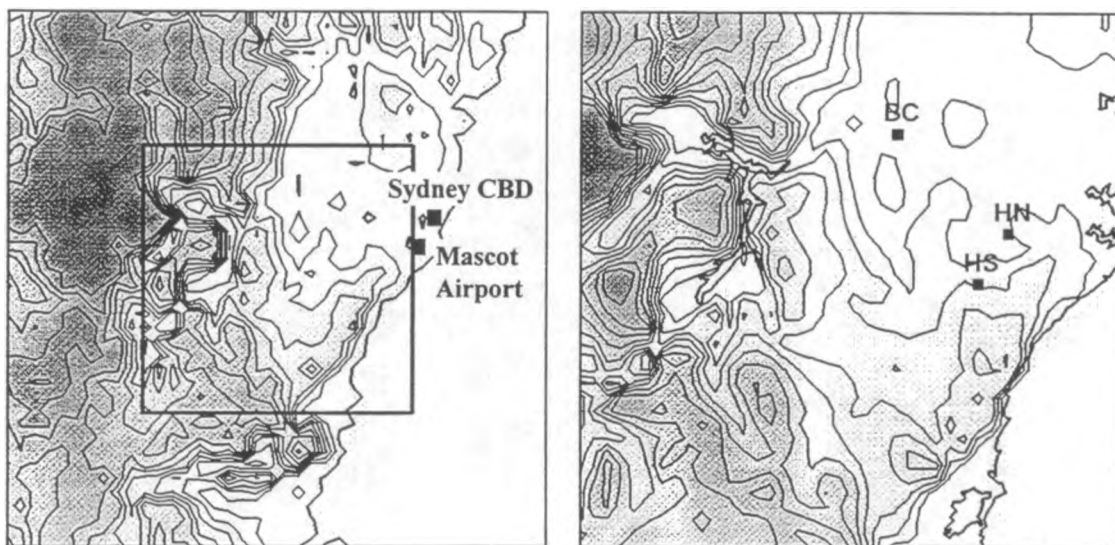


Figure 1. Sydney 5 km spaced grid region (left) showing the location outline of the Sydney 2.5 km spaced grid (right). Grid dimensions are 40x40 points with a domain width of 195 km and 97.5 km for the 5 km and 2.5 km spaced grids respectively. Terrain contours are shown at 100 m height intervals with darker shading corresponding to higher terrain heights. Proposed Airport locations are marked for Holsworthy North (HN), Holsworthy South (HS), and Badgery's Creek (BC) sites.

## 2.1 Summer Day 1: 9 February 1994

Analysis of the synoptic charts and the available upper wind data on 9 February 1994 showed a high pressure system off the NSW coast directing northerly gradient winds over the Sydney region. Figure 2 shows simulated wind fields at 1200 hr and 1600 hr on the inner 2.5 km spaced grid at 10 m and 100 m above the ground. Before sunrise, predicted winds at the coast were moderate northeasterly, while with increasing distance inland, the winds were much lighter and turned to be southerly at the foot of the Blue Mountains (western part of the domain). Drainage flows occurred into the Sydney basin from surrounding slopes. In the morning after sunrise, surface heating reversed the overnight drainage flows, and the sea breeze began to form at the coast (1200 hr). By mid-afternoon (1600 hr) the sea breeze had travelled across most of the grid area producing northeasterlies at the coast and easterlies inland.

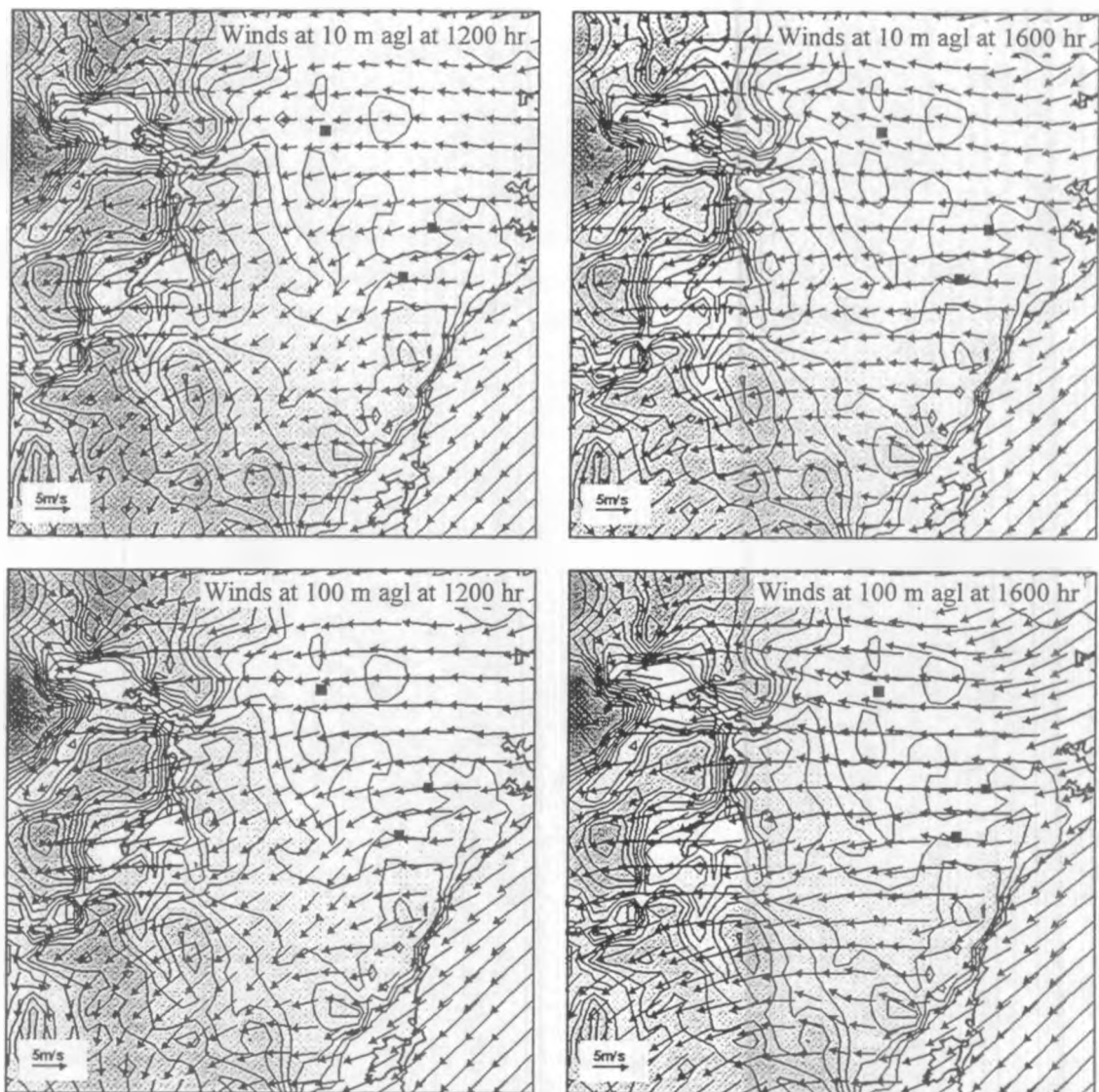


Figure 2. Predicted wind vectors at 10 m (top) and 100 m above ground level (agl) (bottom) on the 2.5 km spaced grid at 1200 hr (left) and 1600 hr (right), on the 9 February 1994. See Figure 1 for details of the grid domain and topographic contour levels. A  $5 \text{ m s}^{-1}$  wind scale is also shown.

## 2.2 Summer Day 2: 4 February 1991

Analysis of the synoptic charts on the morning of 4 February 1991 showed generally north-northwesterly winds over the Sydney region. Figure 3 shows simulated wind fields at 1200 hr and 1600 hr on the inner 2.5 km spaced grid at 10 m and 100 m above the ground. Overnight, drainage flows developed around the edges of the Sydney basin. With heating of the ground after sunrise, the drainage flows were replaced by upslope flows around the basin, and the sea breeze began to form at the coast. At 1200 hr, the northeasterly sea breeze had formed along the coast and started to penetrate inland. By 1600 hr the sea breeze front had reached the foot-hills of the Blue Mountains. The direction of the sea breeze was northeasterly at the coast and inland in the northern part of the basin, and east-northeast in the southern part of the basin.

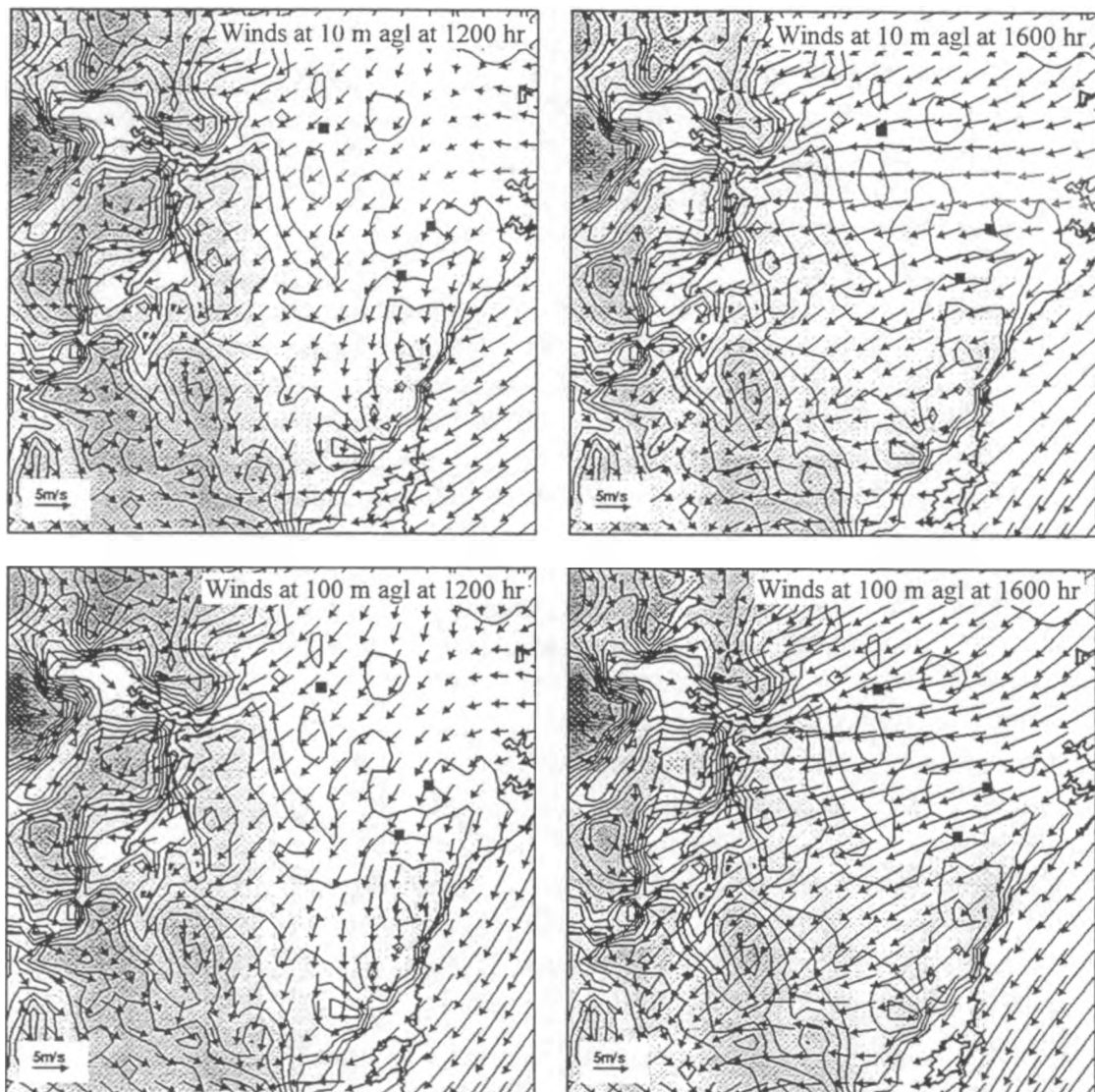


Figure 3. Predicted wind vectors at 10 m (top) and 100 m above ground level (agl) (bottom) on the 2.5 km spaced grid at 1200 hr (left) and 1600 hr (right), on the 4 February 1991. See Figure 1 for details of the grid domain and topographic contour levels. A  $5 \text{ m s}^{-1}$  wind scale is also shown.



### 3. Dispersion Modelling

Photochemical smog simulations were performed for emissions from each of the three alternative Second Sydney Airport sites at Holsworthy North, Holsworthy South, and Badgery's Creek (Option 2) for afternoon sea-breeze conditions on each of the two high smog days described in Section 2. LADM was run on the 2.5 km spaced grid domain for six airport sources with representative background smog conditions characteristic of the existing pollution levels (without the proposed airport), for Case 3b - additional noise scenario, 2016 (see CPI, 1997). The calculations used concentration grid dimensions of 30x30 points with horizontal grid spacing of 2.5 km (75 km x 75 km domain) and vertical grid box height of 50 m. The concentration grid was centred on the 2.5 km spaced meteorological grid. Emissions were released from 1100 hr until 1700 hr, and results are presented only for the late afternoon (eg: 1600 hr and 1700 hr), as concentrations at earlier times are not representative of sea-breeze air polluted with Sydney emissions passing over the relevant sites. Existing background sources downwind of the proposed sites could potentially interact with the airport emissions, particularly for the Holsworthy sites, and so a sensitivity run was performed in Section 3.3 which included an extra area source downwind of the Holsworthy site.

#### 3.1 Source characteristics and background conditions

Source characteristics for the six sources representing emissions from the Second Sydney Airport were based on information contained in the draft emissions inventory report (CPI, 1997). The temporal factor relevant to afternoon emissions is 0.055 (ie: 5.5% of the total daily emissions were taken as being emitted each hour). Three of the sources (A, C, and D) were represented by volume sources and the other three (B, R1, and R2) were represented by line sources (see Appendix 2, CPI 1997, for the source layout for each of the three sites, and Table 26 for the nitrogen oxides and hydrocarbon emissions relevant to each source or line segment). For the orientation of the approach and climb-out line segments, aircraft were assumed to take-off into the sea breeze. The emission rates for hydrocarbons and nitrogen oxides are summarised in Table 1, and the sources were represented by:

- Source A - the terminal/apron emissions as a Gaussian ellipsoid at a height of 10 m with standard deviations of  $(\sigma_x, \sigma_y, \sigma_z) = (400, 400, 3)$  m.
- Source B - the access road emissions as a line of length ~3300 m, width 300 m, and depth 20 m.
- Source C - the emissions due to aircraft maintenance as a Gaussian ellipsoid at a height of 10 m with standard deviations of  $(\sigma_x, \sigma_y, \sigma_z) = (200, 200, 3)$  m.
- Source D - the fuel storage emissions as a Gaussian ellipsoid at a height of 10 m with standard deviations of  $(\sigma_x, \sigma_y, \sigma_z) = (50, 50, 3)$  m.
- Source R1 - the first runway emissions as a line source with the first segment (H1) representing the approach (length ~15 km, height decreasing from 1000 m to 10 m, width decreasing from 400 m to 300 m, and depth 20 m), the second segment (F1) representing the taxiing/idle/take-off (length ~3 km, height increasing from 10 m to 100 m, width 300 m, and depth increasing from 20 m to 200 m), and the third

segment (G1) representing the climb-out (length ~8 km, height increasing from 100 m to 1000 m, width increasing from 300 m to 8000 m, and depth 20 m).

- Source R2 - the second runway emissions as a line source in a similar manner to the R1 distribution.

Table 1: Emission rates for the proposed airport sources.

Source	Hydrocarbons (kg day <sup>-1</sup> )	Nitrogen Oxides (kg day <sup>-1</sup> )
A	227.0	1280.0
B	445.0	239.0
C	235.0	126.0
D	23.4	0.0
R1:F	682.6	1759.0
R1:G	40.6	2830.0
R1:H	47.9	567.0
R2:F	682.6	1759.0
R2:G	40.6	2830.0
R2:H	47.9	567.0

Note that we use non-methane hydrocarbons and 10 % of the nitrogen oxides are nitrogen dioxide.

The dispersion model was run using the Integrated Empirical Rate (IER) smog calculation procedure, which can predict the ozone (O<sub>3</sub>) and nitrogen dioxide (NO<sub>2</sub>) concentration, given emissions of hydrocarbons and oxides of nitrogen. According to the IER procedure, there are two regimes in the formation of photochemical smog in an air parcel:

- a light-limited regime in which the smog produced is a function of the cumulative product of the rate coefficient for nitrogen dioxide photolysis, the hydrocarbon concentration, and temperature; while there is light, ozone will be produced;
- a NO<sub>x</sub>-limited regime in which sufficient light has been incident on the air parcel that photolysis effectively ceases. Additional NO<sub>x</sub> is needed for further ozone production.

The model uses a variable called Rsmog (ppb) which can be derived from hydrocarbon concentration (ppbC) in terms of the molecular weight of CH<sub>2</sub> and using an urban activity coefficient of 0.0067 (Johnson, personal communication, CSIRO, 1997).

We have assumed that worst-case conditions occur following the sea breeze on the days being simulated. The sea breeze brings with it polluted air from Sydney sources. Monitoring data from MAQS stations on these days after the sea-breeze arrival has been used to characterise the background air. The modelling approach used is to simulate the proposed emissions in this background air. Background concentrations have been derived by Azzi and Johnson (1997) as:

- 9/2/94:      Holsworthy:      NO<sub>x</sub>-limited, SP=100 ppb, Rsmog=1.8 ppb;
- 9/2/94:      Badgery's Creek:      NO<sub>x</sub>-limited, SP=140 ppb, Rsmog=3.2 ppb;
- 4/2/91:      Holsworthy:      NO<sub>x</sub>-limited, SP=130 ppb, Rsmog=2.4 ppb;
- 4/2/91:      Badgery's Creek:      NO<sub>x</sub>-limited, SP=145 ppb, Rsmog=3.2 ppb.

### 3.2 Results on Summer Day 1: 9 February 1994

Figures 4, 5, and 6 show predicted hourly average ozone concentration (ppb) at 1600 hr and 1700 hr on 9 February 1994, for each of the Holsworthy North (HN), Holsworthy South (HS), and Badgery's Creek (BC) sites respectively. Note that the sea breeze reaches the Holsworthy sites by approximately 1300 hr, and it reaches the Badgery's Creek site by approximately 1400 hr.

The results for emissions from the three proposed airport sites show an increase in ozone of approximately 15-25 ppb above the Sydney background levels (see Table 2). The  $\text{NO}_x$ -limited background air is temporarily transformed to light-limited conditions as fresh nitrogen oxide emissions from the airport site are added, but due to the high reactivity of the plume,  $\text{NO}_x$ -limited conditions soon re-establish within 15-25 km downwind of the airport.

Plume impact on the Blue Mountains to the west has the potential to increase levels in localised places by even more than 15-25 ppb, particularly for the Badgery's Creek site which is closer to the mountains.

The aircraft approach emissions (line segment H) and the ground and take-off emissions (sources A-D, and line segment F) have the major impact on ground level concentrations, compared to the climb-out emissions (line segment G). This is due to the highly dispersed nature of the climb-out emissions when averaged over an hour. Note that the aircraft approach lines and climb-out region are shown on the Figures. For the Badgery's Creek site, the alignment of the aircraft approach direction with the wind direction on this day also serves to increase the impact of the emissions on the mountains, whereas particularly for the Holsworthy North site the approach emissions form a separate (minor) plume to the south of the plume resulting from the ground and take-off emissions.

Nitrogen dioxide concentrations were predicted to be less than 10 ppb, with maximum values predicted within 5 km of the source. However, due to the large box size used to calculate the concentrations, the near-source concentrations of nitrogen oxides are under-predicted (although box size does not affect predictions further downwind). Predictions of nitrogen dioxide rapidly decrease with downwind distance.

Table 2: Summary of the effect of proposed airport emissions on ozone concentration.

9 Feb. 1994. (ppb)	Holsworthy North	Holsworthy South	Badgery's Creek
Sydney background.	75	75	105
Increment in Basin due to airport.	15-25	15-20	15-20
4 Feb. 1991. (ppb)	Holsworthy North	Holsworthy South	Badgery's Creek
Sydney background.	98	98	109
Increment in Basin due to airport.	15-25	15-20	5-10

### 3.3 Results on Summer Day 2: 4 February 1991

Figures 7, 8, and 9 show predicted ozone concentration (ppb) at 1600 hr and 1700 hr on 4 February 1991, for each of the Holsworthy North (HN), Holsworthy South (HS), and Badgery's Creek (BC) sites respectively. Note that the sea breeze reaches the Holsworthy sites by approximately 1400 hr, and it reaches the Badgery's Creek site by approximately 1500 hr. The later arrival of the sea breeze on 4 February (~1 hour), due to the westerly component of the synoptic wind holding back the sea breeze, means that less ozone could form in the time available until sunset, compared to 9 February, particularly for the Holsworthy South and Badgery's Creek sites further inland.

The increase in ozone varies for the proposed airport sites, ranging from 5-10 ppb at Badgery's Creek to 15-25 ppb at Holsworthy North (see Table 2). Note that the second plume along the southern edge of the grid (particularly for the Holsworthy North simulation) should be ignored due to the break-down of the modelling assumption that we have characterised the background as representative of Sydney emissions arriving with the sea breeze - the southern plume has reacted in the model with emissions not emitted into the sea breeze.

Plume impact on the foot-hills of the Blue Mountains was not apparent on 4 February (up to 1700 hrs), due to the slower progression of the sea-breeze front across the domain. Nitrogen dioxide concentrations were similar to those for 9 February.

### 3.4 Sensitivity to downwind nitrogen oxide sources

In order to assess the impact of existing downwind sources on the Holsworthy simulations, we have included a broad area source (emissions are uniformly distributed over 30 km x 30 km) based on the emissions of nitrogen oxides and hydrocarbons in the region downwind of Campbelltown and Holsworthy, and repeated the simulation for the Holsworthy North site on 9 February 1994. Emission rates and source characteristics were determined from information in Carnovale *et al.* (1996). Note that for all Holsworthy simulations, the characteristics of the background air used includes the effects of all nitrogen oxide emissions upwind of and including Campbelltown, which is located approximately 10 km to the west-northwest of the Holsworthy North site (see Azzi and Johnson, 1997).

The maximum predicted concentration from this extra source was 1-3 ppb of nitrogen oxides. The addition of fresh nitrogen oxide emissions from the area source into the airport plume was only able to titrate 1-3 ppb of ozone from the plume (hardly noticeable in the plots). Increased ozone was formed in the plume further downwind due to the additional nitrogen oxides and high reactivity of the Sydney air. Figure 10 shows predicted ozone concentration (ppb) at 1600 hr and 1700 hr on 9 February 1994 for the Holsworthy North site, when this extra broad area source is included. The results may be directly compared to those in Figure 4. They show that ozone concentrations are increased near the foot-hills of the Blue Mountains, but are not significantly changed elsewhere.

By analysis of the results we are able to show that the additional ozone formed in this simulation is not attributable to the existence of the airport. The high reactivity of the background air is adequate to ensure the complete generation of the extra ozone - the hydrocarbon emissions from the airport have little effect. Therefore the incremental ozone due to the airport emissions on the days considered (see Table 2) would have been unchanged if the extra downwind source had been included in all simulations. We have confirmed this conclusion by simulating the extra area source in the background conditions without any airport sources.

#### 4. Conclusions

In this report, we have performed photochemical smog simulations examining the impact on late afternoon ozone levels of proposed emissions from three alternative sites for the Second Sydney Airport at Holsworthy North, Holsworthy South, and Badgery's Creek (Option 2). Modelling was performed using LADM for the summer days 9 February 1994 and 4 February 1991, two of the high smog days identified by Hyde *et al.* (1996) for MAQS. Proposed Case 3b airport emissions (see CPI, 1997) for each site were simulated in background air characteristic of the existing Sydney urban emissions arriving at each site in the afternoon sea breeze.

The results for emissions from the proposed sites show an increase in ozone of up to 5-25 ppb above the Sydney background levels (see Table 2 for more detail). These levels were predicted within the south-western part of the Sydney basin, with lower levels produced for 4 February 1991. The later arrival of the sea breeze on 4 February means that less ozone could form in the time available until sunset, compared to 9 February, particularly for the Holsworthy South and Badgery's Creek sites. In each case, the NO<sub>x</sub>-limited background air was temporarily transformed to light-limited conditions as fresh nitrogen oxide emissions from the airport site were added, but due to the high reactivity of the plume, NO<sub>x</sub>-limited conditions re-established within 15-25 km downwind of the airport. Higher concentration on parts of the Blue Mountains to the west are predicted to occur due to terrain impacts. The inclusion of existing sources downwind of the Holsworthy site leads to similar effects, but the incremental increase in ozone due to airport emissions remains approximately the same.

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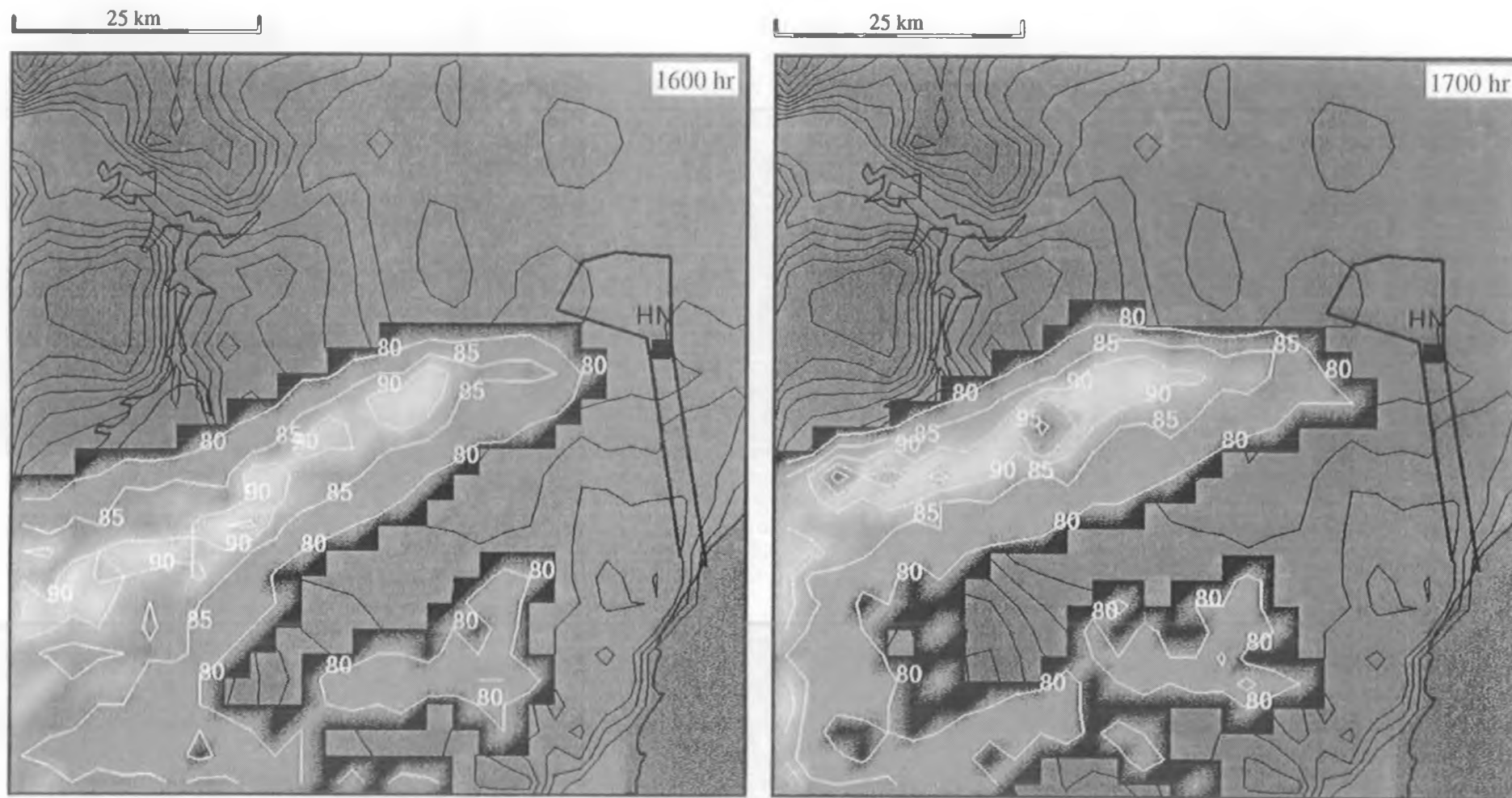


Figure 4. Predicted total ground level ozone concentration (including a background of 75ppb) at 1600 and 1700 hr on 9 February 1994, for the proposed Holsworthy North site. White contour lines are overlaid on colour shaded contour surfaces with contour levels marked.



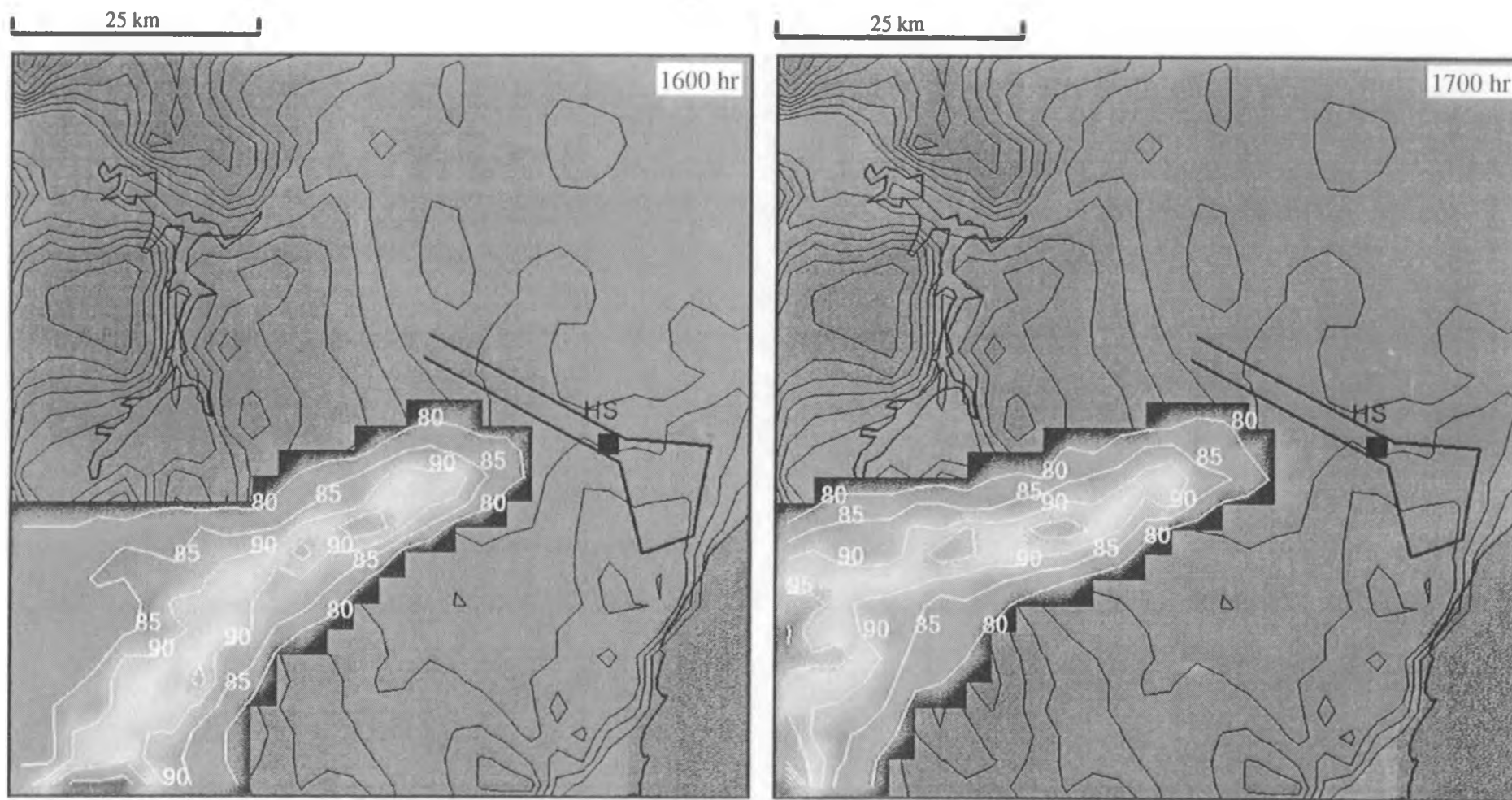


Figure 5. Predicted total ground level ozone concentration (including a background of 75ppb) at 1600 and 1700 hr on 9 February 1994, for the proposed Holsworthy South site. White contour lines are overlaid on colour shaded contour surfaces with contour levels marked.



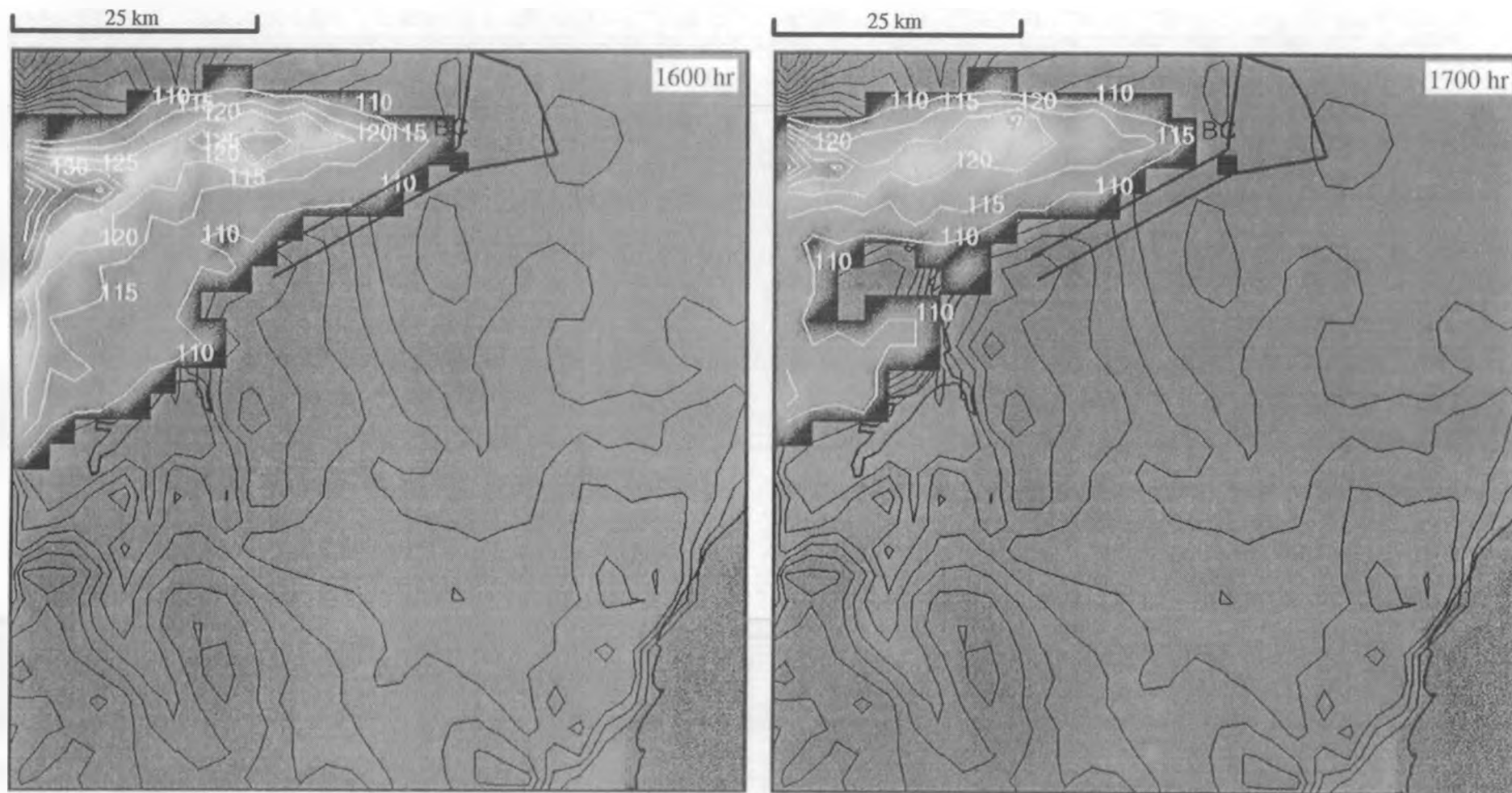


Figure 6. Predicted total ground level ozone concentration (including a background of 105ppb) at 1600 and 1700 hr on 9 February 1994, for the proposed Badgery's Creek site. White contour lines are overlaid on colour shaded contour surfaces with contour levels marked.

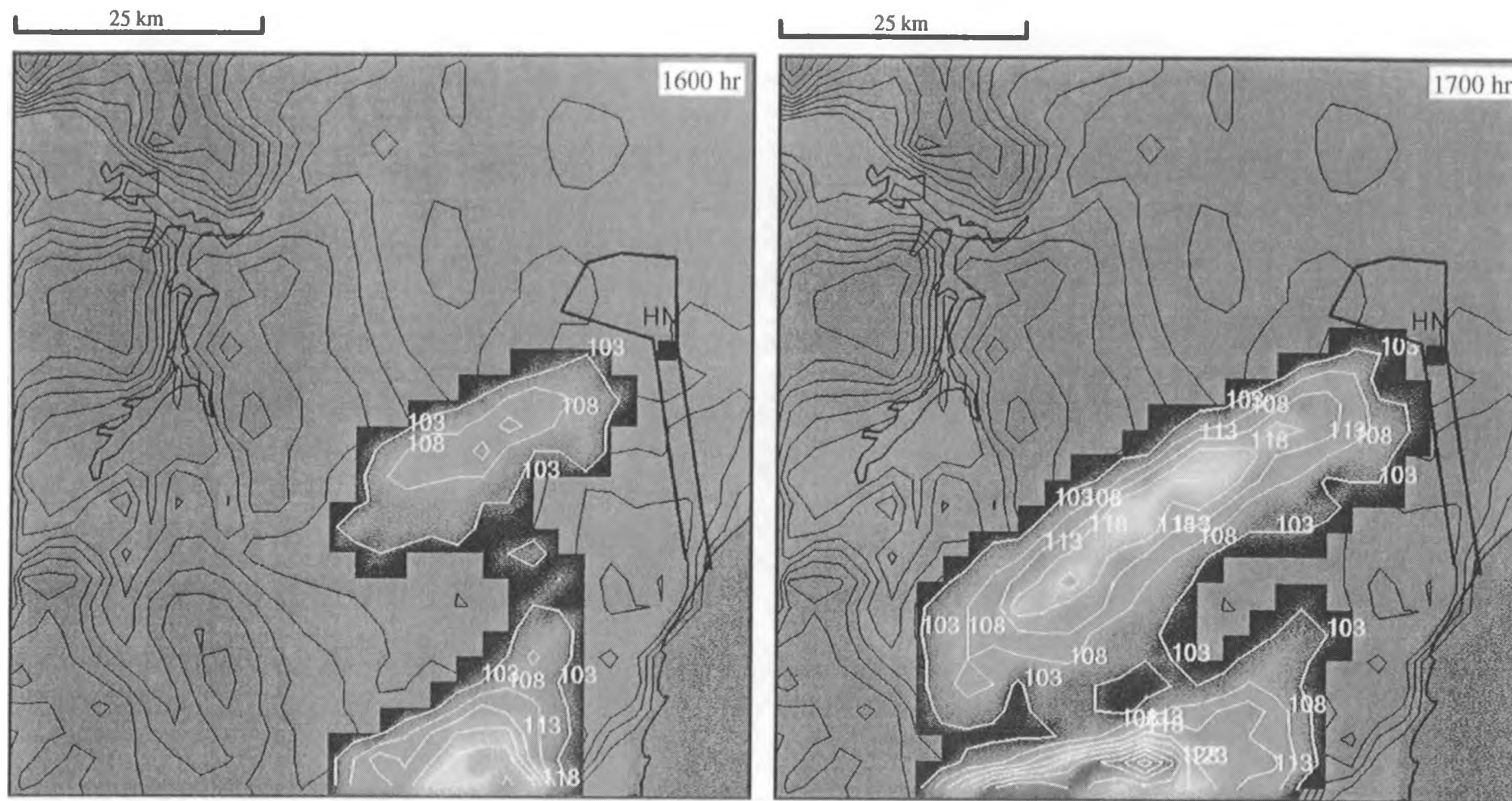


Figure 7. Predicted total ground level ozone concentration (including a background of 98ppb) at 1600 and 1700 hr on 4 February 1991, for the proposed Holsworthy North site. White contour lines are overlaid on colour shaded contour surfaces with contour levels marked. Note that the southern part of the plume should be ignored, due to the inappropriateness of the background concentrations used for pre-sea-breeze emissions.

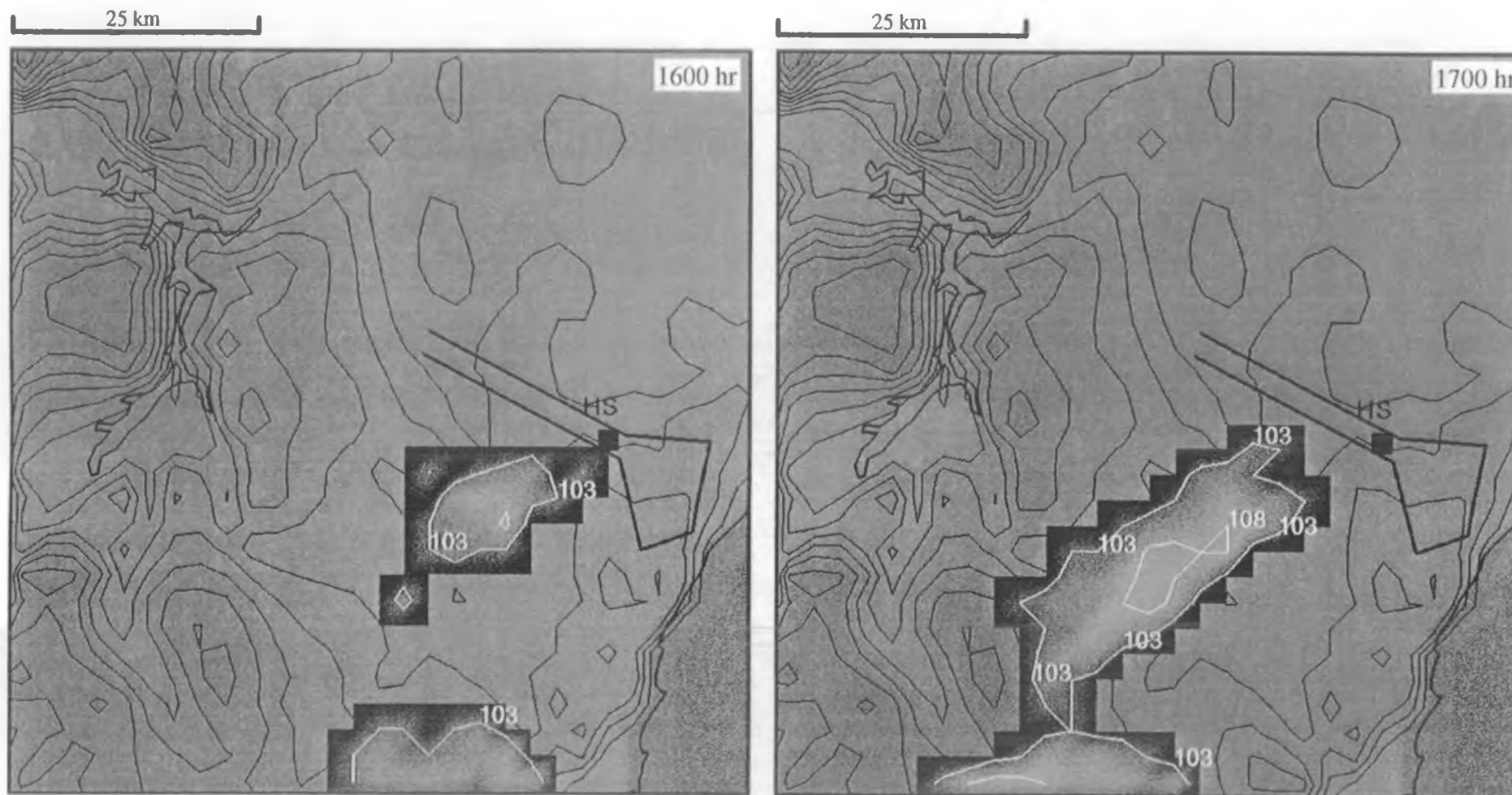


Figure 8. Predicted total ground level ozone concentration (including a background of 98ppb) at 1600 and 1700 hr on 4 February 1991, for the proposed Holsworthy South site. White contour lines are overlaid on colour shaded contour surfaces with contour levels marked. Note that the southern part of the plume should be ignored, due to the inappropriateness of the background concentrations used for pre-sea-breeze emissions.



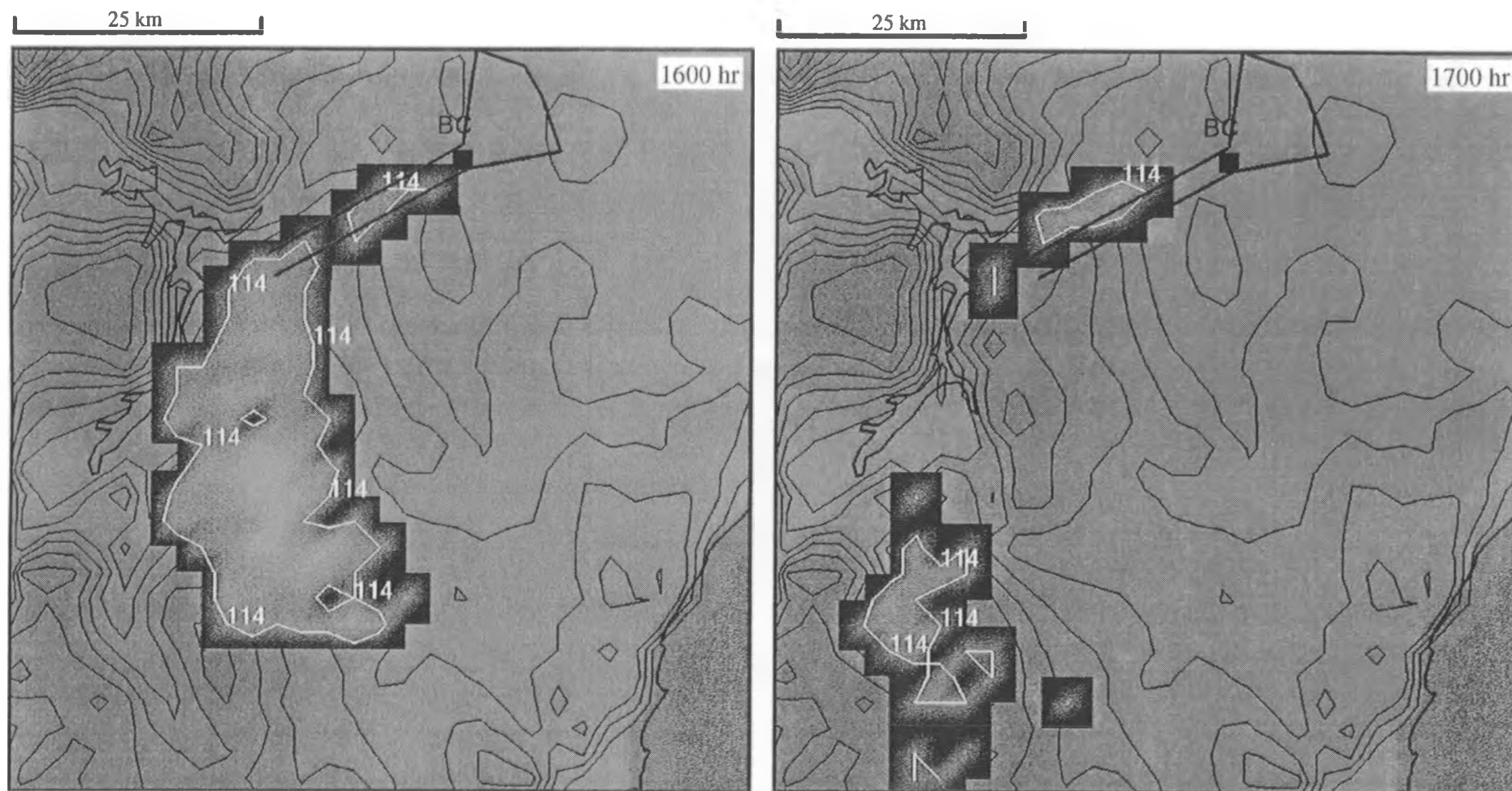


Figure 9. Predicted total ground level ozone concentration (including a background of 109ppb) at 1600 and 1700 hr on 4 February 1991, for the proposed Badgery's Creek site. White contour lines are overlaid on colour shaded contour surfaces with contour levels marked. Note that the southern part of the plume should be ignored, due to the inappropriateness of the background concentrations used for pre-sea-breeze emissions.

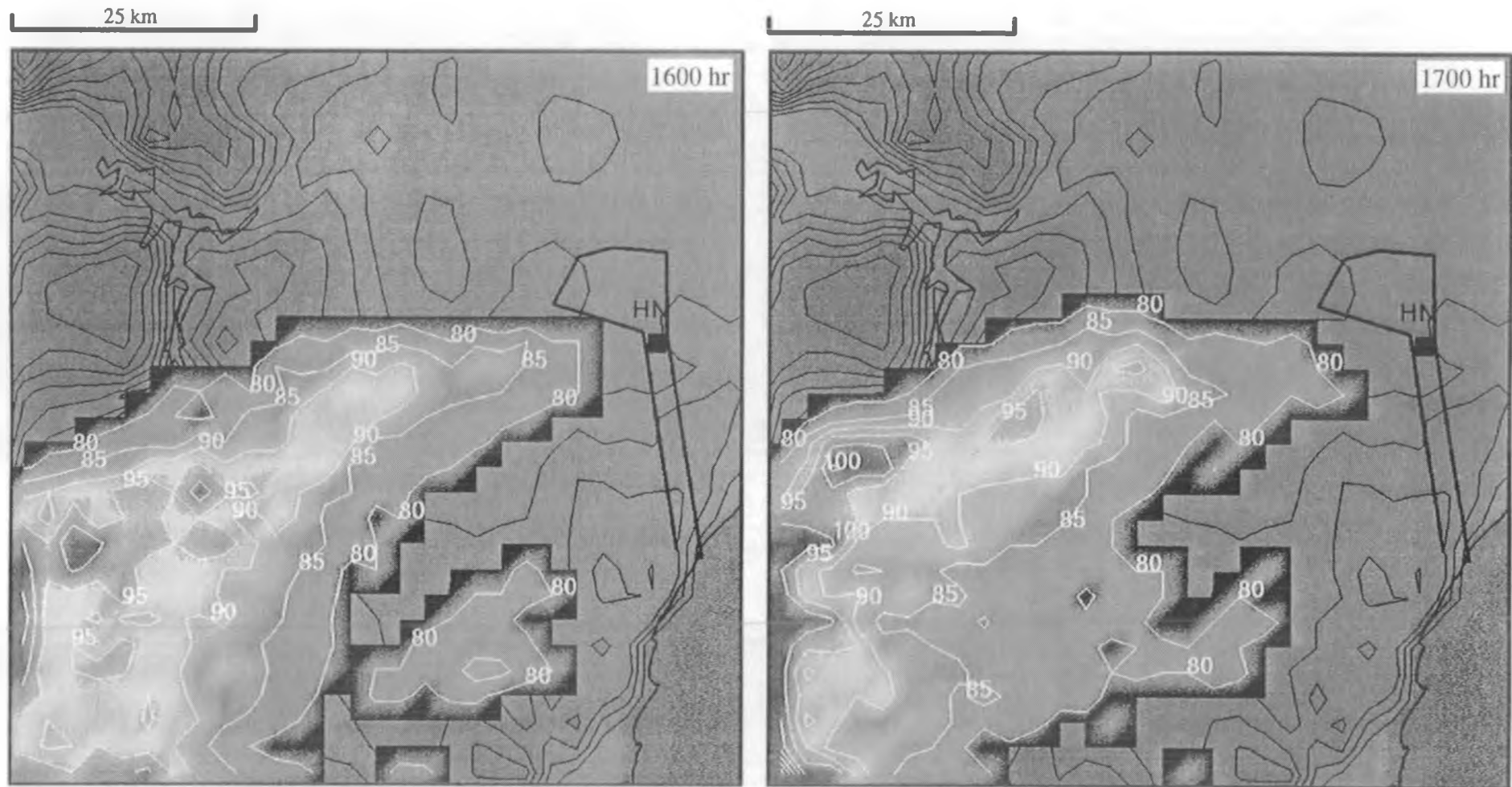


Figure 10. Predicted total ground level ozone concentration (including a background of 75ppb) at 1600 and 1700 hr on 9 February 1994, for the proposed Holsworthy North site, with extra downwind broad area source. White contour lines are overlaid on colour shaded contour surfaces with contour levels marked.

## **Appendix E**

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Katestone Footprint Analysis Report



***Katestone Scientific Pty Ltd***

A.C.N. 011 052 592

**INNOVATIVE INDUSTRIAL SOLUTIONS**

**A REPORT FROM KATESTONE  
SCIENTIFIC  
TO COFFEY PARTNERS  
INTERNATIONAL**

**FOOTPRINT ANALYSIS OF THE  
REGIONAL AIR QUALITY IMPACT  
OF THE  
PROPOSED SYDNEY AIRPORT**

**JUNE 1996**

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## Footprint analysis of the regional air quality impact of the proposed Sydney Airport.

### Executive Summary

1. *The main regional air quality issues for a major airport concern the influence of airport emissions on levels of photochemical compounds and fine particulates. A literature survey and contact with North American aviation authorities have shown that these topics have not been addressed in any detail in recent environmental assessments of major airports.*
2. *Available measurements of ozone and nitrogen oxides ( $\text{NO}_x$ ) have been interpreted in terms of the photochemical age of the ambient air. High smog levels and aged air are necessary for the airport emissions to have a significant impact on ozone levels. Such days occur 5-15 times per year, with a greater frequency in the western suburbs of Sydney. A coincidence of suitable synoptic conditions, delayed seabreeze and high levels of precursor emissions is necessary; this rarely occurs and on most days the photochemical impact of the airport will not be significant.*
3. *If photochemically-old air is incident on any of the three prospective sites, the addition of volatile organic compounds can accelerate the necessary chemical transformations to reach a  $\text{NO}_x$ -limited state. The airport  $\text{NO}_x$  emissions can then give rise to additional ozone. The affected areas are predicted to be 5-20 km downwind (dependent on conditions); within the area covered by the airport emission plumes (typically 3-5 km wide), the increases of hourly ozone levels forecast by the current chemistry scheme are in the range of 5-15 ppb. The areas most frequently affected will be to the south-west to west of each site.*
4. *Sensitivity tests have shown that, if events are chosen from the previous MAQS studies to estimate ozone impacts due to the airport, they will produce much higher results than for most historical high ozone days. For Badgerys Creek, most adverse ozone impacts are expected to be in the range 5-10 ppb, with increases of 20-25 ppb expected under extreme conditions. Such increases would usually cause exceedances of the hourly ozone threshold on more than the required maximum four days per year. For the Holsworthy North site, most ozone increments are expected to range from 3-7 ppb but with extremes of 18-21 ppb. Very few of these events will cause exceedances of the hourly guideline. For the Holsworthy South site, similar increments to the Holsworthy North site are predicted, but will add to a slightly lower background level and total ozone levels are not expected to exceed the guideline.*
5. *The frequency of ozone impacts will be higher for the Badgerys Creek site than the two Holsworthy sites, due to the more inland location and greater prevalence of aged air. There are few significant differences between the ozone impacts for the Holsworthy North and South sites. Emissions from an airport at any of these three sites are likely to have more adverse smog consequences than the current emissions from the coastal airport at Mascot.*

6. *Downwind emissions from residential and traffic activity can be quite important in reducing the initial ozone impact of airport emissions, especially for the Holsworthy sites. For the Badgerys Creek site, current downwind emissions are predicted to have only a minor influence; substantial increases in anthropogenic source emission rates to the west of the airport would be required to cause any significant reductions in predicted ozone impacts.*
7. *Predictions of ozone impacts are relatively sensitive to the adopted mixing depths for seabreeze conditions, for which there is little information at inland sites in the Sydney region. The Holsworthy sites are in the transition zone between inland and coastal areas and greater sensitivity at these sites is expected.*
8. *Fine particulate emissions in airport exhausts are poorly detailed in world literature. Predictions of regional air quality impacts of airport particulate emissions on a short-term and annual average basis require a better quantification of aerosol formation and retention within the boundary layer.*
9. *An investigation of the detailed Sydney air quality database is necessary to determine the level of confidence in these forecasts for each prospective site.*
10. *The models used in this evaluation are idealisations of the true processes and are likely to give conservative results, due to the approximate treatment of deposition, wind-shear and short-term dispersion processes and chemical transformations. The results of this study do suggest that regional air quality should be a significant factor in airport site selection and environment management.*
11. *Ozone impacts can be minimised by a long-term program of reducing NO<sub>x</sub> and VOC emissions from aircraft and ground vehicles.*

## **1. Overview**

### **1.1 Background**

The Sydney Second Airport master plan is for a runway configuration capable of handling 360,000 aircraft movements and 30 million passenger movements per annum. The terms of reference for the Environmental Impact Statement required a description of the existing environment and the principal impacts (both adverse and differential) on the community and the environment. Consideration was recommended of direct and indirect, short-term and long-term, temporary and irreversible and adverse and beneficial effects together with confidence limits for any forecasts and a description of unlikely data and assumptions.

Amongst other items, the air quality component of the study was required to analyse and describe the impacts of the proposed airport development on air quality at the local, regional and Sydney basin scale, having regard for the results of the Sydney Metropolitan Air Quality Study (MAQS). The effects of the increase in ozone-producing compounds from the proposed airport operations on the areas downwind of the development and on the Sydney air-shed are addressed in this report. Further sensitivity analysis would require the detailed use of the full Sydney air quality database and is not attempted in the current project.

The parameters set for the EIS note that there may be off-site or pollutant-related developments that are likely to be attracted to the airport sub-region, such as the increased use of existing or new transport links and commercial and industrial development. These issues have been addressed elsewhere in the project but are not included in the current report. The issues considered in the selection of the current short-listed sites have been summarised in a previous report (1985).

### **1.2 Project objectives and methodology**

Katestone Scientific of Brisbane was contracted to provide a summary of the regional impact of the three proposed airport sites, based on an analysis and interpretation of the existing and available air quality information for the Sydney region. This work was carried out in association with the CSIRO Division of Coal and Energy Technology in Sydney. The objectives of the project were:

- (a) A determination of the basic photochemical characteristics of the Sydney region from available air quality information and set in context of previous studies conducted for the EPANSW and other bodies.
- (b) The selection of a suitable number of events for more detailed analysis, based on an analysis of pollutant trajectories for various hours of the day and any known air quality characteristics.
- (c) The estimation of the likely footprint of downwind ozone concentrations under a wider variety of conditions than analysed elsewhere by more sophisticated techniques.



The photochemical evaluation techniques of CSIRO Division of Coal and Energy Technology (e.g. the Integrated Empirical Rate (IER) scheme) facilitate the interpretation of existing air quality information to characterise the photochemical nature of various parts of the air-shed. They also provide a basis for the extrapolation of air quality information to locations well away from monitoring sites. The same chemical mechanism has been used here in a prediction scheme for forecasting the impact of airport emissions on regional air quality.

Unlike most other previous airport studies, this project has incorporated the embedding of a box model within a set of trajectories constructed for days of unusual photochemical activity. The box model allows a forecasting of ground-level concentrations of photochemical pollutants along these trajectories, taking into account both the subsequent emissions from urban and biogenic sources and the influence of airport emissions. By looking at the differences in the results for simulations with and without the airport emissions, the mid-field impact of airport operations can be assessed in detail for these days. The influence of topography has not been included in the box modelling assessments.

The rest of Section 1 summarises the physical and chemical processes involved, any previous work elsewhere on similar problems and the issues arising from the project community consultation.

Section 2 describes the airport emissions in a regional context and outlines the temporal and spatial variability of the emissions from various activities. The air quality and meteorological information used in this assessment is discussed in Section 3.

Sections 4 and 5 summarise the main results concerning the impact of airport emissions on smog levels for each of the three sites, together with an initial sensitivity analysis. The uncertainties in the analysis are reviewed in Section 6 and recommendations given as to the avenues for providing a more accurate description of both the magnitude and frequency of significant changes in ozone levels due to airport operations.

### **1.3 General concerns for regional air quality impact of a metropolitan airport.**

Emissions inventories for Sydney and other metropolitan areas for Australia show that major airports contribute a small but relatively significant amount of key pollutants to the regional air-shed (such as nitrogen oxides, volatile organic compounds and carbon monoxide). Unlike industrial sources, these emissions occur because of a wide variety of activity, resulting in a strong diurnal variation and a fairly complex distribution with height for key pollutants. They occur within an urban area which itself experiences sometimes considerable spatial and temporal variations in emission rates of the same pollutants.

The impact of an existing or proposed airport on regional air quality will depend quite critically on the location of the airport, the dominant transport mechanisms within this air-shed and the frequency of occurrence of conditions under which high rates of photochemical pollutants may occur.

The principal concerns for regional air quality identified from past studies in Australia and overseas, recent Sydney air-shed work and comments offered during the public consultation stage of the current study have been:-

- (a) The levels of conservative pollutants (such as carbon monoxide and fine particulates) in the near (0-3 km) and mid (3-20 km) field regions downwind of the airport;
- (b) The impact of airport emissions on the levels of ozone and nitrogen dioxide on days with high background photochemical levels.

Near-field characteristics can be dealt with adequately by relatively conventional methodologies. Treating photochemical impacts is much more difficult as it requires a full understanding of the various processes that occur within the air-shed. A literature survey of past airport air quality work and informal contact with the Federal Aviation Authority in the United States have revealed that, although some monitoring of photochemical variables has occurred close to airports in various countries, the only recent and systematic investigations of the photochemical impacts of aircraft operations have focused on stratospheric ozone.

#### **1.4 Overview of chemical, transport and dispersion processes for airport emissions.**

The emissions inventories for the existing Mascot Airport and for the proposed second airport have considered a wide variety of sources. These include aircraft emissions from the terminal, runways and take-off paths, evaporative losses occurring during refuelling activities and the storage of fuels, the various emissions from vehicles using the airport (both internally and by the public accessing from the airport) and other types of industrial sources (e.g. boilers and surface coatings).

The location of aircraft emissions is dependent on wind direction (i.e. via the choice of runway and flight paths) and the relative amounts emitted at various heights will depend on the aircraft congestion at take-off. The main pollutants are likely to be volatile organic compounds (VOC) emitted by motor vehicles, evaporation losses and aircraft, nitrogen oxides (mainly from aircraft and motor vehicles) and carbon monoxide (mainly from vehicles). There will be a gradual mixing of the pollutants downwind from the various types of sources and the local pollutant footprint for a given hour will reflect this complex source structure. The longer-term averages of pollution concentrations will reflect more the local wind distribution and the main flight paths.

These ground-level concentrations will vary considerably with time of day as the emissions and dispersion conditions undergo a fairly regular diurnal cycle. Poor dispersion conditions are likely in the early morning, evening and night unless strong winds occur. The low windspeeds and shallow mixing depths caused by radiation inversions will lead to poor dilution of near-surface emissions (e.g. traffic and refuelling losses). Aircraft emissions will occur mainly above the inversion base during take-off and landing (TOL) phases and will only be important during on-ground operations during these periods.

During daytime the situation is likely to be quite different. As temperatures increase, evaporative losses become significant. The much deeper boundary layer has several effects; more of the TOL emissions are retained below the inversion and mixed to ground. There is likely to be a better local dispersion of the various emissions. Sunlight is likely to encourage the chemical transformations possible with such a mix of pollutants; the urban air quality upwind of the airport also has an important bearing on these reaction rates.

The airport emissions of nitrogen oxides ( $\text{NO}_x$ ) are likely to contain less than 10% nitrogen dioxide, as found in the exhausts of most combustion sources. The subsequent oxidation of nitric oxide to nitrogen dioxide requires free oxygen radicals made available by the action of sunlight on ozone molecules or by the wider range of photochemical reactions that occur in urban air. Close to the airport, the nitric oxide concentrations are high enough to consume most of the ambient ozone - the air is likely to be rich in nitrogen oxides and VOCs. As the airport plume travels downstream, it will expand vertically (to the inversion base) and horizontally and will undergo significant dilution. Eventually (5 km downstream), there will be only minor concentration gradients in the vertical direction - the plume will be well-mixed. The airport VOCs will mix with the urban VOCs (of a different constitution) and probably increase the rate at which photochemical reactions can proceed. Nitrogen dioxide concentrations can then increase as a result of these oxidation processes but also decrease because of ongoing photolytic disassociation. Eventually some form of equilibrium will be established.

On days when the urban air is photochemically old the addition of airport  $\text{NO}_x$  emissions may lead to the generation of additional ozone if the sunlight intensity is sufficient to make the chemistry of the ambient air limited by availability of nitrogen oxides. This ozone generation is likely to occur many kilometres downwind of the airport and will depend on whether the combined airport and urban plumes have passed over any further significant sources of precursor emissions.

For some trajectories, the picking up of nitrogen oxide emissions from traffic or industrial sources will keep the air  $\text{NO}_x$ -rich and the ambient ozone levels low. For other trajectories (e.g. over essentially rural land), there will be only biogenic emissions and the generation of excess ozone becomes a possibility. Even as additional ozone is generated, the horizontal mixing processes act to reduce this impact.

As sunset approaches, the photochemical reactions shut down and other transformation processes become important. Ozone can be deposited on ground surfaces or lost to the "upper atmosphere" as the shallow radiation inversions reform. The air is likely to become  $\text{NO}_x$ -rich at the surface as a result of ongoing traffic emissions and more restricted dispersion. Ozone levels are likely to decrease, nitrogen dioxide levels may peak in the evening rush hour. As the night progresses, the airport emission rates will decrease, with aircraft TOL emissions again being inhibited from entering the surface boundary layer.

Similar complexities may occur for particulate emissions as these small-sized pollutants become involved in the various chemical reactions. Visibility may be affected both by the presence of very fine particles and by the absorption of sunlight by nitrogen dioxide. These impacts are likely to be particularly evident in the early morning and evening periods.

## **1.5 Relevant previous work for regional impacts**

### **1.5.1 North American studies.**

The Federal Aviation Administration has sponsored several studies of the emissions and consequent local air quality impact (including odour) for several major airports (Wayson 1996, Anderson et al 1997). Regional analysis has centred mainly on emission inventories as the use of urban air-shed models was considered “beyond the scope of most projects”.

Emission controls are thought likely to reduce VOC impact although NO<sub>x</sub> emissions may still present problems. There is no current direct research or measurement programme to investigate the photochemical impact of a major airport on a regional air-shed.

The Airports Group of Canada has conducted multi-parameter monitoring studies at various airports since 1980 (Taylor 1996). This monitoring has usually been at sites on or close to the airport. Ozone levels at these sites were generally decreased by the presence of combustion gases from airport activities. It was concluded that “airports did not appear to be the local source of this pollutant”. None of the recommended actions from a review of existing knowledge was concerned with regional impacts.

The North American experience is therefore of little guidance to the present study.

### **1.5.2 European studies.**

Recent British studies (HMSO 1994, Raper et al 1995, Longhurst et al 1996, Stevenson 1996, Somerville 1997) have emphasised the evaluation of local air quality at several British airports. Nitrogen dioxide has been considered the major problem area and attributed mainly to local motor vehicle emissions. On a regional scale, airport emissions are considered to be small compared to those of urban and industrial sources usually found next to airports. Ozone impacts have been mainly considered by the Stratospheric Ozone Review Group.

Monitoring close to Gatwick Airport has facilitated the estimation of source contributions to modelled ground-level concentrations of NO<sub>x</sub>. Outside the boundary, the airport is thought to contribute up to 10-13% of the total ground-level concentrations. Aircraft are considered to be “a relatively small contributor to ambient NO<sub>x</sub> concentrations outside of the airport boundary, compared to regional and background sources.”

Moussiopoulos et al (1997) have investigated the impact of airport operations on ozone levels in Athens, using a set of contemporary air pollution models and two alternative airport operations for the year 2002 and one photochemical event day. Only limited reporting is available and suggests increases in total oxidant (O<sub>3</sub> + NO<sub>2</sub>) close to the airport, but with a reduction in ozone levels at these locations due to titration reactions. This study gives little detail on the impact on regional ozone for this event or the sensitivity to ambient conditions.

Recent German studies (e.g. Ebel and Petry 1995) have used a mesoscale model to look at the impact of aircraft emissions on ozone concentrations at the tropopause. Available results are ambiguous. The recent AERONOX project (Schumann 1997) was set up to determine the emissions of NO<sub>x</sub> from aircraft engines and global air traffic at cruising altitudes, the resultant increase in NO<sub>x</sub> concentrations and the effects on the composition of the atmosphere. These studies included measurements of engine exhaust emissions (Kohler et al 1997), the physics and chemistry in the aircraft wake (Garnier et al, 1997) and global modelling (e.g. Stevenson et al, 1997). None of this work has applied the results to regional air quality.

The literature search found only one European example of the estimation of the impact on regional photochemistry due to airport operations but this has too little detail to be of use in evaluating the current project results.

### 1.5.3 Australian studies.

The emission inventories recently constructed for various Australian cities have included the contributions of airports (e.g. Table 1.1). Regional air-shed modelling for most of the cities has included these sources but has rarely identified explicitly the individual impact of airport operations. The simulations of high ozone days at each city have emphasised the importance of seabreeze circulations, high temperatures and biogenic emissions on levels of photochemical pollutants. One of the sensitivity runs for the photochemical modelling of the Sydney air-shed (Cope and Ischtwan 1996(a)) estimated that Mascot 1993 airport emissions were likely to increase the peak ozone level in the region by an insignificant amount (less than 1% and below the model resolution). Local ozone levels could be changed by 5%, dependent on location and conditions. These are likely to be underestimates (mainly because of the model resolution and technical difficulties in treating seabreeze conditions). The location of Mascot Airport within the industrial area of Botany Bay and close to the urban areas diminishes the applicability of these preliminary results to a second inland airport.

Recent impact assessments for Brisbane, Mascot and Melbourne airports have predicted local air quality impact but have not considered regional matters.

Air quality monitoring is currently taking place at Mascot Airport (two sites) and, to a lesser extent, near Brisbane Airport. Continuous monitoring of NO<sub>x</sub>, ozone and PM<sub>10</sub> levels at these sites gives the potential for evaluating the impact of airport operations - no formal assessments have yet been published.

**Table 1.1 Daily air-shed <sup>1</sup> emissions (kg/day) from international/domestic Australian airports**

	NO <sub>x</sub>	VOC	SO <sub>2</sub>	CO
Melbourne <sup>2</sup>	1,953	1,565	131	6,817
Sydney <sup>3</sup>	5,785	4,271	388	17,511
Perth <sup>4</sup>	410	120	51	2,340
Brisbane <sup>5</sup>	2,064	759	129	2,207

Notes: <sup>1</sup> Sum of emissions from all airports (domestic/international) in the air-shed.

<sup>2</sup> Year 1990: Carnovale et al. (1991).

<sup>3</sup> Year 1992: Carnovale et al. (1996).

<sup>4</sup> Year 1985: Australian Environment Council (1985).

<sup>5</sup> Year 1993: Coffey Partners International (1995).

#### **1.5.4 Relevant regional studies for the Sydney air-shed.**

For Sydney the past air quality and meteorological studies (both measurement and predictive schemes) are summarised in Appendix 1. For this study, the key points are:-

- the development of a smog mechanism for Sydney air, laying the foundation for the current IER scheme;
- the classification of past high ozone days and associated meteorological conditions;
- the differentiation between conditions at the coast, near-coast, metropolitan and inland parts of the Sydney basin;
- the high degree of interannual variability in occurrences of high smog levels;
- the appreciation that VOC emissions accelerate smog formation potential whilst NO<sub>x</sub> emissions determine the ultimate impact on ozone levels, once the air is no longer NO<sub>x</sub> - rich;
- concern that any major industrial developments in the western suburbs should incorporate considerable investigation of air quality impacts; and
- a high quality emission database is available for modelling photochemical impacts.

#### **1.5.5 Ozone impact of industrial sources in Sydney**

The impact of some non-airport sources of precursor emissions on regional photochemistry have been assessed in previous Sydney studies, including both point source emissions of NO<sub>x</sub> (such as power stations) and various generic types of emissions (e.g. motor vehicles, all industrial emissions, biogenic sources). Power station or cogeneration plant sources of strength 10-100 g/s NO<sub>x</sub> (and 1-5 g/s VOC) have been forecast to give rise to 2-15 ppb of additional ozone for some hours of high photochemical activity in Sydney and Brisbane. Motor vehicle sources are predicted to contribute 35-70% of the anthropogenically-produced ozone on such days. Biogenic sources may not increase maximum ozone levels but will increase the total air-shed dosage (Cope and Ischtwan 1996(a)).

These considerations are of particular interest to locations such as Mascot where industrial and urban emissions are high. For fringe urban areas such as Badgerys Creek and Holsworthy, the recent simulations for the methane recovery and combustion plants at Tower and Appin may be of more relevance (Katestone Scientific 1995, CSIRO 1995). For those few hours per year with high ozone levels and photochemically-old air from Sydney and Campbelltown passing through the region, sources with NO<sub>x</sub> emissions of 20-35 g/s emitted at effective heights of 100 m above ground-level were predicted to give an ozone impact of 5-15 ppb. Maximum ozone increments were predicted for 5-15 km downwind, depending on meteorological and source emission conditions.

## **1.6 Summary of relevant studies and recent community concerns**

Previous work elsewhere gives little guidance to the regional significance of emissions from the Second Sydney Airport. For nitrogen dioxide and carbon monoxide, there have been local impacts noted at several airports, with the major contributor being the airport and local motor vehicle fleets. There is little quantitative evidence for the direct regional impact of these pollutants - these are expected to be much less than local effects and therefore of minor concern

For ozone, there is evidence of an overall reduction close to airports due to the titration by airport NO<sub>x</sub> emissions but little evidence of what happens on high smog days. Recent numerical modelling for Mascot Airport and more industrial sources suggests that the maximum impact on ozone due to airport activities is likely to be much less than 5% on high ozone days.

For fine particulates, there is little direct evidence for any significant impacts. Accurate emission estimates and dispersion estimates are necessary on for evaluating the changes in regional air quality. Recent studies have noted the difficulties in measuring the aircraft exhaust emission rates of fine particulates and the aerosol formation that occurs well downwind of an aircraft in flight.

During community consultation and in the discussions of many of the community organisations, it has been asserted that airports are major contributors to poor urban air quality and that increases in regional levels of fine particulates (for example) are likely to give rise to a significant health and economic impact. A report by the Natural Resources Defense Council (1996) noted that many airports rank in the top 10 air pollution sources in their studies and that planes at airports emitted about 1% of smog-forming gases. Such statements concerning the ranking of industrial smog sources for various airports have been based on the emission rates, rather than the actual impacts of pollutants. The resulting concern about the growth of air transport and the consequences on public health is thereby probably overstated.

## 2. Airport emissions in a regional context

### 2.1 Emission scenario for current study

The Coffey Partners International report (1997) on airport-related emissions contains the estimated emissions inventory for various years and flight path scenarios. For this footprint study, the emission scenario for case 3(b) (the additional noise scenario, the 2016 summer day with 245,000 annual aircraft movements) has been adopted. These emissions have been used directly in the box modelling in association with the urban emissions inventory provided from the MAQS study. It is noted that this urban emissions inventory is for the year 1992 and is likely to undergo significant changes by the year 2016, both because of a change in land use and regional population and an expected considerable reduction in per-vehicle traffic emission rates due to the introduction of new emission control technology from 1997 onwards.

### 2.2 Comparison of airport emissions with other sources in the Sydney region

Table 2.1 compares the total airport emissions for the major pollutants with those from other generic type sources in the Sydney region, as deduced from the MAQS emission inventory. It is apparent that the airport is a moderately significant source of nitrogen oxides and hydrocarbons.

**Table 2.1 Estimated daily emissions from the Second Sydney Airport and air-shed emissions from motor vehicles, domestic/commercial area sources, industrial sources and biogenic sources on a summer day.**

Source	VOC (kg/day)	NO <sub>x</sub> (kg/day)	CO (kg/day)	SO <sub>2</sub> (kg/day)	PM <sub>10</sub> (kg/day)
SSA: case 1A <sup>1</sup>	524	1,820	1,820	87	107
SSA: case 2A <sup>2</sup>	985	3,650	3,450	177	421
SSA: case 3A <sup>3</sup>	1,340	6,880	4,570	315	732
SSA: case 3B <sup>4</sup>	2,470	12,000	8,470	587	1,170
Motor vehicles <sup>5</sup>	368,000	270,000	1,792,000	7,000	19,000
Domestic/comm. sources <sup>5</sup>	186,000	15,000	22,000	15,000	12,000
Industrial sources <sup>5</sup>	50,000	39,000	38,000	36,000	25,000
Biogenic sources <sup>5</sup>	885,000	20,000	-	-	-

Notes <sup>1</sup> Overflow scenario year 2006 (63,000 annual movements).

<sup>2</sup> Equal growth scenario year 2006 (117,000 annual movements).

<sup>3</sup> Additional noise scenario year 2006 (131,000 annual movements).

<sup>4</sup> Additional noise scenario year 2016 (245,000 annual movements).

<sup>5</sup> Year 1992 high oxidant day (Carnovale et al. 1996)



### **2.3 Reactivity of airport emissions**

Only limited information is available from past studies on the reactivity of aircraft emissions. This work is summarised in the Coffeys report. Aircraft emissions are likely to be slightly more photochemically reactive than those of the normal urban plume. For the box modelling, it has been assumed that the overall photolytic reaction coefficient for the airport emissions is similar to that for the urban plume. This assumption is unlikely to have a major impact on the subsequent predictions.

### **2.4 General behaviour of airport emissions**

#### **2.4.1 Temporal variation**

The temporal profile of airport operations has been given in the Coffeys report. Most activities occur between 0700-2100 hours with 20% greater emissions in the morning and evening peak hours and a relatively uniform profile between these hours. The box modelling has assumed that similar temporal profiles can be applied to the different types of airport activity.

#### **2.4.2 Retention of emissions within the boundary layer**

Near-field studies have shown that, during those hours when dispersion is poorest, the amount of pollutants retained within the surface boundary layer will contain few contributions from take-off and landing. This is important for predicting near-field pollutant concentrations but less important when considering impacts on ozone levels. As the major photochemical activity usually occurs in the mid-morning to early evening period when the mixing heights may be over 1,000 m (prior to the seabreeze arrival), or in the region 400-600 m (during seabreeze conditions), there will be a significant variability in the amount of TLO emissions contained within the mixed layer and becoming available for photochemical production. For subsequent work, it has been assumed that only those emissions from TLO that occur below the mixing height are important to subsequent photochemical generation.

#### **2.4.3 Spatial extent of the airport plume**

The airport emissions extend over a considerable area, with a maximum extent at the source of around 3.5 km. For the Holsworthy North site (for example), Figure 2.1 shows the vertical concentration profiles at various downwind distances, as forecast by the ISC3 dispersion model and using a spatial allocation of the airport emissions for an hourly time period. An inversion height of 500 m has been assumed. By 3 km downwind in a variety of conditions, the airport emissions are likely to be well-mixed below the assumed inversion. By 6 km downstream the vertical concentrations are very uniform and the horizontal extent of the plume is of the order of 5 km.

From this analysis it has been concluded that:

- (a) An assumption of good vertical mixing by a distance of 3-6 km downstream is well justified, and

- (b) Any box model used for regional impact prediction should not use a horizontal scale smaller than 6 km, since the plume width is initially over 3 km and expands to 6 km by a downwind distance of 6 km.

### 3. Available information for project

#### 3.1 Air quality

Relevant air quality information (Table 3.1) is collected by the Environmental Protection Agency of New South Wales (EPANSW) and the Federal Airports Commission (FAC). The FAC information consists of extensive air quality monitoring at two locations close to Mascot Airport. Previous reports on industrial source impacts have used the detailed records from various EPANSW sites to investigate the statistics of photochemical characteristics.

There is, as yet, little information on the photochemical reactivity of the Sydney air-shed. Relevant Airtrak measurements have been conducted recently (Johnson 1997); guidance has been obtained from the MAQS emissions inventory and past Airtrak studies.

**Table 3.1: Detailed air quality information used in this and previous relevant projects.**

Station	From	O <sub>3</sub>	NO/NO <sub>2</sub>	CO	Particulates
Lidcombe	EPA	1970-92	1970-92	N/A	N/A
Campbelltown	EPA	77-80;82-88;91-94	80/81,91-94	N/A	N/A
Mascot	FAC	94-95	94-95	94-95	94-95
Botany	FAC	94-95	94-95	94-95	94-95

#### 3.2 Meteorology

A considerable body of meteorological information was made available for this project and is summarised in Table 3.2. Wind information from a significant number of weather stations run by the Sydney Water Board (SWB) has been augmented by data from the automatic weather stations run by the Bureau of Meteorology (BM) and the FAC and by detailed monitoring conducted over many years at Lucas Heights by the Australian Nuclear Science and Technology Organisation (ANSTO). For Badgerys Creek, a limited amount of on-site information was available.

Upper-level wind and temperature information has been obtained from the two radiosonde flights per day conducted on a routine basis at Mascot Airport. These have been used in constructing hourly estimates of mixing height at various locations within the region.

**Table 3.2: Available meteorological information for this project.**

Station	From	Wind Direction Wind Speed	Temperature	Radiation	Relative humidity
Bondi	SWB	94/95	94/95	N/A	94/95
Malabar	SWB	94/95	N/A	N/A	N/A
Northern Head	SWB	94/95	N/A	N/A	N/A
Quakers Hill	SWB	94/95	N/A	N/A	N/A
West Camden	SWB	94/95	N/A	N/A	N/A
Castle Hill	SWB	94/95	N/A	N/A	N/A
Liverpool	SWB	94/95	N/A	N/A	N/A
Penrith	SWB	94/95	N/A	N/A	N/A
Rouse Hill	SWB	94/95	N/A	N/A	N/A
South Creek	SWB	94/95	N/A	N/A	N/A
Lucas Heights	ANSTO	94/95	94/95	94/95	N/A
Badgerys Creek	Project	90/92	90/92	90/92	N/A
Mascot	FAC	94/95	94/95	N/A	94/95
Botanby	FAC	94/95	94/95	N/A	94/95
Mascot	BM	94/95	94/95	N/A	94/95
Richmond	BM	94/95	94/95	N/A	94/95

### **3.3 Regional emissions inventory.**

The EPANSW has made available the emissions inventory for 1992, as determined in the MAQS studies. The provided information consists of gross values for the key pollutants differentiated into traffic sources, area sources, biogenic emissions and industrial emissions at a spatial resolution of 3 km. The detailed buoyancy characteristics of the industrial plumes have not been utilised as the plumes have been assumed to be well-mixed within a chosen 6 x 6 km box. The emissions inventory was constructed for a summer day with temperatures sufficiently high to ensure that smog formation can be quite rapid.

For other types of summer day and for winter days, the emission rates are likely to be significantly different. Table 3.3 gives approximate estimates of the likely emissions on three types of day. On high smog days, evaporative losses and biogenic emissions are significantly greater than on more normal days.

**Table 3.3(a): Daily emissions (tonnes per day) in the Greater Sydney Region (year 1992) for a high oxidant summer week day and an average summer week day.**

Source category	VOC	NO <sub>x</sub>	CO	SO <sub>2</sub>	TSP
Mobile Sources	368/217	270/227	1,792/1509	8/8	21/12
Domestic/Commercial Activity	186/186	15/15	22/22	15/15	12/12
Industrial	50/50	39/39	38/38	36/36	25/25
Biogenic	885/442	20/9	-	-	-
Total	1,489/895	344/290	1570/1570	59/59	58/58

Note: First figures give the values for the high oxidant day, the second for an average weekday.

**Table 3.3(b): Daily emissions in the Greater Sydney Region (year 1992) for a average winter week day.**

Source category	VOC	NO <sub>x</sub>	CO	SO <sub>2</sub>	TSP
Mobile sources	240	245	2,569	8	23
Domestic/Commercial Activity	219	19	269	17	47
Industrial	50	39	38	36	25
Biogenic	78	2	-	-	-
Total	587	305	2,875	61	95

### 3.4 Emissions upwind and downwind of the three airport sites

For the year 2016 scenario, maximum hourly emission rates and average values (in brackets) from the airport are 135 (103) kg/hr of ROC and 658 (498) kg/hr of NO<sub>x</sub>. Table 3.4 lists estimated average hourly emissions at various locations upwind and downwind of the airport sites, within distances which can be traversed by parcels of air 1-2 hours after emission during normal seabreeze and synoptic events. The emissions are given for unit areas of 36 km<sup>2</sup>. Depending on the meteorological conditions, these emissions may produce smog within 1-2 hours and may also realise their full potential to form smog. These emissions can therefore be considered as the main contributors to background air quality at the proposed airport sites and at locations downwind of the airport sites.

For the Badgerys Creek site the largest emission sources are located to the east and north-east at a distance of 25-30 km. To the west of Badgerys Creek, only emissions from biogenic sources would make a significant contribution to smog development.

For the Holsworthy North site, the largest emission sources are located to the north-east and east of the airport site at distances 15-30 km. These emissions would normally be transported to the airport site within less than one hour. The NO<sub>x</sub> sources to the west and north-west of Holsworthy North have emission strengths of approximately 25-50% of the sources to the east. They may contribute to smog formation at the same times as the airport emissions.

The nearby upwind emission sources for the Holsworthy South site for north-easterly and easterly winds are much lower than for the Holsworthy North site.

**Table 3.4: Estimated hourly emission rates (kg/hr) at 15 km and 30 km upstream and downstream of each site for various wind directions.**

Wind direction	Upwind VOC			Upwind NO <sub>x</sub>			Downwind VOC			Downwind NO <sub>x</sub>		
	BC	HN	HS	BC	HN	HS	BC	HN	HS	BC	HN	HS
15km												
North-east	218	387	230	36	105	20	143	161	177	10	1	16
East	452	644	300	143	275	33	146	190	150	1	18	14
South East	213	220	227	32	31	40	190	243	371	1	64	122
30 km												
North-east	466	895	362	164	366	90	143	165	184	10	1	4
East	625	446	446	249	117	224	0	147	207	0	22	53
South-east	286	50	0	43	1	0	167	197	141	1	27	19

### 3.5 Wind analysis

The provided wind and temperature information has been used in a simple interpolation procedure to estimate wind speed and direction and temperature for key locations throughout the air-shed. The density of wind observation stations is sufficient that the influences of topography can be neglected to a first approximation. Figure 3.1 shows the interpolated daytime wind roses for key locations within the air-shed, including the three airport sites. Although there is considerable variability for nighttime flows (dominated by cold air drainage), there is a general uniformity of daytime wind directions throughout the region. On days with high photochemical activity, most important trajectories are almost linear.

### 3.6 Dispersion analysis

Radiosonde information for Mascot (6 am and 2 pm) has been processed to retrieve the temperature and mixing ratio profiles and to determine the mixing height at these times. The afternoon flights for on-shore winds show good evidence of seabreeze flows (typically 400-600 m in depth) and occasionally thermal internal boundary layers (TIBL depths usually 200-300 m). The seabreeze depths will be applicable to sites further inland; the TIBL will grow with inland distance. The afternoon information confirms the conclusions of Clark (1982) on seabreeze depths at Lucas Heights and has been to forecast TIBL depths for the airport sites, where necessary.

The morning temperature profile has been used in conjunction with the available wind, temperature and net radiation data to forecast hourly mixing heights, using the energy budget method of Clarke (1990). For seabreeze and on-shore flows these mixing heights (and corresponding convective velocities) have been modified, using the seasonal depths recommended by Clark (1982) from acoustic sounder measurements at Lucas Heights, and a standard square root dependence of TIBL height on overland distance. The seabreeze depths are assumed to decay with time (ie incoming radiation) as found by Pitts and Brown (1992) at a flat near-coastal site in Western Australia. Seabreeze occurrence has been based on the surface wind data (ie a given direction sector and speed history).

Atmospheric stability estimates have been based on the ratio of convective velocity to windspeed (for daytime) and windspeed and net radiation (at night). The stability distributions have been checked with those determined by Clark (1982), and Petersen and Clark (1986), using a variety of other methods.

For the scenario analysis the values of the wind speed, mixing height and temperature have been chosen from the available information to represent the conditions likely to be experienced along the chosen trajectories.

#### **4. Assessment of existing air quality at the airport sites**

##### **4.1 Air quality guidelines and measures**

The main focus of this report is the likely increase in short-term ozone concentrations on days of high smog levels. National guidelines currently exist for one hour and four hour averaging periods and state that threshold levels of 100 ppb and 80 ppb respectively should not be exceeded more than a specified number of times per year. Current considerations are to allow up to 4 exceedances per year of the hourly guideline but to restrict exceedances of the four hourly guideline to one event every 5 years. The results below have been reviewed mainly in terms of the hourly guideline. It is noted that the current air quality in the vicinity of the proposed airport sites may already exceed these national guidelines. The key aspect is therefore the likelihood of significantly increasing the exceedance rate (e.g. how many events are there just below the threshold that may give rise to exceedances when including the predicted impact of the airport emissions).

The severity of the airport impact is very dependent on these choices for threshold concentrations. It is noted that the national hourly guideline was recently revised downwards from 120 ppb to 100 ppb.

##### **4.2 Background air quality at the airport sites**

The estimation of the existing air quality upwind and downwind of each perspective airport site has used a box model on generic types of days to forecast the ozone levels along key trajectories. These have been interpreted in the light of the known exposures at the nearest air quality monitoring site, as quoted in recently published reports and supplemented by EPANSW monthly summaries of average and extreme conditions from the expanded Sydney air quality network.

For the Badgerys Creek site, the nearest air quality stations are those of Bringelly (for the recent information) and the Campbelltown site for longer-term monitoring. The main characteristics on high ozone days for this region occur as photochemically-old air arrives from the eastern suburbs. Under these conditions, the ambient air arriving at the airport site is likely to have ozone levels in the range 80-120 ppb and to be NO<sub>x</sub>-limited.

For the Holsworthy sites, the nearest air quality information is from Woolooware, Liverpool and Campbelltown for the recent monitoring data and from Campbelltown and Lidcombe on an historical basis. An analysis of the Lidcombe information (Katestone Scientific 1995, Lunney 1995) showed that high smog events can occur from midday onwards, with air which is often still in the light-limited regime (e.g. NO<sub>x</sub>-rich). The transition to NO<sub>x</sub>-limited conditions occurs for the inland region between Lidcombe and Campbelltown. The Holsworthy sites are generally upwind of Campbelltown on high smog days and are expected to be at the beginning of this transition point.

The available exceedance statistics for published information are shown in Table 4.1.

Previous investigations for the Lidcombe and Campbelltown sites have derived the frequency of occurrence of high smog conditions with NO<sub>x</sub>-limited conditions being approached or achieved. Similar information for the recent Mascot Airport information confirms that the photochemical regimes change markedly between the three sites (Figure 4.1).

**Table 4.1: Number of exceedences of hourly average ozone concentrations over 8 pphm and 12 pphm during the summers of 1993/94 and 1994/95.**

Site	Exceedances of 8 pphm		Exceedances of 12 pphm	
	93/94	94/95	93/94	94/95
Bringelly	17	35	2	3
St Marys	16	17	1	1
Liverpool	14	13	0	0
Richmond	9	4	0	0
Woolooware	3	10	0	3
Earlwood	0	0	0	0
Kensington	0	0	0	0
Lidcombe	n/a	0	n/a	0
Smithfield	8	n/a	0	n/a
Campbelltown	10	n/a	2	n/a
Douglas Park	11	n/a	1	n/a

### 4.3 Inter-annual variability

Previous studies of air quality at Lidcombe have shown a considerable variation in exceedance statistics between the years (Table 4.2). The published long-term information on maximum hourly concentrations per month is available for all monitoring sites but is of limited use to look at photochemical characteristics. The frequencies of days with high levels of smog (over 80 ppb) and relatively old air (extent parameter above 0.7) for Lidcombe and Campbelltown as given in previous reports suggests that the highest photochemical activity is likely to have occurred in the 1982, 1987 and 1991, with significantly lower levels of activity in the period 1993-95. These results compare fairly well with the available information from the Bureau of Meteorology (Sparks and Leighton 1994) on the relative occurrence of days of high anti-cyclonicity.

**Table 4.2(a): Number of exceedances per year of ozone hourly thresholds for the Lidcombe data (1980-1992 (after Lunney 1995)).**

Year	Number of exceedances over hourly level (pphm) of ozone			
	>6	>8	>10	>12
1980	146	42	15	6
1981	48	15	5	0
1982	135	47	25	5
1983	102	38	17	9
1984	68	18	6	0
1985	45	14	3	1
1986	48	16	1	0
1987	45	13	6	1
1988	38	11	1	0
1989	29	15	2	1
1990	31	8	0	0
1991	29	12	5	1
1992	18	1	0	0

**Table 4.2(b): Monthly variation of ozone hourly exceedances, 1972-1992 for Lidcombe site.**

Ozone thresholds	J	F	M	A	M	J	Jl	A	S	O	N	D
6 pphm	391	316	296	158	45	8	22	26	126	169	317	336
8 pphm	173	128	111	54	14	2	6	7	39	62	125	107
10 pphm	84	62	49	13	5	1	3	2	16	31	62	40
12 pphm	39	30	23	4	2	0	2	0	4	16	24	12



#### **4.4 Classification of high ozone days**

The MAQS study concentrated on the available monitoring information up to the middle of 1994. Building on this and previous meteorological studies of the air-shed, an ozone classification was given concerning the likely diurnal profiles at inland sites. These profiles are shown in Figure 4.2

The main types of days are when a sea breeze front advances into the western suburbs in the early afternoon bringing with it the recirculated emissions from the main Sydney region. The air following this seabreeze front consists of much cleaner air with a consequent drop in ozone concentrations.

A second important type of day is that where photochemical levels are high in the morning, decrease in the midday period (as the mixing height in the inland region increases dramatically) and reach a second peak as the sea breeze front passes through the regions. The MAQS studies discuss the likely reasons for the early morning ozone concentrations and conclude that they are most likely due to a trapping of the previous day's smog in the air above the overnight inversions. This smog is then mixed down to ground as the morning mixing height reaches these levels.

Most of this analysis of monitoring information and the numerical simulations themselves have looked at essentially single event days. In addition, no evidence was available of the likely intrusion of emissions from the Illawarra region into the western suburbs, as might be expected. The MAQS numerical simulations do, however, show a clear transport of pollutants from the main Sydney CBD area into the western suburbs on the afternoons of high oxidant days.

### **5. Ozone impacts from Lagrangian box modelling and footprint analysis**

#### **5.1 Selection of scenarios**

In the absence of detailed air quality information, the following approach has been undertaken:

- (a) The available wind information has been used to estimate particle trajectories passing through the airport sites for the main types of high smog days. The initial conditions for forecasting downwind concentrations has been based on an interpretation of information from the various MAQS studies and professional judgement. Sensitivity testing for different initial conditions has been undertaken.
- (b) The main downwind trajectories have been used to forecast the development of smog in the presence of the airport emissions. Alternative cases have been chosen where different types of downwind land use (corresponding to changes in wind directions) have resulted in different emission profiles. This allows the sensitivity testing of results to changes in wind direction and future enhancement of urban emissions in the relevant locations.

- (c) The above work produces a range of likely ozone impacts and an indication of those conditions under which any significant increase in ozone levels is likely to occur. The increment for these generic cases, the wind data for each site and an appreciation of the likely widths of the airport plumes for various downwind distances have then been synthesised to provide approximate footprints of likely ozone impact.

Two types of generic events have been considered for the current analysis. The first is a day without a seabreeze but with north-easterly winds throughout the day. The second event corresponds to a fairly common ozone day when a north-easterly seabreeze arrives at the Holsworthy site in the mid-afternoon and at Badgerys Creek one hour later. In both cases the incident air will contain moderate to high concentrations of emissions from the main metropolitan region.

## 5.2 General discussion of Lagrangian IER Box Model

Detailed modelling was performed for those types of days when ozone concentrations close (80 ppb) have been observed in the Greater Sydney region. Concentrations of smog produced along the trajectories were estimated both with and without the airport emissions. The present model consists of a single cell whose y-z plane is oriented perpendicular to the mean wind direction, thus establishing a two-dimensional grid system. The width and depth of the single cell are chosen to be 6 km while the height is defined by the mixing depth. As the calculation proceeds the box moves with the mean wind like a parcel of air; the ground-level emissions are added to the cell. The pollutants in the box are distributed uniformly and instantaneously within the box and are allowed to interact and change chemically according to the IER model.

There are some major idealisations in the approach:

- (a) The wind velocity is constant through the depth of the mixed layer (so that the box retains its integrity); this is suspect in a situation where there are sea breezes at low levels and return flows at high levels;
- (b) Emissions are spread uniformly throughout the box; this implies that lateral dispersion is immediate over a width of a few kilometres and does not continue thereafter.

Such a model may be most suitable for a situation where the box is trapped within a convergence zone, although in that case there are unresolved questions about ventilation through the sides and top of the box (Wratt et al. (1990)).

Other assumptions made in the modelling work include an IER hydrocarbon reactivity coefficient of 0.0067 (the value given by Johnson (1984) for ambient Sydney hydrocarbons, and close to the value expected for vehicle exhaust emissions). The NO/NO<sub>x</sub> ratio for the precursor emissions is assumed to be 0.9, as commonly used for automobile emissions (Scherer and Demerjian, 1978). The model does not cater for deposition or the entrainment of the airmass from the top of the box as the mixed layer grows.

The area of the box was chosen to be 6 x 6 km. At the locations of the proposed airport sites an area of this size would encompass the major ground-level sources (categories A,B,C,D,E,F of the Coffey report). The horizontal dimension of these sources is approximately 4x5 km. Emissions from line sources such as those of aircraft approaching the airport or taking off from the airport in a distance of 6-15 km from the airport centre point would not be included in the box, unless the trajectory of the air parcel passes the region of these corridors. The horizontal size of this box was chosen such that:

- (i) The photochemical impacts of area sources (such as motor vehicles, domestic/commercial area sources, surface-level industrial sources, biogenic sources) are invariant to small changes of this domain; and
- (ii) A uniform dispersion of the airport emissions can be assumed.

The results are given below for given values of smog produced (SP) ozone and the photochemical nature (extent parameter) of the incident air.

### 5.3 Ozone impacts on generic high smog days

#### 5.3.1 Badgerys Creek site

On high smog days, the adverse aspects of the Badgerys Creek site arise because of the greater age (and more NO<sub>x</sub>-limited) nature of the incident air. Ozone generation can then occur as long as there is sufficient time and sunlight energy available before sunset for the photochemical reactions to proceed to this stage.

For the seabreeze day, the incident air is assumed to have ozone levels of 10.4 pphm behind the seabreeze front (Table 5.1). After an initial period of titration by the airport emissions of NO<sub>x</sub>, a return to NO<sub>x</sub>-limited conditions is predicted within one hour and ozone generation occurs with a maximum downwind increment of 2.4 pphm. This is a very significant increase but, as is shown below, is at the upper end of the range of realistic estimates of impact for different sets of conditions.

**Table 5.1: Sensitivity analysis for the impact of a Badgerys Creek airport (levels in pphm).**

Event type	Initial conditions			Upwind sources	Downwind sources	Change in ozone	Time (hrs)
	SP	O <sub>3</sub>	Extent				
1. Post seabreeze	13.3	10.4	1	Urban	Urban	2.4	3
	13.3	10.4	1	Urban	Rural	2.4	3
	12.1	9.2	0.9	Urban	Rural	0.9	3
2. Synoptic	16.2	12.6	1	Urban	Urban	0.6	6
	16.2	12.6	1	Urban	Rural	0.5	6
	13.1	9.5	0.8	Urban	Rural	0.6	6
3. Rural only trajectories	8.6	6.7	1	Rural	Rural	2.2	3
	9.1	7.1	1	Rural	Rural	0.6	6

For the post-seabreeze event the calculations are summarised in Figure 5.1. Emissions from the metropolitan region lead to the build-up in smog concentrations of approximately 9.0 pphm at a distance of 30 km upwind of Badgerys Creek. This smog would have increased to 12.5 pphm at 16 km downwind of the airport. During this build-up, the smog formation would remain light-limited. Without airport emissions, smog production would cease at the airport site and (neglecting deposition effects) smog levels would remain constant as the air characteristics would have progressed to the  $\text{NO}_x$ -limited regime. For this trajectory there are no significant anthropogenic  $\text{NO}_x$  sources downwind of Badgerys Creek.

If airport emissions are now added, smog formation is initially pushed further into the light-limited regime. Within one hour downwind of the airport, the air parcel will have travelled approximately 18 km, smog production would continue to rise and the  $\text{NO}_x$ -limited regime would again be reached. The net increase of photochemical products during this period would result from an initial titration of ozone in the vicinity of the airport and ozone production further downwind due to the reactivity of the airport hydrocarbons.

Figure 5.2 shows the concentrations of  $\text{NO}_x$  and photochemical reactivity ( $R_{\text{smog}}$ ) for the trajectory and including airport emissions. The air parcels arrive at the airport site with an  $R_{\text{smog}}$  concentration of 1.8 ppb and a VOC/ $\text{NO}_x$  emissions ratio of 7.5.

For the synoptic event, the significantly higher mixed layer leads to ozone levels of 12.6 pphm at the Badgerys Creek site, with the main contributors being again the mainly motor vehicle emissions from the metropolitan and central-western regions. This smog would arrive early in the afternoon with the mixing depth in the range 2,000-2,500 m. The addition of airport emissions would increase smog and ozone concentrations by 0.7 pphm in an area 3-5 km wide and stretching from 7-15 km downstream.

The impact of the airport should not depend significantly on the age of the urban smog. The increment in ozone levels is relatively insensitive to the magnitude of downwind urban emissions. Smog production downwind of Badgerys Creek would achieve the  $\text{NO}_x$ -limited regime after one hour since there are no significant anthropogenic  $\text{NO}_x$  emissions to the west of Badgerys Creek.

Sensitivity tests have also considered air parcels for which the photochemical age of the instant air is much less. For the post-seabreeze case, the ozone impacts will be reduced by 63%, compared to the situation of photochemically-old air. Smog production downwind of Badgerys Creek would again reach the  $\text{NO}_x$ -limited regime after one hour of travel time.

An additional simulation has looked at a more rural emission scenario downwind of Badgerys Creek (basically removing the contribution from motor vehicles in the previous scenarios). Lower ozone levels are predicted as the smog will be depleted of additional  $\text{NO}_x$  emissions.

### 5.3.2 Holsworthy North site

On high smog days, adverse aspects for the Holsworthy North location arise from both (a) the urban smog plume impacting at Holsworthy North in the afternoon and combining with airport emissions and (b) the impacts of airport emissions on populated areas to the west of Holsworthy North. The urban plume can be either light-limited or NO<sub>x</sub>-limited and little information available to determine the frequency of occurrence of such conditions. If the incident air is NO<sub>x</sub>-limited, the increments from the airport emissions in the afternoon can be as large as those for Badgerys Creek.

The urban smog levels for parcels of air traversing the Holsworthy North site in the afternoon are generally significantly lower than those at Badgerys Creek. The Holsworthy North airport emissions would rarely increase the total smog levels above 10 pphm.

Figure 5.3 displays the estimates of smog produced, ozone concentrations and extent for the generic post-seabreeze event. On arrival at Holsworthy North, the smog production would be just in the light-limited regime (extent of 0.9). The concentrations of R<sub>smog</sub> are assumed to be 1.6 ppb. At the airport site, the airport emissions would reduce ozone concentrations and push smog production further into the light-limited regime, with NO<sub>x</sub>-limited conditions only occurring at 30 km downwind of the site. In this area (basically the rural area located south of Campbelltown and Camden) the airport emissions are predicted to increase hourly ozone levels by 1.8 pphm.

For the synoptic event, the hourly ozone increases are confined to 0.7 pphm as the urban smog has already reached the NO<sub>x</sub>-limited regime on its arrival at the airport.

The results of the sensitivity analyses are shown in Table 5.2.

**Table 5.2: Sensitivity analysis for the impact of the Holsworthy North airport (levels in pphm).**

Event type	Initial condition			Upwind sources	Downwind sources	Change in ozone	Time (hrs)
	SP	O <sub>3</sub>	Extent				
1. Post seabreeze	11.0	8.5	0.9	Urban	Rural	1.8	3
	11.0	8.5	0.9	Urban	Urban	1.1	3
	7.8	5.7	0.8	Urban	Rural	0.3	3
2. Synoptic	8.5	6.6	1	Urban	Rural	0.7	6
	8.5	6.6	1	Urban	Urban	0.6	6
	6.5	5.3	0.8	Urban	Rural	0.6	6
3. Rural only trajectories	8.4	6.5	1	Rural	Rural	2.1	3
	8.2	6.4	1	Rural	Rural	0.6	6

5.3.3 Holsworthy South site

On high smog days, the adverse aspects for the Holsworthy South site arise from the urban smog plume being brought in by the seabreeze, as for the Holsworthy North site. The main differences are that smog formation will be slightly further in the NO<sub>x</sub>-limited regime and the downwind areas do not include as many population centres. The results are shown in Table 5.3 and Figure 5.4 where the R<sub>smog</sub> concentrations have been assumed to be 1.4 ppb.

Table 5.3: Sensitivity analysis for the impact of a Holsworthy South airport (levels in pphm).

Event type	Initial condition			Upwind sources	Downwind sources	Change in ozone	Time (hrs)
	SP	O <sub>3</sub>	Extent				
1. Post seabreeze	9.6	7.5	1	Rural	Rural	1.8	3
	9.6	7.5	1	Urban	Urban	1.5	3
	7.8	5.7	0.8	Rural	Rural	0.2	3
2. Synoptic	8.3	6.4	1	Urban	Rural	0.7	6
	8.3	6.4	1	Urban	Urban	0.6	6
	6.2	4.9	0.8	Urban	Rural	0.5	6
3. Rural only trajectories	8.5	6.9	1	Rural	Rural	2.2	3
	8.2	6.3	1	Rural	Rural	0.6	6

5.4 Footprint considerations

The above results for impacts on particular hours of high smog days need to be viewed with respect to the likely areas affected, the people likely to be exposed and the magnitude and frequency of occurrence of these exposures. The locations of the affected areas have been estimated from

- (a) Available coincident air quality and meteorological data (Badgerys Creek meteorology with Campbelltown air quality for 1992, Lucas Heights meteorology with Botany Bay (upwind of Mascot Airport) for 1994/95;
- (b) An assumption that the main impact will occur for areas one hour downwind of the airport for all relevant conditions when additional smog formation is likely.
- (c) An assumption of a 3-6 km wide airport plume in which the additional impact is possible.
- (d) For each site, a significant impact may occur if upwind ambient ozone levels are 7 pphm or above, the extent parameter is above 0.6 and daytime conditions apply.

Figures 5.5 - 5.7 show the centroids of the impact zones for the available 12 months information at each set of sites.

#### 5.4.1 Badgerys Creek site

Nearly all of the 26 hourly ozone events have photochemical extents close to 1, with half having ozone levels over 8 pphm (and therefore possibly close to the guideline if an airport impact of 1-2 pphm (worst-case) is used). Apart from 4 anomalous events, all occur for north-north-easterly to easterly winds and usually in seabreeze conditions. The impact zones (Figure 5.5) are clustered to the south-west to west of the airport, and mainly in the less populated areas. The three points on the airport site are due to very light wind conditions and are not high ozone events (as described in Table 5.4). The two points to the north-east are morning events and not properly treated by this analysis. The remaining points, generally have ozone levels in the range 7 - 9 pphm with 4 events over 10 pphm for this dataset. Table 5.4 shows that, if the airport ozone impact is taken to be 1 pphm, an extra 2 exceedances per year will occur (and thereby the area will not attain the ozone guideline for the year).

The published Bringelly data for 1994/95 suggest more frequent exceedances than given by the Campbelltown data. The bracketed figures in Table 5.4 give estimates of the exceedance statistics for the more recent data.

**Table 5.4: Exceedance statistics for hourly ozone guideline of 10 pphm, for the Badgerys Creek site and various ozone increments due to the airport operation. Bracketed values are estimates for the Bringelly air quality measurements.**

Airport impacts (pphm)	Exceedances
0 (existing)	4 (6)
1.0	6 (13)
1.5	8 (19)
2.0	13 (28)

#### 5.4.2 Holsworthy North site

The Botany Bay high ozone dataset for 1994/95 consists of 13 days, with 38 hourly ozone events over 7 pphm. Most of these events are before the arrival of the seabreeze and with wind direction from the west to north-west. These data may not apply well to the Holsworthy sites and may overestimate the frequency of impact to the south-east (and underestimate those to the south-west). The two events to the north of the site are morning events with lower ozone levels (and thereby of less concern). Of more concern are the three events on 27 December 1994 with south-easterly winds in the afternoon and ozone levels over 8.5 pphm. These are photochemically-old air parcels probably originating from the Illawarra region.

The likely ozone exceedance statistics shown in Table 5.5 may be overestimates, based on the above considerations.

5.4.3 Holsworthy South site

With the adopted assumptions and available data, the results for the Holsworthy South site are very similar (Table 5.5 and Figure 5.7) to the Holsworthy North site. The main difference is that the main population centres are less affected, except for those in the Stanwell Park area. It is again noted that the impact of the airport in north-westerly winds in the pre-seabreeze period has not been treated by the adopted approach and the indicated impact may be too conservative.

**Table 5.5: Exceedance statistics for hourly ozone guideline of 10 pphm for the Holsworthy North and South sites and various ozone increments due to the airport operations.**

Airport impacts (pphm)	Exceedances
0 (existing)	5
1.0	9
1.5	10
2.0	16

Figure 5.6 showing the likely impact zones suggest that only a few events will impact on the major residential area at Campbelltown.

5.5 Implications for locating airports

The air quality at the proposed airport site at Badgerys Creek on days of high photochemical activity is determined by emissions released in the central and eastern Sydney region. Smog from those urban areas would impact at Badgerys Creek when approaching or having reached their maximum levels. Moreover most of the urban smog would be aged; the impact of NO<sub>x</sub> and VOC emissions from airport activities would then be maximised.

The proposed Holsworthy North site would be located close to the major urban emissions sources and the air over Holsworthy North would in most cases be NO<sub>x</sub>-rich. However, aged smog resulting from emissions released in the Wollongong region may also impact on Holsworthy North. Photochemical smog impacts from airport activities can therefore be both (a) maximised in the presence of aged urban smog, and (b) minimised through the presence of high NO<sub>x</sub> concentrations from urban emissions sources.

The considerations to date suggest that the impact on existing populations for Holsworthy South is likely to be the least of the three sites (lower impact, less often, lower exposures). The other two sites are relatively similar. For Badgerys Creek, it is expected that a slightly higher impact and more frequent occurrence will be moderated by a lower population likely to be exposed. For the Holsworthy North site, the slightly lower impact and lower frequency is countered by the higher downwind population.



## 5.6 Consideration of other emissions scenarios

In the simulations the year 1993 MAQS emissions inventory was used. Future VOC emissions from the motor vehicle fleet are expected to decrease. As urban emissions play an important role in the smog impacts of airport emissions, the smog impacts of airport sources are likely to be reduced in the future, unless there is a significant increase in vehicle flow rates.

VOC emissions from biogenic emissions play a very important role for the impacts of airport emissions from Badgerys Creek.

## 5.7 Other pollutants

The box model has also been used to estimate changes in regional air quality for carbon monoxide and fine particulates. The predicted increments are small for the considered scenarios (less than 0.5 ppm for carbon monoxide, below 5  $\mu\text{g}/\text{m}^3$  for fine particulates). The fine particulate increments can only be considered first estimates in the light of recent measurements of ultrafine particulates being formed in the near-field of the airport (probably due to nucleation processes - see Hager et al (1996)).

## 6. Uncertainties and potential resolution

The results presented above have been based on generic air quality information for the Sydney region and estimates of the impacts of the preferred airport for a single chosen emission scenario. The predicted impacts are dependent on: (a) the characteristics of the urban photochemical smog, (b) the chosen meteorological parameters, and (c) emissions. The model predictions are based on available ground-level meteorological data, the 1993 emissions estimates and estimated air quality information.

The uncertainties in the predicted increases in regional air quality include the following:

- (a) The estimation of the magnitude and frequency of occurrence of ozone impacts, and the likely area to be affected, would be made more accurate if air quality information for the nearest EPANSW air monitoring sites was available. As there is a considerable inter-annual variability in concentration statistics, at least three years of information should be utilised.
- (b) The prediction of ozone impact for the Holsworthy sites is quite sensitive to the existing ambient air quality. If an accurate assessment is required, on-site monitoring is recommended. This should include a determination of the reactivity of ambient air and should extend over at least one summer season.
- (c) The predicted ozone impacts are sensitive to the values chosen for the mixing height. Few measurements are available for the more inland Badgerys Creek site. Remote sensing equipment (e.g. electromagnetic radar and/or radio-acoustic sounding systems) operated for a 12 month period would remove this uncertainty.

- (d) The predicted air quality impacts from the airports are confined to afternoon smog events, when the height of the mixed layer has usually reached its maximum; for morning events emissions may be advected over Sydney's west under quite different meteorological conditions. The photochemical impacts of the airport may be quite different in these circumstances.
- (e) Most considerations to date have been based on the evaluation of photochemical levels along a trajectory to the end of a given day. The Sydney air quality measurements to date suggest that there are several episodes of a multi-day nature. Existing methodologies experience difficulties in forecasting the overnight deposition rate of ozone levels and cannot be used confidently in predicting ozone levels of the second day. From an overall air-shed viewpoint, such multi-day episodes should be investigated via a variety of methods.
- (f) Consideration has been given in this report only to the use of the 1993 Sydney metropolitan emissions inventory together with one scenario for the airport emissions. By the years 2010 - 2016, the metropolitan area will have expanded considerably but the introduction of better emission controls will have reduced the per-vehicle emission rates substantially. Further work is recommended to quantify the net result by investigating the metropolitan emissions for the future years and repeating the above calculations for several airport emission scenarios.
- (g) Sensitivity analyses suggest that any major changes in land-use could have a significant impact on the predicted ozone concentrations. Downwind of Badgerys Creek, biogenic sources contribute most to the ROC concentrations. Changes in land-use may increase the significance of motor vehicle emissions there and also the ambient ROC:NO<sub>x</sub> concentration ratio. The non-linear nature of the chemical transformations complicate the assessment of whether the effects would be beneficial or not, without doing the detailed modelling.
- (h) As noted in the terms of reference and as is the case for the existing Mascot Airport, the airport is likely to attract a significant amount of commercial and industrial activity with additional significant sources of smog precursors to those considered in this report. The estimation of the impact of these sources would require more information on the likely industries and a re-modelling of key smog events. The use of the 1993 MAQS emission inventory does not cater for the increased traffic along transport routes to the second Airport. The airport emissions inventory constructed for the EIS considers only emissions from roads leading into the airport. The airport could increase the transport emissions within the nearby part of the transport network.
- (i) The MAQS inventory does not include the emissions from the Tower and Appin methane drainage and combustion facilities to the south-west of Campbelltown. These are significant point sources of nitrogen oxides that may exert a significant influence on ozone formation for trajectories that have already passed over the airport site.

- (j) It has been assumed that the aircraft emissions above the mixing layer will not subsequently be available downwind for smog production. There may be some events where this assumption breaks down and the general level of aircraft-related pollutants may be an important factor for forecasting ozone levels during prolonged pollution episodes.
- (k) A relatively small number of ozone events has been considered, very few if any of which involve the interaction of the second airport emissions with that part of the urban plume that contained Mascot airport emissions. The consideration of the combined impact of operations of the two airports would require the identification of those events on moderate to high ozone days for which the airport emissions may overlap and interact significantly.
- (l) The predictions of this report utilised a VOC/NO<sub>x</sub> ratio based on the Sydney urban emissions inventory. Future work could utilise recent Airtrak measurements of the photochemical reactivity within the Sydney air-shed to determine the sensitivity of ozone production to variations in photochemical background.
- (n) Technology is now available for estimating the ozone impacts of a major facility such as Mascot Airport from historical information of ground-level concentrations of nitrogen oxides and ozone. The information collected to date at Mascot and at sites up to 20 km downstream could be used to determine any evidence for Mascot airport having a significant impact on regional ozone levels. Such work would allow some validation of the methodologies used in the air quality assessments for a second airport.

## 7. Conclusions

- (a) A literature survey and contact with North American aviation authorities have shown that the impact of airport emissions on regional photochemistry has rarely been addressed in any detail in recent environmental assessments of major airports.
- (b) For the Sydney air-shed, high smog levels and aged air are necessary for the airport emissions to have a significant impact on ozone levels. Such days occur 5-15 times per year, with a greater frequency in the western suburbs of Sydney. A coincidence of suitable synoptic conditions, delayed seabreezes and high levels of precursor emissions is necessary, this rarely occurs and on most days the photochemical impact of the airport will not be significant.
- (c) When photochemically old air is incident on any of the three prospective sites, the addition of volatile organic compounds can accelerate the necessary chemical transformations to reach a NO<sub>x</sub>-limited state. The airport NO<sub>x</sub> emissions can then give rise to additional ozone. The affected areas are predicted to be 5-20 km downwind (dependent on conditions); within the area covered by the airport emission plumes (typically 3-5 km wide), the increases of hourly ozone levels forecast by the current chemistry scheme are in the range of 0.5-1.5 pphm. The areas most frequently affected will be to the south-west to west of each site.

- (d) The number of significant events is small. From the available air quality information, there appear to be few events for the Holsworthy sites where the airport emissions can cause exceedances of the hourly ozone guideline. For the Badgerys Creek site, predictions using the available data suggest 5-10 episodes per year of guideline exceedances may be caused by the airport emissions.
- (e) Sensitivity tests have shown that if events are chosen from the previous MAQS studies to estimate ozone impacts due to the airport, they will produce much higher results than for most historical high ozone days. For Badgerys Creek, most adverse ozone impacts are expected to be in the range 0.5-1.0 pphm, with increases of 2.0-2.5 pphm expected under extreme conditions. Such increases would usually cause exceedances of the hourly ozone threshold on more than the required maximum four days per year. For the Holsworthy North site, most ozone increments are expected to range from 0.3-0.7 pphm but with extremes of 1.8-2.1 pphm. Very few of these events will cause exceedances of the hourly guideline. For the Holsworthy South site, similar increments to the Holsworthy North site are predicted, but will add to a slightly lower background level and total ozone levels are not expected to exceed the guideline.
- (f) The frequency of ozone impacts will be higher for the Badgerys Creek site than the two Holsworthy sites, due to the more inland location and greater prevalence of aged air. There are few significant differences between the ozone impacts for the Holsworthy North and South sites. Emissions from an airport at any of these three sites is likely to have more adverse smog consequences than the current emissions from the coastal airport at Mascot.
- (g) Downwind emissions from residential and traffic activity can be quite important in reducing the initial ozone impact of airport emissions, especially for the Holsworthy sites. For the Badgerys Creek site, current downwind emissions are predicted to have only a minor influence; substantial increases in anthropogenic source emission rates to the west of the airport would be required to cause any significant reductions in predicted ozone impacts.
- (h) Predictions of ozone impacts are relatively sensitive to the adopted mixing depths for seabreeze conditions, for which there is little information at inland sites in the Sydney region. The Holsworthy sites are in the transition zone between inland and coastal areas and greater sensitivity at these sites is expected.
- (i) Fine particulate emissions in aircraft exhausts are poorly detailed in world literature. Predictions of regional air quality impacts of airport particulate emissions on a short-term and annual average basis require a better quantification of aerosol formation and retention within the boundary layer.
- (j) The results of this study do suggest that regional air quality should be a significant factor in airport site selection and environmental management.
- (k) Ozone impacts can be minimised by a long-term program of reducing NO<sub>x</sub> and VOC emissions from aircraft and ground vehicles.

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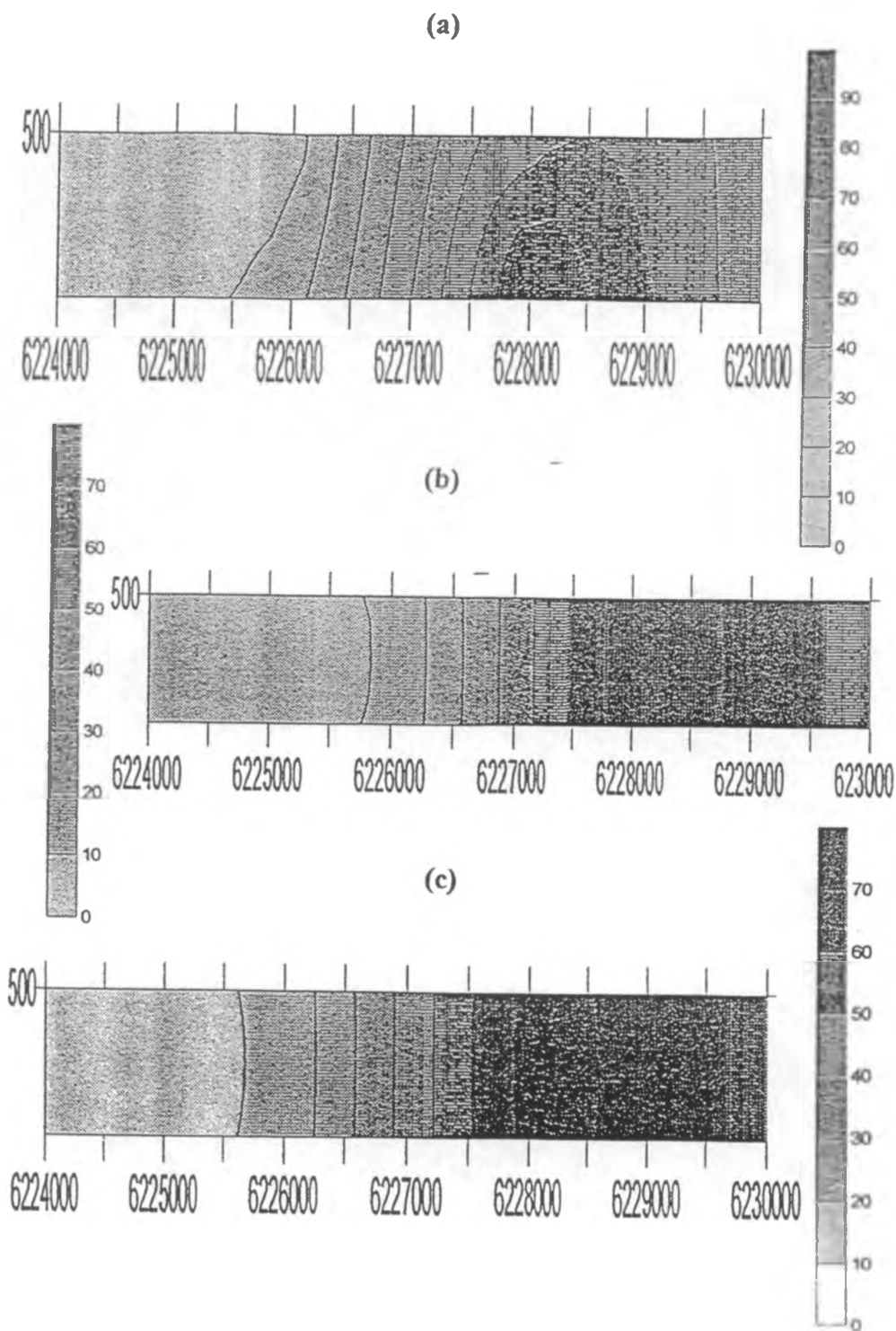
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**Figure 2.1:** Cross-sections of airport pollutant plumes at various distances downwind of the Holsworthy North airport site computed with the ISC3 dispersion model for a worst-case meteorological scenario; (a) downwind distance: 500 m, (b) downwind distance: 3 km, (c) downwind distance: 5 km.





**Figure 3.1:** Windroses for daytime in spring and summer for (a) Mascot Airport, (b) Lucas Heights, (c) South Creek and (d) Badgerys Creek.

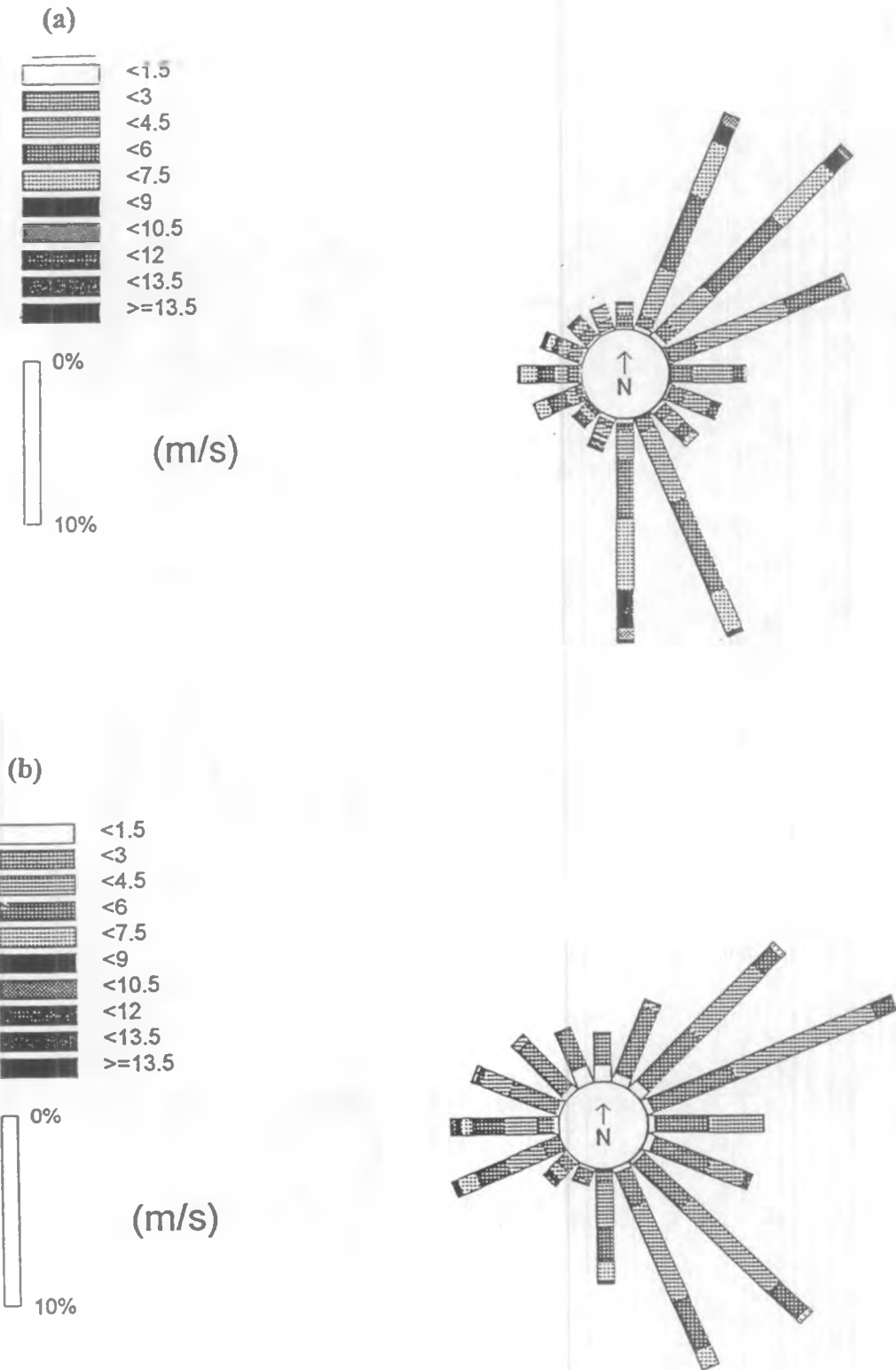


Figure 3.1 Continued.....

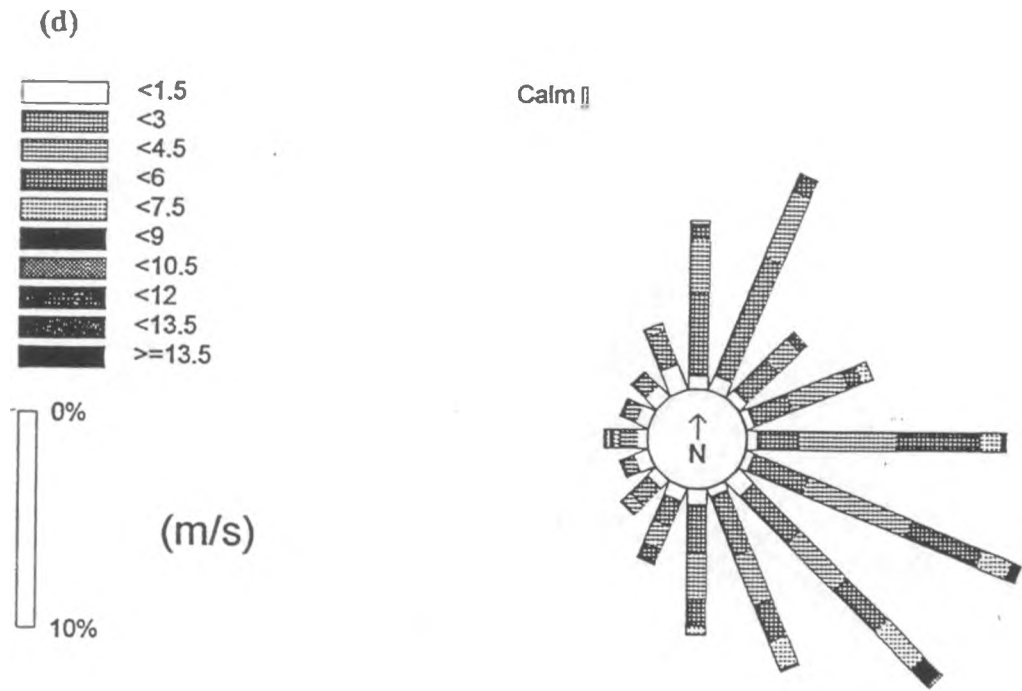
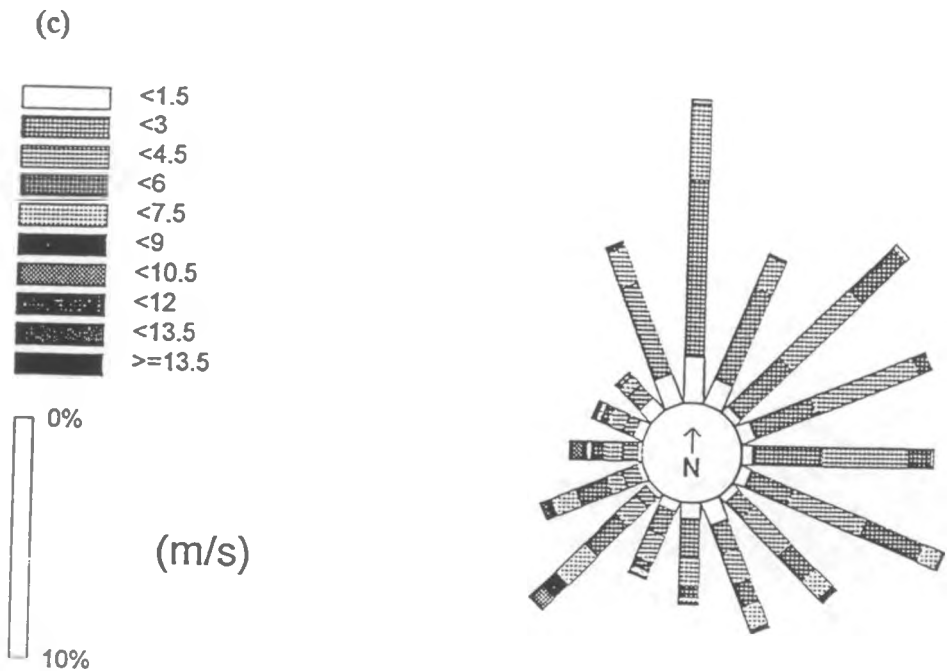
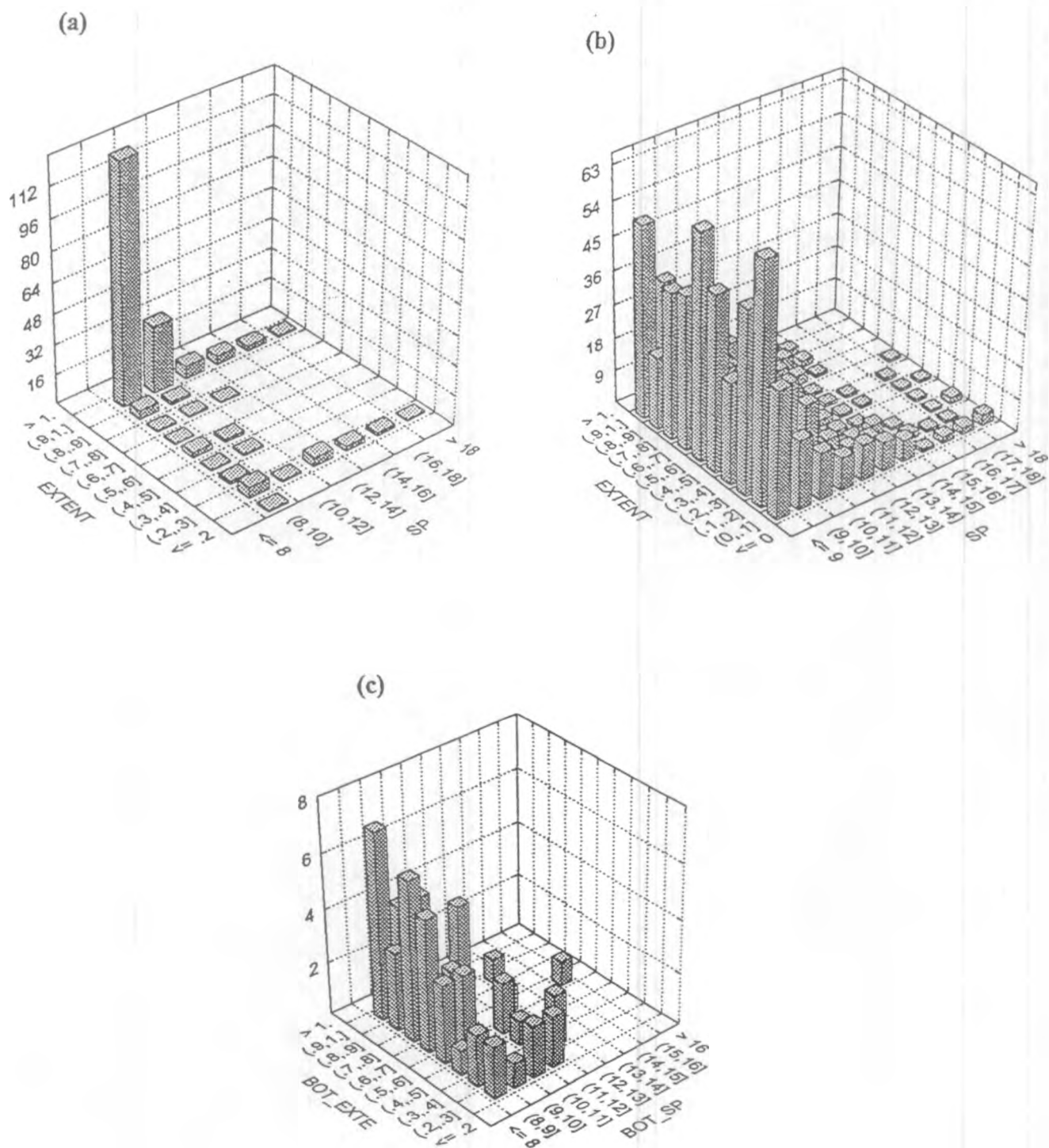
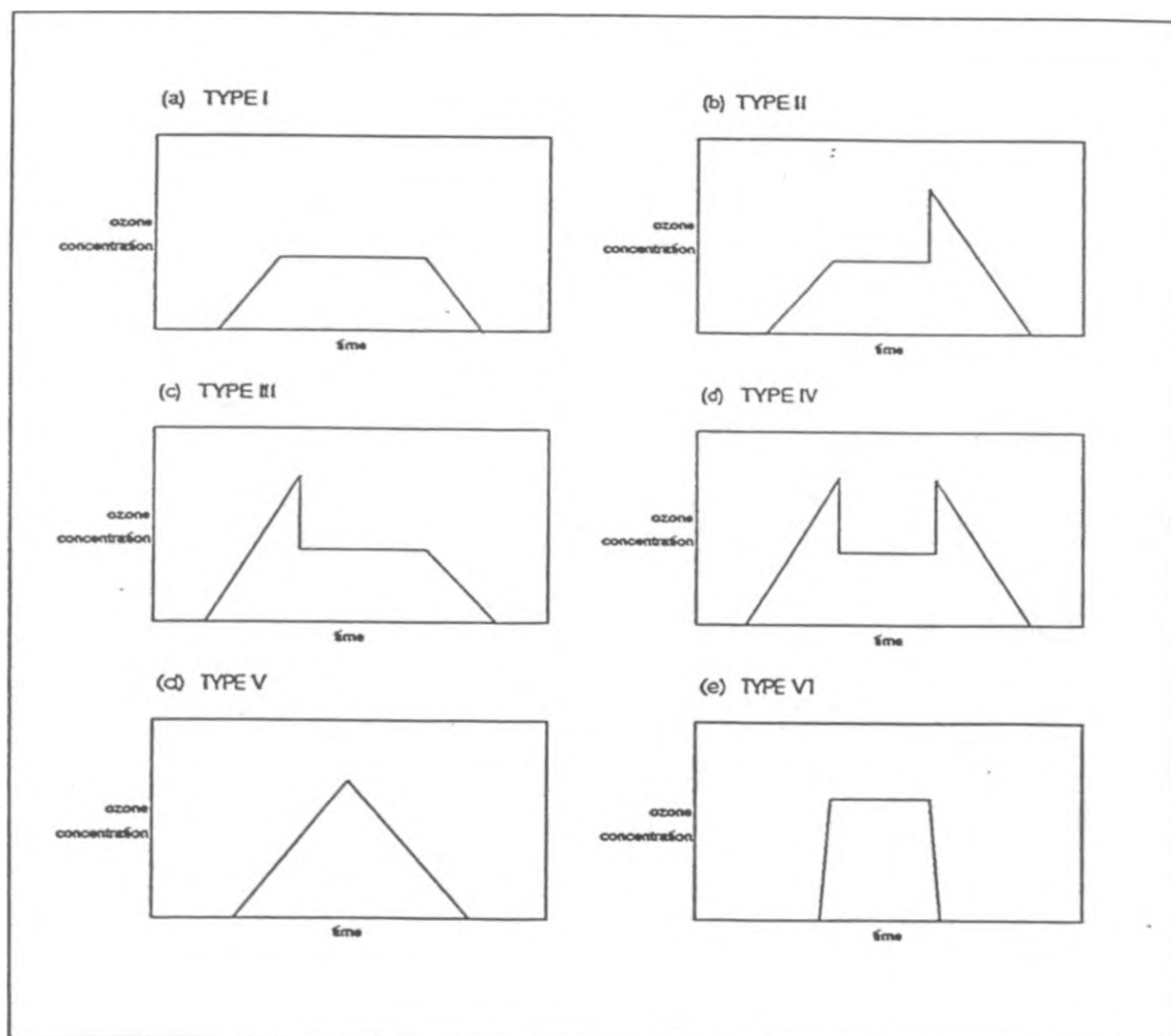


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**Figure 5.1:** IER estimates of concentrations (ppb) of Smog Produced (SP), ozone ( $O_3$ ) and photochemical extent for a generic post-seabreeze event at Badgerys Creek for trajectories with and without airport emissions. The distances upwind of Badgerys Creek are indicated as negative numbers, the downwind distances as positive numbers.

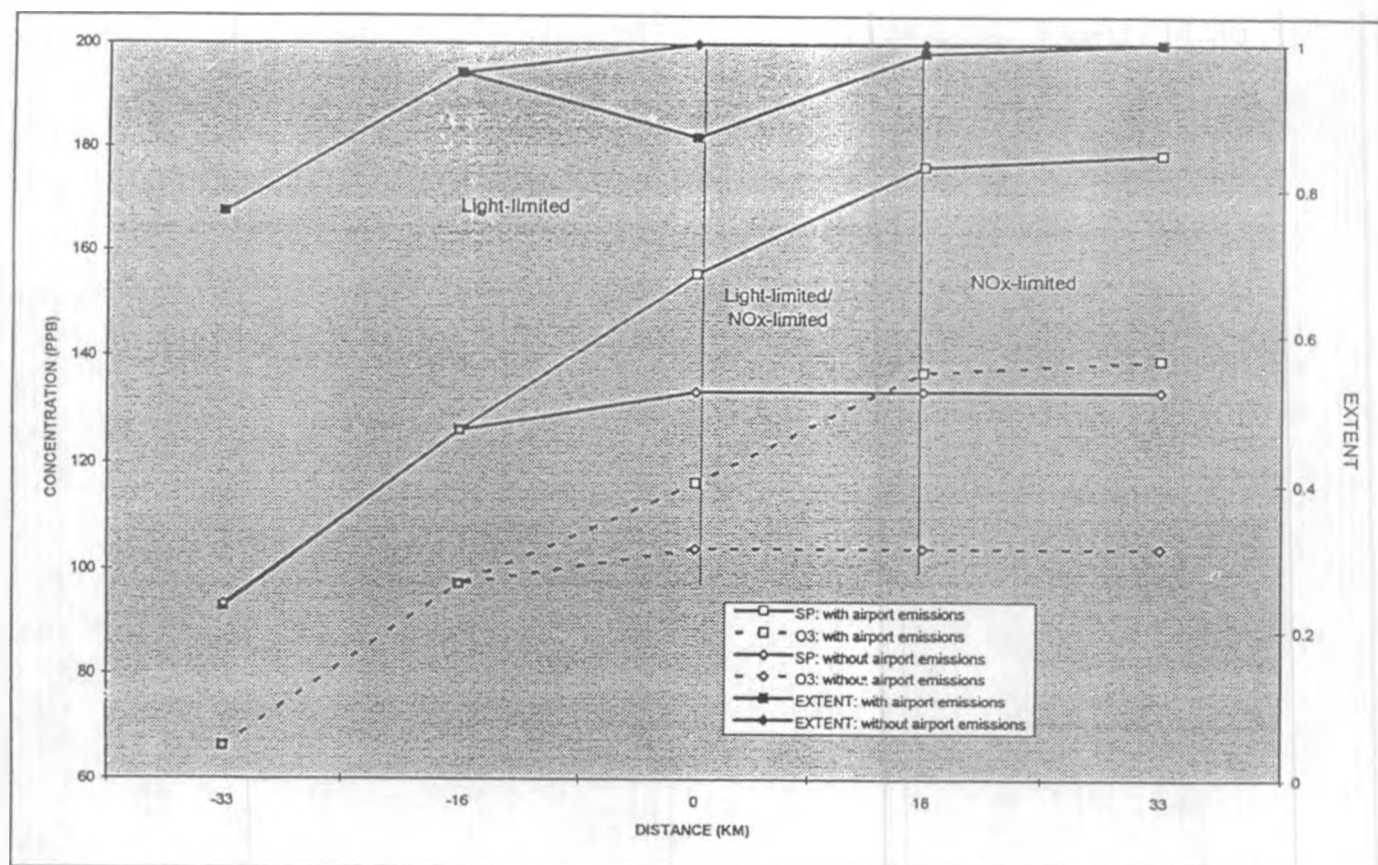
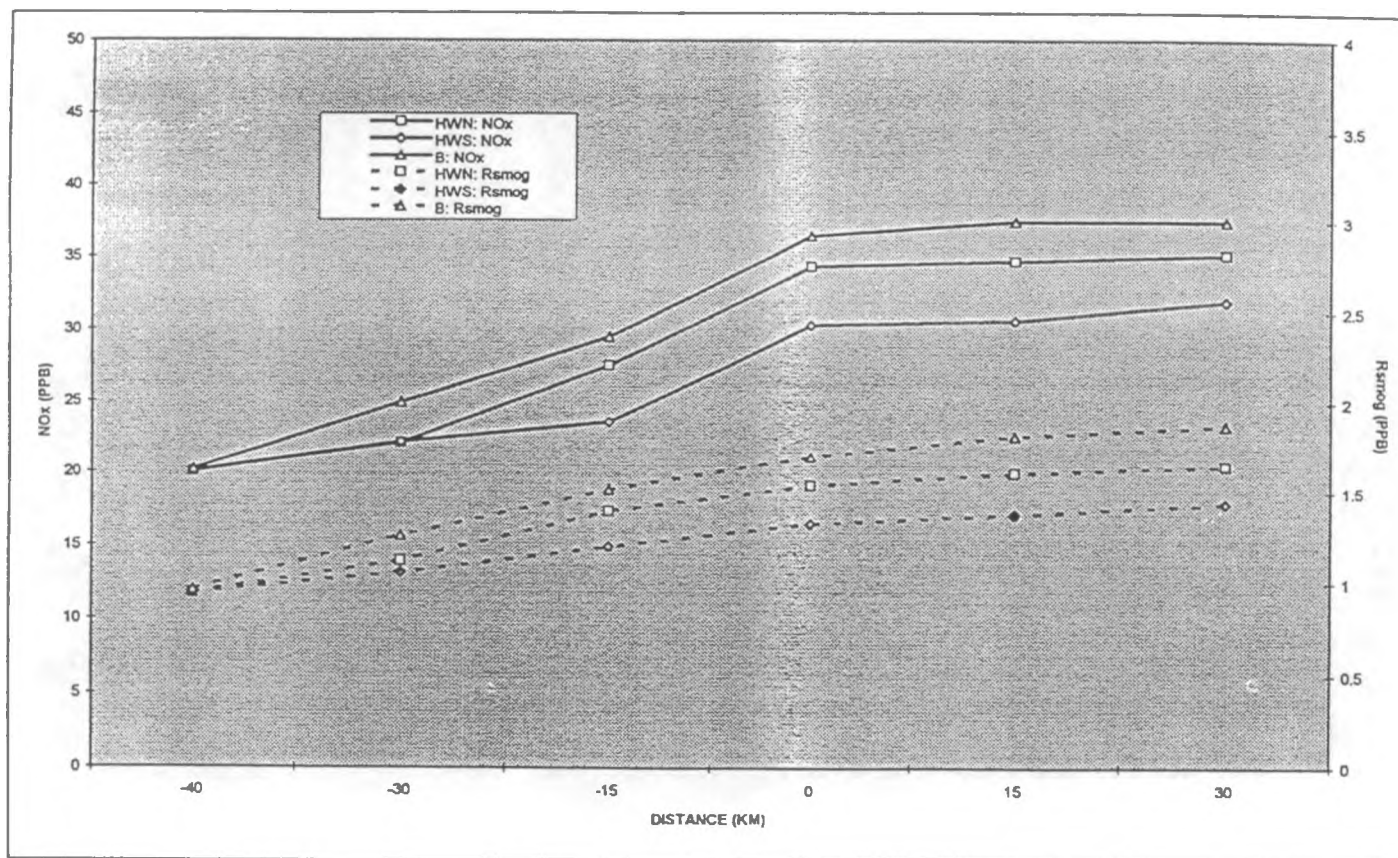


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**Figure 5.3:** IER estimates of concentrations (ppb) of Smog Produced (SP), ozone ( $O_3$ ) and photochemical extent for a generic post-seabreeze event at Holsworthy North for trajectories with and without airport emissions. The distances upwind of Holsworthy North are indicated as negative numbers, the downwind distances as positive numbers.

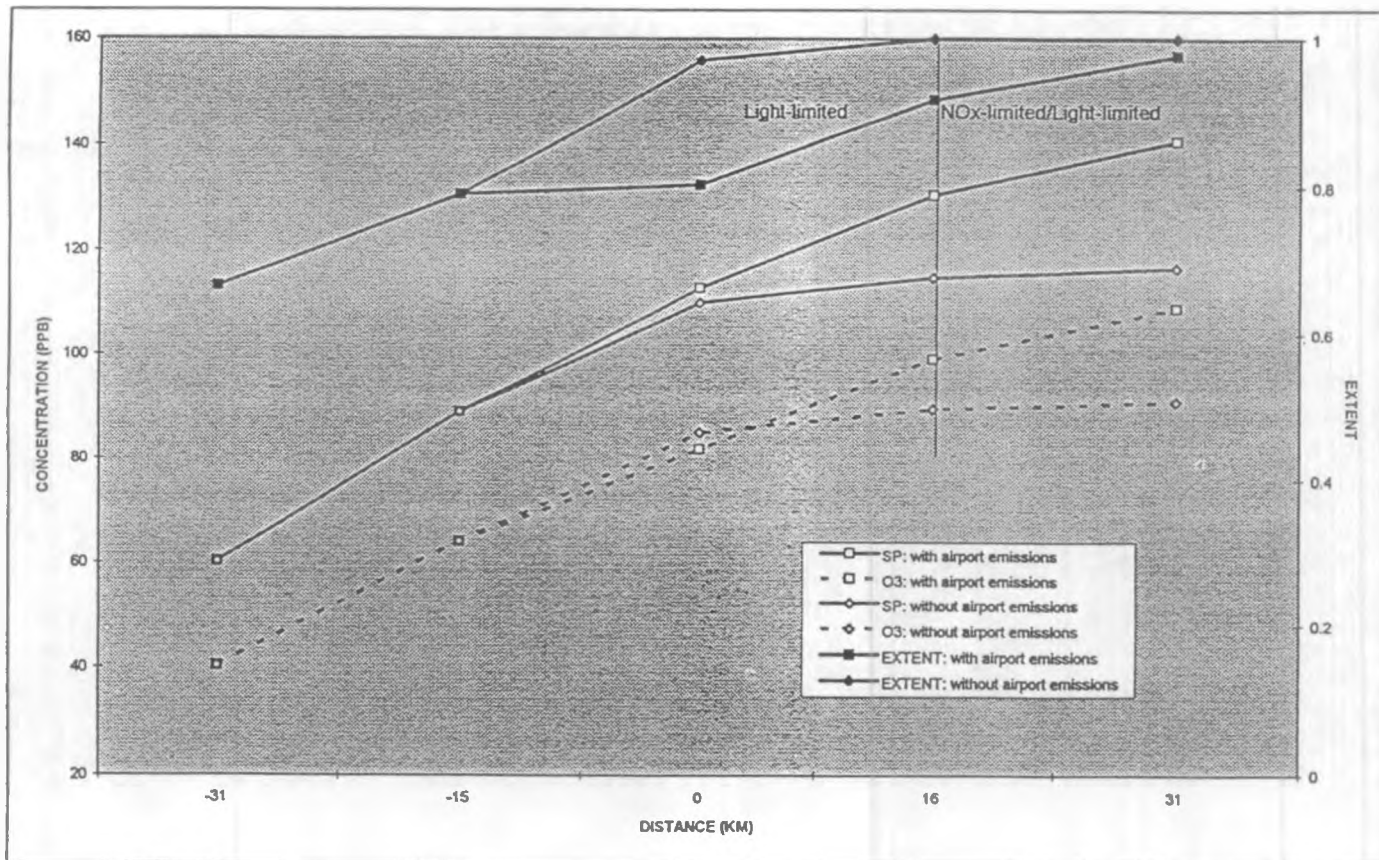
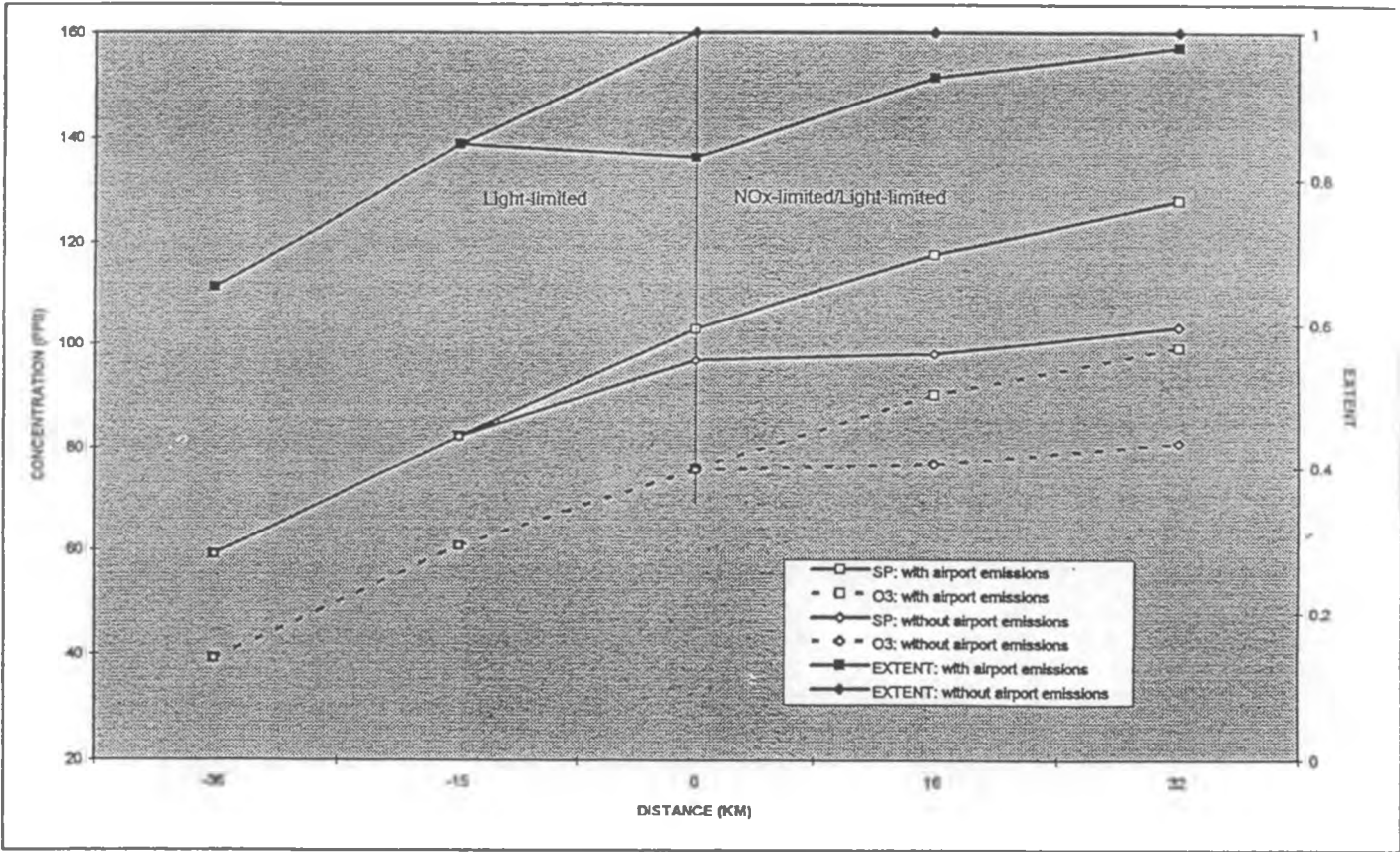




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**Figure 5.5:** Estimated centroids of zones of maximum ozone impact for airport emissions from Badgerys Creek on days of high photochemistry, as judged from Campbelltown air quality data and Badgerys Creek wind information for 1992. Each point is one hour downwind of the airport.

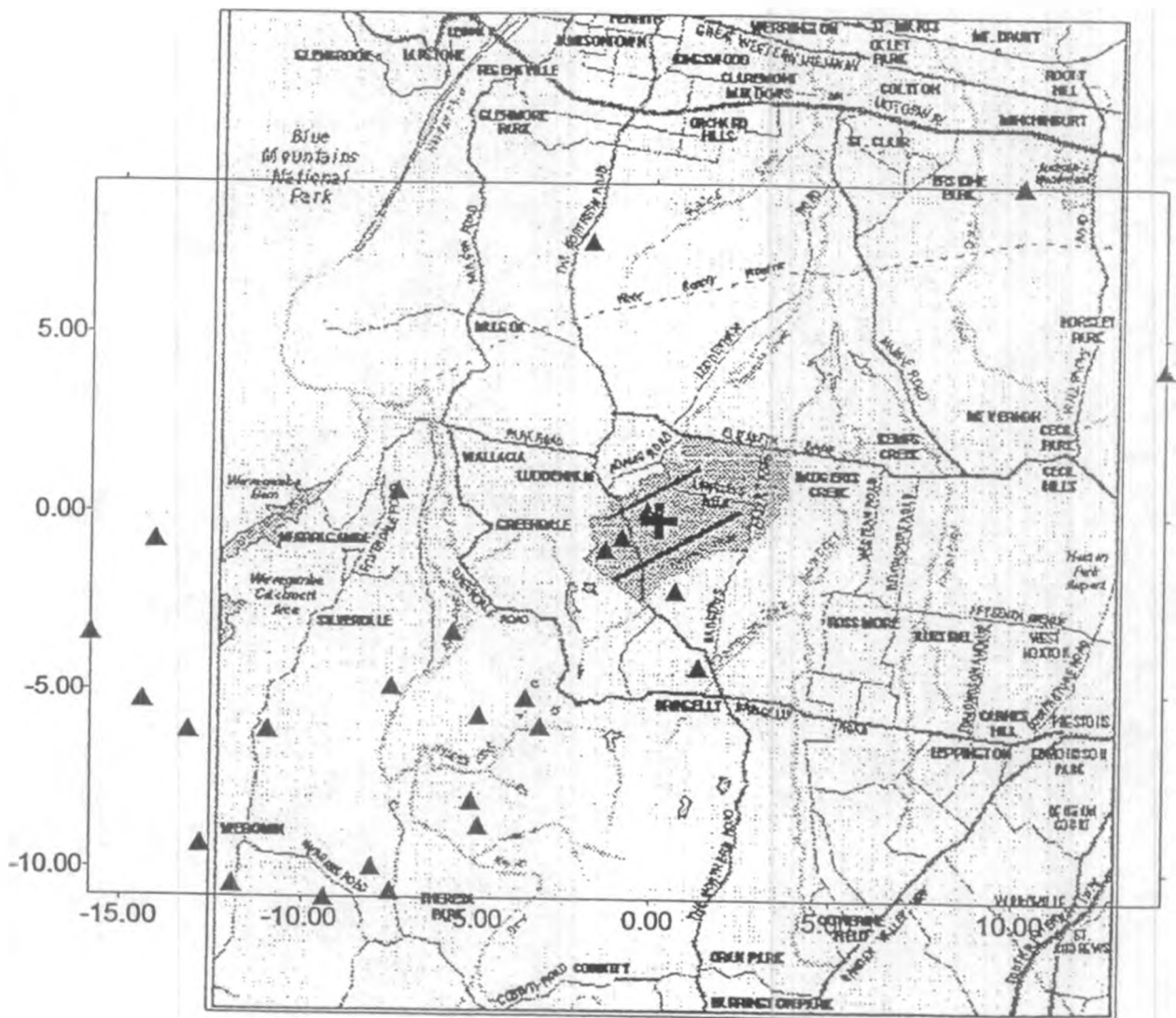


Figure 5.6: Estimated centroids of zones of maximum ozone impact for airport emissions from Holsworthy North judged from Botany Bay air quality and Lucas Heights wind data for 1994/1995. Each point is one hour downwind of the airport.

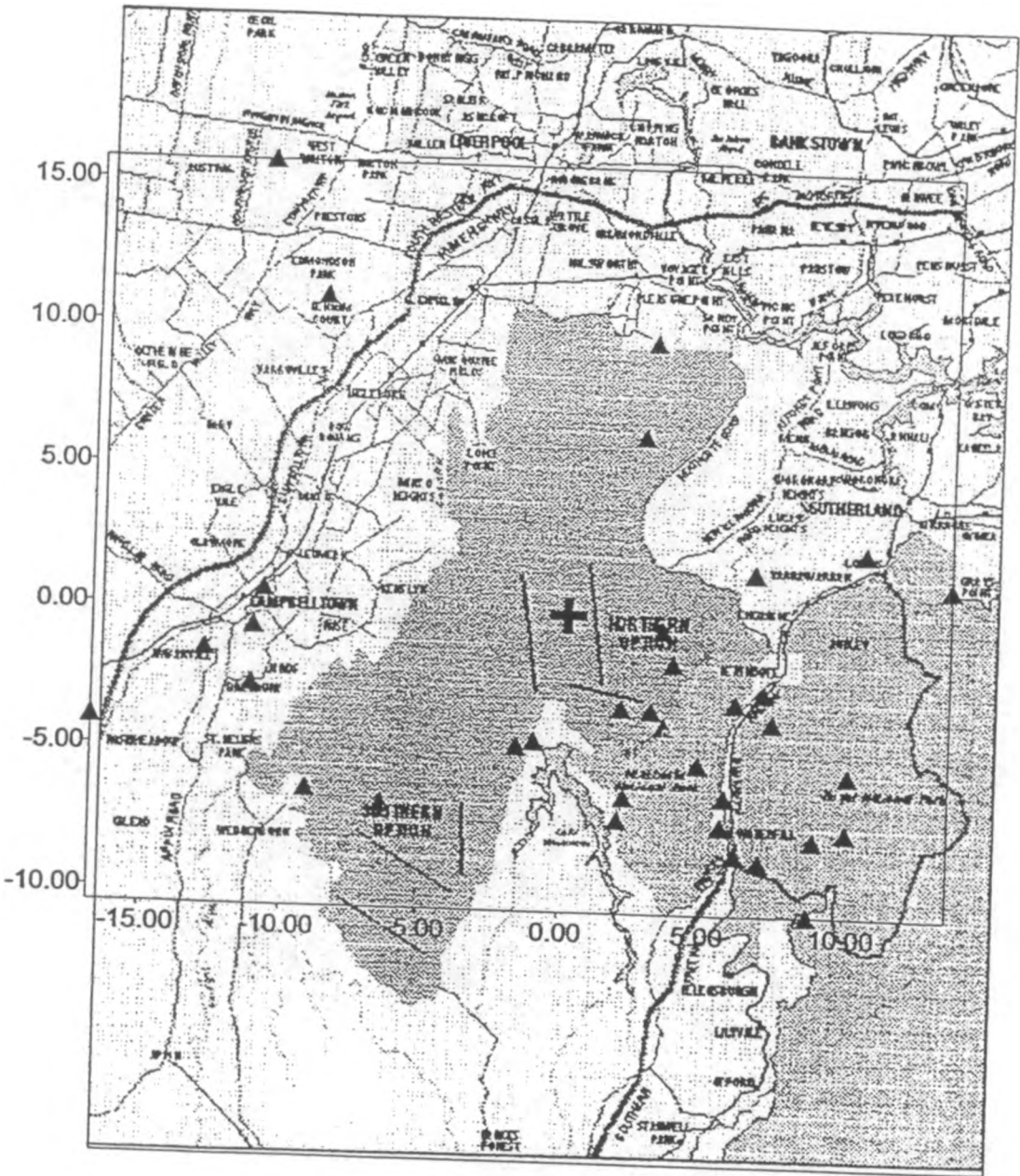
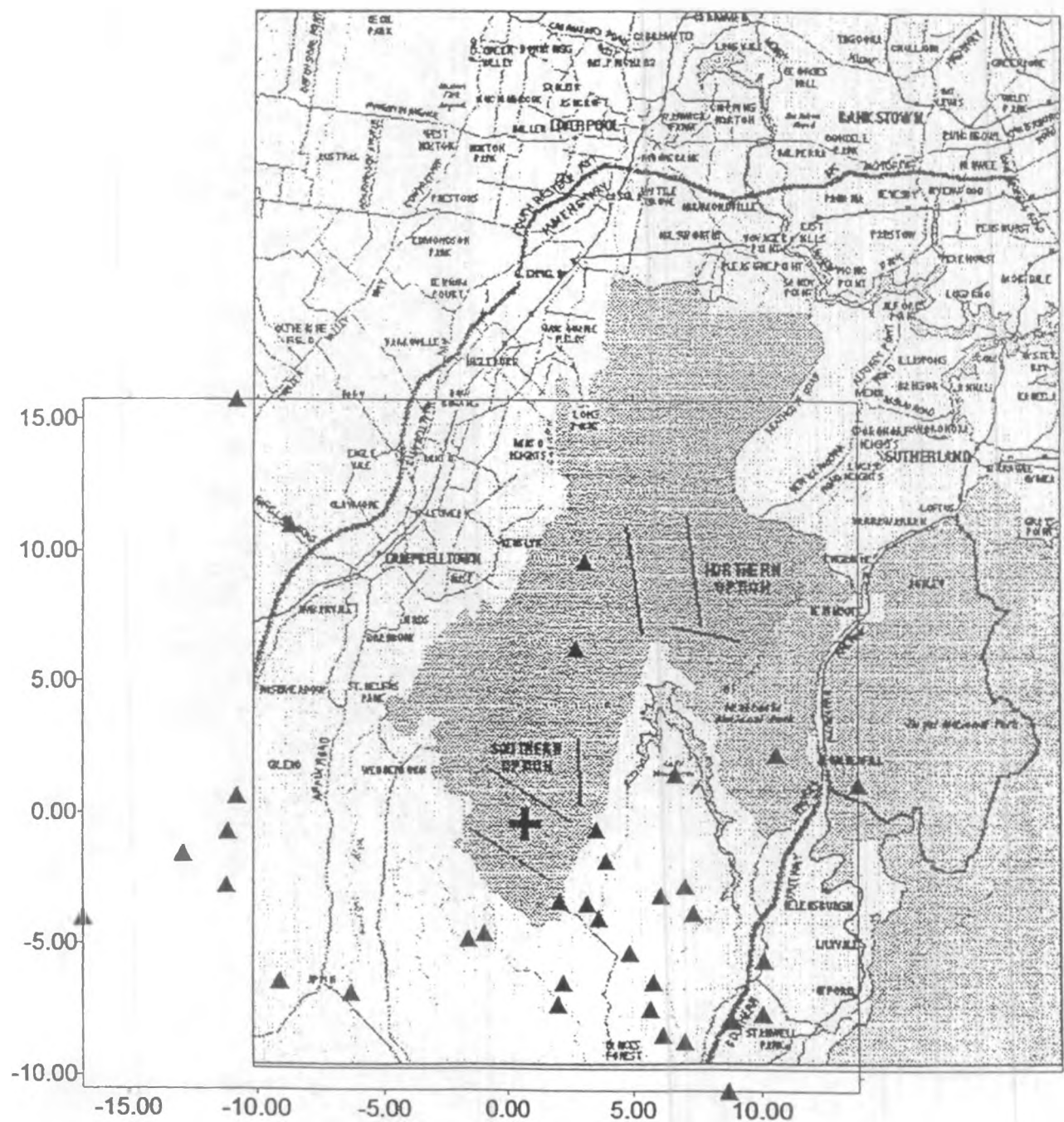


Figure 5.7: Estimated centroids of zones of maximum ozone impact for airport emissions from Holsworthy South judged from Botany Bay air quality and Lucas Heights wind data for 1994/1995. Each point is one hour downwind of the airport.



# **Appendix 1**

## Appendix 1

### A1.1 Pre-1990 (Sydney Oxidant Study, Hyde and Johnson).

There is a long history of ambient air quality monitoring in the Sydney air-shed, stretching back to the early 1970's. This monitoring occurred at a number of sites and showed that, even in the mid-1970's, significant concentrations of photochemical oxidants were occurring in the central Sydney area and at locations further west. A series of associated meteorological studies at a wide variety of sites was also being conducted by research workers at Macquarie University and other organisations. These studies culminated in the Sydney Oxidant Study which was reported in 1982. This study identified some of the main processes and conditions necessary for the formation of photochemical smog in the regions. The importance of seabreeze and drainage flow circulations was emphasised and preliminary work conducted on the likely causes of such high smog events.

During the same period detailed meteorological monitoring (both surface and upper-level) was being conducted by ANSTO at their Lucas Heights site (e.g. Clark 1986). This work is of particular interest to the current study as it included a climatological study of seabreeze occurrence and mixing depths. The Lucas Heights site is also fairly close to the proposed Holsworthy sites.

Other meteorological assessments have been carried out for the New South Wales region, including a series of balloon flights conducted by Malfroy et al (1985) at four sites, including the Hunter Valley, the Sydney area and a site near Wollongong. These studies consisted of surface and tethered balloon measurements of temperature and wind. From their results, a clear indication is given of the depths of morning drainage flows, the often quite complex wind profiles that can occur in such conditions, and the relatively low mixing depths that can occur during the passage of a seabreeze.

Of particular significance to the Sydney air-shed are the studies of the group at the CSIRO Division of Coal and Energy Technology during the 1980's. This group constructed and operated a smog chamber in which measurements could be made of the photochemical processes that can occur for sunlight conditions and using background air samples from the site at North Ryde. Controlled injections of various types and quantities of volatile organic compounds and nitrogen oxides allowed a determination of the important chemical processes and a parameterisation of the rate of smog formation under a wide range of conditions. This smog chamber studies resulted in both the semi-empirical IER model that has been used in the current project and in a more complex but still relatively straightforward set of chemical kinetic equations to describe the smog development. This work emphasised the division of photochemical formation into two phases, the first with hydrocarbons controlling the rate of smog formation and a second phase where smog formation is limited by the amount of nitrogen oxides in the air.

As a result of the above monitoring and laboratory work, a team of workers was able to produce an assimilation of the available Sydney information and provide an interpretation of the importance of photochemical smog and air quality in general. This was used for identifying potential air quality constraints on the development of the western Sydney suburbs. This work emphasised that, although the ozone levels in the near-coastal and central Sydney sub-regions had not risen over the past decade, the smog levels in the western suburbs have remained at their relatively high levels and were likely to worsen as urbanisation increased, despite the forecast decrease in per capita and per vehicle emission rates. This work led to a wider appreciation of the differences between controlling  $\text{NO}_x$  and VOC emissions in a large metropolitan air-shed such as Sydney. This work was subsequently extended to estimating the relative impacts of cogeneration facilities located at various locations in the Sydney air-shed (Johnson et al. 1993).

## **A1.2 Metropolitan Air Quality Study**

As a result of public concern on particular days of poor air quality and more recent air quality monitoring, the New South Wales Government commissioned a set of air quality projects for the period 1992-1996. This Metropolitan Air Quality Study (MAQS) consisted of four components. Firstly, the continuous air quality monitoring network was expanded considerably with an emphasis on providing more information in the inner suburbs of Sydney and those areas close to the Great Divide.

The second component consisted of an assimilation of the knowledge of meteorology of the region, together with various numerical simulations of windfields on days of particular interest. These days included the high oxidant days of the Sydney region, days for which the Sydney emissions might be carried to nearby districts such as the Hunter Valley and the Illawarra regions and other days on which an import of emissions into the Sydney air-shed could be substantiated.

The third component consisted of the construction of a detailed emissions inventory for the region for the year 1993. This emission inventory (Carnovale et al. 1995) used a variety of techniques, and provided a much sounder, more elaborate and comprehensive basis for determining the relative impact of various emissions sources in the Sydney air-shed than previous studies.

The fourth component (Cope and Ischtwan 1996(a)) consisted of the use of the photochemical modelling scheme developed by the Victorian EPA. For several days chosen from the windfield work, this detailed scheme was used to track the air parcel movement and chemical transformations that take place within the air-shed. The model utilised both a detailed (LCC) photochemistry scheme developed in the United States and the local GRS/IER description and accessed directly the detailed emissions inventory. The model could predict well several of the types of ozone exposures monitored at the various sites and showed that the Sydney air-shed in its western part was likely to experience  $\text{NO}_x$ -limited conditions on high ozone days. Under these conditions the addition of additional  $\text{NO}_x$  sources could give rise to higher concentrations of ozone downstream of the source.

The three-dimensional model was not particularly successful in forecasting the early-morning ozone events at various inland Sydney sites or in predicting the details of ozone concentrations during seabreeze conditions. Preliminary work with a one-dimensional Lagrangian box model and the IER chemistry showed encouraging agreement for this important set of events.

### **A1.3 Other EPANSW - commissioned studies.**

The Lidcombe monitoring station represents one of the longest continuous sets of records in the Sydney region. An analysis of the long-term trends in various pollution parameters, concentrating on the photochemical nature, suggested that there was a very large degree of inter-annual variability in maximum ozone concentrations that was unlikely to be explained by changes in emissions. The feasibility of a short-term (4 hour) and day-ahead ozone forecasting system was investigated (Lunney 1996, Katestone Scientific 1995).

The Bureau of Meteorology undertook a classification of the weather types for Sydney to determine whether the high interannual variability of ozone concentrations was likely to be related to a similar variability in synoptic conditions.

A long-term survey of fine particulate and aerosol levels at many locations throughout the Sydney air-shed has been conducted by ANSTO over the past 5 years. Measurements for one in every 6 days on a continuing basis and a chemical analysis of these samples have allowed a determination of the important sources of fine particulates throughout the region. Two of these sites have been relatively close to the existing Mascot Airport. The records for these sites have shown the importance of motor vehicle emissions.

### **A1.4 Recent EPANSW internal studies.**

Current interests within the EPANSW concern the division of the Sydney and associated regions into air quality zones and the development of a forecasting system for particulate and photochemical levels, both on a regional basis and for the air quality zones. Heip and Anh (1995,1996) have used a relatively simple statistical analysis of the long-term air quality records to obtain a fairly similar classification to that obtained from the IER chemical scheme, as previously determined by the CSIRO. Some of this work has been conducted in association with the CSIRO Division of Coal and Energy Technology and has a long-term aim to provide a new type of air-shed modelling for the region.

### **A1.5 Other transport related studies (RTA, Mascot Airport).**

In recognition of the importance of determining the local air quality impact of major transport routes, the Road Traffic Authority of New South Wales has undertaken a series of monitoring studies at key locations throughout the Sydney region. Continuous monitoring of key pollutants and meteorological variables has been undertaken at seven sites, each chosen to represent a typical main road situation (e.g. close to a freeway, an arterial road, a congested area such as a toll booth). This information has shown that the levels of nitrogen dioxide, although generally relatively low, can, on occasions, approach the national guidelines for sites within 15 metres of the road. A model validation study has shown that the predicted ground-level concentrations of nitrogen dioxide are likely to be over-predicted by the currently recommended CALINE-4



scheme. Similar results might be expected for other similar regulatory models such as the AUSPLUME and ISC3 models used in the current study.

The Federal Airport Commission has conducted a number of studies at Mascot area, including the air quality monitoring previously referenced, an evaluation of the odour characteristics of the ambient air near airport operations and a detailed emission inventory.

This brief review of relevant studies for the Sydney air-shed shows that there is now a sufficient database of monitoring information and knowledge of the main characteristics of the region to assess individual sub-regions for suitability of accommodating major new emission sources. Much is known about the necessary conditions for high smog days in Sydney but a set of sufficient conditions has yet to be demonstrated (in common with other Australian cities). The 1993 emissions inventory is a very useful tool for indicating the overall scale of airport emissions and for use in a detailed assessment.



## **Appendix F**

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### Respiratory Health Effects Report

# **Second Sydney Airport Environmental Impact Statement Technical Report on Respiratory Health Effects of Air Quality**

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**Department of Transport and Regional  
Development**

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## APPENDICES

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## **PART A: INTRODUCTION**

## 1

## OVERVIEW OF FINDINGS

An overview of the findings of this study is as follows:

- This paper provides an analysis of health impacts which could be expected to occur as a result of projected increases in ozone, nitrogen dioxide and particulate air pollution attributable to the Second Sydney Airport proposal.
- Asthma and chronic obstructive pulmonary disease are the two illnesses most relevant to concerns about air pollution. Asthma is an inflammatory disease of the airways characterised by episodes of airway narrowing causing wheeze, chest tightness and shortness of breath. Environmental exposure to allergens (such as house dust mite) is important in initiating and aggravating this disease. Chronic obstructive pulmonary disease (emphysema) is the end result of an accelerated decline in lung function over many years. Sufferers experience breathlessness on exertion. Cigarette smoking is the most important cause.
- Within the study area Campbelltown, Penrith and Wollondilly have the highest proportion of children and Hurstville has the most elderly residents.
- Overall asthma is not more common in Western and South Western Sydney than in other parts of Sydney and NSW. However, within this area, Campbelltown has a slightly higher proportion of adults who say they have asthma than other areas in South Western Sydney. Hospitalisation rates for lung disease are higher than average for Sydney in Blacktown, Auburn, Bankstown and Campbelltown, and hospital admission rates for children with asthma are higher in Bankstown and Blacktown. Death rates for lung and heart disease are higher than the NSW average in Hurstville but not in other parts of the study area.
- Exposure to ozone causes a transient reduction in breathing capacity, the extent of which is related to the ozone concentration, the duration of exposure and the level of activity undertaken during exercise. In many cases reduction in lung function is not accompanied by any symptoms, but some people (more commonly adults rather than children) experience chest discomfort or difficulty in taking a deep breath in. Individuals vary in their sensitivity to ozone but the elderly and those with pre-existing respiratory diseases (including asthma) are not more susceptible than others. The population sub-group most likely to be affected by ozone exposure are those whose work or recreation entails strenuous outdoor physical activity.

- There is evidence from some studies but not others that slightly more people die or are hospitalised for lung problems on high ozone pollution days than low ozone days. This seems to mainly affect the elderly and those with pre-existing heart or lung problems. It is not known whether these events (deaths or hospitalisations) are truly premature or they occur just a few days earlier than they otherwise would.
- Exposure to nitrogen dioxide at levels seen under ambient conditions does not cause any change in lung function in healthy people and probably only causes concern in people with asthma or other respiratory disease at levels above those found in outdoor air in Australia. The available data do not allow quantification of the relation between nitrogen dioxide exposure and changes in lung function at levels below 0.30 parts per million. Evidence that variation in nitrogen dioxide exposure is associated with risk of hospitalisation for respiratory disease is conflicting and there is evidence that nitrogen dioxide exposure is not linked to daily death rates.
- Increased exposure to particulate exposure is associated with increased symptoms and a small decrease in lung function. This has been most clearly shown in children and the effect is more marked in children with pre-existing respiratory disease such as asthma.
- It seems likely that mortality rates and hospitalisation rates for lung disease are slightly higher on high particulate pollution days than low pollution days. As stated above, it is not certain whether this represents a shift in these events from one day to another, nearby day, or it signals are true increase in premature deaths and hospitalisations.
- The air quality impact of the proposed Sydney Airport is expected to be a very small increase in ozone, nitrogen dioxide and particulate pollution on a few days each year (at either site). The estimated health effects associated with these small changes must be interpreted with caution.
- It is estimated that, on days when particulate (PM<sub>10</sub>) exposure increases by 3 micrograms per cubic metre the prevalence of cough will increase by 2.4 percent compared to lower pollution days. It is calculated that, across the study area, this may cause up to 300 people to report a single extra day of cough per year or one person to report an additional 300 days of cough per year (or any combination in between). This is most likely to affect children and people with pre-existing lung disease. The expected increases in ozone and nitrogen dioxide levels are unlikely to cause any additional symptoms.
- No clinically significant changes in lung function are anticipated.



- It is estimated that ozone events associated with the Second Sydney Airport may increase hospital admissions for respiratory disease by up to a total of 0.02 to 0.9 admissions per year and the mortality rate by up to 0.01 to 0.34 deaths per year. Particulate events may result in an additional 0.034 to 0.068 hospital admissions for respiratory disease each year and an additional 0.006 to 0.012 deaths per year. However, it is likely that even these very small numbers are an over-estimate of the effect over one year. This is because many admissions and deaths will simply be transferred from one day to an earlier day in the same year and this will not increase the total number occurring over one year. It is possible that the pollution exposures associated with the Second Sydney Airport will have no overall effect on hospital admission or death rates.
- It is concluded that the health impact of the infrequent, small increases in ozone, nitrogen dioxide and particulate pollution which are expected to occur cannot be estimated with certainty. However, it seems likely that very few, if any, people will experience serious acute adverse health effects which can be attributed to these pollution changes. For this reason it is difficult to distinguish between the site options on the basis of the health impact of changes in these pollutants.

## 2

## SCOPE OF STUDY

The Institute of Respiratory Medicine at the University of Sydney and Royal Prince Alfred Hospital was commissioned by PPK Environment & Infrastructure to undertake a study of potential effects of air pollution on respiratory health. The report was prepared by Dr Guy B Marks, Senior Research Fellow at the Institute.

This was in response to issues raised in the November 1996 Guidelines for conducting the Draft EIS which were developed by Environment Australia (formerly the Commonwealth Environment Protection Agency). The Guidelines (p.14) stated that the specific air quality issues to be considered and assessed included:

*“impact of changes to air quality on the health of potentially affected populations, including long and short term effects, impacts on especially sensitive groups (for example, children, the elderly, sufferers of respiratory illnesses such as asthma), and on childhood developments and learning”*

Thus the scope of this study was to:

- conduct a literature review; and
- assess potential adverse health effects, for example asthma, resulting from reduced air quality associated with each of the airport options.

While effects on childhood development and learning have not been specifically addressed, they have been assumed to be related both to asthma (which is covered in this study), and to the effects of airborne lead, which are discussed within *Technical Paper No. 6 - Air Quality*.

## 3

**BACKGROUND**

This paper provides an analysis of health impacts which can be expected to occur as a result of projected increases in ozone, nitrogen dioxide and particulate air pollution attributable to the Second Sydney Airport proposal.

An introduction to asthma and chronic obstructive pulmonary disease, the illnesses most relevant to concerns about air pollution, is followed by a description of some relevant health characteristics of the population in the EIS study areas. This is followed by a review of the range of health impacts which can be attributed to air pollution. The types of evidence linking air pollution to adverse health effects, the ways in which this evidence can be used to quantify the expected effects of changes in pollution, and the pitfalls and limitations of this approach are described.

For each pollutant the evidence linking exposure to adverse health effects is evaluated and used to quantify the expected effects in the EIS study areas. Conclusions are then drawn on the probability and extent of adverse health effects due to airport-associated air pollution and differences in these values between the proposed options.

### **3.1 SPECIFIC DISEASES RELEVANT TO AIR POLLUTION**

#### **3.1.1 ASTHMA**

Asthma is a chronic disorder of the airways which causes them to narrow too easily and too much in response to a wide range of stimuli. It is manifest as episodes of wheeze, chest tightness, shortness of breath and, sometimes, cough which are accompanied by reduced lung function. Airways of people with asthma usually exhibit a special form of inflammation which is present even when the person has no symptoms (Djukanovic, 1990). It is this inflammation which predisposes to episodic airway narrowing and hence symptoms (James, 1989). One of the key factors promoting inflammation is exposure to allergens (Custovic, 1996) although other factors probably also play a role. In Sydney most patients with asthma are allergic to house dust mite but many are also allergic to animal danders, pollens and moulds (Peat, 1995).

Asthma commonly starts in early childhood but may occur for the first time at any age. Being allergic to environmental allergens (such as house dust mite etc) is the strongest risk factor for having asthma (Peat, 1995). The most clearly identified environmental risk factors for the onset of asthma are the level of house dust mite allergen exposure in early life, maternal smoking during pregnancy, and, in adults, certain occupational exposures (Peat,

1996). There is no evidence that exposure to pollutants is important in the onset of asthma. Indeed there is contrary evidence. Comparison of more and less polluted cities in Europe demonstrates more cough and bronchitis symptoms among people living in the polluted cities but more allergy and asthma in the less polluted cities (Braback, 1994, von Mutius, 1994). Within New South Wales variation between communities in the prevalence of asthma in children was not related to ambient pollution levels (Peat, 1995).

Among people who have asthma various stimuli may cause exacerbations of the disease. These exacerbations may range from long-lasting and severe events to mild, transient events. The long-lasting exacerbations are commonly attributed to viral infections (Johnston, 1995), allergen exposure (Platts-Mills, 1995), or adverse reactions to certain medications. On the other hand transient airway narrowing is seen in response to a wide range of stimuli including: exercise, laughter, crying and coughing, ingesting certain food additives, inhaling strong smells and irritants such as perfumes, fly sprays, cigarette smoke, and sulphur dioxide, and breathing cold, dry air. Air pollutants probably play a role in the exacerbation of asthma. This is discussed further in Sections 3.3 and 3.4.

### **3.1.2 CHRONIC OBSTRUCTIVE PULMONARY DISEASE**

Chronic obstructive pulmonary disease refers to a group of diseases characterised by an irreversible reduction in expiratory airflow. Included in this disease category are patients with emphysema, many of those with chronic bronchitis and some with chronic asthma. Chronic obstructive pulmonary disease is the end result of an accelerated age-related decline in lung function over many years (Fletcher, 1976). Patients with chronic obstructive pulmonary disease have impaired lung function and complain of exertional breathlessness. In severe cases patients with this disease may be breathless even while resting. The end result of the slow progression of chronic obstructive pulmonary disease is death due to respiratory failure (ie lung function is insufficient to support life).

The most clearly established risk factor for the development of chronic obstructive pulmonary disease is smoking which both increases the rate of decline in lung function (for example, Fletcher, 1976) and induces an earlier onset of decline (Tager, 1988). The risks of symptoms (Lebowitz, 1981) and death (Doll, 1976) due to chronic obstructive pulmonary disease are strongly related to smoking. Occupational exposure to dust and fumes (Kauffmann, 1982) may also be a risk factor. It has recently been shown that early life, and even ante-natal, factors influence the risk of having impaired lung function in later life (Barker, 1991). The role of air pollution as a risk factor for chronic obstructive pulmonary disease will be discussed in Sections 3.3 and 3.4.

3.2 SUSCEPTIBLE POPULATIONS IN THE EIS STUDY AREAS

There is concern in the community that certain sub-groups may be more at risk to adverse health effects due to exposure to air pollutants. In this section the distribution of people at the extremes of age and those with pre-existing respiratory or cardiac illness is described. In the subsequent sections the special risk, if any, faced by these sub-groups is examined.

3.2.1 AGE STRUCTURE

Local government areas in western and south western Sydney were analysed for demographic variations. Several of the local government areas within the EIS study area have a greater number of children as a proportion of their total population than the Sydney average. The highest proportion of children is found in the Campbelltown, Penrith and Wollondilly local government areas (Figure 3.1). Hurstville has the lowest proportion of children and the highest proportion of people aged 65 years and over (Figure 3.2). Campbelltown, Penrith, Blacktown and Liverpool local government areas have a relatively low proportion of elderly residents.

Proportion of population under the age of 15

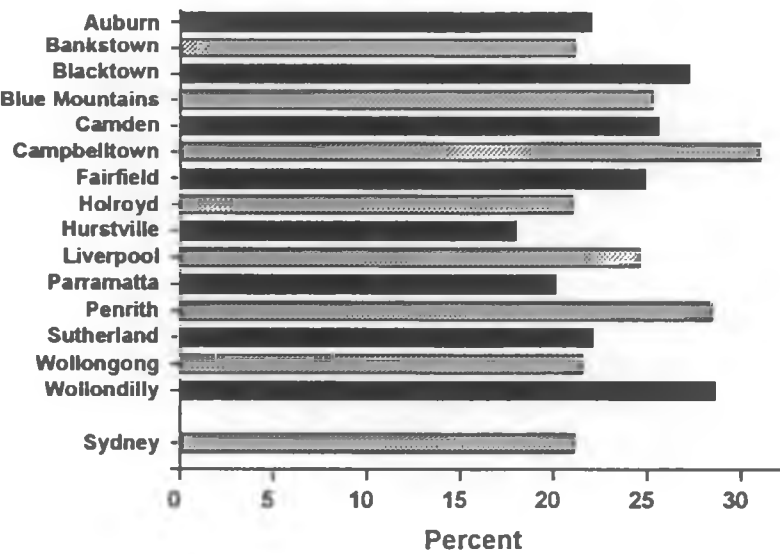


FIGURE 3.1 PROPORTION OF PEOPLE AGED LESS THAN 15 YEARS BY LOCAL GOVERNMENT AREA

Proportion of population 65 years or older

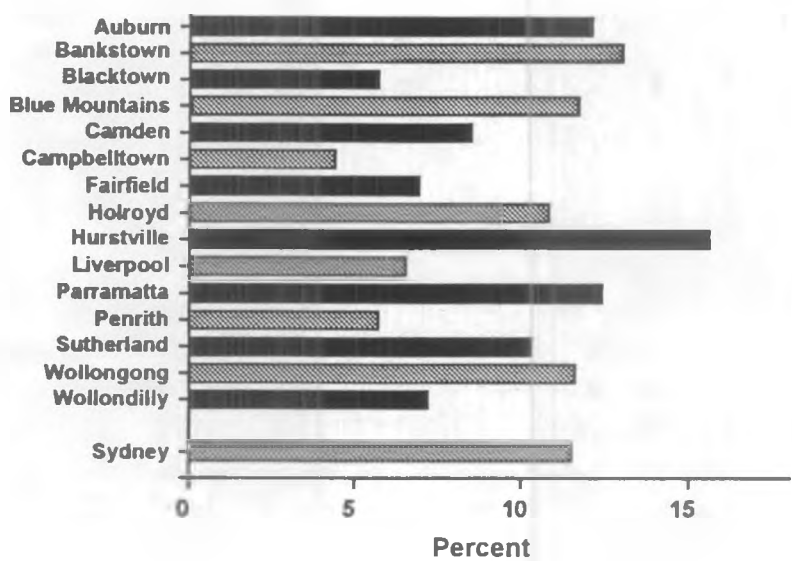


FIGURE 3.2 PROPORTION OF PEOPLE AGE 65 YEARS AND OVER BY LOCAL GOVERNMENT AREA

3.2.2 PREVALENCE OF ASTHMA

Measurement of the prevalence of disease in the community requires population surveys in which a randomly selected sample of people are examined. While many such surveys have been conducted in local areas in Australia and overseas there are no data which allow precise estimation of the prevalence of asthma in the EIS study areas.

Peat *et al* examined the prevalence of asthma among primary school children in seven areas of New South Wales, including the western Sydney corridor (Peat, 1995). Importantly they used exactly the same methods in all seven areas (including objective tests for airway abnormality and allergy) and hence their results allow a valid comparison to be made. Data for the western Sydney area were collected during 1993 from children attending schools in St Clair, Blacktown, Parramatta, Regents Park, Lurnea, and Campbelltown. Figure 3.3 shows the proportion of children in each area whose parents reported they had experienced symptoms of asthma (wheeze or cough at night) in the preceding 12 months.

### Prevalence of wheeze, night cough and current asthma in seven regions of NSW

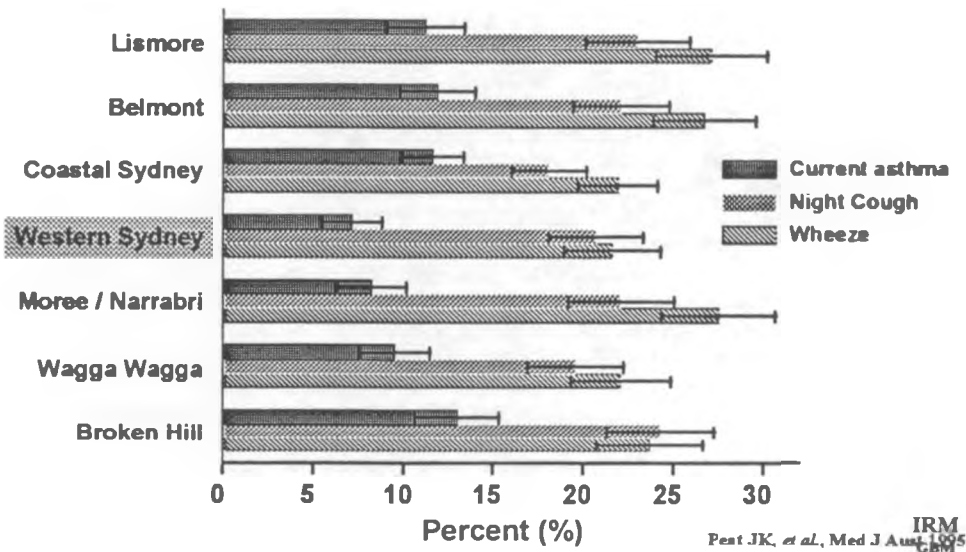


FIGURE 3.3 PREVALENCE OF REPORTED WHEEZE, NIGHT COUGH AND CURRENT ASTHMA AMONG 8 TO 11 YEAR OLD CHILDREN IN SEVEN AREAS OF NEW SOUTH WALES.

Lines represent 95 percent confidence intervals.  
Source: Peak J.K, et al, Medical Journal of Australia, 1995.

The term ‘current asthma’ in Figure 3.3 refers to those children who reported wheeze in the last 12 months and who also had airway hyperresponsiveness, an objectively measurable abnormal irritability of the airways which is characteristic of asthma. It is clear that, as a whole, the EIS study area does not have a higher prevalence of asthma than other areas in NSW.

Some questionnaire-based health surveys have been conducted in the study area by government agencies. These surveys have collected information on subject-reported diagnoses of asthma. Unfortunately, this information is greatly influenced by the inclination of doctors to diagnose asthma and likelihood that patients will recall this diagnosis (Burney, 1992). Regional variation in these attributes may be as large as variation in the actual prevalence of asthma, making the results of surveys based on doctors’ diagnoses of asthma difficult to interpret.

During 1994, NSW Health conducted a State-wide Health Promotion Survey among adults (aged 18 and over). Figure 3.4 shows the proportion of people in each NSW Health Area who stated that they had been diagnosed with asthma and still had it. There is little variation across the State and no evidence that the prevalence is higher in western, south western or southern Sydney. (Health Promotion Survey 1994, Health Promotion Branch, NSW Health Department)

Diagnosed asthma - still present  
NSW Health Promotion Survey 1994

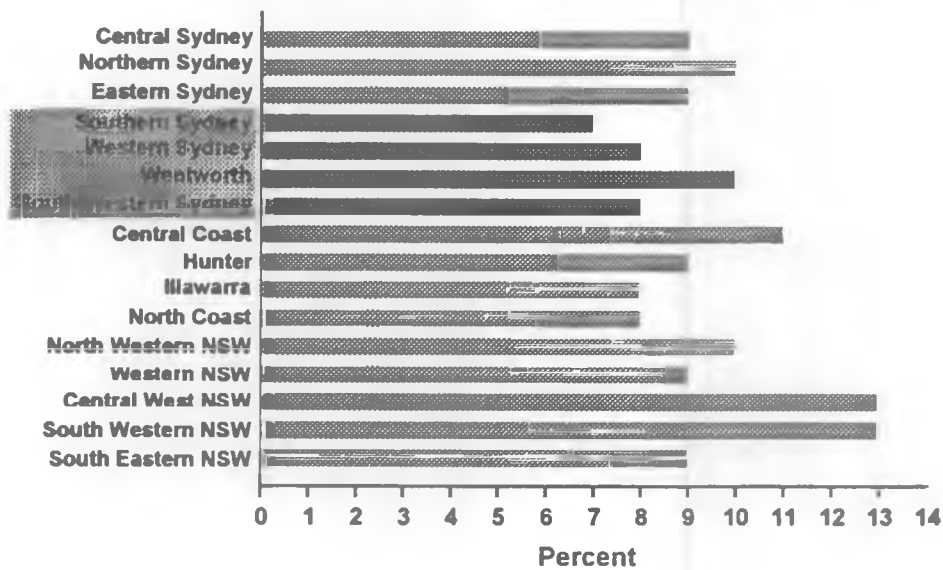


FIGURE 3.4 PREVALENCE OF DIAGNOSED ASTHMA WHICH WAS STILL PRESENT AMONG ADULTS SURVEYED IN THE 1994 NSW HEALTH PROMOTION SURVEY (NSW HEALTH).

The South Western Sydney Area Health Service Public Health Unit conducted a more detailed survey, using a similar methodology, in their Area in 1995. The prevalence of a reported diagnosis of asthma in health sectors equivalent to local government areas is shown in *Figure 3.5*.

The numbers are not directly comparable with those from the 1994 Survey (*Figure 3.4*) because they include people who have ever been diagnosed with asthma (ie not just those who still have asthma). There is significant variation among the health sectors ( $P = 0.004$ ) with Fairfield having a prevalence below the Area average ( $P = 0.006$ ) and Campbelltown having a prevalence above the Area average ( $P = 0.03$ ). The prevalence in the other sectors was not significantly different from the Area average. (*South Western Sydney Health Promotional Survey 1995, Epidemiology and Health Promotion Units, South Western Sydney Area Health Service*).



## Ever diagnosed asthma

### *South Western Sydney Health Promotion Survey 1995*

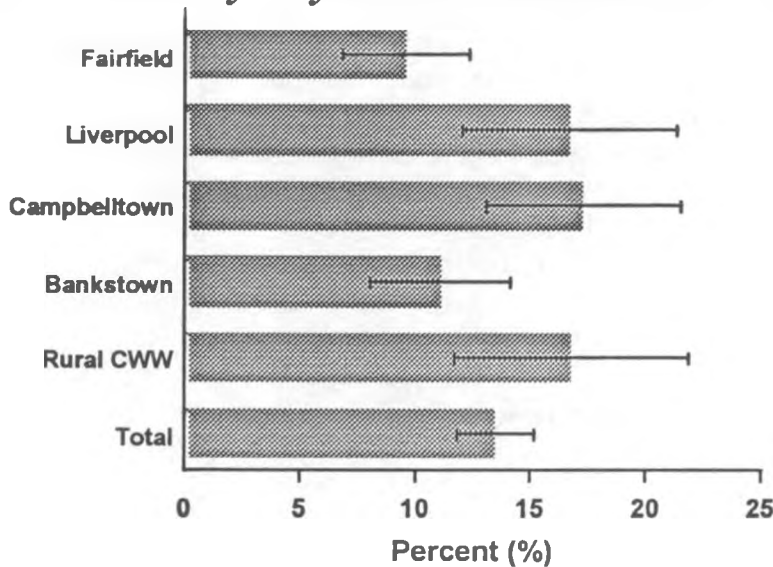


FIGURE 3.5 PREVALENCE OF DIAGNOSED ASTHMA (EVER) AMONG ADULTS IN SOUTH WESTERN SYDNEY BY HEALTH SECTOR (EQUIVALENT TO LOCAL GOVERNMENT AREA).

Error bars represent the 95 percent confidence interval. CWW refers to combined data for Camden, Wollondilly and Wingecarribee local government areas.

Source: Health Promotion Unit and Epidemiology Unit, South Western Sydney Area Health Service.

Taken as a whole the areas of western and south western Sydney do not have more asthma or respiratory illness than the rest of Sydney. However, within south western Sydney, Campbelltown has a slightly higher proportion of adults who report a diagnosis of asthma than other local government areas.

### 3.2.3 HOSPITALISATION AND DEATH RATES FOR ASTHMA, OTHER RESPIRATORY DISEASE AND HEART DISEASE

Since detailed prevalence data are not available for most local areas, it is common practice to examine hospitalisation rates for asthma, respiratory disease and heart disease. However, these data really provide information on a combination of factors including the prevalence of the disease, the frequency of severe exacerbations, and the inclination of doctors in the area to hospitalise patients.

Local death rates for specific diseases give some information about the problem caused by those diseases. This rate is influenced by the prevalence and severity of the disease, factors which cause severe or fatal exacerbations of the disease and the standard of medical care which is available.

Data on hospital separation rates (*NSW Inpatients Statistics Collection and Australian Bureau of Statistics population estimates (HOIST)*), Epidemiology

and Surveillance Branch, NSW Health) and death rates (Australian Bureau of Statistics mortality data and population estimates (HOIST), Epidemiology and Surveillance Branch, NSW Health Department) for respiratory and circulatory disease among people living in each local government area in the study area were obtained from the NSW Health Department. Separation rates refers to the number of people admitted to hospital and then discharged with a specific diagnosis. The rates were adjusted to take into account differences in age distribution between local government areas. Data for the Sydney metropolitan area and for NSW as a whole were also obtained.

These data show that, within the study area, only Blacktown had admission rates for respiratory disease which were higher than the State average (Figure 3.6).

Separation rates for Respiratory Diseases - all ages

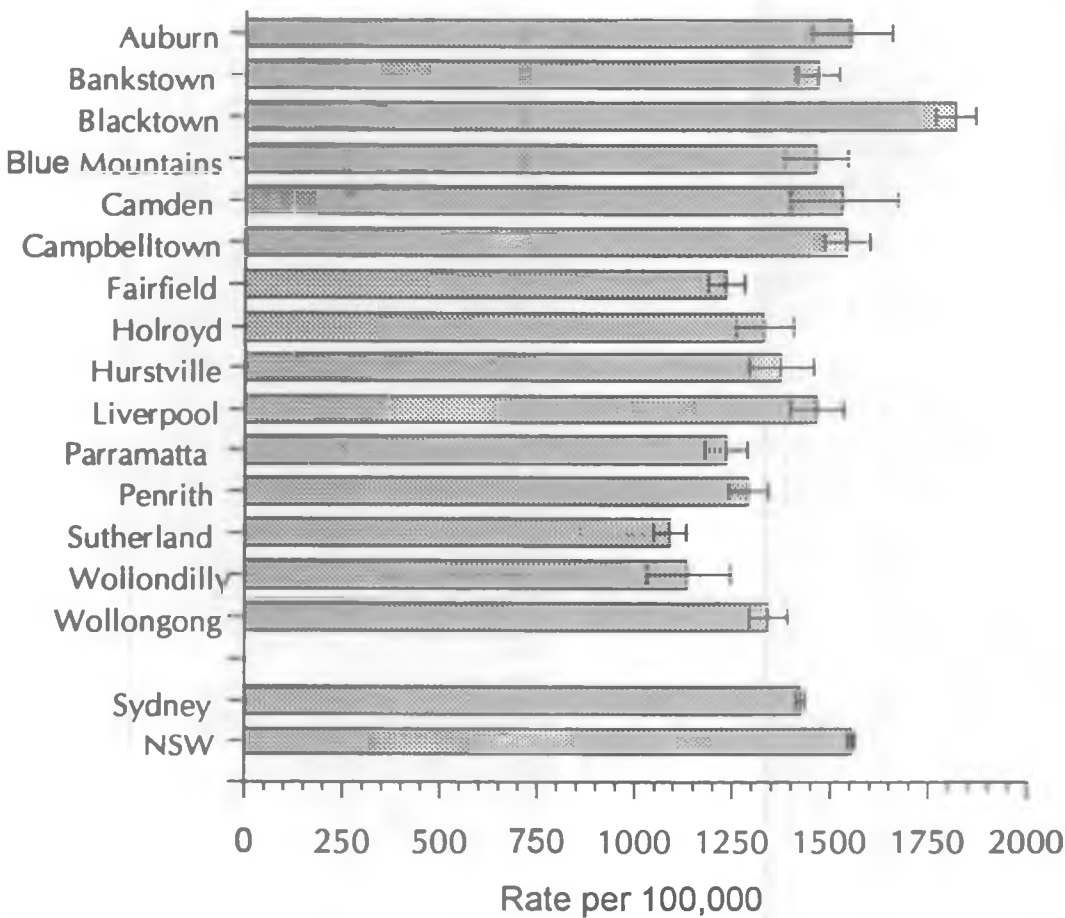


FIGURE 3.6 AGE STANDARDISED HOSPITAL SEPARATION (ADMISSION) RATES FOR RESPIRATORY DISEASE BY LOCAL GOVERNMENT AREA, IN THE SYDNEY AREA (1990 TO 1994)

Error bars represent the 95 percent confidence interval.  
Source: NSW Inpatients Statistics Collection and Australian Bureau of Statistics population estimates (HOIST), Epidemiology and Surveillance Branch, NSW Health.

In addition, rates in Auburn, Bankstown and Campbelltown were higher than the average for metropolitan Sydney. For circulatory diseases (mainly affecting the heart and blood vessels), admission rates were higher than average in Bankstown, Wollongong and Auburn (Figure 3.7). Hospitalisation rates for asthma among children were significantly higher than the Sydney average in Blacktown and Bankstown (Figure 3.8).

Separation rates for Diseases of the Circulatory System  
- all ages

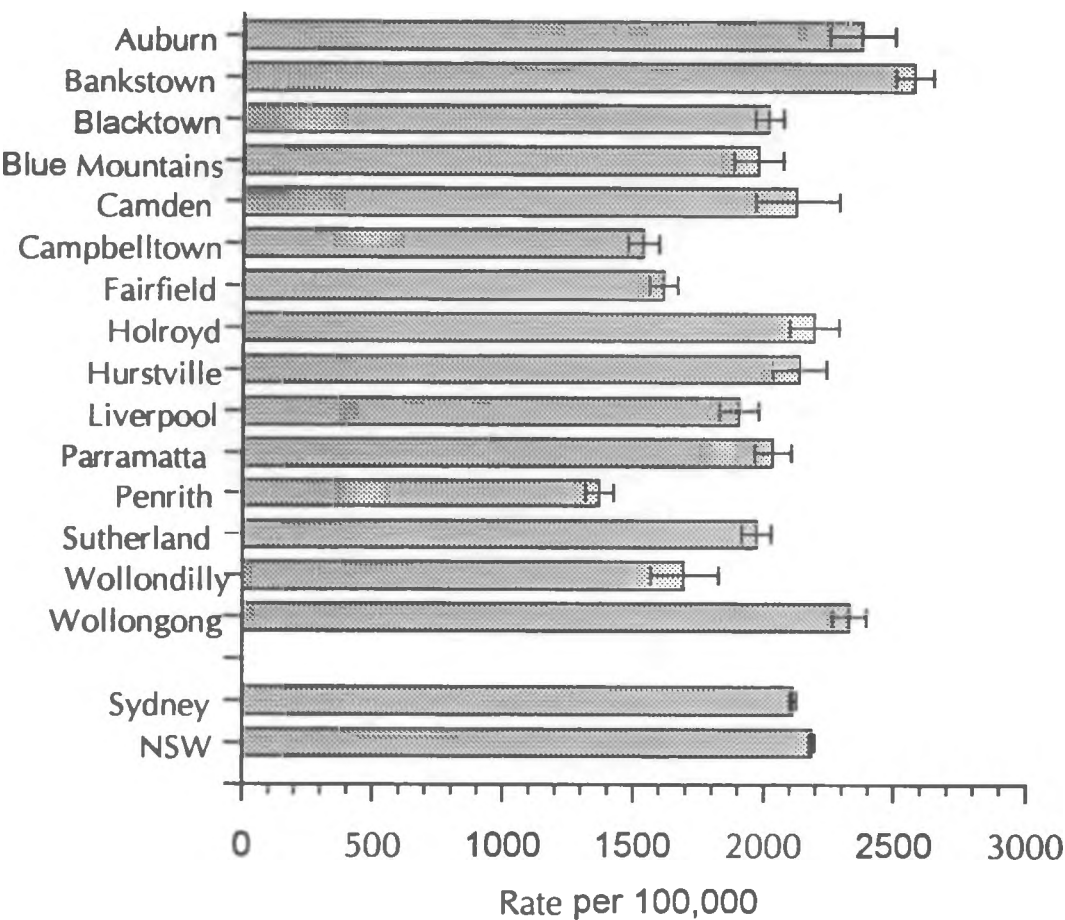


FIGURE 3.7. AGE STANDARDISED HOSPITAL SEPARATION (ADMISSION) RATES FOR DISEASES OF THE CIRCULATORY SYSTEM BY LOCAL GOVERNMENT AREA, IN THE STUDY AREA (1994 TO 1995).

Error bars represent the 95 percent confidence interval.  
Source: NSW Inpatients Statistics Collection and Australian Bureau of Statistics population estimates (HOIST), Epidemiology and Surveillance Branch, NSW Health.

### Separation rates for Asthma - 0 to 14 year olds

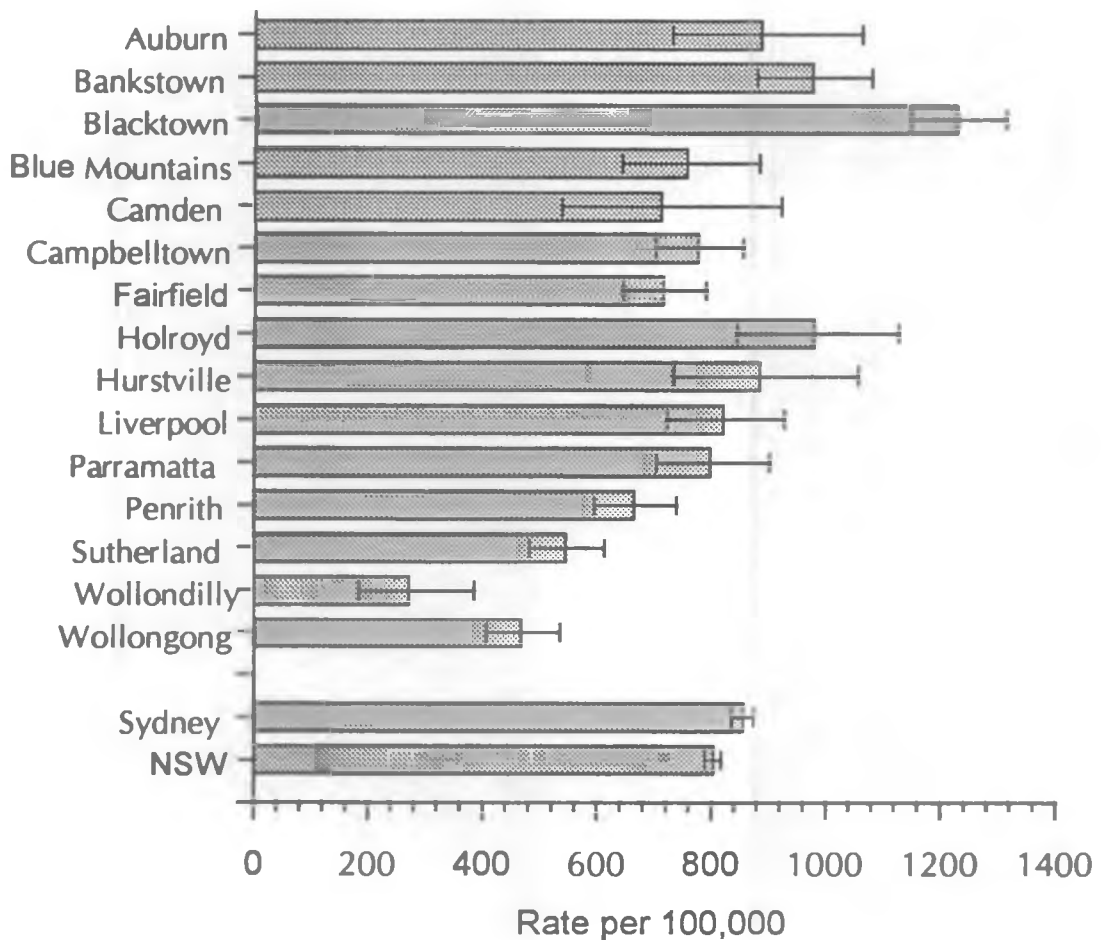


FIGURE 3.8. HOSPITAL SEPARATION (ADMISSION) RATES FOR ASTHMA AMONG 0 TO 14 YEAR OLDS BY LOCAL GOVERNMENT AREA IN THE STUDY AREA (1994 TO 1995).

Error bars represent the 95 percent confidence interval.

Source: NSW Inpatients Statistics Collection and Australian Bureau of Statistics population estimates (HOIST), Epidemiology and Surveillance Branch, NSW Health.

Death rates for diseases of the respiratory system were significantly higher than the State and metropolitan Sydney average in Hurstville (*Figure 3.9*). Death rates for diseases of the circulatory system were higher than average in Hurstville and Parramatta (*Figure 3.10*). Deaths due to asthma were too rare to make meaningful comparisons between local government areas.

Deaths due to Respiratory Diseases - all ages

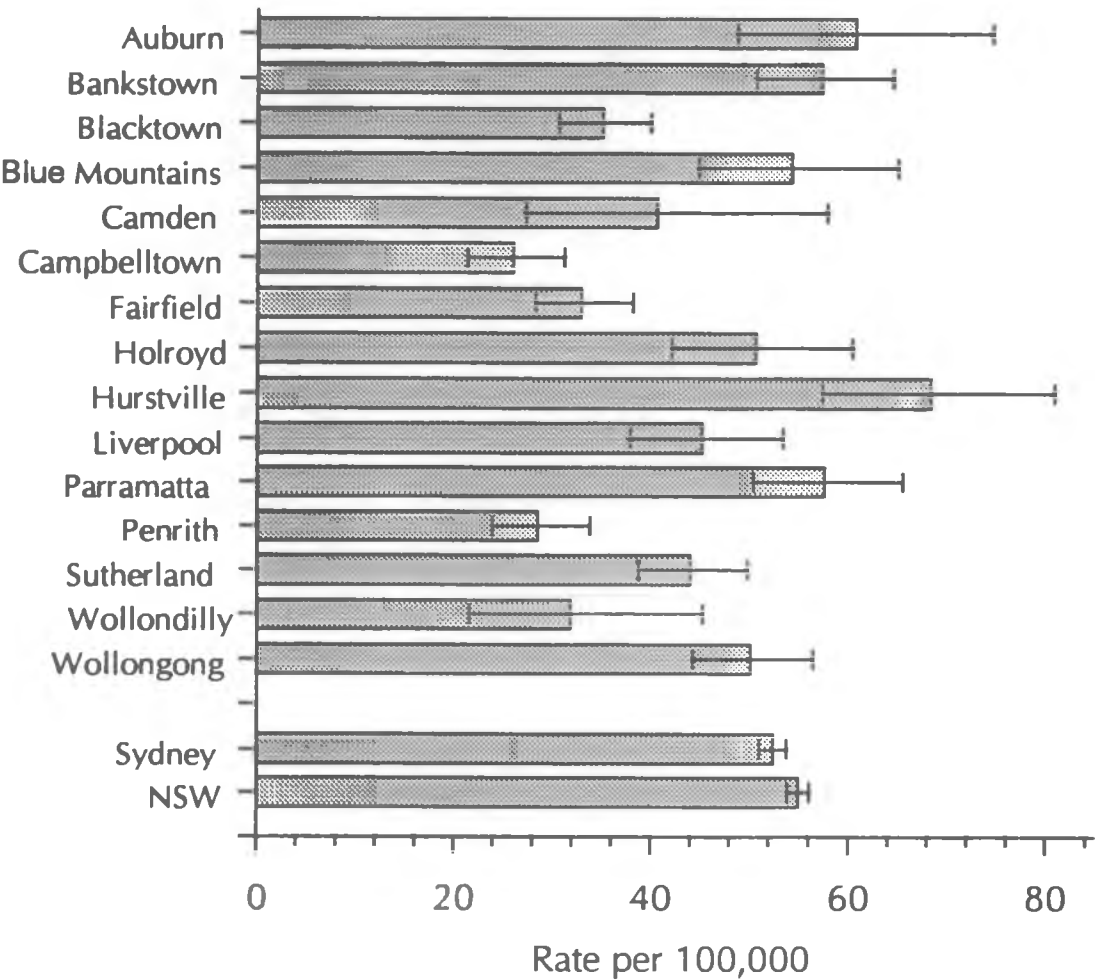


FIGURE 3.9. AGE STANDARDISED DEATH RATES FOR RESPIRATORY DISEASE BY LOCAL GOVERNMENT AREA IN THE STUDY AREA (1990 TO 1994).

Error bars represent the 95 percent confidence interval.  
Source: Australian Bureau of Statistics mortality data and population estimates (HOIST), Epidemiology and Surveillance Branch, NSW Health.

## Deaths due to Diseases of the Circulatory System - all ages

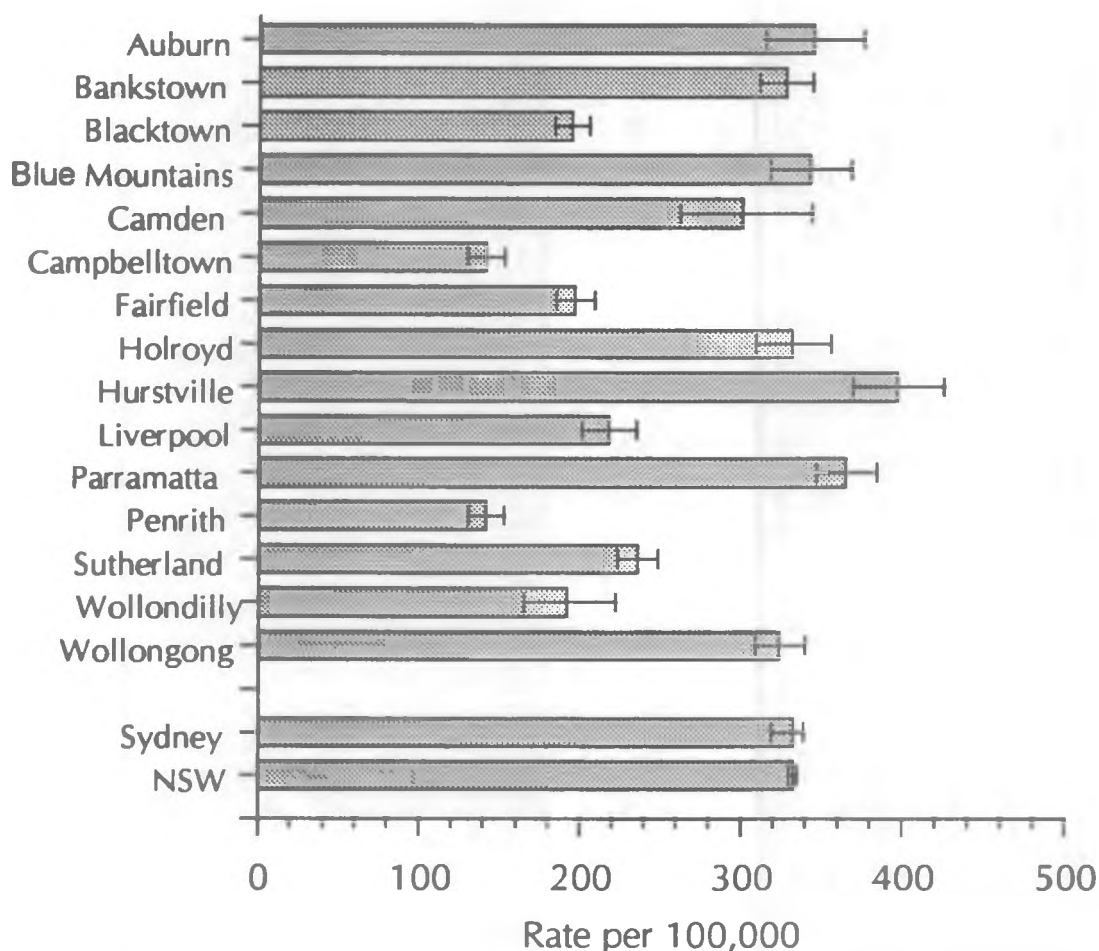


FIGURE 3.10 AGE STANDARDISED DEATH RATES FOR DISEASES OF THE CIRCULATORY SYSTEM BY LOCAL GOVERNMENT AREA IN THE STUDY AREA (1990 TO 1994).

Error bars represent the 95 percent confidence interval.

Source: Australian Bureau of Statistics mortality data and population estimates (HOIST), Epidemiology and Surveillance Branch, NSW Health.

### 3.3 WAYS IN WHICH AIR POLLUTANTS CAN AFFECT HEALTH

Gases, vapours and particles in the air can cause problems for people when they come into contact with relatively unprotected parts of the body. The skin is well protected and generally not susceptible to air pollution effects. Most effects of air pollutants occur on the surfaces of the eyes, nose, mouth and throat and in the lungs. It is possible that some reactions occurring deep in the lungs may have more widespread effects on the body. The site within the body which is most at risk depends on physical and chemical characteristics of the specific pollutant: for example, particle size, gas solubility and chemical reactivity. The characteristics of ozone, nitrogen

dioxide and particulates, and the way in which they can cause adverse health effects, are described in *Chapter 5*.

The potential short-term adverse effects of exposure to air pollutants include the occurrence of discomforting symptoms and a decrease in the ability to perform tasks. The symptoms may be irritation of the eyes, nose, mouth and throat, breathlessness, wheeze or chest tightness and discomfort. The main disability seen is reduced exercise capacity. Transient impairment of the lung function may occur and is relevant mainly as an objective indicator of risk of respiratory symptoms or disability. The spectrum of severity of possible health impacts ranges from mild symptoms or disability through to illness episodes severe enough to warrant medical attention or hospitalisation, to rare episodes resulting in premature death.

The evidence linking these adverse health impacts with exposure to ozone, nitrogen dioxide and particulate air pollution is discussed in *Sections 5,6 and 7*.

### **3.4 TYPES OF EVIDENCE LINKING AIR POLLUTION TO HEALTH OUTCOMES**

There are several different lines of experimental and observational evidence linking exposure to air pollutants to adverse health effects. Each type of investigation has strengths and weaknesses and no single study can be interpreted as conclusive.

Experimental studies in humans entail exposing volunteers to a specified pollutant or combination of pollutants while measuring their response. This type of study is commonly used to investigate the short term effects of ozone, which is a single chemical entity, but is not feasible for particulates since they occur as a heterogeneous mixture which varies from place to place. The possible impact of external factors is removed by the use of a randomised controlled trial format. With this experimental design the investigator can be certain that any observed effect is attributable to the pollutant being tested. However, this is also a disadvantage of these exposure chamber studies since the other environmental factors may be important in enhancing (or ameliorating) the pollutant effect in real life. Experimental studies in humans can only be used to study transient effects of pollutants.

Animal experiments enable mechanisms of adverse effects to be shown and may be used to investigate long term effects (Chitano, 1995). However, it is very difficult to relate levels of exposure in animals to those which are relevant to humans and hence these data are not reviewed within this report.

A common form of observational study is the short-term panel or cohort study. A group of volunteers (for example, at a summer camp or a school)

record symptoms and lung function measurements every day over a period of weeks or months during which time air pollutants and other environmental variables are measured at the site. This is a more powerful way of assessing air pollution effects but it is often difficult to separate out the relative importance of specific pollutants.

Investigations of the types described above provide valuable information on the relation between exposure to pollutants and human physiology and can detect subtle effects. However, it can be difficult to extrapolate the information that they provide to health effects which are of public health importance. For example, risks for new onset of asthma, severe exacerbations of respiratory disease, hospitalisation and death cannot be evaluated in these small populations of volunteers. Data on these important outcomes can only be obtained by observing large populations. Unfortunately, there are many extraneous factors, for example socio-economic factors, distribution of occupations, ethnic mix, and current and previous smoking prevalence, which cannot be adequately measured or adjusted for in these observational studies. It is often impossible to tell whether the health effect is actually attributable to exposure to the pollutant or rather to one of these extraneous factors (confounders). Furthermore, the actual pollution intake of individuals cannot be directly measured. Hence, the limitation of such studies is that the link between the air pollutant exposure and a corresponding health outcome is less certain.

In summary, understanding the adverse health effects of air pollutants requires the evaluation of range of different types of evidence: each of which has important advantages and limitations. Conclusions must be drawn from the synthesis of these sources.

### **3.4.1 INTERPRETING CHANGES IN LUNG FUNCTION**

The rate and total volume of air which can be forcibly exhaled after a full, deep inhalation can, be measured and is used as an index of the state of a person's airways. The rate of exhalation is quantified as the volume expired in the first second, known as the forced expiratory volume-one second (FEV<sub>1</sub>), or as the peak expiratory flow rate (PEFR), and the total volume is referred to as the forced vital capacity. (FVC)

Many studies use changes in the rate of exhalation (measured as FEV<sub>1</sub>) as an outcome variable to assess the impact of exposure to pollutants. Interpreting these studies requires knowledge of what represents a clinically important transient change in lung function. There is evidence of asymptomatic variability in lung function over the course of the day in healthy subjects (Higgins, 1989) and, in clinical practice, induced or spontaneous changes in FEV<sub>1</sub> of the order of 15 to 20 percent are needed to support the diagnosis of asthma. The US Environment Protection Agency expert panel concluded that



a greater than 10 percent fall in FEV<sub>1</sub> should be regarded as an adverse effect (United States Congress Office of Technology Assessment, 1989). A FEV<sub>1</sub> reduction of less than five percent is clearly not clinically important; however, there is some uncertainty about the importance of a transient five to 10 percent fall in FEV<sub>1</sub>.

### **3.4.2 HOSPITAL UTILISATION AND DEATHS**

Patients with severe exacerbations of illness may require hospital care. Hence, day to day fluctuations in hospital attendance rates are a useful marker of short term variation in factors contributing to exacerbations of illness. Time series analysis, with adjustment for variation in other possibly related factors such as temperature, humidity, day of the week, season, influenza epidemics and hospital strikes, is used to test the relation between the level of pollution on a given day and the risk of hospital attendance for respiratory illness on that day. A similar method is used to examine the effect of air pollution on the risk of dying on a given day.

The problem in interpreting these data is that they only tell us about the events occurring on a single day. We have no way of knowing whether the air pollution event caused a hospitalisation or death which would not otherwise have occurred (at least not for a long time) or simply caused it to happen a day or two earlier than it otherwise would. The public health importance of these two alternative scenarios is substantially different.

## 4

**METHODOLOGY****4.1 LITERATURE REVIEW AND QUANTIFYING RISKS**

A previous review of the literature concerning adverse respiratory health effects of ozone and particulate pollution (Marks, 1994) was updated. The 1992 to 1997 Medline database was searched for human studies dealing with the adverse effects of particulate pollution, ozone and nitrogen dioxide exposure.

Evidence for associations between pollutant exposures and health outcomes was reviewed and regression coefficients and rate ratios quantifying these relations were tabulated.

Where it could be concluded that an association between a pollutant exposure and an adverse health outcome does exist, a summary measure of that association was selected. In cases where a comprehensive meta-analysis or a single very large study had been conducted, the summary estimate from that analysis was selected. In other cases, where the data were in such a form that a weighted average of individual study's measures of association could be calculated, this was done. For each calculated summary measure of association the range of values for that measure which could be consistent with the data (the 95 percent confidence interval), was also calculated. Unfortunately, in some cases there was no obvious way to combine the data from several studies which used quite different methods to derive their principal outcome measures. In these instances, a reasonable summary measure has been selected by inspection of the tabulated data.

**4.2 APPLICATION OF LITERATURE FINDINGS TO THE EIS STUDY AREAS**

Estimation of the adverse health impact of the five alternative airport options, proceeded in the following steps:

- the magnitude of lung function changes and frequency (or risk) of symptoms, hospitalisation and death was calculated for a 3 micrograms per cubic metre increase in PM<sub>10</sub> pollution and 0.01 parts per million increases in one hour ozone levels;
- The populations affected by 3 micrograms per cubic metre increases in PM<sub>10</sub> pollution, 0.01 parts per million increases in one hour ozone levels, and 0.05 parts per million increases in one hour nitrogen dioxide levels were estimated for each of the five airport scenarios;

- the impact on these populations of projected changes in air pollution, due to each of the Second Sydney Airport options, was calculated.

**PART B: LITERATURE REVIEW: HEALTH  
EFFECTS OF POLLUTANTS**

## 5

## OZONE

### 5.1 PHYSICO-CHEMICAL FEATURES RELEVANT TO HEALTH EFFECTS

Ozone is an insoluble gas which means it can exert effects throughout the airways from the mouth to the periphery of the lung (Sandstrom, 1995). As a highly reactive chemical with potent oxidant activity, it produces direct and indirect toxic effects on cell constituents (Sandstrom, 1995).

There are few domestic indoor sources of ozone. Furthermore, ozone which enters the house from outdoors is quickly inactivated by a chemical reaction with household surfaces. Hence ozone is predominantly an outdoor pollutant.

### 5.2 CURRENT AIR QUALITY GOALS

The current Australian air quality goals for ozone are 0.10 parts per million averaged over one hour and 0.08 parts per million averaged over four hours.

### 5.3 SHORT-TERM HEALTH EFFECTS

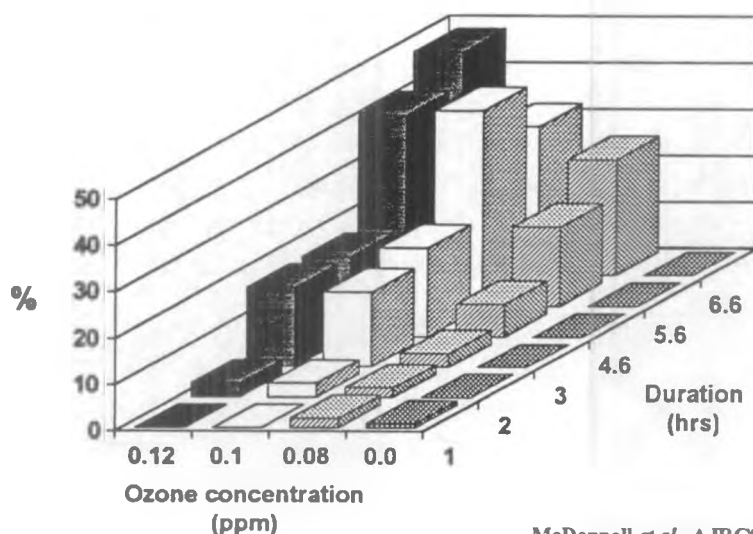
#### 5.3.1 RESULTS OF EXPERIMENTAL STUDIES IN HUMANS

The short-term effects of ozone on lung function have been extensively investigated in exposure chamber studies. Detailed reviews of this research have been published previously (Lippmann, 1989; Marks, 1994; Koenig, 1995; Sandstrom, 1995; Woodward, 1995). The key conclusions from this research are summarised as follows:

- the impact of ozone on lung function is dependent on the concentration of ozone and the duration of exposure. Prolonged exposures to levels as low as 0.08 parts per million during exercise can be associated with clinically relevant reductions in FEV<sub>1</sub> (forced expiratory volume-one second) (Horstman; 1990, McDonnell, 1991). For example, among young adults exercising for 6.6 hours during exposure to 0.12 parts per million ozone, 47 percent can be expected to experience a 10 percent or greater decrease in FEV<sub>1</sub> (*Figure 5.1*) (McDonnell, 1995). However, brief exposures are much less likely to induce such changes (Avol, 1984, Kulle, 1985, Linn, 1986);

## Effect of ozone exposure

### Proportion experiencing $\geq 10\%$ decrease in FEV<sub>1</sub>



McDonnell *et al.*, AJRCCM 1995; 152:589-96

FIGURE 5.1 PROPORTION OF ADULT SUBJECTS EXPERIENCING A GREATER THAN 10 PERCENT FALL IN FEV<sub>1</sub> BY DURATION AND LEVEL OF OZONE EXPOSURE.

Source: McDonnell *et al.*, AJRCCM 1995; 152:589-96

- the lung function response to ozone exposure is proportional to the level of exercise (and hence the ventilation, or breathing rate) being undertaken during the exposure (McKittrick, 1995);
- lung function changes may persist for 24 hours after the episode of exposure (Weinmann, 1995b). Furthermore, repeated exposure to ozone after 24 hours leads to an enhanced lung function response (Bedi, 1985; Brookes, 1989; Schonfeld, 1989). However, these prolonged effects have only been demonstrated after relatively high level exposures;
- the effect of ozone is not substantially enhanced by exposure to sulphur dioxide or nitrogen dioxide at the same time (Folinsbee, 1981; Bedi, 1982; Hazucha, 1994);
- increases in airway responsiveness to non-specific inhaled stimuli (ie airway "twitchiness" or irritability) have been seen in healthy subjects during or after exposure to ozone at levels above 0.35 parts per million for one or two hours (Seltzer, 1986; Kreit, 1989; Lippmann, 1989). Under conditions of strenuous exertion or prolonged exposure this effect is seen at lower levels of ozone (Gong, 1986; Horstman, 1990; McDonnell, 1991). While substantially increased airway responsiveness (or airway hyperresponsiveness) is a characteristic feature of asthma, the

clinical significance of minor increases in airway responsiveness is unknown;

- coughing, pain on taking a deep breath, chest discomfort, shortness of breath and chest tightness have all been observed after exposure to ozone concentrations equal to or greater than 0.15 parts per million. Symptoms are more likely to occur in adults than children;
- there is marked variability among individuals in responsiveness to ozone (Weinmann, 1995a) but this does not seem to be related to pre-existing disease or age (Sandstrom, 1995).

people with asthma, chronic obstructive pulmonary disease or pre-existing respiratory symptoms do not have an enhanced lung function response to ozone (Linn, 1982; Solic, 1982; Koenig, 1987; Koenig, 1988a; Koenig, 1988b; Koenig, 1990; Hoek, 1993; Scannell, 1996). However, in one study patients with chronic obstructive pulmonary disease demonstrated a small reduction in arterial oxygen saturation (Solic, 1982) the clinical significance of which is uncertain; and

- older adults are less responsive to ozone exposure than younger adults (Drechsler-Parks, 1989). Within the adult age range, the response to ozone decreases with increasing age (Seal, 1996);
- smokers are less responsive to ozone than non-smokers, both in terms of symptoms and reduction in lung function (Frampton, 1997)
- ozone does not enhance the susceptibility of people with asthma to experience transient airway narrowing after exercise (Fernandes, 1994, Weyner, 1994) but it does enhance the response to subsequent inhalation of sulphur dioxide (Koenig, 1990) and allergens (Molfino, 1991, Jorres, 1996). It is clear that this increased allergen responsiveness occurs after high level exposures to ozone but it is not yet established whether it occurs with low level exposure; and
- exposure to a high concentration of ozone (0.4 parts per million) increases the extent of airway narrowing which can be induced by other non-specific inhaled stimuli (Hiltermann, 1995). This effect is observed both in people with asthma and in non-asthmatic subjects. The effect of exposure to lower levels of ozone is not known.

### 5.3.2 QUANTIFYING THE RELATION BETWEEN OZONE CONCENTRATION AND CHANGE IN LUNG FUNCTION

McDonnell and colleagues measured change in FEV<sub>1</sub> (litres) in 290 healthy, non-smoking males aged 18 to 35 exposed to clean air or one of several concentrations of ozone (0.12 parts per million to 0.40 parts per million) for

two hours during moderate, intermittent exercise (McDonnell, 1993). They estimated that the expected decrease in FEV<sub>1</sub> (in litres) over the exposure period would be:

$$0.773 / [1 + e^{-20.35(\text{ozone} - 0.178)}]$$

Over the age range included in this study the expected decrease in FEV<sub>1</sub> (litre) diminished with age:

$$[0.855 - 0.053(\text{age} - 23.17)] / [1 + e^{-14.33(\text{ozone} - 0.197)}]$$

In a similar study of 372 men and women, it was estimated (Seal, 1996) the percentage change in FEV<sub>1</sub> from baseline would be:

$$28.5 / [1 + e^{-10.5(\text{ozone} - 0.275)}]$$

or, with adjustment for age:

$$[27.7 - 1.12(\text{age} - 23.9)] / [1 + e^{-10.6(\text{ozone} - .271)}]$$

In both instances ozone concentration and age only explained 35 percent of the variation in change in FEV<sub>1</sub>. Even after allowing for the decrease in responsiveness with increasing age, this is a large degree of unexplained variation between individuals in responsiveness to ozone.

5.3.3 COHORT OR PANEL STUDIES

A number of panel or short-term cohort studies have evaluated the relation between day-to-day variation in pollutant levels and changes in lung function. This relation is summarised for each child as a regression coefficient which is then averaged across the study population. The mean regression coefficient represents the change in FEV<sub>1</sub> predicted to occur with a given change in ozone exposure. Several such studies are summarised in Table 5.1.

TABLE 5.1 FINDINGS OF SHORT-TERM PANEL (COHORT) STUDIES OF THE RELATION BETWEEN DAILY PEAK OZONE LEVELS (PPM) AND LUNG FUNCTION (FEV<sub>1</sub>, L)

Each study is summarised by a mean regression coefficient for subjects studied <sup>a</sup>

Age Group	Country	Max. Hourly Ozone (parts per million)	Number of Subjects	Mean Regression Coefficient (β)	STD Error	Citation
children	USA	< 0.11	58	-0.78	-	(Lippman, 1983)
children	USA	< 0.185	39	-0.28	-	(Liroy, 1985)
children	USA	0.12	91	-1.42	0.17	((Spektor, 1988a)
adults	USA	0.12	30	-1.35	0.35	(Spektor, 1988b)
children	USA	0.08	154	-0.99	0.36	(Kinney, 1989)
children	USA	0.25	43	-0.59	0.13	(Higgins, 1990)
children	USA	0.15	46	-1.6	0.3	(Spektor, 1991)



Age Group	Country	Max. Hourly Ozone (parts per million)	Number of Subjects	Mean Regression Coefficient ( $\beta$ )	STD Error	Citation
adults	USA	0.2	10	-0.57	0.36	(Berry, 1991)
children	USA	0.2	14	-0.82	0.33	(Berry, 1991)
children	Netherlands	0.12	553	-0.42	0.08	(Hoek, 1993)
children	Netherlands	0.11	208	-0.223	0.244	(Cuijpers, 1995)

Notes: a. An additional study, not shown here because it used FEV<sub>0.75</sub> rather than FEV<sub>1</sub> as an outcome measure, was conducted among 154 primary schoolchildren in the United Kingdom (Scarlett, 1996). It showed no evidence of an association between daily peak ozone concentration and FEV<sub>0.75</sub> ( $\beta$  = 0.018, 95 percent confidence interval -0.089 to 0.13).

The effect of ozone on lung function was greater in the North American studies than in the two European studies. Combining the information from the nine studies which report variance estimates, it is calculated that FEV<sub>1</sub> decreases by 0.649 litres (95 percent confidence interval 0.387 to 0.912 litres) every part per million increase in ozone. For example, a 0.02 part per million increase in hourly maximum ozone concentration on one day would be estimated to cause a 0.013 litre (95 percent confidence interval 0.008 to 0.018 litres) decrease in FEV<sub>1</sub> on that day.

A recent one year cohort study among children with asthma in western Sydney has shown a relation between variation in daily mean ozone concentration and lung function, although the effect was smaller than that seen in other studies. Change from the minimum (near zero) to the maximum observed daily average ozone concentration (0.05 parts per million) was associated with a two percent reduction in evening peak expiratory flow rate (Jalaludin, 1996).

The estimated effects in some of the panel studies are larger than those seen in the exposure chamber studies. In part, this is due to the interacting and confounding effects of other environmental exposures, the longer duration of exposure, and the fact that exposure occurs on successive days.

#### 5.3.4 SYMPTOMS

The main symptoms observed after ozone exposure arise in the lower respiratory tract although eye irritation may also occur. Cough, pain on taking a deep breath, chest discomfort, and shortness of breath have all been observed after exposure to ozone at concentrations of 0.15 parts per million for one to two hours and after exposure for six hours to concentrations as low as 0.08 parts per million. Panel studies have demonstrated either no significant association between symptoms and ozone levels (Spektor, 1988a; Spektor, 1991; Schwartz, 1994e; Hoek, 1995) or an association only above 0.12 parts per million (Berry, 1991). Low or moderate levels of ozone appear to cause symptoms more frequently in adults than children

(Lippmann, 1989). However, it is possible that this difference is due to the difficulty in measuring respiratory symptoms in children.

Panels of people with asthma have also been studied. Ozone exposure is one of many irritants which can induce lung function change and symptoms in people with asthma but the effects are probably small (Higgins, 1995; Delfino, 1996; Romieu, 1996). For example, in a study of 71 children with asthma in Mexico City, a 0.05 parts per million increase in ozone was associated with a nine percent increased risk of respiratory symptoms on that day (Romieu, 1996).

### 5.3.5 HOSPITALISATIONS AND EMERGENCY DEPARTMENT VISITS

In Ontario, Canada, Bates *et al* were the first to suggest that the rate of hospital admission for respiratory disease may be correlated with the peak hourly ozone level on the preceding two days as well as with the air temperature, sulphur dioxide and sulphate levels (Bates, 1983; Bates, 1989). There was a seven percent increase in respiratory admissions if the ozone level was above 0.08 parts per million. However, in the month with the greatest number of high ozone days, the admission rate was not particularly high. This observation, together with the correlation between the exposure variables, led the authors to question whether ozone was the cause of increased hospitalisations.

*Table 5.2* presents the results of several time series studies which have quantified the relation between peak daily ozone levels and daily rates of hospital admission or Emergency Department attendance for asthma or respiratory diseases. The effect of ozone was larger among children in Mexico City and among the elderly in several US cities, than in series in Europe and other US cities which covered all ages. For the studies summarised in *Table 5.2* the average rate ratio for hospitalisation or Emergency Department attendance for a 0.01 part per million increase in ozone was 1.014.

**TABLE 5.2 EFFECT OF CHANGES IN DAILY PEAK OZONE CONCENTRATION ON RATES OF EMERGENCY DEPARTMENT ATTENDANCE AND HOSPITAL ADMISSION FOR RESPIRATORY DISEASES**

Lag refers to number of days between the ozone measurement and the associated outcome measurement (for example lag = 1, means ozone measurement predicts hospitalisations on the following day). Rate ratios for a given change in ozone concentration are shown. The rate ratio is the ratio of the admission rate on two days separated in ozone concentration by the amount shown in the increment column. The value shown in the rate ratio column is the estimated (most likely) value based on the outcome of the regression analysis. The 95 percent confidence interval is the range of values within which the actual rate ratio may lie and still be consistent with the data. Where the confidence interval excludes the value 1 we can be fairly certain that ozone exposure is related to admission rates in that study (that is P is less than 0.05).

City	Outcome	Lag (days)	Increment (parts per million) <sup>b</sup>	Rate Ratio	95 percent Confidence Interval	Citation
Mexico City <sup>a</sup>	ED for asthma	1	0.05	1.43	1.24 to 1.66	(Romieu, 1995)
Ontario	respiratory admission	1	0.05	1.05	p < 0.001	(Burnett, 1994)
Amsterdam	asthma admission	1	0.05	1.06	0.92 to 1.21	(Schouten, 1996)
Amsterdam	COPD admissions	0	0.05	1.02	0.92 to 1.13	(Schouten, 1996)
Rotterdam	COPD admissions	2	0.05	1.03	0.93 to 1.14	(Schouten, 1996)
Paris	asthma admission	1	0.05	0.97	0.90 to 1.04	(Dab, 1996)
Paris	COPD admissions	1	0.05	1.04	0.96 to 1.14	(Dab, 1996)
London	respiratory admission	1	0.003 to 0.029 <sup>c</sup>	1.03 <sup>d</sup>	1.01 to 1.05	(Ponce de Leon, 1996)
Tacoma (USA)	respiratory admission <sup>e</sup>	2	0.025	1.21	1.06 to 1.38	(Schwartz, 1995)
New Haven (USA)	respiratory admission <sup>e</sup>	2	0.025	1.06	0.99 to 1.13	(Schwartz, 1995)
Spokane (USA)	respiratory admission <sup>e</sup>	0	0.025	1.38	1.09 to 1.75	(Schwartz, 1996)
Detroit	pneumonia admission <sup>e</sup>	0	0.005	1.026	1.01 to 1.04	(Schwartz, 1994b)
Detroit	COPD admission <sup>e</sup>	0	0.005	1.028	1.01 to 1.05	(Schwartz, 1994b)
Minneapolis	pneumonia admission <sup>e</sup>	1	0.05	1.15 <sup>f</sup>	0.97 to 1.36	(Schwartz, 1994c)

ED: Emergency Department attendance

- Notes:
- a. January to June only. Adjusted for effect of sulphur dioxide. This study is in children; all others include all ages.
  - b. Increment in one hour ozone concentration tested
  - c. Represents change from 10<sup>th</sup> to 90<sup>th</sup> percentile of 8 hour ozone
  - d. Effect is stronger in the warm season and weaker in the cool season.
  - e. People aged 65 and over
  - f. Adjusted for effect of particulates.

Some further studies, which could not be summarised by a rate ratio, have also been performed. In London a rather confusing picture emerged with

high presentation rates for asthma among children on high and low ozone days (Buchdahl, 1996). A more recent study in Ontario confirmed that, in that section of the country, daily ozone concentration was related to risk of hospitalisation, even after taking sulphate, acidity and particulates into account (Thurston, 1994). In nearby Quebec it was estimated that, in summer, an increase in one hour maximum ozone concentration equal to the mean level, that is 0.036 parts per million, was associated with a 21 percent increase in Emergency Department presentations for respiratory illness on the following day (Delfino, 1997). In New Jersey, Emergency Department visits for asthma occurred 28 percent more frequently when mean ozone levels were above 0.06 parts per million than when they were less than this (Weisel, 1995). Other investigators in America, Europe and Australia (Richards, 1981; Bates, 1990; Rennick, 1992; Delfino, 1994; Castellsague, 1995) have not found an association between ozone exposure and the rate of hospitalisation for respiratory disease.

In summary, there is conflicting evidence on the role of ozone in causing severe exacerbations of asthma and respiratory illness. In some settings, notably among children in Mexico City (where ozone levels are high) and among the elderly in Washington State, USA (where ozone levels are relatively low), there is a strong effect of ozone on respiratory admissions. In other settings the effect is much less or not apparent at all.

### **5.3.6 MORTALITY**

Daily levels of ambient ozone in Los Angeles and New York are correlated with daily all cause mortality and cardiovascular mortality but not respiratory mortality (Kinney, 1991; Kinney, 1992). This observation implies that ozone may have effects beyond the lung. A number of studies from Europe and America have now reported the relation between ozone exposure and risk of death (refer Table 5.3). For these studies, the average rate ratio for risk of death for a 0.01 part per million increase in ozone was 1.0097.

TABLE 5.3 EFFECT OF CHANGES IN DAILY PEAK OZONE CONCENTRATIONS ON DAILY DEATH RATES.

Lag refers to number of days between the ozone measurement and the associated outcome measurement (for example lag = 1, means ozone measurement predicts hospitalisations on the following day). Rate ratios for a given change in ozone concentration are shown. The rate ratio is the ratio of the admission rate on two days separated in ozone concentration by the amount shown in the increment column. The value shown in the rate ratio column is the estimated (most likely) value based on the outcome of the regression analysis. The 95 percent confidence interval is the range of values within which the actual rate ratio may lie and still be consistent with the data. Where the confidence interval excludes the value 1 we can be fairly certain that ozone exposure is related to admission rates in that study (that is P is less than 0.05).

City	Lag (days)	Increment (parts per million)	Rate ratio	95 percent Confidence Interval	Citation
Sao Paulo <sup>a</sup>	0	0.015	1.006 <sup>f</sup>	0.993 to 1.108	(Salvida, 1995)
Lyon	0	0.025	1.04	0.94 to 1.16	(Zmirou, 1996)
Barcelona	0	0.05	1.05 <sup>d</sup>	1.01 to 1.09	(Sunyer, 1996)
Paris	0	0.05	1.04 <sup>c</sup>	0.93 to 1.16	(Dab, 1996)
Philadelphia	1	0.1	1.15 <sup>e,f</sup>	1.07 to 1.24	(Moolgavkar, 1995a)
London	0	0.005 to 0.036 <sup>b</sup>	1.026 <sup>d</sup>	1.013 to 1.039	(Anderson, 1996)

- Notes:
- a. People aged 65+
  - b. Representing range from 10<sup>th</sup> to 90<sup>th</sup> percentile
  - c. Respiratory mortality
  - d. Stronger effect seen in summer
  - e. Summer only
  - f. Remains significant after adjustment for other pollutants.

These studies yield conflicting results with some finding significant associations and others not doing so.

5.4 LONG-TERM HEALTH EFFECTS

Studies of the effects of long term ozone exposure in animals have demonstrated localised abnormalities in the deep parts of the lungs (small airways and air spaces). These changes are at least partly reversible when exposure stops and there is no evidence of lung destruction (that is no evidence of emphysema) (Chitano, 1995).

Evidence from human studies is limited. Several epidemiological studies have compared the occurrence of respiratory symptoms and/or impaired lung function in communities with varying levels of long-term (annual average) ozone exposure (for example, Schwartz, 1989; Abbey, 1993). While some of these studies have claimed to show an association, it is very difficult to be confident about this conclusion in view of the number of additional extraneous factors which could be involved.

## 5.5 CONCLUSIONS AND SUMMARY OF INDICES

Exposure to ozone causes a transient reduction in lung function, the extent of which is related to the ozone concentration, the duration of exposure and the level of activity undertaken during exercise. In many cases reduction in lung function is not accompanied by any symptoms, but some people (more commonly adults rather than children) experience chest discomfort or difficulty in taking a deep breath in. Individuals vary in their sensitivity to ozone but the elderly and those with pre-existing respiratory diseases (including asthma) are not more susceptible than others. The population sub-group most likely to be affected by ozone exposure are those whose work or recreation entails strenuous outdoor physical activity.

Three indices, two derived from exposure chamber studies and the other from short-term cohort studies, will be used to quantify the lung function changes in response to ozone (measured in parts per million):

- a) change in FEV<sub>1</sub> from baseline (in litres) =  $0.773 / [1 + e^{-20.35(\text{ozone} - 0.178)}]$
- b) change in FEV<sub>1</sub> from baseline (percent) =  $28.5 / [1 + e^{-10.5(\text{ozone} - 0.275)}]$
- c) change in FEV<sub>1</sub> (in litres) = 0.649 x change in ozone (parts per million)

Based on these equations, the exposure chamber studies predict that a 0.01 part per million increase in ozone for one hour will be associated with a 0.024 litre or 1.7 percent reduction in FEV<sub>1</sub> (forced expiratory volume - one second). The cohort studies predict that a similar change in ozone concentration will lead to a 0.0065 litre reduction in FEV<sub>1</sub>.

At this stage the available data do not allow us to conclude whether there is a relation between day-to-day variation in ozone levels and risk of hospital admissions or attendance for respiratory disease. If there is an effect it is likely to be small. For the purposes of this analysis it is assumed that an increment of 0.05 parts per million is associated with a 1.4 percent increased risk of admission for respiratory disease.

There is similar uncertainty about the effect of ozone concentrations on risk of death. However, since most estimated rate ratios are greater than one it is safest to assume there is an association. For this analysis it is assumed that a 0.01 part per million increase in peak daily ozone is associated with a one percent increased risk of death on any given day.

## 6

**NITROGEN DIOXIDE****6.1 PHYSICO-CHEMICAL FEATURES RELEVANT TO HEALTH EFFECTS**

Nitrogen dioxide is a poorly water soluble gas which reaches the small airways of the lungs. Like ozone, it is highly reactive and causes damage by oxidising cell membranes (Sandstrom, 1995).

Nitrogen dioxide is a by-product of combustion of fossil fuels and is also generated in the atmosphere by reaction among other pollutant gases. The major outdoor source is the motor vehicle. Gas heaters and stoves are important indoor sources of nitrogen dioxide. Indoor concentrations of nitrogen dioxide in some homes are higher than those found in outdoor air.

**6.2 CURRENT AIR QUALITY GOALS**

The current National Health and Medical Research Council goal for nitrogen dioxide is a one hour maximum of 0.16 parts per million.

**6.3 SHORT-TERM HEALTH EFFECTS****6.3.1 LUNG FUNCTION**

The effect of short-term exposure to nitrogen dioxide on lung function have been reviewed previously (Sandstrom, 1995). Some of the ensuing data are conflicting but the key findings can be summarised as:

1. there is no evidence of that exposure to nitrogen dioxide at levels seen under normal outdoor conditions affects lung function in healthy people (for example, Koenig, 1988a; Frampton, 1991; Kim, 1991; Scarlett, 1996) although effects are seen at very high levels of exposure (reviewed in Sandstrom, 1995),
2. in people with asthma, exposure to nitrogen dioxide at a moderate concentration (eg greater than 0.25 parts per million) during exercise is capable of inducing minor airway narrowing (for example Koenig, 1988a; Avol, 1989) and enhanced airway responsiveness to other, non-specific stimuli (Bauer, 1986; Strand, 1996). There appears to be a wide range of susceptibility among people with asthma to the adverse effects of exposure to nitrogen dioxide;

3. in subjects with asthma exposure to 0.4 parts per million, nitrogen dioxide can cause a significant increase in allergen responsiveness, that is the tendency of the airways to narrow when they are subsequently exposed to allergen (Devalia, 1994; Tunnicliffe, 1994); and
4. in one study, elderly subjects with chronic obstructive pulmonary disease experienced a decline in lung function after exposure to 0.3 parts per million of nitrogen dioxide for four hours during intermittent exercise (Morrow, 1992). However, the difference was not statistically significant and there were conflicting findings in another study in which similar subjects exposed to much higher levels of nitrogen dioxide for a shorter period (one hour) did not demonstrate any significant change in lung function (Linn, 1985).

### 6.3.2 HOSPITALISATIONS AND EMERGENCY DEPARTMENT ATTENDANCES

Evidence for an association between outdoor nitrogen dioxide exposure and the risk of hospitalisation for respiratory disease is conflicting (refer Table 6.1). In addition to the studies summarised as rate ratios, other studies, using different methodologies, have not shown any association between nitrogen dioxide and admission rates in Vancouver (Bates, 1990) or in Toronto (Thurston, 1994).

However, a recent study covering the Sydney metropolitan area has shown that an increase in daily nitrogen dioxide levels from 10<sup>th</sup> centile (nearly the lowest) to the 90<sup>th</sup> centile (nearly the highest) was associated with 7.2 percent increase in hospitalisations for asthma in children and a 6.4 percent increase in admissions for heart disease (Morgan, 1996b).

TABLE 6.1 EFFECT OF CHANGES IN HOURLY MAXIMUM NITROGEN DIOXIDE CONCENTRATION ON RATES OF HOSPITAL ADMISSION FOR RESPIRATORY DISEASES.

Lag refers to number of days between the ozone measurement and the associated outcome measurement (for example lag = 1 means ozone measurement predicts hospitalisations on the following day). Rate ratios for a given change in ozone concentration are shown. The rate ratio is the ratio of the admission rate on two days separated in ozone concentration by the amount shown in the increment column. The value shown in the rate ratio column is the estimated (most likely) value based on the outcome of the regression analysis. The 95 percent confidence interval is the range of values within which the actual rate ratio may lie and still be consistent with the data. Where the confidence interval excludes the value 1 we can be fairly certain that ozone exposure is related to admission rates in that study (that is P is less than 0.05).

City	Outcome	Lag (days)	Increment (parts per million)	Rate ratio	95 percent Confidence interval	Citation
Barcelona	ED for asthma	0 - 3	0.014	1.07	1.01 to 1.13	(Castellsague, 1995)
Amsterdam	asthma admissions	2	0.056	1.035	0.92 to 1.17	(Schouten, 1996)
Amsterdam	COPD admissions	1	0.056	0.95	0.86 to 1.04	(Schouten, 1996)
Rotterdam	COPD admissions	2	0.056	1.16	1.07 to 1.27	(Schouten, 1996)



City	Outcome	Lag (days)	Increment (parts per million)	Rate ratio	95 percent Confidence interval	Citation
Paris	asthma admissions	0 to 1	0.056	1.08	1.02 to 1.15	(Dab, 1996)
Paris	COPD admission	2	0.056	0.96	0.92 to 1.01	(Dab, 1996)
London	respiratory admissions	2	0.024 to 0.051 <sup>a</sup>	1.011	1.001 to 1.022	(Ponce de Leon, 1996)

Notes: a. 10th versus 90th percentile

Comparison among localities in the Midlands of England showed that cross-sectional differences in admission rates were correlated with differences in outdoor nitrogen dioxide exposure (Walters, 1995). This may be evidence for longer term effects of nitrogen dioxide exposure on severity of respiratory illness. However, as mentioned previously, it is difficult to exclude the possibility that the apparent association is due to extraneous factors.

### 6.3.3 MORTALITY

In contrast to the findings for hospitalisations, there is consistency among several studies which have demonstrated that variation in outdoor nitrogen dioxide levels is not related to daily death rates (refer Table 6.2).

TABLE 6.2 EFFECT OF CHANGES IN HOURLY MAXIMUM NITROGEN DIOXIDE CONCENTRATIONS ON DAILY DEATH RATES IN SEVERAL EUROPEAN CITIES.

Lag refers to number of days between the ozone measurement and the associated outcome measurement (for example lag = 1 means ozone measurement predicts hospitalisations on the following day). Rate ratios for a given change in ozone concentration are shown. The rate ratio is the ratio of the admission rate on two days separated in ozone concentration by the amount shown in the increment column. The value shown in the rate ratio column is the estimated (most likely) value based on the outcome of the regression analysis. The 95 percent confidence interval is the range of values within which the actual rate ratio may lie and still be consistent with the data. Where the confidence interval excludes the value 1 we can be fairly certain that ozone exposure is related to admission rates in that study (that is P is less than 0.05).

City	Lag (days)	Increment (parts per million)	Rate ratio	95 percent Confidence Interval	Citation
Sao Paolo <sup>a</sup>	0	0.15	1.03	0.95 to 1.10	(Salvida, 1995)
Lyon	1	0.028	1.01	0.99 to 1.02	(Zmirou, 1996)
Barcelona	1	0.056	1.03	1.01 to 1.06	(Sunyer, 1996)
Paris <sup>b</sup>	1	0.056	1.02	0.94 to 1.13	(Dab, 1996)
Cologne	1	0.025 to 0.079 <sup>c</sup>	1.000	0.9998 to 1.0004	(Spix, 1996)
London	0	0.038 to 0.081 <sup>d</sup>	1.004	0.997 to 1.012	(Anderson, 1996)

Notes: a. Aged 65+  
b. Deaths from respiratory causes only  
c. 5th versus 95th percentile  
d. 10th versus 90th percentile.

## 6.4 LONG-TERM HEALTH EFFECTS

Evidence concerning the long-term consequences of nitrogen dioxide exposure is lacking. A ten year follow-up of Seventh Day Adventists living in various localities in California failed to show any relation between average nitrogen dioxide exposure levels and the development of respiratory illness (Abbey, 1995b). The two-fold increased risk of asthma symptoms among women (but not men) in East Anglia, United Kingdom, who lived in houses with gas stoves is indirect evidence that indoor exposure to nitrogen dioxide may be a risk factor for respiratory disease. Interestingly, another recent study has also shown a gender difference in risk. Among young children (aged up to four years) in Stockholm the risk for wheezing illness due to nitrogen dioxide exposure was apparent in girls but not boys (Pershagen, 1995).

The importance of these findings for assessing the impact of outdoor exposure to nitrogen dioxide remains very uncertain. In particular, these data are not helpful in drawing any conclusions about the quantitative relation between nitrogen dioxide exposure and risk of respiratory illness.

## 6.5 CONCLUSIONS AND SUMMARY OF INDICES

Exposure to nitrogen dioxide at levels seen under ambient conditions does not cause any change in lung function in healthy people and probably only causes concern in people with asthma or other respiratory disease at levels above 0.25 to 0.30 parts per million. This accords with the conclusion of an expert review commissioned by the UK Department of Health which recommended that health advice should be given to people with asthma when levels of nitrogen dioxide were above 0.30 parts per million (Advisory Group on the Medical Aspects of Air Pollution Episodes, 1993)

The available data do not allow quantification of the relation between nitrogen dioxide exposure and changes in lung function at levels below 0.30 parts per million.

Evidence that variation in nitrogen dioxide exposure is associated with risk of hospitalisation for respiratory disease is conflicting and there is evidence that nitrogen dioxide exposure is not linked to daily death rates. For both these outcomes it is not appropriate to attempt to quantify an association with nitrogen dioxide exposure levels.

## 7

**PARTICULATES****7.1 PHYSICO-CHEMICAL FEATURES RELEVANT TO HEALTH EFFECTS**

Particulate pollution is a mixture of everything in the air which is not a gas. The size, solubility and hygroscopicity of atmospheric particles are heterogeneous and these characteristics influence the biological consequences of exposure. Only those particles which are small enough to enter the lungs are clinically important. Particles with a mass median aerodynamic diameter greater than ten micrometres are filtered out by the upper respiratory tract. Particles with a mass median aerodynamic diameter near five micrometres tend to deposit in the airways of the lower respiratory tract and particles less than two micrometres reach the alveoli (Heyder, 1986). Some ultra-fine particles, which reach the periphery of the lung, are capable of inducing an inflammatory reaction which may have effects within and beyond the lung.

For many years, the assessment of particulate pollution, quantified as 'Black Smoke' or Total Suspended Particulates, did not include the measurement of particle size. More recently, dosimetry which takes account of particle size has improved the assessment of biologically-relevant particulate exposure. PM<sub>10</sub>, the concentration of particles with a mass median aerodynamic diameter less than 10 micrometres, is the most commonly cited index but PM<sub>2.5</sub> and other size thresholds have been used.

**7.2 CURRENT AIR QUALITY GOALS**

There is no Australian National Health and Medical Research Council guideline for particulates at present. The US Environment Protection Agency's goals for particulate matter with mass median aerodynamic diameter less than 10 micrometres (PM<sub>10</sub>) are an annual mean less than 50 micrometres per cubic metre and a 24 hour mean less than 150 micrograms per cubic metre. The UK Department of Environment Expert Panel of Air Quality standards for Particles has recommended a standard of 50 micrograms per cubic metre as a 24 hour running average.

**7.3 SHORT-TERM HEALTH EFFECTS****7.3.1 LUNG FUNCTION**

Panel studies in children living in the Utah Valley, USA, and in the Netherlands, have shown that changes in peak expiratory flow rates were

correlated with changes in daily average particulate levels (Figure 7.1) (Pope, 1991b; Pope, 1992a; Roemer, 1993).

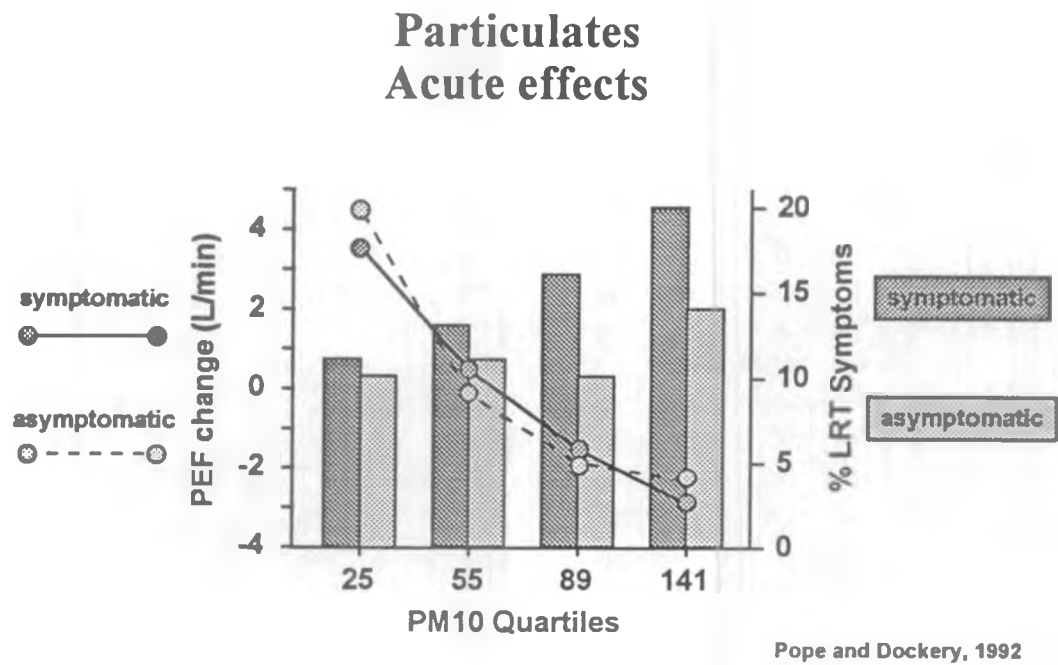


FIGURE 7.1 COHORT (PANEL) STUDY OF THE RELATION BETWEEN DAILY PM<sub>10</sub> (SEE TEXT FOR DEFINITION) LEVEL AND RESPIRATORY SYMPTOMS AND LUNG FUNCTION IN CHILDREN

Source: Pope and Dockery, 1992

Difference from individual's average peak expiratory flow rate (lines) and percentage reporting lower respiratory tract symptoms (bars) are plotted by quartiles of daily PM<sub>10</sub> levels among children with a history of asthma-like symptoms (solid line and dark bars) and other children (Pope, 1992a).

The effect was cumulative and in Utah it was estimated that three successive days with 24 hour PM<sub>10</sub> levels greater than 150 micrograms per cubic metre would result in a six percent decrease in peak flow (Pope, 1991b). There was also evidence that increases in PM<sub>10</sub> below the threshold of 150 micrograms per cubic metre had an adverse effect on lung function (Pope, 1992a). In children attending a primary school adjacent to a major motorway near London, daily measures of lung function were correlated with daily PM<sub>10</sub> levels (Scarlett, 1996). However, the effect was very small, equivalent to a one percent change in forced vital capacity across the range of PM<sub>10</sub> levels observed (20 to 150 micrograms per cubic metre). Similarly, the western Sydney cohort study in children with asthma also demonstrated a small effect: a change in daily average PM<sub>10</sub> from the lowest to the highest value over the one year period was associated with a one percent reduction in evening peak expiratory flow rate (Jalaludin, 1996). A recent study in Pennsylvania revealed a non-significant reduction in peak flow associated with increases in fine particulates (Neas, 1995).

### 7.3.2 SYMPTOMS

Short-term effects of particulate pollution on the prevalence of respiratory symptoms have been observed. Using data from the United States Health Interview Survey, Ostro found that respiratory-related restricted activity days over a two week period correlated with particulate levels in the preceding two week period (Ostro, 1989, Ostro, 1990).

Panel studies in the USA (Whittemore, 1980; Love, 1981; Pope, 1991b; Schwartz, 1994e; Neas, 1995), Germany (von Mutius, 1995), Sweden (Forsberg, 1993) and the Netherlands (Roemer, 1993) have shown an association between fluctuations in the level of particulate pollution and the prevalence of respiratory symptoms (cough, wheeze etc) and/or medication use in adults and children. For example, for one study that examined six United States cities (Schwartz, 1994e) it was estimated that a 30 micrograms per cubic metre increase in  $PM_{10}$  was associated with a 27 percent increase in incidence of reported cough (95 percent confidence interval: six to 52 percent). In Uniontown, Pennsylvania, a 15 micrograms per cubic metre increase in fine particulate levels was associated with a 25 percent increase in risk of evening cough (95 percent confidence interval: 1.04 to 1.50) (Neas, 1995). Children with chronic respiratory symptoms were found to be more likely to experience the adverse effects of particulate pollution than asymptomatic children (*Figure 7.1*) (Pope, 1992a).

### 7.3.3 HOSPITALISATIONS AND EMERGENCY DEPARTMENT ATTENDANCES

The correlation between daily hospital admission rates for respiratory disease and particulate ( $PM_{10}$ ) levels was first shown in Utah (Pope, 1989). This part of the United States of America has low levels of sulphur dioxide and aerosol acidity: a pattern of pollutants is similar to that seen in Australia. Admission rates for children in months when the maximum 24 hour  $PM_{10}$  concentration was greater than 150 micrograms per cubic metre were three-fold higher than in months when there were no days greater than 150 micrograms per cubic metre. The adverse effect of high  $PM_{10}$  levels on admission rates carried over from one month to the next (Pope, 1991a).

Similar associations between hospital admission or emergency room attendance have been observed in Canada (Bates, 1983; Bates, 1989, but not in Thurston, 1994), the United States (Richards, 1981; Schwartz, 1993), Australia (Churches, 1991; Rennick, 1992) and Spain (Sunyer, 1993). Recently, a series of European and American studies have been performed using a sophisticated time series regression approach (Refer *Table 7.1*). Interestingly, the European studies did not demonstrate the association between particulate pollution and an increased risk of hospitalisation which was seen in the American studies. However, the confidence limits on these

negative studies are broad and they do not exclude the results seen in the other, positive studies.

**TABLE 7.1 EFFECT OF CHANGES IN DAILY AVERAGE PARTICULATE CONCENTRATION ON RATES OF HOSPITAL ADMISSION FOR RESPIRATORY DISEASES**

Lag refers to number of days between the ozone measurement and the associated outcome measurement (for example lag = 1 means ozone measurement predicts hospitalisations on the following day). Rate ratios for a given change in ozone concentration are shown. The rate ratio is the ratio of the admission rate on two days separated in ozone concentration by the amount shown in the increment column. The value shown in the rate ratio column is the estimated (most likely) value based on the outcome of the regression analysis. The 95 percent confidence interval is the range of values within which the actual rate ratio may lie and still be consistent with the data. Where the confidence interval excludes the value 1 we can be fairly certain that ozone exposure is related to admission rates in that study (that is P is less than 0.05).

City	Exposure	Type of admission	Lag (days)	Increment (micrograms per cubic metre)	Rate ratio	95 percent Confidence Interval	Citation
Amsterdam	Black smoke	asthma	0	100	0.80	0.44 to 1.48	(Schouten, 1996)
Amsterdam	Black smoke	COPD	0	100	1.13	0.73 to 1.74	(Schouten, 1996)
Rotterdam	Black smoke	COPD	2	100	0.93	0.72 to 1.19	(Schouten, 1996)
Paris	PM <sub>10</sub>	asthma	2	100	0.975	0.90 to 1.05	(Dab, 1996)
Paris	PM <sub>10</sub>	COPD	2	100	0.95	0.87 to 1.04	(Dab, 1996)
London	Black smoke	respiratory	1	8 to 23 <sup>a</sup>	0.997	0.99 to 1.01	(Ponce de Leon, 1996)
Milan	Total suspended particulates	respiratory	2	25 to 125	1.05 <sup>b</sup>	1.00 to 1.10	(Vigotti, 1996)
New Haven	PM <sub>10</sub>	respiratory <sup>c</sup>	0	50	1.06	1.00 to 1.13	(Schwartz, 1995)
Tacoma (USA)	PM <sub>10</sub>	respiratory <sup>c</sup>	0	50	1.10	1.03 to 1.17	(Schwartz, 1995)
Spokane (USA)	PM <sub>10</sub>	respiratory <sup>c</sup>	0	50	1.083	1.03 to 1.14	(Schwartz, 1996)
Detroit	PM <sub>10</sub>	pneumonia <sup>c</sup>	0	10	1.012	1.00 to 1.02	(Schwartz, 1994b)
Detroit	PM <sub>10</sub>	COPD <sup>c</sup>	0	10	1.02	1.00 to 1.03	(Schwartz, 1994b)
Minneapolis	PM <sub>10</sub>	pneumonia <sup>c</sup>	0	100	1.17 <sup>d</sup>	1.02 to 1.33	(Schwartz, 1994c)
Minneapolis	PM <sub>10</sub>	COPD <sup>c</sup>	1	100	1.34	1.08 to 1.67	(Schwartz, 1994c)
Barcelona <sup>e</sup>	Black smoke	ED for asthma	0 - 3	25	1.11	1.01 to 1.16	(Castellsague, 1995)
Birmingham (UK)	PM <sub>10</sub>	respiratory	0	10	1.024	1.01 to 1.04	(Wordley, 1997 #2263)

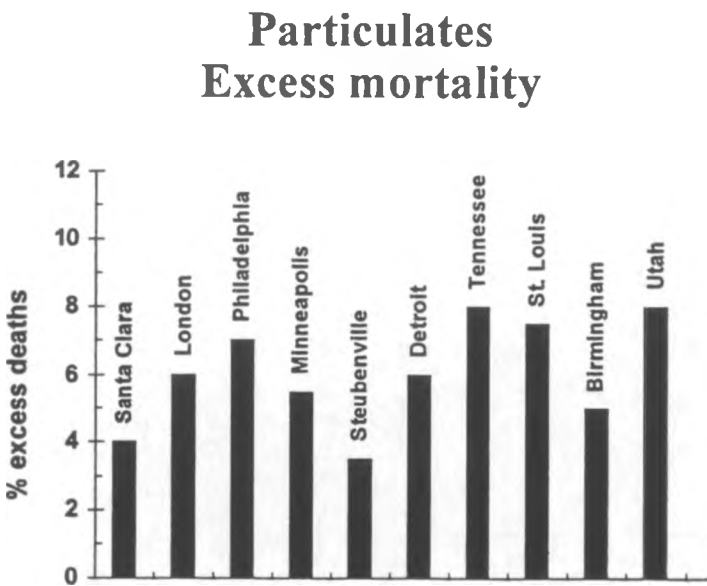
- Notes:
- a. Represents change from 10th to 90th percentile
  - b. There was a stronger effect in the warm season among 15 to 64 year olds and a stronger effect in cold season in over 64 year olds.
  - c. People aged 65 and over
  - d. Adjusted for effect of ozone
  - e. Summer only

### 7.3.4 MORTALITY

The relation between daily particulate levels and daily death rates has been extensively investigated. Schwartz and colleagues have analysed a series of data from London and several American cities (Schwartz, 1990; Schwartz,

1991; Pope, 1992b; Schwartz, 1992b; Schwartz, 1992a; Schwartz, 1994a; Salvida, 1995) using a similar methodology in all studies. This is a sophisticated time series regression technique which takes into account a variety of seasonal and other factors which may be related to both daily death rate and pollution levels.

Schwartz has conducted a meta-analysis of data from several cities (Refer Figure 7.2) and has estimated that a 100 micrograms per cubic metre increase in total suspended particulates is associated with a 1.06 relative risk of death on that day (95 percent confidence interval 1.05 to 1.07) (Schwartz, 1994a).



Schwartz, 1994

FIGURE 7.2 ESTIMATED EXCESS IN DAILY DEATH RATE IN SEVERAL CITIES ATTRIBUTABLE TO A 100 MICROGRAMS PER CUBIC METRE INCREASE IN TOTAL SUSPENDED PARTICULATES (SCHWARTZ, 1994a)

Source: Schwartz, 1994

For a more realistic change of 30 micrograms per cubic metre (an increase above average which might be seen on a high pollution day in Sydney) this corresponds to a relative risk of 1.018, that is a 1.8 percent increase in the risk of dying on that day.

A number of similar studies have been conducted in Europe. All used similar regression techniques and adjusted for external factors such as the season of the year, day of the week, meteorological factors, holidays, influenza epidemics, and other unusual events. The results which are summarised in Table 7.2, are broadly in accord with the findings of Schwartz’ meta-analysis.

TABLE 7.2 EFFECT OF CHANGES IN DAILY AVERAGE PARTICULATE CONCENTRATIONS ON DAILY DEATH RATES IN SEVERAL EUROPEAN CITIES.

Lag refers to number of days between the ozone measurement and the associated outcome measurement (for example lag = 1 means ozone measurement predicts hospitalisations on the following day). Rate ratios for a given change in ozone concentration are shown. The rate ratio is the ratio of the admission rate on two days separated in ozone concentration by the amount shown in the increment column. The value shown in the rate ratio column is the estimated (most likely) value based on the outcome of the regression analysis. The 95 percent confidence interval is the range of values within which the actual rate ratio may lie and still be consistent with the data. Where the confidence interval excludes the value 1 we can be fairly certain that ozone exposure is related to admission rates in that study (that is P is less than 0.05).

City	Exposure	Lag (days)	Increment (micrograms per cubic metre)	Rate ratio	95 percent Confidence Interval	Citation
Lyon	PM13	0	50	1.01	0.97 to 1.05	(Zmirou, 1996)
Barcelona	Black smoke	1	100	1.07	1.03 to 1.11	(Sunyer, 1996)
Bratislava	Total suspended particulates	0	100	1.008	0.96 to 1.04	(Bacharova, 1996)
Paris <sup>a</sup>	PM13	0 - 1	100	1.17	1.04 to 1.31	(Dab, 1996)
Athens	Black smoke	1	100	1.05 <sup>c</sup>	1.03 to 1.08	(Touloumi, 1996)
Cologne	PM7	1	20 vs 82 <sup>b</sup>	1.02	1.00 to 1.04	(Spix, 1996)
Milan <sup>a</sup>	Total suspended particulates	0	25 vs 125	1.12	1.02 to 1.23	(Vigotti, 1996)
London	Black smoke	1	8 vs 22 <sup>d</sup>	1.017	1.01 to 1.03	(Anderson, 1996)
Birmingham	PM <sub>10</sub>	1	10	1.011	1.00 to 1.02	(Wordley, 1997 #2263)

- Notes:
- a. Deaths due to respiratory causes only
  - b. Represents change from 5th to 95th percentile
  - c. Rate ratio is 1.03 (1.01 to 1.06) on low SO<sub>2</sub> days
  - d. Represents change from 10th to 90th percentile

It is important to point out that many of these studies also showed risks attributable to other pollutants. Levels of these other pollutants, in particular sulphur dioxide and nitrogen dioxide, tend to be strongly correlated with particulate levels and there appears to be some dispute in the literature as to whether the mortality effects can be correctly attributed to particulates (Moolgavkar, 1995a; Moolgavkar, 1995b).

In a recent study of deaths in the Sydney metropolitan area during the period 1989 to 1993, the number of deaths on days with high levels of particulate pollution was 2.6 percent higher when compared to low particulate pollution days (Morgan, 1996a). In this case the conclusion was not changed when the results were adjusted for the effect of other pollutants (ozone and nitrogen dioxide).



The reason that particulate pollution causes increased mortality is not known. Most deaths occur in the elderly and in those with pre-existing cardiac or respiratory disease (Schwartz, 1994d). One hypothesis is that very fine particles provoke an inflammatory reaction deep in the lung tissue releasing substances into the blood which may have deleterious effects on the circulation (Seaton, 1995). The mechanism underlying the adverse effect of particulates is the subject of intense current scientific interest.

## 7.4 LONG-TERM HEALTH EFFECTS

Epidemiological studies such as those referred to in the section of this report on long-term health effects of ozone have found small increases in risks for symptoms of respiratory illness attributable to particulate exposure (for example Abbey, 1995a). The same difficulties in interpreting these studies apply, we cannot be certain that the effects are not explained by one of the many other factors that differ between the communities studied.

## 7.5 CONCLUSIONS AND SUMMARY OF INDICES

Increased exposure to particulate exposure is associated with increased symptoms and decreased lung function. This has been most clearly shown in children and the effect is more marked in children with pre-existing respiratory disease such as asthma. Based on the results of a single study, it is assumed here that a 30 micrograms per cubic metre increase in  $PM_{10}$  is associated with a 27 percent increase in risk of cough. This equates to a 2.4 percent increased risk for a three microgram per cubic metre increase in  $PM_{10}$ . It seems that the effect on lung function is small however there are insufficient data to reliably quantify this effect.

Despite some inconsistencies in the data it seems highly likely that particulate pollution is associated with an increase in hospitalisation rates for respiratory disease. In this analysis it is assumed that a 50 micrograms per cubic metre increase in  $PM_{10}$  is associated with an eight percent increase in hospitalisation. A three microgram per cubic metre increase in particulate pollution would be expected to be associated with a 0.46 percent increase in risk of hospitalisation.

Day to day variation in particulate levels is correlated with variation in daily death rates. The correlations are strongest for deaths in the elderly and deaths due to cardiac and respiratory diseases. Here it is predicted that on a given day, a 30 micrograms per cubic metre increase in particulate exposure (a large increase) is predicted to cause, on average, a 1.8 percent increase in the risk of dying on that day. A three microgram per cubic metre increase

particulate exposure will be expected to be associated with a 0.17 percent increase in risk of death on that day.

## **PART C:    IMPACT ASSESSMENT**

# 8 ESTIMATION OF HEALTH EFFECTS ATTRIBUTABLE TO PREDICTED CHANGES

Health effects attributable to predicted changes in air quality are based upon the outcomes of air quality modelling studies, which are presented in *Technical Paper No.6 - Air Quality*. This technical paper should be referred to for additional information.

## 8.1 OZONE

The number of person-days of exposure to a 0.01 part per million or greater increase in ozone concentration resulting from the Second Sydney Airport for the year 2016 was calculated by multiplying the predicted number of exposure days per year by the number of people exposed to this hazard (Table 8.1). Although these figures refer to populations exposed to a greater than 0.01 parts per million increase in ozone, examination of the ozone contour plots (Figures 7.1, 8.2 and 8.3 in *Technical Paper No. 6 - Air Quality*) demonstrates that 0.01 parts per million is a reasonable approximation of the increased exposure these people are predicted to experience on the ozone event days. This section describes the likely health consequences of these episodes of exposure.

TABLE 8.1 ESTIMATED PERSON DAYS (FOR YEAR 2016) EXPOSURE TO 0.01 PARTS PER MILLION INCREASE IN MAXIMUM ONE HOUR OZONE CONCENTRATION.

Site-Option	Number of days per year *	Population	Person days exposure / year
Badgerys Creek Option A	6	7,500	45,000
Badgerys Creek Option B	6	7,500	45,000
Badgerys Creek Option C	6	8,000	48,000
Holsworthy Option A	9	185,000	1,665,000
Holsworthy Option B	9	28,000	252,000

\* Number of days per year with increments greater than or equal to 0.01 parts per million ozone

The exposure chamber studies predict that a person exercising for two hours during a 0.01 parts per million increase in ozone exposure would be expected to experience a 1.7 percent decline in lung function (FEV<sub>1</sub>). This

change in lung function is at least three fold lower than that which would be perceived by the individual and hence be clinically significant.

It is uncertain whether increases ozone pollution cause severe exacerbations of illness. If we assume that they may, then the time series data analyses predict that, on the days when these populations are exposed to a 0.01 part per million increase in ozone concentration the hospitalisation rate for respiratory disease will be 1.4 percent higher and the mortality rate will be 1.0 percent higher than on other days.

The baseline annual hospital admission rate for respiratory disease in Sydney is 1400 per 100,000 (*Figure 3.6*) or 3.83 per 100,000 per day. The projected ozone events associated with the Second Sydney Airport would increase this to 3.89 per 100,000 per day; an increase of 0.054 per 100,000 per day. In the study area this corresponds to less than one hospital admission episode annually for all site options (*Table 8.2*). The actual increase in hospital admissions over one year would be less than shown here. This is because some admissions attributed to ozone events may have been going to occur anyway and were simply brought forward a few days by the ozone event.

TABLE 8.2 PROJECTED NUMBER OF ADDITIONAL HOSPITAL ADMISSIONS FOR RESPIRATORY DISEASE PER YEAR ON OZONE EVENT DAYS (IN 2016) COMPARED TO OTHER DAYS

Badgerys Creek Option A	0.024
Badgerys Creek Option B	0.024
Badgerys Creek Option C	0.026
Holsworthy Option A	0.9
Holsworthy Option B	0.14

The crude annual mortality rate for NSW is 740 per 100,000; a daily rate of 2.02 per 100,000. A one percent increase in this represents an absolute increase of 0.02 deaths per 100,000 per day. Table 8.3 shows the absolute difference in daily deaths which this represents over one year. It should be noted that the actual increase in deaths each year is probably much less than this since deaths attributed to the ozone event may have occurred on another day in the year, in the absence of the ozone event.

Investigation Report CET/IR584R

**Proposed Sydney Second Airport**

**REGIONAL AIR QUALITY and AIRPORT ASSOCIATED DEVELOPMENTS:  
LIKELY OUTCOMES for AIR QUALITY**

Graham M. Johnson

for

Coffey Partners International

CSIRO, Division of Coal and Energy Technology

July 1997

## **SUMMARY of FINDINGS: Regional Impacts of Airport Associated Developments**

The operation of the proposed airport would generate motor vehicle traffic and stimulate airport associated commercial and urban development. It is expected that emissions of air pollutants from these activities would be similar to the emissions produced by other similar scale Sydney urban/commercial areas.

The location of these emissions would be near the airport but also would extend many kilometres away from the airport site, mainly along the routes of the major airport access roads. As heavy industry is an unlikely airport associated development, the composition of the emissions is expected to be closely similar to that of suburban/commercial districts. The emissions composition would be dominated by motor vehicle exhaust.

The airshed dynamics of Sydney are complex, however the meteorology pertaining to daytime air pollution can be categorised into two cases:

- (1) conditions with sea breeze airflows and,
- (2) non-sea breeze airflows.

In both cases there are significant gaps in the current state of knowledge of the dynamics of air movements and this limits the usefulness of attempts to quantitatively predict pollutant concentrations that may arise from proposed developments. However, the general patterns of the progress of the sea breeze front across the region and the associated transport of pollution from eastern districts of Sydney inland to the west and south west is well established.

On the other hand, at present there is no generally accepted characterisation of the dynamics of pollution events that occur in the mornings or before the arrival of the sea breeze front. For non-sea breeze conditions therefore, the effects on air

quality of airport associated developments are very uncertain. As a substantial proportion of the observed occurrences of ozone concentrations greater than 0.08ppm in the greater Sydney region occur as non-sea breeze pollution events, this gap in knowledge is a limitation on the assessment of the impacts of airport associated developments.

The emissions emitted by developments associated with an airport will predominantly arise from motor vehicle traffic and include carbon monoxide, fine particulate matter, nitrogen oxides and reactive organic compounds (which are mostly hydrocarbons). Concentrations of these pollutants near to their sources of emission are expected to be comparable to source areas with similar emissions strengths and at present these occur widely in the Sydney Region.



## **Regional Air Quality**

The Holsworthy and Badgerys Creek localities have many similarities with respect to regional air quality. Both Regions receive air containing pollutants from major Sydney urban, industrial and motor vehicle emissions source areas. Winds from the coast are a common occurrence. Frequently the trajectories of these winds pass over Sydney's emissions source areas prior to their arrival at the proposed airport development sites.

This source – receptor relationship is demonstrated by the results of the NSW Metropolitan Air Quality Study (MAQS) Consultancy. That study interpreted extensive, recent years, NSW EPA air monitoring records and showed that when ambient ozone concentrations were greater than 0.08 ppm, then characteristically it was the case that the air had received pollutant emissions at least a few hours or more earlier.

The geographical distribution of ozone pollution events recorded in the Greater Sydney Region are mapped in the MAQS Consultancy; Air Chemistry Task, Final Report (Johnson et al, 1996). Although currently both the Holsworthy and Badgerys Creek Regions have relatively small emissions fluxes of ozone precursors, these ozone maps show that, like all the outlying ring of Sydney districts, Holsworthy and Badgerys Creek are on occasions receptor regions for Sydney emissions. This data is consistent with advection of Sydney pollution into these regions being a primary cause of adverse air quality

There are substantial and diverse data to support the above conclusion for Badgerys Creek, while the data sources for Holsworthy are more limited. This is because Holsworthy lies somewhat beyond the south eastern edge of the main band of air quality monitoring stations. However, data from the NSW EPA monitoring records for monitoring sites around Holsworthy, namely at

Woollooware, Liverpool, Bringelly, Camden, Campbelltown, Douglas Park and Albion Park support the conclusion.

A second type of air pollution event occurring in western Sydney areas is also described in the findings of the MAQS Consultancy. This type of pollution event is not clearly due to advection from the more densely developed regions of Sydney. This second type occurs both in winter and summer. In winter the main pollutant is particles. In summer the events are characterised by the occurrence of significant concentrations of ozone occurring before the arrival of easterly sector (sea breeze) winds.

This second type of pollution dynamic is a significant consideration for both Badgerys Creek and Holsworthy developments. At present the dynamics of air movements for these conditions are not well characterised. Also strong local sources of pollutant emissions do not currently occur near the proposed airport locations and therefore at present sources of emissions are not available to give an indication of the sensitivity of these localities to emissions from the proposed developments. The combination of these two circumstances means that for non-sea breeze conditions the currently existing air quality does not provide a useful guide to the potential effects of proposed new developments.

## **Likely Effects of Airport Associated Developments on Air Quality**

Areas adjacent to the proposed Airport are likely to undergo development during the operational life of the airport. The probable types of developments are those stimulated by the commercial opportunities of a 24 hours per day international transport node. Typical of these are road transport, freight handling and administration, communications, general business, tourism, retailing and residential and hotel accommodation. This mix is not atypical of Sydney generally.

For sea breeze type air flows (described in the section above), the subject air can receive pollutant emissions from across the broad sweep of Greater Sydney before arriving at the proposed airport development sites. For this type of case one might expect air quality impacts analogous to that experienced from recent green field urban developments in the west of Greater Sydney, for example say like from recent urban development of semi rural land in the South Penrith or Campbelltown South districts.

For the Second Type of airshed dynamic, impact assessments are more uncertain. This is because the dynamics of these non sea breeze types of events have not as yet been proven and the current hypotheses are highly speculative.

( See MAQS Consultancy; Final Report, Coffey Partners International,1996 for discussions of this matter. ).

Currently pollutant emissions are small at both the proposed airport site localities because these regions are largely undeveloped. Nevertheless, at times during the Second Type of airshed dynamic conditions, the Badgerys Creek district is sometimes subject to significantly degraded air quality. From this observation it follows that the regions near and downwind of the proposed sites may have a relatively small capacity to assimilate air pollutant emissions.

Note: There are no air quality monitoring data available for the Holsworthy district. Also there are major differences between Badgerys Creek and Holsworthy. Holsworthy has steeper terrain and is closer to the coast than is Badgerys Creek. It is possible that the Holsworthy area is differently and possibly better ventilated than Badgerys Creek during Second Type meteorological conditions.

### **Evaluation of Potential Air Quality Impacts Arising from Associated Developments**

For sea breeze type conditions, methods are available to estimate the likely magnitude of the effects of airport associated developments on downwind ambient ozone concentrations. To facilitate comparison with the effects predicted for airport and aircraft operations, the approach adopted was to follow the approach used to model the impacts of airport emissions on regional air quality, ( see: 'Footprint analysis of the regional air quality impact of the proposed Sydney airport', Katestone Scientific Pty Ltd., 1997 ). This was accomplished by selecting a relevant example sea breeze air trajectory. The emissions predicted for airport associated developments along this trajectory were included in the model formulation. The changes in predicted air quality along the path of the trajectory due to the associated emissions were evaluated. The results obtained are presented below.

#### **Air Pollutants of Relevance to Airport Associated Developments**

An inventory of emissions for the proposed airport and associated developments was made by Coffey Partners International and is reported elsewhere ( Working paper, Sydney Second Airport EIS, 1997 ). As it would take some time for the range of associated developments to become established, the inventory for the year 2016 is used.

For the present work the most significant emissions are judged to be non methane hydrocarbons and nitrogen oxides, these species are precursors for photochemical smog production. The inventory also included carbon monoxide. Particulate emissions may also be relevant to airport associated developments, but these impacts cannot be reliably predicted because particulate matter tends to reach its highest concentration under non-sea breeze conditions and these conditions are not sufficiently well characterised to warrant modelling.

An inventory has been made of emissions for the airport and airport associated developments (Coffey, 1997). The results for operations in year 2016 are summarised in Table 1, based on Air Traffic Forecast 3, Airport Operation 2.

TABLE 1  
Inventory Estimates of Air Pollutant Emissions Predicted for Operations  
in 2016 from Proposed Airport and Airport Associated Developments,  
including Motor Vehicle Traffic  
( kilograms per day, data from Coffey,1997 )

	<u>AIRPORT</u>	<u>ASSOCIATED DEVELOPMENTS</u>		
		Badgerys Creek	Holsworthy Option A	Holsworthy Option B
Hydrocarbons	2,470	10,300	8,860	13,000
Nitrogen Oxides	12,000	9,580	8,440	12,500
Carbon Monoxide	8,400	48,000	42,400	62,600

Table 1 shows that emissions of nitrogen oxides from associated developments, including motor vehicle traffic occurring outside of the airport site, are estimated to be approximately of the same magnitude as emissions from the airport itself. Hydrocarbon emissions from associated developments are predicted to be about

four times greater and carbon monoxide emissions about six times greater than those from the airport.

These increases in emissions from regions around the airport are primarily (greater than 90%) due to increases in motor vehicle traffic. These emissions would be diffuse and be distributed across a wide land area with the main focus being along the main roads servicing the airport. The differing emission rates for airport associated developments obtained for the three airport options is mainly due to the expected differences in the trip distance required for vehicle journeys to each proposed site.

The air emissions inventory (Coffey 1997) showed that compared with a 'do nothing' base case, vehicular traffic flows can be influenced by a second airport for distances greater than 30km from the airport site. These changes can be increases or decreases in traffic volume, depending on road location and the airport option being considered. The expected geographical distribution of vehicle traffic is given in Coffey 1997 for the cases of.

- (a) 'Do nothing', second airport not established
- (b) Badgerys Creek option
- (c) Holsworthy A option
- (d) Holsworthy B option

The emissions from airport associated developments are expected to occur predominantly near the ground. Therefore they would firstly mix in the lowest layer of the atmosphere and be advected along the trajectory of the surface wind. Because airport associated developments occur over a wide area, the plume of these emissions would be broad and diffuse.

Table 1 shows the greatest emission flux to be that of carbon monoxide. However carbon monoxide pollution is unlikely to become a pollution problem because the air can assimilate substantial quantities without breaching the ambient air carbon

monoxide guideline. For the atmospheric conditions prevailing in Sydney, inner city street canyons are recognised as being the only type of locality where carbon monoxide concentrations can approach the guideline value. This situation is unlikely to result from airport associated developments.

#### Emissions of NO<sub>x</sub> and Hydrocarbons

Nitrogen oxides are emitted predominantly (ca 95%) as nitric oxide (NO). In pure air NO reacts very slowly with oxygen to produce nitrogen dioxide (NO<sub>2</sub>), although for most ambient air situations this reaction is too slow to be of practical consequence. In sunlight however other oxidation processes can convert emitted NO to NO<sub>2</sub> in less than an hour. These photochemical reactions require both the presence of reactive organic hydrocarbons (ROC), which are emitted to the air predominantly as hydrocarbons, and sunlight. The NO<sub>2</sub> produced can undergo further photochemical reaction to produce ozone gas (O<sub>3</sub>), and give rise to episodes of photochemical smog.

There are no ambient air quality criteria for nitric oxide concentrations and the present National Health and Medical Research Council guideline for nitrogen dioxide is 0.16ppm. In the Sydney region the maximum nitrogen dioxide concentrations reported by the NSW EPA in Quarterly Air Quality Monitoring Reports have for the period since 1990 rarely exceeded 0.16ppm. There are no current air quality goals for ambient concentrations of hydrocarbons.

The rates predicted for nitrogen oxides and hydrocarbon emissions from airport associated developments are listed in Table 1. For nitrogen oxides, the airport associated emissions are of similar magnitude to those from airport operations; for hydrocarbons, emissions arising from airport associated developments are predicted to be about four times greater than those from airport operations. Airport associated developments are expected to be distributed over a wide geographical area and the concentrations of nitrogen dioxide that are likely to result are expected to be analogous to those currently experienced in districts of

Sydney that have traffic densities similar to those predicted for the various Airport Options. Therefore, on the basis of nitrogen dioxide concentrations currently occurring across the Greater Sydney region, the proposed airport associated developments are unlikely to cause ambient nitrogen dioxide concentrations to exceed 0.16ppm.

#### Prediction of Photochemical Smog Impacts

Ozone concentrations are widely used as an indicator of photochemical smog. However, understanding of the determinates of ozone concentrations in the region of and downwind of the proposed airport sites is largely qualitative. Prediction of the impacts of precursor emissions by the usual types of airshed modelling cannot at present be considered quantitative because of several unknowns, especially the lack of detailed knowledge of the vertical structure of the atmospheric boundary layer for the range of meteorological conditions conducive to the occurrence of photochemical smog events.

To minimise the limitations of these unknowns on the present assessment, the approach adopted was as follows. Results of the airport emissions 'footprint analysis' (Katestone Scientific, 1997) was used as a base case. The Integrated Empirical Rate (IER) method of describing photochemical smog production (Johnson 1984, Johnson and Quigley 1989) was then applied to estimate the resulting changes in predicted ozone concentrations when additional emissions due to airport associated developments occur along the path of relevant air trajectories that cross the proposed airport sites. The emissions fluxes employed are for a summer weekday, year 2016 and represent the predicted changes in population and motor vehicle travel for the airport site options. The emissions inventory has a 3x3 km grid and covers 7,200 square kilometres (Coffey, 23May,1997).



## **Assessment of Potential Effects on Photochemical Smog of Emissions from Airport Associated Developments**

Air flow trajectories representative of sea breeze, ozone event days were mapped onto the inventory and emissions from associated developments in a six kilometre wide band were evaluated. The results of the IER calculations given in the report, Katestone June 1997 were then adjusted to take account of these changes in emissions fluxes. The results give a viable estimate of the effects of associated emissions on air quality upwind and downwind of the proposed airports for sea breeze photochemical smog situations.

### Badgerys Creek Option

For the Badgerys Creek options, motor vehicle emissions would be significantly increased to the north along the main access road to the M4 motorway. These would tend to increase the effects of emissions from the airport by 20 to 30 percent over that of the airport alone.

The effect would be greatest when north easterly winds pass over the major access road to the M4 and bring these emissions to pass over the airport. In addition to this trajectory passing over the airport there would also be more widespread impacts of lower magnitude due to other, broadly distributed airport associated emissions.

In the area immediately downwind of the sources of emissions, the general effect of hydrocarbon emissions is to move the boundary of the onset of increased ozone concentrations towards the source of the hydrocarbon emissions. Conversely, the effect of nitrogen oxides emissions is to extend downwind the zone of ozone suppression caused by the presence of nitric oxide (Johnson, 1984). In summary, these near field effects due to hydrocarbon and nitrogen oxides emissions have opposite effects and, depending on the relative magnitudes of the emission strengths can be self compensating. However, at

distances further downwind the effects are different, with both hydrocarbons and nitrogen oxides increases tending to increase ozone concentrations.

For the Badgerys Creek airport options, emissions of nitrogen oxides and hydrocarbons from airport associated developments would tend to occur upwind of the airport for events leading to significant ozone concentrations. Taking into account the opposing effects in the near field of hydrocarbon and nitrogen oxides emissions, emissions from airport associated developments would tend to give no great change in the location of the upwind boundary of ozone increases due to emissions from the airport. The location of impacts would be similar to that predicted in Katestone, June 1997, for the cases of airport emissions alone.

#### Holsworthy Options

For Holsworthy Option A, increased emissions due to associated development tend to be concentrated to the north of the airport along the main transport corridors. Under meteorological conditions where increases in ozone concentrations as a result of airport operations are predicted (Katestone, June 1997), the impacts would tend to add to impacts from airport ground based and aircraft operations. The increase in emissions was estimated for a six kilometre wide band along a sea breeze wind trajectory. This amounted to a 34% increase in  $\text{NO}_x$  emissions over airport emissions alone. This would produce increases in the ozone impacts of the airport development of a similar magnitude. Because of the wind trajectories impacts of this magnitude are likely only to the south east of the airport site. On the other hand little impact is expected to the south west of the airport as these trajectories do not result in the associated emissions being received by the same air as the airport emissions. The location of airport impacts is predicted not to change substantially.

For Holsworthy Option B increased ozone impacts of up to 28% are predicted compared to that of the airport alone. The locations affected are to the south east

and south west of the airport, where airport emissions are predicted to impact. The zone of impact to the south west would tend to shift downwind as a result of the associated emissions sources being concentrated to the west of the airport.

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## **Appendix H**

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### Construction Impacts Report

Rust PPK

**SECOND SYDNEY AIRPORT  
CONSTRUCTION IMPACT ASSESSMENT**

Report No E2057/1-CT      May 1997

**Coffey Partners International Pty Ltd**

A.C.N. 003 692 019

Consulting Engineers, Managers and Scientists  
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## 1.0 INTRODUCTION

This report presents an assessment of air quality impacts due to construction works associated with the Second Sydney Airport (SSA). The report represents one of the air quality tasks of the SSA Environmental Impact Assessment (EIS) and has been undertaken by Coffey Partners International Pty Ltd (Coffey) on behalf of Rust PPK Pty Ltd.

The aim of this work was to identify and quantify the major emission sources that would be associated with the construction of a major international airport at Badgery's Creek or Holsworthy. The main pollutant of concern is particulate matter (PM) or dust which is generated by the action of mechanical apparatus and wind on exposed surfaces. Dust particles that are fine enough to remain suspended in the atmosphere constitute a health risk and have aesthetic effects such as reducing visibility. Larger particles that are deposited can reduce amenity of an area by soiling surfaces and materials. Diesel and petrol-fuelled construction equipment also emit pollutants such as oxides of nitrogen ( $\text{NO}_x$ ) and carbon monoxide (CO), however, the magnitude of these emissions is not expected to be large enough to warrant inclusion in the inventory.

Estimates of construction emissions were made for airport construction to Stage 1 and Master Plan configurations. Construction emissions from the Badgery's Creek and Holsworthy sites show significant variation due to the difference in the magnitude of earthworks required at the respective sites.

The local scale impacts of these dust emissions were assessed using the Fugitive Dust Model (FDM), which is a Gaussian model specifically designed for computing concentration and deposition impacts from fugitive dust sources. FDM is the modelling tool recommended by the USEPA for use in regulatory applications.

## 2.0 CONSTRUCTION OPERATIONS

Details of the construction operations at the proposed sites were provided by Airplan (1997). Construction activities would include building demolition and construction, pavement construction, removal of structures such as fences and bridges, vegetation clearance and excavation/earthworks. The main impacts of dust emissions on air quality would be expected to occur during topsoil stripping, excavation/earthworks and concrete batching/transport. Dust emissions during other phases of construction would be expected to be much smaller in magnitude and were not considered in the inventory.



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Construction work at the airport site would generally occur between 7am and 5pm from Monday to Saturday. Some out of hours work may be required according to construction schedules and concreting operations may be undertaken 24 hours per day.

### 3.0 EMISSION FACTORS

Atmospheric dust is produced from the action of mechanical implements on surface materials or from the erosion of exposed surfaces by the action of wind. A number of studies have attempted to relate dust emissions to various construction activities and associated wind erosion (SPCC, 1983 & 1988; USEPA, 1995; Axetell & Cowherd, 1981). Australian studies undertaken in the Hunter Valley have developed emission factors for the types of operations that would be part of the airport construction. Agreement between emission factors developed in Australia and those developed elsewhere are generally good, giving confidence in their use (Holmes, 1993).

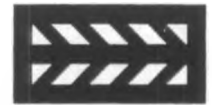
Dust emission factors for the various construction activities are shown in Table 1. These factors have been sourced from the Australian and US studies referenced above. It should be noted that the emission factors represent average conditions whereas the amount of dust produced can vary significantly according to a number of factors such as wind speed, rainfall, surface moisture and temperature.

**TABLE 1: DUST EMISSION FACTORS FOR CONSTRUCTION OPERATIONS**

OPERATION	EMISSION FACTOR	UNITS	SOURCE
<b>Vegetation Clearance</b>			
Topsoil removal (scraper) <sup>a</sup>	28.5	kg/hr	USEPA (1995)
Topsoil removal (dozer)	14	kg/hr	SPCC (1983)
Haulage	2	kg/km	SPCC(1988)
<b>Excavation/Earthworks</b>			
Drilling	0.6	kg/hole	USEPA (1995)
Blasting <sup>b</sup>	19.7	kg/blast	Axetell & Cowherd (1981)
Loading	0.025	kg/t	SPCC(1988)
Removal (scraper)	28.5	kg/hr	USEPA (1995)
Haulage	2	kg/km	SPCC(1988)
Dumping	0.012	kg/t	SPCC(1988)
Spreading (dozer)	4.3	kg/hr	SPCC(1988)
Grading	6	kg/hr	USEPA(1995)
<b>Exposed Areas</b>			
Wind Erosion	0.4	kg/ha/hr	SPCC (1983)

a. Average speed of travel assumed to be 5 km/hr.

b. Average area of blast assumed to be 2000 m<sup>2</sup>.



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#### 4.0 SOURCES OF DUST EMISSION

##### 4.1 Topsoil Stripping

The proposed sites would be cleared of vegetation to allow subsequent airport development. The major source of dust emission during the clearing operations would be the topsoil stripping phase, which will involve removal of soil by bulldozers/scrapers and transport of soil to storage stockpiles.

Dust emissions for both the Badgery's Creek and Holsworthy sites were estimated on the assumption that topsoil stripping would involve the use of 2 dozers and 2 scrapers for a typical 10 hour day shift. Applying the relevant emission factors as shown in Table 1, this level of activity results in a daily emission of approximately 850 kg. Haul trucks transporting topsoil and other material on unsealed roads are assumed to travel a combined distance of 100 km per day, resulting in the daily emission of a further 200 kg of dust.

##### 4.2 Excavation/Bulk Earthworks

Excavation and earthworks would be required at the proposed airport sites to produce the graded areas suitable for construction and create trenches for various services and conduits. The equipment used for these operations would include bulldozers, scrapers, excavators, graders and haul trucks.

There would be significant differences in the magnitude of earthworks required at the respective sites. Development of the Holsworthy sites would involve drilling and blasting of the underlying sandstone formation and will require more extensive earthworks than Badgery's Creek due to the complex topography of the Holsworthy plateau. In addition, it would be necessary to create large borrow areas on the Holsworthy sites to supply the amount of fill material required.

Expected volumes of earthworks for each of the proposed airport sites are shown in Tables 2 and 3. The construction equipment inventories for the earthworks phase of construction appear in Tables 4 and 5.



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**TABLE 2: VOLUME AND DURATION OF EARTHWORKS AT BADGERY'S CREEK<sup>a</sup>**

	Option A		Option B		Option C	
	Stage 1	Master Plan	Stage 1	Master Plan	Stage 1	Master Plan
Cut ( $10^6 \text{ m}^3$ )	11	24	26	35.5	13	26.5
Fill ( $10^6 \text{ m}^3$ )	13.5	27	7	36	15	29
Spread/Stockpile ( $10^6 \text{ m}^3$ )	1.9	-	19	-	-	-
Borrow Pit ( $10^6 \text{ m}^3$ )	2.5	3	-	0.5	2	2.5
Excavation rate <sup>b</sup> ( $10^3 \text{ m}^3/\text{day}$ )	20	30	45	41	20	30
Years	1.5	2.2	2.2	2.8	1.5	2.3

a. Reproduced from Airplan (1997)

b. Based on a 20 hour work day.

**TABLE 3: VOLUME AND DURATION OF EARTHWORKS  
AT HOLSWORTHY ( $10^6 \text{ m}^3$ )<sup>a</sup>**

	Option A		Option B	
	Stage 1	Master Plan	Stage 1	Master Plan
Cut ( $10^6 \text{ m}^3$ )	30	102.5	110	170
Fill ( $10^6 \text{ m}^3$ )	115	205	95	180.5
Spread/Stockpile ( $10^6 \text{ m}^3$ )	-	-	15	-
Borrow Pit ( $10^6 \text{ m}^3$ )	85	102.5	-	10
Excavation rate <sup>b</sup> ( $10^3 \text{ m}^3/\text{day}$ )	110	110	110	96
Years	3.5	6.5	3.8	6.5

a. Reproduced from Airplan (1997)

b. Based on a 20 hour work day.



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**TABLE 4: CONSTRUCTION EQUIPMENT INVENTORY (EARTHWORKS)**  
**FOR BADGERY'S CREEK**

Equipment	Option A		Option B		Option C	
	Stage 1	Master Plan	Stage 1	Master Plan	Stage 1	Master Plan
Scrapers	8	10	10	12	8	10
Bulldozers	2	2	2	2	2	2
14 m <sup>3</sup> Haul Trucks	8	10	12	14	8	10
Excavators	1	1	1	1	1	1
Loaders	1	1	1	1	1	1
Graders	1	1	1	1	1	1

a. Reproduced from Airplan (1997)

**TABLE 5: CONSTRUCTION EQUIPMENT INVENTORY (EARTHWORKS)**  
**FOR HOLSWORTHY**

Equipment	Option A		Option B	
	Stage 1	Master Plan	Stage 1	Master Plan
25m <sup>3</sup> Haul Trucks	14	24	14	20
Dragline	2	3	2	3
Loaders	1	1	1	1

a. Reproduced from Airplan (1997)

To estimate the average daily emissions during the excavation/earthworks phase of construction, it was assumed that the entire equipment plant as specified in Tables 4 and 5 would be operating on the site during a worst case 20 hour working day. Detailed assumptions relating to the emissions calculations were based on information contained in the draft construction report (Airplan,1997) and are as follows :

- drilling operations (Holsworthy only) would be undertaken 24 hours per day with 600 holes being drilled each day.
- blasting (Holsworthy only) would occur at dawn and/or dusk, with eight separate blast events required at 4 locations. Each blast will cover an area of approximately 2000 m<sup>2</sup>.



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- loading/dumping emissions were calculated on the expected daily excavation rates for the proposed sites as shown in Tables 4 and 5;
- scrapers (Badgery's Creek only) would be the single largest source of dust emissions and for this reason, control measures such as wetting of work surfaces would be most intense for these units. A control efficiency of 50% is assumed.
- trucks transporting fill material over the site were assumed to cover a haul distance of 1 km (round trip) 5 times per hour.

Estimates of daily dust emissions from earthworks operations at Badgery's Creek and Holsworthy are shown in Tables 6 and 7.

**TABLE 6: DAILY DUST EMISSIONS (kg) FROM EARTHWORKS OPERATIONS  
AT BADGERY'S CREEK**

	Option A		Option B		Option C	
	Stage 1	Master Plan	Stage 1	Master Plan	Stage 1	Master Plan
Scrapers	2,280	2,850	2,280	3,420	2,280	2,850
Bulldozers	172	172	172	172	172	172
Haulage	1,600	2,000	1,600	2,800	1,600	2,000
Loading	750	1,125	750	1,538	750	1,125
Dumping	360	540	360	738	360	540
Graders	120	120	120	120	120	120
<b>TOTAL</b>	<b>5,282</b>	<b>6,807</b>	<b>5,282</b>	<b>8,788</b>	<b>5,282</b>	<b>6,807</b>

**TABLE 7: DAILY DUST EMISSIONS (kg) FROM EARTHWORKS OPERATIONS  
AT BADGERY'S CREEK**

	Option A		Option B	
	Stage 1	Master Plan	Stage 1	Master Plan
Haulage	2800	4800	2800	4000
Dragline	618	618	618	618
Loading	3726	3726	3726	3201
Dumping	1788	1788	1788	1536
Drilling	360	360	360	360
Blasting	157	157	157	157
<b>TOTAL</b>	<b>9450</b>	<b>11450</b>	<b>9450</b>	<b>9873</b>



4.3 Wind Erosion

Dust would be generated from the action of wind on exposed earth. It has been assumed that the area left bare at any time during airport development will be approximately 100 hectares. Using the recommended emission factor of 0.4 kg/ha/hr (Table 1), an area of this size subject to wind erosion would generate 960 kg per day. This should be regarded as a conservative estimate given that dust reduction strategies would be utilised on the sites, including regular wetting of cut surfaces with water or biodegradable wetting agents.

4.4 Concrete Batching and Transportation

Large volumes of concrete would be used for structures and pavements during the development of SSA. Concrete batches would be prepared in batching plants located on the proposed sites. It is anticipated that the total volume of concrete required for building and pavement construction at the Badgery's Creek and Holsworthy sites to Stage 1 configuration would be in the order of 850,000m<sup>3</sup>. More than double these quantities would be required for development up to the Master Plan configuration (Airplan, 1997).

Sources of dust emission associated with concrete preparation include transfer of raw materials (cement, sand and aggregate), truck loading, mixer loading, vehicle traffic and erosion of sand and aggregate piles (USEPA, 1995). The movement of trucks over unpaved surfaces could be the major emission source without control measures such as wetting of the road surface.

Emission factors published by the USEPA (1995) were adopted in this study and are shown in Table 8. Note that cement unloading to the storage silo is assumed to be via an uncontrolled pneumatic conveyor.

**TABLE 8: EMISSION FACTORS FOR CONCRETE BATCHING PROCESSES**

Emissions Source	Emission Factor	unit
Sand/Agg transfer	0.014	kg/t
Cement unloading (pneumatic)	0.13	kg/t
Weigh hopper loading	0.01	kg/t
Mixer loading	0.02	kg/t
Truck mix loading	0.01	kg/t
Truck haulage (unpaved)	2 <sup>a</sup>	kg/km
Wind erosion (storage piles)	3.9	kg/ha/day

a. SPCC (1988).



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Emissions from concrete preparation and transporting were estimated according to the following assumptions :

- density of concrete = 2,373 kg/m<sup>3</sup>;
- equal volume of concrete used for each year of airport development;
- concrete formulation comprising 12.5% cement, 31% sand, 47.5% aggregate and 9% water;
- storage piles covering an area of 1 ha;
- truck loading capacity of 6m<sup>3</sup> and round trip haul distance of 1 km; and
- volume of concrete required for the master plan configuration would be 2.5 times that required for stage 1 construction.

Estimates of dust emissions from concrete for Stage 1 and Master Plan construction are presented in Tables 9 and 10.

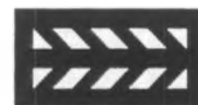
**TABLE 9: DUST EMISSIONS FROM CONCRETE  
PREPARATION/TRANSPORTATION AT BADGERY'S CREEK**

Operation	Option A		Option B		Option C	
	Stage 1	Master Plan	Stage 1	Master Plan	Stage 1	Master Plan
Sand/Agg transfer	13.50	23.36	12.15	23.36	13.50	25.31
Cement unloading - pneumatic	19.96	34.54	17.96	34.54	19.96	37.42
Weigh Hopper load	11.18	19.34	10.06	19.34	11.18	20.95
mixer load	12.28	21.25	11.05	21.25	12.28	23.03
truck mix load	6.14	10.63	5.53	10.63	6.14	11.51
truck haulage	172.50	298.56	155.25	298.56	172.50	323.44
wind erosion	3.90	3.90	3.90	3.90	3.90	3.90
TOTAL	239.45	411.58	215.89	411.58	239.45	445.55

**TABLE 10: DUST EMISSIONS (kg/day) FROM CONCRETE  
PREPARATION/TRANSPORTATION AT HOLSWORTHY**

	Option A		Option B	
	Stage 1	Master Plan	Stage 1	Master Plan
Sand/Agg transfer	10.12	16.87	9.34	15.18
Cement unloading - pneumatic	14.97	24.94	13.82	22.45
Weigh Hopper load	8.38	13.97	7.74	12.57
mixer load	9.21	15.35	8.50	13.82
truck mix load	4.61	7.68	4.25	6.91
truck haulage	129.38	215.63	119.42	194.06
wind erosion	3.90	3.90	3.90	3.90
TOTAL	180.56	298.34	166.97	268.89





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## 5.0 CONSTRUCTION EMISSIONS SUMMARY

A summary of daily emissions for each of the scenarios and sites considered are presented in Tables 11 and 12.

**TABLE 11: DUST EMISSIONS (kg/day) FROM ALL EARTHWORKS  
OPERATIONS AT BADGERY'S CREEK**

Emission Source	Option A		Option B		Option C	
	Stage 1	Master Plan	Stage 1	Master Plan	Stage 1	Master Plan
Topsoil Stripping	1,900	1,900	1,900	1,900	1,900	1,900
Excavation/earthworks	5,282	6,807	5,282	8,788	5,282	6,807
Wind Erosion	957	957	957	957	957	957
Concrete Batching	239	412	216	412	239	446
<b>TOTAL</b>	<b>8,379</b>	<b>10,076</b>	<b>8,355</b>	<b>12,056</b>	<b>8,379</b>	<b>10,110</b>

**TABLE 12: DUST EMISSIONS (kg/day) FROM ALL EARTHWORKS  
OPERATIONS AT HOLSWORTHY**

Emission Source	Option A		Option B	
	Stage 1	Master Plan	Stage 1	Master Plan
Topsoil Stripping	1,900	1,900	1,900	1,900
Excavation/earthworks	9,450	11,450	9,450	9,873
Wind Erosion	957	957	957	957
Concrete Batching	181	298	167	269
<b>TOTAL</b>	<b>12,488</b>	<b>14,605</b>	<b>12,474</b>	<b>12,999</b>

## 6.0 DISPERSION MODELLING OF PARTICULATE MATTER EMISSIONS

The Fugitive Dust Model (USEPA, 1992) was used for the dispersion modelling of dust emissions associated with the construction of SSA for the various scenarios. FDM is an air quality model designed for computing concentration and deposition impacts from fugitive dust sources. The model is based on the Gaussian plume formulation with gradient transfer deposition algorithm.

### 6.1 Meteorological Data

Wind speed and direction monitoring records gathered between March 1990 and April 1992 at a Macquarie University monitoring station near Badgery's Creek were compiled for dispersion modelling of particulate matter emitted from the Badgery's Creek airport sites. Data from the



Lucas Heights monitoring station (10 metre mast) gathered between January 1994 and December 1995 were used for the proposed airport sites at Holsworthy. Processing of meteorological data carried out in preparation for dispersion modelling was as for local scale modelling of operational impacts and is discussed in the Air Quality Working Paper for the Sydney Second Airport Draft EIS.

## 6.2 Modelling Assumptions

For the purposes of modelling, construction emission sources comprising topsoil stripping, earthworks and wind erosion were represented as an area source in the centre of the airport site covering an area of 2 square kilometres.

Concrete batching plant emissions were assumed to be within the vicinity of the contractors compound as specified on plans supplied by Airplan with space allowance for truck haulage emissions. Location of borrow areas for the Badgery's Creek and Holsworthy sites were based on maps supplied by Airplan (1997). Emissions from borrow areas are based on the proportion of borrow volumes compared to total earthworks volumes.

Most of the vegetation/topsoil stripping and overburden removal work would occur between 7am and 5pm from Monday to Saturday. Work may also be undertaken on Sunday depending on the construction schedule or other factors. Worst case conditions would involve a 20 hour work day (double shift) 6 days per week. This was approximated in the dispersion modelling by conservatively assuming a 24-hour operation. Similarly, operations involving the pouring of concrete could occur 24 hours per day.

The assumptions concerning key modelling parameters are as follows :

- terrain effects have been ignored for the proposed airport sites as FDM does not simulate rough terrain. For both Badgery's Creek and Holsworthy, however, the airport sites are elevated in comparison to surrounding areas so that it is considered conservative to assume flat terrain in the dispersion modelling. Badgery's Creek has a reduced level of approximately 90m AHD compared with a level of about 40m AHD for the surrounding terrain. The difference is more marked for the Holsworthy sites with airport site at 150m to 190m AHD and surrounding terrain being at about 50m AHD;
- the landuse category for all sites was described by a surface roughness height of 0.6 metres; and



- three particle size classes were adopted to represent fine, inhalable and coarse particulate matter fractions. The mean diameters for these fractions were given values of 1.0, 6.1 and 21.1 microns as adopted by SPCC (1988).

### 6.3 Results

Ground level particulate matter concentrations and deposition rates were computed for the Master Plan construction scenario only. Given the relatively small difference in total dust emissions for the Stage 1 and Master Plan inventories, the Master Plan results are considered to give a reasonable indication of Stage 1 construction impacts. Results are presented as daily maxima (dust concentration) and long term averages (dust deposition) to enable comparisons to be made with the relevant air quality criteria adopted by EPANSW and other authorities.

The dispersion modelling of PM emissions using FDM yields results in terms of Total Suspended Particulates (TSP) which refers to dust particles of size ranging from zero to approximately 30 microns. To compare the levels of smaller size fractions such as  $PM_{10}$  with the recommended limits, the proportion of such fractions in TSP must be considered. This analysis suggests that  $PM_{10}$  accounts for between 50 and 60% of TSP. Such factors were applied to the TSP results to derive estimates of  $PM_{10}$ .

The location of the earthworks emission sources within the airport sites and in borrow areas will vary over the duration of the construction phase. This variation in source location was simulated by superimposing and moving the contours of particulate matter impacts over plans of the airport sites. The use of this method means that the long term average dust concentration could not be reliably estimated.

Dispersion modelling results for dust concentration and deposition are presented in Figures 1 and 2.

### 6.4 Discussion

The recommended maximum concentration of Total Suspended Particulate (TSP) in residential areas is  $90 \mu\text{g}/\text{m}^3$  annual average. Additional criteria for particles smaller than 10 microns ( $PM_{10}$ ) are currently  $50 \mu\text{g}/\text{m}^3$  (annual average) and  $150 \mu\text{g}/\text{m}^3$  (24 hour average).

The criteria for atmospheric particulate matter concentration in the U.S. is currently under review, with much stricter standards planned for fine particulate matter up to  $2.5 \mu\text{g}$  in diameter ( $PM_{2.5}$ ). The proposed standards comprise an annual  $PM_{2.5}$  standard set at  $15 \mu\text{g}/\text{m}^3$  and a 24-hour  $PM_{2.5}$  standard set at  $50 \mu\text{g}/\text{m}^3$ . It should be noted, however, that the fraction of fine particulate in dust emissions from construction operations is generally less than 10%.



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Deposition standards for particulate matter vary according to the existing deposition levels in the area of concern. The standards are expressed in terms of the maximum acceptable increase in deposition rate and range from 0 to 2 g/m<sup>2</sup>/month.

A summary of the air quality guidelines relating to the concentration and deposition of particulate matter is shown in Table 13.

**TABLE 13**  
**AIR QUALITY CRITERIA FOR PARTICULATE MATTER (PM)**

PM FRACTION	CRITERIA	AGENCY
Total Suspended Particulate (TSP)	90 µg/m <sup>3</sup> (annual maximum)	NHMRC
PM <sub>10</sub> (< 10 µm)	50 µg/m <sup>3</sup> (annual average)	USEPA
PM <sub>10</sub> (< 10 µm)	150 µg/m <sup>3</sup> (24 hour average)	USEPA
PM <sub>2.5</sub> (< 2.5 µm) - under review	15 pphm (annual average)	USEPA
PM <sub>2.5</sub> (< 2.5 µm) - under review	50 pphm (24 hour average)	USEPA

The shaded areas on Figures 1 and 2 indicate where there is potential for breaches of the concentration and deposition goals. For the purposes of this analysis it was assumed that a daily average maximum concentration of more than 100 µg/m<sup>3</sup> PM<sub>10</sub> constituted a breach of the recommended limit of 150 µg/m<sup>3</sup>, which allows for a background PM<sub>10</sub> level of 50 µg/m<sup>3</sup>. For deposition, a breach is considered to occur where the long term average deposition rate exceeds 2 g/m<sup>2</sup>/month.

As no advice was received regarding the likely area under construction at any one time, an area of 1 square kilometre representing emissions from topsoil removal and earthworks was used in the dispersion modelling. Contours derived from this representation were superimposed on airport site maps at various locations around the airport site to ascertain at which locations the construction operations would have significant impact on surrounding areas. It was assumed that the major construction activities extended to the edges of runways and to the limits of areas designated for clearing as indicated on Airport site maps.

The dispersion modelling results for 24 hour maximum PM<sub>10</sub> concentrations indicate that there is potential for significant air quality impacts at the Badgerys Creek and Holsworthy sites (Figure 1). The potential impact is greater at the Badgerys Creek sites given the proximity of residential areas



and the fact that certain areas of the Holsworthy Range provides a buffer zone for the Holsworthy airport options.

Figure 1 shows the largest 24 hour dust concentration impacts at Badgerys Creek Options A and B to be towards the north west and north east of the respective sites. In these areas the  $100 \mu\text{g}/\text{m}^3$  contour extends up to 4 km from the airport boundaries. Badgerys Creek option B had the largest total dust emission as shown in Table 11 which is reflected in the dust concentration results with the  $100 \mu\text{g}/\text{m}^3$  contour extending 5 km past the airport boundary to the north east.

The 24 hour dust concentrations for Holsworthy Option A indicate that the Holsworthy Range generally has the effect of buffering the potential impacts on areas to the north and west of the site. Significant impacts are shown to occur 4 to 5 km from the site boundary on the eastern and southern sides of the site. The results for Holsworthy Option B show that large dust impacts could occur to the east and around the southern half of the site. Impacts to the north are shown to occur within the Holsworthy range with limited potential for exceedence to the north west.

The results for long term average dust deposition at the airport sites are shown in Figure 2. They indicate that breaches of the  $2 \text{ g}/\text{m}^2/\text{month}$  deposition limit will occur although such breaches will be small in comparison to the daily results. Generally, impacts could be expected to occur up to 1 km from the respective airport boundaries. The results for the Holsworthy options indicate that the Holsworthy Range will buffer the deposition impacts to some extent.

The conservative nature of these estimates should be noted. In particular, the use of 24 hourly maximum concentrations show the worst outcomes possible and do not indicate average daily conditions. Also, the method adopted to model the movement of the dust emissions sources over the airport sites assumes that construction operations occurring near the boundaries of the sites will coincide with the worst-case meteorological conditions, which will not necessarily be the case. In addition, effects such as retention of dust for excavation undertaken in pits below ground level have not been modelled. Finally, the assumption of an existing daily average  $\text{PM}_{10}$  concentration of  $50 \mu\text{g}/\text{m}^3$  may be overly conservative.

The concentration and deposition results attest to the importance of adequate dust controls during the earthworks phase of airport construction. Under adverse meteorological conditions, the use of more intensive control measures may be required or in extreme cases it may be appropriate to halt construction operations with the highest potential for dust generation. Established dust management practices include the following :

- use of water sprays to reduce dust emissions during earthworks,
- sealing and revegetation of finished surfaces as soon as practicable; and



- minimising of the areas where earthworks are actively being carried out.

This analysis assumed a single large area source for the bulk of the earthworks activities. Impacts were found to be significant in areas surrounding the sites, particularly for 24 hour  $PM_{10}$  concentrations. Another form of dust management could be the scheduling of work so that spreads would not be concentrated in one area. Spreads operating at different areas on the sites would have the effect of spreading the dust burden around the site and decreasing overall impact.

## 7.0 CONCLUSION

Inventories of particulate matter (PM) emissions were established for the proposed airport sites at Badgerys Creek and Holsworthy. Emission estimates were based on earthworks volumes and related information supplied by Airplan (1997) and emission factors for the various construction activities sourced from Australian and US work. The local scale impact of these PM emissions were assessed through the use of the Fugitive Dust Model (FDM) Gaussian dispersion software package.

The local scale impact analysis suggests that potential exists for significant air quality impacts due to PM emissions on areas surrounding the airport sites. In particular, results for 24 hour maximum concentrations show that unacceptable  $PM_{10}$  impacts can occur large distances from the airport boundaries. In general, potential impacts are more severe for the Badgerys Creek airport sites due to the buffering effect of the Holsworthy Range on  $PM_{10}$  emissions from the Holsworthy airport sites.

The study limitations are as follows :

- Yearly average concentrations were not computed by reason of the method used to simulate the movement of construction operations across the site. It would be expected, however, that potential would exist for breaches of the applicable long term concentration criteria;
- Area sources were used to represent construction activities at the airport sites. Actual emissions will include point, line and area sources of varying strength and duration; and
- There is considerable uncertainty in the use of emission factors presented as they have been established for typical conditions.

The analysis suggested that potential exists for significant impacts on air quality from construction operations associated with the second airport. In addition to incorporating stringent dust control measures into the construction plan, it is recommended that dust sampling equipment be installed as



part of the construction effort to monitor the amount of dust generated and take preventative actions where necessary.

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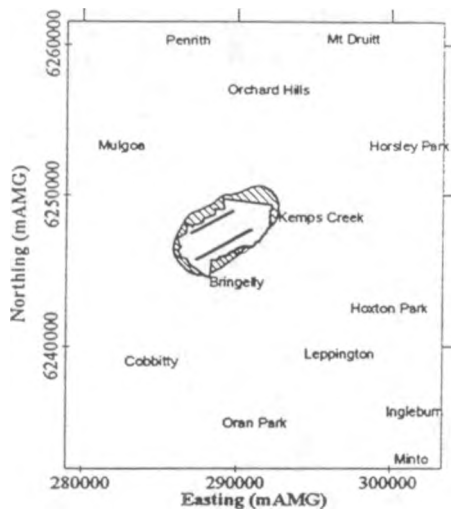
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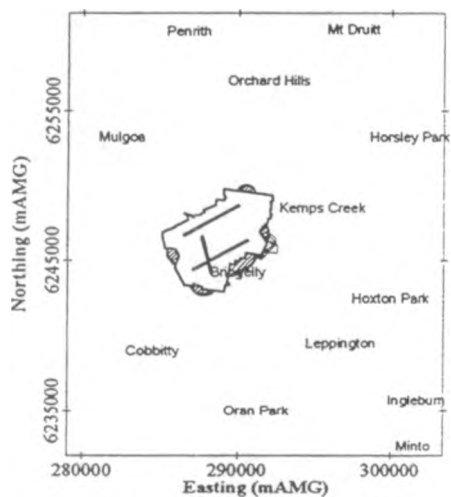
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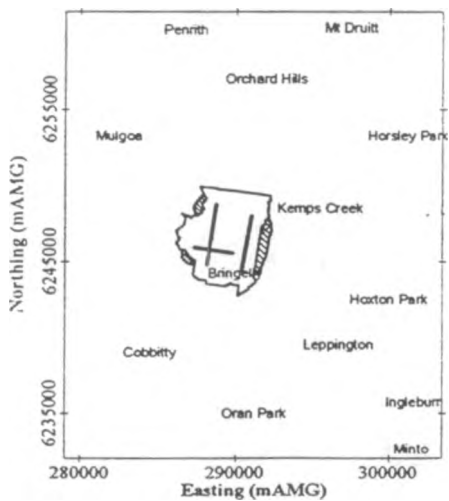
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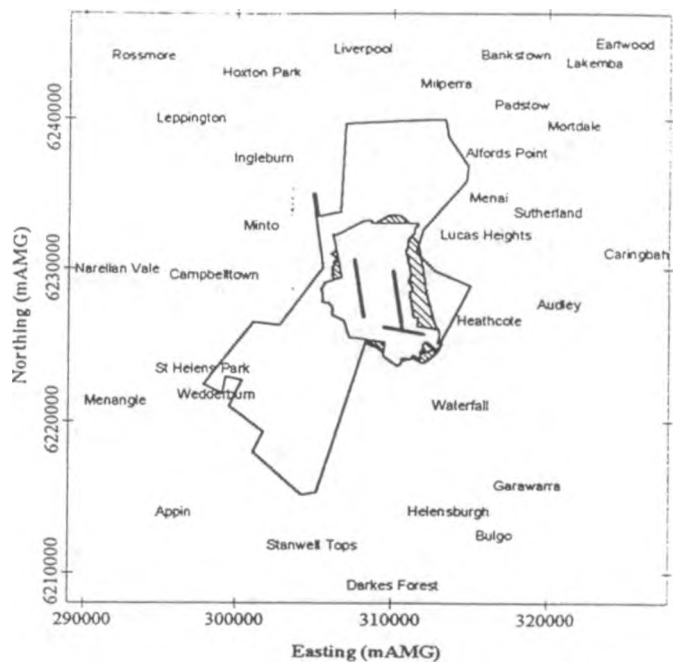
BADGERYS CREEK OPTION A



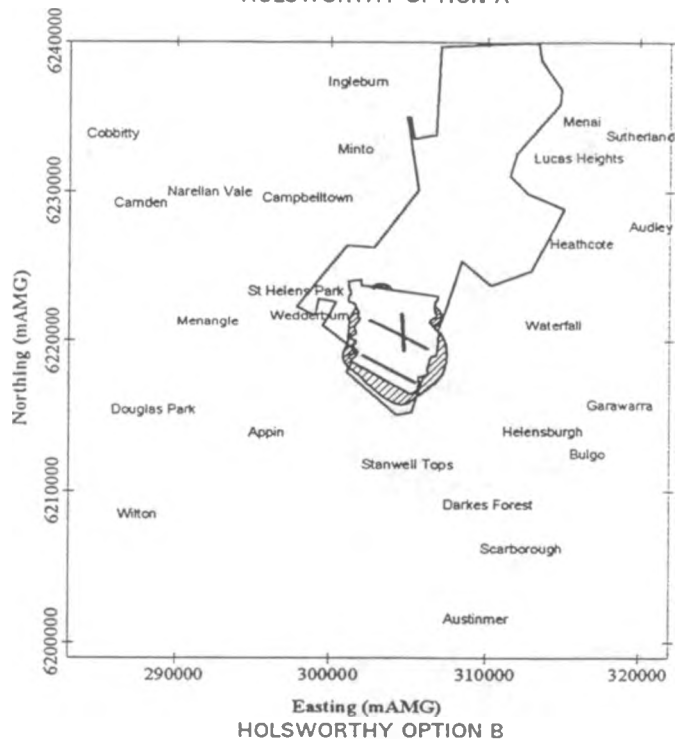
BADGERYS CREEK OPTION B



BADGERYS CREEK OPTION C



HOLSWORTHY OPTION A



HOLSWORTHY OPTION B

NOTES:

Shaded region shows maximum increase in dust deposition by more than  $2 \text{ g/m}^2/\text{mth}$ .

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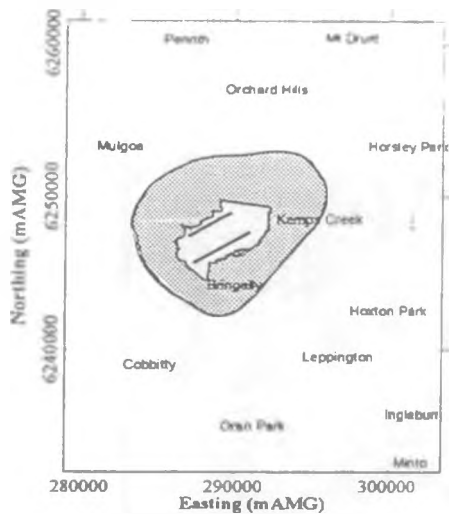
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PREDICTED MAXIMUM CONSTRUCTION DUST IMPACT



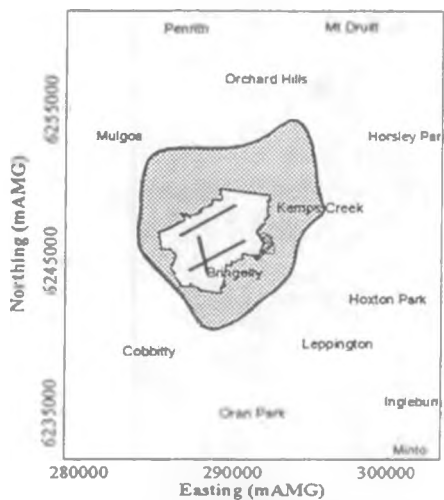
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FIGURE 1

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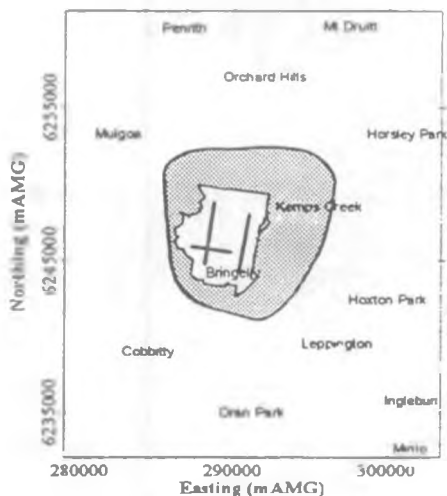




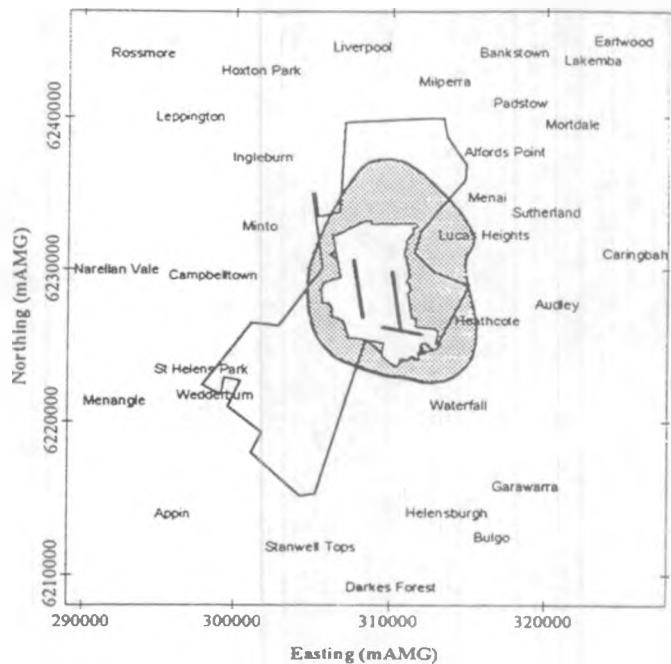
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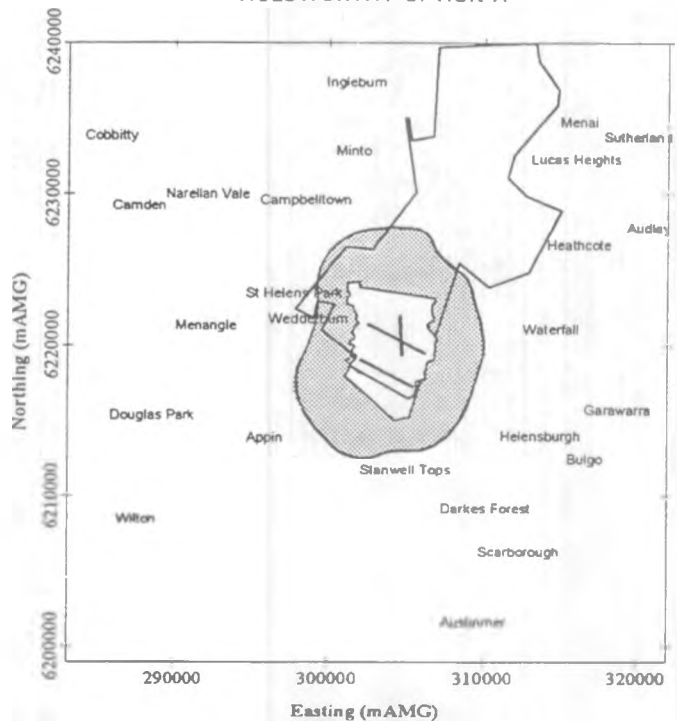
BADGERYS CREEK OPTION B



BADGERYS CREEK OPTION C



HOLSWORTHY OPTION A



HOLSWORTHY OPTION B


NOTES:

Shaded region shows predicted increase in  $PM_{10}$  particulate concentration by more than  $100\mu g/m^3$

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MAXIMUM PREDICTED CONSTRUCTION  $PM_{10}$  IMPACT ( $\mu g/m^3$ )



figure no.

FIGURE 2

job no: E2057/1-DA

## **Appendix I**

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### Sewage Treatment Plant Odour Assessment

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E2057/1-DF  
11 June 1997

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Attention: Mr David Gamble

Dear Sir,

**RE: SYDNEY SECOND AIRPORT EIS -**  
**ODOUR IMPACTS OF SEWAGE TREATMENT PLANT**

## 1.0 INTRODUCTION

This report presents an assessment of air quality impacts due to the operation of a sewage treatment plant (STP) at the sites under consideration for the Second Sydney Airport (SSA). The report represents one of the air quality tasks of the SSA Environmental Impact Assessment (EIS) and has been undertaken on behalf of Rust PPK Pty Ltd.

The aim of this work was to identify and quantify the odour sources that would be associated with an STP at the Badgerys Creek and Holsworthy airport sites. Estimates of odour emissions are made for SSA for Stage 1 and Master Plan configurations.

The local scale impacts of these odorous emissions have been assessed using the AUSPLUME Gaussian plume dispersion model. Odour strength contours were compared with the design criterion adopted by the Environment Protection Authority of NSW (EPANSW).

## 2.0 DEMAND FOR SERVICES

Preliminary estimates of the demand for sewerage services have been provided by Airplan (1997). It is estimated that the Stage 1 development would have an Equivalent Population (EP) loading of 28,000 (7.5 ML/day) while the Master Plan development would have an EP loading of 84,000 (22.5 ML/d).





3.0 EVALUATION CRITERIA

Odour concentration is expressed in the form of several types of odour units. Odour detection units represent the number of dilutions of odourous air which are required to reduce the odour to a level at which it is at the threshold of detection by an expert panel of sniffers. Odour can be detected in the time it takes to sniff the air which is of the order of one second. NSW EPA have identified a design criterion of 2 odour units using the threshold of detection for the 99.5th percentile concentrations of 3-minute averages from predictive modelling (Dean, 1995). This is a level at which annoyance from nearby residents should be limited to an acceptable level. Sydney Water Corporation stipulate 400m buffer zones around sewage treatment plants for protection against adverse odour impacts.

4.0 ODOUR EMISSIONS

It is expected that the STP would treat sewage on site with disposal of treated effluent to nearby creeks. Sewage treatment to tertiary level incorporating nutrient removal would be required to produce an effluent with a quality suitable for this method of disposal. An area of 5 ha was adapted for the STP.

Recent work by Ramsey and Thiele (1995) was sourced to estimate odor emission rates from the STP for the Stage 1 development. The Springvale Farm STP considered in their analysis currently has a service capacity of 30,000 EP and produces a high quality effluent suitable for discharge into a creek. It is assumed that Springvale Farm is an appropriate surrogate for the Stage 1 STP proposed for SSA and the odour emission rates derived by Ramsey and Thiele (1995) were adopted for the purposes of this study.

Odour emission rates for the second airport STP are presented in Table 1. Emission rates are for both normal operation. Ramsay and Thiele print out that in the event of disruption to normal operations STP odour emission could increase dramatically and increase odour strength by a factor of 7 were predicted under such conditions. Odour strengths for the Master Plan development have been derived by scaling the Stage 1 emission rates by the expected increase in plant capacity.

TABLE 1  
ODOUR EMISSION RATES FOR THE SEWAGE TREATMENT WORKS AT SSA

Odour Emission Rate (OU.vol/sec)	
Stage 1 Development	Master Plan Development
6,000	18,000
43,000	130,000



## 5.0 DISPERSION MODELLING

### 5.1 Meteorological Data

Meteorological data files were prepared using air quality data sourced from Macquarie University and ANSTO monitoring stations. Data gathered between March 1990 and April 1992 at a Macquarie University monitoring station near Badgerys Creek was compiled for dispersion modelling of odour emitted from the Badgerys Creek STP. Data from the Lucas Heights monitoring station (10 metre mast) gathered between January 1994 and December 1995 were used for the proposed airport sites at Holsworthy.

### 5.2 Modelling Assumptions

AUSPLUME version 3.3 (EPA Victoria, 1996) was used for the dispersion modelling. The assumptions concerning major modelling parameters are as follows :

- terrain effects have been ignored for the proposed airport sites. For both Badgerys Creek and Holsworthy the airport sites are elevated in comparison to surrounding areas meaning that it is considered conservative to assume flat terrain in the dispersion modelling. Badgerys Creek has a reduced level (RL) of approximately 90m compared with an RL of 40m for the surrounding terrain. The difference is more marked for the Holsworthy sites with airport site RL and surrounding terrain RL being 150-190m and 50m respectively;
- a complete set of hourly data describing the standard deviation of wind direction fluctuations (sigma-theta) were not available in the meteorological files. Plume dimensions have therefore been based on Pasquill-Gifford dispersion curves;
- the landuse category for all sites is described by a surface roughness height of 0.6 metres; and
- the wind profile exponents are based on the Irwin urban scheme.

In the absence of a layout design for the STP emissions were treated as occurring uniformly over an area of 5 ha considered to be appropriate given that the local scale dispersion modelling task for SSA is to investigate air quality impacts outside the airport boundary.

The receptor grid size and density chosen for each of the airport sites was chosen based on the proximity of residential areas. The receptor grid for the Badgerys Creek sites consists of 3000 receptor locations spaced 100m apart, covering an area of approximately 10 square kilometres. The



grids for the Holsworthy sites comprise 1600 receptors spaced 1000m apart, covering an area of approximately 1520 square kilometres.

## 6.0 RESULTS

Contour plots showing the percentage exceedence of 2 OU for Stage 1 and Master Plan development scenarios are presented in Figures 1 and 2. Contours with values greater than 0.5% have been shaded to indicate where predicted odour frequency exceeds the EPANSW odour criteria. Dispersion modelling results were generated in the form of frequency of exceedence of 2 odour units (OU). According to current EPANSW design criteria for non-scheduled premises, the 2 OU level must not be exceeded for more than 0.5% of the year (approximately 44 hours) to ensure that annoyance levels are kept at an acceptable level.

## 7.0 DISCUSSION

Figure 1 indicates that there is a negligible odour impact from the proposed STP for the Stage 1 development scenario under normal operating conditions. Frequency of exceedence contours that reach to the airport boundaries are below 0.5%.

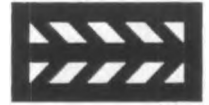
Figure 2 shows a potential impact arising from the STP at the SSA sites for the Master Plan development under normal operating conditions. The 0.5% frequency of exceedence contour extends up to approximately 0.5 km outside of the airport boundaries. For Holsworthy option A, the odour impact is contained within the Holsworthy Military Reserve. The frequency contours for Holsworthy B indicate potential odour impacts on surrounding areas at the south west corner of the airport boundary that are outside of the Holsworthy Military Reserve.

## 8.0 CONCLUSION

Estimates of odorous emissions were made for the proposed sewage treatment works. Emission rates estimates for the Stage 1 development scenario were based on those of a modern plant incorporating similar levels of sewage treatment as specified for the SSA treatment works. Emissions for later years conservatively based on the increase in demand for services rather than taking into account likely changes in plant technology and operating procedures.

The conclusions of this study are as follows :

Stage 1 development - the potential odour impacts are acceptable according to the criteria adopted by the EPANSW. That is, the odour levels impacting on surrounding areas are above 2 OU for less than 44 hours per year.



Master Plan development - there is potential for small odour impacts short distances from the airport boundaries at certain points along the airport boundaries. For the Holsworthy sites, these impacts are mostly confined to the Holsworthy Military Range.

The main limitation of the study is that detailed information on the likely configuration of the STP was not available. Plant emission rates for the Master Plan development were based on service capacity increases rather than on a detailed investigation of the various options for future treatment plant design. It should be noted, however, that the actual development of an STP for SSA would be subject to a separate environmental review.

For and on behalf of

COFFEY PARTNERS INTERNATIONAL PTY LTD

ROSS BEST

#### REFERENCES

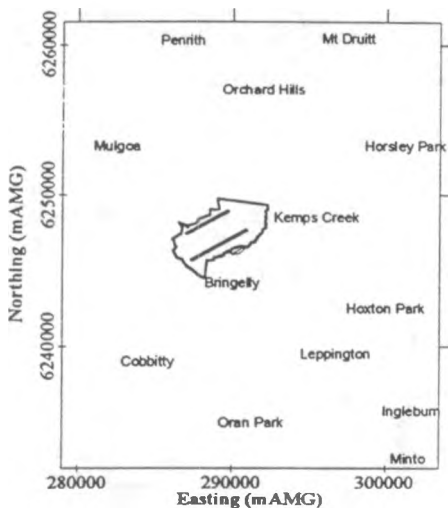
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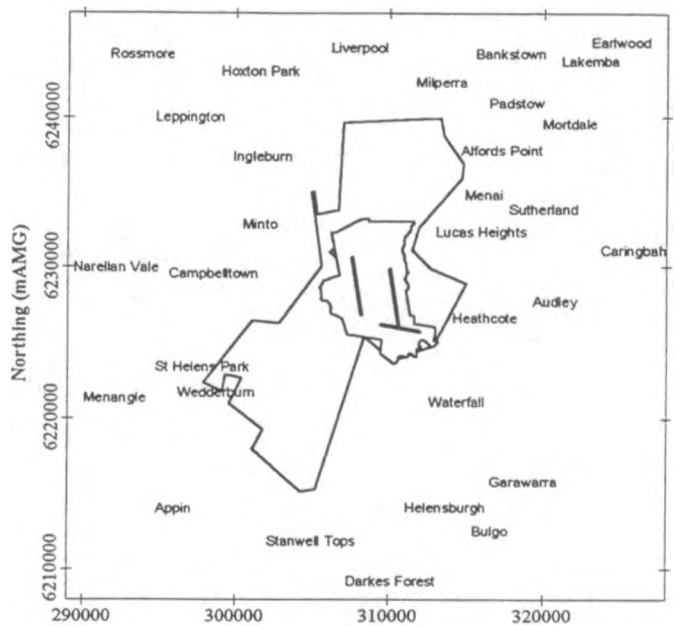
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#### ATTACHMENTS

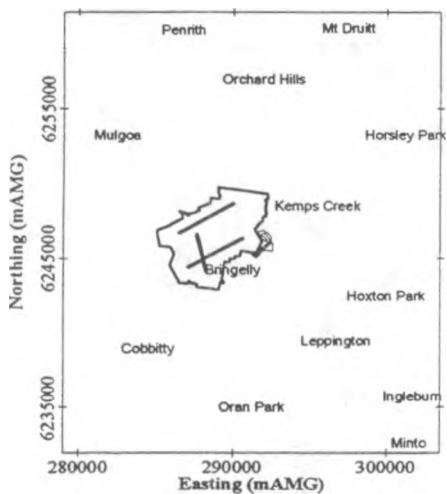
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| Figure 1 | % frequency of exceedence of 2OU (Stage 1)     |
| Figure 2 | % frequency of exceedence of 2OU (Master Plan) |



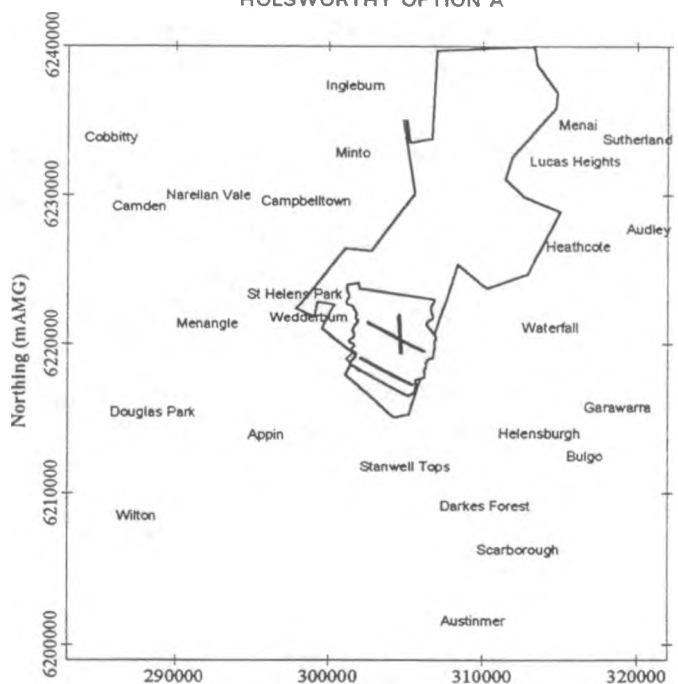
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HOLSWORTHY OPTION A

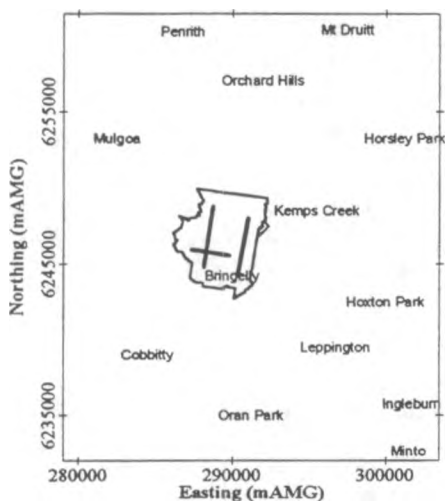


BADGERYS CREEK OPTION B



HOLSWORTHY OPTION B

NOTES:



BADGERYS CREEK OPTION C

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date	23/5/97
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% frequency of exceedance of 2 OU (Stage 1 Normal)

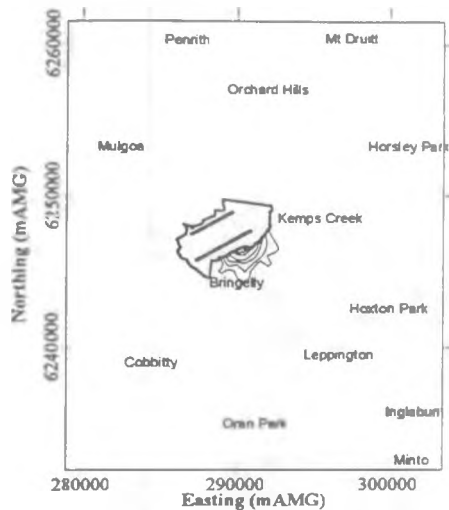


figure no.

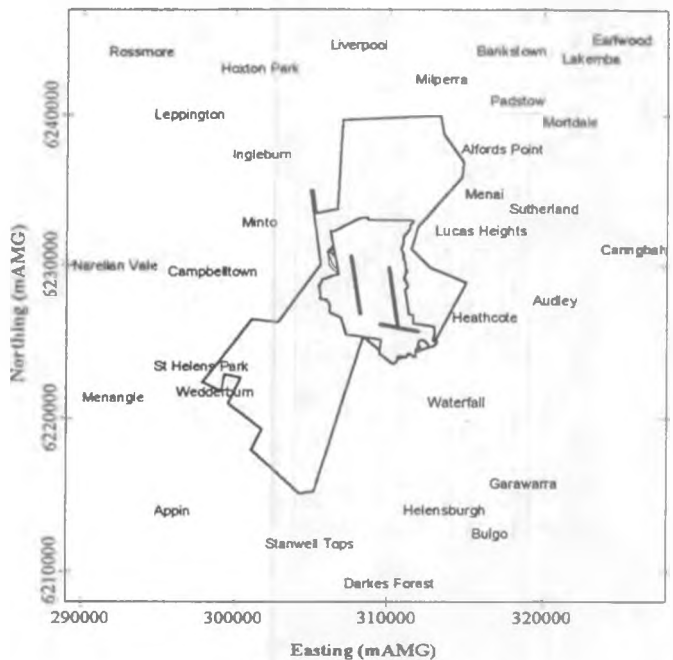
FIGURE 1

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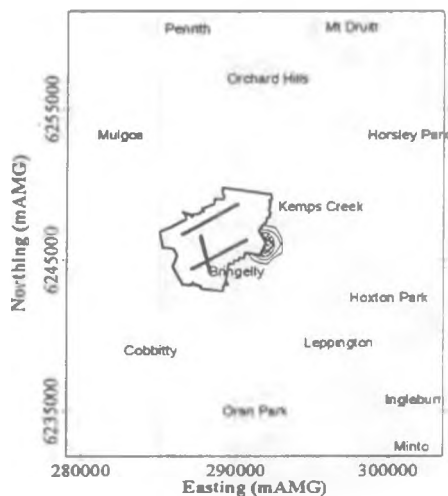




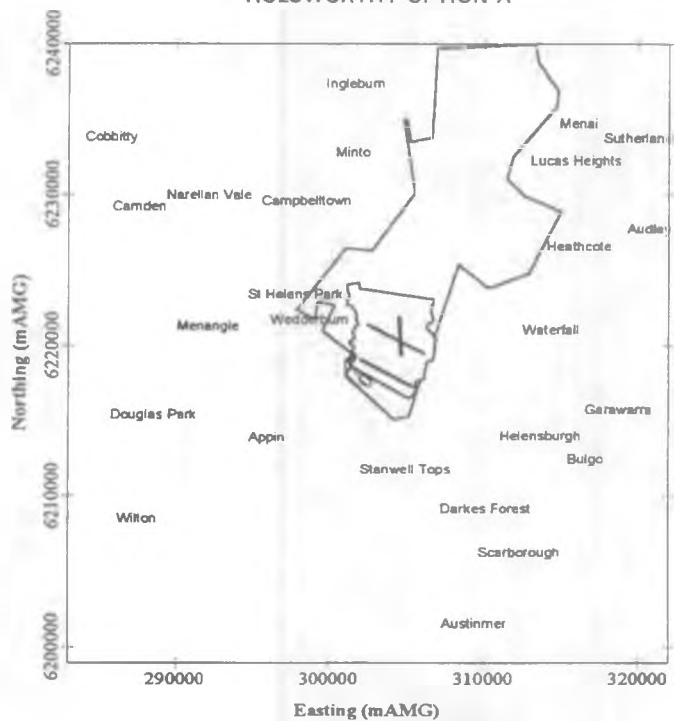
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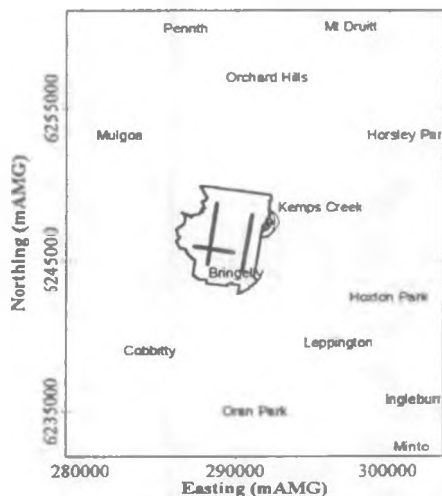
HOLSWORTHY OPTION A



BADGERYS CREEK OPTION B



HOLSWORTHY OPTION B



BADGERYS CREEK OPTION C

NOTES:

Shaded regions indicated location where in excess of 2 odour units would occur for more than 0.5% of the time (more than 44 hours per year)

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% frequency of exceedence of 2 OU (Master Plan)



figure no.  
FIGURE 2

job no: E2057/1-D

## **Appendix I**

---

Regional Air Quality and Airport  
Associated Developments

TABLE 8.3 PROJECTED NUMBER OF ADDITIONAL DEATHS PER YEAR ON OZONE EVENT DAYS (IN 2016) COMPARED TO OTHER DAYS

Badgerys Creek Option A	0.009
Badgerys Creek Option B	0.009
Badgerys Creek Option C	0.01
Holsworthy Option A	0.34
Holsworthy Option B	0.05

8.2 NITROGEN DIOXIDE

TABLE 8.4 POPULATIONS (FOR YEAR 2016) PROJECTED TO BE EXPOSED TO INCREASES IN MAXIMUM ONE HOUR NITROGEN DIOXIDE CONCENTRATION ONCE PER YEAR

	≥0.055 parts per million	≥0.03 parts per million
Badgerys Creek Option A	1,300	
Badgerys Creek Option B	700	
Badgerys Creek Option C	< 200	
Holsworthy Option A		17,000
Holsworthy Option B		7,000

Table 8.4 shows the populations predicted to be exposed, once a year, to increases in outdoor nitrogen dioxide exposure. It is not possible to quantify health effects which could be attributed to changes of this magnitude. For the Badgerys Creek options the sum of the maximum background levels and the predicted maximum increase is less than the National Health and Medical Research Council air quality guideline of 0.16 parts per million (refer *Technical Paper No.6*). In the event that the maximum background level at the Holsworthy site coincided with the predicted maximum increase in nitrogen dioxide at that site, a one hour nitrogen dioxide concentration of 0.18 parts per million may occur (refer *Technical Paper No.6*). This exceeds the National Health and Medical Research Council air quality goal but the evidence cited above suggests that adverse health effects are unlikely to occur at this level.

### 8.3 PARTICULATES

Table 8.5 shows the frequency with which various populations will be exposed to a three micrograms per cubic metre increase in PM<sub>10</sub> particulate pollution. By assuming members of each group were exposed on 3, 12, 35 and 70 days per year, respectively, approximate person-days of exposure to a three micrograms per cubic metre increase in PM<sub>10</sub> pollution were calculated for each site option. These are shown in Table 8.6

TABLE 8.5 POPULATIONS (FOR YEAR 2016) PROJECTED TO BE EXPOSED TO A GREATER THAN 3 MICROGRAMS PER CUBIC METRE INCREASE IN 24 HOUR PM<sub>10</sub> BY NUMBER OF OCCASIONS PER YEAR

	1 to 5 days per year	5 to 20 days per year	20 to 50 days per year	> 50 days per year
Badgerys Creek Option A	4,800	2,000	900	600
Badgerys Creek Option B	5,200	1,900	1,000	300
Badgerys Creek Option C	6,600	3,000	1,200	300
Holsworthy Option A	25,000	5,000	0	0
Holsworthy Option B	55,000	1,500	150	0

TABLE 8.6 PERSON-DAYS (FOR YEAR 2016) PROJECTED FOR A GREATER THAN 3 MICROGRAMS PER CUBIC METRE INCREASE IN 24 HOUR PM<sub>10</sub>

Badgerys Creek Option A	111,900
Badgerys Creek Option B	94,400
Badgerys Creek Option C	118,800
Holsworthy Option A	135,000
Holsworthy Option B	188,250

The expected impact of these episodes of increased PM<sub>10</sub> exposure was estimated by multiplying the number of person-days of exposure by the three micrograms per cubic metre effect estimate for symptoms of cough, risk of hospitalisation and risk of death. However, some of these person-days of exposure will actually be to PM<sub>10</sub> increases greater than three micrograms per

cubic metre. Smaller populations will be exposed less frequently to higher levels: the maximum increase is estimated to be 10 micrograms per cubic metre. Examination of the contour plots for PM<sub>10</sub> (refer *Technical Paper No.6*) suggests that multiplying the final impact estimates by a factor of two would be appropriate to adjust for this aspect of the exposure data. This factor is included in the calculations used for *Tables 8.7, 8.8 and 8.9* below.

Based on the short term cohort studies from the USA a three micrograms per cubic metre increase in PM<sub>10</sub> pollution would be expected to be associated with a 2.4 percent higher prevalence of cough on those days compared to other days. The baseline daily prevalence of cough is unknown. However, if we assume it is 3 percent (the median prevalence in the US Six Cities study (Schwartz, 1994e)) then this increase would result in a prevalence of 3.072 percent, that is an absolute increase of 0.072 percent or 72 per 100,000. *Table 8.7* shows the expected additional number of person-days of reported cough due to the airport-associated three micrograms per cubic metre increase in particulate pollution.

TABLE 8.7 NUMBER OF ADDITIONAL PERSON-DAYS PER YEAR (IN 2016) OF REPORTED COUGH DUE TO EPISODES OF INCREASED PM<sub>10</sub>

Badgerys Creek Option A	162
Badgerys Creek Option B	136
Badgerys Creek Option C	172
Holsworthy Option A	194
Holsworthy Option B	272

Similarly, the time series data analyses predict that, on the days when these populations are exposed to the higher PM<sub>10</sub> concentrations, the rate of hospital admissions for respiratory disease will be 0.46 percent higher and the mortality rate will be 0.17 percent higher than on other days. This corresponds to a 0.018 per 100,000 per day increase in hospital admissions for respiratory disease and a 0.0034 per 100,000 increase in daily mortality rate. The impact of these changes is shown in *Tables 8.8 and 8.9*.

TABLE 8.8 NUMBER OF ADDITIONAL PEOPLE (IN 2016) PROJECTED TO BE HOSPITALISED FOR RESPIRATORY DISEASE DUE TO EPISODES OF INCREASED PM<sub>10</sub>

Badgerys Creek Option A	0.040
Badgerys Creek Option B	0.034
Badgerys Creek Option C	0.042
Holsworthy Option A	0.048
Holsworthy Option B	0.068

TABLE 8.9 PROJECTED NUMBER OF ADDITIONAL DEATHS ON A GIVEN DAY (IN 2016) COMPARED TO OTHER DAYS DUE TO EPISODES OF INCREASED PM<sub>10</sub>

Badgerys Creek Option A	0.008
Badgerys Creek Option B	0.006
Badgerys Creek Option C	0.008
Holsworthy Option A	0.010
Holsworthy Option B	0.012

For the reasons stated above in relation to ozone, these are over-estimates of the number of additional hospital admissions and deaths over one year.

## SUMMARY AND CONCLUSIONS

### 9.1 HEALTH IMPACT OF PREDICTED CHANGES IN OZONE, NITROGEN DIOXIDE AND PARTICULATE POLLUTION

#### 9.1.1 POLLUTION LEVELS AND ESTIMATED HEALTH EFFECTS

The projected increases in ozone, nitrogen dioxide and particulate pollution associated with all the airport options are very small and, for the most part, affect small populations infrequently. The health effects estimates employed in this report are based on extrapolation from studies in which much larger variations in pollution levels were observed affecting large populations. Their use in this report relies on the assumption that interventions (such as the Second Sydney Airport) which alter pollution levels will have the same effect as that observed with day-to-day variation in pollution levels. This assumption has never been tested.

#### 9.1.2 RESPIRATORY SYMPTOMS AND LUNG FUNCTION

It is estimated that, on days when particulate ( $PM_{10}$ ) exposure increases by three micrograms per cubic metre the prevalence of cough will increase by 2.4 percent compared to lower pollution days. For Holsworthy Option B it is estimated that approximately 300 additional person days of cough would occur in the study area. This may result from 300 people experiencing a single extra day of cough per year or one person reporting an additional 300 days of cough per year (or any combination in between). These episodes may occur in adults or children and are most likely to affect people with pre-existing lung disease (for example asthma or emphysema). However, the absence of any substantial increase in hospitalisation rates for respiratory disease implies that these episodes will be fairly mild.

Changes in nitrogen dioxide and ozone pollution are not expected to be associated with any increase in symptoms in the general population or in people with asthma.

No perceptible or clinically relevant changes in lung function are anticipated to occur as a result of the projected increases in pollution exposure.

#### 9.1.3 HOSPITALISATION AND MORTALITY RATES

Hospitalisation rates for respiratory disease are estimated to be 1.7 percent higher on the high ozone pollution days (six to nine times per year in the affected areas) and 0.5 percent higher on the high particulate pollution days

than on the remaining days of the year. Similarly mortality rates may be 1 percent higher on high ozone days and 0.2 percent higher on high particulate pollution days than on other days. Nitrogen dioxide will probably not have an effect on either hospitalisation or mortality risk.

As both hospital admissions for respiratory disease and death are fairly rare events on a day-to-day basis these small proportional differences result in absolute numbers of events which are less than one per year. Indeed, for the Badgerys Creek site options, it is less than one per 14 years for both hospitalisations and deaths.

It is important to point out that it is not known whether the projected changes in pollution levels will have any overall effect on hospitalisation rates or death rates. This is because there are no data to show whether the hospitalisations and deaths observed in the cited studies are simply transfers from one day to another, nearby, day, or alternatively, they represent events which would otherwise not have occurred for a long time. Intuitively, the former situation seems likely. This is supported by the fact that the elderly and those with pre-existing heart and lung disease are most at risk. If this is correct then there would be no overall change in hospital admission or death rates.

## **9.2 IMPORTANCE OF THE DIFFERENCES BETWEEN OPTIONS IN HEALTH IMPACT**

The Holsworthy site options are associated with more person-days of exposure to elevated ozone and particulate pollution than the Badgerys Creek options.

The health impact of the infrequent, small increases in pollution levels which are projected to occur due to the Second Sydney Airport cannot be estimated with certainty but it seems likely that very few, if any, people will experience serious acute adverse health effects which can be attributed to these pollution changes. For this reason it is difficult to distinguish between the airport site options on the basis of the health impact of changes in ozone, nitrogen dioxide and particulate pollution.



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## **Appendix 1**

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### Glossary of Terms

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A

AHR	airways hyperresponsiveness
airway hyperresponsiveness	abnormality of the airways which makes them narrow too easily and too much in response to various stimuli; an abnormality seen in people with asthma
airways	air conducting tubes or passages of the lungs
all cause mortality	deaths due to all causes (except accidents)
allergen responsiveness	the extent to which airways narrow in response to allergen exposure
allergen	an environmental substance (usually a protein) which the body's immune system recognises and reacts adversely to
allergic	being capable of recognising and reacting to an allergen
ambient	in the air as it exists in our breathing zone under usual circumstances
ante-natal	before birth, during pregnancy
arterial oxygen saturation	level of oxygen in the blood
asthma	see page 6
asymptomatic	no experiencing any symptoms
bronchitis	cough with phlegm
BS	Black smoke, an index of particulate pollution

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B

bronchitis	cough with phlegm
BS	Black smoke, an index of particulate pollution

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C

cardiac illness	heart disease
cardiovascular mortality	death due to heart attacks and related diseases
chronic asthma	asthma with permanently impaired lung function
chronic bronchitis	long standing cough with phlegm
chronic obstructive pulmonary disease	see page 7
cohort study	a well defined group of subjects are followed over time to measure the relation between an exposure (eg pollution level) and an outcome (eg symptoms or lung function)

confounding	where one or more extraneous factors explain an apparent association (ie the apparent association does not really exist)
COPD	chronic obstructive pulmonary disease

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**D**

diagnosis	disease label
disability	inability to perform tasks

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**E**

ED	Emergency Department
EIS	Environmental Impact Statement
Emergency Department	also known as Casualty, Accident and Emergency or Emergency Room
emphysema	disease in which lung tissue is gradually destroyed (usually due to smoking); causes breathless
exacerbations	temporary deterioration in illness state
expiratory airflow	rate at which air can be exhaled (blown out)
exposure chamber	a device for exposing experimental subjects to known concentrations of gases (eg ozone or NO <sub>2</sub> )

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**F**

FEV <sub>1</sub>	forced expiratory volume in one second, a measure of expiratory airflow
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**H**

heterogeneous	a non-uniform mixture of various different components
house dust mite	an important source of allergen; lives in bedding and carpets; invisible to the human eye
hygroscopicity	tendency to take up water

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**I**

impaired lung function	lung function lower than expected for age, gender and height
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impairment                      reduced function

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## L

LGA	local government area
local government areas	local administrative area; Municipality or Shire
lower respiratory tract	airways within the lungs (ie below the nose, mouth and throat)
lung function	see page 11

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## M

mass median aerodynamic diameter	a measure of particle size
measure of association	a way of expressing the relation between an exposure (eg pollutant) and an outcome (eg symptoms or lung function) in a numeric form
meta-analysis	a systematic overview of related investigations which summarises the information they contain in one or more measures of association
MMAD	mass median aerodynamic diameter
mortality	deaths

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## N

NH&MRC	National Health and Medical Research Council
nitrogen dioxide	see page 18
NO <sub>2</sub>	nitrogen dioxide

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## O

occupational exposures	exposures occurring at work
oxidant	a chemical which oxidises
oxidising	a type of chemical reaction
ozone	see page 13

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**P**

panel study	see cohort study
particulate	see page 20
peak expiratory flow rate	the maximum flow rate during a exhalation with effort; a measure of lung function
peak hourly ozone	the highest hourly average ozone concentration during one day
PEFR	peak expiratory flow rate
PM <sub>10</sub>	particulate matter with MMAD < 10µm
ppm	parts per million; a measure of gas concentration
prevalence	the proportion of a population who have a condition at any given time

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**Q**

questionnaire	a series of standardised questions used to collect information for analysis
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**R**

randomised controlled trial	an experimental research design in which subjects are randomly allocated (that is by chance) to one of two or more conditions and followed over time to measure an outcome or response
randomly selected	selected or allocated by chance (for example toss of coin or throw of a dice)
rate ratio	ratio of the rate in one group to the rate in another group; in the usage here it refers to the ratio of the admission or death rate on two days separated in pollutant concentration by a specified amount (shown in the increment column of the tables).
reactive chemical species	chemical entities which are unstable and tend to react with other substances
regression coefficients	a measure of association between two variables (eg pollutant concentration and lung function) derived from a form of statistical analysis known as regression
respiratory mortality	deaths due to respiratory disease
risk factors	factors which, if possessed by an individual, increase the likelihood of that individual having a specified disease or other outcome

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S

SO <sub>2</sub>	sulphur dioxide
std error	a statistical measure of uncertainty about an estimate

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T

Time series analysis	a form of analysis which examines factors influencing change in an observation (eg hospital admission rates) over time
toxic	harmful and damaging to living things
TSP	total suspended particulates, a measure of particulate pollution

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W

weighted average	average of several estimates giving greatest weight to the most certain estimates and least weight to the least certain
µg/m <sup>3</sup>	micrograms per cubic metre; a measure of particle or gas concentration in air
24 hour mean	average over a 24 hour period
95% CI	95% confidence interval
95% confidence interval	the range of values within which the actual measure lies; it is based on the estimated value and the uncertainty of the estimate (std error). Where the confidence interval for a rate ratio excludes the value 1 we can be fairly certain that exposure is related to outcome (admission or death rates) in that study (that is P < 0.05).

## **Appendix 2**

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### Acknowledgements

Dr Charles Guest and Professor Ann Woolcock reviewed the manuscript and made helpful comments.

Nathan Brown gave assistance in the production of figures.

Dr Ben Smith, from the Health Promotion Unit, South Western Sydney Area Health Service and Drs Louisa Jorm and Michele Puech, from the Epidemiology and Surveillance Branch, NSW Health, assisted in the provision of the health statistics.

## **Appendix G**

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Air Quality Field Survey Report

# Coffey Partners International Pty Ltd

A.C.N. 003 692 019

Consulting Engineers, Managers and Scientists  
Environment • Geotechnics • Mining • Water Resources



E2057/1-CS  
29th April, 1997

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Australia

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Attention: Mr David Gamble

Dear Sir,

**RE: SYDNEY SECOND AIRPORT EIS - AIR QUALITY FIELD STUDIES**

This letter presents the results of field studies carried out to measure the odour and composition of emissions for aircraft operating from Sydney Kingsford Smith Airport. This work forms part of air quality studies carried out by Coffey Partners International Pty Ltd to contribute to the EIS for Sydney Second Airport. This work was carried out as proposed in our letter E2057/1-AB of 8th October, 1996. The work involved collection of air samples in the vicinity of aircraft at Sydney's Kingsford Smith Airport and testing these samples for odour and chemical composition to assess the relationship between odour strength and composition.

Field studies were carried out by Coffey Partners in association with Australian Water Technologies. Odour testing was carried out by Australian Water Technologies and chemical testing was carried out by CSIRO Division of Coal and Energy Technology.

## **Field Studies**

A total of eight air samples were collected at Sydney Kingsford Smith Airport on the morning of 15 November, 1996. These samples were collected using a vehicle driven by Federal Airports Corporation operational staff. Samples were selected at locations where air quality was expected to be significantly affected by ground level aircraft emissions. Locations for sampling were selected during the sampling program. Samples were taken downwind from turboprop aircraft, exhaust from the auxiliary power unit (APU) of a passenger jet and samples from the exhaust stream of several passenger jets.

Air samples from the exhaust stream of passenger jets were obtained by following taxiing aircraft at a safe distance determined by the FAC driver. Samples were collected into sample bags by pumping air from an intake on a pole held by an operator experienced in odour sampling. The sample bags were stored in a light proof chests. Sample collection took place over a period from 7:51am to 9:05am. Weather during sampling was fine and clear and temperature as advised on the





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airport weather system increased from 18°C to 23°C. Wind was light at the start of the sampling period and increased to 10 to 15 knots by 9:05am. Wind direction was northerly.

Following completion of collection of samples, part of each sample was transferred to one litre air sample canisters and transported to the CSIRO laboratory at North Ryde for chemical testing. The bagged air samples were taken to Australian Water Technologies odour laboratory and tested within 10 hours of sample collection.

## Results

The results of testing are summarised in Table 1 and laboratory reports are attached. Engine types for each aircraft were obtained by enquiries of airlines and from field observations. Concentration of substances measured in laboratory testing are presented as a volumetric concentration in parts per billion (ppb) or as parts per million carbon (ppmC). Concentrations are also shown as mass per unit volume( $\mu\text{g}/\text{m}^3$ ).

Odour level is measured by the increase in concentration over that which is at the threshold of detection by 50% of an odour panel. An odour level of one odour unit applies to a pollutant concentration for which half an odour panel can detect an odour. If the concentrations were increased by a factor of two, the odour level would be two.

A range of odour levels from 31 to 275 odour units were measured. The highest value were recorded in the exhaust of taxiing jets. The variability in odour level is attributed to the varying sampling conditions. Hydrocarbon concentrations varied from 0.5ppmC to 8.6ppmC with the kerosene fraction making up from 12.5% to 60% of the measured non-methane hydrocarbon content. For engine exhaust (as opposed to exhaust from the auxiliary power unit) the kerosene fraction generally accounted for more than 50% of non-methane hydrocarbons.



**TABLE 1: RESULTS OF AIR QUALITY TESTING  
KINGSFORD SMITH AIRPORT 15 OCTOBER 1996**

No	Source	Engines	Time	Conditions	Odour Strength		Component						
					OU <sub>50D</sub>	OU <sub>50R</sub>	NMHC <sup>a</sup> (ppmC)	Kerosene (ppmC)	1,3butadiene (ppbV)	Benzene (ppbV)	Toluene (ppbV)	Ethylbenzene (ppbV)	Xylene (ppbV)
1	Ansett 737 auxiliary power unit exhaust - Bay 12	General Electric CFM 56	7:51am	wind light	32	25	1.6 [920] <sup>c</sup>	0.2 [110]	n/d <sup>d</sup> [0]	1.6 [5.1]	2.9 [11.0]	0.4 [1.7]	2.8 [12.2]
2	Ansett 737 taxiing to Bay 2	General Electric CFM 56	8:00am	wind light	31	22	2 [1150]	1.1 [630]	2.7 [6.0]	4.2 [13.4]	6.6 [24.9]	0.6 [2.6]	3 [13.1]
3	Ansett 737 taxiing to Bay 10	General Electric CFM 56	8:09am	wind light	33	22	0.5 [290]	0.3 [170]	3.8 [8.4]	3.8 [12.2]	3.2 [12.1]	0.4 [1.7]	2 [8.7]
4	Ansett 767 idling at Bay 16	General Electric CF6 (ST9D)	8:15am	wind light	23	22	2.2 [1260]	1.7 [980]	2.8 [6.2]	2.9 [9.3]	3.7 [14.0]	1.9 [8.3]	12.7 [55.2]
5	QANTAS Airbus300 taxiing to terminal	General Electric CF6	8:20am	wind light	43	26	8.6 [4950]	2.2 [1265]	11.4 [25.3]	7.7 [24.6]	5.9 [22.3]	1.6 [7.0]	11.2 [48.7]
6	Hazelton SAAB 220 idling prior to taxi for takeoff	SAAB 240 twin prop	8:30am	wind 360° 6kts Temp 18°	42	26	0.5 [290]	0.3 [170]	0.4 [0.9]	1.9 [6.1]	3.7 [14.0]	0.5 [2.2]	2.8 [12.2]
7	Nippon 747/300 taxiing to terminal	Uncertain	8:45am	wind 010° 10 to 15kts	275	115	2 [1150]	1.1 [630]	37.4 [83.0]	17.6 [56.3]	7.8 [29.5]	2 [8.7]	9.6 [41.8]
8	JAL 747/300 taxiing to terminal	Rolls Royce RBT 211	9:05am	010° 10 to 15kts Temp 23°	95	37	2.1 [1210]	0.8 [460]	5.8 [12.9]	5.6 [17.9]	9.5 [35.9]	0.9 [3.9]	3.6 [15.7]

<sup>a</sup> Odour strength is recorded as the factor by which odour exceeds the threshold of detection (OU<sub>50D</sub>) and the fraction by which odour exceed the threshold of recognition (OU<sub>50R</sub>).

<sup>b</sup> NMHC - Non-methane hydrocarbons

<sup>c</sup> Values in square brackets indicate concentrations in  $\mu\text{g}/\text{m}^3$ .

<sup>d</sup> n/d - not detected.



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Ruth (1986) has a compiled odour threshold levels for a wide range of organic compounds based on published data. This compilation includes a range for detection and a concentration at which odour becomes irritating. The results refer to testing of substances in isolation. As the emissions of aircraft contain a complex mixture of organic compounds the results presented by Ruth cannot be related directly to aircraft emissions. Nevertheless, the results provide a useful basis for comparison with the results obtained from the present work. Table 2 presents odour thresholds taken from Ruth (1986).

**TABLE 2: ODOUR THRESHOLDS - ISOLATED SUBSTANCES**

Substance	Low Detection Threshold ( $\mu\text{g}/\text{m}^3$ )	High Detection Threshold ( $\mu\text{g}/\text{m}^3$ )	Irritating Concentration ( $\mu\text{g}/\text{m}^3$ )
Benzene	4,500	270,000	9,000,000
1,3 Butadiene	350	2,860	
Ethylbenzene	8,700	870,000	870,000
Kerosene	550	550	123,000
Toluene	8,000	262,000	750,000
Xylenes	350	174,000	435,000

Source: Ruth, JH (1986) Odor Thresholds and Irritation Levels of Several Chemical Substances: A Review.

Measured concentrations of benzene, butadiene, ethylbenzene, toluene and xylenes are well below odour threshold levels but measured kerosene concentration is generally above the level for detection of odour. The fact that measured odour levels are substantially higher than would be expected by considering the kerosene fraction alone suggests that there is a major contribution to odour from the non-kerosene fraction of hydrocarbon emissions. A threshold level for odour of aircraft emissions measured as total hydrocarbons was calculated by dividing the measured odour level  $OV_{50D}$  by the measured hydrocarbon concentration. These threshold levels are presented in Table 3 for each of the samples except for sample 1 which relates to auxiliary power unit exhaust rather than aircraft engine exhaust.



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**TABLE 3: CALCULATED THRESHOLD ODOUR CONCENTRATION -  
HYDROCARBON EMISSIONS**

Sample	Odour Threshold Concentration ( $\mu\text{g}/\text{m}^3$ )
2	37
3	9
4	55
5	115
6	7
7	4
8	13
Average	34

Based on the results presented in Table 3 an odour threshold concentration for aircraft engine exhaust hydrocarbon emissions of  $34\mu\text{g}/\text{m}^3$  was adopted. This is taken as the concentration at which the average person could detect an odour.

The results of the test program provide a useful basis for comparison of aircraft engine emissions composition adopted in the emissions inventory study. This comparison is presented in Table 4. For the substances measured, the percentage of total hydrocarbon concentration is presented together with the percentage adopted in the air emissions inventory report (Coffey Partners International 1997).

**TABLE 4: COMPARISON OF EMISSIONS INVENTORY SPECIATION  
WITH MONITORING RESULTS**

Substance	Proportion of Hydrocarbon Content	
	Measured range (%)	Emissions Inventory (%) <sup>a</sup>
Benzene	0.5 to 4.9	2.15
1,3 Butadiene	0.32 to 7.22	0.23
Ethylbenzene	0.45 to 4.8	0.58
Toluene	0.14 to 0.76	0.19
Xylene	1.0 to 4.4	0.53

Source: Coffey Partners International (1997) Sydney Second Airport EIS - Air Emissions Inventory.



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There is significant variation in the proportion of each substance as a percentage of total hydrocarbons. The proportion adopted in the emissions inventory is generally within or just below the range of proportions measured. Given that the measured data correspond to a limited range of operating conditions, the results are considered broadly consistent with the speciation profile adopted during emissions inventory studies. Should health studies indicate that air toxic compounds pose a significant risk to human health, it is recommended that additional speciated hydrocarbon testings be carried out to test the speciation profile adopted for analysis of the second airport.

### CONCLUSIONS

A field program for measurement of ground level odour and hydrocarbon emissions from aircraft at Sydney Kingsford Smith Airport was carried out. An odour threshold for hydrocarbon emissions from aircraft was assessed as  $34\mu\text{g}/\text{m}^3$  based on monitoring results. This value is substantially lower than would have been anticipated by consideration of the kerosene fraction of emissions in isolation. Therefore, application of this level of assessment of odour impacts of the Sydney Second Airport may result in a conservative assessment of odour impacts.

The speciation data obtained from testing is broadly consistent with the speciation profile adopted in the emissions inventory study for the Sydney Second Airport (Coffey Partners International 1997) though the measured proportions of the substances considered including 1,3 butadiene were generally higher than that was adopted in the inventory study. Given the limited nature of the monitoring program it is not considered warranted to change the speciation profile adopted in the emissions inventory study. If health studies indicated that exposure to air toxic compounds such as benzene and 1,3 butadiene is a significant health risk it is recommended that additional speciated hydrocarbon testing is carried out to test the speciation profile adopted for analysis of the second airport.

For and on behalf of

COFFEY PARTNERS INTERNATIONAL PTY LTD

MR ROSS BEST

Attachments: Laboratory Result Reports:  
Australian Water Technologies  
CSIRO Division of Coal and Energy Technology



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~~29th April, 1997~~

7.

## REFERENCES

Coffey Partners International Pty Ltd (1997). Sydney Second Airport EIS - Draft Air Emissions Inventory. Report E2057/1-AY, January, 1997.

Ruth, JH (1986) Odor Thresholds and Irritation Levels of Several Chemical Substances: A Review, American Industrial Hygiene Association Journal, Vol. 47, March 1986, pp 142-151.



COFFEY PARTNERS INTERNATIONAL PTY LTD	
RECEIVED 6 DEC 1996 SYDNEY	
	RJB

18 November 1996

Coffey Partners International Pty Ltd  
P O Box 125  
North Ryde NSW 2113

Attention Mr. Ross Best

RE: Results from Sydney Airport odour sampling and analysis 15/11/96.

Eight samples were analysed for odour strength and hedonic tone. This produced the result tabulated below in the terminology of the Draft Procedures for Dynamic Olfactometry from the EPA - WB. The results are considered average results based on panel odour threshold analysis. The panel returned odour threshold values in the upper part of the 0.5 - 2.0 ppb range sometimes deemed acceptable for olfactometers as odour threshold values for Hydrogen Sulphide.

TABLE 1

	Date	Odour Strength OU <sub>50D</sub>	Odour Strength OU <sub>50R</sub>	Hedonic Tone
747/300 follow during taxi (Sample 7)	15/11/96	275	115	-1
JAL 747/300 taxi on landing (Sample 8)	15/11/96	95	37	-1
Hazelton SAAB 220 Idling (Sample 6)	15/11/96	42	26	-1
Airbus 300 taxi to terminal (Sample 5)	15/11/96	43	26	-2
737 Aux power unit exhaust (Sample 1)	15/11/96	32	25	-2
737 Exhaust taxi to bay 10 (Sample 3)	15/11/96	33	22	-1
ANSETT 737 to bay 2 (Sample 2)	15/11/96	31	22	-1
767 Idling bay 16 (Sample 4)	15/11/96	23	22	-2

The analysis was carried out on AWT's IITRI Dynamic Dilution Forced Choice Triangle Olfactometer (Model 103), which traditionally determines three thresholds, namely: Best Estimate (Z) deemed equal to OU<sub>50D</sub> (EPA), Detection (D) deemed equal to OU<sub>50R</sub> (EPA) and Recognition (R) which is not recognised as a threshold by the EPA at this stage.

Regards,

*Er. Andersen* 18/11/96  
Er. Andersen, Air Quality Coordinator.



**CSIRO**  
AUSTRALIA

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Page 1 of 2

RE: AWT AIRPORT SAMPLES

Dear Ross

Results for NMHC, total HCs in the kerosene fraction, and various speciated concentrations follow. Numbers in brackets are duplicate analyses done by GC which use a separate (and less accurate) calibration method. Even so the agreement is quite good. Please ring me if you have any queries.

Regards

Peter

Peter Nelson  
Senior Principal Research Scientist

AWT Sample Number	Canister No.	NMHC (ppmC)	Kerosene HC (ppmC)	1,3-butadien (ppbV)	benzene (ppbV)	toluene (ppbV)	ethylbenzene (ppbV)	xylene (ppbV)
1	21762	1.6	0.2	-	1.6	2.9	0.4	2.8
2	21770	2	1.1	2.7	4.2 (3.1)	6.6	0.6	3
3	21765	0.5	0.3	3.8	3.8	3.2 (2.8)	0.4	2
4	21773	2.2	1.7	2.8	2.9	3.7	1.9	12.7
5	21774	8.6 (8.2)	2.2	11.4	7.7 (7.2)	5.9	1.6 (1.7)	11.2 (11.9)
6	21763	0.5	0.3	0.4	1.9	3.7	0.5	2.8
7	21768	2	1.1	37.4	17.6	7.8	2	9.6
8	21775	2.1	0.8	5.8	5.6	9.5	0.9	3.6