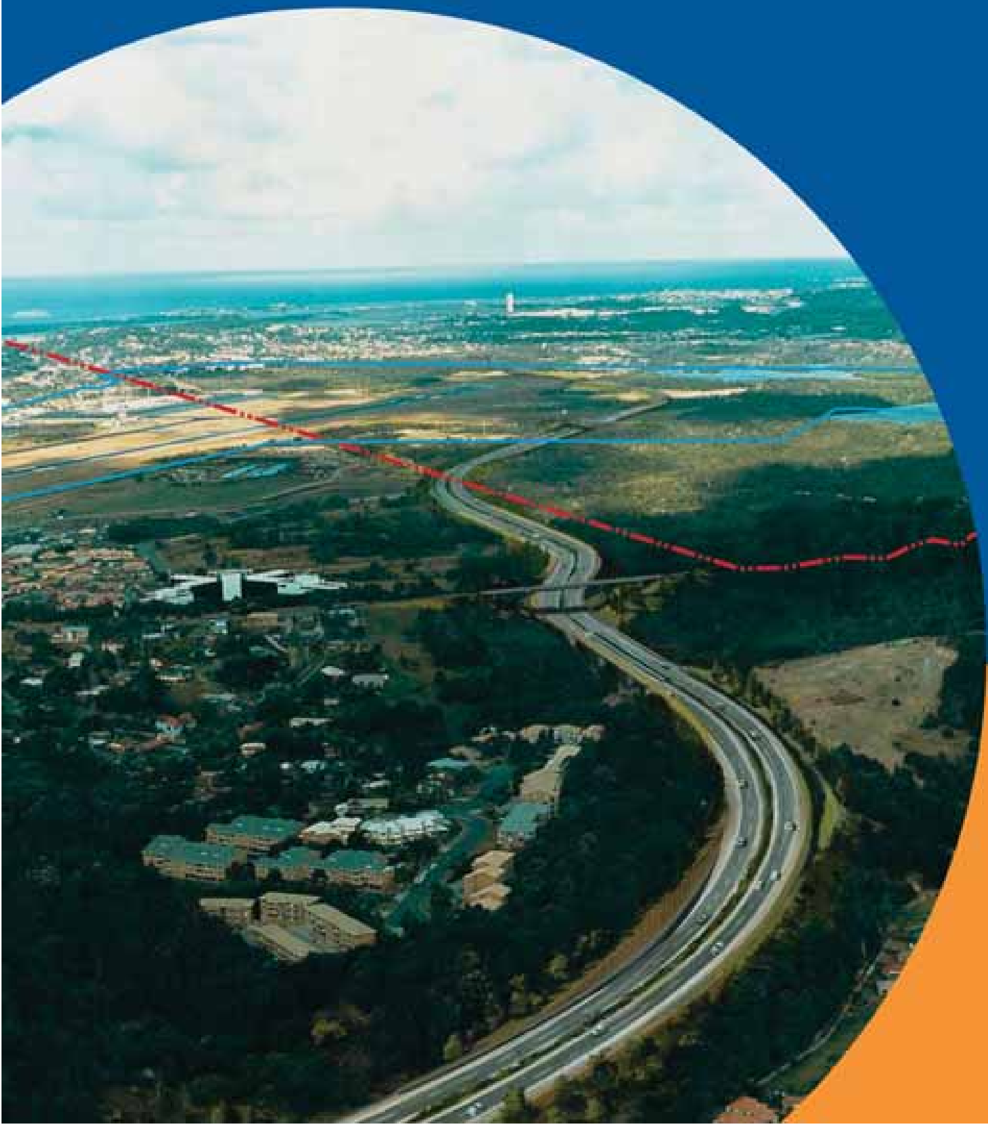
Australian Government
Department of Transport and Regional Services

RTA

Queensland Government
Department of Main Roads

TUGUN BYPASS

stewart road to kennedy drive



Technical Papers

December 2004

Tugun Bypass Environmental Impact Statement

Technical Paper Number 11
Air Quality Assessment

Tugun Bypass Alliance

Prepared by Katestone Environmental for:

Parsons Brinckerhoff

348 Edward Street
Brisbane Qld 4000

GPO Box 2907
Brisbane Qld 4001
Australia

Telephone: + 61 7 3218 2222
Facsimile: + 61 7 3831 4223
E-mail: brisbane@pb.com.au

ABN 84 797 323 433

NCSI Certified Quality System to ISO9001

Parsons Brinckerhoff Australia Pty Limited ACN 078 004 798 and
Parsons Brinckerhoff International (Australia) Pty Limited ACN 006 475 056 trading as Parsons Brinckerhoff
ABN 84 797 323 433

Queensland Department of Main Roads – South Coast Hinterland District

36-38 Cotton Street
Nerang Qld 4211

PO Box 442

Nerang Qld 4211
Australia

Telephone: + 61 7 5583 8111
Facsimile: + 61 7 5583 8100
E-mail: www.SouthCoast@mainroads.qld.gov.au

November 2004
2134070A-PR053Car

Contents

List of Tables

List of Figures

List of Appendices

Glossary

Term	Meaning
EIS	Environmental Impact Statement
IAS	Impact Assessment Study
EPP	Environmental Protection Policy
$\mu g/m^3$	micrograms (millionths of a gram) per cubic metre
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
NO_x	total oxides of nitrogen
PM_{10}	particulate matter (e.g. dust) less than 10 microns (millionths of a metre) in diameter
pphm	parts per hundred million, equivalent to 0.01 ppm
ppm	parts per million by volume
WHO	World Health Organisation

1. Introduction

1.1 Summary of the Technical Paper

Over most of its length the proposed Tugun Bypass is to be constructed at a significant distance to the west of the nearest major road (Gold Coast Highway). There are currently few significant sources of pollutants in the immediate vicinity other than minor roads and the Gold Coast Airport.

The main pollutants emitted by motor vehicles are oxides of nitrogen, carbon monoxide, particulates and hydrocarbons. The greenhouse gas, carbon dioxide is also emitted in considerable quantities from internal combustion engines.

Elevated concentrations of nitrogen dioxide, carbon monoxide and particulates have potential direct health effects and studies have indicated that components of hydrocarbon emissions can also cause damage to health. Hydrocarbons and oxides of nitrogen can also react in the presence of suitable precursor compounds and sunlight to produce ozone and smog.

High concentrations of nitrogen dioxide and particulates have been reported to result in damage to sensitive plant species. As well as impacts on human health, these substances can at high concentrations also affect other organisms such as native animals and plants. Studies, mainly overseas, have established that exposure to concentrations exceeding thresholds for certain periods can lead to damage of sensitive species. Some of these thresholds have also been considered in establishing Australian air quality guidelines.

As the proposed road straddles the Queensland-NSW border and crosses Commonwealth leased airport land, air quality issues must be considered in relation to all three jurisdictions. Air quality guidelines relating mainly to health impacts are in place in Queensland (*Environmental Protection (Air) Policy 1997*) and *Action for Air 1998* (NSW Environment Protection Authority 1998). Ambient air quality guidelines are also included in the Airports (Environment Protection) Regulations 1997. There are also national guidelines in the form of the *National Environment Protection Measure (NEPM) for Ambient Air Quality* (National Environment Protection Council 1998).

These environmental guidelines generally present acceptable limits for air quality in terms of concentrations of indicator substances not to be exceeded for more than a specified period.

Measurements of air quality in the Gold Coast region by the Queensland Environmental Protection Agency indicate that existing air quality is acceptable in terms of these guidelines. There will be variations in local air quality with location due to proximity of sources such as major roads. There are also variations with meteorological conditions such as wind speed, wind direction and atmospheric stability.

Motor vehicles are the main source of carbon monoxide in an urban environment and measured levels can approach guideline levels near major congested roads. Other pollutants, such as particulates, can be produced by a variety of sources and measured levels may not relate solely to the road being monitored. The proposed rail extension from Robina to Gold Coast Airport will be an electrified line, therefore the train movements will not generate exhaust fumes and so would not have any significant impacts on local air quality. The impact of the rail link has therefore not been assessed in this technical paper.

During this study, measurements of carbon monoxide were made at two locations near the Gold Coast Highway to provide an indication of existing air quality near the road and to determine whether these levels were consistent with the prediction model used to assess traffic impacts (CALINE 4). Existing carbon monoxide levels were found to be well below health guidelines and to be generally consistent with the predictions of the dispersion model.

Emission rates of pollutants were predicted for the years 2007 (without bypass), 2007 (with and without bypass) and 2017 (with and without bypass). These were based on emission factors determined for the Brisbane vehicle fleet, corrected for vehicle speed and road gradient, and on predicted traffic levels for the various scenarios.

The computer dispersion model CALINE 4 was used to calculate pollutant concentration at various distances from the Tugun Bypass and Pacific Motorway, Pacific Highway, Gold Coast Highway and Tweed Heads Bypass. The locations chosen corresponded to those with maximum predicted traffic flows to represent potential worst-case air quality impacts. Calculations were made for both moderate dispersion and worst-case poor dispersion conditions.

Pollutant concentrations 10 m from the kerb of both the proposed Tugun Bypass and the Pacific Motorway are predicted to remain below current guidelines for the years 2007 and 2017 with the bypass. Increased congestion would occur along the Pacific Motorway in the absence of the bypass, resulting in concentrations of pollutants exceeding the relevant guidelines in both 2007 and 2017.

Impacts of the road tunnel within the airport site were assessed using a model which spreads the emissions from the ramps and tunnel over the ramp areas for peak traffic flows and worst-case dispersion conditions. Maximum concentrations are predicted to remain below relevant guidelines 10 m from the road.

Construction impacts relating to the proposed bypass in terms of air quality would generally be small, as a result of the distance between the proposed bypass and existing residential areas. Appropriate management strategies are put forward in this report to minimise the impacts of air pollutants, principally dust and vehicle fumes, emitted during construction of the road. A program of monitoring of dust levels is also recommended for the construction period, to ensure that strategies are working as planned.

An assessment of greenhouse gas emissions was also undertaken. Greenhouse gases such as carbon dioxide, nitrous oxide and methane have a potential to contribute to global warming. An assessment of total emissions from the Gold Coast road network was made, based on predicted traffic levels. The construction of the proposed bypass is predicted to marginally reduce the total greenhouse gas emissions in 2017.

Impacts on vegetation were assessed by comparing predicted concentrations of nitrogen dioxide and particulates to levels reported in the literature to result in plant damage to sensitive species. Levels of both pollutants 10 m from the road are predicted to remain below levels reported to give significant vegetation stress for sensitive plants.

In summary, the overall impact of the proposed bypass in terms of air quality can be considered acceptable. Pollutant concentrations in existing populated areas near the Gold Coast Highway would be lower if the bypass were constructed. Health impacts and impacts on native species from the proposed road are considered to be acceptable as concentrations would remain below relevant guidelines.

1.2 Reporting of Study Findings in the EIS

The studies for the Tugun Bypass environmental impact assessment commenced in 2000. In the subsequent four years the results of the various studies have been used to refine the concept design of the proposal. Further studies were also commissioned to ensure that all aspects of the various environmental issues were fully understood.

The long time period of the assessment has meant that the content of some of the earlier reports has been superseded by newer work. Changes to the design of the bypass have also been introduced to take account of these studies.

In the event that there is a contradiction between the technical papers and the text of the EIS, the EIS takes precedence as it reports the current understanding of issues, impacts and the concept design.

2. Existing Environment

2.1 Sources of Air Pollution

There are a number of sources of air pollutants in the vicinity of the proposed bypass. The Tweed Heads West Sewage Treatment Plant has a capacity of 10,000 equivalent persons using trickling filter treatment. There are no current plans to augment or close the plant. A sewage pumping station operated by Gold Coast Water is located off Boyd Street near Gold Coast Airport. Tugun Landfill, located adjacent to Boyd Street, is likely to be replaced by a transfer station at the same location. These sources have not caused significant air quality impacts to date. No regional air quality concerns have been reported because of the lack of large industrial sources, the narrowness of the zone of residential/commercial land near the coast and the prevalence of on-shore winds and sea breezes. Current land uses in the study area are illustrated in Figure 2.1.

Sensitive land uses in the area include the John Flynn Hospital and Medical Centre, the Lakeside Christian College, residential areas near the existing roads and the wetland areas near the Cobaki Creek and Broadwater (Figure 2.1).

There is no evidence of air quality in the existing environment exceeding relevant guidelines. This is to be expected, as there is limited large-scale industry in the region and only a 2 km strip of mainly residential and commercial land lies to the east between the proposed road alignment and the sea in the direction of prevailing winds.

A large proportion of pollutant emissions in the area are generated by traffic on the Pacific Motorway and Gold Coast Highway, mainly in the form of particulates, carbon monoxide (CO) and nitrogen oxides (NO_x). Contributions of carbon monoxide, nitrogen oxides and particulates can also be expected from the various operations at Gold Coast Airport. Tugun Landfill and the sewage treatment plant (Figure 2.1) may contribute odour and pollutant gases such as methane.

2.2 Site Specific Monitoring of Carbon Monoxide

Site specific monitoring of carbon monoxide was undertaken along the Gold Coast Highway at Tugun over a period of two days to determine existing maximum pollutant levels near one of the major roads adjacent to the proposed bypass and to validate predicted pollutant levels. The results of the monitoring are shown in Appendix A.

As an aid to interpretation, long–term ambient data from the northern Gold Coast at Helensvale, 29 km to the north-north-west and 7 km from the coast (subject site is 1.5 to 2 km from the coast) were also analysed to provide an indication of existing background levels of pollutants in residential areas near the proposed bypass. These latter data, although obtained from a site that is not directly comparable with the subject site, represent the closest match available. Wind patterns and regional land use are similar at the two locations and both are located on the low coastal plain.

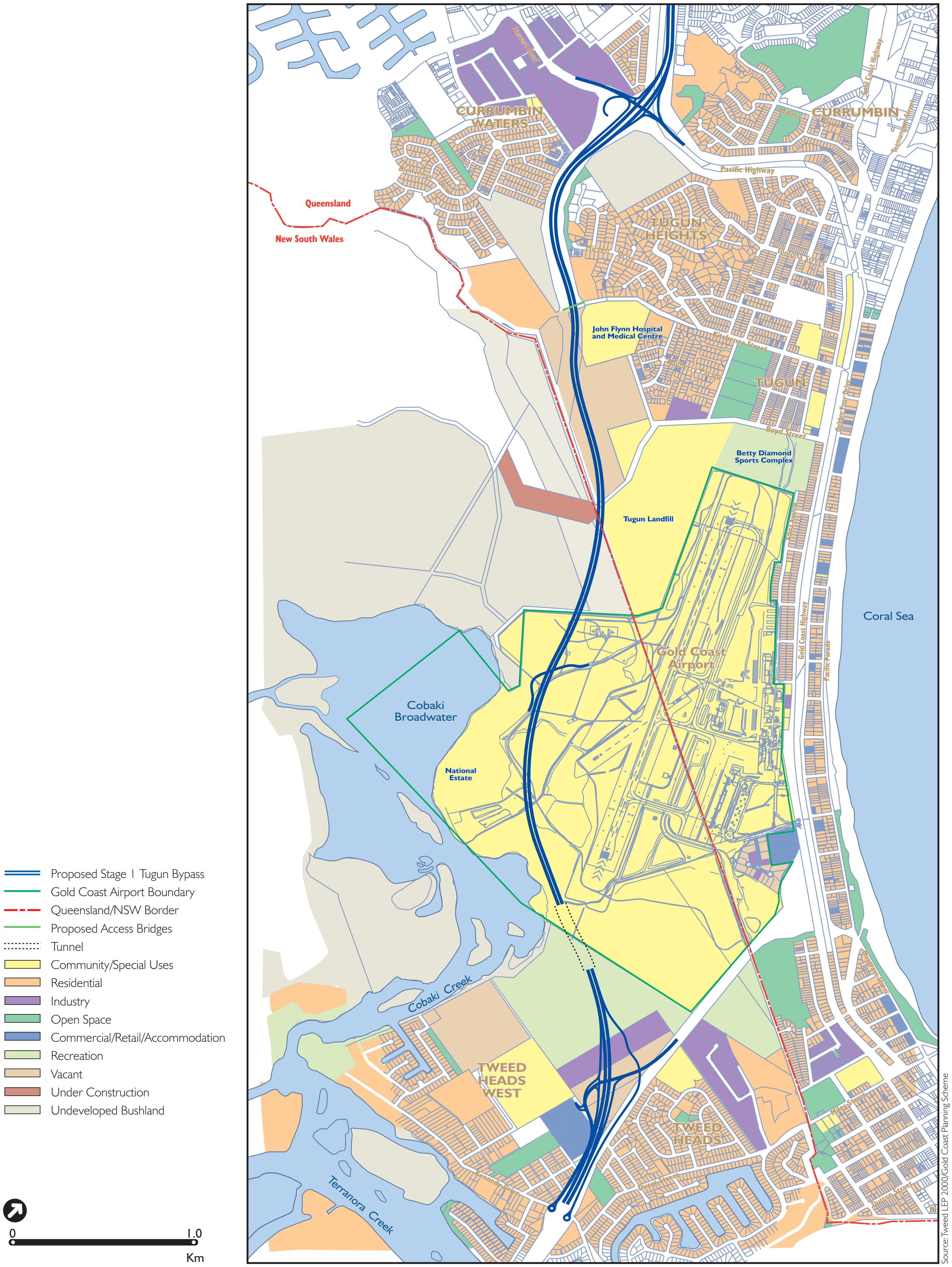


Figure 2.1 **Existing Land Uses in the Study Area**

Site specific measurements of carbon monoxide levels were made on Wednesday 20 and Thursday 21 December 2000 for the existing Gold Coast Highway. Measurements are representative of a peak station according to Australian Standard AS-2922 and measurements were recorded using equipment complying with AS-2695. Monitoring locations are shown in Figure 2.2.

For the measurements taken on 20 December 2000, the carbon monoxide monitoring unit was located 16 m from the western kerb of the Gold Coast Highway on the eastern side of Coolangatta Road, approximately 20 m south of Kitchener Street. Local access roads near the monitoring location carry very little traffic. Traffic flows were noted to be free flowing. Traffic flow data are included in Table 2.1.

On 21 December 2000, the carbon monoxide analyser was located 13 m from the kerb of the Gold Coast Highway, near the corner of Karana Street. Traffic was noted to queue for brief periods at the intersection of the Pacific Motorway and Gold Coast Highway and also at the traffic lights at Tooloona Street. Otherwise, the traffic was relatively free flowing.

Table 2.1: Traffic Flows During the Carbon Monoxide Monitoring Period

Date	Time	Number of Vehicles Northbound per Hour		Number of Vehicles Southbound per Hour		Total of all Vehicles
		Light Duty Vehicles	Heavy Duty Vehicles	Light Duty Vehicles	Heavy Duty Vehicles	
Wednesday 20 December 2000 Tugun Park South of Kitchener Street	7:40 am	2,040	168	2,760	252	5,220
	8:10 am	1,980	168	2,400	96	4,644
	8:45 am	1,716	180	2,640	48	4,584
	9:10 am	1,680	120	1,800	192	3,792
	2:30 pm	2,040	132	2,160	144	4,476
	3.45 pm	2,520	72	3,840	168	6,600
	5:00 pm	1,920	84	2,760	132	4,896
	6:10 pm	1,200	48	1,212	96	2,556
Thursday 21 December 2000 Corner Karana Street	7:05 am	1,380	144	1,800	108	3,432
	8:30 am	1,956	96	1,680	108	3,840
	9:48 am	2,208	96	2,760	156	5,220
	11:25 am	2,040	120	2,640	84	4,884
	2:30 pm	2,472	96	2,076	192	4,836
	4:00 pm	2,640	36	2,160	36	4,872
	4:54 pm	2,280	60	2,400	60	4,800

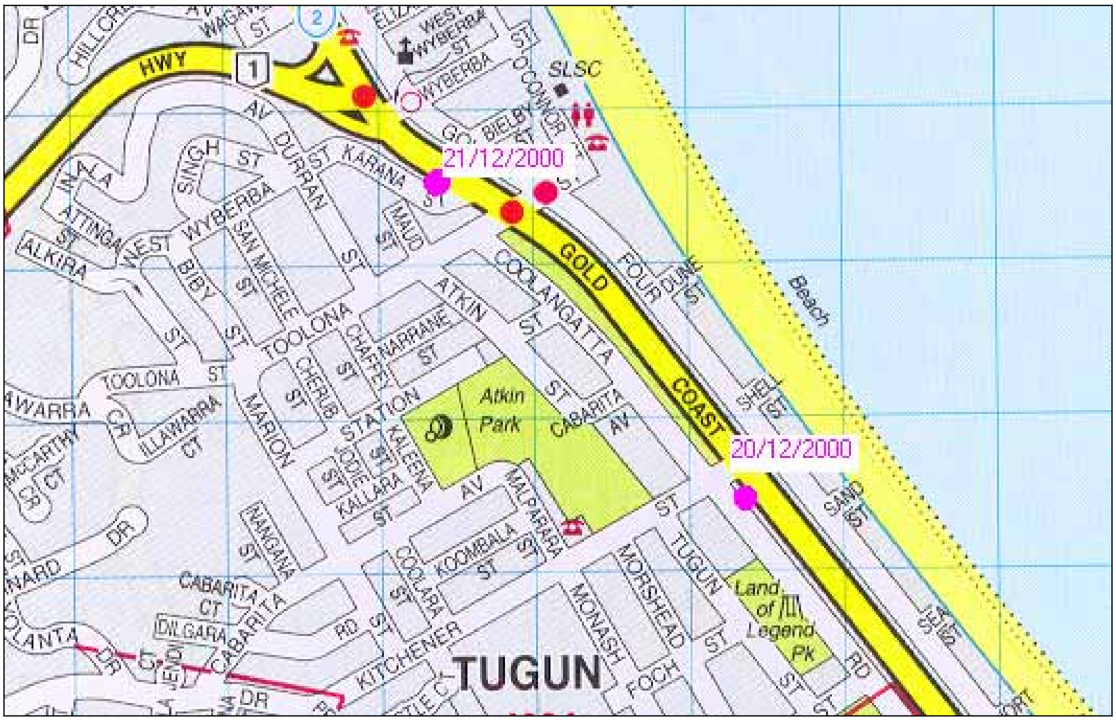


Figure 2.2: Locations of Carbon Monoxide Monitors, December 2000

The monitoring sites were selected so that the onshore winds would transport vehicle emissions towards the carbon monoxide analyser. The site selected on the first day was chosen to indicate concentrations in a relatively free-flowing situation while that for the second day was chosen to indicate concentrations in a worst-case situation where traffic flow was affected by traffic lights. The hourly vehicle flow rates were estimated from five-minute vehicle counts, including the number of heavy duty (commercial) vehicles. Wind speed and wind direction measurements from the nearby Gold Coast Airport monitoring station were also obtained. These are shown in Figures 3.5 and 3.6.

Plots of five-minute average carbon monoxide concentrations are shown in Figures 2.3 and 2.4 for monitoring data taken on 20 and 21 December respectively. These indicate that concentrations were typically 1.4 ppm on 20 December and 2.4 ppm on 21 December. Concentration peaks did not tend to correspond with traffic peaks during the monitoring periods reported in Figure 2.3, although this degree of variation is typical for atmospheric processes. The variation in concentration is attributed in part to variability in local dispersion conditions. Higher traffic levels will slightly increase local turbulence and dispersion, while there is a complex variation resulting from the combination of vehicle numbers, wind speed, wind direction and atmospheric stability. A higher proportion (87.1 percent) of concentrations were less than or equal to 1.5 ppm on 20 December and 67.9 percent were below 2.5 ppm on 21 December 2000 (Figures 2.5 and 2.6).

All measured concentrations were well below the 8-hour health-related guidelines of 8 ppm for Queensland *(Queensland Environmental Protection (Air) Policy 1997)* and 9 ppm for NSW (NSW Environment Protection Authority 1998), with 8-hour average concentrations of 1.3 ppm on 20 December and 2.6 ppm on 21 December.

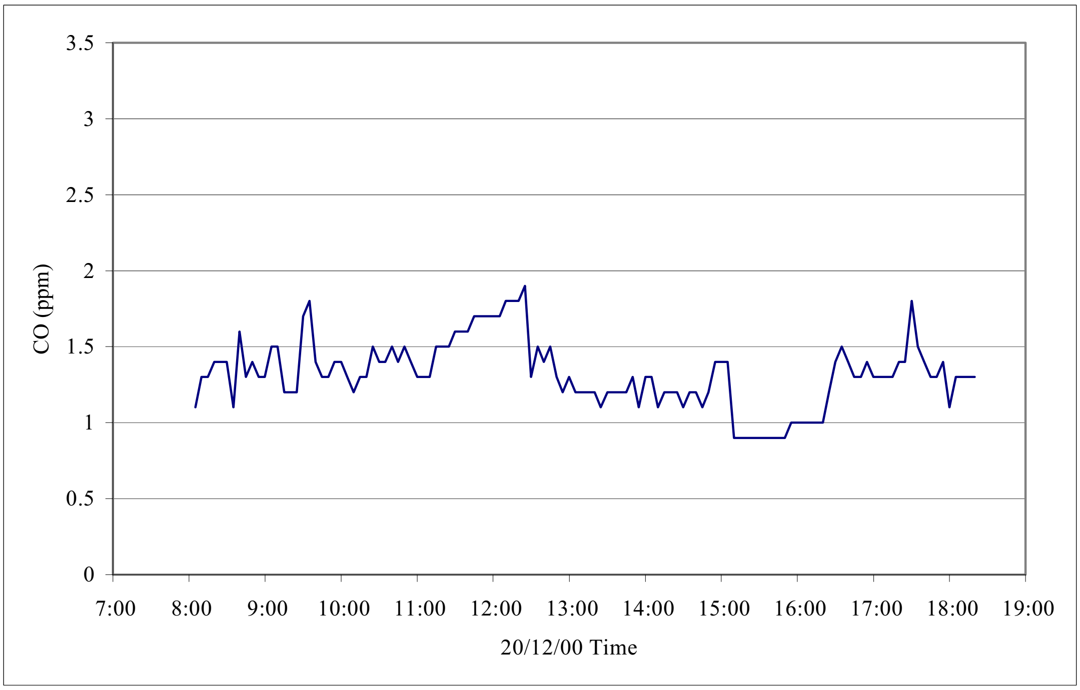


Figure 2.3: Time Series of Five Minute Average Carbon Monoxide Monitoring Results (ppm) 20 December 2000 near Kitchener Street, Gold Coast Highway

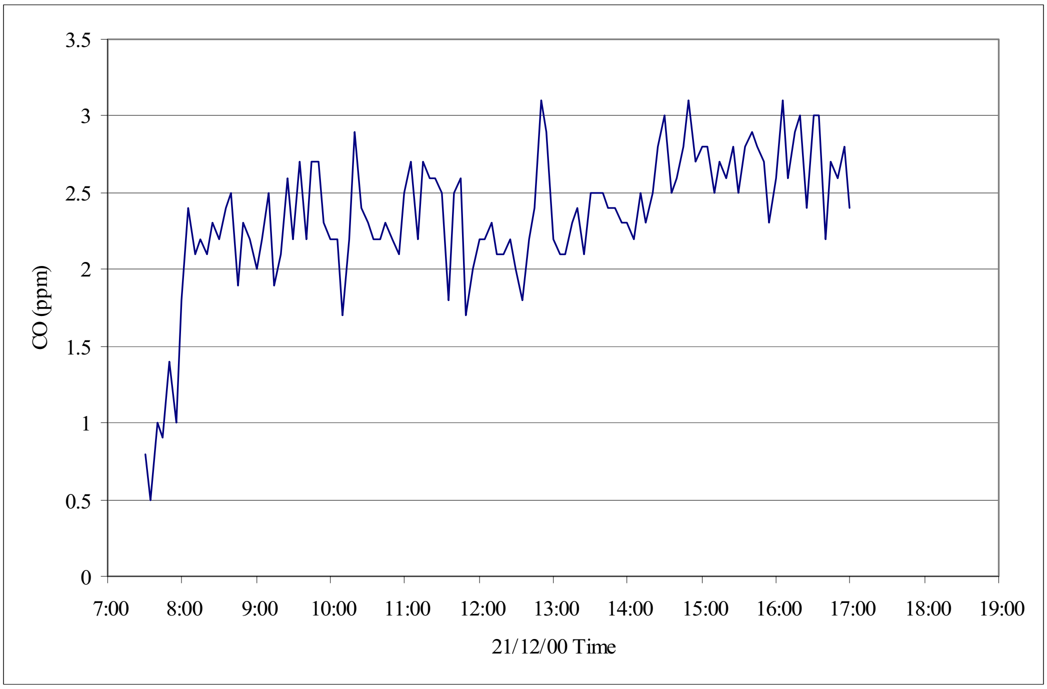


Figure 2.4: Time Series of Five Minute Average Carbon Monoxide Monitoring Results (ppm), 21 December 2000 near Karana Street, Gold Coast Highway

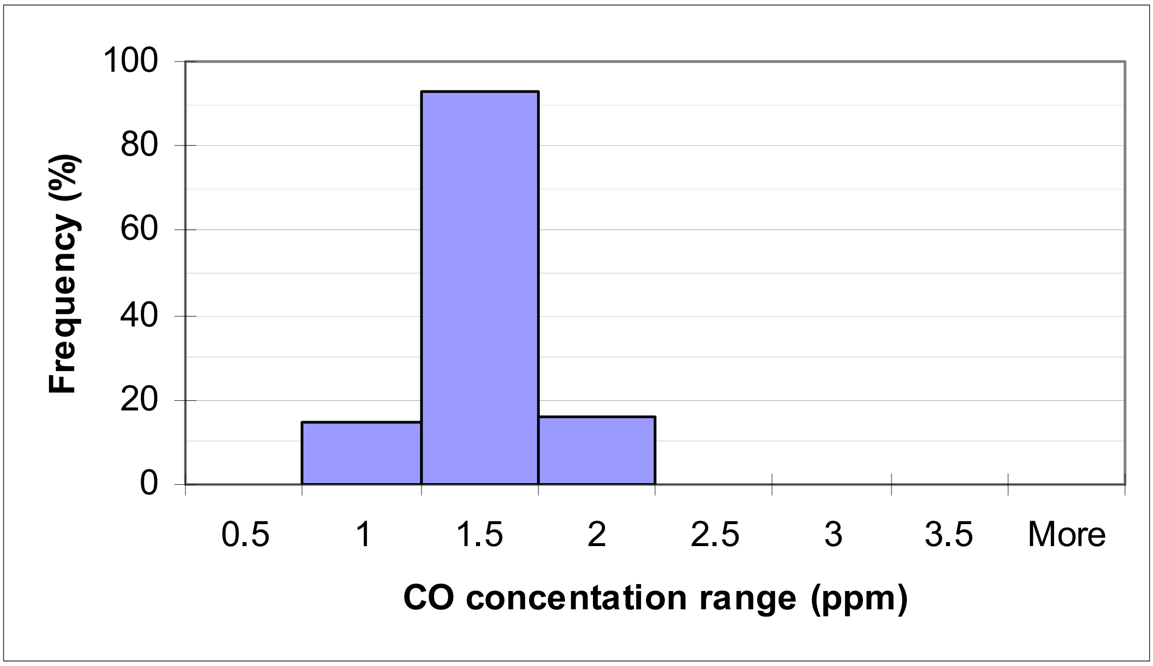


Figure 2.5: **Frequency Distribution of Carbon Monoxide Measurements, 20 December 2000 near Kitchener Street.**

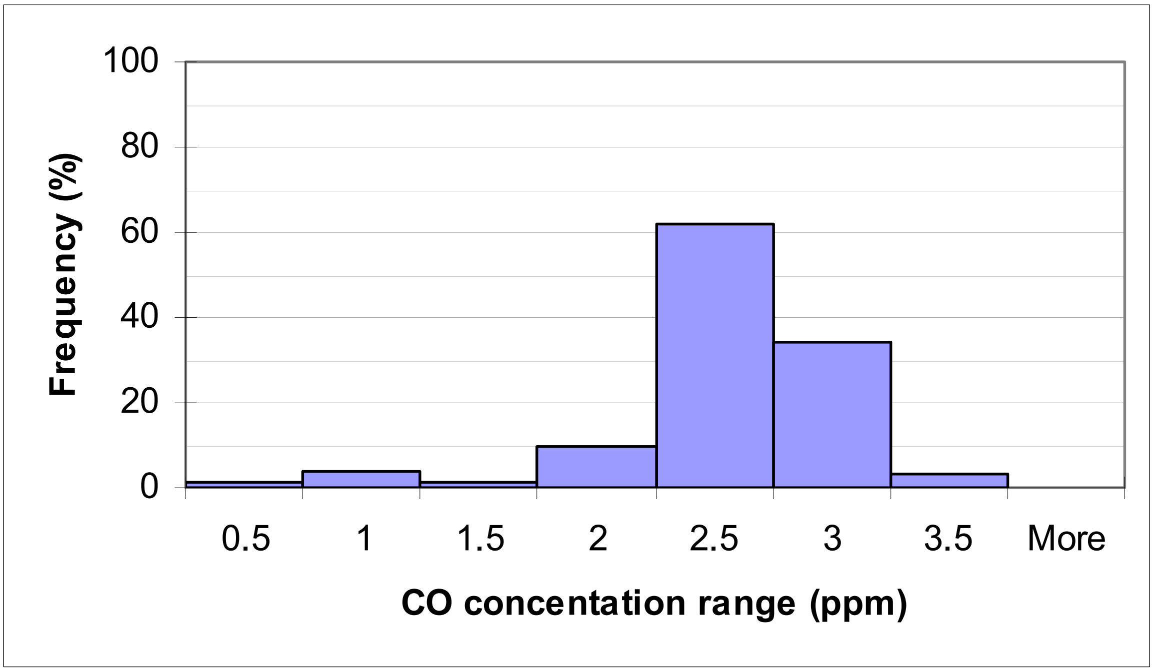


Figure 2.6: **Frequency Distribution of Carbon Monoxide Measurements, 21 December 2000 near Karana Street.**

The monitoring results indicate that at distances of more than 10 m from the road, the five-minute average carbon monoxide concentration should be less than 3 ppm for the free–flowing traffic with hourly traffic flows of around 5,000 vehicles. The proportion of heavy vehicles ranged between 4 percent and 9 percent during the monitoring period.

The projected traffic flows for 2007 and 2017 without the bypass would be up to four times higher than those during the monitoring period, which would result in ground–level concentrations of carbon monoxide that could exceed relevant guidelines at 10 m from the kerb. Predicted traffic flows with the bypass would be approximately the same or slightly higher than noted during the monitoring period, which should result in slightly lower carbon monoxide concentrations at 10 m than measured due to improving vehicle emission technology.

2.3 Background Air Quality

No existing background air quality information is available for the immediate region evaluated in this technical paper. The most representative air quality information is from the Queensland Environmental Protection Agency's monitoring site at Helensvale to the north. Dust, ozone and nitrogen dioxide data for two years from February 1998 to March 2000 were analysed.

Dust that can readily enter the lungs and affect human health is generally less than 10 microns (millionths of a metre) in diameter. Guidelines for dust are often specified in terms of particulate matter less than 10 microns in diameter (PM_{10}). The directionality of winds associated with dust measurements can give an indication of the source of the dust.

The PM_{10} rose of Figure 2.7 represents the frequency of PM_{10} concentrations occurring from each direction by the length of the corresponding radial spoke and the length of each coloured bar on the spoke represents the frequency of readings for the range of concentrations represented by that colour.

The dust rose shows that there is a slight tendency for the lowest particulate concentrations to be associated with winds from the west and west-south-west. Most frequent high concentrations are from the east-north-east to south-south-west, reflecting the higher frequency of winds from these directions. It is likely that sea salt or aerosol may be a contributor for more easterly directions.

A plot of hourly PM_{10} concentrations is shown in Figure 2.8. An early peak at 7 am is probably associated with peak morning traffic emissions. This suggests that there may be a greater variability in traffic flows in suburban Helensvale than at the short-term monitoring location on the Gold Coast Highway.

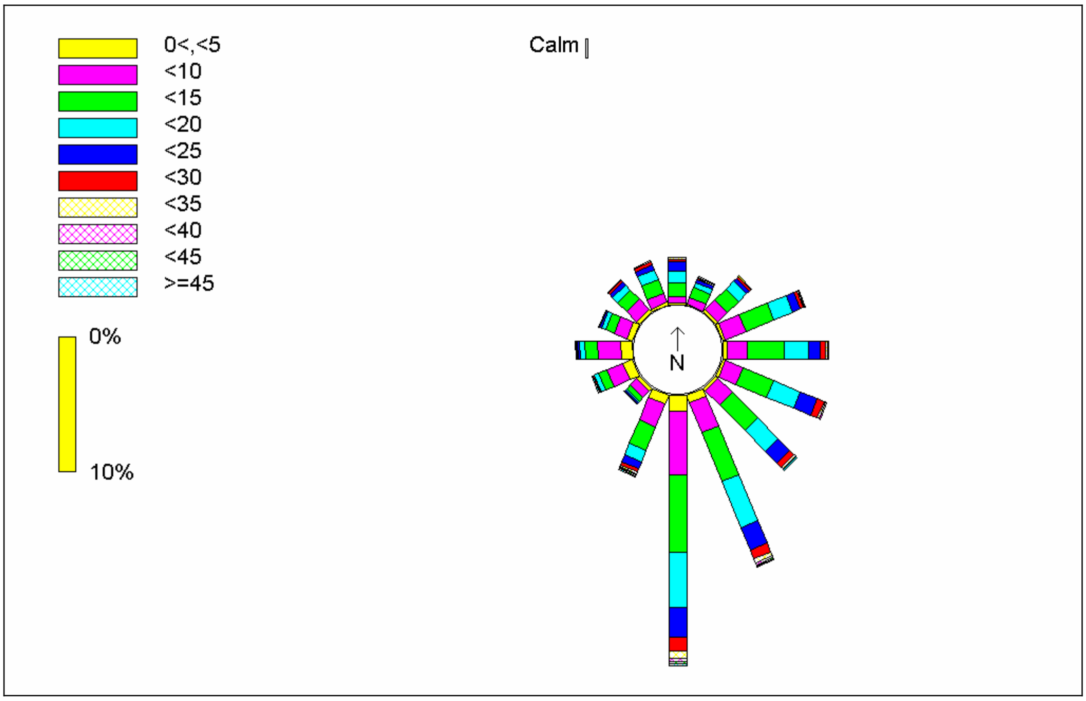


Figure 2.7: Pollution Rose Showing Distribution of One-Hour Average Concentration of PM_{10} with Wind Direction at Helensvale ($\mu g/m^3$)

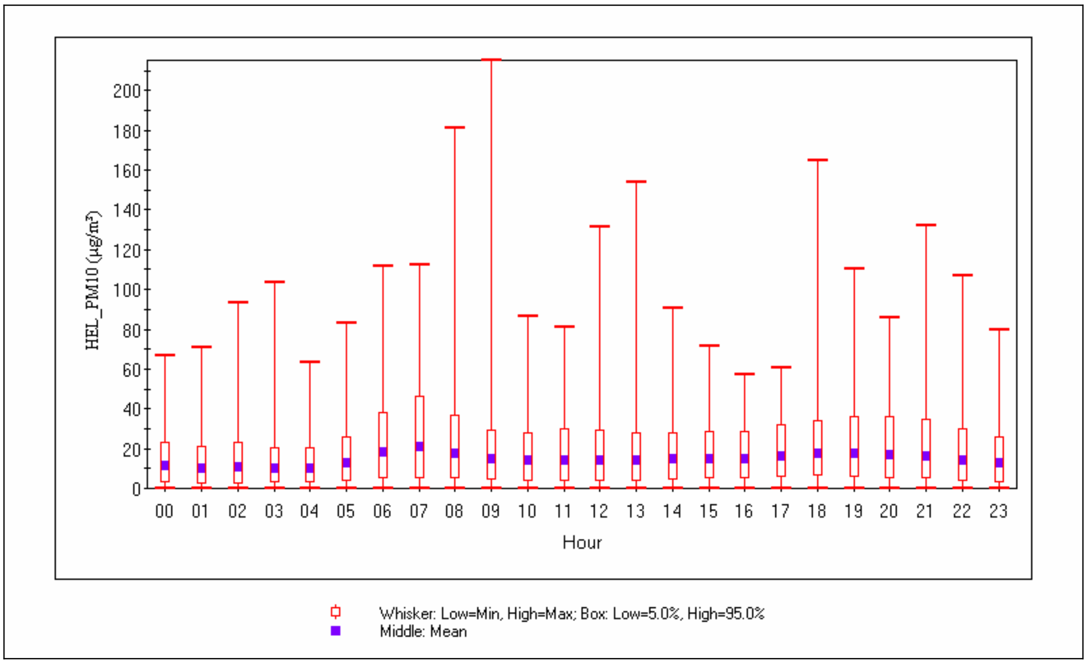


Figure 2.8: Box and Whisker Plot of PM_{10} Concentration vs Hour at Helensvale ($\mu g/m^3$)

Ozone levels are typically 20 percent of the NSW Environment Protection Authority and Queensland Environmental Protection Agency ozone guideline level of 10 pphm, as shown in Figure 2.9. Ozone is generated by photochemical activity associated with urban industry and traffic. Ozone is usually formed as a result of photochemical activity in an airshed with significant emissions of hydrocarbons and nitrogen oxides.

Low ozone levels are more frequent for winds from the south, as expected from regional settlement patterns. Higher ozone levels would be expected for winds blowing from the more industrialised and populous Brisbane airshed to the north than from the less populous airshed of coastal NSW to the south. A clear diurnal pattern is apparent in Figure 2.10.

Most combustion sources emit around 10 percent of nitrogen oxides as nitrogen dioxide (NO_2) and 90 percent as nitric oxide (NO). Over a period of minutes to hours the nitric oxide oxidises and the proportion of nitrogen dioxide increases. At Helensvale approximately 63 percent of nitrogen oxides is in the form of nitrogen dioxide, but the proportion drops to around 12 percent as the total nitrogen oxides concentration increases. This suggests that the high concentrations represent freshly emitted pollutants that have blown directly toward the monitor from a nearby road. Median nitrogen dioxide concentrations are below 1 pphm (20.5 $\mu g/m^3$), as shown in Figures 2.11 and 2.12.

A recent evaluation of the NSW Roads and Traffic Authority air-monitoring program (Holmes 1997) recommended background levels of carbon monoxide and nitrogen dioxide covering most situations. These were 1 to 2 ppm for carbon monoxide and 0.02 ppm for nitrogen dioxide. Background levels would be representative of mean hourly values. Given the prevailing wind directions and the limited number of sources between the coast and the road, background nitrogen dioxide levels at Tugun are likely to be lower. Background levels of pollutants assumed in this assessment are presented in Table 2.2, based on the Holmes recommendations and measurements at urban Environmental Protection Agency monitoring sites in Queensland.

Table 2.2: Background Concentration of Air Pollutants used in Dispersion Modeling

Pollutant	Background Concentration
Carbon monoxide (CO)	1250 $\mu g/m^3$ (1 ppm)
Nitrogen dioxide (NO_2)	20 $\mu g/m^3$
Particulate matter (PM_{10})	30 $\mu g/m^3$

Note: ppm = parts per million by volume;
$\mu g/m^3$ = micrograms per cubic metre

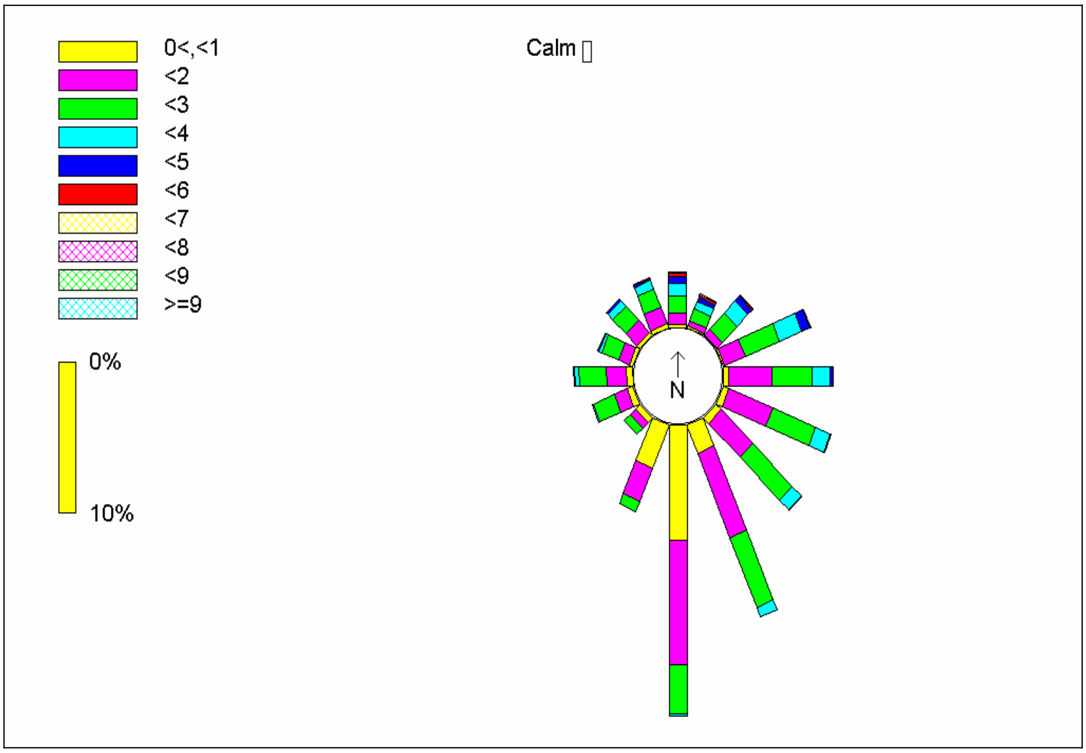


Figure 2.9: Pollution Rose Showing Distribution of Ozone with Wind Direction at Helensvale (pphm)

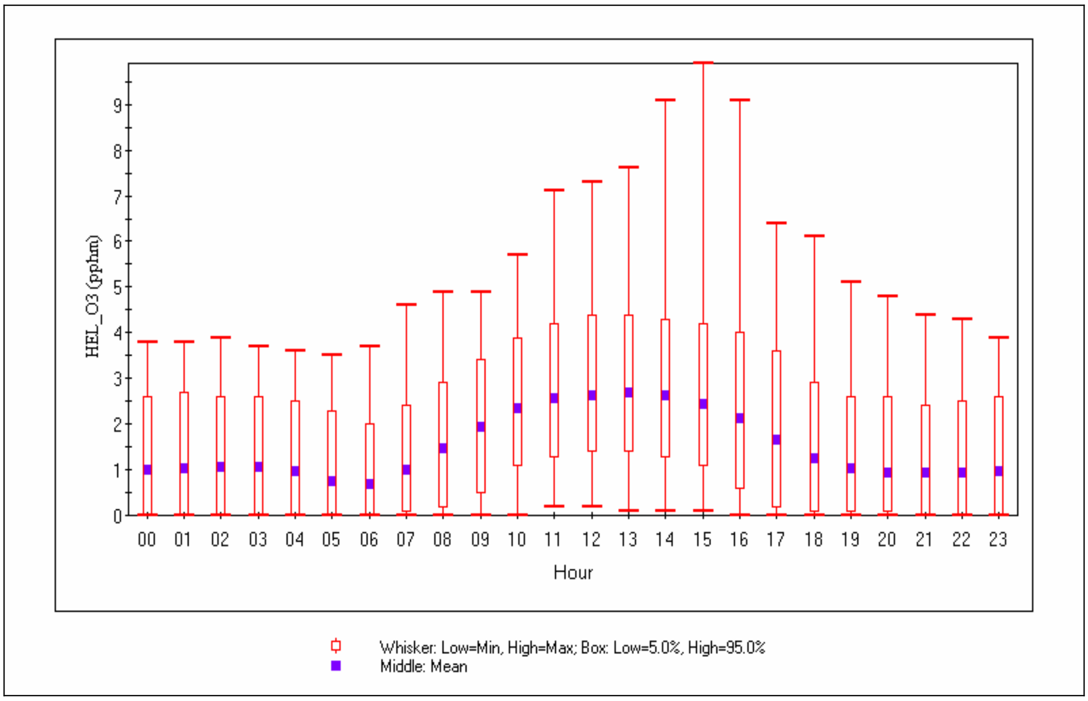


Figure 2.10: Box and Whisker Plot of Ozone Concentration vs Hour at Helensvale (pphm)

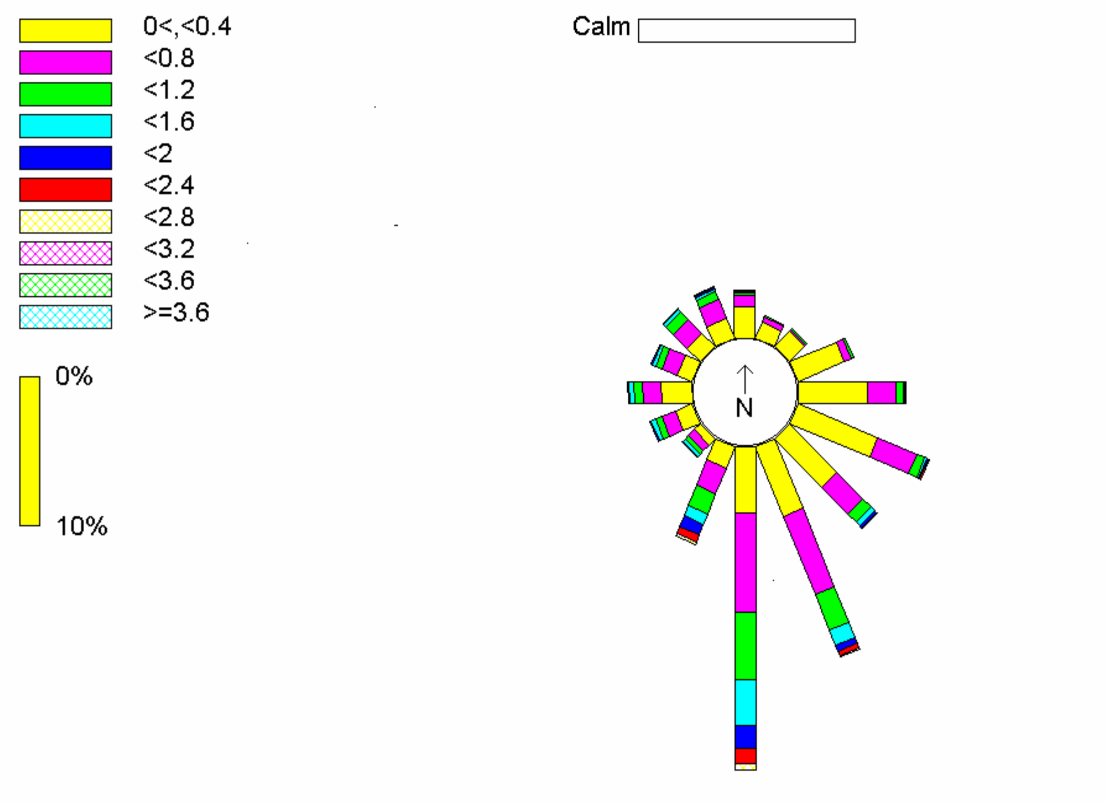


Figure 2.11: Pollution Rose Showing Distribution of NO_2 with Wind Direction at Helensvale (pphm)

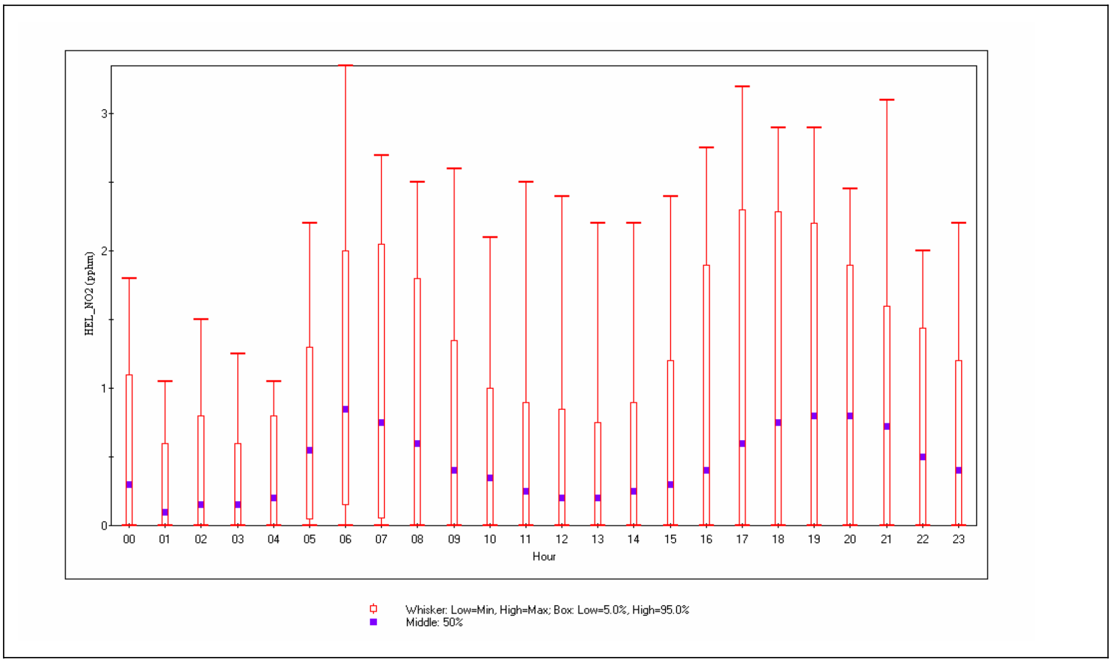


Figure 2.12: Box and Whisker Plot of NO_2 Concentration vs Hour at Helensvale (pphm)

3. Local Meteorology

Figure 3.1 shows the wind rose for Helensvale for all hours, with most winds from the south to east-north-east. For the period from 6:00 to 18:00 when traffic emissions are greatest, the southerly component is reduced and the easterly components increased (Figure 3.2).

The majority of winds at Helensvale are from the east-north-east to south (64.9 percent for all hours and 67.4 percent for 6:00 to 18:00). Winds greater than 3 m/s are relatively infrequent (10.1 percent for all hours, 13.7 percent for 6:00 to 18:00).

The majority of winds at Gold Coast Airport are from the south-south-east to west-south-west (56.1 percent), with 73.2 percent of winds greater than 3 m/s (Figure 3.3).

The majority of winds at the Gold Coast Seaway are from the east to south–west (57.9 percent), with 65 percent of winds greater than 3 m/s (Figure 3.4).

Wind direction appears to shift slightly to the west as the monitoring location moves southward, from south-south-east to south at Helensvale, to south at the Gold Coast Seaway, to south to south-south-west at Gold Coast Airport. Wind speed and direction at the Gold Coast Airport monitoring station during the carbon monoxide monitoring period are shown in Figures 3.5 and 3.6.

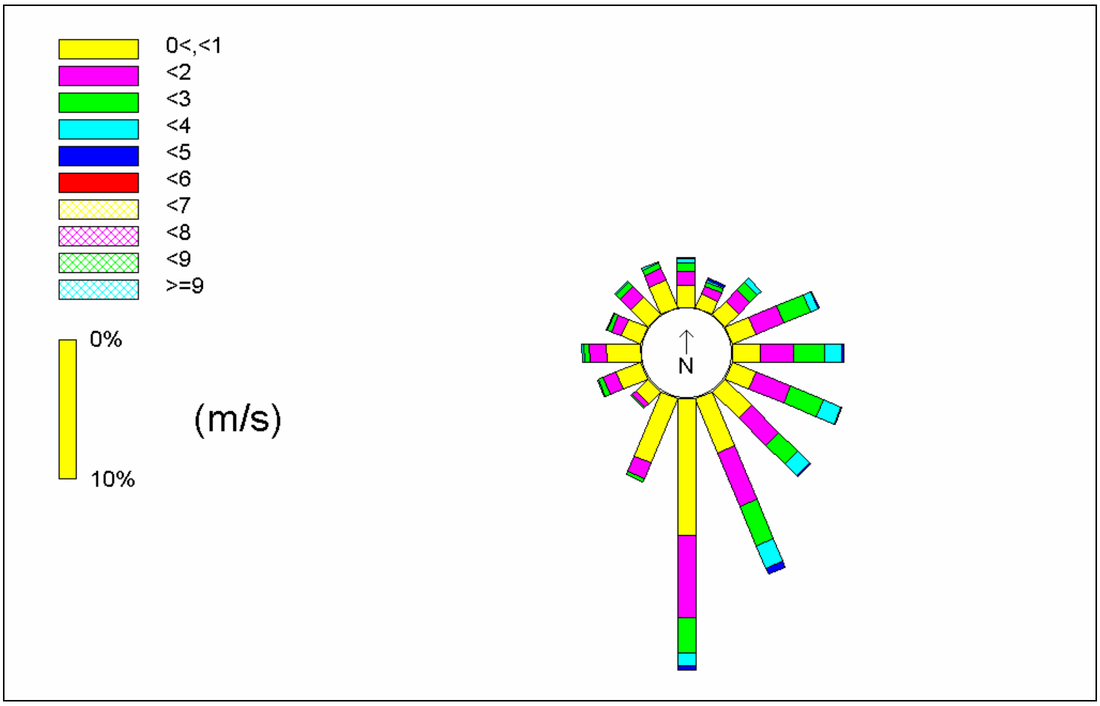


Figure 3.1: Wind Rose for All Hours for the Queensland Environmental Protection Agency Weather Station at Helensvale for the Period from 1998 to 2000

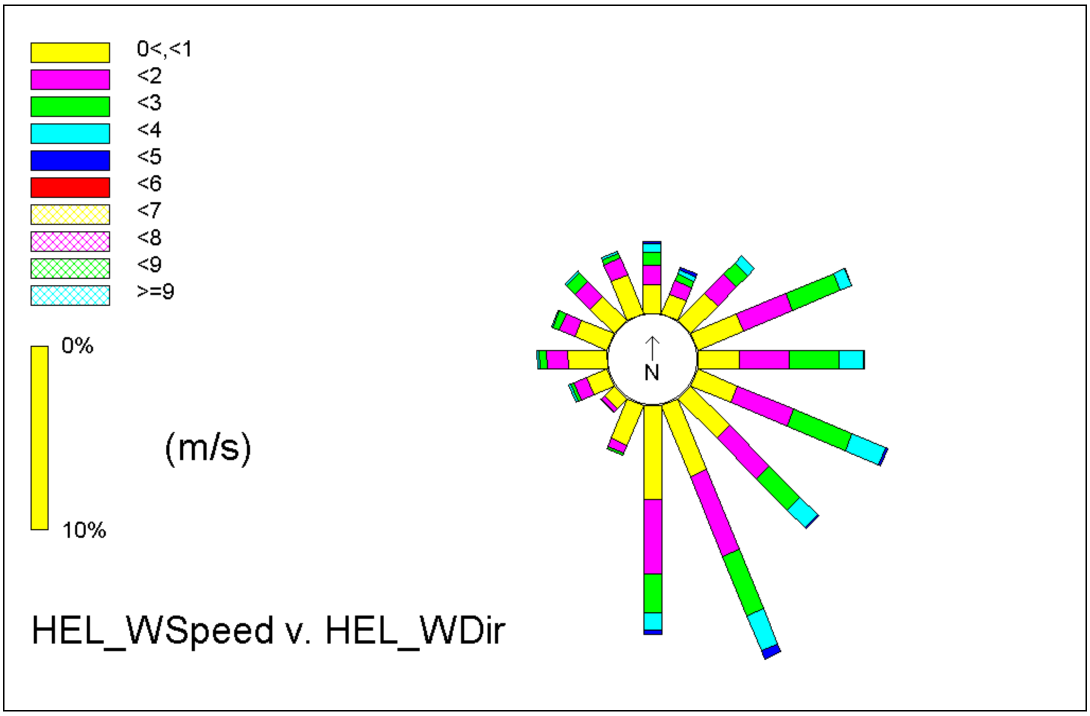


Figure 3.2: Wind Rose for Queensland Environmental Protection Agency Weather Station at Helensvale for the Period from 1998 to 2000, 6:00 to 18:00 Each Day

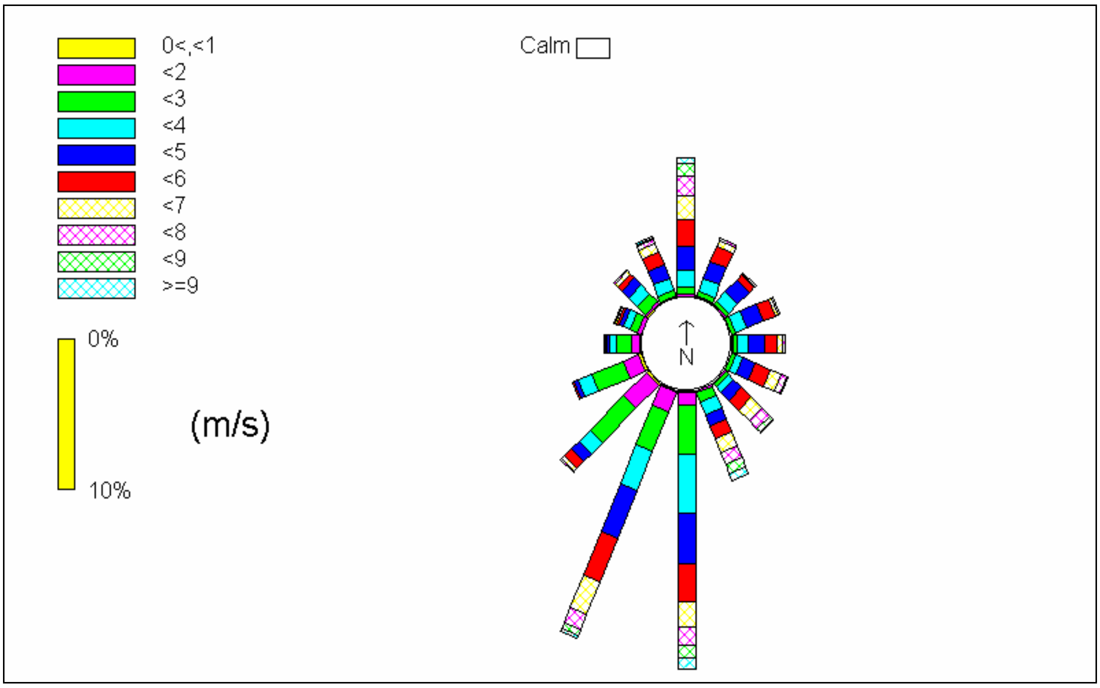


Figure 3.3: Wind Rose for All Hours for the Bureau of Meteorology Weather Station at Coolangatta for the Period from 1998 to 2000

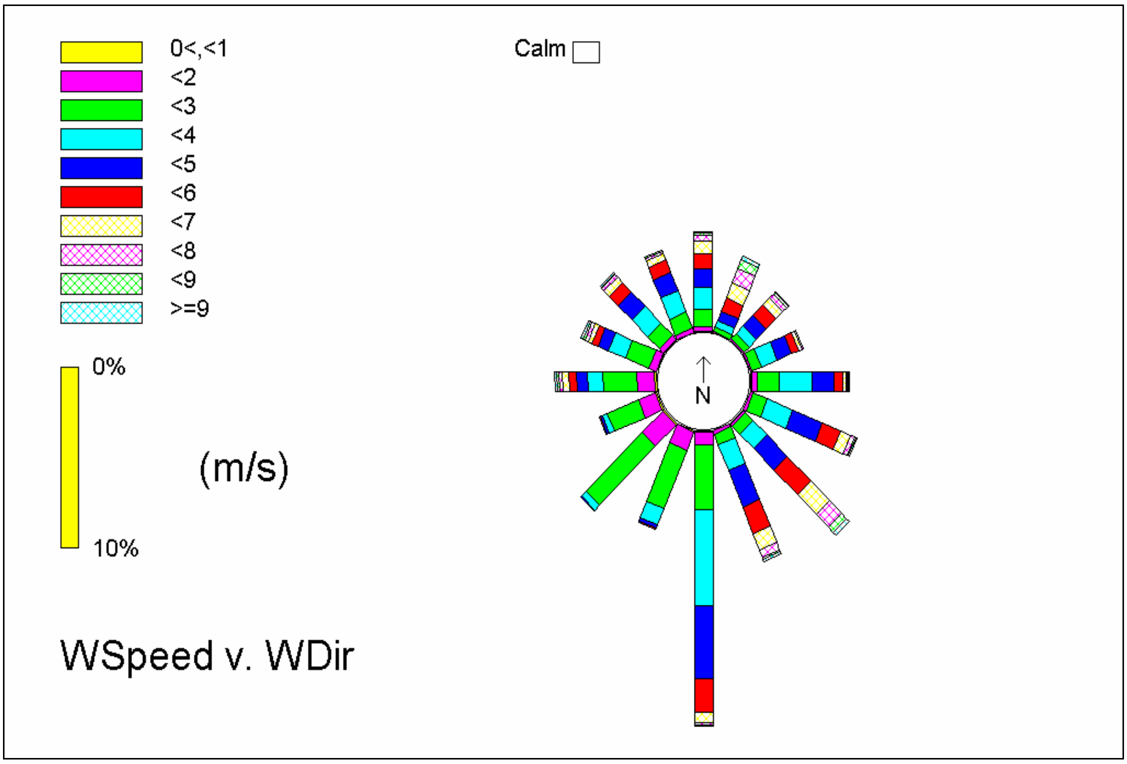


Figure 3.4: Wind Rose for All Hours for the Gold Coast Seaway, Bureau of Meteorology Data for the Period From 1994 to 2000

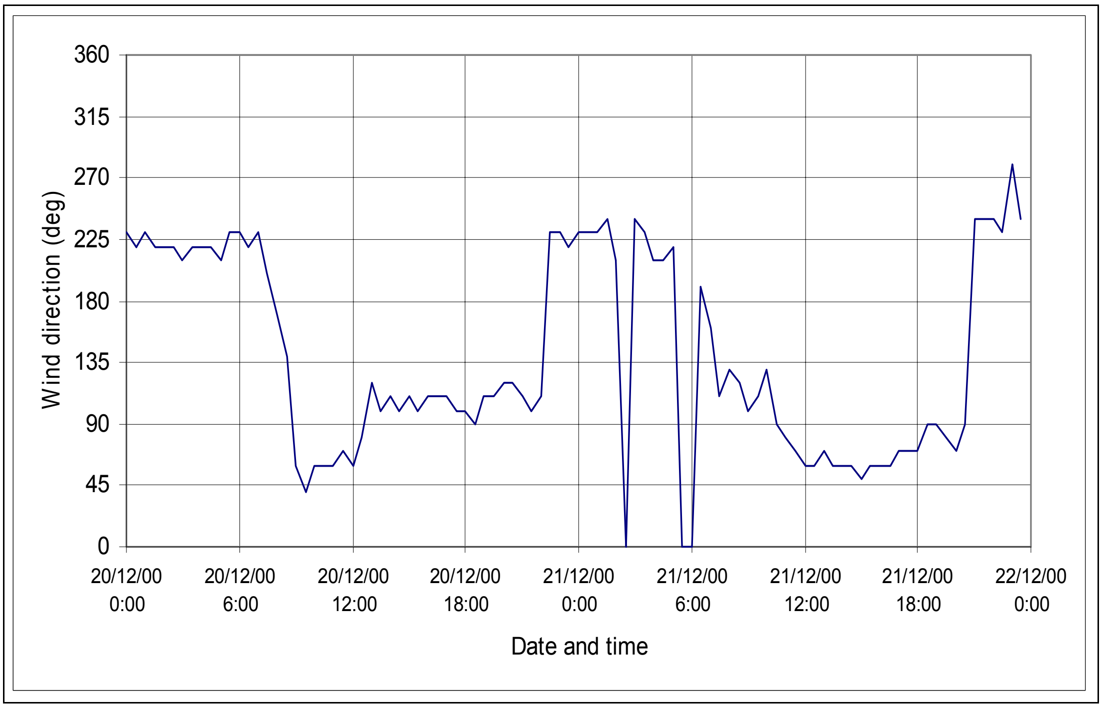


Figure 3.5: Wind Direction at Gold Coast Airport During Monitoring Period (Bureau of Meteorology Data)

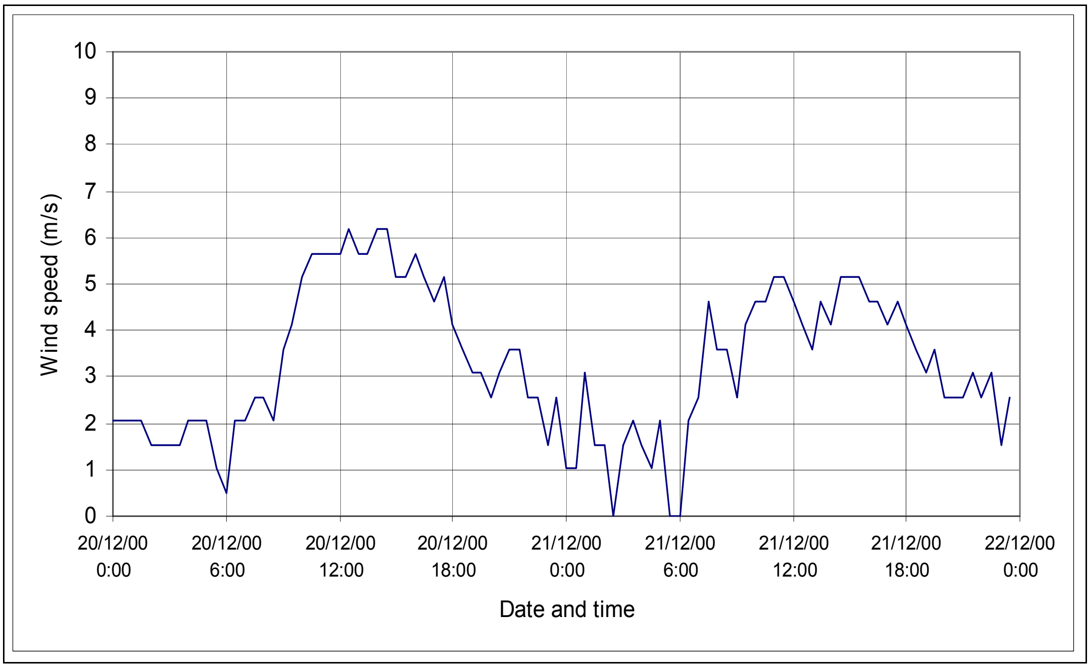


Figure 3.6: Wind Speed (m/s) at Gold Coast Airport During Monitoring Period (Bureau of Meteorology Data)

Atmospheric stability determines the rate of spread of a pollutant release. It is generally classified into six stability classes according to the method of Pasquill (Pasquill 1974). The classes range from highly unstable (Class A) through neutral (Class D) to highly stable (Class F). Pollutants disperse most rapidly during unstable conditions and least rapidly during stable conditions.

The Queensland Environmental Protection Agency commissioned the production of representative regional meteorological files for locations throughout the state for the Ausplume computer dispersion model. Thirty-nine years of Bureau of Meteorology data were analysed to produce a one year representative file for Southport. The frequencies of Pasquill Stability Classes from this file are summarised in Table 3.1. The stable Class F conditions which result in poor dispersion occur for around 21 percent of the time. The highest concentrations at any receptor will be less frequent than this, as they will only occur when the wind is in the appropriate direction, the wind speed is low and traffic flow is high.

Table 3.1: Frequency of Pasquill Stability Classes, Southport, Regional Modelling File

Pasquill Stability Class	Frequency of Occurrence (%)
A	1.0
B	12.0
C	16.0
D	31.9
E	18.4
F	20.7

Source: Queensland Environmental Protection Agency.

4. Air Quality Criteria

4.1 Guidelines

National air quality goals have been formulated by the National Environment Protection Council, and published in the *National Environmental Protection Measure for Ambient Air Quality* (National Environment Protection Council 1998). In addition to these, the NSW Environment Protection Authority has formulated air quality guidelines as published in the *Action for Air 1998*. The Queensland Environmental Protection Agency has formulated air quality guidelines which are published in the *Environmental Protection (Air) Policy 1997*. The Airports (Environment Protection) Regulations 1997 administered by the Department of Transport and Regional Services include ambient air quality guidelines in Schedule 1. Details on these guidelines are presented below.

The NSW Environment Protection Authority goals are based on National Health and Medical Research Council of Australia (NHMRC), World Health Organisation (WHO) and United States Environmental Protection Agency (USEPA) air quality goals, and guideline levels are shown in Table 4.1 (NSW Environment Protection Authority 1998). These are interim goals formulated as part of a 25-year plan, which provides for even stricter long-term reporting goals.

Table 4.1: NSW Environment Protection Authority Air Quality Goals

Pollutant	Averaging Period	Goal	Allowable exceedances[1]
Nitrogen dioxide	1 hour	0.125 ppm (257 $\mu g/m^3$)	1 day a year
Nitrogen dioxide	Annual	0.03 ppm (62 $\mu g/m^3$)	None
PM_{10}	24 hours	50 $\mu g/m^3$	5 days a year
Ozone	1 hour	0.10 ppm	1 day a year
Ozone	4 hours	0.08 ppm	1 day a year
TSP	Annual	90 $\mu g/m^3$	

[1] NSW Environment Protection Authority interim goals from Action for Air (1998)

There is currently no ambient air quality guideline for the assessment of volatile organic compounds. The National Health and Medical Research Council's indoor air quality goal of 500 $\mu g/m^3$ for one hour can be used as a guide to potential health impacts.

Relevant Queensland goals are found in Schedule 1 of the *Environmental Protection (Air) Policy 1997*, and summarised in Table 4.2.

Table 4.2: Queensland Air Quality Indicators and Goals

Pollutant	Averaging Period	Goal
Carbon monoxide	8 hours	8 ppm (10,000 $\mu g/m^3$)
Nitrogen dioxide	1 hour	0.16 ppm (320 $\mu g/m^3$)
Nitrogen dioxide	4 hours	0.05 ppm (95 $\mu g/m^3$)
Nitrogen dioxide	Annual	0.01 ppm (30 $\mu g/m^3$)
PM_{10}	24 hours	150 $\mu g/m^3$
PM_{10}	Annual	50 $\mu g/m^3$
Ozone and photo-chemical oxidants	1 hour	0.1 ppm (210 $\mu g/m^3$)
	4 hours	0.08 ppm (170 $\mu g/m^3$)
TSP	Annual	90 $\mu g/m^3$

Source: Queensland Environmental Protection Agency, *Environmental Protection (Air) Policy 1997.*

National air quality goals have been set by the National Environment Protection Council in a *National Environment Protection Measure for Ambient Air Quality* (NEPM) for various pollutants (National Environment Protection Council 1998). These goals are designed to assess the level of exposure of the population of a region to air pollution and hence are not strictly applicable to pollutant levels near major industries or busy roads. They are summarised in Table 4.3. Both Queensland and NSW will use these national goals to assess regional air quality but it is not expected that areas near major sources will achieve these levels, especially in the short-term.

Table 4.3: National Environment Protection Measure for Ambient Air Quality – Schedule 2, Standards and Goals

Pollutant	Averaging Period	Maximum Concentration	Goal for 2008 Maximum Allowable Exceedances
Carbon monoxide	8 hours	9 ppm (11,250 $\mu g/m^3$)	1 day a year
Nitrogen dioxide	1 hour	0.12 ppm (246 $\mu g/m^3$)	1 day a year
Nitrogen dioxide	1 year	0.03 ppm (62 $\mu g/m^3$)	none
Photochemical oxidants (as ozone)	1 hour	0.10 ppm (214 $\mu g/m^3$)	1 day a year
	4 hour	0.08 ppm (171 $\mu g/m^3$)	1 day a year
Particulate matter (PM_{10})	1 day	50 $\mu g/m^3$	5 days a year

Source: National Environment Protection Council 1998.

No relevant ambient objective included in Schedule 1 of the Airports (Environment Protection) Regulations 1997 is any more stringent than the most stringent of the equivalent NSW, Queensland and NEPM goals.

The NSW government has adopted NEPM goals as interim goals for its 25–year air quality management plan and stated its commitment to adopting them when finalised (NSW Environment Protection Authority 1998). The NEPM goals have been advised for use at reference monitoring locations, taken to be 1 km distant from the nearest roads or industry. Applying the NSW interim goals to near-road locations would result in considerable conservatism. Air quality goals do not have the same status as air quality guidelines. NEPM and current State goals have been used for comparison purposes in this document.

Dispersion model calculations are usually for hourly average concentrations and need correction for emission and meteorological variability to apply to longer–term periods, based on averaging time correction factors derived from kerbside monitoring. The most extensive results available to the authors are from a kerbside location in Central Brisbane (with several years of carbon monoxide monitoring).

While these factors might be expected to be site-specific, other monitoring sites in Brisbane and other cities give similar results. The factors are similar to those recommended by the California Transportation Board and found in Californian studies (California Department of Transportation 1988; McGuire and Noll 1970). For averaging periods of eight hours, 24 hours, 90 days and 12 months, the maximum concentrations can be obtained from peak one hour concentrations by using multiplicative concentration ratios (persistence factors) of 0.4, 0.24, 0.14 and 0.06 respectively.

4.2 Health Impacts of Air Pollutants

The main pollutants emitted from spark-ignition exhausts are carbon dioxide, carbon monoxide, traces of nitrogen oxides, sulphur dioxide, particulate matter and unburned hydrocarbons. Uncontrolled diesel emissions are similar, but generally with lower carbon monoxide emissions.

Carbon dioxide is usually not considered in terms of health impacts, but is considered in terms of greenhouse impact. An analysis of greenhouse impacts is included in Chapter 6. Ultrafine particles form a subset of particulate emissions. Ozone is generated by photochemical activity involving hydrocarbon and nitrogen oxide emissions from vehicles and other sources. Unburned hydrocarbons and particles can contribute to odour emissions from vehicles.

4.2.1 Carbon Monoxide

Carbon monoxide (CO) is a colourless, odourless, toxic gas. It binds strongly to haemoglobin in the bloodstream forming carboxyhaemoglobin (CoHb). Because CO has an affinity for haemoglobin 250 times that of oxygen, it interferes with the capacity of the blood to transport oxygen to the tissues. Moderate carbon monoxide concentrations of around 50 ppm correspond to a CoHb concentration of around 10 percent and give rise to light symptoms – such as dizziness or headache.

Carbon monoxide concentrations of around 1,000 ppm give rise to a CoHb concentration of 65 percent which is likely to be fatal for extended exposure. The time required for effects to be evident depends on the level of activity of an individual. No adverse effects have been reported for the concentrations expected near the Tugun Bypass.

4.2.2 Oxides of Nitrogen

The majority of emissions from a combustion process is in the form of nitric oxide (NO). This compound is generally oxidised in the order of minutes to hours, to form nitrogen dioxide (NO_2). Other compounds such as nitrous oxide (N_2O) and nitrogen tetroxide (N_2O_4) can be formed in smaller quantities. The total of all oxidised nitrogen species is referred to as nitrogen oxides. At the point of emission, nitrogen oxides from vehicle exhausts typically comprises 95 percent by volume of nitric oxide and 5 percent of nitrogen dioxide. Conversion factors of nitric oxide to nitrogen dioxide are reported to be 10 percent and 15 percent for predictions at 10 m and 30 m from the roadway respectively (Holmes 1997).

Nitric oxide is a colourless, odourless gas. It is slightly soluble in water and has a strong affinity for blood haemoglobin, forming methaemoglobin. This results in a reduction in the capacity to supply oxygen to the tissues. In the presence of oxidising agents or solar radiation, nitric oxide is rapidly oxidised to nitrogen dioxide.

Nitrogen dioxide is a reddish-brown gas with a pungent odour that is irritating and toxic. It is almost insoluble, but combines with water in the lungs to form nitrous and nitric acids. Concentrations of 100 to 150 ppm are dangerous for exposures of 30 to 60 minutes and it is also a mutagen. The toxic effect of nitrogen dioxide are reported to be five times more toxic than nitric oxide. In combination with hydrocarbons and sunlight, it is a major contributor to the formation of smog. No adverse effects have been reported for the nitrogen dioxide concentrations expected near the Tugun Bypass.

4.2.3 Particulate Matter

Particulate material from vehicle exhausts can irritate mucous membranes lining the respiratory tract and may give rise to breathing difficulties. Some constituents (for example, polyaromatic hydrocarbons, derived from hydrocarbons in fuel) may be carcinogenic.

The size of particles has an important bearing on their respiratory effects. Particles with an aerodynamic diameter of 10 μm (PM_{10}) are inhaleable, (small enough to be breathed in). Thoracic particles are defined as those which penetrate beyond the larynx and those with a diameter of less than 2.5 μm (often referred to as respirable particles) are small enough to penetrate to the deep lung where they are retained. Particulates may be amongst the most harmful components of vehicle exhaust.

Several international studies indicate a link between mortality rate and high annual average concentrations of airborne particles (Dockery *et al.* 1993; Schwartz *et al.* 1996a; Schwartz *et al.* 1996b, Schwartz 1998). Concentrations of particulate matter near the Tugun Bypass are expected to be below the relevant guideline levels.

4.2.4 Ultrafine Particles

Ultra–fine particles are those of sub-micron size, generally considered as part of fine particles (those with a diameter of less than 2.5 μm). The issue of ultra–fine particles in causing respiratory problems for residents near roads has recently emerged. United Kingdom studies have reported that even small concentrations of ultra–fine particles can cause alveolar inflammation and exacerbation of lung disease in susceptible individuals (Seaton *et al*. 1995; Donaldson *et al*. 1996).

High emissions of ultra–fine particles can be expected from poorly maintained diesel vehicles under high load. Poorly maintained catalyst-equipped gasoline engines can also be significant sources.

Recent work indicates that there is likely to be a large degree of protection from the health impact of ultra–fine particles contained within recently suggested air quality guidelines for PM_{10} and $PM_{2.5}$. Modelling indicates that residential areas near the proposed road would not be exposed to levels exceeding the unimplemented USEPA 24 hour $PM_{2.5}$ guideline of 65 -μg/m^3 or the 24 hour $PM_{2.5}$ guideline of 20 to 25 μg/m^3 suggested for Australia (Streeton 1997). The National Environment Protection Council has recently released a discussion paper that may lead to a $PM_{2.5}$ guideline in the National Environment Protection Measure for Air, but does not yet recommend a specific guideline (National Environment Protection Council 2001).

4.2.5 Sulphur Dioxide

Sulphur dioxide (SO_2) can give rise to respiratory symptoms, but only at concentrations well above those experienced due to traffic at this location (Grant *et al*. 1992). The NEPM provides sulphur dioxide guidelines of 0.20 ppm for 1-hour average (maximum exceedances 1 day per year), 0.08 pm for 4-hour average (maximum exceedances 1 day per year) and 0.02 ppm for 1 year average (no exceedances).

4.2.6 Ozone

There is evidence that high concentrations of ozone increase susceptibility to infections, irritate mucous membranes and reduce lung function resulting in temporary respiratory difficulties in sensitive individuals and in those taking vigorous exercise. Overseas studies found that exposure to ozone concentrations of 160 to 300 μg/m^3 for periods of an hour reduced lung function in adults and children taking vigorous exercise (McDonnell *et al*.1983; Avol *et al*. 1984; Linn *et al*. 1986).

Studies also found a wide variation in ozone sensitivity (Adams and Schelegle 1983; Folinsbee *et al*. 1984; Schelegle and Adams 1986) but, although 5 to 10 percent of the population is sensitive, asthmatics appear to be no more or less so than others.

It is noted that high concentrations of ozone are intermittent and essentially a regional problem. Ozone levels near a roadway are likely to be depressed below those elsewhere in the area because of the scavenging action of nitrogen oxides.

4.2.7 Odours

Odours associated with transport arise as a result of the volatile or gaseous nature of fuels and their combustion products. There is, as with noise pollution, a subjective element in the perception of odour as a nuisance. Some persons object to the smell of kerosene, petrol or diesel fuel itself, others do not. Diesel vehicles are generally less odorous than they were 10 or 20 years ago with improvements in engine technology and many people are now more concerned about the smell of hydrogen sulphide which is released from cars with new three–way catalysts under certain driving conditions (Southwest Research Institute 2001).

Vehicle speeds of more than 50 km/h, freely moving traffic and open layout are conducive to rapid dispersion of odours. Construction of the bypass would therefore be expected to reduce the potential for odour nuisance at residential areas.

4.3 Vehicle Emissions and Photochemical Smog

Photochemical smog is a complex mixture of compounds produced by reactions between nitrogen oxides and reactive hydrocarbons in the presence of sunlight. Motor vehicle emissions are generally found to be major contributors to photochemical smog in and near large cities. Assuming comparable traffic volumes, improvements in vehicle emissions technology and traffic flow characteristics should reduce the volume of nitrogen oxide and hydrocarbon emissions from vehicles travelling on the road network with the proposed bypass compared to the existing road network.

5. Impacts and Mitigation Measures

5.1 Modelling Methodology

The CALINE–4 model (California Department of Transportation 1989) was used to estimate the concentrations of carbon monoxide, nitrogen dioxide, PM_{10} and hydrocarbons that would occur as a result of predicted traffic flows. These pollutants are those with the greatest potential to affect health and vegetation near the road. The model has been used extensively in NSW and Queensland and is currently accepted by regulatory agencies and councils to be appropriately conservative for the forecasting of near-field impacts near major roads (Holmes 1997; Katestone Scientific 1995).

The approach to modelling was as follows:

- emission rates were based on factors reported in recent Australian studies (Environment Australia 2000);
- dispersion modelling was based on two worst-case scenarios with two sets of meteorological conditions. This ensures that estimated concentrations are the worst that would be encountered in practice, in order for conclusions to be conservative. Class F stability with 1 m/s winds was chosen to represent worst-case and night time dispersion conditions near the time of peak traffic flows and Class D stability with 2 m/s winds was chosen to represent worst-case daytime dispersion conditions near the time of peak traffic flows;
- persistence factors were used to convert one hour concentrations to eight hour, 24 hour, 90 day and annual concentrations, based on recent Queensland data (Katestone Scientific 1995);
- road gradient of up to 5 percent from gradient maps (minimum of 4 percent assumed);
- future traffic flows were based on projections for the years 2007 and 2017 (Parsons Brinckerhoff 2003, refer to Appendix D and Technical Paper Number 3), and
- a conversion rate of 15 percent was assumed to estimate concentrations of nitrogen dioxide from predicted levels of nitrogen oxides, as relevant for distances to 60 m from the kerb (Holmes 1997).

5.1.1 Estimates of Traffic Emissions

General Considerations

Ground–level concentrations at nearby receptors are strongly dependent on traffic flow and composition, meteorological conditions, topography and local road conditions (e.g., slope).

Traffic flow rates along the route vary between daytime, evening and night time periods, with day of the week and with season. The road use is mixed, with substantial local traffic and long-distance transport (both commercial and tourist vehicles).

Traffic count information for the Tweed Heads Bypass just south of Gold Coast Airport for a summer day (Figure 5.1 and Appendix B) shows that there is relatively little traffic in the early morning (4 to 6 am) and early evening (8 to 10 pm) periods when poor dispersion conditions are more likely. The main traffic period is 6 am to 8 pm, both for weekdays and weekends. High flows of westerly traffic in the morning and evening are approximately half an hour earlier than those for the easterly direction, probably representing the departure and return of longer-distance commuters.

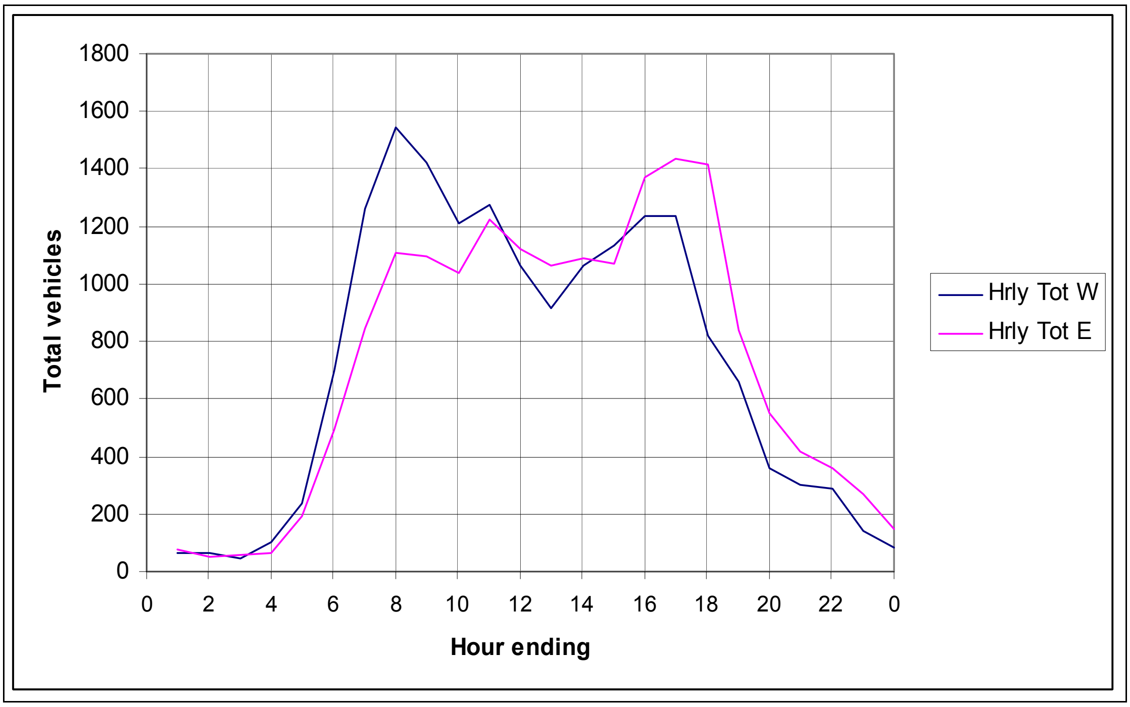


Figure 5.1: Hourly Traffic Counts, Tweed Heads Bypass – 13 December 2000

A recent report commissioned by Environment Australia (known as the *Review of Fuel Quality Requirements for Australian Transport*) included an estimation of vehicle emission factors for the Australian capital cities up to 2020 (Environment Australia 2000). The study included the adoption of the European Union's Euro vehicle emissions standards for petrol and diesel vehicles, and the reduction of petrol volatility. The proposed schedule is the introduction of petrol vehicle emissions standards of Euro 2 by 2004, Euro 3 by 2006 and Euro 4 by 2008. The proposed diesel vehicle emissions standards include the adoption of Euro 3 for medium and heavy diesel trucks by 2003, Euro 2 for light duty diesel vehicles and buses by 2003 and Euro 4 for all diesel vehicles by 2007. Adoption of these increasingly stringent standards means that the emissions of pollutants on a per kilometre basis will be progressively decreased.

The emission data for carbon monoxide, particulate matter, nitrogen dioxide and hydrocarbons were obtained for Brisbane for 2000, 2010 and 2020 (Environment Australia 2000). These factors were adjusted to the projected vehicle speed, number of vehicles, grade of the road and to represent the projected vehicle fleet composition in 2007 and 2017 as explained later.

Emissions from aircraft have been estimated from the projected number of daily aircraft movements for 2020 (Gold Coast Airport Limited 1999) for international (12.88), domestic (139.18), regional (29.59) and general aviation flights. The United States Environmental Protection Agency (2001b) has defined takeoff/landing cycles for engine cycles for various classes of engine in the Code of Federal Regulations, Title 40, Volume 14, Part 87 and specified emission limits for engines manufactured by various dates – hydrocarbons (1 January 1984), carbon monoxide (7 July 1997) and nitrogen oxides (31 December 1999).

Assuming that aircraft emit at these limits and operate on cycles approximating those specified in Title 40, emissions have been calculated for year 2020. Assuming an average speed of 100 knots over the cycle period (other than the taxi/idle portion) the emissions were apportioned over the aircraft flight path. Over the 3.5 km corresponding to the airport boundary, emissions are calculated as carbon monoxide (684 t/year), hydrocarbons (114 t/year) and nitrogen oxides (10 t/year). These are significantly lower than emissions for the existing road and are largely emitted at an altitude from which they can disperse widely. Because of their relatively small effect, aircraft emissions have not been considered further.

Emissions from existing vehicular traffic on the Gold Coast Highway near the airport can be compared with emissions from vehicle use associated with the airport. Emissions in tonnes per year from airport vehicles and plant in 2010 are estimated at: carbon monoxide (12), hydrocarbons (2) and total nitrogen oxides (2). For passenger and meeter/greeter vehicles, the 2010 emission estimates are: carbon monoxide (582), hydrocarbons (70) and total nitrogen oxides (39) (Gold Coast Airport Limited 1999).

Airport emissions can be compared with emissions for the 3.5 km section of the Gold Coast Highway adjacent to the airport, currently (in tonnes per annum): carbon monoxide (2,300), hydrocarbons (270) and total nitrogen oxides (150). Emission rates for particulates were not provided by Gold Coast Airport Limited. However, based on the methods of Section 5.2, PM_{10} emissions are predicted to be 48 tonnes per annum (airport traffic) and 189 tonnes per annum (Gold Coast Highway). Thus emissions from vehicles using the airport facilities are significantly less than from the Gold Coast Highway and will not be considered further.

Speed and Grade Correction Factors

Traffic data provided by Parsons Brinckerhoff (Appendix D) included predicted vehicle speeds and indicated that around 8 percent of traffic during the evening peak would be commercial vehicles. Expected road slopes (with a minimum of 4 percent) were used for all calculations to represent the potential maximum vehicle emissions.

Studies in the United States and Australia (Cicero-Fernandez *et al.* 1997; Williams *et al.* 1994) have shown that grades and vehicle speed have synergistic effects on the emission rates of carbon monoxide, nitrogen oxides, particulates and hydrocarbons from passenger vehicles. Fine particulate emissions from heavy vehicles can increase by a factor of between 1 and 24 (average of 8.5) when under high load compared to emissions when idling (Morawska *et al*. 1997). Attention has been given to the correction of standard fleet emission factors for essentially flat terrain for local road conditions. The corrections for speed and grade are combined when estimating vehicle emissions up a hill.

The traffic emission rates have been based on recent emission factors determined for the Brisbane fleet (Environment Australia 2000), together with adaptations for terrain and speed influences based on a power-based emissions methodology (Williams *et al*. 1994). The CSIRO technique of Williams *et al*. (1994) has been suggested for use on steep grades by a draft report on the NSW Roads and Traffic Authority air quality monitoring program (Holmes *et al*. 1998).

The emission estimation scheme for this study uses the power-based methodology for different classes of vehicle but with various parameters chosen to ensure a close correspondence to the fleet emission factors of recent vehicle emission inventories when used for flat terrain and average speeds and idling times appropriate to the Australian Design Rule ADR27 drive cycle. The estimates of hydrocarbon emissions include exhaust and evaporative components (as detailed in Carnovale *et al*. 1995).

The emission factors for arterial free-flow (average speed of 31 km/hr and idle time of 15 percent) have been adjusted to the anticipated vehicle speed for the treatment of flat terrain, using relationships of pollutant emissions with vehicle speed derived from Australian (Stewart *et al*. 1982), North American (United States Environmental Protection Agency 1991) and European studies (Corinair 1995).

Emission rates of carbon monoxide and volatile organic compounds are expected to decrease with vehicle speed while there is likely to be an increase in nitrogen oxide emission rates with an increase in vehicle speed. It is noted that there is considerable disparity between the available published information on speed dependencies for nitrogen oxide emissions, especially for vehicles equipped with a three way catalyst and being used for extended high-speed driving. It is assumed that this is due to differences in the experimental methods. The dimensionless factors to correct for assumed speed (V) dependencies for light duty petrol vehicles, heavy duty petrol vehicles and heavy duty diesel vehicles have been taken as follows (Xu 1996):

Light duty petrol vehicles:

CO: $26.33/V + 0.15$ for $V \leq 31$ km/h;

$31.0/V$ for $V > 31$ km/h.

NO_x: $\text{Exp}((0.4757 - 0.02104V + 0.0001837V^2)/0.7485)$.

Heavy duty petrol vehicles:

CO: $\text{Exp}(1.48 - 0.061V + 0.000429V^2)$;

HC: $\text{Exp}(1.567 - 0.0606V + 0.000324V^2)$;

NO_x: $0.829 + 0.0055V$;

Heavy duty diesel vehicles:

CO: $\text{Exp}\,(1.363 - 0.055V + 0.000355V^2)$;

HC: $\text{Exp}\,(0.889 - 0.034V + 0.000172V^2)$;

NO_x: $\text{Exp}\,(0.664 - 0.03V + 0.000277V^2)$

Emission rates for steep terrain are also uncertain with earlier work (Kelly and Groblicki 1993) reporting increases by several orders of magnitude for emissions of carbon monoxide and volatile organic compounds during the brief enrichment events that occur during hard acceleration or hill climbing. This report has used the power-based model (Williams *et al*. 1994) with a component to include the power necessary to climb a slope and overcome aerodynamic and frictional forces. This methodology also produces significant emission increases on even moderate grades and is therefore considered to be conservative.

5.2 Emission Factors and Rates for 2007 and 2017

Locations along the major roads with maximum predicted traffic flows were used in the dispersion modelling to determine the potential worst-case air quality impacts. These were the northern section of the existing route from the intersection of the Pacific Motorway with the Gold Coast Highway to Boyd Street and that section of the Tweed Heads Bypass from Coolangatta Road to Kennedy Drive. These were used to determine the changes expected with the completion of the Tugun Bypass.

Taking into account the likely changes of fleet composition and age and the predicted transport pattern for the region (Environment Australia 2000), the vehicle emission rates for 2007 and 2017 were determined using the appropriate emission factors and corrections documented in the previous sections. Table 5.1 gives the estimated vehicle emission rates for each road section studied for the existing roads and for the proposed Tugun Bypass.

When evaluating the emission rates for the existing road network from 2007 to 2017, the emission rate of carbon monoxide shows the most variation. This is due to the large number of vehicles travelling on the road during peak hour, with resultant congestion of the road network and consequent reduced vehicle speed and increased emission of carbon monoxide.

The emission rates for nitrogen dioxide are predicted to decrease over time, as more stringent emission control measures are implemented to improve the emissions from new vehicles. Likewise, the emission rate of particulate matter should decrease as the control technology and engine efficiencies improve. The emission rates of carbon monoxide and hydrocarbons are predicted to increase dramatically if no bypass is constructed, due to increased congestion at peak times. Total traffic emissions would be reduced, particularly for carbon monoxide and hydrocarbons, with the proposed Tugun Bypass in operation.

Table 5.1 Estimated Vehicle Emission Rates

Scenario		Road Section	Average Speed (km/h)	Vehicles[1] in Peak Hour	Emission Rate of Pollutant[2] (g/veh/km)			
Year	Bypass Present				CO	NO_2	PM_{10}	HC
2007	No	Pacific Motorway - Stewart Road to Gold Coast Highway	33	5,000	8.4	0.17	0.05	1.9
	Yes		60	2,700	4.6	0.15	0.05	1.2
	No	Gold Coast Highway - North of Boyd Street	3	7,400	69.2	0.30	0.05	9.5
	Yes		59	3,600	4.7	0.15	0.05	1.3
	No	Tweed Heads Bypass - North of Tugun Bypass	75	4,900	3.7	0.18	0.06	1.1
	Yes	Tugun Bypass	94	3,800	2.9	0.23	0.06	0.9
2017	No	Pacific Motorway - Steward Road to Gold Coast Highway	13	5,000	8.6	0.10	0.04	0.7
	Yes		60	3,500	1.9	0.06	0.04	1.0
	No	Pacific Motorway - North of Boyd Street	2	7,400	40.5	0.13	0.04	9.5
	Yes		57	5,400	2.0	0.06	0.04	1.0
	No	Tweed Heads Bypass - North of Tugun Bypass	35	4,900	5.1	0.09	0.04	2.0
	Yes	Tugun Bypass	94	4,800	1.2	0.10	0.04	0.7

Note: 1: Rounded to nearest hundred
2: Pollutants are:
CO = Carbon monoxide
NO_2 = Nitrogen dioxide
PM_{10} = Particulate matter
HC = Hydrocarbons
Source: Katestone Scientific

5.3 Predictions of Air Quality Effects

Maximum predicted hourly ground level concentrations of key pollutants due to emissions from vehicles only (without background contributions), estimated at 10 m, 25 m and 50 m from the kerbside, both with and without the proposed Tugun Bypass, are summarised in Table 5.2 for 2007. Results for 2017 are presented in Table 5.3.

Residences are unlikely to be located as close as 10 m from the kerb of the road, but this has been taken to represent worst-case conditions (the 25 m results should be conservative for the current situation). Table 5.4 summarises the total pollutant concentrations, accounting for background concentrations, for each year and scenario studied at 10 m from the kerb. These are compared to the relevant health-related air quality guideline to determine the potential for adverse impacts on nearby residents.

Predicted worst-case concentrations at 10 m are presented graphically in Figure 5.2. These results indicate that relevant health guidelines for carbon monoxide and nitrogen dioxide would be exceeded near the busiest road sections without the bypass, but would not be exceeded even for the worst-case meteorological and traffic conditions with the bypass. The maximum nitrogen dioxide concentration is predicted not to exceed 59 percent of the air quality guideline for stable atmospheric conditions for the estimated vehicle emissions in 2007 and 2017.

Table 5.2: Predicted Increment in Hourly Ground Level Concentrations of Air Pollutants at Various Distances from the Kerb due to Traffic for 2007 for the Road Network, With and Without the Proposed Tugun Bypass.

Pollutant	2007, Gold Coast Highway North of Boyd Street, No Bypass					
	Class F[1], (1 m/s Wind Speed)			Class D[2], (2 m/s Wind Speed)		
	10 m	25 m	50 m	10 m	25 m	50 m
CO (ppm)	37.3	21.3	14.2	20.5	11.1	6.8
NO_2 ($\mu g/m^3$)	200.5	114.3	76.5	110.2	59.4	36.5
PM_{10} ($\mu g/m^3$)	35.7	20.3	13.6	19.6	10.6	6.5
HC ($\mu g/m^3$)	6415.8	3657.1	2447.2	3528.0	1901.7	1166.8
Pollutant	**2007 Gold Coast Highway North of Boyd Street, With Bypass,**					
	Class F, (1 m/s Wind Speed)			**Class D, (2 m/s Wind Speed)**		
	10 m	**25 m**	**50 m**	**10 m**	**25 m**	**50 m**
CO (ppm)	1.4	0.8	0.6	0.7	0.4	0.3
NO_2 ($\mu g/m^3$)	125.5	73.3	49.5	64.5	36.2	23.0
PM_{10} ($\mu g/m^3$)	31.3	18.3	12.3	16.1	9.0	5.7
HC ($\mu g/m^3$)	534.0	312.1	210.6	274.5	154.2	97.8
Pollutant	**2007, Tugun Bypass, With Bypass**					
	Class F, (1 m/s Wind Speed)			**Class D, (2 m/s Wind Speed)**		
	10 m	**25 m**	**50 m**	**10 m**	**25 m**	**50 m**
CO (ppm)	0.9	0.5	0.4	0.5	0.3	0.2
NO_2 ($\mu g/m^3$)	91.8	53.3	36.5	48.4	26.7	16.8
PM_{10} ($\mu g/m^3$)	24.2	14.0	9.6	12.7	7.0	4.4
HC ($\mu g/m^3$)	361.7	210.0	143.9	190.6	105.0	66.1

Note: 1 Class F stability: high stable conditions (low dispersion)
2 Class D stability: neutral stability (moderate dispersion)
Stability Class is explained in Chapter 3

Table 5.3: Predicted Increment in Hourly Ground Level Concentrations of Air Pollutants at Various Distances from the Kerb due to Traffic for 2017 for the Road Network, With and Without the Proposed Tugun Bypass

Pollutant	2017, Gold Coast Highway North of Boyd Street, No Bypass					
	Class F, (1 m/s Wind Speed)			Class D, (2 m/s Wind Speed)		
	10 m	25 m	50 m	10 m	25 m	50 m
CO (ppm)	21.8	12.4	8.3	12.0	6.5	4.0
NO_2 ($\mu g/m^3$)	85.5	48.8	32.6	47.0	25.3	15.6
PM_{10} ($\mu g/m^3$)	26.9	15.3	10.3	14.8	8.0	4.9
HC ($\mu g/m^3$)	6388.9	3641.2	2437.2	3512.3	1892.4	1163.0

Pollutant	2017, Gold Coast Highway North of Boyd Street, With Bypass					
	Class F, (1 m/s Wind Speed)			Class D, (2 m/s Wind Speed)		
	10 m	25 m	50 m	10 m	25 m	50 m
CO (ppm)	0.8	0.5	0.3	0.4	0.2	0.2
NO_2 ($\mu g/m^3$)	80.4	46.3	30.2	44.2	24.1	15.1
PM_{10} ($\mu g/m^3$)	35.4	20.4	13.3	19.5	10.6	6.6
HC ($\mu g/m^3$)	579.9	333.4	217.5	318.9	174.0	108.7

Pollutant	2017, Tugun Bypass, With Bypass					
	Class F, (1 m/s Wind Speed)			Class D, (2 m/s Wind Speed)		
	10 m	25 m	50 m	10 m	25 m	50 m
CO (ppm)	0.4	0.3	0.2	0.2	0.1	0.1
NO_2 ($\mu g/m^3$)	44.2	25.1	17.1	24.4	13.5	8.3
PM_{10} ($\mu g/m^3$)	19.5	11.1	7.5	10.8	6.0	3.7
HC ($\mu g/m^3$)	318.9	181.2	123.2	176.3	97.6	59.8

Table 5.4: Predicted Total Ground level Concentrations of Pollutants at 10 m from the Kerb With and Without Proposed Tugun Bypass, Representing the Worst Exposure to Vehicle Pollutants

Pollutant	Averaging Time	Background Concentration	Predicted Concentration for Class F, (1 m/s)	Predicted Concentration for Class D, (2 m/s)	Ambient Air Quality Guideline[1]
2007, Gold Coast Highway North of Boyd Street, No Bypass					
CO (ppm)	8 hr	1	15.9	9.2	9
NO_2 ($\mu g/m^3$)	1 hr	20	220.5	130.2	246
PM_{10} ($\mu g/m^3$)	24 hr	30	38.6	34.7	50
HC ($\mu g/m^3$)	1 hr	not available	6415.8	3528.0	not applicable
2007, Gold Coast Highway North of Boyd Street, With Bypass					
CO (ppm)	8 hr	1	1.6	1.3	9
NO_2 ($\mu g/m^3$)	1 hr	20	145.5	84.5	246
PM_{10} ($\mu g/m^3$)	24 hr	30	37.5	33.9	50
HC ($\mu g/m^3$)	1 hr	not available	534.0	274.5	not applicable
2007, Tugun Bypass, With Bypass					
CO (ppm)	8 hr	1	1.4	1.2	9
NO_2 ($\mu g/m^3$)	1 hr	20	111.8	68.4	246
PM_{10} ($\mu g/m^3$)	24 hr	30	35.8	33.1	50
HC ($\mu g/m^3$)	1 hr	not available	361.7	190.6	not applicable
2017, Gold Coast Highway North of Boyd Street, No Bypass					
CO (ppm)	8 hr	1	9.7	5.8	9
NO_2 ($\mu g/m^3$)	1 hr	20	105.5	67.0	246
PM_{10} ($\mu g/m^3$)	24 hr	30	36.5	33.6	50
HC ($\mu g/m^3$)	1 hr	not available	6388.9	3512.3	not applicable
2017, Gold Coast Highway North of Boyd Street, With Bypass					
CO (ppm)	8 hr	1	1.3	1.2	9
NO_2 ($\mu g/m^3$)	1 hr	20	100.4	64.2	246
PM_{10} ($\mu g/m^3$)	24 hr	30	38.5	34.7	50
HC ($\mu g/m^3$)	1 hr	not available	579.9	318.9	not applicable
2017, Tugun Bypass, With Bypass					
CO (ppm)	8 hr	1	1.2	1.1	9
NO_2 ($\mu g/m^3$)	1 hr	20	64.2	44.4	246
PM_{10} ($\mu g/m^3$)	24 hr	30	34.7	32.6	50
HC ($\mu g/m^3$)	1 hr	not available	318.9	176.3	not applicable

Note 1: CO, NO_2 and PM_{10} goals from NEPC 1998. An indoor guideline of 500 $\mu g/m^3$ for HC has in the past been recommended by NHMRC

It is predicted that there would be a very slight increase (approximately 2 µg/m^3) in PM_{10} concentrations with the proposed Tugun Bypass. These concentrations are expected to be no greater than 77 percent of the NSW Environment Protection Authority goal (NSW Environment Protection Authority 1998).

The worst–case peak hour concentrations of carbon monoxide are predicted to vary with the scenario modelled. The existing road network would experience greater congestion and thus lower peak hour vehicle speeds in future years, resulting in ground-level concentrations of carbon monoxide that exceed the guideline. By contrast, the construction of the Tugun Bypass is predicted to result in carbon monoxide concentrations that are less than 18 percent of the air quality guideline.

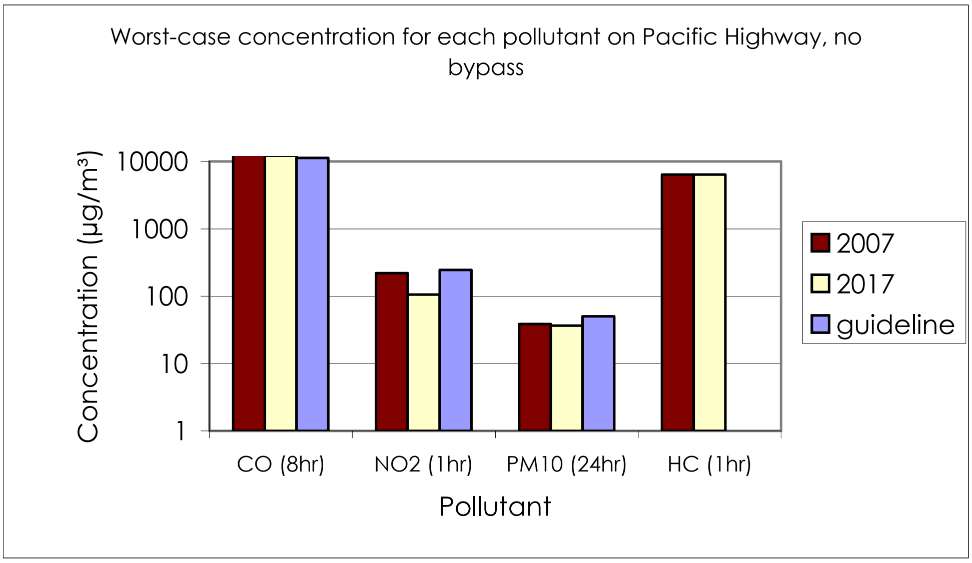
The NHMRC guideline for hydrocarbons noted in Table 5.4 relates to indoor air quality. Thus, the guideline is not strictly applicable to the predicted ambient ground-level concentrations. However, the comparison of results in Table 5.3 shows that the existing road network would result in much higher ground-level concentrations close to the road than for the proposed Tugun Bypass. This effect is particularly noticeable for the estimated ground-level concentrations in 2017.

Table 5.4 presents estimates of the worst-case ground level concentrations that could occur at residential locations if houses were allowed to be constructed as close as 10 m. However, houses are currently further away from the road than this conservatively estimated worst-case scenario, and are unlikely to be constructed this close in future. Lower ground level concentrations are therefore likely to be experienced at the closest affected residences.

The worst–case concentrations due to vehicles are based on the concurrence of the peak hour traffic flow with poor dispersion conditions (Class F stability with 1 m/s wind speed). These atmospheric conditions normally occur in the early hours during cold weather (typically a winter morning before 7 am). During the peak hour, better dispersion conditions would normally be expected. The air quality assessment presented in this report is thus conservative as the maximum number of vehicles using the roads would generally not occur at the same time as the poor dispersion conditions.

5.4 Vegetation Impacts

The main pollutants implicated in plant damage, sulphur dioxide and ozone, have little relevance to vehicle emissions. There is a small quantity of sulphur in fuel, but the concentrations of sulphur dioxide near roads are negligible. Emissions of nitric oxide by vehicles will actually reduce ambient ozone concentrations as they react to form nitrogen dioxide.



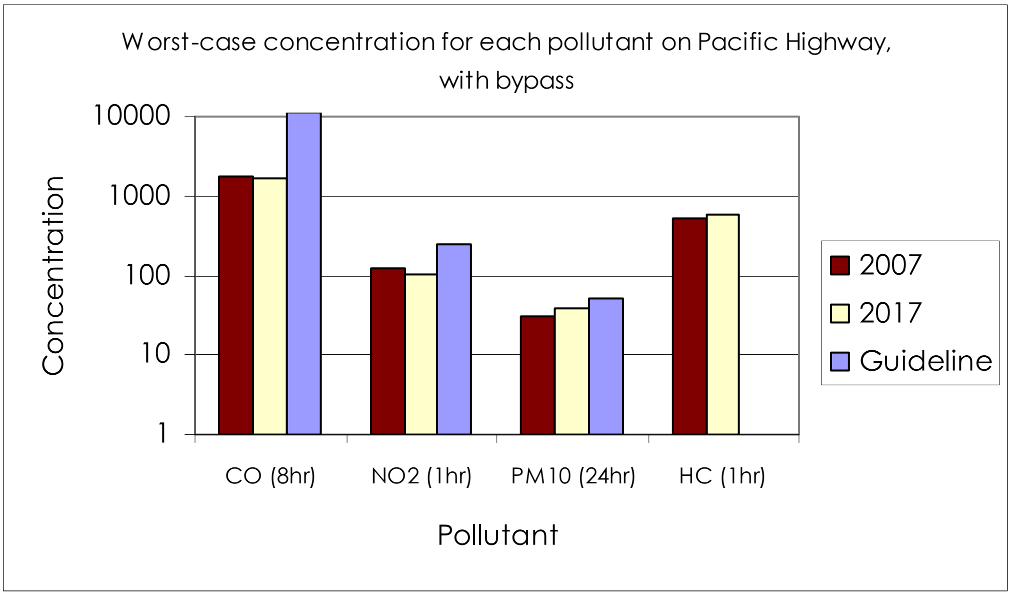


Figure 5.2: Predicted Total Ground level Concentrations ($\mu g/m^3$) of Pollutants at 10 m from the Kerb With and Without Proposed Tugun Bypass, Representing the Worst Exposure to Vehicle Pollutants.

Oxides of nitrogen generally only reduce plant growth if concentrations of 1,000 µg/m³ are applied for periods of three hours or more. Visible injury requires approximately three times the concentration for this exposure duration (Doley 1981; National Academy of Science 1977). Nitrogen dioxide generally comprises 10 to 20 percent of total nitrogen oxides near roads. The Queensland *Environmental Protection (Air) Policy 1997* provides as indicators for biological integrity, nitrogen dioxide goals of 95 µg/m³ for four hours and 30 µg/m³ for one year, based on studies for sensitive species.

The vehicle emission rates and dispersion modelling presented in this report has assumed peak hour traffic emission rates combined with poor dispersion conditions. No account has been made of the change in total emissions with non–peak hour traffic flow rates. However, an assessment of the worst–case four hour average concentration can be made by using an assumed persistence factor of 0.6 as explained in Section 4.1.

The maximum four hour average ground-level concentration of nitrogen dioxide for the existing road network is predicted to be 140 µg/m³ at 10 m from the road including the assumed background concentration based on the results presented in Table 5.4. The maximum total four hour average ground level concentration of nitrogen dioxide for the proposed Tugun Bypass is predicted to be less than 95 µg/m³ at 10 m from the kerb in 2007. Thus emissions due to the proposal would meet the goal for protection of biological integrity (four hour average of 95 µg/m³).

Particulates affect plants only if they have a pH greatly different from neutral or if they form a hard crust on plant leaves. Rates of deposition of alkaline dust up to 1.5 g/m²/day have little harmful effect on plants (Lerman and Darley 1975). Particulates from the proposed road are expected to comprise a variety of material including wind-blown soil and organic matter, asphalt and concrete particles, tyre rubber, brake linings, oil and particulates from vehicle emissions.

The organic and soil matter should be close to neutral in pH. Cement particles are likely to be slightly alkaline. Motor vehicle particulate emissions are typically 38 to 50 percent organic carbon and 28 to 38 percent elemental carbon (United States Environmental Protection Agency 2001b). Exhaust particles comprise a solid carbon core with a coating of organic compounds, sulphate and trace elements. Tyre rubber and brake lining material are relatively inert. For these reasons, particles deposited are expected to be close to neutral in pH and so should not produce a significant effect on vegetation. In addition, it has been found that a suspended dust level of 75 µg/m³ typically corresponds to a dust deposition rate of 50 mg/m²/day (Parrett 1992). A deposition rate of 25 mg/m²/day, much less than the 1,500 mg/m²/day level reported above to cause little harm, would then be expected for the predicted particulate levels from the road. Damage would not be expected even if dust were alkaline.

5.5 Impacts of the Tunnel

The 460 m long tunnel under the obstacle limitation surface at Gold Coast Airport would have the effect of increasing the concentration of pollutants near the tunnel portals (Permanent International Association of Road Congresses 1991). Levels in the tunnel itself may be higher, but drivers would only be exposed for a short period. Workers in the tunnel would need to be aware of the potential air pollution hazard.

For the proposed tunnel, there is a gentle slope at each end of the tunnel, and retaining walls extend above the existing surface to 3 m AHD to provide flood protection. The length of the northbound ramp is approximately 300 m and the southbound ramp 300 m.

The southbound and northbound traffic directions are separated, and hence the exit portal of each stream of traffic has been considered separately in the modelling. It has been assumed that tunnel ventilation air exits from the portals only.

Emissions from vehicles tend to move as a plug both through the tunnel and within the walls of the exit ramps (Permanent International Association of Road Congresses 1991). Emissions from the tunnel portal would be gradually mixed into the air above due to turbulence from the vehicles and the upward incline of the tunnel exit ramp. This means that emissions from the entire length of tunnel and both inbound and outbound ramps can conservatively be assumed to be emitted over the length of the exit ramp. This has been considered in the estimation of vehicle emission rates.

The vehicle flow rate through the tunnel is predicted to be the highest during the afternoon peak hour. The entry and exit ramps for the tunnel have different slopes: the north–west ramp has a slope of approximately 4.8 percent, and the south-east ramp approximately 4.5 percent. The slope through the tunnel itself is relatively flat. Vehicle speeds are based on the proposed bypass speed limit, number of lanes and slope. Vehicle emission rates, with appropriate slope and speed enhancement factors, were estimated using the methodology presented in Section 5.1.1. The vehicle emissions from 2017 are presented in Table 5.5, along with the estimated vehicle flow rate in both the southbound and northbound directions.

Table 5.5: Estimated Vehicle Emission Rates (g/veh/km) for 2017 for the Tugun Bypass Road Tunnel

Traffic Direction	Vehicles through Tunnel Section (Peak Hour)	Emission Rate of Pollutant (g/veh/km)			
		CO	NO_2	PM_{10}	HC
Southbound	2,554	4.47	0.30	0.14	2.50
Northbound	2,272	4.46	0.30	0.14	2.50

The vehicle emission rates for the tunnel portals are around two to four times higher than the data reported in Table 5.1 for the rest of the proposed Tugun Bypass in 2017. This is because the emissions from the length of the tunnel will be released in the vicinity of the tunnel portal. The predicted incremental ground-level concentrations of air pollutants due to vehicles using the tunnel at various downwind distances are summarised in Table 5.6, and the predicted total pollutant concentrations, including background concentration, at 10 m from the kerb are summarised in Table 5.7.

Table 5.6: Predicted Increment in One Hour Average Ground Level Concentrations of Air Pollutants due to Traffic for 2017 for the Proposed Tugun Bypass Road Tunnel at various Distances from the Kerb

	Class F[1], (1 m/s Wind Speed)			Class D[2], (2 m/s Wind Speed)		
	10 m	25 m	50 m	10 m	25 m	50 m
			2017, Southbound Tunnel			
CO (ppm)	1.1	0.7	0.4	0.5	0.3	0.2
NO_2 ($\mu g/m^3$)	88.6	53.8	36.4	43.9	24.8	15.7
PM_{10} ($\mu g/m^3$)	42.6	25.9	17.5	21.1	11.9	7.6
HC ($\mu g/m^3$)	748.2	454.5	307.7	370.6	209.8	132.9
			2017, Northbound Tunnel			
CO (ppm)	1.0	0.6	0.4	0.5	0.3	0.2
NO_2 ($\mu g/m^3$)	81.4	49.0	33.2	39.9	22.4	14.1
PM_{10} ($\mu g/m^3$)	39.1	23.5	16.0	19.2	10.8	6.8
HC ($\mu g/m^3$)	685.8	412.9	279.9	335.9	188.9	119.0

Note 1: Class F stability: highly stable conditions (low dispersion)
Note 2: Class D stability: neutral stability (moderate dispersion)

Table 5.7: Predicted Total Ground Level Concentrations of Pollutants at 10 m from the Kerb for Tugun Bypass Road Tunnel, Representing the Worst Exposure to Vehicle Pollutants

Pollutant	Averaging Time	Concentration			Air Quality Guideline
		Background	Class F (1m/s)	Class D (2m/s)	
			2017, Southbound Tunnel		
CO (ppm)	8 hr	1	1.4	1.2	8
NO_2 ($\mu g/m^3$)	1 hr	20	108.6	63.9	246
PM_{10} ($\mu g/m^3$)	24 hr	30	40.2	35.1	50
HC ($\mu g/m^3$)	1 hr	not available	748.2	370.6	not applicable
			2017, Northbound Tunnel		
CO (ppm)	8 hr	1	1.4	1.2	8
NO_2 ($\mu g/m^3$)	1 hr	20	101.4	59.9	246
PM_{10} ($\mu g/m^3$)	24 hr	30	39.4	34.6	50
HC ($\mu g/m^3$)	1 hr	not available	685.8	335.9	not applicable

Table 5.7 indicates that predicted ground level concentrations of carbon monoxide and PM_{10}, from the Tugun Bypass road tunnel would be below the relevant health guidelines 10 m from the road. Nitrogen dioxide concentrations are predicted to be 44 percent of the air quality guideline if the worst-case emission and dispersion conditions are met simultaneously. The hydrocarbon concentration is predicted to exceed the indoor air guideline for low wind speed dispersion conditions (Class F stability with 1 m/s wind speed). No residences would be constructed in the immediate vicinity of the tunnel portals due to the proximity of the airport runway. Drivers would only be exposed to high levels for limited periods.

5.6 Construction Impacts and Mitigation Measures

Potential air quality impacts during construction include airborne dust and exhaust fumes from construction plant. Airborne dust would be generated from a number of sources:

- clearing of vegetation and topsoil;
- excavation and transport of materials;
- loading and unloading of trucks;
- re-entrainment of deposited dust by vehicle movements; and
- wind erosion from stockpiles and unsealed roads.

The Queensland guidelines for dust deposition from construction activities are equivalent to approximately 130 $mg/m^2/day$ monthly average of insoluble dust at residences (Queensland Environmental Protection Agency 1994). The NSW Environment Protection Authority provides goals for acceptable increments in average dust deposition depending on the existing dust levels. An appropriate goal for construction of this project would be a total dust deposition rate of 4 $g/m^2/month$ measured on an annual basis (equivalent to 130 $mg/m^2/day$).

High wind conditions would increase the emission rates of airborne dust from stockpiles and exposed areas, while reducing the concentration of vehicle fumes. During high wind conditions, particular attention should be paid to dust suppression.

Because the majority of the length of the proposed bypass is distant from residences, fugitive dust should not be a major issue. Air quality management planning should consider the following measures:

- applying water by truck sprays on all exposed areas as required to minimise dust emissions;
- restricting dust-generating activities such as blasting or topsoil removal during high winds or during more stable conditions with winds blowing toward nearby residences;
- siting the construction compound away from residences;
- avoiding spillages and prompt cleanup;
- covering haul vehicles moving outside the construction site;

- restricting speed of construction vehicles;
- visually checking particulate emissions from diesel vehicles and regular maintenance;
- monitoring odours and hydrocarbon emissions from pavement, spray sealing work and line painting;
- monitoring emissions from on-site concrete batching plants and bitumen batching plants;
- prohibiting burning or incineration on site; and
- monitoring dust near residences close to high activity areas identified during the construction period using dust gauges, high volume sampling or other ambient monitoring techniques to determine whether controls are being applied appropriately. Dust gauges should be adequate for areas where impact is likely to be low. If levels approaching air quality guidelines are found, more frequent high-volume sampling is recommended.

These control methods will be formalised in the project environmental management plan prior to the commencement of construction. The environmental management plan should also identify any maintenance requirements of the proposed air quality management measures.

The extent of monitoring including duration, number of locations and type of equipment to be used would be determined in consultation with the appropriate government advisory bodies depending on jurisdiction. As a minimum this would include the Department of Environment and Conservation (incorporating the Environment Protection Authority) and Roads and Traffic Authority in NSW, the Environmental Protection Agency in Queensland, and the Department of Transport and Regional Services (Airport Planning and Regulation Branch).

6. Greenhouse Gas Impacts

Greenhouse gases affect the balance between incoming solar energy and losses due to radiation from the earth and atmosphere. Australia is a signatory to the *International Framework Convention on Climate Change* (Pearman 1999) with commitments to monitor and report greenhouse gas emissions. Government agencies assessing road projects are committed to ensuring that their environmental goals and policies are consistent with those outlined in the Intergovernmental Agreement on the Environment.

Pollutants of importance to greenhouse warming and associated with transport activities are water vapour (H_2O), nitrous oxide (N_2O), carbon dioxide (CO_2), ozone (O_3), chlorofluorocarbons (CFCs) and methane (CH_4). Indirect greenhouse gases such as carbon monoxide (CO), nitrogen oxides other than N_2O and non methane volatile organic compounds (NMVOCs) do not have a strong radiative forcing effect in themselves, but influence atmospheric concentrations of the direct greenhouse gases.

Water vapour is the major contributor to the greenhouse effect but is not normally considered in inventories because human output is negligible compared to the day-to-day precipitation cycle (Bureau of Transport and Communications Economics 1995). Carbon dioxide is the next most significant greenhouse gas and the major anthropogenic contributor.

The efficiency of a greenhouse gas is measured in terms of its global warming potential (GWP), usually related to a GWP of one for carbon dioxide. Nitrous oxide and carbon dioxide are both significant greenhouse gases associated with transport activities. Carbon dioxide tends to remain active for a lifetime of around 150 years and has a GWP of one. Nitrous oxide has a lifetime of 120 years and a GWP of 320 on a 100 year time horizon. Methane, potentially generated from decaying vegetation cleared for the road and also emitted by motor vehicles, has a lifetime of 14.5 years and a GWP of 24.5 on a 100 year time horizon (Seinfeld and Pandis 1998).

Emission rates for these gases can be estimated by various means. That of carbon dioxide can be calculated directly from anticipated fuel consumption rates. The emission rates of nitrogen oxides (NO_x), hydrocarbons (HC), carbon monoxide (CO), total suspended particles (TSP), nitrous oxide (N_2O) and methane (CH_4) were derived using emission factors described in Section 5.2 (Environment Australia 2000). These factors accounted for changes in vehicle emissions at different travel speeds.

The fuel consumption for cars and heavy vehicles as a function of vehicle speed was calculated using a procedure developed by CSIRO (Williams *et al.* 1994). Emission rates were normalised against reported average fuel consumption rates for the Australian vehicle fleet in the *National Greenhouse Gas Inventory Workbook for Energy* (National Greenhouse Gas Inventory Committee 1998). Carbon dioxide emission factors per litre of fuel were also derived from the workbook. Carbon dioxide emission rates were determined from the product of hourly emission factors and vehicle flow rates, using the anticipated flow rates for 2007 and 2017 for the appropriate roads in the bypass and non-bypass scenarios.

The *Review of Fuel Quality Requirements for Australian Transport* (Environment Australia 2000) presented an estimate of total greenhouse gas emissions from transport sources in the Brisbane region. This information has been used to estimate the ratio of nitrous oxide (N_2O) emissions to nitrogen oxides emissions and also the ratio of methane (CH_4) to total HC emissions. Using these factors, the annual emissions of N_2O and CH_4 for the network of roads considered as part of the Tugun Bypass assessment were estimated.

The emission rates require adjustment to take account of the levels of congestion that would occur on the Gold Coast Highway in the absence of the bypass and the reduction in congestion that would occur with the bypass operating.

Extremely low vehicle speeds due to congestion on some roads at peak hours can adversely affect fuel usage, as would the repeated acceleration and deceleration cycles associated with the existing network.

Conversely, increased fuel efficiency due to the reduction in congestion resulting from the introduction of the bypass would tend to reduce fuel consumption and hence greenhouse emissions. However, higher vehicle speeds can also result in increased fuel consumption and encourage increased use of the road network. Both these factors would tend to reduce the benefits of a decrease in congestion.

Emission factors for congested and uncongested flow were reported in the South East Queensland Emissions Inventory for hydrocarbons, NO_x and CO (Coffey Partners 1995). The ratio of uncongested to congested emissions was used as a congestion factor to adjust emissions as roads became congested. The CO_2 congestion factor was assumed to be the same as for CO, the N_2O factor the same as for NO_x and an average value was used for the TSP factor.

These factors were applied to four traffic scenarios, with and without the Tugun Bypass at 2007 and 2017. Calculations were based on predicted traffic levels for the entire Gold Coast City network. Table 6.1 summarises the emissions of greenhouse gases for each scenario considered. Greenhouse gas calculations are provided as Appendix C.

The 2007 bypass scenario is expected to cause small changes in total emissions of the various greenhouse gases when compared to the situation of increasing congestion without the upgrade. Small increases in total emissions of carbon dioxide, the main greenhouse gas could be expected in 2007, offset by reductions in 2017. The increase in carbon dioxide emissions is a direct consequence of the increase in speed and the consequent additional consumption of fuel. This would apply to both the Tugun Bypass and the Gold Coast Highway where traffic would be free flowing on both. In the absence of the bypass, congested conditions on the Gold Coast Highway would result in a different pattern of emissions including higher hydrocarbon concentrations resulting from the constant acceleration and deceleration caused by the prevailing conditions. Greenhouse emissions are based on average vehicle speeds for the various classifications of roads. This could result in an underestimate in the emissions for the non-bypass situation, as worst-case emissions for the highest and lowest vehicle speeds would be replaced by the lower emissions expected for average vehicle speeds.

Emissions of all greenhouse gases are predicted to reduce in 2017, with the bypass in place. Reductions would range from 3.5 percent to 3.8 percent. Emissions of carbon dioxide would be least affected as a result of the greater fuel consumption resulting from the improvement in average speed as a result of the implementation of the proposal.

Table 6.1: Emissions of Greenhouse Gases from the Road Network With and Without the Tugun Bypass for 2007 and 2017.

Greenhouse Gas	Total Emissions for All Vehicles (tonnes per year)					
	2007			2017		
	Without Bypass	With Bypass	% Change	Without Bypass	With Bypass	% Change
Main Greenhouse Gases						
Carbon Dioxide	4,633,132	4,654,699	0.5%	5,424,742	5,235,881	-3.5%
Nitrous Oxide	1,411	1,410	-0.1%	1,666	1,603	-3.8%
Methane	1,331	1,315	-1.2%	1,597	1,539	-3.6%
Indirect Greenhouse Gases and TSP						
Hydrocarbons	26,614	26,295	-1.2%	31,945	30,781	-3.6%
Oxides of Nitrogen	19,232	19,593	1.9%	22,727	21,937	-3.5%
Carbon Monoxide	107,531	104,506	-2.8%	130,108	125,608	-3.5%
Total Suspended Particles	938	980	4.4%	1,108	1,066	-3.8%

The total greenhouse contribution (emission rate weighted by global warming potential) for the major components (carbon dioxide, nitrous oxide and methane) is presented in Table 6.2 for 20-year and 100-year horizons. The numerical values are dominated by the carbon dioxide contribution. The overall greenhouse contribution is predicted to be approximately 3.5 percent lower with the bypass in 2017.

Table 6.2: Global Warming Potential Predictions for the Road Network With and Without the Tugun Bypass for 2007 and 2017

Greenhouse Gas	Total Emissions for All Vehicles (tonnes per year)					
	2007			2017		
	Without Bypass	With Bypass	% Change	Without Bypass	With Bypass	% Change
20 Year Total	5,124,942	5,145,213	0.4	6,006,871	5,796,088	-3.5
100 Year Total	5,117,383	5,138,221	0.4	5,996,950	5,786,454	-3.5

7. Conclusions

The main pollutants emitted by vehicles that would potentially affect human health or biological integrity are nitrogen oxides, particulates and carbon monoxide. Background air quality measurements in the region from the Helensvale monitoring site show that existing measured pollutant levels are generally well below relevant air quality guidelines.

Air quality modelling of the existing Pacific Motorway, Pacific Highway, Tweed Heads Bypass and the proposed Tugun Bypass indicate that without the construction of the Tugun Bypass, worst-case air pollutant concentrations for the years 2007 and 2017 would exceed relevant guidelines at a distance of 10 m from the kerb (representing the potential highest exposure at a residential location). Growth in traffic flows on the Gold Coast Highway without the bypass would exceed the capacity of the road, resulting in congestion. Pollutant concentrations would remain below relevant guidelines with the construction of the Tugun Bypass.

Worst–case concentrations occur when winds are closely aligned with the road (within 25°). Historically, over a two year monitoring period, winds from the south–east occur 4.5 percent of the time and winds from the north–west occur for 3.3 percent of the time for the section of the road aligned south-east to north–west. Thus the worst-case wind direction is infrequent. Considering also the situation where wind speeds are less than 1 m/s, the observed frequencies drop to zero and 0.2 percent for south–east and north-west winds respectively. In addition, class F stability conditions (see Chapter 3) occur for approximately 20 percent of the time, so the proportion of winds with the appropriate wind speed, direction and stability would be even lower because all Class F conditions do not correspond to the worst-case wind speed and directions.

In addition, concentrations are calculated for worst-case traffic flows, which may not coincide with the worst–cast meteorological conditions. The highest road gradient (4 percent, and 5 percent for the tunnel ramp) has also been assumed for the general emissions modelling, although it only occurs for a limited section of the road. Emissions for most of the road would be significantly lower, resulting in lower predicted ground-level concentrations.

Air quality impacts due to the proposed Tugun Bypass road tunnel were estimated for the southbound and northbound traffic lanes separately. All vehicle emissions from the approach ramp, tunnel and exit ramp were assumed to be concentrated along the exit ramp to be conservative. Worst-case emissions from the vicinity of the tunnel portals were approximately two to four times higher than the peak emissions elsewhere. The dispersion modelling indicated that the predicted ground-level concentrations 10 m from the road meet the Queensland and NSW air quality guidelines (Queensland *Environmental Protection (Air) Policy 1997;* NSW Environment Protection Authority 1998). There should be no residential receptors near the tunnel portals, given the location on low-lying ground near the airport runway. Hence the tunnel emissions should not be significant for health related impacts due to vehicle exhaust.

The construction of the proposed Tugun Bypass and tunnel should have a net positive effect on human amenity and quality of life. The proposed road has the potential to significantly improve the air quality of residents near the Gold Coast Highway over the situation that would develop with increased traffic flows.

Construction impacts could be readily controlled because most of the route is located away from residences, and the control measures recommended for the construction environmental management plan are known to be effective and readily managed.

Greenhouse gas emissions are predicted to increase slightly in 2007 with the Tugun Bypass due to the expected increase in average vehicle speed and consequent increase in carbon dioxide emissions. The use of the Tugun Bypass in 2017 would decrease the global warming potential from vehicle emissions by about 3.5 percent compared to the use of the local network without the bypass at that date.

References

Adams W.C. and Schelegle E.S. 1983, Ozone and High Ventilation Effects on Pulmonary Function and Endurance Performance, *Journal of Applied Physiology,* Vol 55.

Australian Government 1992, *National Strategy for Ecologically Sustainable Development,* Australian Government Publishing Service, Canberra.

Avol E.L., Linn W.S., Shamoo D.A., Venet T.G., Hackney J.D. 1984, Acute Respiratory Effects of Ozone and Ambient Oxidant Pollutant Exposure During Heavy Exercise, *Journal of the Air Pollution Control Association* Vol 34.

Bureau of Transport and Communications Economics 1995, *Greenhouse Gas Emissions from Australian Transport. Long-Term Projections*, Report 88, Australian Government Publishing Service, Canberra.

California Department of Transportation 1988, *Air Quality Technical Analysis Notes*.

California Department of Transportation 1989, *CALINE–4 – A Dispersion Model for Predicting Air Pollutant Concentrations Near Roadways*.

Carnovale F., Tilly K., Stuart A., Carvalho C., Summers M and Eriksen P. 1995, *Metropolitan Air Quality Study – Air Emissions Inventory,* In: Metropolitan Air Quality Study Coffey Partners International, Sydney.

Cicero-Fernandez P., Long J.R. and Winer A.M. 1997, Effects of Grades and Other Loads on On-Road Emissions of Hydrocarbons and Carbon Monoxide, *Journal of Air and Waste Management Association*, Vol 47: pp 898-904.

Coffey Partners 1995, *South East Queensland Air Emissions Inventory,* Report Number E260/1BB.

Corinair 1995, *Inventaire des Emissions de Dioxide de Soufre, d'oxydes d'azote et de Composes Organiques Volatils dans la Communaute Europeene en 1985* Commission Europeene, Luxembourg.

Dockery D.W., Pope C.A., Xu Xiping, Spengler J.D., Ware J.H., Fay M.E., Ferris B.G., and Speizer F.E. 1993, An Association Between Air Pollution and Mortality in Six US Cities, *The New England Journal of Medicine*, V 329 (24), pp 1753-1759.

Doley D. 1981, *Biological Effects of Power Station Stack Emissions,* report to the Queensland Electricity Generating Board.

Donaldson K. and MacNee W. 1996, *The Free Radical Activity of Ultrafine Materials and PM_{10} as a Factor of Their Adverse Health Effects,* discussion paper of the Biomedicine Research Group and Unit of Respiratory Medicine at the University of Edinburgh.

Environment Australia 2000, *Review of Fuel Quality Requirements for Australian Transport,* prepared by Coffey Geosciences.

Folinsbee L.J., Bedi J.F. and Horvath S.M. 1984, Pulmonary Function Changes After 1h Continuous Heavy Exercise in 0.21 ppm Ozone, *Journal of Applied Physiology*: Respir. Environ. Exercise Physiol. Vol 57.

Gold Coast Airport Limited 1999, *Coolangatta Airport Environmental Strategy*.

Grant L.D., Raub J.A., Kotchmar D.J. and Tilton B.E. 1992, *Health Effects of Motor Vehicle-Related Criteria for Air Pollutants,* International Workshop on Human Health and Environmental Effects of Motor Vehicle Fuels and their Exhaust Emissions, Clean Air Society of Australia and New Zealand, Sydney.

Holmes 1997, *RTA Air Quality Monitoring Program,* NSW Roads and Traffic Authority.

Holmes K.T., Holmes N.E. and Jones R. 1998, *Generic Monitoring Studies to Provide a Database for Assessing Roadway Impacts,* 14th International Conference of the Clean Air Society of Australia and New Zealand, Melbourne.

Katestone Scientific 1995, *Road Traffic Pollution at Facilities Housing Sensitive Receptors - Design Criteria,* prepared for the Brisbane City Council, Brisbane.

Kelly N.A. and Groblicki J. 1993, Real–World Emissions from a Modern Production Vehicle in Los Angeles, *Journal of the Air and Air Waste Management Association*, Vol 43, pp 1351–1357.

Lerman, S.L. and E.F. Darley 1975, *Particulates*. In Mudd J.B.and Kozlowski T.T. Eds, *Responses of Plants to Air Pollution,* Academic Press, New York.

Linn W.S., Avol E.L., Shamoo D.A., Spier C.E., Valencia L.M., Venet T.G., Fischer D.A. and Hackney J.D. 1986 A Dose-Response Study of Healthy, Heavily-Exercising Men Exposed to Ozone at Concentrations Near the Ambient Air Quality Standard, *Toxicology and Industrial Health* Vol 2.

McDonnell W.F., Horstman D.H., Hazucha M.J., Seal E. Jr, Haak E.D., Salaam S.A., House D.E. 1983, Pulmonary Effects of Ozone Exposure During Exercise: Dose-Response Characteristics, *Journal of Applied Physiology,* Vol 54.

McGuire T. and Noll K.E. 1970, Relationship Between Concentrations of Atmospheric Pollutants and Averaging Time, *Atmospheric Environment,* Vol 5.

Morawska L., Bofinger N. and Ristovski Z. 1997, *Comprehensive Characterisation of Emissions of Small Particulates from Motor Vehicles,* summary of the report prepared by Queensland University of Technology for Environment Australia.

National Academy of Science 1977, *Biological and Health Effects of Atmospheric Pollutants: Nitrogen Oxides*, National Research Council, Washington.

National Environment Protection Council 2001, *Issues Paper: The Need for a $PM_{2.5}$ Standard in Australia*.

National Environment Protection Council 1998, *National Environment Protection Measure for Ambient Air Quality*.

National Greenhouse Gas Inventory Committee 1998, *Energy Workbook for Transport (Mobile Sources),* Workbook 3.1, Australian Greenhouse Office.

NSW Environment Protection Authority 1998, *Action for Air,* 98/16, Air Policy Section, NSW Environment Protection Authority, Chatswood.

National Health and Medical Research Council 1996, *Revisions of National Health and Medical Research Council (NHMRC) Public Health Air Quality Goals,* letter from NHMRC secretary, 17 May.

Parrett F.W. 1992, *Dust Emissions, Applied Environmetrics*, Balwyn, London.

Pasquill F. 1974, *Atmospheric Diffusion,* 2nd Edition, Van Nostrand, London.

Pearman G.I. 1999, *Progress in Climate Science and its Role in Greenhouse Policy,* Australian Institute of Engineers National Conference.

Permanent International Association of Road Congresses 1991, *Proceedings of the* XIXth *World Road Congress - Road Tunnels,* Marrakech, 22-28 September.

Parsons Brinckerhoff 2003, *Traffic Flow Predictions, Tugun Bypass*. Information supplied by Parsons Brinckerhoff, June 2003, Brisbane.

Queensland Environmental Protection Agency 1994, Personal communication, I. Badham, May 1994.

Schelegle E.S. and Adams W.C. 1986, Reduced Exercise Time in Competitive Simulations Consequent to Low Level Exposure, *Medicine and Science in Sports and Exercise*, Vol 18.

Schwartz J. 1998, Air Pollution and Hospital Admissions for Heart Disease in Eight US Counties, *Epidemiology* 9**:** S76.

Schwartz J., Dockery D.W. and Neas L.M. 1996a, Is Daily Mortality Associated Specifically with Fine Particles, *Journal of the Air and Waste Management Association* Vol 46, 927-939.

Schwartz J., Spix C., Touloumi G., Bachárová L., Barumamdzadeh T., le Tertre A., Piekarksi T., Ponce de Leon A., Pönkä A., Rossi G., Saez M. and Schouten J.P. 1996b, Methodological Issues in Studies of Air Pollution and Daily Counts of Deaths or Hospital Admissions, *Journal of Epidemiology and Community Health*, 50 (Suppl 1), S3-S11.

Seaton A., Macnee W., Donaldson K. and Godden D. 1995, Particulate Air Pollution and Health Effects*, Lancet* 345:176-8.

Seinfeld, J.H. and S.N. Pandis 1998, *Atmospheric Chemistry and Physics,* John Wiley, New York.

Southwest Research Institute 2001, *How Catalytic Converters Work,* http://www.swri.edu/10light/catalyst.htm.

Standards Australia 1987, *AS-2922: Ambient Air – Guide for the Siting of Sampling Units*.

Standards Australia 1984, *AS-2695: Ambient Air-Determination of Carbon Monoxide – Direct Reading Instrument Method*.

Stewart A.C., Pengilley M.R., Brain R., Haley J.J. and Mowle M.G. 1982, *Motor Vehicle Emissions into the Sydney Air Basin*, in Carras JN and Johnson GM (eds) *The Urban Atmosphere – Sydney, A Case Study,* Proceedings of a conference organised by the CSIRO Division of Fossil Fuels, Leura, 5-6 May.

Streeton J.A. 1997, *A Review of Existing Health Data on Six Air Pollutants*, report prepared for the National Environment Protection Council.

United States Environmental Protection Agency 2001a, *Code of Federal Regulations – Title 40 – Protection of Environment,* Volume 14, Part 87, July 1.

United States Environmental Protection Agency 2001b, *Sources and Emissions of Atmospheric Particles,* National Centre for Environmental Assessment, Internet www.epa.gov/nceawww1/pdfs/067ch05.pdf.

United States Environmental Protection Agency 1991, *Volatile Organic Compounds from On–Road Vehicles*, (United States Environmental Protection Agency, Washington D.C., USA).

Williams D.F., Carras J.N., Shenouda D., Drummond M.S. and Langgen A.L. 1994, *Traffic Generated Pollution Near Roads and Highways: Models and Measurements,* CSIRO Coal and Energy Technology, North Ryde.

Xu CH 1996, *A Study in Air Pollution from Brisbane Urban Traffic,* Unpublished PhD Thesis Material, Griffith University.

Legislation

NSW

Environmental Planning and Assessment Act 1979.

Queensland

Environmental Protection (Air) Policy 1997.

Appendix A

Carbon Monoxide Monitoring Data

Appendix A: Carbon Monoxide Monitoring Data

Table A-1: Carbon Monoxide Monitoring Data Collected on the Gold Coast Highway, Tugun, and Associated Wind and Temperature Measurements from Gold Coast Airport, Coolangatta.

Date and Time	Wind Speed (m/s)	Wind Direction (deg)	CO (ppm)	Temperature (°C)
20 December 2000				
8:05	1.9	51.4	1.1	28.6
8:10	3.5	39.3	1.3	29.4
8:15	1.8	24.9	1.3	29.9
8:20	0	63.4	1.4	30
8:25	0	63.4	1.4	30
8:30	1.9	46.4	1.4	30.1
8:35	0	63.4	1.1	30.2
8:40	0	63.4	1.6	30.3
8:45	0	63.4	1.3	30.2
8:50	0	63.4	1.4	30.5
8:55	1.8	53.6	1.3	30.5
9:00	0	63.4	1.3	30.6
9:05	0	63.4	1.5	30.6
9:10	0	63.4	1.5	30.5
9:15	0	63.4	1.2	30.4
9:20	0	63.4	1.2	30.5
9:25	0	63.4	1.2	30.6
9:30	0	63.4	1.7	30.6
9:35	0	63.4	1.8	30.5
9:40	0	63.4	1.4	30.4
9:45	0	63.4	1.3	30.2
9:50	0	63.4	1.3	30.3
9:55	0	63.4	1.4	30.6
10:00	1.8	43	1.4	30.9
10:05	0	63.4	1.3	31.2
10:10	1.8	46.5	1.2	31.3
10:15	0	63.4	1.3	31.3
10:20	0	63.4	1.3	31.5
10:25	0	63.4	1.5	31.6
10:30	0	63.4	1.4	31.6
10:35	1.8	16.6	1.4	31.7
10:40	0	63.4	1.5	31.8
10:45	0	63.4	1.4	32
10:50	1.9	35.8	1.5	32.3
10:55	1.8	11.1	1.4	32.6
11:00	0	63.4	1.3	32.6
11:05	0	63.4	1.3	32.6
11:10	1.8	28.6	1.3	32.7

Date and Time	Wind Speed (m/s)	Wind Direction (deg)	CO (ppm)	Temperature (°C)
11:15	1.8	5.8	1.5	33.2
11:20	1.8	0.2	1.5	33.8
11:25	0	63.4	1.5	34.3
11:30	1.8	20.9	1.6	34.8
11:35	1.7	16.4	1.6	35.1
11:40	1.8	10.5	1.6	35.4
11:45	1.7	6.2	1.7	35.6
11:50	0	63.4	1.7	35.7
11:55	0	63.4	1.7	35.7
12:00	0	63.4	1.7	35.7
12:05	1.7	346.9	1.7	36
12:10	0	63.4	1.8	36.3
12:15	1.7	341	1.8	36.5
12:20	1.7	6.9	1.8	36.8
12:25	0	63.4	1.9	36.9
12:30	0	63.4	1.3	37.1
12:35	0	63.4	1.5	37
12:40	0	63.4	1.4	37.1
12:45	1.7	7.7	1.5	37.1
12:50	0	63.4	1.3	37.1
12:55	0	63.4	1.2	37.1
13:00	0	63.4	1.3	37
13:05	1.8	5.1	1.2	36.9
13:10	0	63.4	1.2	36.7
13:15	1.7	352.8	1.2	36.6
13:20	0	63.4	1.2	36.5
13:25	1.7	353.7	1.1	36.4
13:30	0	63.4	1.2	36.4
13:35	0	63.4	1.2	36.4
13:40	0	63.4	1.2	36.4
13:45	0	63.4	1.2	36.1
13:50	0	63.4	1.3	36.1
13:55	1.8	6.6	1.1	35.8
14:00	3.6	30.8	1.3	35.5
14:05	0	63.4	1.3	35.3
14:10	0	63.4	1.1	35.5
14:15	0	63.4	1.2	35.6
14:20	1.8	9.6	1.2	35.6
14:25	0	63.4	1.2	35.7
14:30	0	63.4	1.1	35.6
14:35	0	63.4	1.2	35.5
14:40	1.9	30.7	1.2	35.4
14:45	0	63.4	1.1	35.2
14:50	1.8	15.8	1.2	34.9
14:55	1.8	40.6	1.4	34.9

Date and Time	Wind Speed (m/s)	Wind Direction (deg)	CO (ppm)	Temperature (°C)
15:00	0	63.4	1.4	35
15:05	0	63.4	1.4	35
15:10	0	63.4	0.9	35
15:15	0	63.4	0.9	34.8
15:20	1.8	41.4	0.9	34.5
15:25	3.7	46.5	0.9	34.1
15:30	0	63.4	0.9	33.9
15:35	1.8	23.3	0.9	34
15:40	0	63.4	0.9	34
15:45	0	63.4	0.9	34.1
15:50	0	63.4	0.9	34.1
15:55	0	63.4	1	34.2
16:00	0	63.4	1	34.1
16:05	0	63.4	1	34.2
16:10	0	63.4	1	34.1
16:15	0	63.4	1	33.7
16:20	1.9	42.7	1	33.5
16:25	0	63.4	1.2	33.4
16:30	1.8	51	1.4	33.4
16:35	0	63.4	1.5	33.5
16:40	0	63.4	1.4	33.7
16:45	0	63.4	1.3	33.5
16:50	0	63.4	1.3	33.3
16:55	1.9	49	1.4	33
17:00	1.8	30.1	1.3	32.8
17:05	0	63.4	1.3	32.8
17:10	0	63.4	1.3	33
17:15	0	63.4	1.3	33
17:20	0	63.4	1.4	33
17:25	1.9	47.2	1.4	33.2
17:30	0	63.4	1.8	33.3
17:35	0	63.4	1.5	33.1
17:40	0	63.4	1.4	33.1
17:45	1.9	48.6	1.3	33
17:50	0	63.4	1.3	33
17:55	1.8	28.8	1.4	32.8
18:00	1.9	53.2	1.1	32.4
18:05	3.5	44.1	1.3	32.1
18:10	0	63.4	1.3	32
18:15	3.7	54.2	1.3	31.5
18:20	5.3	50	1.3	30.6
21 December 2000				
7:30	1.8	51	0.8	27.2
7:35	1.8	71.4	0.5	27.4
7:40	0	63.4	1	27.7

Date and Time	Wind Speed (m/s)	Wind Direction (deg)	CO (ppm)	Temperature (°C)
7:45	1.8	43.4	0.9	28
7:50	1.9	61.5	1.4	28.3
7:55	0	63.4	1	28.5
8:00	1.8	39.3	1.8	28.7
8:05	0	63.4	2.4	28.9
8:10	1.8	56.6	2.1	29.1
8:15	0	63.4	2.2	29.4
8:20	1.8	37.3	2.1	29.7
8:25	3.6	32.3	2.3	30.2
8:30	0	63.4	2.2	30.5
8:35	1.9	53.3	2.4	30.7
8:40	0	63.4	2.5	31
8:45	1.8	54.7	1.9	31.2
8:50	0	63.4	2.3	31.2
8:55	0	63.4	2.2	31.1
9:00	0	63.4	2	31.1
9:05	0	63.4	2.2	31.2
9:10	0	63.4	2.5	31.4
9:15	1.8	27.7	1.9	31.7
9:20	0	63.4	2.1	31.8
9:25	1.9	49.2	2.6	31.9
9:30	0	63.4	2.2	31.8
9:35	0	63.4	2.7	31.9
9:40	0	63.4	2.2	32.2
9:45	1.9	47.7	2.7	32.7
9:50	1.9	42.2	2.7	33.1
9:55	0	63.4	2.3	33
10:00	0	63.4	2.2	32.9
10:05	0	63.4	2.2	33
10:10	0	63.4	1.7	32.8
10:15	0	63.4	2.2	32.7
10:20	0	63.4	2.9	32.8
10:25	0	63.4	2.4	32.9
10:30	1.8	44.4	2.3	33
10:35	0	63.4	2.2	33.1
10:40	0	63.4	2.2	33.2
10:45	3.5	38.9	2.3	33.6
10:50	8.7	17.3	2.2	36.3
10:55	8.5	358.7	2.1	39.2
11:00	5.4	27.1	2.5	38.3
11:05	8.8	33.6	2.7	35.9
11:10	5.3	30.8	2.2	34.8
11:15	3.5	35.9	2.7	34.3
11:20	0	63.4	2.6	34.2
11:25	0	63.4	2.6	34.2

Date and Time	Wind Speed (m/s)	Wind Direction (deg)	CO (ppm)	Temperature (°C)
11:30	0	63.4	2.5	34.3
11:35	0	63.4	1.8	34.4
11:40	1.9	44.7	2.5	34.7
11:45	5.4	30.2	2.6	35.4
11:50	5.3	26.4	1.7	36.4
11:55	6.9	9.6	2	38
12:00*	8.4	352.9	2.2	40.6
12:05*	9.8	333.8	2.2	43.5*
12:10*	7.9	321.7	2.3	46.2*
12:15*	7.6	297.9	2.1	48.8*
12:20*	9.1	281.7	2.1	51.4*
12:25*	9.1	266.2	2.2	53.7*
12:30*	8.9	244.9	2	55.6*
12:35*	9	229.3	1.8	57.5*
12:40*	43.5*	132.6	2.2	59*
12:45*	53.7*	94.7	2.4	60.1*
12:50*	50.4*	60.6	3.1	61*
12:55*	48.3*	24.3	2.9	61.9*
13:00*	43.7*	351.6	2.2	62.8*
13:05*	47.9*	321.2	2.1	63.6*
13:10*	55.4*	295.7	2.1	64.2*
13:15*	51*	276.6	2.3	64.1*
13:20*	17.1*	293.6	2.4	60.3*
13:25*	19.8*	33.2	2.1	56.3*
13:30*	43.5*	75.4	2.5	53.7*
13:35*	53.9*	111.7	2.5	52.2*
13:40*	10.1*	178.9	2.5	50.2*
13:45*	10.1*	250.1	2.4	47.9*
13:50*	8.6*	267.2	2.4	46.3*
13:55*	10.3*	278.5	2.3	44.4*
14:00*	10.2*	288.3	2.3	42.6*
14:05	1.8	311.8	2.2	42.6*
14:10	3.5	311.3	2.5	42.1*
14:15	3.5	314.3	2.3	41.4*
14:20	6.8	318.2	2.5	40
14:25	3.5	330.5	2.8	39.7
14:30	1.8	350.2	3	39.3
14:35	3.5	347.7	2.5	38.8
14:40	3.4	355.1	2.6	38.1
14:45	3.6	6.8	2.8	37.5
14:50	3.5	0.9	3.1	37.5
14:55	0	63.4	2.7	37.9
15:00	1.8	349.1	2.8	38.2
15:05	0	63.4	2.8	38.2
15:10	0	63.4	2.5	38.2

Date and Time	Wind Speed (m/s)	Wind Direction (deg)	CO (ppm)	Temperature (°C)
15:15	0	63.4	2.7	38.1
15:20	0	63.4	2.6	38.1
15:25	1.8	348.6	2.8	37.8
15:30	1.8	9.9	2.5	37.7
15:35	1.8	350.6	2.8	37.6
15:40	0	63.4	2.9	37.6
15:45	1.8	353.2	2.8	37.2
15:50	0	63.4	2.7	36.9
15:55	1.7	12.5	2.3	36.7
16:00	3.6	7.7	2.6	36.5
16:05	1.9	23.4	3.1	36
16:10	3.5	19.2	2.6	35.5
16:15	1.8	9.2	2.9	35
16:20	1.9	34.2	3	34.8
16:25	1.9	36.4	2.4	34.4
16:30	1.9	39.1	3	34.2
16:35	1.8	19.1	3	34.2
16:40	0	63.4	2.2	34.2
16:45	0	63.4	2.7	34.3
16:50	0	63.4	2.6	34.5
16:55	0	63.4	2.8	34.6
17:00	1.8	38.6	2.4	34.8

* Readings of wind speed and temperature between approximately 12:00 and 14:00 on 21 December appear anomalous. These results can not be explained, but have not influenced the results. The CO readings, which were recorded by a separate analyser, appear consistent with preceding subsequent valves.

Appendix B

Traffic Counts

Appendix B: Traffic Counts

Table B-1: Traffic Count Information Collected on 13 December 2000, Tweed Heads Bypass, South of Gold Coast Airport.

Date and Time	Westbound			Eastbound		
	Cars	Heavy	Total W	Cars	Heavy	Total E
13 December 2000						
0:15	14	11	25	17	6	23
0:30	6	5	11	15	1	16
0:45	12	5	17	21	3	24
1:00	6	4	10	10	2	12
1:15	7	12	19	9	5	14
1:30	12	7	19	15	5	20
1:45	8	4	12	7	3	10
2:00	2	9	11	5	3	8
2:15	5	3	8	15	3	18
2:30	8	9	17	15	6	21
2:45	6	2	8	6	1	7
3:00	8	6	14	7	5	12
3:15	12	8	20	5	2	7
3:30	3	9	12	8	7	15
3:45	22	11	33	12	3	15
4:00	18	20	38	19	8	27
4:15	15	14	29	16	8	24
4:30	34	15	49	28	4	32
4:45	65	15	80	34	6	40
5:00	70	11	81	82	13	95
5:15	116	29	145	83	17	100
5:30	74	9	83	48	16	64
5:45	168	36	204	130	26	156
6:00	224	45	269	158	14	172
6:15	264	30	294	137	16	153
6:30	359	44	403	171	18	189
6:45	295	49	344	216	31	247
7:00	201	21	222	237	19	256
7:15	273	30	303	229	22	251
7:30	326	28	354	318	22	340
7:45	334	32	366	234	25	259
8:00	503	19	522	233	23	256
8:15	360	25	385	221	26	247
8:30	266	14	280	249	22	271
8:45	342	33	375	249	18	267
9:00	340	39	379	287	24	311
9:15	301	30	331	254	30	284

Date and Time	Westbound			Eastbound		
	Cars	Heavy	Total W	Cars	Heavy	Total E
9:30	265	24	289	215	12	227
9:45	286	27	313	248	26	274
10:00	243	32	275	229	23	252
10:15	286	23	309	258	30	288
10:30	301	29	330	267	29	296
10:45	350	27	377	310	27	337
11:00	229	29	258	273	27	300
11:15	211	22	233	235	8	243
11:30	180	19	199	271	28	299
11:45	271	24	295	219	24	243
12:00	302	35	337	303	34	337
12:15	183	19	202	234	28	262
12:30	217	22	239	305	33	338
12:45	210	22	232	174	33	207
13:00	218	22	240	230	26	256
13:15	208	23	231	259	27	286
13:30	231	30	261	212	22	234
13:45	269	20	289	248	30	278
14:00	247	33	280	260	33	293
14:15	298	24	322	201	35	236
14:30	207	25	232	271	29	300
14:45	271	19	290	239	23	262
15:00	262	29	291	244	28	272
15:15	292	28	320	300	19	319
15:30	292	20	312	317	25	342
15:45	280	12	292	328	18	346
16:00	294	19	313	341	23	364
16:15	329	28	357	352	29	381
16:30	347	20	367	321	21	342
16:45	254	5	259	314	20	334
17:00	238	14	252	357	22	379
17:15	238	16	254	359	23	382
17:30	196	10	206	371	15	386
17:45	203	13	216	289	16	305
18:00	134	9	143	317	25	342
18:15	173	13	186	271	22	293
18:30	185	11	196	205	13	218
18:45	143	6	149	157	13	170
19:00	123	6	129	136	24	160
19:15	93	6	99	147	13	160
19:30	96	5	101	124	16	140
19:45	81	5	86	109	23	132
20:00	66	7	73	94	22	116

Date and Time	Westbound			Eastbound		
	Cars	Heavy	Total W	Cars	Heavy	Total E
20:15	69	4	73	95	13	108
20:30	65	7	72	98	10	108
20:45	69	17	86	91	10	101
21:00	66	7	73	84	14	98
21:15	74	4	78	89	14	103
21:30	57	5	62	72	11	83
21:45	74	7	81	78	13	91
22:00	61	5	66	75	9	84
22:15	47	7	54	67	8	75
22:30	29	6	35	63	3	66
22:45	28	6	34	64	10	74
23:00	17	2	19	49	2	51
23:15	21	5	26	45	3	48
23:30	18	3	21	38	5	43
23:45	18	3	21	31	4	35
14 December 2000						
0:00	14	3	17	16	7	23

Appendix C

Greenhouse Gas Calculations

Appendix C: Greenhouse Gas Calculations

Table C-1: 2007 No Tugun Bypass

Link Description	Average Speed (km/hr)	Daily Vehicle Kilometres Travelled	Daily Vehicle Hours Travelled
Interstate Highway	95.8	6,969,305	72,767
Regional Arterial	50.3	12,950,373	257,482
Arterial	38.4	19,436,152	506,034
Sub-Arterial	39.8	6,672,736	167,642
Distributor	44.5	1,613,539	36,219
Minor Road	32.4	766,296	23,620
Total	45.5	48,408,400	1,063,764

Notes:
Interstate Highway: Roads whose primary function is to service large traffic movements from one region to another;
Arterial: Roads whose main function is to form the principal avenue of communication for metropolitan traffic movement;
Distributor: Roads which distribute traffic between the sub-arterial roads and the local road system; and
Minor Road: Roads whose primary function is to collect traffic and/or provide access to abutting properties.

Table C-2: 2007 With Tugun Bypass

Link Description	Average Speed (km/hr)	Daily Vehicle Kilometres Travelled	Daily Vehicle Hours Travelled
Interstate Highway	95.6	7,295,523	76,340
Regional Arterial	50.9	12,878,543	253,259
Arterial	40.1	19,313,443	481,907
Sub-Arterial	39.7	6,572,533	165,356
Distributor	45.0	1,601,524	35,596
Minor Road	36.7	710,543	19,377
Total	46.9	48,372,109	1,031,835

Table C-3: 2017 No Tugun Bypass

Link Description	Average Speed (km/hr)	Daily Vehicle Kilometres Travelled	Daily Vehicle Hours Travelled
Interstate Highway	92.5	8,749,440	94,629
Regional Arterial	52.8	15,345,803	290,716
Arterial	36.5	22,510,739	617,349
Sub-Arterial	36.8	7,536,708	204,812
Distributor	43.0	2,063,056	47,944
Minor Road	28.0	929,946	33,246
Total	44.3	57,135,692	1,288,696

Table C-4: 2017 With Tugun Bypass

Link Description	Average Speed (km/hr)	Daily Vehicle Kilometres Travelled	Daily Vehicle Hours Travelled
Interstate Highway	91.7	9,161,614	99,938
Regional Arterial	54.3	15,284,509	281,313
Arterial	40.0	22,350,631	558,543
Sub-Arterial	36.8	7,507,882	203,808
Distributor	44.2	2,001,686	45,329
Minor Road	31.7	856,862	27,018
Total	47.0	57,163,184	1,215,949

Table C-5: Total Greenhouse and TSP Emissions (t/yr) Including Congestion Factor

2007 No Tugun Bypass

Link Description	HC	NOx	CO	TSP	CO_2	N_2O	CH_4
Interstate Highway	2,256	3,609	7,458	135	1,065,810	203	113
Regional Arterial	6,655	4,662	26,008	251	1,167,541	378	333
Arterial	12,179	7,505	51,092	377	1,632,785	567	609
Sub-Arterial	4,073	2,546	16,925	129	561,929	195	204
Distributor	907	596	3,661	31	139,082	47	45
Minor Road	544	315	2,387	15	65,985	22	27
Total	26,614	19,232	107,531	938	4,633,132	1,411	1,331

2007 With Tugun Bypass

Link Description	HC	NOx	CO	TSP	CO_2	N_2O	CH_4
Interstate Highway	2,391	3,864	7,850	148	1,108,888	213	120
Regional Arterial	6,628	4,740	25,617	261	1,166,524	375	331
Arterial	11,847	7,529	48,729	391	1,627,675	563	592
Sub-Arterial	4,061	2,571	16,750	133	553,411	192	203
Distributor	903	604	3,602	32	138,465	47	45
Minor Road	465	285	1,959	14	59,737	21	23
Total	26,295	19,593	104,506	980	4,654,699	1,410	1,315

2017 No Tugun Bypass

Link Description	HC	NOx	CO	TSP	CO_2	N_2O	CH_4
Interstate Highway	2,900	4,264	9,675	170	1,223,141	255	145
Regional Arterial	7,609	5,491	29,367	298	1,412,982	447	380
Arterial	14,640	8,846	62,250	436	1,893,292	656	732
Sub-Arterial	4,872	2,953	20,672	146	633,491	220	244
Distributor	1,190	769	4,844	40	176,153	60	59
Minor Road	734	404	3,301	18	85,684	27	37
Total	31,945	22,727	130,108	1,108	5,424,742	1,666	1,597

2017 Tugun Bypass

Link Description	HC	NOx	CO	TSP	CO_2	N_2O	CH_4
Interstate Highway	3,055	4,404	10,214	178	1,256,545	267	153
Regional Arterial	4,450	3,271	17,051	178	854,582	267	223
Arterial	5,572	3,490	23,122	178	771,974	267	279
Sub-Arterial	5,923	3,590	25,129	178	770,023	267	296
Distributor	5,178	3,390	20,929	178	787,673	267	259
Minor Road	6,604	3,793	29,164	178	795,084	267	330
Total	30,781	21,937	125,608	1,066	5,235,881	1,603	1,539

Table C-6: Total Greenhouse and TSP Emissions t/yr Including Congestion Factor

	HC	NOx	CO	TSP	CO_2	N_2O	CH_4
2007 No Tugun Bypass	26,614	19,232	107,531	938	4,633,132	577	1,331
2007 With Tugun Bypass	52,589	39,187	209,013	1,960	9,309,399	1,176	2,629
2017 No Tugun Bypass (B1)	63,890	45,453	260,215	2,215	10,849,484	1,364	3,195
2017 Tugun Bypass (B3)	61,562	43,874	251,216	2,131	10,471,762	1,316	3,078

Table C-7: Emissions of Greenhouse Gases from the Road Network With and Without the Tugun Bypass for 2007 and 2017

	2007			2017		
	Without Bypass	With Bypass	% Change	Without Bypass	With Bypass	% Change
Main Greenhouse Gases						
Carbon Dioxide (CO_2)	4,633,132	4,654,699	0.5%	5,424,742	5,235,881	-3.5%
Nitrous Oxide (N_2O)	1,411	1,410	-0.1%	1,666	1,603	-3.8%
Methane (CH_4)	1,331	1,315	-1.2%	1,597	1,539	-3.6%
Indirect Greenhouse Gases and TSP						
Hydrocarbons (HC)	26,614	26,295	-1.2%	31,945	30,781	-3.6%
Oxides of Nitrogen (NO_x)	19,232	19,593	1.9%	22,727	21,937	-3.5%
Carbon Monoxide (CO)	107,531	104,506	-2.8%	130,108	125,608	-3.5%
Total Suspended Particles (TSP)	938	980	4.4%	1,108	1,066	-3.8%

Table C-8: Global Warming Potential Predictions for the Road Network With and Without the Tugun Bypass for 2007 and 2017

Total Emissions for All Vehicles (tonnes per year)

	2007			2017		
	Without Bypass	**With Bypass**	**% Change**	**Without Bypass**	**With Bypass**	**% Change**
20 Year Total	5,124,942	5,145,213	0.4	6,006,871	5,796,088	-3.5
100 Year Total	5,117,383	5,138,221	0.4	5,996,950	5,786,454	-3.5

GWP Calculations	**20 Year Factor**	**20 Year GWP**					
		2007			2017		
		Without Bypass	**With Bypass**	**% Change**	**Without Bypass**	**With Bypass**	**% Change**
Carbon Dioxide (CO_2)	1	4,633,132	4,654,699	0.5	5,424,742	5,235,881	-3.5
Nitrous Oxide (N_2O)	290	409,307	409,001	-0.1	483,099	464,785	-3.8
Methane (CH_4)	62	82,503	81,513	-1.2	99,030	95,422	-3.6
Total		5,124,942	5,145,213	0.4	6,006,871	5,796,088	-3.5

GWP Calculations	**100 Year Factor**	**100 Year GWP**					
		2007			2017		
		Without Bypass	**With Bypass**	**% Change**	**Without Bypass**	**With Bypass**	**% Change**
Carbon Dioxide (CO_2)	1	4,633,132	4,654,699	0.5	5,424,742	5,235,881	-3.5
Nitrous Oxide (N_2O)	320	451,650	451,311	-0.1	533,075	512,866	-3.8
Methane (CH_4)	24.5	32,602	32,211	-1.2	39,133	37,707	-3.6
Total		5,117,383	5,138,221	0.4	5,996,950	5,786,454	-3.5

Appendix D

Traffic Data

Table D-1: Traffic Data for 2007 and 2017 Tweed Heads Bypass, Pacific Highway North of Boyd Street and Pacific Motorway (without bypass) and Pacific Highway North of Boyd Street and South of Tugan Bypass , Pacific Motorway and Tugan Bypass (with bypass)

Year	Section	Bypass	Direction	Lanes	Flow	Modelled Traffic Speed	Speed Limit
2007	Tweed Hds Bypass - 6	N	NB	2	2,120	83	100
			SB	2	2,756	68	100
2007	Pacific Hwy- 4	N	NB	2	3,598	4	70
			SB	2	3,772	3	70
2007	Pacific Mwy - 2	N	WB	2	2,494	31	80
			EB	2	2,474	35	80
2007	Pacific Hwy - 7	Y	NB	2	2,000	94	100
			SB	2	2,490	94	100
2007	Tugun Bypass - 8	Y	NB	2	1,738	95	100
			SB	2	2,076	94	100
2007	Pacific Hwy - 4	Y	NB	2	1,860	59	70
			SB	2	1,704	59	70
2007	Pacific Mwy - 2	Y	WB	2	1,488	60	80
			EB	2	1,256	60	80
2017	Tweed Hds Bypass - 6	N	NB	2	2,119	63	100
			SB	2	2,756	13	100
2017	Pacific Hwy- 4	N	NB	2	3,598	3	70
			SB	2	3,771	2	70
2017	Pacific Mwy - 2	N	WB	2	2,494	15	80
			EB	2	2,475	10	80
2007	Pacific Hwy - 7	Y	NB	2	2,612	94	100
			SB	2	3,212	92	100
2017	Tugun Bypass - 8	Y	NB	2	2,272	94	100
			SB	2	2,554	94	100
2017	Pacific Hwy - 4	Y	NB	2	2,676	57	70
			SB	2	2,752	57	70
2017	Pacific Mwy - 2	Y	WB	2	1,958	60	80
			EB	2	1,526	60	80