Kempsey to Eungai Upgrading the Pacific Highway

Technical Report 4 Climate and Air Quality Assessment

May 2007

NSW Road and Traffic Authority

PARSONS BRINCKERHOFF

Parsons Brinckerhoff Australia Pty Limited ABN 80 078 004 798

Ernst & Young Centre,
Level 27, 680 George Street
Sydney NSW 2000
GPO Box 5394
Sydney NSW 2001
Australia
Telephone +61 2 9272 5100
Facsimile +61 2 9272 5101
Email sydney@pb.com.au

NCSI Certified Quality System ISO 9001

2116519A PR_5804

Author: ....Aaron McKenzie/Shane Harris/Larissa Brisbane

Signed: ....

Reviewer: ....Shane Harris/Bruce Lean

Signed: ....

Approved by: ....Bruce Lean

Signed: ....

Date: .... May 2007

Distribution: ....

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1. Introduction

In July 2004, the New South Wales (NSW) Minister for Roads announced the eastern route (passing east of Kempsey and Frederickton) and sub-options as the preferred route for the proposed Kempsey to Eungai Pacific Highway Upgrade (the 'proposed upgrade').

Since the announcement of the preferred route, the NSW Roads and Traffic Authority (the RTA) has conducted extensive community consultation, environmental and engineering investigations to develop a concept design for the proposed upgrade. The design reflects a sustainable and acceptable outcome by minimising impacts on the environment and the local community.

The proposed upgrade involves the construction of approximately 40.8 kilometres of four-lane divided carriageway (capable of being upgraded to six lanes), from the existing Pacific Highway dual carriageway south of Kempsey, to the existing Pacific Highway dual carriageway north of Eungai Rail. The proposal is shown in Figure 1-1.

The proposed upgrade would diverge in an easterly direction from the existing Pacific Highway south of Kempsey, pass over the Macleay River floodplain and cross the Macleay River north-east of Frederickton. From Frederickton, the proposed upgrade would pass to the west of the existing Pacific Highway through Collombatti and the edge of the Tamban State Forest, and north through Barraganyatti and Eungai Rail to join the existing highway.

Other features of the proposed upgrade include:

- construction of bridging over the Macleay River and its floodplain in the Frogmore area
- provision of 20-year flood immunity for the highway south of the Macleay River crossing and 100-year flood immunity for the highway north of the Macleay River crossing
- provision of grade-separated interchanges at three locations:
  - South Kempsey — south of the South Kempsey industrial area providing access to the town of Kempsey
  - Frederickton — between Frederickton golf course and the sewage treatment plant, providing access to the town of Frederickton, Smithtown and Gladstone
  - Stuarts Point Road — south of Eungai Rail, connecting the areas of Barraganyatti and Eungai Rail to the highway and providing access to Stuarts Point
- construction of a flood levee at Frederickton, providing 100-year flood immunity to residential and commercial premises.

The alignment would be integrated with the existing terrain and landscape, retaining views across the floodplain, rural areas and bushland. Rest areas, emergency access and U-turn facilities would be provided at appropriate locations along the highway.

1.1 Purpose of the report

The purpose of this technical paper is to:

- identify and describe the existing meteorological and air quality conditions in the vicinity of the proposed upgrade

- identify potential air quality impacts of the proposed upgrade and nominate suitable mitigation measures (where required)
- ensure that potential air quality impacts are adequately addressed.

1.2 Scope and approach

The scope of works for this study was to prepare an air quality impact assessment for the construction and operation of the proposed upgrade. This required completion of the following tasks:

- detailing the relevant meteorological and air quality conditions for the region
- reviewing the proposed construction works and operations
- compiling a greenhouse gas emissions inventory
- providing a concise summary of potential air quality impacts and required mitigation.

This technical paper addresses potential dust generation during the proposed construction works, and proposes mitigation measures.

The anticipated operational impacts have been assessed with consideration of existing air quality levels, land uses and traffic flow conditions for a number of identified time horizons. Predicted air quality impacts and emission profiles for identified traffic volumes have been compared for 2011 and 2021 conditions, with the assessment of impact profiles both with and without the proposed upgrade presented.

A greenhouse gas emissions inventory for both construction and operation of the proposed upgrade has also been prepared.

1.3 Structure of the report

Sections 2 and 3 of the report outline existing air quality and meteorological conditions in the vicinity of the proposed upgrade and the Kempsey region, and the relevant goals and standards for air quality.

Sections 4 and 5 outline the various sources of emissions and potential impacts during the construction and operation of the proposed upgrade. Section 6 provides an assessment of greenhouse gas issues.

Section 7 summarises the likely impacts on air quality and greenhouse gases during construction and operation, and outlines mitigation measures.

Meteorological data for the region is presented within the Climatic Summary report in Appendix A.

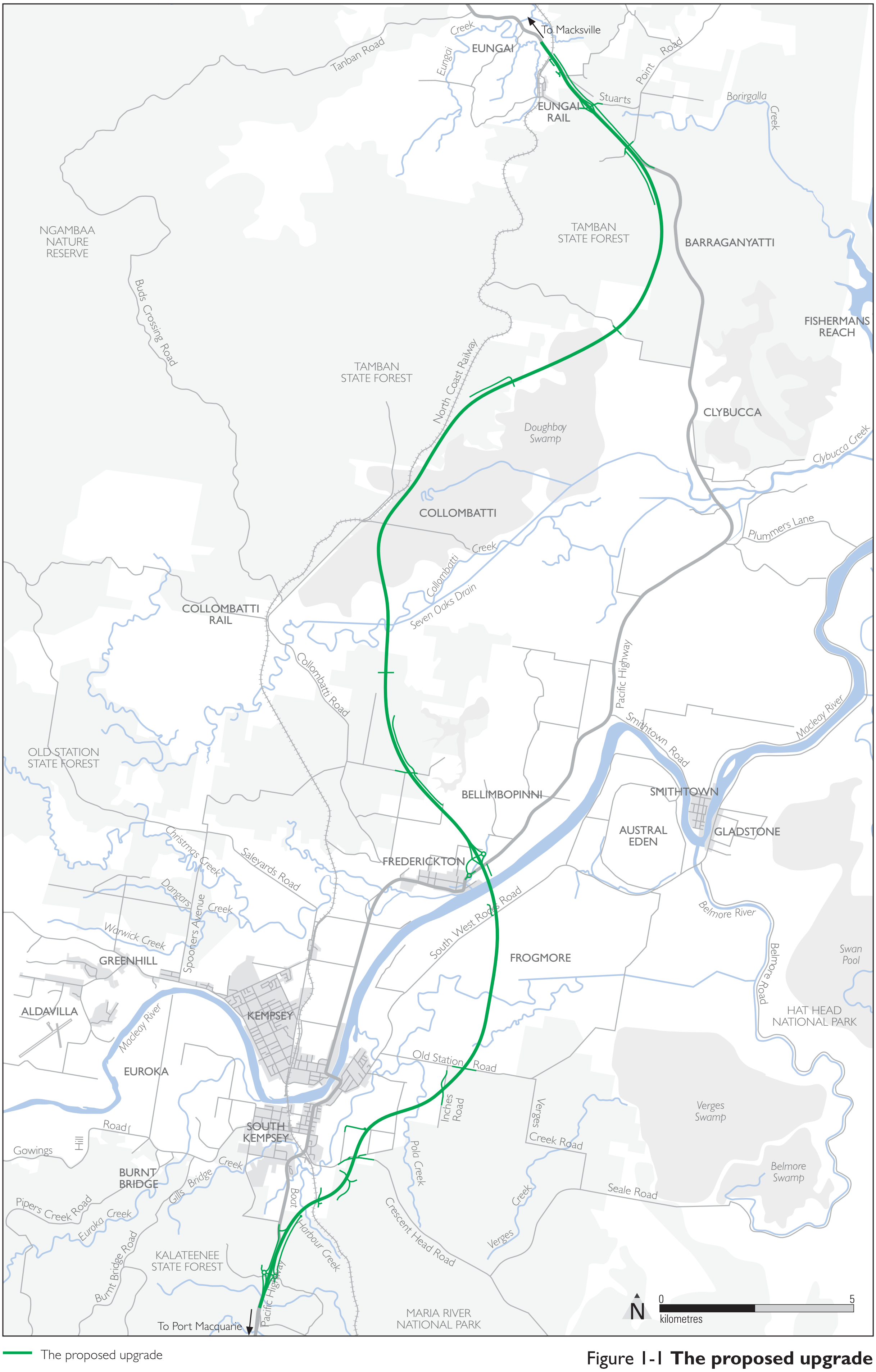

Figure 1-1 **The proposed upgrade**

2. Air quality goals and standards

National and NSW ambient air quality goals relevant to emissions from motor vehicles and construction works have been adopted for this air impact assessment. These standards were established to protect the health of local communities and minimise potential annoyance from the construction and operation of new developments and infrastructure.

The identified national goals are based on the recommendations of the National Health and Medical Research Council (NHMRC 1995) and the National Environmental Protection (Ambient Air Quality) Measure (NEPM) prepared by the National Environment Protection Council (NEPC 1998).

NSW ambient air quality goals are provided in the Department of Environment and Conservation document: *Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in NSW* (2005).

Relevant standards/goals applicable to this technical paper are presented in Table 2-1.

The pollutants assessed are emitted from construction equipment/works and motor vehicles, with the exception of the secondary pollutant ozone, which is formed from the interaction of oxides of nitrogen and reactive hydrocarbons in the presence of sunlight.

No air quality goals are prescribed for reactive hydrocarbons, as existing air quality guidelines for these pollutants are not specific for reactive species. Reactive species are the key elements in the formation of photochemical smog.

The adopted guidelines apply to sensitive receptors at site boundaries and beyond. Air quality at any given receptor may be a composite of emissions from a number of sources, contributing various proportions to the overall pollutant burden (depending on the location of the receptor with respect to sources and dispersion conditions). Further, compliance with the NEPM regional goal requires management and control of all sources and is, therefore, considered beyond the scope of an individual project. However, large air quality sources (such as the proposed upgrade) should be assessed with respect to their influence on regional air quality. This has been undertaken qualitatively within this report and with the assessment of annual impacts.

An NEPM ‘advisory’ standard has been established for 24-hour and annual particulate matter ($PM_{2.5}$) concentration levels. However, given the existing ‘advisory’ status of the $PM_{2.5}$ criterion, detailed assessment of impact potential has not been undertaken. (The advisory limits are not applied to projects and have been provided for information purposes only.)

The NEPC (2004) air toxics NEPM provides a framework for monitoring, assessing and reporting ambient levels of a number of air toxics managed by the Department of Environment and Conservation. As with the approach applied to the $PM_{2.5}$ standard, the air toxic goals are ‘investigation levels’ only and do not necessarily require detailed assessment. The investigation levels are established to assist in the interpretation of monitored data and are not intended as compliance air quality goals. The framework levels are intended to improve the information database on air toxics, thereby facilitating the development of future standards.

Table 2-1: Ambient air quality criteria

Pollutant	Averaging period	Goal	Source
Carbon monoxide	15 minute maximum	100 mg/m^3	WHO (2000)
	1 hour maximum	30 mg/m^3	WHO (2000)
	8 hour maximum	10 mg/m^3	NEPC (1998)
Nitrogen dioxide	1 hour maximum	246 μg/m^3	NEPC (1998)
	annual mean	62 μg/m^3	NEPC (1998)
Lead	annual mean	0.5 μg/m^3	NEPC (1998)
Photochemical oxidants (as ozone)	1 hour maximum	214 μg/m^3	NEPC (1998)
	4 hour maximum	171 μg/m^3	NEPC (1998)
Sulfur dioxide	10 minute maximum	712 μg/m^3	NHMRC (1996)
	1 hour maximum	570 μg/m^3	NEPC (1998)
	1 day	228 μg/m^3	NEPC (1998)
	annual mean	60 μg/m^3	NEPC (1998)
TSP	annual TSP concentration	90 μg/m^3	NHMRC (1996)
	annual TSP deposition[1]	2 g/m^2/month	NERDDC (1988)
	annual TSP deposition[2]	4 g/m^2/month	NERDDC (1988)
PM$_{10}$	24-hour PM$_{10}$ concentration	50 μg/m^3	NEPC (1998)
	annual PM$_{10}$ concentration	30 μg/m^3	EPA (1998)
PM$_{2.5}$	annual PM$_{2.5}$ concentration	8 μg/m^3	NEPM advisory standard
	24-hour PM$_{2.5}$ concentration	25 μg/m^3	
Benzene	annual average	10 μg/m^3	NEPM investigation level
	1-hour average	0.029 mg/m^3	DEC (2005)

Notes:

1 = maximum allowable increase

2 = maximum total deposited level

□g/m^3 = micrograms per cubic metre

mg/m^3 = milligrams per cubic metre

g/m^2/month = grams per metre squared per month

TSP = Total suspended particulates ≤ 30□m in aerodynamic diameter

PM$_{10}$ = Particulate matter ≤ 10□m in aerodynamic diameter

PM$_{2.5}$ = Particulate matter ≤ 2.5□m in aerodynamic diameter

WHO = World Health Organisation

NEPC = National Environment Protection Council

NHMRC = National Health and Medical Research Council

NERDDC = National Energy Research Development and Demonstration Council

EPA = Environment Protection Authority

NEPM = National Environment Protection (Ambient Air Quality) Measure

DEC = Department of Environment and Conservation

The above values are ambient air quality goals. Wherever possible, cumulative assessment of particulate matter impacts is required.

In assessing short-term impact potential, it should be noted that the 24-hour PM$_{10}$ targets specified in the NEPM should not be exceeded on more than 5 days in a single year.

3. Existing air quality, dispersion meteorology and nearest receptors

3.1 Ambient air quality

3.1.1 Overview

The existing air quality for the Kempsey region is characteristic of a rural environment with some urban development. The regional airshed relevant to the proposed upgrade comprises the Macleay River floodplain and the lower reaches of the Macleay River valley including Kempsey and Frederickton.

The area surrounding the proposed upgrade comprises a combination of rural, residential, commercial and light industrial land uses. No major pollutant-generating activities are located in the immediate study area. Local, minor sources of dust include a combination of quarrying and general rural and residential activities, light industry, and local and arterial roads. Emissions from motor vehicles would, therefore, be a primary contributor to air pollution in the local setting.

Monitoring information relating to existing ambient air quality levels is not available for either the local or regional area, and no background air quality monitoring has been undertaken for this assessment. However, acceptable ranges of particulate matter, dust, hydrocarbons, oxides of nitrogen and sulfur would be expected throughout the study area for the majority of the time, owing to the relatively undeveloped nature of the study area and surrounds.

3.1.2 Adopted background levels

This assessment is based on air quality data supplied by the NSW Environment Protection Authorities Air Monitoring Network (Quarterly Air Monitoring Reports 2003).

Data measured for the Beresfield monitoring location (in 2003) was adopted. This monitoring station is located on the main street of Beresfield (Lawson Street), approximately 300 kilometres south of the proposed upgrade. The measured air quality at this site would be influenced by higher traffic flow profiles and greater industrial emissions than would be expected at Kempsey.

Although this data is not site-specific, it is considered suitable for use as a conservative estimate of typical (or indicative) ambient air quality for the study area (i.e. baseline conditions). Air quality at Kempsey would be expected to be better than the reported Beresfield data given the difference in land use for the two regions.

Table 3-1: Adopted background levels (Beresfield, 2003)

Month	Pollutant								
	PM_{10} [TEOM] ($\mu g/m^3$) 24-hour average			NO_2 (pphm) 1-hour average			SO_2 (pphm) 1-hour average		
	Avg.	Max.	days > goal	Avg.	Max.	days > goal	Avg.	Max.	days > goal
January	nd	nd	nd	0.7	2.7	0	0.1	2	0
February	20	39	0	0.5	3.9	0	0.1	4.2	0
March	19	59	1	0.8	2.5	0	0.1	1.7	0
April	16	34	0	1.0	3.3	0	0.2	1.5	0
May	16	30	0	1.0	3.3	0	0.2	7.0	0
June	18	31	0	1.0	3.3	0	0.2	2.3	0
July	17	27	0	1.1	3.2	0	0.2	2.9	0
August	20	35	0	1.1	2.9	0	0.2	2.3	0
September	25	51	1	0.9	4.0	0	0.2	2.4	0
October	17	88	1	0.8	3.4	0	0.2	2.1	0
November	17	49	0	0.8	3.3	0	0.2	3.2	0
December	20	34	0	0.5	2.8	0	0.2	2.0	0
NSW GOAL		30			12			20	
Annual Average		**18.6**			**0.9**			**0.2**	
NSW GOAL		50			10.5			8	
Peak		**88**			**4.0**			**7.0**	

Notes:

PM_{10} = Particulate matter ≤ 10□m in aerodynamic diameter

NO_2 = nitrogen dioxide

SO_2 = sulfur dioxide

□g/m^3 = micrograms per cubic metre

pphm = parts per hundred million

TEOM – I-hour average

nd – no data

Source: NSW EPA Quarterly Air Monitoring Report (2003)

The TEOM (tapered element oscillating microbalance) measurements for PM_{10} (particulate matter ≤ 10μm [microns] in aerodynamic diameter) provide continuous recordings of PM_{10} with 24-averaged measurements reported. The 2003 annual average of 18 micro-grams per cubic metre was below the Department of Environment and Conservation long-term reporting goal of 30 micro-grams per cubic metre. The maximum 24-hour average of 88 micro-grams per cubic metre exceeded the 24-hour goal of 50 micro-grams per cubic metre. The TEOM measurements indicate that the 24-hour PM_{10} goal was exceeded on 3 days in 2003. Local sources or regional bushfire conditions are expected to be the cause of this measured level.

A maximum nitrogen dioxide level of 4 parts per hundred million (pphm) was measured during 2003 for the Beresfield monitoring station. The NEPM goal of 8 pphm was achieved.

A maximum sulfur dioxide level of 7 pphm was measured during 2003 for the Beresfield monitoring station, which was below the NEPM goal of 12 pphm.

Roadside air quality monitoring was undertaken in 1993 as part of the assessments for the upgrade of the Pacific Highway at Bulahdelah (monitoring sites at Coolongolook and Possum Brush). The data was collected by Peter Stephenson and Associates, summarised by Holmes Air Sciences, and provided in the *Upgrading of the Pacific Highway Environmental Impact Statement (Bulahdelah), Technical Paper No. 15 — Air Quality Impact Assessment*. (RTA 2004). While not site-specific and now dated, this study provides indicative background levels adjacent to a heavily used arterial road. Measurements were presented at five roadside sites along the Pacific Highway and at five back-road locations. Grab samples were taken during peak traffic flows and under worst-case dispersion conditions. The results cannot be compared with continuous monitoring data as they do not reflect diurnal changes in traffic flows or varying meteorological conditions.

The 1-hour carbon monoxide levels along the Pacific Highway were measured in the range of 0.3 to 14.7 pphm (0.4 to 18.4 milligrams per cubic metre). Back-road sites were generally lower and all readings were less than half the air quality level of 30 milligrams per cubic metre. Congestion and higher fleet carbon monoxide emissions influenced the measured levels. It would be reasonable to expect that current carbon monoxide roadside and back-road levels would be lower.

No records relating to dust deposition monitoring in the vicinity of the proposed upgrade are available for reference in this technical paper. However, from experience of dust deposition levels in similar receiving environments, it is anticipated that existing ambient levels would be less than 2 grams per square metre per month.

3.1.3 Industrial sources

A search of the national pollution inventory database indicated four industrial sources report emissions to the local airshed. These included a brickworks, two petroleum wholesalers and a timber sawmill. No diffuse sources of air emissions, such as traffic and agricultural sources, were reported. (Department of Environment and Heritage, 2005).

Air quality in the local and regional airshed is not expected to be influenced by existing industrial sources.

3.2 Existing meteorology

Details of existing meteorological conditions have been provided in the Climatic Summary in Appendix A. A brief outline of key findings is presented below.

Air quality impacts are driven by both regional meteorological conditions, primarily in the form of gradient wind flow regimes, and by local conditions, generally driven by topographical features in the form of drainage flows. Topography, wind speed and wind direction affect the potential dispersion and transport of air pollutants. Local dispersion meteorology specific to the proposed upgrade has been estimated based on the available data for the factors described above.

Regional wind patterns have been referenced from hourly data compiled from the Kempsey Wide Street automatic weather station (Bureau of Meteorology station no. 059017). A review of the wind rose data indicated that wind directions are generally variable at this location.

Westerly and south-westerly winds predominate during winter, with northerly through to south-easterly winds generally present during the summer and spring months. South-westerly and south-easterly winds are common during autumn.

High frequencies of events within the 1 to 10 kilometres per hour range were noted and few calm conditions were recorded.

A site-specific meteorological data file was configured for the year 2001. The 2001 data was generated through the use of the Commonwealth Scientific and Industrial Research Organisation developed TAPM (The Air Pollution Model) program. Coordinates of –31°03' South and 152°51' East were referenced. This approach provides for a more detailed and robust assessment.

Annual and seasonal wind rose plots have been included in Appendix A. An annual average wind speed of 4.3 metres per second was noted. Primary wind directions are from the north-west and west. Gradient wind flows from the north-east predominate during summer, while westerlies and north-westerlies dominate throughout the rest of the year.

The primary seasonal wind flow patterns have similar frequencies to the annual wind rose plot. The site-specific wind rose diagrams are consistent with wind flow regimes for the northern NSW region and generally confirm the reviewed Bureau of Meteorology wind rose plots for Kempsey.

A summary of the data referenced in compiling the wind roses and the occurrence of stability classes has been provided in Appendix A.

Worst-case dispersion conditions from the proposed upgrade would generally be associated with F-class and to a lesser degree E-class stability conditions (i.e. still/light winds and clear skies during the night-time or early morning period, that is, stable conditions). Analysis of the referenced site-representative meteorological data indicates that F-class dispersion conditions were present for approximately 9% of the time for the year 2001. E-class conditions were present for approximately 22% of the time. The high frequency of E and F-class stabilities indicates that pollutants would be likely to disperse slowly for a significant proportion of the time.

3.3 Topography

When assessing the impact potential from ground-level sourced air pollutants, it is important to consider local drainage flows. The movement of cold air down a slope (generally under stable atmospheric conditions) is referred to as 'katabatic drift' and can result in plume entrapment and poor dispersion of air-borne pollutants and the potential to cause greater off-site impacts. Katabatic drift follows local topography.

The proposed upgrade passes through both forested areas and cleared agricultural land. The forested sections of the corridor are gently undulating, with hills 10 to 30 metres high. Where the proposed upgrade passes through agricultural areas, the land is typically flat, low-lying floodplain. Therefore, significant occurrences of katabatic drift are not expected.

3.4 Nearest potentially affected receptors

The nearest potentially affected receptors have been identified to include, but not necessarily be limited to, the following:

- Kempsey Seventh Day Adventist Church, 108 Crescent Head Road, Kempsey
- Kempsey Adventist Primary School, 108 Crescent Head Road, Kempsey
- Frederickton Public School, Great North Road, Frederickton
- Frederickton Golf Course, Yarrabindinni Road, Frederickton
- Kempsey East Public School, Innes Street, Kempsey
- East Kempsey Cemetery, Naiooka Street, Kempsey
- Frederickton Uniting Church, Macleay Street (Pacific Highway), Frederickton
- Frederickton Cemetery, Great North Road, Frederickton
- Bellimbopinni Public School, Pacific Highway, Bellimbopinni.

4. Air emission sources

4.1 Construction

4.1.1 Particulate matter

Fugitive dust sources during the construction phase of the project would include traffic on paved and unpaved roads, aggregate storage piles, clearing of groundcover and topsoil, earthmoving activities, and the transporting or stockpiling of spoil and construction materials.

Emissions from paved and unpaved roads relate to silt loading and the volume of traffic on the road. Emissions from aggregate storage piles depend on factors such as the age of the pile, moisture content, and proportion of aggregate fines. Particulate matter emissions from general construction activities depend on site characteristics, moisture content of disturbed soil and the particular type of construction activities carried out.

The impact of fugitive dust sources is related to the quantity and drift potential of the particles. Larger particles generally settle out close to the source, whereas fine particles (generally referred to as PM10) can be dispersed over greater distances.

4.1.2 Mobile vehicular emissions

Vehicular emissions during construction are likely to be associated with both diesel and petroleum-fuelled vehicles. The operation of on-site machinery during the construction works and general site operations would generate carbon monoxide, carbon dioxide, oxides of nitrogen, sulfides and trace amounts of non-combustible hydrocarbons.

Emission rates and impact potential would depend on the power output of the combustion engines, the quality of the fuel, and the condition of the combustion engines.

The construction contractor and site management would ensure that all equipment does not release smoke in contravention of Section 124 of the Protection of the Environment Operations Act 1997 and clause 9 of the Protection of the Environment Operations (Clean Air) Regulation 2002.

Some odour may be detectable close to the source(s). Based on the rural setting of the proposed upgrade, the relatively minor number of mobile sources, the existing ambient air quality characteristics, the low population density of the study area, the anticipated location of potential sources and short-term nature of emissions, the potential for odour impacts from vehicle emissions would be minimal.

Provided that the construction contractor meets the requirements of the relevant legislation and regulations, emissions from vehicles are unlikely to result in air quality impacts, and are therefore not considered further in this assessment.

4.2 Operation

An assessment of emission rates from operating vehicles is outlined below. Pollutants considered include carbon monoxide, nitrogen oxides, hydrocarbons and particulate matter. A vehicle emissions inventory was prepared for NSW travel conditions as part of the Metropolitan Air Quality Study (MAQS) for Sydney. The MAQS divided roads into different categories, with emissions determined based on the anticipated make up of traffic along the road portion. Five categories were specified:

- freeway/highway
- arterial
- commercial (arterial)
- commercial (highway)
- residential/minor.

This technical paper has assumed that the proposed upgrade would be equivalent to freeway/highway conditions. No consideration of change in traffic flow profiles for local roads has been made.

The MAQS data was updated and developed by the NSW Department of Environment and Conservation's Motor Vehicle Emission Projection System (MVEPS). This technical paper has used emission estimates for 2006 and 2016 (generally consistent with Bulahdelah Pacific Highway Upgrade [RTA 2004] as a recent comparable project). MVEPS data provides allowances for vehicle fleet age structures, fleet turnover, implementation of improved emission standards and significant variations in fuel characteristics. Adopted emission rate data for freeway flows is outlined in *Table 4-1*.

Table 4-1: Adopted vehicle emission rates (grams per vehicle-kilometre)

Vehicle Type	Pollutant				
	CO	NO_X	HC	PM_{10}	PM_{10} (brake and tyre wear)
Passenger petrol vehicles – 2006	8.135	1.614	0.667	0.013	–
Passenger petrol vehicles – 2016	3.725	1.349	0.304	0.010	–
Heavy duty diesel vehicles – 2006	3.947	12.432	0.531	0.245	–
Heavy duty diesel vehicles – 2016	2.335	7.799	0.372	0.090	–
Heavy duty petrol vehicles – 2006	43.711	3.276	3.914	0.057	–
Heavy duty petrol vehicles – 2016	28.229	2.075	1.836	0.033	–
All vehicles	–	–	–	–	0.009

Notes:

CO = carbon monoxide

NO_X = oxides of nitrogen

HC = hydrocarbons (benzene and associated)

PM_{10} = Particulate matter ≤ 10□m [microns] in aerodynamic diameter

Source: Bulahdelah Pacific Highway Upgrade (RTA 2004)

Emission rates per vehicle are expected to decrease between 2006 and 2016 based on improved fuel and combustion technologies.

5. Air quality impacts

5.1 Construction

During construction of the proposed upgrade, generation of dust could affect the local ambient air environment.

Atmospheric dust arises from the mechanical disturbance of granular material exposed to the air. Dust generated from these open sources is termed 'fugitive', because it is not discharged to the atmosphere in a confined flow stream. Common sources of fugitive dust include unpaved roads, aggregate storage piles, and heavy construction operations, all of which would be evident during the construction phase of proposed upgrade.

Fugitive dust generation is caused by:

- pulverisation and abrasion of surface materials by application of mechanical force through implements (wheels, blades)
- entrainment of dust particles by the action of turbulent air currents, such as wind erosion of an exposed surface.

Given the transient nature of the proposed construction works, a qualitative assessment of particulate matter impacts has been carried out.

Conservative estimates of dust-generating potential were primarily based on guidance provided in the United Stated Environment Protection Authority document *AP-42 Compilation of Air Pollutant Emission Factors* (1995). Emission factors applied relate to the dust-generating potential for varying sources and modes of operation.

Particulate emissions would be associated with a number of mobile sources and potential wind erosion of freshly exposed areas. It has been assumed that intensive daytime construction works would be carried out, with dust-generating potential limited to short-term periods of intensive work.

An indicative breakdown of anticipated sources and dust-generating activities follows. The assumptions made may require verification upon selection of the preferred construction schedule:

- Dust from loading aggregate material on trucks may result in emission rates of 0.04 kilograms per tonne of total suspended particulates (TSP) and 0.01 kilograms per tonne of PM10. The loading of 10 by 15 cubic metre capacity trucks over a 10-hour working day would result in a total of 150 cubic metres, or approximately 300 tonnes, of material per day. Dust generation from truck loading would, therefore, be expected in the range of 12.0 kilograms of TSP to 3.0 kilograms of PM10 per day.
- Operation of a bulldozer (or scraper) could result in emission rates of 2.3 kilograms per hour of TSP and 0.5 kilograms per hour of PM10. During a typical 10-hour working day, dust generation from a bulldozer would be expected in the range of 23.0 kilograms of TSP to 5.0 kilograms of PM10 per day.
- Emissions of dust from the movement of vehicles on unsealed roads have been estimated at values of 1.4 kilograms per vehicle per kilometre of TSP and 0.5 kilograms per vehicle per kilometre of PM10. Two movements per hour, travelling an average of 1,500 metres, could be expected to result in dust generation of 42 kilograms per day of TSP to 15 kilograms per day of PM10 over a 10-hour working day.

- Wind erosion from exposed surfaces may occur for disturbed areas. Dust entrainment rates from exposed surfaces would vary with wind gusts, threshold wind speeds, friction velocities, precipitation events, silt loadings and the number of disturbances that restore the erosion potential. Dust emissions from exposed surfaces could be expected to range between 0.4 kilograms per hectare per hour of TSP to 0.2 kilograms per hectare per hour of PM10 (NSW Minerals Council, 2000, Particulate Matter and Mining Interim Report). Over a nominal 1000 metre by 200 metre area (20 hectares), and a 10-hour working day, dust generation from exposed surfaces could be expected between 80 kilograms of TSP to 40 kilograms of PM10.

The air quality impact of a fugitive dust source primarily depends on the quantity and drift potential of the dust particles injected into the atmosphere. In addition to large dust particles that settle out near the source (often creating a local nuisance problem), considerable amounts of fine particles are usually also emitted and dispersed over far greater distances. PM_{10} represents a relatively fine particle size range and, as such, is not overly susceptible to gravitational settling. PM_{10} particulate matter, therefore, contributes to the concentration of dust levels in the surrounding ambient air environment.

The potential drift distance of particles is governed by the initial injection height of the particle, the terminal settling velocity, the reflection co-efficient and the specific gravity of the particle(s). The degree of atmospheric turbulence is also important. The total amount of dust generated would depend on the properties of the soil material (silt and moisture content), the activities undertaken and the prevailing meteorological conditions.

From the above, the worst-case total dust levels generated over a 10-hour construction day were calculated to be between 157 kilograms of TSP to 63 kilograms of PM_{10} over a typical work area of 1,000 metres by 200 metres. Although the qualitative construction air impact assessment cannot provide a statement of compliance with current air quality goals, the anticipated levels of particulate matter are not considered excessive. Received impacts would be expected to decrease significantly with distances from the source. Negligible dust impacts from the construction works would be anticipated beyond 200 metres from the work areas.

During unfavourable meteorological conditions, such as dry and windy conditions, dust emissions may be higher and would require specific corrective measures. The Construction Environmental Management Plan (CEMP) would identify triggers and procedures for dealing with these conditions.

Notwithstanding the above, the calculated dust loads generated over a typical construction day are small and would not be expected to result in reduced local air quality at the nearest potentially affected receptors, given the implementation of the recommended safeguards (see Section 7.1.2).

5.1.1 Concrete batching plants

At this stage, and depending on finalisation of design, two concrete batching plants are expected to be required for construction of the proposed upgrade. The locations of these compounds are anticipated to be at the northern and southern extremities of the proposed upgrade. The operation of the concrete batching plants would have the potential to affect local ambient air quality.

The operation of the concrete batching plants would require ongoing transport of materials to and from the site via truck. Trucks would transport fly ash, cement and aggregate to the batching site, and would be used for the ongoing transport of batched concrete to particular construction sites. While it is anticipated that the maximum output would be 1,000 cubic metres per day, batching plants would nominally produce between 600 and 700 cubic metres per day.

These nominal daily production rates would be expected to require approximately eight trucks over eight hours at four runs per day (a total of 250 movements). Vehicular emissions and dust generated during transport would not be expected to result in adverse air quality impacts given the safeguard measures proposed and because the road delivery vehicles would typically use the existing travel lanes of the Pacific Highway.

Final site selection for concrete batching plants would be carried out with consideration to potential air quality impacts. Ideally, concrete batching plants should not be located within 250 metres of a sensitive land use area (without further assessment and implementation of mitigation measures).

Mitigation measures are proposed to minimise the potential for adverse air quality impacts (see Section 7).

5.1.2 Asphalt batching plants

Depending on the final pavement design, there may be a requirement for one or more asphalt batching plants.

Site selection would be carried out within consideration to potential air impacts. Consistent with the concrete batching plants, any required asphalt batching plant(s) should not be located within 250 metres of a sensitive land use area (without further assessment and implementation of mitigation measures). It is expected that odour emissions would be a key consideration in final asphalt batching plant placement.

5.2 Operation

5.2.1 Input data

Annual average daily traffic flows for the proposed upgrade are provided in Tables 5-1 and 5-2. Traffic flows would be expected to increase between 2011 and 2021 on the proposed upgrade, as shown in Table 5-1.

Table 5-1: Annual average daily traffic (proposed upgrade)

Link	Direction	2011	2021
Bypass, south of South Kempsey Interchange	Northbound	7,676	11,153
	Southbound	7,623	11,095
Bypass, north of South Kempsey Interchange	Northbound	2,779	5,028
	Southbound	3,128	5,904
Bypass, north of Frederickton Interchange	Northbound	6,037	8,908
	Southbound	6,566	9,829
Bypass, north of Stuarts Point Road Interchange	Northbound	6,460	9,643
	Southbound	5,915	8,883

Notes:
Source: Kempsey to Eungai Upgrading the Pacific Highway, Traffic and Transport Assessment technical paper

Traffic flows at the three locations considered in Table 5-2 would decrease with the proposed upgrade.

Table 5-2: Comparison of annual average daily traffic (two way)

Road	Location	2011		2021	
		Without upgrade	With upgrade	Without upgrade	With upgrade
Pacific Highway	South of South Street	15,298	10,676	22,247	15,194
Pacific Highway	North of Frederickton	12,041	10,989	14,631	16,473
Bypass	North of Stuarts Point Interchange	12,376	12,376	18,525	18,525

Notes:

Source: Kempsey to Eungai Upgrading the Pacific Highway, Traffic and Transport Assessment technical paper

For ease of assessment, this study assessed potential emission rates for the factors presented in Table 4-1 with the assumption that the 2006 data closely represents 2011 conditions, and the reported 2016 data provides a reasonable representation of 2021 conditions. Given the vehicular emission typically reduce over time (with improvements in fuel and combustion technologies), the adopted approach is considered to provide emission rates that are conservative.

Emission rate estimates have been calculated with consideration of the modelled traffic flow data. Emission estimates were based on emission rates for Passenger Petrol Vehicles and Heavy Duty Diesel Vehicles only. Calculated peak hour emission rates are provided in Tables 5-3 and Table 5-4.

Table 5-3: AM 1-hour emission rates (proposed upgrade)

Link assessed	AM 1-hour traffic flow (veh/hr)		Emission rate by pollutant (kg/km/hr)			
	Car	Heavy vehicle	CO	NO_X	HC	PM_{10}
Bypass, south of South Kempsey Interchange						
Northbound 2011	506	69	4.39	1.67	0.37	0.03
Southbound 2011	414	69	3.64	1.53	0.31	0.03
Northbound 2021	736	100	2.98	1.77	0.26	0.02
Southbound 2021	603	101	2.48	1.60	0.22	0.02
Bypass, north of South Kempsey Interchange						
Northbound 2011	176	29	1.55	0.64	0.13	0.01
Southbound 2011	193	14	1.63	0.49	0.14	0.01
Northbound 2021	328	47	1.33	0.81	0.12	0.01
Southbound 2021	351	35	1.39	0.75	0.12	0.01
Bypass, north of Frederickton Interchange						
Northbound 2011	289	39	2.50	0.95	0.21	0.02
Southbound 2011	373	47	3.22	1.19	0.27	0.02
Northbound 2021	430	56	1.73	1.02	0.15	0.01
Southbound 2021	559	70	2.25	1.30	0.20	0.02

Link assessed	AM 1-hour traffic flow (veh/hr)		Emission rate by pollutant (kg/km/hr)			
	Car	Heavy vehicle	CO	NO_X	HC	PM_{10}
Bypass, north of Stuarts Point Road Interchange						
Northbound 2011	294	49	2.59	1.08	0.22	0.02
Southbound 2011	305	62	2.73	1.26	0.24	0.02
Northbound 2021	443	72	1.82	1.16	0.16	0.02
Southbound 2021	460	92	1.93	1.34	0.17	0.02

Notes:

Veh/hr = vehicles per hour

Kg/km/hr = kilograms per kilometre per hour

CO = Carbon Monoxide

NO_X = Oxides of Nitrogen

HC = hydrocarbons (benzene and associated)

PM_{10} = Particulate matter ≤ 10µm [microns] in aerodynamic diameter

Table 5-4: AM 1-hour comparative emission rates (two way)

Road / location assessed	AM 1-hour traffic flow (veh/hr)		Emission rate by pollutant (kg/km/hr)			
	Car	Heavy vehicle	CO	NO_X	HC	PM_{10}
Pacific Highway, south of South Street						
Without upgrade 2011	920	138	8.03	3.20	0.69	0.06
With upgrade 2011	617	113	5.47	2.40	0.47	0.04
Without upgrade 2021	1339	200	5.45	3.37	0.48	0.05
With upgrade 2021	862	171	3.61	2.50	0.33	0.03
Pacific Highway, north of Frederickton						
Without upgrade 2011	759	92	6.54	2.37	0.56	0.04
With upgrade 2011	675	79	5.80	2.07	0.49	0.03
Without upgrade 2021	981	115	3.92	2.22	0.34	0.03
With upgrade 2021	989	119	3.96	2.26	0.34	0.03
Bypass, North of Stuarts Point Interchange						
Without upgrade 2011	599	112	5.31	2.36	0.46	0.04
With upgrade 2011	599	112	5.31	2.36	0.46	0.04
Without upgrade 2021	903	164	3.75	2.50	0.34	0.03
With upgrade 2021	903	164	3.75	2.50	0.34	0.03

Notes:

Veh/hr = vehicles per hour

Kg/km/hr = kilograms per kilometre per hour

CO = Carbon Monoxide

NO_X = Oxides of Nitrogen

HC = hydrocarbons (benzene and associated)

PM_{10} = Particulate matter ≤ 10µm [microns] in aerodynamic diameter

Emissions of pollutants from surrounding roads have not been considered within this assessment.

Calculated emission rates were compared to emission estimates for the Pacific Highway Bulahdelah Upgrade (RTA 2004), which for carbon monoxide, nitrogen oxides and particulate matter were in the respective range of 7.5, 2.9 and 0.06 kilograms per kilometre per hour under the assessments 10 year time horizon upgrade conditions. Air quality impacts for the Pacific Highway Bulahdelah Upgrade, a recent comparable project, were within acceptable limits.

Impact potential is a function of flow conditions, vehicle speed, traffic composition, topography, meteorological conditions and existing background levels. However, the following impact profiles are considered likely for each link assessed comparatively: Pacific Highway, south of South Street — decrease with proposed upgrade for 2011 flow conditions:

- *Pacific Highway, south of South Street* — decrease with proposed upgrade for 2021 flow conditions.
- *Pacific Highway, north of Frederickton* — decrease with proposed upgrade for 2011 flow conditions.
- *Pacific Highway, north of Frederickton* — slight increase with proposed upgrade for 2021 flow conditions, reflecting the traffic forecasts for this section with increased traffic flow expected from local traffic choosing to travel along the proposed upgrade to the Frederickton interchange, accessing Kempsey from the north via Frederickton to avoid congestion across the existing Macleay River bridge and in south Kempsey.
- *Bypass, North of Stuarts Point Interchange* — no material change in pollutant levels for 2011 flow conditions.
- *Bypass, North of Stuarts Point Interchange* — no material change in pollutant levels for 2021 flow conditions.

An assessment of air quality issues has been carried out and presented in the following Section of this report.

5.2.2 Air quality impact modelling

Approach to modelling

Estimates of incremental air quality impacts were made through the use of the CALINE4 dispersion model. Concentrations of carbon monoxide, nitrogen oxides, hydrocarbons and particulate matter likely to be produced in the vicinity of the proposed upgrade were determined. CALINE4 uses Gaussian diffusion algorithms with a mixing zone concept that characterises pollutant dispersion from a low level line based source (e.g. a roadway).

Maximum 1-hour (and where relevant 8-hour) concentrations were predicted for identified pollutants. CALINE4 has the limitation that long-term 24-hour and annual averages cannot be predicted. In the case of particulate matter predictions, 1-hour levels were used as a worst-case representation of 24-hour impacts (to allow comparison with adopted ambient air goals).

Nitrogen dioxide impacts were assessed by assuming a conversion rate of 20% by weight from nitric oxide to nitrogen dioxide. Although the conversion value would be expected to change depending on the time of day and distance from the kerb, the 20% ratio is generally consistent with works presented within the RTA (1997) document: RTA Air Quality Monitoring Program.

Hydrocarbon impacts were assessed by adopting benzene as the key component of emissions that required assessment. Hydrocarbon analysis of vehicle exhausts, petrol and petrol vapour presented in Atmospheric Hydrocarbons in Sydney: Compositions of the Sources (Nelson and Quigley 1982) indicated a benzene component, by mass, of 2.6% in petrol and 5% in vehicular exhaust. A 5% benzene component has been adopted for this study.

Three off-set distances (10, 20 and 50 metres) from the near-side carriageway were assessed. Model scenarios were assessed for 2011 and 2021 conditions, with and without the proposed upgrade. Two-way traffic flow and associated emission rates, consistent with values presented in Table 5-4, were adopted.

A wind speed of 0.5 metres per second was selected with a worst-case wind angle (and standard deviation) of 45°. An atmospheric stability class of 7, a mixing height of 1,000 metres and an ambient temperature of 20 °C were also adopted for all predictions.

Table 5-5: Maximum predicted incremental concentrations (2011)

Road/location assessed	Off-set distance (metres)	Pollutant									
		CO – 1 hour		CO – 8 hour		NO_2 – 1 hour		Benzene – 1 hour		PM_{10} – 1 hour	
		Without upgrade	With upgrade	Without upgrade	With upgrade	Without upgrade	With upgrade	Without upgrade	With upgrade	Without upgrade	With upgrade
Pacific Highway, south of South Street											
	0	2.77	1.92	1.40	0.96	396.5	303.4	0.033	0.023	17.1	13.3
	10	1.27	0.89	0.90	0.62	182.3	141.9	0.015	0.011	7.8	6.2
	50	0.38	0.27	0.33	0.23	54.2	43	0.005	0.003	2.3	1.9
Pacific Highway, north of Frederickton											
	0	2.28	2.03	1.14	1.02	297.2	261.3	0.027	0.024	12.6	11.0
	10	1.06	0.95	0.74	0.66	137.7	121.5	0.012	0.011	5.8	5.1
	50	0.32	0.29	0.27	0.24	41.3	36.8	0.004	0.003	1.8	1.6
Bypass, North of Stuarts Point Interchange											
	0	1.87	1.87	0.93	0.93	298.5	298.5	0.022	0.022	13.2	13.2
	10	0.87	0.87	0.60	0.60	139.3	139.3	0.010	0.010	6.1	6.1
	50	0.26	0.26	0.22	0.22	42.2	42.2	0.003	0.003	1.8	1.8
Ambient air quality goal		30 mg/m^3 – 1 hour		10 mg/m^3 – 8 hour		246 $\mu g/m^3$ – 1 hour		0.029 mg/m^3 – 1 hour		50 $\mu g/m^3$ – annual	

Notes:

Values shown as shaded are incremental impacts predicted above the adopted ambient air quality goal

CO = Carbon Monoxide

NO_2 = Nitrogen Dioxide

PM_{10} = Particulate matter ≤ 10□m [microns] in aerodynamic diameter

mg/m^3 = milligrams per cubic metre

$\mu g/m^3$ = micrograms per cubic metre

Table 5-6: Maximum predicted incremental concentrations (2021)

Road/location assessed	Off-set distance (metres)	Pollutant									
		CO – 1 hour		CO – 8 hour		NO_2 – 1 hour		Benzene – 1 hour		PM_{10} – 1 hour	
		Without upgrade	With upgrade	Without upgrade	With upgrade	Without upgrade	With upgrade	Without upgrade	With upgrade	Without upgrade	With upgrade
Pacific Highway, south of South Street											
	0	1.83	1.25	0.94	0.63	405.9	309.6	0.022	0.016	13.7	10.4
	10	0.83	0.57	0.60	0.41	183.6	142.6	0.010	0.007	6.2	4.7
	50	0.24	0.17	0.21	0.15	53.3	42.6	0.003	0.002	1.8	1.6
Pacific Highway, north of Frederickton											
	0	1.35	1.36	0.68	0.69	274.5	279.5	0.016	0.016	9.3	9.3
	10	0.62	0.63	0.44	0.44	126.1	128.6	0.007	0.008	4.3	4.3
	50	0.18	0.19	0.16	0.16	37.6	38.0	0.002	0.002	1.2	1.3
Bypass, North of Stuarts Point Interchange											
	0	1.29	1.29	0.65	0.65	309.2	309.2	0.016	0.016	10.4	10.4
	10	0.59	0.59	0.42	0.42	142.2	142.2	0.007	0.007	4.7	4.7
	50	0.18	0.18	0.15	0.15	42.2	42.2	0.002	0.002	1.4	1.4
Ambient air quality goal		30 mg/m^3 – 1 hour		10 mg/m^3 – 8 hour		246 $\mu g/m^3$ – 1 hour		0.029 mg/m^3 – 1 hour		50 $\mu g/m^3$ – annual	

Notes:

Values shown as shaded are incremental impacts predicted above the adopted ambient air quality goal

CO = Carbon Monoxide

NO_2 = Nitrogen Dioxide

PM_{10} = Particulate matter ≤ 10□m [microns] in aerodynamic diameter

mg/m^3 = milligrams per cubic metre

$\mu g/m^3$ = micrograms per cubic metre

Limitations of modelling

The assessment technique adopted for this study provided a conservative estimate of air quality impacts. The CALINE4 downwind predictions are likely to be over-predicted for the following reasons:

- The model ignores, or only partly accounts for, horizontal and vertical variation in turbulence, wind speed and wind direction within the boundary layer.
- The model assume-state steady conditions, precluding simulation of events such as inversion breakup fumigation.
- The model ignores longitudinal diffusion (parallel to the plume axis), which restricts applications to wind speeds above about 0.5 metres per second.
- The complex flow in the wakes of obstacles cannot be precisely parameterised.

However, these limitations are well understood in the industry and the CALINE4 model is widely used by environmental regulators throughout Australia. It is generally understood that the CALINE4 model is suited to a wider range of applications than most other Gaussian Plume models.

5.2.3 Comment on predicted air impact profiles

Carbon monoxide

Compliance with the adopted 1-hour goal of 30 milligrams per cubic metre was predicted to be achieved for each off-set distance assessed. With the proposed upgrade, an improvement in incremental pollutant levels would be expected. Given that the peak 1-hour incremental pollutant level was predicted at 1.92 milligrams per cubic metre (with the proposed upgrade), no cumulative carbon monoxide issues would be expected.

Predictions for 8-hour pollutant levels were all well below the adopted ambient air quality standard of 10 milligrams per cubic metre.

Nitrogen dioxide

An exceedance of the 1-hour nitrogen dioxide goal of 246 micro-grams per cubic metre was predicted both with and without the proposed upgrade (in 2021) at each road assessed. Incremental pollutant levels above the adopted ambient goal occurred at the road side kerb, with a zero metre separation distance.

At distances of 10 metres and beyond, compliance with the nitrogen dioxide ambient air quality goals would be expected.

It is anticipated that future improvements in emission controls for road vehicles would significantly reduce the actual level of pollutant impact.

Benzene

Compliance with the adopted 1-hour goal for benzene of 0.029 milligrams per cubic metre was predicted at each off-set distance with the proposed upgrade (under 2011 and 2021 conditions).

A single exceedance was predicted at the road-side (separation distance of zero metres), at the Pacific Highway, south of the South Street location under 2011 conditions, without the proposed upgrade. With consideration of the worst-case 1-hour benzene predictions, it is reasonably assumed that annual concentrations would be well within acceptable ranges.

PM_{10}

The predicted dust concentration levels were all well below the adopted ambient air goal for PM_{10} of 50 micrograms per cubic metre. No cumulative issues are anticipated.

Summary

A decrease in emissions to air, and associated pollutant levels, from operational sources would be expected between without upgrade and with upgrade conditions due to the improvement in daily traffic flow conditions. Emissions, and associated pollutant levels, would be further expected to improve between 2011 and 2021 conditions due to improved fuel composition and associated combustion technologies. Potential carbon monoxide, hydrocarbon, particulate matter, and sulfur dioxide levels would be expected to be within acceptable levels at all sensitive receiver locations based on the predictive calculations.

At distances of 10 metres and greater from the near-side kerb, nitrogen dioxide pollutant levels would be anticipated to fall well below the ambient air quality goals.

With the proposed upgrade, emission rates and associated pollutant levels are predicted to generally decrease when compared with conditions without the proposed upgrade. An improvement in impact potential would also be expected given that the source of emissions would generally have moved away from existing urban areas (compared to the existing through town highway situation).

6. Greenhouse gases

This Section identifies greenhouse gas emission sources relevant to the proposed upgrade construction and operation. In order to quantify the emissions, a number of estimates have been made, according to the methodology in Section 6.1.

6.1 Methodology

Management of Australian greenhouse gas issues is undertaken through the Australian Government agency, the Australian Greenhouse Office (AGO).

As part of the Environmental Assessment, an assessment of likely greenhouse gas emissions, and their significance, was conducted. All emissions reported below are estimates, prepared in accordance with the methodology in the *Factors and Methods Workbook* (AGO 2006). All greenhouse gas estimates are reported as tonnes of carbon dioxide equivalent (t $CO_{2\text{-}e}$) except where noted otherwise.

A range of greenhouse gas emissions would be attributed to the proposed upgrade. Emissions are typically divided into:

- emissions directly caused by an activity, such as operation of construction plant and clearing of vegetation
- emissions to provide supplementary energy for an activity, such as generating the electricity used on-site
- indirect emissions, such as those emitted to produce materials used for construction, or from fuel used by vehicles driving on the road
- emissions associated with traffic on the proposed upgrade and on the Pacific Highway (base case) under 2011 and 2021 conditions.

Information sources and assumptions are detailed below.

6.1 Construction

Sources of greenhouse gases during the construction period would be likely to include:

- fuel use by construction plant and equipment
- vegetation clearing
- indirect emissions for extraction of fuel used on-site, emissions embodied in key construction materials, and emissions from putrescible wastes generated (such as domestic-type waste and sewage).

6.1.1 Fuel consumption

A review of other Pacific Highway Upgrade Program projects was conducted, to provide an estimate of fuel use during construction of the proposed upgrade. Estimated fuel use for other Pacific Highway projects is shown in Table 6-1.

Table 6-1: Estimated construction fuel requirements, Pacific Highway works

Section of Pacific Highway	Diesel (L)	Petrol (L)	Length	Fuel est. kL/km
Coopernook to Moorland	2,100,000	22,400	10.2	208
Moorland to Herons Creek	15,000,000	Not identified	22.2	676
Tugun bypass	5,000,000	Not identified	7	714
Karuah to Bulahdelah	9,000,000	3,000,000	36.75	327

Notes:

L = Litres

kL/km = kilolitres per kilometre

Table 6-1 shows the different estimates of fuel use, with an average of 481 kiloLitres per kilometre during construction.

The proposed upgrade is approximately 40.8 kilometres long and is, therefore, estimated to use approximately 20 million litres of fuel. The construction works would predominantly use industrial plant and vehicles, which were assumed to be 100% diesel. The resulting greenhouse gas emissions were estimated at 53,000 t $CO_{2\text{-}e}$.

6.1.2 Vegetation clearing

It is expected that a total of 261 hectares of vegetation would be permanently cleared for the proposed upgrade (refer to Table 11-4 of the Environmental Assessment). Vegetation clearing was assessed using the AGO's (2004) *National Carbon Accounting Toolbox* and data viewer. This software models the carbon content in the vegetation, which is then assumed to be emitted on clearing. The toolbox only accounts for carbon dioxide emissions.

The model was run for seven locations along the length of the route, to determine the level of carbon that could be supported by local species. A range of levels of tree carbon was identified, from 112–115 tonnes of carbon per hectare in the floodplain and wetland areas, through to 186–188 tonnes of carbon per hectare at both the southern and northern extremes of the range.

When assessed against the average level of tree carbon for the local area, emissions of 139,000 tonnes of carbon dioxide were estimated.

6.1.3 Indirect emissions

Indirect emissions identified as potentially significant for the construction works are:

- emissions associated with the extraction of diesel, identified as 'Scope 3' emissions in the AGO (2006) *Factors and Methods Workbook*
- emissions embodied in the products used on-site, particularly concrete and steel.

Additional clearing for work sites, access, and ancillary facilities, such as batching plants, would also be required, but this would be temporary and revegetation is planned for such locations. No greenhouse gas emissions were attributed to temporary clearing, in accordance with AGO reporting standards, as this is not considered a land use change.

Indirect emissions associated with diesel use were calculated at 0.3 t $CO_{2\text{-}e}$ per kilolitre (full fuel cycle factor), resulting in an additional 6,000 t $CO_{2\text{-}e}$.

Quantities identified in the concept design phase, and the emissions required to produce these materials, are shown in Table 6-2 below. Concrete quantities were estimated from the concept design, and the likely cement portion was then assessed. Steel would predominantly be associated with reinforcing for structures and pipes. Greenhouse gas emissions were estimated in accordance with BlueScope Steel's (2004) *Health, Safety, Environment and Community Report.*

Table 6-2: Estimated construction material requirements and embodied emissions

Material	Quantity	Greenhouse gas emissions (t CO_{2-e})
Concrete (pavement, piping, bridge structures)	4,188,149 (m^3)	59,830
Steel (reinforcing)	11,190 (t)	8,070
TOTAL		**67,904**

Notes:

m^3 = cubic metres

t = tonnes

6.1.4 Overall construction emissions

The calculations above show the following emissions:

- fuel consumption: 53,000 t CO_{2-e}
- vegetation clearing: 139,000 t CO_2
- indirect emissions from diesel use: 6,000 t CO_{2-e}
- indirect emissions from materials: 67,900 t $CO_{2-e.}$

The total anticipated emissions are approximately 266,000 t CO_{2-e}.

The Australian Greenhouse Office's national greenhouse gas inventory for 2004 (AGO 2006b) reported that 76,200,000 tonnes of carbon dioxide equivalent was emitted by transport sources, throughout Australia out of a total of 564,700,000 tonnes. Greenhouse gas emissions attributable to construction of the proposed upgrade would represent a contribution of less than 0.05% to this total.

6.2 Operation

Ongoing greenhouse gas emissions from operation of the proposed upgrade are expected to largely relate to the use of the road. Although the road itself would not produce emissions, the use of the road by motor vehicles would. These are therefore considered indirect emissions. Maintenance activities would be considered direct emissions; however they are not anticipated to be a major source for this project.

The greenhouse gas emissions during operation were estimated by comparing two scenarios. Firstly, estimated greenhouse gas emissions were calculated for continued use of the existing Pacific Highway, without the proposed upgrade. Secondly, estimated emissions were calculated for traffic predicted to use both the proposed upgrade and the existing highway after the proposed upgrade is opened to traffic.

The traffic model used to calculate greenhouse gas emissions associated with the operation of the proposed upgrade compares the total vehicle kilometres travelled on the existing highway (without the proposed upgrade) with the total vehicle kilometres travelled on both the existing highway and the proposed upgrade following project completion. Traffic using other parts of the local network have not been considered quantitatively. Other assumptions made for the calculation of greenhouse gas emissions during operation are outlined below.

Assumptions used in calculation of greenhouse gas emissions during operation

For the operational fuel use assessment, the following methodology and assumptions were used to limit the complexities and uncertainties associated with the analysis:

- The assessment compared traffic on the proposed upgrade against a base case of traffic on the Pacific Highway, should the proposed upgrade not proceed. This comparison was made for 2011 and for 2021.
- The proposed upgrade and the Pacific Highway were assessed in segments, using the same traffic model as elsewhere in the Environmental Assessment.
- As with the traffic model, no network improvements have been assumed for the existing Pacific Highway between Kempsey and Frederickton. The conditions currently experienced on this section of the existing highway, particularly in Kempsey, are predicted to deteriorate over time due to the ongoing constraints on local traffic (refer Chapter 14), which is reflected in modelled future scenarios with and without the proposed upgrade. Although these local traffic conditions may be addressed by another party at some time in the future, the timing and implementation of any improvements are beyond the scope of this project. As such, the greenhouse gas assessment is based on the worst-case scenario for local traffic conditions without any improvements.
- Each segment was classified as having either free-flowing traffic (such as a rural road or freeway), or stop-start traffic (such as Kempsey town centre). No further allowance was made for intersections, grade or other factors.
- Based on the classification, fuel use in each situation was calculated (stop-start fuel efficiency from CSIRO 2004; free-flow fuel efficiency from Apelbaum Consulting Group 2001) and then converted to greenhouse gas emissions, in accordance with the Australian Greenhouse Office's (2006a) Factors and Methods Workbook.
- Potential changes to the vehicle fleet (such as fuel mix, alternative fuels, use of public transport or vehicle efficiency) and changes to the transport network (such as increased or decreased use of freight rail) were not considered.

Trends with significant implications for the greenhouse gas analysis for the project are evident within the traffic modelling results. Analysis of the total distances travelled on sections of the existing and proposed highway, as described above, clearly indicates that due to local traffic conditions some motorists would be expected use the proposed upgrade during local trips rather than continue to use the local routes currently followed. These changes in route would result in additional distance travelled on the existing highway and the proposed upgrade when taken in combination and compared to the distance travelled on the existing highway without the upgrade in place.

The travel choices predicted for local motorists would partly result from improvements to road safety and travel efficiency on the proposed upgrade. However, this predicted behaviour is considered to be mostly associated with the proposed upgrade providing opportunities for local traffic to avoid perceived constraints on local roads. For example, rather than exiting the proposed upgrade at the South Kempsey interchange to get to a destination in Kempsey, some motorists are expected to choose to exit at Frederickton and drive back down the existing highway to Kempsey, in order to avoid perceived travel constraints around the Kempsey town centre. These trips, while longer in distance, may reduce perceived or actual travel times for motorists. This scenario would most likely change if the prevailing local traffic conditions in Kempsey were addressed. However, consideration of the timing and nature of any such improvements are beyond the scope of this project.

While these trends are associated with driver choices over the entire local network around the proposed upgrade, they relate most clearly to traffic behaviour on the existing highway between Kempsey and Frederickton, in particular in Kempsey town centre.

The proposed upgrade would help to address local traffic conditions by providing a safer, more efficient means of travel for through traffic between Kempsey and Frederickton, thereby improving fuel efficiency and reducing the contribution of through traffic to greenhouse gas emissions.

The trip choice decisions discussed above have certain implications for this project. The significant greenhouse benefits that would arise from the rerouting of through traffic from stop-start conditions in Kempsey and Frederickton to free-flowing conditions on the proposed upgrade would be countered (when considering only the existing highway and the proposed upgrade), by the aggregated impacts of local traffic trips diverting onto the proposed upgrade.

Based on these assumptions and using traffic modelling results for 2011 and 2021, the total volume of greenhouse gas emissions were calculated. These are outlined in Table 6-3.

Table 6-3 Ongoing greenhouse gas emissions from vehicles using the existing highway and the proposed upgrade

Scenario	Annual greenhouse gas emissions 2011	Annual greenhouse gas emissions 2021
Without proposed upgrade	96,000 t $CO_{2\text{-}e}$	131,000 t $CO_{2\text{-}e}$
With proposed upgrade	109,000 t $CO_{2\text{-}e}$	159,000 t $CO_{2\text{-}e}$

Note $CO_{2\text{-}e}$ = carbon dioxide equivalent

t = tonnes

The results shown in Table 6-3 indicate an increase in greenhouse gas emissions from traffic using the bypassed sections of the existing highway and the proposed upgrade. The estimated annual greenhouse gas emissions detailed in Table 6-3 for the scenario with the proposed upgrade clearly indicate the implications of the additional travel on the existing highway and the proposed upgrade discussed above. The apparent increase in greenhouse gas emissions following opening of the upgrade to traffic does not take into account or isolate the impacts of the related changes in behaviour on the local road network that have contributed to these estimates.

A more detailed study of the local network would be necessary to determine the particular features that are driving the increased distances travelled on the sections of existing and proposed upgrade that are addressed in this analysis. The offsets against the predicted greenhouse gas emissions detailed in Table 6-3 have not been quantified because a sufficiently detailed local network traffic model is not available at this time. Further to this, while it is recognised that travel efficiency would be a factor in the individual travel choices made, the model does not allow for any potential reductions in greenhouse gas emissions due to associated fuel usage efficiencies.

7. Summary of impacts and mitigation

7.1 Construction air quality impacts

7.1.1 Summary of potential impacts

Based on the scale of the proposed construction works, only intermittent localised impacts would be expected. Particulate matter impacts would be confined to the general work areas and would be short-term.

It is expected that the proposed works would comply with the NSW Department of Environment and Conservation's ambient air quality criteria for particulate matter. Potential nuisance impacts would be minimised during construction through the implementation of appropriate safeguard measures as described below.

Short-term 24-hour PM_{10} concentration impacts could occur during major earthworks activities and during worst-case meteorological conditions. Assuming adherence with the recommended mitigation measures and safeguards, the referenced air quality goals would be unlikely to be infringed during the construction activities.

7.1.2 Mitigation measures and safeguards

An Air Quality Management Sub-plan would be developed by the nominated construction contractor and included with the CEMP for the project. Required reporting, measurements and mitigation measures would be outlined as required.

Dust and vehicle emissions represent the greatest potential for air quality impacts during construction. Dust suppression is proposed during all construction works to minimise impacts on the local air shed. The implementation of effective management practices would minimise the potential for impacts. The following mitigation measures and safeguards are proposed for the construction phase of the project:

- Undertake a pre-construction air quality monitoring program to collate baseline conditions (to be referenced during the construction stage air quality monitoring).
- Apply water to aggregate storage piles, internal unsealed access roads and work areas. (Application rates should be related to atmospheric conditions and the intensity of construction operations.)
- Where applicable, sweep sealed roads to remove deposited material that could generate dust.
- Revegetate and stabilise disturbed areas as soon as work activities are completed to prevent or minimise wind blown dust.
- Avoid or minimise dust-generating activities (particularly clearing and excavating) during dry and windy conditions.
- Impose site speed limits on all construction vehicles.
- Restrict vehicle and machinery movements to designated areas during the construction works.

- Use rumble grids and wheel-wash facilities at the site exit(s) to remove mud and dust from vehicles.
- Cover vehicles transporting material to and from the site(s) immediately after loading to prevent wind-blown dust emissions and spillages. Securely fix tailgates of road transport trucks prior to loading and immediately after unloading.
- Maintain and regularly service construction plant and equipment so that vehicular emissions remain within relevant air quality guidelines and standards.
- Carry out site selection for the concrete batching plants (and any required asphalt batching plants), with consideration of potential air quality impacts.
- Consider prevailing meteorological conditions (north-easterlies during summer for example) when establishing construction compounds and the batching plant conveyors.
- Adequately store all bulk materials. In particular, cement would be stored in silos fitted with fabric pulse filters, designed, serviced and maintained to accommodate the maximum allowable emission level of particulates per cubic metre in the exhaust gas stream.

7.2 Operational air quality impacts

7.2.1 Summary of potential impacts

A decrease in air emissions, and associated pollutant levels, from operational sources would be expected between without upgrade and with upgrade conditions due to the improvement in daily traffic flow conditions. Emissions, and associated pollutant levels, would be further expected to improve between 2011 and 2021 conditions due to improved fuel composition and associated combustion technologies. Potential carbon monoxide, hydrocarbon, particulate matter, and sulfur dioxide levels would be expected to be within acceptable levels at all sensitive receiver locations based on the predictive calculations.

With the proposed upgrade, emission rates and associated pollutant levels were predicted to generally decrease when compared with conditions without the proposed upgrade. An improvement in impact potential would also be expected given that the source of emissions would generally have moved away from existing urban areas (compared to the existing through town highway situation).

Final pollutant levels would be typical of rural-residential areas adjacent to major roads.

Concentrations owing to emissions from the proposed upgrade at nearby residences and key receptors such as local schools would be expected to be significantly lower than the adopted Department of Environment and Conservation air quality goals.

Specifically, compliance with ambient air quality goals, and satisfactory local ambient air shed environs would be expected for the following nearest potentially affected receptors (given an off-set distance of more than 10 metres from the nearside carriageway is present):

- Kempsey Seventh Day Adventist Church, 108 Crescent Head Road, Kempsey
- Kempsey Adventist Primary School, 108 Crescent Head Road, Kempsey
- Frederickton Public School, Great North Road, Frederickton
- Frederickton Golf Course, Yarrabindinni Road, Frederickton

- Kempsey East Public School, Innes Street, Kempsey.
- East Kempsey Cemetery, Naiooka Street, Kempsey
- Frederickton Uniting Church, Macleay Street (Pacific Highway), Frederickton
- Frederickton Cemetery, Great North Road, Frederickton
- Bellimbopinni Public School, Pacific Highway, Bellimbopinni.

7.2.2 Mitigation measures and safeguards for operation

No project-specific operational controls are considered necessary.

The preferred approach to addressing road-based air quality impacts is through state-wide or region-wide strategies, such as progressive reduction of vehicle air emission standards; in-service inspections to ensure vehicle mufflers/exhaust systems are well maintained; and the integration of transportation and land use planning. These strategies offer the most promise in addressing existing (and potential) air quality impacts.

7.3 Greenhouse gas impacts

7.3.1 Summary of impacts

The anticipated emissions are compared against Australia's national greenhouse gas inventory for 2004, in Table 7-1 below.

Table 7-1: Greenhouse gas emissions assessment for the proposed upgrade

	Greenhouse gas emissions 2011 (t CO_{2-e})	Comparable Australian greenhouse gas emissions 2004 (t CO_{2-e})	Proportion attributable to project
Construction-related	266,000	564,700,000[1]	<0.005%
Operational (2011)	109,000	76,200,000[2]	<0.01%

Note: 1 – Total greenhouse gas emissions, 2004; 2 – transport-related greenhouse gas emissions, 2004

7.3.2 Mitigation measures

Greenhouse gas emissions during the construction phase relate to energy use, land use change, and material consumption. Improved efficiency in any of these areas will additionally reduce greenhouse gas emissions.

Management and mitigation measures to reduce construction related greenhouse gas emissions are limited. As previously discussed, a number of initiatives have been implemented by the RTA to minimise potential greenhouse gas generation from road transport. Minimum requirements for management / mitigation would include:

- Assess energy (fuel/electrical) efficiency when selecting equipment.
- Maintain equipment regularly to retain fuel efficiency.
- Purchase a minimum of 50% accredited renewable energy in order to reduce greenhouse gas emissions associated with electricity production.
- Where feasible, use of biofuels (biodiesel, ethanol, or blends such as E10 and B80), to reduce greenhouse gas emissions from construction plant and equipment.

- Minimise vegetation clearing and replant vegetation where feasible.
- If vegetation must be cleared, consider beneficial reuse of cleared material and avoid on-site burning; where land is to be purchased, pre-clearance for beneficial reuse should be encouraged, particularly State Forest land with harvestable materials.
- Use local material and local staff where possible to reduce transport-related emissions.
- Substitute recycled materials, such as replacement of cement with fly ash, recycled aggregate, and recycled content in steel, where feasible, to minimise the lifespan impact of greenhouse gas emissions in production.
- Substitute low greenhouse-intensity materials where appropriate.

In accordance with the RTAs normal practise, landscaping and revegetation of batters and medians, along with any suitable cleared areas in the road corridor would be included as part of the proposed upgrade, as detailed in Chapter 19 or the Environmental Assessment. While this would help to reduce the impact of vegetation clearing during the construction phase, landscaping and revegetation of a proposed road corridor is not normally considered to be a mitigation measure for greenhouse gas emissions.

During the operational phase, fuel consumption of motor vehicles is directly proportional to emissions of carbon dioxide and other greenhouse gases from motor vehicles. RTA programs that encourage better vehicle maintenance and, therefore, improved fuel economy, would be beneficial in reducing fuel usage and greenhouse gas emissions.

The RTA have implemented or have been actively involved in the development of a number of initiatives to help minimise potential greenhouse gas generation from road transport. An outline of the RTA and NSW Government involvement in addressing greenhouse gas emissions is provided below:

- *National Greenhouse Response Strategy* (AGO 1998), which includes reducing fuel consumption in motorised transport; improving the technical and economic efficiency of operation of the road network and traffic management; and encouraging the use of bicycles
- RTA Greenhouse Reduction Plan, included in the RTA document *The Journey Ahead: The RTA's corporate plan 2003-2008* (RTA 2003) corporate plan for 2003 to 2008, which covers the reduction of greenhouse gases as a priority issue
- continued enhancement of the States' vehicle emission enforcement standards
- implementation and revision of the *Australian Design Rules* (ADRs), in particular, ADR37/01 Emission Control for Light Vehicles, ADR70 Exhaust Emission Control for Diesel Engined Vehicles, ADR79/00 Emissions Control for Light Vehicles and ADR80/00 Emissions Control for Heavy Vehicles
- continuing involvement of the *Diesel National Environment Protection Measure* (NEPM) which continues to set the framework for the management of emissions, enables the development of regulations on diesel emissions testing standards, and facilitates the development and implementation of enforcement and alternative compliance strategies for vehicle emissions.

8. Conclusions

The results of this air quality assessment indicate that substantial adverse air quality issues would not be expected as a result of construction or operation of the proposed upgrade.

Emissions of particulate matter during construction should be manageable through the air quality management component of the CEMP. The requirements for control would be determined once construction techniques and construction schedules are known.

Site selection of the concrete batching plants and asphalt batching plants (where required) would be carried out with reference to potential air pollutant levels.

No adverse operational impacts (2011 and 2021), due to carbon monoxide, nitrogen oxides, hydrocarbons and particulate matter emissions, would be expected, and no specific control options are considered necessary.

With the proposed upgrade, emission rates and associated pollutant levels were predicted to generally decrease when compared with conditions without the proposed upgrade.

The operation of the proposed upgrade is not expected to degrade the existing air quality environment, nor detract from existing local ambient air quality at potentially affected receptors, including Frederickton Public School.

Construction and operation of the proposed upgrade would result in the generation of additional greenhouse gas emissions. However, ongoing greenhouse gas efficiency standards are being adopted as part of the RTA's strategic principles. The contribution of the proposed upgrade to Australia's net greenhouse gas emissions would be relatively small.

9. References

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Appendix A

Climatic Summary

Introduction

This report provides a summary of the climatic conditions that are typical for the region surrounding the proposed upgrade. Annual, seasonal and monthly weather characteristics have been assessed with regard to the proposed upgrade.

The site is located within the Macleay Valley district of the mid-north coast region. The climate in Kempsey can be described as being warm and humid with very warm and humid summers and mild winters.

Regional conditions have also been considered in this climatic summary. The Bureau of Meteorology has collected weather data for the Kempsey area since 1882 from the Wide Street monitoring location (station number 059017). Review of wind flow patterns has been made with consideration to the Port Macquarie Hill Street anemometer (station number 060026).

Meteorology in the study area is dependent on prevalent weather, local conditions and local topography. Land form in the study area was noted as comprising floodplain surrounded by gently undulating country to the north and the south.

A detailed assessment of temperature and humidity, precipitation, cloud cover, frost/fog occurrence and winds is provided below.

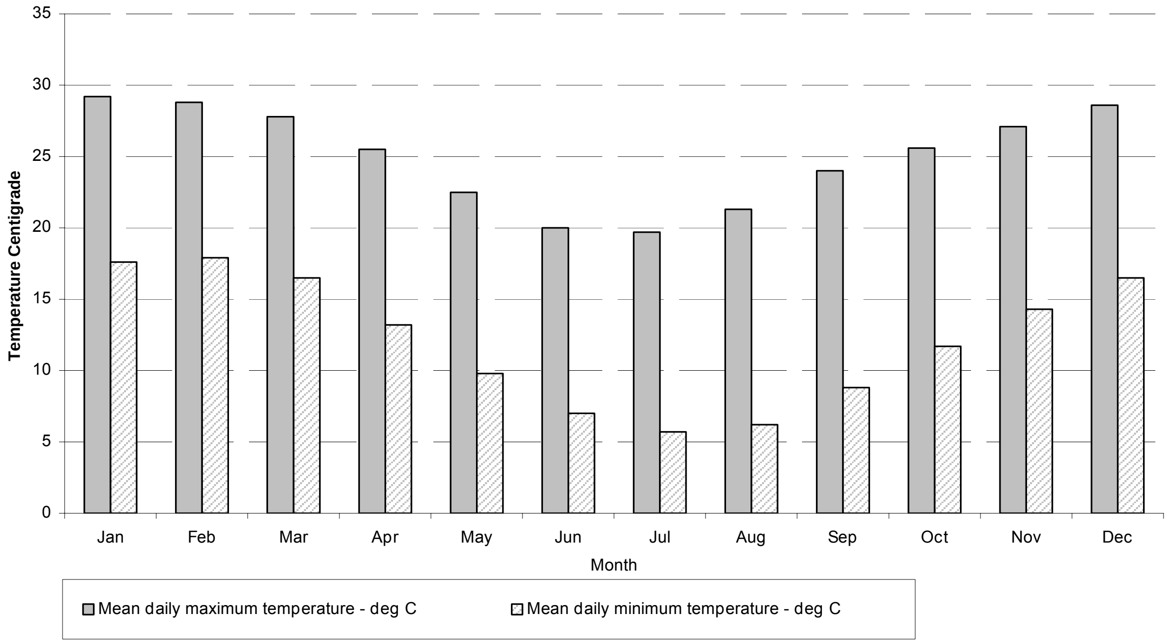
Temperature and humidity

Temperature

Based on an 84 year data set, the mean maximum temperatures in Kempsey during January and July are 29.2^{o}C and 19.7^{o}C respectively with a maximum temperature of 43^{o}C recorded during both January and February. Mean minimum temperatures of 17.6^{o}C and 5.7^{o}C for January and July have been recorded respectively. A minimum temperature of -1.8^{o}C has been recorded in Kempsey during June.

Temperatures similar to those recorded at the Kempsey meteorological station are expected for the study area.

Mean monthly temperatures for Kempsey are presented in Figure A-1.



Source: Bureau of Meteorology, Kempsey Wide Street (station number 059017)

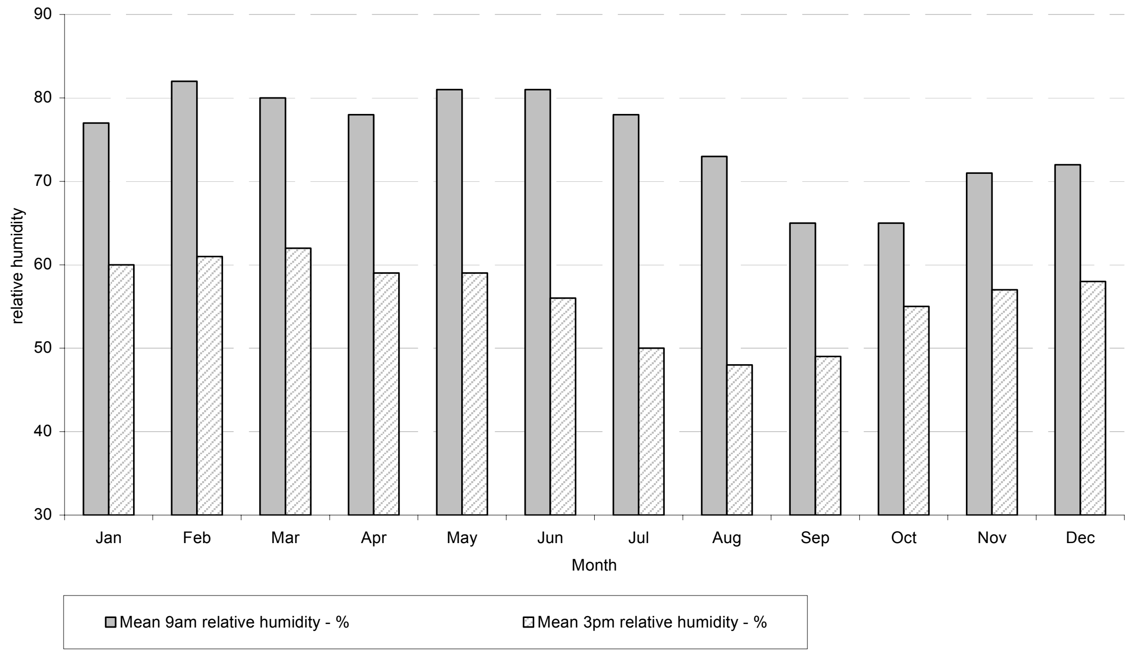
Figure A-1: Mean monthly maximum and minimum temperatures – Kempsey (Wide Street)

Humidity

Humidity or air moisture content is typically expressed as relative humidity and is a measure of vapour saturation. The water vapour capacity of air is dependent on temperature with warmer air having a greater moisture capacity than colder air. When air reaches the 100 per cent saturation level no further vapour can be held and excess moisture condenses into moisture droplets becoming cloud or fog.

Based on a 31 year data set, the annual mean relative humidity is 75% at 9 am and 56% at 3 pm. The 9 am mean monthly relative humidity varies between 82% in February and 65% in September/October. The 3 pm relative humidity varies between 62% in March and 48% in August. This is presented in Figure A-2.

The relative humidity is typically higher during the night and early morning periods. Humidity levels are higher in autumn and winter and lowest in spring. The combination of temperature and humidity has an impact on human comfort.



Source: Bureau of Meteorology, Kempsey Wide Street (station number 059017)

Figure A-2: Mean monthly 9 am and 3 pm relative humidity – Kempsey (Wide Street)

Precipitation

Based on a 120 year data set, the mean annual rainfall for Kempsey is 1,211 millimetres, with February and March the wettest months on average and September the driest month on average. Mean monthly rainfall averages for February, March and September were reported at 153, 154 and 55 millimetres respectively.

Median rainfalls are a preferred measure of average rainfall from a statistical point of view because of the high variability of daily rainfall. A single extreme weather event can skew the mean rainfall to a greater extent than it can the median. Median monthly rainfall values have been provided in Table A-1.

The variation in annual and monthly rainfall is the result of a range of interplaying factors. These factors include large-scale climatic influences such as El Nino and the southern oscillation that drive general trends of below and above average rainfall, and small-scale local weather patterns. Smaller short-term influences, such as localised storm activity, influence rainfall patterns with higher intensity rainfalls associated with thunderstorm activity during the warmer months.

The mean number of rainy days tends to fluctuate with a high of 12.7 days in March and a low of 6.4 days in August.

Table A-1 illustrates the annual variability in rainfall. Monthly rainfall can vary significantly with February showing a range of no rainfall in its driest recorded month to 883 millimetres during its wettest recorded month.

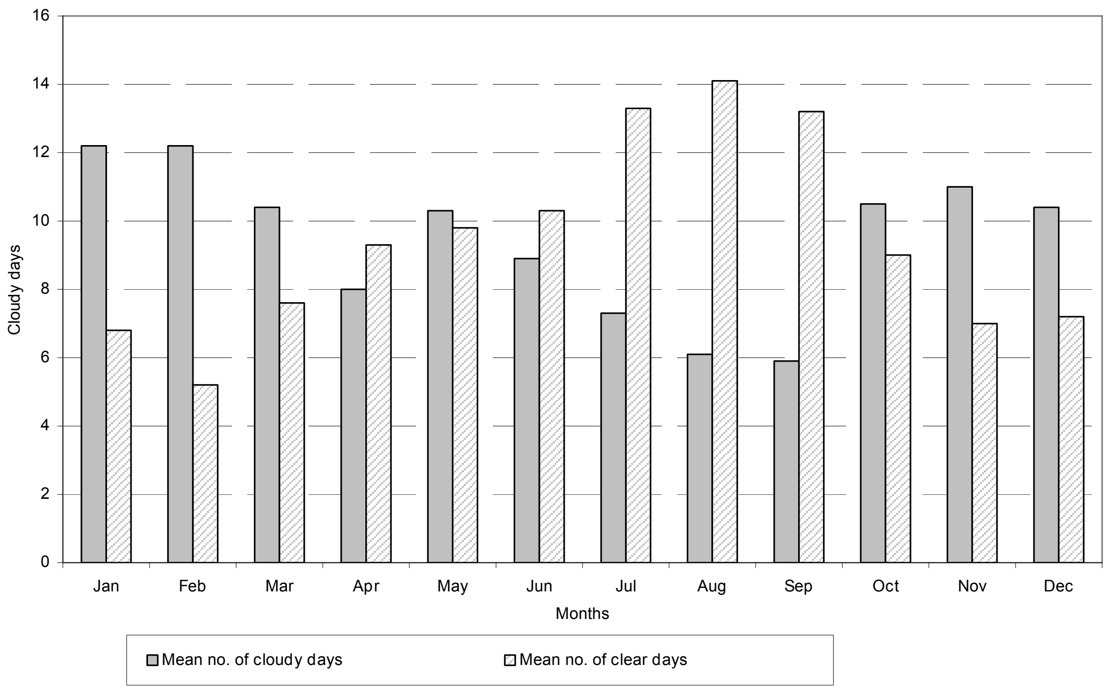
Table A-1: Rainfall statistics for Kempsey (Wide Street)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Rainfall (mm)	133	153	154	116	95	96	68	62	55	77	92	110
Median Monthly Rainfall (mm)	104	110	131	77	63	57	34	33	36	56	77	93
Mean Number of Rainy Days	11.0	11.5	12.7	10.0	8.7	7.5	6.5	6.4	6.7	8.6	9.5	10.5
Mean Rainfall per Rain Day (mm)	12.1	13.3	12.1	11.6	10.9	12.9	10.4	9.7	8.2	9.0	9.7	10.5
Highest Monthly Rainfall (mm)	575	883	618	577	481	558	440	376	303	587	377	354
Lowest Monthly Rainfall (mm)	8	0	9	4	0	0	0	0	0	4	1	9

Source: Bureau of Meteorology, Kempsey Wide Street (station number 059017)

Cloud

The mean number of cloudy and clear days for Kempsey is shown in Figure A-3.



Source: Bureau of Meteorology, Kempsey Wide Street (station number 059017)

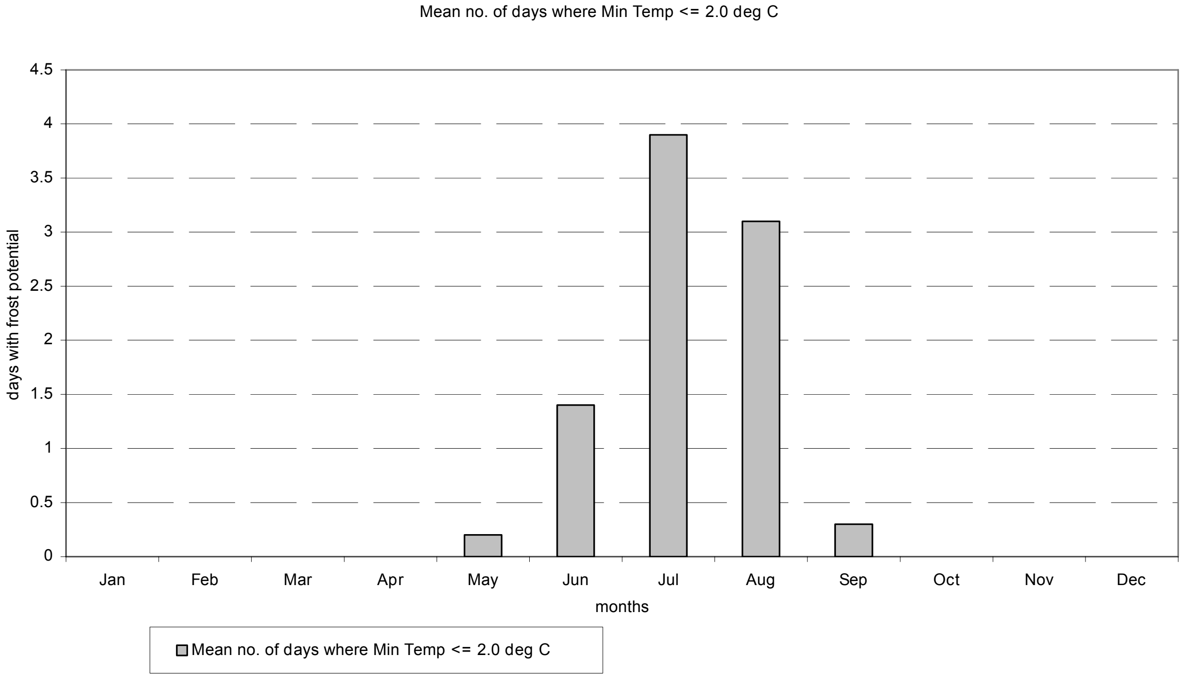
Figure A-3: Mean monthly cloudy and clear days – Kempsey (Wide Street)

Frost and Fog

Frost

During the night-time, the ground temperature is typically slightly cooler than air temperature, hence, frosts can form when air temperatures are above freezing. Daily minimum temperatures of less than 2^{o}C indicate potential frost occurrence. On average 8.8 days a year experience temperatures below 2^{o}C.

Details on the mean occurrence of minimum temperatures less than or equal to 2^{o}C are indicated in Figure A-4.



Source: Bureau of Meteorology, Kempsey Wide Street (station number 059017)

Figure A-4: Mean number of days with the potential for frost – Kempsey (Wide Street)

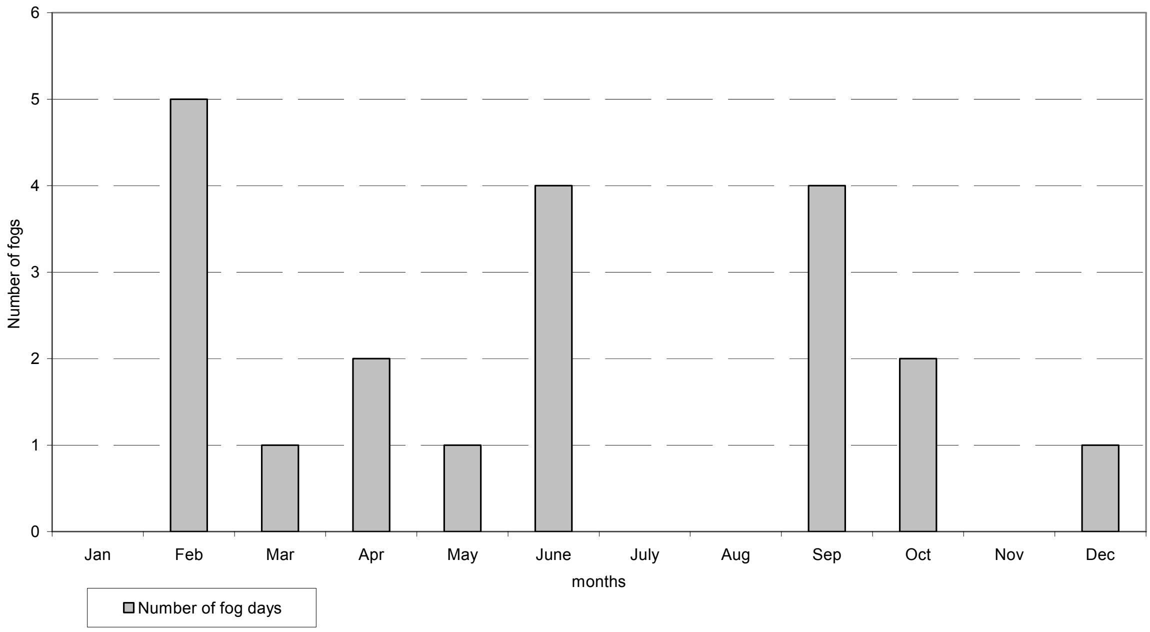
Fog

Fog is defined as an obscurity in the surface layers of the atmosphere by a suspension of water droplets with or without smoke particles. International agreement defines a fog as having a visibility of less than 1,000 metres. The two major types of fog that occur are radiation fogs and advection fogs.

Radiation fogs form over land more commonly during the winter months during clear nights with light winds. Re-radiation of heat from the ground escapes out into space and cools the ground. This in turn cools the air and forms condensation. During still conditions this condensation forms as dew on the ground. However, if there is slight air movement condensation forms on condensation nuclei and forms a suspended fog of moisture droplets. The fog becomes the radiating surface and further cools and deepens the fog.

Advection fogs occur when warm moist air flows over a surface cooler than the dewpoint. Advection fogs (also known as sea fogs), rarely occur over land, however, they can occur in valleys open to the sea when temperature falls in the evening combined with a sea breeze. These fogs can persist in winter even under a cloud layer.

A year's worth of observation data from the Kempsey Wide Street weather station was screened for fog occurrence. During the period February 2001 to February 2002 fog was noted on 20 days. A graphical representation of fog occurrence has been provided as Figure A-5. The data indicated that fogs occur during any time of the year.



Source: Bureau of Meteorology, Kempsey Wide Street (station number 059017)

Figure A-5: Fog occurance in 2001 – Kempsey (Wide Street)

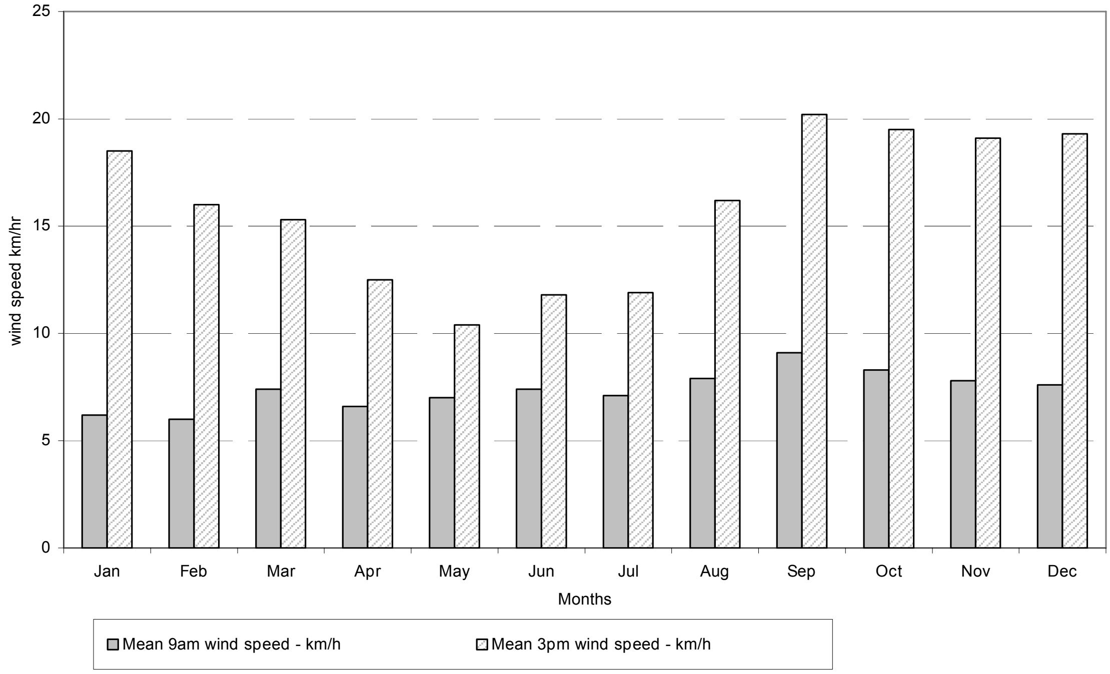
Wind flow patterns

Wind flow patterns are influenced by both regional meteorological conditions, primarily in the form of gradient wind flow regimes, and by local conditions, generally driven by topographical features in the form of drainage flows. Topography, wind speed and wind direction all dispersion plume transportation. An effort to define both the regional and local dispersion meteorology at the project site has been made.

Regional surface wind profiles have been obtained from the 9.00 am and 3.00 pm monthly observations compiled for Kempsey Airport (station number 059007) and Port Macquarie (station number 060026).

Kempsey Airport

A graphical representation of wind speeds recorded at Kempsey has been provided as Figure A-6.



Source: Bureau of Meteorology, Kempsey Wide Street (station number 059017)

Figure A-6: Mean monthly 9 am and 3 pm wind speeds - Kempsey (Wide Street)

Gradient wind flows are noted in the range of 6 km/h to 10 km/h in the morning (9 am) period. An annual average wind speed of 7.4 km/h was noted. Afternoon (3 pm) wind flows are higher with wind speeds noted between approximately 10 km/h through to 20 km/h, with an annual average of 15.9 km/h.

Wind events are generally higher during the spring and summer.

Port Macquarie

Wind rise plots for Port Macquarie, approximately 30 kilometres from the proposed route and located on a coastal setting, are presented as Figure A-7. Although the Port Macquarie data would be subject to coastal breezes and processes, it is considered suitable for use in this technical paper and is considered to be a conservative estimate of baseline conditions.

North-easterly through south-easterly winds dominate at 9 am. Flow vectors are noted to rotate approximately 180 degrees at 3 pm.

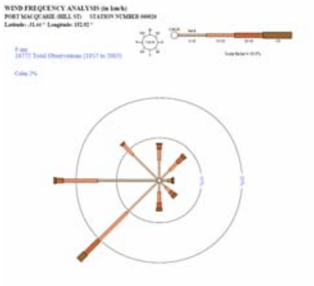
Wind speeds exceeding 30 km/h occur with few calm conditions recorded.

Seasonal wind rose plots follow, review of the data indicates that wind directions are generally variable throughout each season but north-easterly through south-westerly winds predominate throughout the year.

A review of the 9 am recorded wind patterns showed that north-east through to easterly winds were present. Morning winds are predominately from the east in winter and autumn, and the north-east through south-west in spring and summer.

Wind patterns recorded for the 3 pm observations indicate predominant north-easterly and south-westerly winds during autumn and winter months. Throughout spring and summer, south-westerly aspects are noted.

Annual



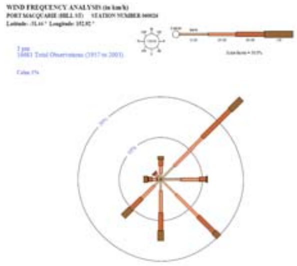
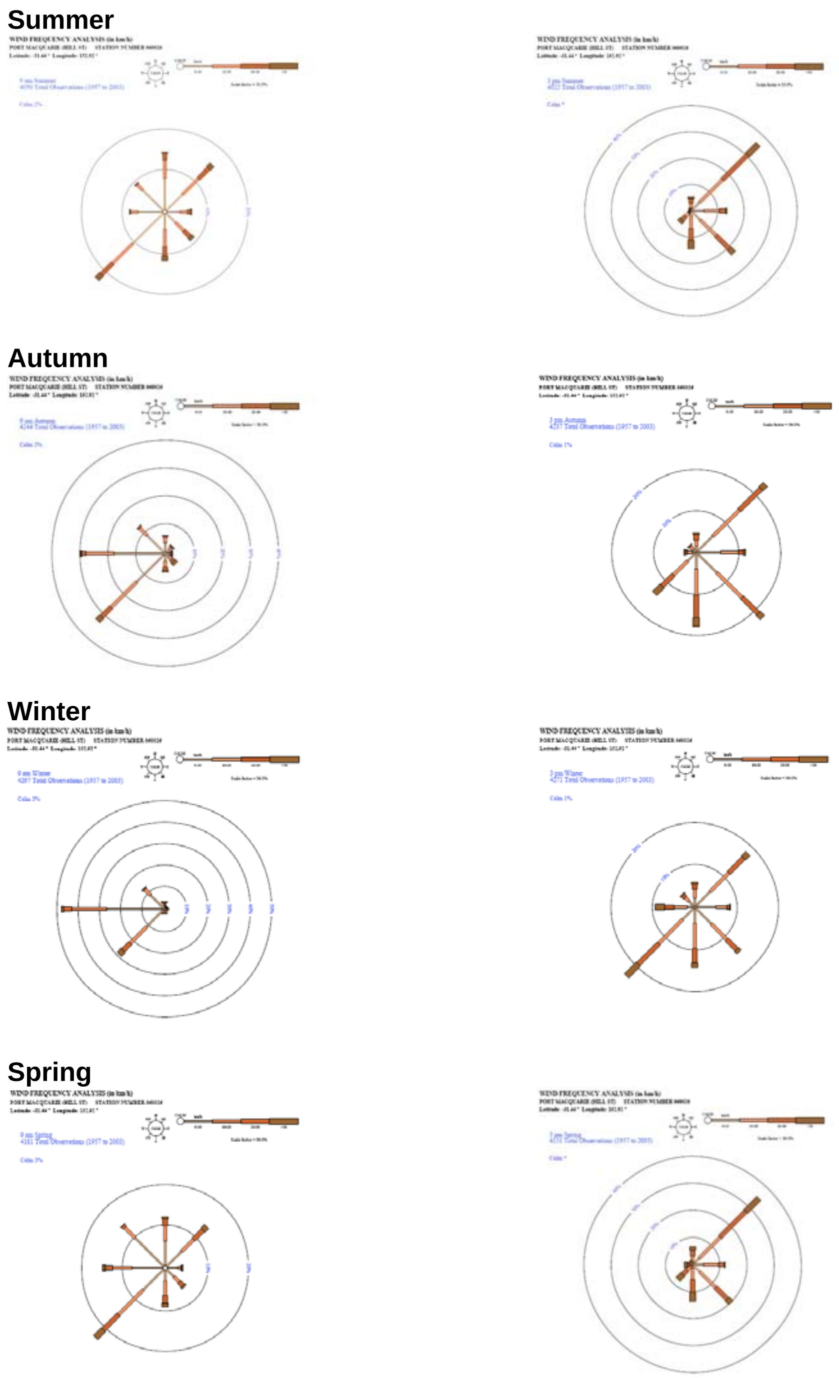


Figure A-7: Mean 9 am and 3 pm wind speeds (Port Macquarie — annual)



Source: Bureau of Meteorology (station number 060026)

Figure A-8: Mean 9 am and 3 pm wind speeds (Port MacQuarie — seasonal)

Kempsey (Synthetic Data)

A synthetic site-representative meteorological data file was configured for the year 2001. The 2001 data was generated through the use of the CSIRO developed TAPM program. Coordinates of –31°03' South and 152°51' East were referenced. It is the experience of PB that such an approach provides a more detailed and robust assessment.

Annual and seasonal wind rose plots have been included as Figure A-9.

An annual average wind speed of 4.3 m/s was noted. Upon review of the plots it can be seen that the primary wind directions are from the north-west and west.

Gradient wind flows from the north-east predominate during summer, while westerlies and north-westerlies dominate throughout the rest of the year.

The primary seasonal wind flow patterns were noted with similar frequencies as the annual wind rose plot. The site-representative wind rose diagrams are consistent with wind flow regimes for the northern NSW region and generally confirm the reviewed BOM wind data for Kempsey and wind rose plots for Port Macquarie.

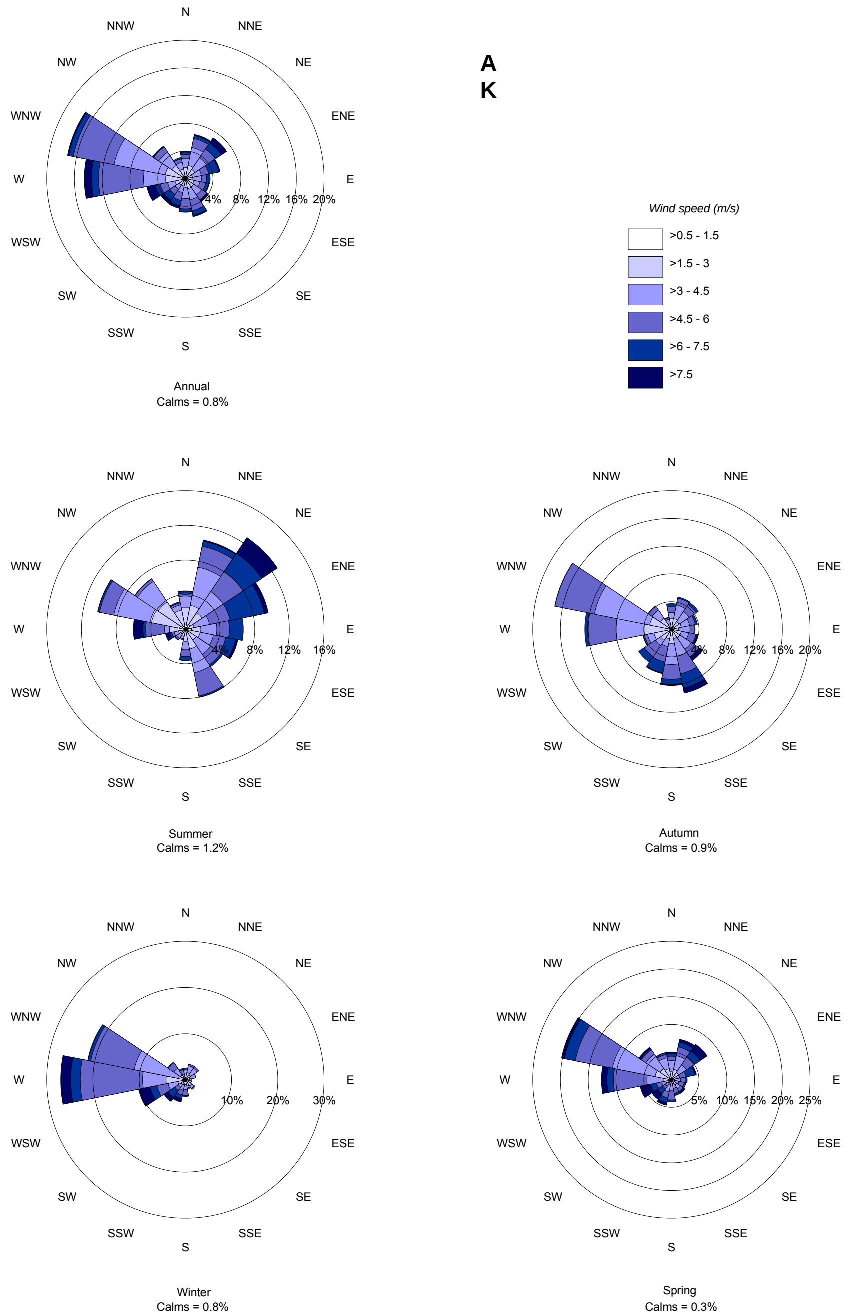


Figure A-9: Annual and seasonal wind roses for Kempsey (TAPM, 2001)

Topographical influences

Topography can influence air movements by several means. Hill and valley features influence wind direction by steering and channelling air flows. Topographical changes can also create drainage flow regimes moving air from higher to lower ground during the night-time. These effects become more pronounced during stable atmospheric conditions.

The movement of cold air down a slope (generally under stable atmospheric conditions) is referred to as katabatic drift and this condition can result in plume entrapment and poor dispersion of air-borne pollutants with the potential to cause greater off-site impacts. Katabatic drift would follow the topography of the site.

The proposed route lies within the Macleay River catchment.

Topographic information available for the site indicates that localised catchments could be formed within the site towards Doughboy Swamp to the north and Macleay River to the south and the surrounding smaller tributary gullies. There would most likely be minimal potential for plume entrapment and minimal horizontal or vertical diffusion in these areas.

Although general patterns can be determined with confidence, it is difficult to accurately predict the influence of local drainage flows without detailed site-specific meteorological information.

Seasonal summary

A summary of seasonal climatic conditions for the Kempsey region as applicable for the proposed upgrade follows.

Summer

Summer conditions in Kempsey are warm to hot during the daytime and mild during the night-time. Maximum temperatures are above 30^{o}C on 1 in every 3 days. However temperatures above 35^{o}C only occur on average once a month in December and less during January and February. Mean minimum temperatures were noted as being above 16^{o}C during summer.

Summer is the wettest season for the Kempsey region with rainfalls occurring on average 1 in every 3 days during summer. Median monthly rainfalls vary between 93 millimetres in December to 110 millimetres in February. Monthly falls of up to 883 millimetres have occurred during February. Lows of less than 10 millimetres have also been recorded.

North-east through south-west winds generally dominated during the morning period (9 am) with average wind speeds of 6 to 7 km/hr. Similar patterns were noted in the afternoon (3 pm) with south-westerly aspects predominating, with average wind speeds of approximately 18 to 19 km/hr.

The synthetic wind flow data generated by TAPM for Kempsey (2001) indicated that wind flows for the north-east dominated.

Autumn

Temperatures during autumn drop from warm to hot during March to mild during May. Average maximum and minimum temperatures drop by 5°C and 6°C respectively during autumn. The average number of days with temperatures above 30°C drops from 5.5 per month in March to 0.1 in May.

Median monthly rainfall data reaches a peak in March at 131 millimetres and halved to 63 millimetres by May. The number of rainy days during autumn followed a similar trend, reducing from 12.7 in March to 8.7 in May. The wettest month recorded 618 millimetres of precipitation during March and the driest recorded was no rainfall during May.

Easterly through north-easterly winds generally dominated during the autumn morning period (9 am) with average wind speeds of 5 to 6 km/hr. Afternoon (3 pm) wind patterns were noted in the north-easterly through south-westerly quadrant, with average wind speeds of approximately 13 to 16 km/hr.

Autumn wind flows presented in the Kempsey (2001) TAPM file indicated that west north-westerly wind flows were predominant.

Winter

Temperatures during winter are mild with an average monthly maximum varying between 19°C and 21°C. Mean minimum temperatures vary between 5°C and 7°C. Frost conditions where air temperatures are lower than 2°C occur on average 8.8 days in a year, and are typically confined to these winter months.

Median monthly rainfall reduces further during winter to a minimum in August of 33 millimetres. Rainy days decrease from 7.5 in June to 6.4 in August. The wettest winter month recorded 558 millimetres falling in June. No precipitation has been recorded during the driest winter months.

During the morning period, 9 am wind patterns showed that easterly winds are common. Average morning wind speeds of between 6 to 7 km/hr were noted. Afternoon (3 pm) winter wind flows predominated from the north-east and south-west directions, with average wind speeds of approximately 10 to 12 km/hr.

The Kempsey (2001) TAPM file winter flow regimes were predominately from the west and west north-west.

Spring

Mean maximum temperatures during spring increase from 24°C in September to 27°C in November. Mean minimum temperatures increased from 8°C in September to 14°C in November. The average number of days with temperatures above 30°C increased from 1.3 per month in September to 4.8 in November.

Median monthly rainfall during spring tends to increase from 36 millimetres during September to 77 millimetres during November. The mean number of rainy days followed a similar trend of increasing from 6.7 to 9.5 days during September and November respectively. The wettest spring month recorded 587 millimetres falling in October. Less than 10 millimetres of precipitation has been recorded during the driest spring months.

Directions of 9 am (morning) wind movement during spring demonstrated variable flow patterns with north-east through south-westerlies occurring frequently and average wind speed of 7 to 8 km/hr. Afternoon (3 pm) wind flow conditions from the south-west are dominant, with average wind speeds of 16 to 20 km/hr.

Throughout the spring westerly north-westerly wind flows were present for the majority of the time within the Kempsey (2001) TAPM file.

Summary of meteorological influences

A number of meteorological factors influence the construction and usability of the proposed route, as well as the transportation of air pollutants and the transmission of noise from road traffic and highway operations.

Climatic impacts on the construction and operation of the proposed upgrade have been discussed in the following sections. The limited amount of meteorological data available for the proposed site has meant that preliminary conclusions only can be made relating to the effect of meteorology on air quality in the vicinity of the site of the proposed upgrade operations.

Construction

Climatic conditions with the potential to cause construction delays or otherwise increase construction costs are of primary interest. This section discusses these influences.

Rain is the major cause of disruption to construction activities with higher intensity rain having the potential for localised flood and erosion, while low intensity rain can be more persistent and cause long-term delays. High intensity events are associated with thunderstorm activity and are more likely during the warmer months. The possibility and duration of rainfall disruptions is also dependent on ground moisture contents and ambient temperatures in associated with evaporation rates. As such smaller precipitation events during the winter can cause delays similar to larger events during the warmer months.

Periods of low rainfall leading to low ground moisture content increase the potential for surface drying and dust formation. During the warmer months, low rainfall and higher temperatures can lead to greater levels of dust generation from construction activities. During hot dry periods with winds, dust generated from construction activities are at their greatest.

Operation

Operation of the proposed upgrade will be effected by a variety of adverse meteorological conditions. These effects apply similarly to the existing highway.

Weather conditions associated with increased hazard for drivers have been indicated below:

- Precipitation events potentially cause slippery surface conditions and reduced visibility for drivers. These conditions depend on rainfall frequency and ambient temperatures, which effect drying times. Consideration of surface roughness and skid resistance would be required.
- Heavy rainfall events cause runoff and pooling of water on the road surface. These events are more common during the warmer months of the year when thunderstorm activity and higher intensity rainfall occur. These effects can be controlled by road design and drainage. The proposed upgrade would be an improvement on the existing highway.

- Visibility can be adversely affected by fog formation. Fogs can occur during suitable conditions on calm clear nights during any month of the year. Fog formation is at its greatest in low-lying areas and under ideal conditions can last well into the following day. Clear visible line markings will be required to ensure drivers can identify travel lanes during fogs and other periods of low visibility.
- Potential frost conditions occur on average 8.8 days per a year. Heavy frosts capable of affecting the road surface are unlikely to occur as mean minimum temperatures of less than 0^{o}C occur on average only 0.9 days in a year.
- High winds that affect vehicle stability are typically associated with westerly winds that accompany strong frontal changes. Terrain can influence high wind impacts with exposed locations being more adversely affected. Ridge lines and other elevated sections of road are typically most affected by high winds.