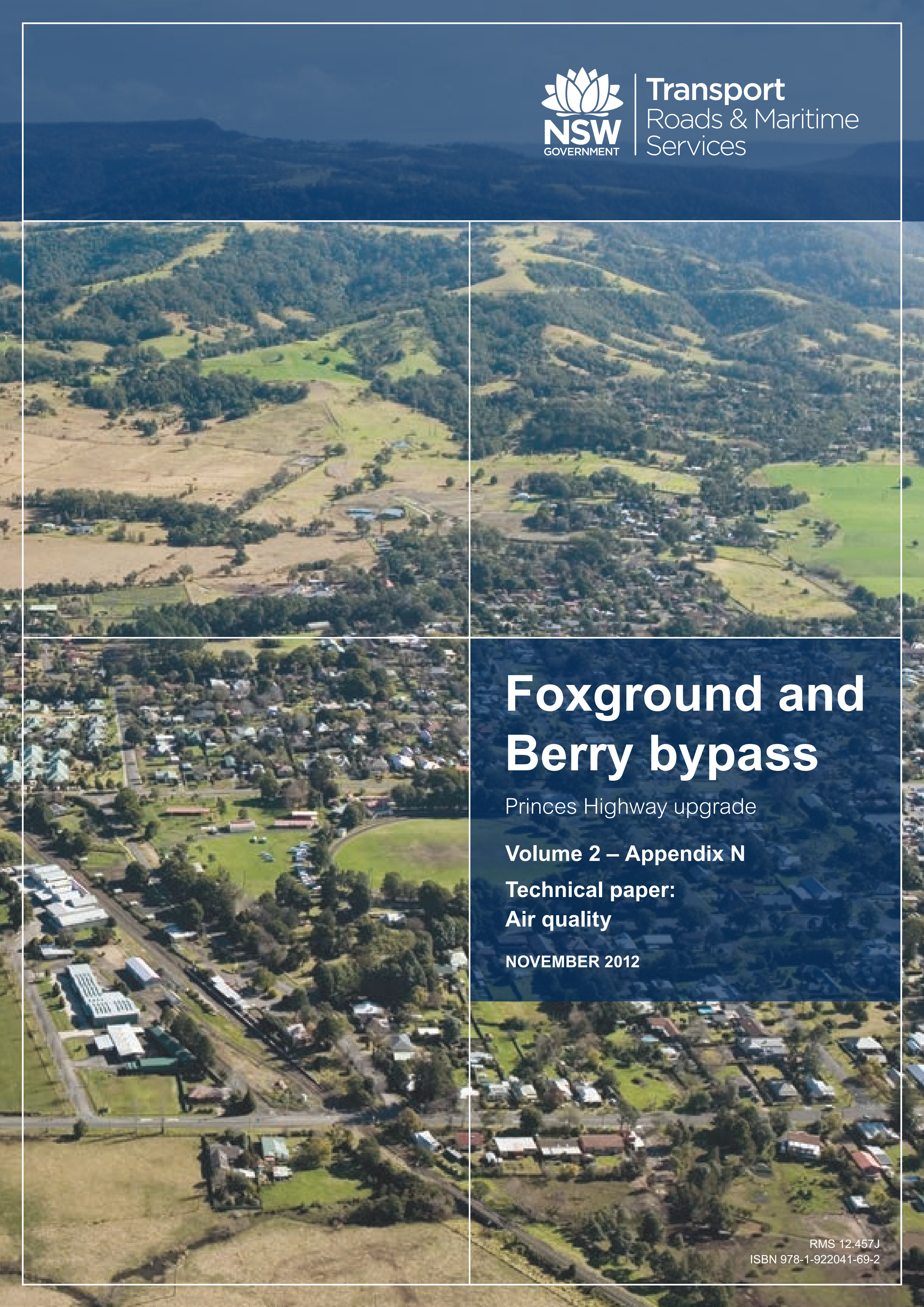

Foxground and Berry bypass

Princes Highway upgrade

Volume 2 – Appendix N

Technical paper:
Air quality

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Foxground and Berry bypass

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Glossary of terms and abbreviations

Abbreviation	Meaning
CO	Carbon Monoxide
$\mu g/m^3$	Microgram per cubed metre
ABS	Australian Bureau of Statistics
AQMP	Air Quality Management Plan
CAL3QHCR	Software model used for predicting air pollution concentrations of carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter (PM), and other inert gases from idle or moving motor vehicles
Caline, CALINE3/4	Software models which estimate dispersion of vehicle exhaust based on a Gaussian diffusion equation
CALRoads	An air dispersion modelling software package for predicting air quality impacts of pollutants near roadways.
Carboxyhaemoglobin	A stable complex of carbon monoxide and haemoglobin that forms in red blood cells when carbon monoxide is inhaled or produced in normal metabolism
CEMP	Construction Environmental Management Plan
DEC	NSW Department of Environment and Conservation. (now OEH)
DECCW	NSW Department of Environment, Climate Change and Water
DEH	Department of Environment and Heritage
EPA	NSW Environment Protection Authority (formerly part of DECCW)
Expectorating	To cough up and spit out phlegm, thus clearing the bronchial passages
Gaussian Model	A way of calculating concentrations of polluting chemicals from stationary industrial sources. The substance goes downwind and disperses (gets weaker) as it travels, according to Gaussian mathematics.
GLC	Ground level concentration
HC	Hydrocarbons
HGVs	Heavy Goods Vehicles
ISCMOD	Industrial Source Complex model
Lassitude	A state of weariness accompanied by listlessness or apathy
NEMP	National Environment Protection Measures.
NEPC	National Environment Protection Council of Australia
NEPC	National Environmental Protection Council
NHMRC	National Health and Medical Research Council of Australia
NO_2	Nitrogen dioxide

Abbreviation	Meaning
NO_X	Nitrogen oxides
NSW	New South Wales
OEH	NSW Office of Environment and Heritage
EPA	NSW Environment Protection Authority
Photochemical	Relating to, or caused by the chemical action of light.
PIARC	Permanent International Association of Road Congresses
PM_{10}	Particulate matter < 10 µm
POEO	*Protection of the Environment Operations Act 1997*
Ppm	Parts per million
RAN	Royal Australian Navy
RMS	Roads and Maritime Services of New South Wales
RTA	Roads and Traffics Authority of NSW (now RMS)
SO_2	Sulphur dioxide
TOEM	Tapered Element Oscillating Microbalance (PM_{10} Monitor)
TSP	Total suspended particulates
TSP	Total Suspended Particulates
USEPA	United States Environmental Protection Agency
WHO	World Health Organisation
Windrose	A graphic tool used by meteorologists to give a succinct view of how wind speed and direction are typically distributed at a particular location

1 Introduction

The Roads and Maritime Services (RMS) (formerly the Roads and Traffic Authority of NSW (RTA)) is seeking approval under Part 3A of the *Environmental Planning and Assessment Act 1979* to upgrade 11.6 kilometres of the Princes Highway between Toolijooa Road north of Foxground and Schofields Lane south of Berry, in New South Wales (NSW) (the project), to achieve a four lane divided highway (two lanes in each direction) with median separation. The project includes bypasses of Foxground and Berry.

The project would form part of the Princes Highway upgrade which aims to provide a four lane divided highway between Waterfall and Jervis Bay Road, Falls Creek. The upgrade of the Princes Highway would improve road safety and traffic efficiency, including for freight, on the NSW south coast.

The report comprises the following components:

- Project description.
- Regional meteorology and air quality issues.
- Local air quality and dispersion conditions.
- Impacts of the existing highway alignment.
- Estimation of emissions based on traffic volumes and vehicle mix.
- Assessment of construction impacts.
- Assessment of air quality impacts associated with the project in two representative years following completion – 2017 and 2027.
- Identification of mitigation and management measures.

1.1 Study area

The project is located west of Gerringong, between the junctions of the Princes Highway with Toolijooa Road (north of Foxground) and Schofields Lane (south of Berry). South of Schofields Lane, a u-turn facility would be provided at Mullers Lane.

The study area is shown in **Figure 1-1**.

From north-east to south-west, the project traverses Toolijooa Ridge, bypasses the Foxground bends, crosses Broughton Creek in three locations and bypasses the town of Berry. An illustration of local terrain features in the study area is shown in **Figure 1-2**.

The project study area mainly comprises the existing road reserve, privately owned rural agricultural, rural residential and suburban (Berry) properties. The main agricultural land use in the study area is cattle grazing.

The project deviates from the existing Princes Highway corridor in two locations:

- Across Toolijooa Ridge and the Broughton Creek floodplain between Toolijooa Road and east of Austral Park Road.
- A northern bypass of Berry from the ridgeline to the east of Woodhill Mountain Road to the south of Berry, rejoining the existing route south-west of Kangaroo Valley Road.

Remaining portions of the project follow the existing route of the Princes Highway where potential impacts would typically affect isolated rural residences and properties fronting the existing highway.

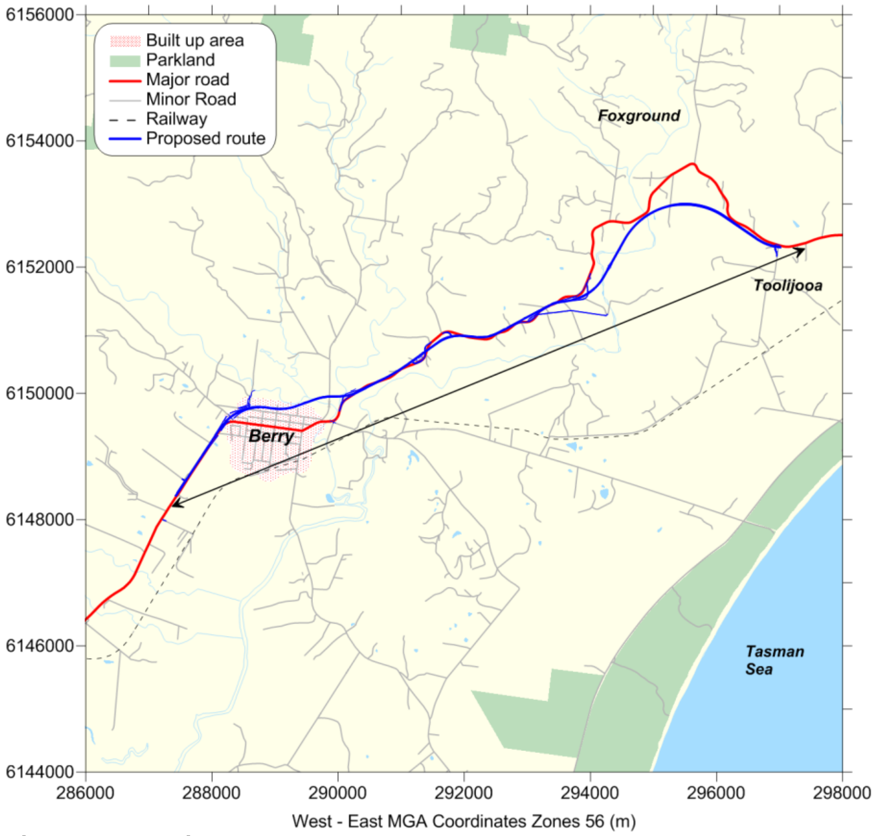

Figure 1-1: Study area

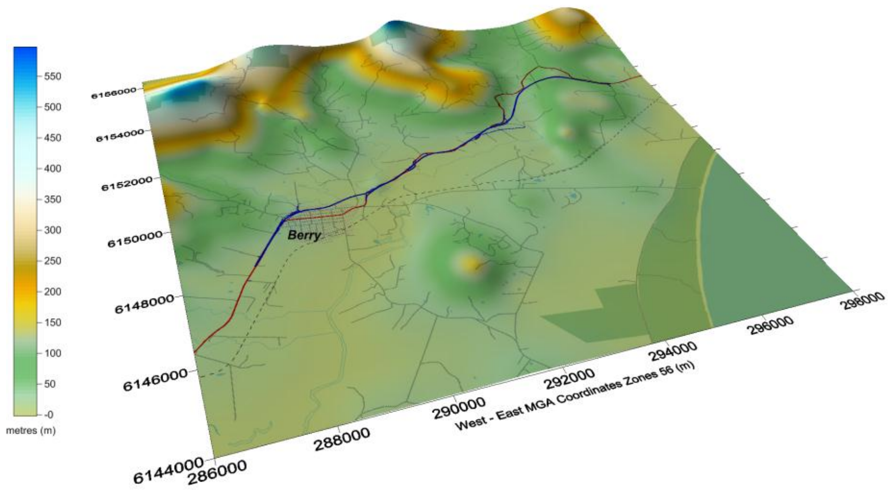

Figure 1-2: Local terrain features in the study area

2 Project description

Roads and Maritime Services (RMS) propose to upgrade 11.6 kilometres of the Princes Highway between Toolijooa Road north of Foxground and Schofields Lane south of Berry, in New South Wales (NSW) (the project), to achieve a four lane divided highway (two lanes in each direction) with median separation. The project includes bypasses of Foxground and Berry.

The project comprises the following key features:

- Construction of a four lane divided highway (two lanes in each direction) with median separation (wire rope barriers or concrete barriers where space is constrained, such as at bridge locations).
- Bypasses of the Foxground bends and the Berry township.
- Construction of around 6.6 kilometres of new highway where the project deviates from the existing highway alignment at Toolijooa Ridge, the Foxground bends and the Berry township.
- Provision for the possible widening of the highway (if required in the future) to six lanes within the road corridor and, in some areas, construction of the road formation to accommodate future additional lanes where safety considerations, traffic disruption and sub-optimal construction practices are to be avoided.
- Grade-separated interchanges at:
  - Toolijooa Road.
  - Austral Park Road.
  - Tindalls Lane.
  - East of Berry at the existing Princes Highway, referred to as the northern interchange for Berry.
  - West of Berry at Kangaroo Valley Road, referred to as the southern interchange for Berry.
- A major cutting at Toolijooa Ridge (around 900 metres long and up to 26 metres deep).
- Six lanes (two lanes plus a climbing lane in each direction) through the cutting at Toolijooa Ridge for a distance of 1.5 kilometres.
- Four new highway bridges:
  - Broughton Creek bridge 1, a four span concrete structure around 170 metres in length and nine metres in height.
  - Broughton Creek bridge 2, a three span concrete structure around 75 metres in length and eight metres in height.
  - Broughton Creek bridge 3, a six span concrete structure around 190 metres long and 13 metres in height.
  - A bridge at Berry, an 18 span concrete structure around 600 metres long and up to 12 metres in height.

- Three highway overbridges:
  - Austral Park Road interchange, providing southbound access to the highway.
  - Tindalls Lane interchange, providing southbound access to and from the highway.
  - Southern interchange for Berry, providing connectivity over the highway for Kangaroo Valley Road along its existing alignment.
- Eight underpasses including roads, drainage structures and fauna underpasses:
  - Toolijooa Road interchange, linking Toolijooa Road to the existing highway and providing northbound access to the upgrade.
  - Property access and fauna underpass in the vicinity of Toolijooa Ridge at chainage 8400.
  - Dedicated fauna underpass in the vicinity of Toolijooa Ridge at chainage 8450.
  - Property access underpass between Toolijooa Ridge and Broughton Creek at chainage 9475.
  - Combined drainage and fauna underpass in the vicinity of Austral Park Road at chainage 12770.
  - Combined drainage and fauna underpass in the vicinity of Tindalls Lane at chainage 13320.
  - Dedicated fauna underpass in the vicinity of Tindalls Lane at chainage 13700.
  - Property access underpass between the Tindalls Lane interchange and the northern interchange for Berry in the vicinity of at chainage 15100.
- Modifications to local roads, including Toolijooa Road, Austral Park Road, Gembrook Road, Tindalls Lane, North Street, Queen Street, Kangaroo Valley Road, Hitchcocks Lane and Schofields Lane.
- Diversion of Town Creek into Bundewallah Creek upstream of its confluence with Connollys Creek and to the north of the project at Berry.
- Modification to about 47 existing property accesses.
- Provision of a bus stop at Toolijooa Road and retention of the existing bus stop at Tindalls Lane.
- Dedicated u-turn facilities at Mullers Lane, the existing highway at the Austral Park Road interchange, the extension to Austral Park Road and Rawlings Lane.
- Roundabouts at the southern interchange for Berry and the Woodhill Mountain Road junction with the exiting Princes Highway.
- Two culs-de-sac on North Street and the western end of Victoria Street in Berry.
- Tie-in with the existing highway about 75 metres north of Toolijooa Road and about 440 metres south of Schofields Lane.
- Left in/left out only provisions for direct property accesses to the upgraded highway.
- Dedicated public space with shared pedestrian/cycle facilities along the southern side of the upgraded highway from the playing fields on North Street to Kangaroo Valley Road.
- Ancillary operational facilities, including permanent detention basins, stormwater treatment facilities and a permanent stockpiling site for general road maintenance.

Construction activities as part of the project would include the following:

- Site preparation and establishment works.
- Temporary construction facilities, including construction compounds, stockpile sites, creek crossings, sediment control basins and haulage roads.
- Temporary works, including relocation/protection of services, tie-ins, traffic facilities and side tracks.
- Earthworks and bridge construction.
- Pavement construction.
- Drainage construction.
- Road furniture installation.
- Site restoration.

The project and the key features of the project are shown in **Figure 2-1**.

During the detailed design phase of the project, refinements could be made to the design features and construction methods.

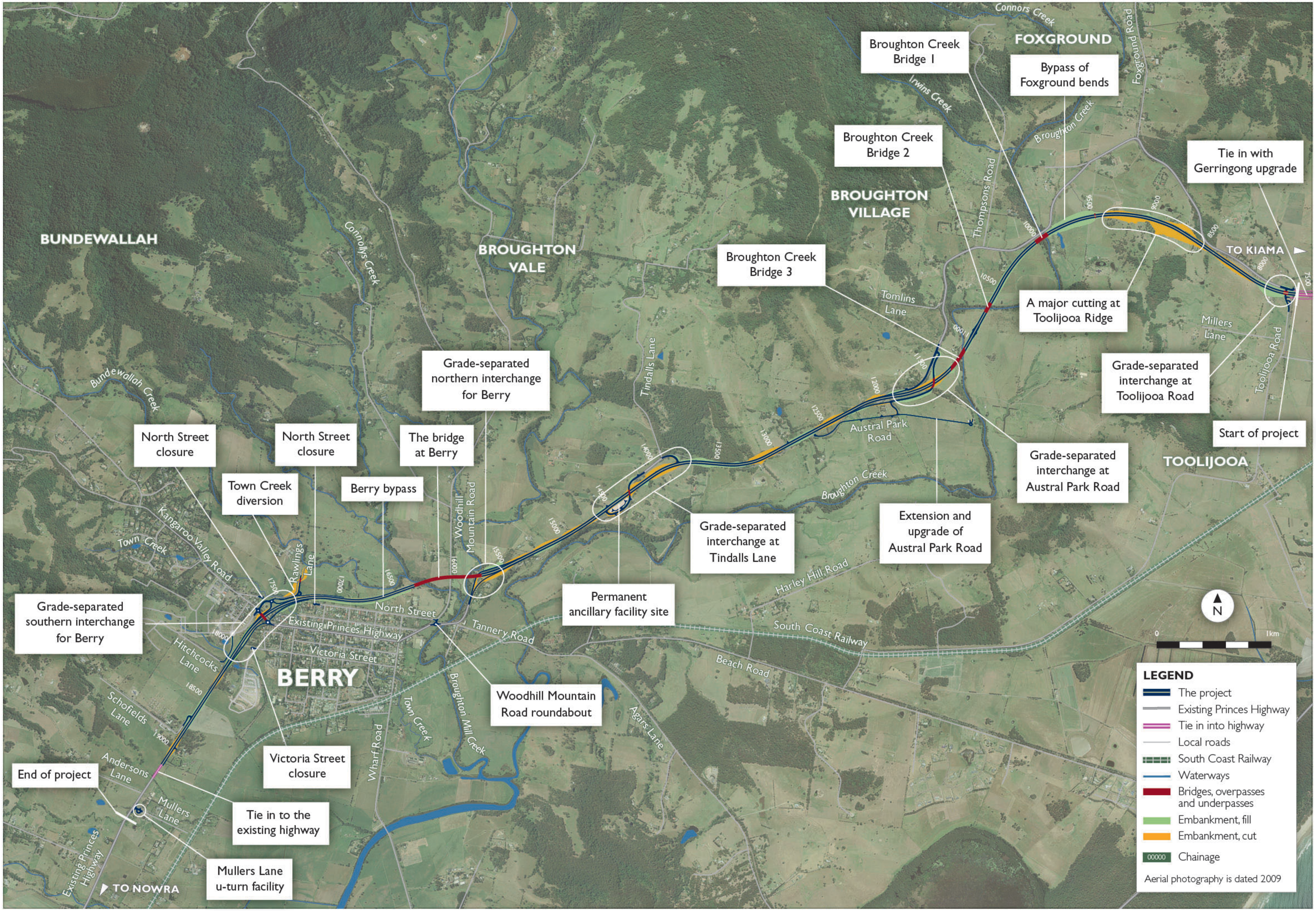

Figure 2-1: Key features of the project

3 Air quality criteria

Motor vehicles emit a number of pollutants that are known to be potentially harmful to human health. These pollutants are carbon monoxide (CO), nitrogen oxides (NO_x), hydrocarbons (HC, including benzene), sulphur dioxide (SO_2) and particulate matter. Each of these pollutants has the capacity to adversely affect health if the concentration is too great over a particular exposure period. Emissions of SO_2 are minor and are not considered further in this assessment.

The NSW Environmental Protection Authority[1] (EPA) (formerly included in the Department of Environment, Climate Change and Water, DECCW) has historically noted air quality goals determined by the World Health Organisation (WHO), the United States Environmental Protection Agency (US EPA) and the National Health and Medical Research Council of Australia (NHMRC).

In 1998, the National Environment Protection Council of Australia (NEPC) determined a set of air quality goals for adoption at a national level, which are part of the National Environment Protection Measures (NEPM). New air quality goals for nitrogen dioxide and particulate matter were adopted by the EPA in its publication "*Action for Air*" (NSW EPA, 1998).

The EPA specifies ground-level concentration (glc) criteria for criteria pollutants (NSW Department of Environment and Conservation (DEC), 2005), as listed in **Table 3-1**. The basis of these air quality goals and, where relevant, the safety margins which they provide are outlined in the following sections.

Table 3-1: EPA air quality assessment criteria

Pollutant	Goal	Averaging period	Source
Carbon monoxide	30 mg/m^3 10 mg/m^3	1-hour 8-hour	WHO (2000) NEPC (1998)
Nitrogen dioxide	246 µg/m^3 62 µg/m^3	1-hour Annual	NEPC (1998) NEPC (1998)
Particulate matter < 10 µm (PM_{10})	50 µg/m^3 30 µg/m^3	24-hour Annual	NEPC (1998) EPA (1998)

mg/m^3 – milligrams per cubic metre
ppm – parts per million
µg/m^3 – micrograms per cubic metre

3.1 Carbon monoxide

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

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

[1] OEH was previously part of the Department of Environment, Climate Change and Water (DECCW). The DECCW was also recently known as the Department of Environment and Climate Change (DECC), and prior to that the Department of Environment and Conservation (DEC). The terms NSW OEH, DECCW, DECC and DEC are used interchangeably in this report.

Symptoms of carbon monoxide intoxication are lassitude and headaches. These symptoms are not however generally reported until the concentration of carboxyhaemoglobin in the blood is in excess of 10 per cent of saturation. This is about the equilibrium value achieved with an ambient atmospheric concentration of 70 milligrams per cubic metre for a person engaged in light activity. Further, there is evidence of an increased risk for individuals with cardiovascular disease once carboxyhaemoglobin concentration reaches four per cent, and the WHO recommends that ambient concentrations be kept to values which would protect individuals from exceeding the four per cent level.

The 15 minute, one hour and eight hour goals noted by the EPA provide a significant margin for safety in protecting the community, including the very young and elderly. The 15 minute, one hour and eight hour goals are 100 milligrams per cubic metre, 30 milligrams per cubic metre and 10 milligrams per cubic metre respectively.

3.2 Oxides of nitrogen

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

Nitrogen oxides emitted by motor vehicles are comprised mainly of nitric oxide (approximately 95 per cent at the point of emission) and nitrogen dioxide (approximately five per cent at the point of emission). Nitric oxide is much less harmful to humans than nitrogen dioxide and is not generally considered a pollutant at the concentrations normally found in urban environments. Monitoring data collected in Sydney (RTA, 1997) indicates that close to roadways, nitrogen dioxide makes up between five to 20 per cent by weight of the total oxides of nitrogen.

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

The EPA has not set any air quality goals for nitric oxide, however it has adopted the NEPM standard one hour and annual average goals for nitrogen dioxide as shown in **Table 3-1**.

3.3 Particulate matter

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

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

The current project will be assessed using the NEPM standards for particulate matter shown in **Table 3-1**, adopted by the EPA.

3.4 Vehicle emissions and photochemical smog

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

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

4 Existing air quality

4.1 Monitoring data

Air quality standards and goals refer to pollutant levels resulting from a combination of both the project and existing sources. To fully assess impacts against all the relevant air quality standards and goals (detailed in Section 3 and listed in **Table 3-1**) it is therefore necessary to have information or estimates on existing background pollutant concentrations for the area in which the project is likely to contribute to these levels.

The closest EPA monitoring station was located at Croom Road in Albion Park, approximately 15 kilometres north of Gerringong. This site was however decommissioned in early 2005 and a new station was commissioned at Terry Reserve (Albion Park South) in December 2005. **Table 4-1** presents a summary of air monitoring data from both sites from 1997 to 2007, which includes the most recent available data[2]. Pollutants monitored at these sites were nitrogen dioxide, ozone, sulphur dioxide and PM_{10}. The data is taken from the *National Ambient Air Quality Status and Trends Report, 1991 – 2001* (DEH, 2004) and the EPA quarterly air quality reports (NSW DECCW, 2002 - 2007).

Maximum one hour average and annual average nitrogen dioxide concentrations are well below the EPA air quality criteria. The maximum measured one hour average nitrogen dioxide concentration over the 11 year monitoring period was 166 micrograms per cubic metre in 1998. The maximum annual average was measured at 31 micrograms per cubic metre in 2003, with an average over the whole monitoring period of 11 micrograms per cubic metre.

The maximum one hour and four hour ozone air quality goals were regularly exceeded during the monitoring period. These exceedances can be attributed, in part, to variability in meteorological conditions and often occurred in the warmer summer months when sunlight hours are higher. Bushfires are also known to cause elevated ozone concentrations.

Maximum PM_{10} concentrations were on occasions above the 24 hour goal of 50 micrograms per cubic metre. For example, in 2003 the maximum recorded 24 hour average concentration recorded was 281 micrograms per cubic metre. The EPA *Annual Compliance Report* (NSW DEC, 2004) notes that dust storms occurred on the day this value was recorded. Particle pollution is affected by environmental factors such as bushfires and dust storms and some of the other high levels may also be attributed to these factors. Annual average concentrations of PM_{10} are below the EPA air quality goal of 30 micrograms per cubic metre, except in 2003. Exceedances in that year were likely to be the result of dust storms.

4.2 Modelled existing alignment

In 2007, PAEHolmes (then Holmes Air Sciences) conducted a modelling study, *Air Quality Impact Assessment – Gerringong to Bomaderry Princes Highway Upgrade* (Holmes Air Sciences, 2007), which investigated air quality impacts of the existing highway alignment in the study area. The results of this modelling are provided in **Table 4-2** and show all predicted concentrations as well below their respective air quality goals. The nearest residences through the township of Berry are about 10 metres from the kerb. Levels at this distance due to existing traffic volumes are very low and well below air quality criteria.

[2] *Data from 2008 – 2010 is not available in this format at this time.*

Table 4-1: Summary of monitoring data from 1997 to 2007

	NO_2		O_3		TEOM PM_{10}		CO[d]	
Year	Maximum 1 hour average	Annual average	Maximum 1 hour average	Maximum 4 hour average	Maximum 24 hour average	Annual average	Maximum 1 hour average	Maximum 8 hour average
Goal	**246 (µg/m^3)**	**62 (µg/m^3)**	**214 (µg/m^3)**	**171 (µg/m^3)**	**50 (µg/m^3)**	**30 (µg/m^3)**	**30 (mg/m^3)**	**10 (mg/m^3)**
1997[a]	90	8	308	265	62	18*	ND	ND
1998[a]	166	8	300	248	64	15	5.5	2.8
1999[a]	100	8	193	173	49	13	5.1	3.0
2000[a]	113	10	227	178	63	15	5.6	3.0
2001[a]	105	8	188	175	59	16	10.6	5.3
2002[b]	98	10	201	178	88	20	4.8	2.9
2003[b]	113	31	278	235	281	40	4.1	2.6
2004[b]	90	8	235	197	195	18	4.0	2.6
2005	ND	ND	ND	ND	ND	ND	3.5	2.3
2006[c]	104	9	205	167	60	18	3.4	1.9
2007[c]	92	9	197	171	54	16	3.2	1.6
Median	102	9	216	178	63	17	4.5	2.7
Maximum	166	31	308	265	281	40	10.6	5.3

ND = No data available
TOEM = Tapered Element Oscillating Microbalance (PM_{10} Monitor)
** one or more quarters of the year had data availability less than 75 per cent*
[a] *DEH (2004)*
[b] *EPA (2002-2007)*
[c] *Monitoring site now located at Albion Park Reserve*
[d] *Wollongong monitoring site*

Table 4-2: Predicted maximum ground level concentrations for existing alignment

Direction of traffic flow	Distance from kerb (m)	CO		NO_2		PM_{10}	
		1 hour average	8 hour average	1 hour average	Annual average	24 hour average	Annual average
		EPA assessment criteria					
		30 (mg/m^3)	10 (mg/m^3)	246 (µg/m^3)	62 (µg/m^3)	50 (µg/m^3)	30 (µg/m^3)
Northbound	0	0.9	0.2	231	6.1	10.8	3.6
	10	0.4	0.1	158	1.9	4.0	1.1
	30	0.2	0.1	94	0.9	2.1	0.5
	50	0.2	0.0	37	0.6	1.5	0.3
Southbound	0	0.9	0.2	297	6.2	9.2	3.7
	10	0.6	0.1	171	1.9	3.3	1.1
	30	0.3	0.1	88	0.9	1.8	0.5
	50	0.2	0.1	66	0.7	1.3	0.4

Note: The values for the NO_2 annual averages in the Holmes Air Sciences (2007) document were incorrect by a factor of 10. They have been corrected for this table.

5 Dispersion meteorology and climate

The dispersion model used for this assessment, CAL3QHCR, requires information about the dispersion characteristics of the area. In particular, data is required on wind speed, wind direction, temperature, atmospheric stability class[3] and mixing height[4].

5.1 Wind speed and direction

Meteorological data is available from two sites in the vicinity of the project. The data collected in 2000 was collected from a site located at Gerroa Tip, which is approximately five kilometres to the south-west of Gerringong. Data was also collected in 2001 from a site on Beirnfels Lane, approximately three kilometres to the south-west of Gerringong. The data was collected by the PAEHolmes (formerly Holmes Air Sciences) on behalf of Veolia Water. Permission has been granted by Veolia Water to use this data.

The Beirnfels data has an unusually high percentage of calms (wind speed of 0.5 metres per second or less) which have been attributed to some equipment malfunction during spring and early summer. For this reason data from Gerroa Tip was used in the air quality impact assessment. The data consists of hourly records of wind speed, wind direction and temperature and is presented in a format suitable for dispersion modelling. Windroses prepared from these data are shown in **Figure 5-1**.

On an annual basis, the most common winds were recorded from the west, west-north-west and north-east. During the summer the predominant winds were recorded from the north-east, while in spring they were recorded from the west, west-north-west and north-east. In autumn and winter the winds were mainly from the west and west-north-west. In autumn there were also winds from the north-east. The annual average speed recorded at the Gerroa Tip was 2.4 metres per second.

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[3] In dispersion modelling stability class is used to categorise the rate at which a plume would disperse. In the Pasquill-Gifford stability class assignment scheme, as used in this study, there are six stability classes A through to F. Class A relates to unstable conditions such as might be found on a sunny day with light winds. In such conditions plumes would spread rapidly. Class F relates to stable conditions, such as occur when the sky is clear, the winds are light and an inversion is present. Plume spreading is slow in these circumstances. The intermediate classes B, C, D and E relate to intermediate dispersion conditions.

[4] The term mixing height refers to the height of the turbulent layer of air near the earth's surface into which ground-level emissions would be rapidly mixed. A plume emitted above the mixed-layer would remain isolated from the ground until such time as the mixed-layer reaches the height of the plume. The height of the mixed-layer is controlled mainly by convection (resulting from solar heating of the ground) and by mechanically generated turbulence as the wind blows over the rough ground.

Figure 5-1: Annual and seasonal windroses for Gerroa Tip

5.2 Atmospheric stability

For the Gerroa Tip dataset, a stability class was assigned to each hour of the meteorological data using concurrent cloud cover information and the method of Turner (Turner, 1970). **Table 5-1** shows the frequency of occurrence of the stability categories expected in the area. The most common stability occurrences were calculated to be D class stabilities (21 per cent) suggesting that emissions would disperse quickly for a significant proportion of the time. For 40 per cent of the time conditions are stable (E and F class), indicating poor dispersion at those times.

Mixing height was determined using a scheme defined by Powell (1976) for daytime conditions and an approach described by Venkatram (1980) for night-time conditions. These two methods provide a good estimate of mixing height in the absence of upper air data.

Joint wind speed, wind direction and stability class frequency tables for the Gerroa Tip dataset are presented in Appendix A.

Table 5-1: Frequency of occurrence of stability classes at Gerroa tip

Stability class	Frequency of occurrence (per cent)
A	18.2
B	14.1
C	7.8
D	21.1
E	19.7
F	19.1
Total	100.0

5.3 Climate data

Table 5-2 presents the temperature, humidity and rainfall data from the Nowra Royal Australian Navy (RAN) automatic weather station (Bureau of Meteorology, 2011). Temperature and humidity data consist of monthly averages of 9am and 3pm readings. Also presented are monthly averages of maximum and minimum temperatures, and mean monthly rainfall data.

The annual average maximum and minimum temperatures experienced at Nowra RAN are 21.3 degrees Celsius and 11.3 degrees Celsius respectively. On average, January and February are the hottest months with an average maximum temperature of 25.8 degrees Celsius. July is the coldest month, with average minimum temperature of 6.2 degrees Celsius.

The annual average humidity reading collected at 9am is 70 per cent, and at 3pm the annual average is 58 per cent. The month with the highest humidity on average is February with a 9am average of 76 per cent, and the lowest humidity is in August and September with a 3pm average of 52 per cent.

Rainfall data collected shows that February is the wettest month, with an average rainfall of 120.0 millimetres. The average annual rainfall is 1110 millimetres.

Table 5-2: Temperature, humidity and rainfall data for Nowra RAN

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual average
9am mean dry-bulb and wet-bulb temperatures (^{o}C) and relative humidity (%)													
Dry-bulb	20.8	20.6	19.6	17.1	13.8	11.1	10.0	11.6	14.4	17.0	18.3	19.9	16.2
Wet-bulb	17.6	17.9	16.8	14.1	11.4	9.0	7.8	8.8	10.9	13.1	14.6	16.2	13.2
Humidity	72	76	74	71	74	75	72	68	63	63	66	68	70
3pm mean dry-bulb and wet-bulb temperatures (^{o}C) and relative humidity (%)													
Dry-bulb	24.1	24.3	23.0	20.8	18.0	15.4	14.8	15.9	17.8	19.5	21.3	23.0	19.8
Wet-bulb	19.0	19.3	18.3	15.9	13.5	11.4	10.4	11.0	12.5	14.4	16.0	17.7	15.0
Humidity	62	63	62	59	59	59	54	52	52	57	58	59	58
Daily maximum temperature (^{o}C)													
Mean	25.8	25.8	24.5	22.1	19.0	16.4	15.8	17.1	19.3	21.5	23.1	24.8	21.3
Daily minimum temperature (^{o}C)													
Mean	15.9	16.3	14.8	12.1	9.7	7.6	6.2	6.7	8.3	10.7	12.6	14.6	11.3
Rainfall (mm)													
Mean	88.4	120.0	24.4	97.1	90.5	104.8	56.5	75.8	65.6	107.5	98.1	80.5	1110

Station number 068076; Commenced: 1942, Last record: 2000; Latitude (deg S): - 34.94; Longitude (deg E): 150.55; Elevation: 190 metres
Source: Bureau of Meteorology (2011)

6 Approach to assessment

6.1 Introduction

This chapter provides a description of the methods used to model the emissions from the proposed upgrade following completion of the project. Three sections of the project were modelled, namely:

- Princes Highway, between Toolijooa Road interchange and Berry North interchange.
- Princes Highway, between Berry North interchange and Berry South interchange.
- Princes Highway, between Berry South interchange and Schofields Lane.

6.2 Caline

The Caline series of dispersion models has been used to estimate the concentration of oxides of nitrogen, carbon monoxide and particulate matter that are likely to occur in the vicinity of the existing Princes Highway. The CALINE4 model is widely used in roadway studies throughout Australia and was validated for Australian conditions in a study undertaken in Sydney by Williams et. al. (1994).

This model is an upgrade of CALINE3, the most recently US EPA approved model. It is a steady state Gaussian model which can determine concentrations at receptor locations downwind of ’at grade’, ‘fill’, ‘bridges’ and ‘cut section’ highways located in relatively uncomplicated terrain. The model is applicable for any wind direction, highway orientation and receptor location.

For this study, the CALRoads package was used to assess the impacts. This package incorporates CALINE4 as well as CAL3QHCR, which is an enhanced version of CALINE3 able to process up to a year of meteorological data.

Information needed as input to the model includes:

- Meteorological conditions.
- Traffic volumes.
- Emissions information.
- Receptor location information.

The following sections discuss each of the input requirements.

6.2.1 Meteorological conditions

As discussed in **Chapter 5**, meteorological data from Gerroa Tip for the year 2000 was the closest data to the project site that was available and was deemed to be appropriate for use in the assessment.

6.2.2 Traffic volumes

AECOM provided hourly traffic volumes for each section of highway for both years being assessed. **Table 6-1, Table 6-2** and **Table 6-3** present a summary of this data, as well as the percentage of heavy vehicles for each hour, for the years 2017 and 2027.

Table 6-1: Hourly traffic volumes (vehicles/hour) – Toolijooa Road interchange to Berry north interchange

Hour	2017				2027			
	Northbound		Southbound		Northbound		Southbound	
	Total	% Heavy vehicles	Total	% Heavy vehicles	Total	% Heavy vehicles	Total	% Heavy vehicles
1*	20	30	44	26	30	24	70	21
2	17	44	29	36	25	37	45	29
3	20	54	21	53	29	47	30	45
4	28	45	18	47	42	38	27	39
5	63	37	35	53	95	30	52	45
6	113	21	84	33	180	17	131	27
7	226	16	218	24	363	13	346	18
8	366	12	328	18	595	9	531	14
9	437	12	449	11	711	10	739	9
10	449	12	458	12	729	10	753	9
11	500	10	530	12	817	8	872	9
12	556	9	549	11	912	7	905	8
13	579	10	544	9	949	7	901	7
14	584	9	494	10	957	7	818	7
15	676	9	500	10	1110	7	827	7
16	704	7	544	9	1162	5	903	7
17	673	7	578	8	1112	5	961	6
18	577	6	503	6	955	4	840	4
19	327	6	371	7	540	5	619	5
20	167	7	252	7	276	5	420	5
21	107	10	194	8	176	8	321	6
22	77	14	148	8	124	11	246	6
23	52	19	98	10	84	15	161	8
24	33	27	61	14	51	21	100	10

**1 represents the first hour of the day, between midnight and 1 am*

Table 6-2: Hourly traffic volumes (vehicles/hour) – Berry north interchange to Berry south interchange

Hour	2017				2027			
	Northbound		Southbound		Northbound		Southbound	
	Total	% Heavy vehicles	Total	% Heavy vehicles	Total	% Heavy vehicles	Total	% Heavy vehicles
1*	20	24	41	26	31	21	63	23
2	16	40	27	36	24	36	42	31
3	17	50	19	53	25	45	28	48
4	25	43	17	47	37	38	25	42
5	54	37	33	53	82	33	48	48
6	97	22	78	33	150	19	120	29
7	208	19	201	24	323	16	314	20
8	321	16	303	18	502	14	479	15
9	392	13	414	11	615	11	663	10
10	469	11	423	12	740	9	675	10
11	492	10	489	12	778	8	782	10
12	544	9	507	11	860	8	811	9
13	551	9	502	9	872	8	806	8
14	539	10	456	10	852	8	732	8
15	566	9	462	10	895	8	740	8
16	614	7	502	9	974	6	807	7
17	615	7	533	8	977	6	859	7
18	543	6	464	6	864	5	749	5
19	302	6	343	7	480	5	552	6
20	164	6	233	7	261	5	375	6
21	102	10	179	8	161	9	287	7
22	82	11	137	8	129	10	220	7
23	57	15	90	11	89	13	144	9
24	35	22	56	14	54	19	90	12

**1 represents the first hour of the day, between midnight and 1 am*

Table 6-3: Hourly traffic volumes (vehicles/hour) – Berry south interchange to Schofields Lane

Hour	2017				2027			
	Northbound		Southbound		Northbound		Southbound	
	Total	% Heavy vehicles	Total	% Heavy vehicles	Total	% Heavy vehicles	Total	% Heavy vehicles
1*	26	24	48	26	37	21	68	22
2	20	40	34	35	28	36	48	31
3	22	50	25	49	29	45	34	44
4	32	43	20	38	44	38	28	34
5	68	37	37	42	95	33	52	37
6	121	22	84	33	174	19	120	28
7	261	19	236	22	377	16	341	19
8	403	16	400	16	585	14	586	14
9	492	13	598	10	717	11	886	9
10	589	11	540	11	862	9	798	9
11	618	10	565	14	906	8	832	11
12	683	9	610	13	1002	8	899	11
13	692	9	616	11	1017	8	911	9
14	677	10	606	11	993	8	896	9
15	710	9	636	10	1043	8	942	9
16	770	7	689	9	1135	6	1022	8
17	772	7	690	8	1138	6	1025	7
18	681	6	593	6	1007	5	886	5
19	379	6	404	7	560	5	601	6
20	206	6	265	7	304	5	394	6
21	128	10	190	9	187	9	282	7
22	103	11	155	8	151	10	230	7
23	72	15	107	10	104	13	159	9
24	44	22	71	14	63	19	104	11

**1 represents the first hour of the day, between midnight and 1 am*

6.2.3 Vehicle emission rates

This section provides a brief description of the methods used to calculate the emissions of carbon monoxide, nitrogen oxides and PM_{10} from vehicles.

Vehicle emission data from the Permanent International Association of Road Congresses (PIARC) (PIARC, 2004) was adjusted to reflect the NSW vehicle fleet. The modified tables include emissions of carbon monoxide, nitrogen oxides and PM_{10} by age and type of vehicle. The ages of vehicles are categorised into seven periods which correspond to the introduction of emission standards. The types of vehicle are categorised into light and heavy vehicle groups.

Proportions of traffic within each age category for 2017 and 2027 have been extrapolated from the proportions of traffic within each age category using NSW traffic registration data from the Australian Bureau of Statistics (ABS) Motor Vehicle Census (ABS, 2005). No future improvements in vehicle technology or fuel standards have been included in the emission estimates. The data collected by Australasian Traffic Surveys showed that the proportion of the fleet that is heavy-goods vehicles (HGVs) varies throughout the day. It was assumed that five per cent of the passenger vehicles are diesel and 95 per cent are petrol.

The CAL3QHCR model requires emission factors in units of grams per vehicle mile. The emission factors along each section of road have been calculated from the traffic flow, vehicle mix and the emission rate per vehicle derived from the PIARC tables. Due to the variability of the light and heavy vehicle traffic mix, the emission factors would be different for each hour. **Table 6-4, Table 6-5**, and **Table 6-6** present the estimated carbon monoxide, nitrogen oxide and PM_{10} emission rates for 2017 and 2027, along each section of the highway.

Table 6-4: Estimated vehicle emission rates – Toolijooa Road interchange to Berry north interchange (g/veh-mile)

Hour	Northbound						Southbound					
	CO		NO_2		CO		NO_2		CO		NO_2	
	2017	2027	2017	2027	2017	2027	2017	2027	2017	2027	2017	2027
1*	4.38	3.83	2.97	1.95	0.18	0.10	4.42	3.89	2.72	1.79	0.16	0.09
2	4.19	3.59	3.94	2.59	0.24	0.14	4.29	3.73	3.37	2.20	0.20	0.12
3	4.05	3.40	4.64	3.08	0.29	0.17	4.07	3.43	4.53	3.00	0.28	0.17
4	4.18	3.57	4.01	2.64	0.25	0.15	4.14	3.53	4.15	2.72	0.26	0.15
5	4.28	3.71	3.46	2.27	0.21	0.12	4.07	3.42	4.57	3.01	0.29	0.17
6	4.48	3.97	2.38	1.60	0.14	0.08	4.33	3.78	3.20	2.09	0.19	0.11
7	4.55	4.05	2.05	1.40	0.11	0.07	4.46	3.93	2.54	1.69	0.15	0.09
8	4.61	4.11	1.76	1.23	0.09	0.06	4.53	4.03	2.15	1.45	0.12	0.07
9	4.61	4.11	1.78	1.24	0.09	0.06	4.62	4.13	1.70	1.19	0.09	0.05
10	4.61	4.11	1.78	1.24	0.09	0.06	4.61	4.11	1.76	1.23	0.09	0.06
11	4.63	4.14	1.63	1.16	0.08	0.05	4.61	4.12	1.74	1.22	0.09	0.06
12	4.65	4.16	1.56	1.12	0.08	0.05	4.62	4.13	1.69	1.19	0.09	0.05
13	4.64	4.15	1.58	1.14	0.08	0.05	4.65	4.15	1.57	1.12	0.08	0.05
14	4.64	4.15	1.57	1.13	0.08	0.05	4.64	4.15	1.60	1.13	0.08	0.05
15	4.66	4.17	1.52	1.10	0.08	0.05	4.64	4.15	1.61	1.15	0.08	0.05
16	4.68	4.19	1.40	1.03	0.07	0.04	4.65	4.16	1.54	1.10	0.08	0.05
17	4.68	4.19	1.38	1.02	0.07	0.04	4.67	4.18	1.47	1.07	0.07	0.05
18	4.69	4.20	1.32	0.99	0.06	0.04	4.69	4.20	1.34	0.99	0.06	0.04
19	4.68	4.20	1.36	1.01	0.06	0.04	4.68	4.19	1.41	1.04	0.07	0.04
20	4.67	4.19	1.41	1.04	0.07	0.05	4.67	4.19	1.42	1.04	0.07	0.05
21	4.64	4.14	1.62	1.15	0.08	0.05	4.66	4.17	1.50	1.09	0.07	0.05
22	4.58	4.08	1.87	1.30	0.10	0.06	4.66	4.17	1.50	1.09	0.07	0.05
23	4.52	4.01	2.22	1.50	0.12	0.07	4.63	4.14	1.65	1.17	0.08	0.05
24	4.42	3.88	2.76	1.82	0.16	0.09	4.59	4.09	1.86	1.29	0.10	0.06

g/veh-mile – grams per vehicle mile
**1 represents the first hour of the day, between midnight and 1 am*

Table 6-5: Estimated vehicle emission rates – Berry north interchange to Berry south interchange (g/veh-mile)

Hour	Northbound						Southbound					
	CO		NO_2		CO		NO_2		CO		NO_2	
	2017	2027	2017	2027	2017	2027	2017	2027	2017	2027	2017	2027
1*	4.46	3.89	2.55	1.79	0.15	0.09	4.42	3.86	2.73	1.90	0.16	0.10
2	4.23	3.60	3.69	2.55	0.22	0.14	4.30	3.69	3.38	2.33	0.20	0.13
3	4.11	3.42	4.35	3.02	0.27	0.17	4.07	3.37	4.55	3.14	0.28	0.18
4	4.20	3.55	3.87	2.68	0.24	0.15	4.15	3.47	4.16	2.87	0.26	0.16
5	4.28	3.66	3.45	2.39	0.21	0.13	4.06	3.36	4.57	3.17	0.29	0.18
6	4.48	3.92	2.46	1.73	0.14	0.09	4.33	3.73	3.20	2.21	0.19	0.12
7	4.52	3.98	2.20	1.56	0.12	0.08	4.45	3.90	2.55	1.78	0.15	0.09
8	4.56	4.03	2.02	1.44	0.11	0.07	4.53	3.99	2.16	1.53	0.12	0.08
9	4.59	4.07	1.85	1.34	0.10	0.06	4.62	4.11	1.71	1.25	0.09	0.06
10	4.63	4.11	1.68	1.23	0.09	0.06	4.61	4.09	1.77	1.28	0.09	0.06
11	4.64	4.13	1.59	1.18	0.08	0.05	4.61	4.10	1.75	1.27	0.09	0.06
12	4.64	4.14	1.56	1.17	0.08	0.05	4.62	4.11	1.69	1.23	0.09	0.06
13	4.65	4.14	1.55	1.16	0.08	0.05	4.64	4.14	1.57	1.17	0.08	0.05
14	4.64	4.14	1.59	1.18	0.08	0.05	4.64	4.13	1.60	1.18	0.08	0.05
15	4.65	4.15	1.53	1.15	0.08	0.05	4.64	4.13	1.62	1.19	0.08	0.05
16	4.67	4.17	1.42	1.08	0.07	0.05	4.65	4.14	1.53	1.14	0.08	0.05
17	4.68	4.18	1.38	1.06	0.07	0.05	4.67	4.16	1.47	1.10	0.07	0.05
18	4.69	4.20	1.31	1.01	0.06	0.04	4.69	4.20	1.34	1.02	0.06	0.04
19	4.69	4.20	1.32	1.02	0.06	0.04	4.68	4.18	1.41	1.07	0.07	0.05
20	4.69	4.19	1.35	1.03	0.06	0.04	4.67	4.17	1.42	1.08	0.07	0.05
21	4.64	4.13	1.62	1.19	0.08	0.05	4.66	4.16	1.51	1.13	0.07	0.05
22	4.61	4.10	1.71	1.25	0.09	0.06	4.66	4.15	1.50	1.12	0.07	0.05
23	4.57	4.04	1.97	1.42	0.11	0.07	4.63	4.12	1.64	1.21	0.08	0.06
24	4.48	3.94	2.41	1.70	0.14	0.09	4.58	4.07	1.86	1.35	0.10	0.06

g/veh-mile – grams per vehicle mile
**1 represents the first hour of the day, between midnight and 1 am*

Table 6-6: Estimated vehicle emission rates – Berry south interchange to Schofields Lane (g/veh-mile)

Hour	Northbound						Southbound					
	CO		NO_2		PM_{10}		CO		NO_2		PM_{10}	
	2017	2027	2017	2027	2017	2027	2017	2027	2017	2027	2017	2027
1*	4.46	3.89	2.55	1.79	0.15	0.09	4.43	3.86	2.69	1.87	0.16	0.10
2	4.23	3.60	3.69	2.55	0.22	0.14	4.31	3.70	3.33	2.29	0.20	0.12
3	4.11	3.42	4.35	3.02	0.27	0.17	4.12	3.44	4.31	2.98	0.27	0.17
4	4.20	3.55	3.87	2.68	0.24	0.15	4.26	3.64	3.54	2.43	0.21	0.13
5	4.28	3.66	3.45	2.39	0.21	0.13	4.22	3.57	3.79	2.61	0.23	0.14
6	4.48	3.92	2.46	1.73	0.14	0.09	4.34	3.74	3.16	2.18	0.19	0.12
7	4.52	3.98	2.20	1.56	0.12	0.08	4.48	3.93	2.44	1.71	0.14	0.09
8	4.56	4.03	2.02	1.44	0.11	0.07	4.56	4.03	2.03	1.45	0.11	0.07
9	4.59	4.07	1.85	1.34	0.10	0.06	4.63	4.12	1.63	1.20	0.08	0.06
10	4.63	4.11	1.68	1.23	0.09	0.06	4.62	4.11	1.69	1.24	0.09	0.06
11	4.64	4.13	1.59	1.18	0.08	0.05	4.59	4.07	1.85	1.34	0.10	0.06
12	4.64	4.14	1.56	1.17	0.08	0.05	4.60	4.08	1.79	1.30	0.09	0.06
13	4.65	4.14	1.55	1.16	0.08	0.05	4.63	4.12	1.66	1.22	0.09	0.06
14	4.64	4.14	1.59	1.18	0.08	0.05	4.62	4.11	1.67	1.22	0.09	0.06
15	4.65	4.15	1.53	1.15	0.08	0.05	4.63	4.12	1.63	1.20	0.08	0.06
16	4.67	4.17	1.42	1.08	0.07	0.05	4.65	4.14	1.56	1.15	0.08	0.05
17	4.68	4.18	1.38	1.06	0.07	0.05	4.66	4.15	1.50	1.12	0.07	0.05
18	4.69	4.20	1.31	1.01	0.06	0.04	4.69	4.20	1.32	1.01	0.06	0.04
19	4.69	4.20	1.32	1.02	0.06	0.04	4.67	4.18	1.43	1.08	0.07	0.05
20	4.69	4.19	1.35	1.03	0.06	0.04	4.68	4.18	1.39	1.05	0.07	0.05
21	4.64	4.13	1.62	1.19	0.08	0.05	4.66	4.15	1.52	1.13	0.08	0.05
22	4.61	4.10	1.71	1.25	0.09	0.06	4.66	4.15	1.50	1.12	0.07	0.05
23	4.57	4.04	1.97	1.42	0.11	0.07	4.63	4.12	1.64	1.20	0.08	0.06
24	4.48	3.94	2.41	1.70	0.14	0.09	4.59	4.07	1.86	1.34	0.10	0.06

g/veh-mile – grams per vehicle mile
**1 represents the first hour of the day, between midnight and 1 am*

6.2.4 Receptor locations

Receptors were positioned at the nearest residential receptors along the proposed alignment. **Figure 6-1** shows the locations of residences, as well as the ancillary construction facilities, which would include stockpile compounds that would be used during construction as assessed in Section 8.2. The 69 receptors used for the operational modelling represent those closest to the proposed roadway alignment. An additional number of receptors were chosen for the modelling of wind erosion from stockpiles at the ancillary facilities (discussed in Section 8.2), and those are also shown in **Figure 6-1**.

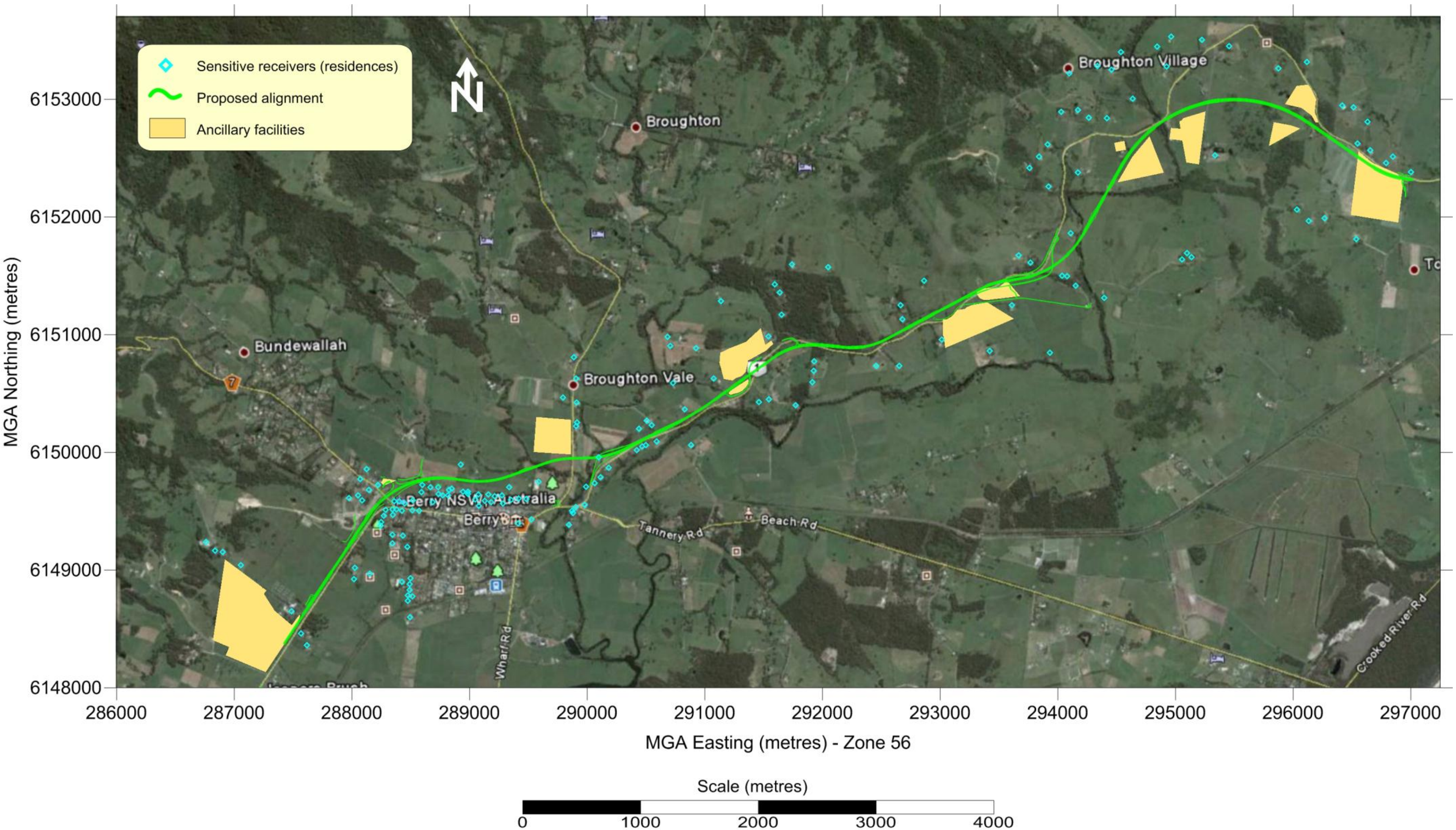

Figure 6-1: Location of sensitive receptors (residences) and potential ancillary facilities locations along the proposed alignment

7 Assessment of impacts

7.1 Introduction

This chapter assesses the predicted local air quality impacts due to emissions from the project. The maximum predicted concentrations for 2017 and 2027 at 69 of the closest receptors are shown in **Table 7-1** and **Table 7-2** respectively.

Table 7-1 Predicted maximum ground-level concentrations in 2017

	EPA criteria					
	CO		NO_2		PM_{10}	
Receptors	30 (mg/m^3)	10 (mg/m^3)	246 (µg/m^3)	62 (µg/m^3)	50 (µg/m^3)	30 (µg/m^3)
1	0.16	0.05	4.1	0.04	0.17	0.01
2	0.15	0.04	4.2	0.23	0.18	0.03
3	0.11	0.03	3.0	0.16	0.27	0.04
4	0.16	0.03	4.7	0.10	0.20	0.02
5	0.16	0.03	4.4	0.09	0.18	0.02
6	0.17	0.03	4.7	0.10	0.17	0.02
7	0.16	0.03	4.5	0.09	0.17	0.02
8	0.16	0.03	4.6	0.09	0.17	0.02
9	0.16	0.03	4.6	0.09	0.19	0.01
10	0.17	0.04	4.8	0.09	0.18	0.01
11	0.17	0.03	4.7	0.08	0.14	0.01
12	0.28	0.05	7.8	0.13	0.23	0.02
13	0.24	0.04	6.7	0.10	0.20	0.02
14	0.25	0.04	6.9	0.09	0.20	0.01
15	0.21	0.04	5.9	0.08	0.17	0.01
16	0.21	0.04	5.9	0.08	0.17	0.01
17	0.14	0.03	3.9	0.06	0.12	0.01
18	0.12	0.03	3.5	0.16	0.15	0.02
19	0.10	0.03	2.9	0.13	0.14	0.01
20	0.17	0.05	4.8	0.24	0.25	0.04
21	0.16	0.04	4.5	0.23	0.22	0.03
22	0.19	0.06	5.3	0.36	0.35	0.07
23	0.25	0.05	7.1	0.10	0.20	0.02
24	0.21	0.04	5.9	0.08	0.10	0.01
25	0.23	0.04	6.4	0.08	0.18	0.01
26	0.12	0.02	3.3	0.05	0.11	0.01
27	0.11	0.02	3.3	0.07	0.09	0.01
28	0.27	0.05	6.9	0.28	0.26	0.04
29	0.14	0.03	3.3	0.17	0.15	0.02
30	0.16	0.03	4.1	0.15	0.14	0.02
31	0.20	0.06	5.9	0.25	0.29	0.05
32	0.20	0.05	5.7	0.21	0.22	0.04

Receptors	EPA criteria					
	CO		NO_2		PM_{10}	
	30 (mg/m^3)	10 (mg/m^3)	246 ($\mu g/m^3$)	62 ($\mu g/m^3$)	50 ($\mu g/m^3$)	30 ($\mu g/m^3$)
33	0.21	0.05	5.9	0.21	0.25	0.04
34	0.23	0.06	6.3	0.23	0.28	0.04
35	0.27	0.05	7.6	0.19	0.24	0.04
36	0.28	0.05	7.7	0.18	0.26	0.04
37	0.29	0.05	8.0	0.19	0.31	0.04
38	0.20	0.04	5.3	0.16	0.21	0.03
39	0.32	0.06	8.9	0.24	0.38	0.05
40	0.21	0.04	5.8	0.18	0.23	0.03
41	0.21	0.04	6.2	0.20	0.31	0.04
42	0.23	0.04	6.7	0.21	0.31	0.04
43	0.18	0.04	5.4	0.16	0.22	0.02
44	0.21	0.04	6.2	0.20	0.26	0.03
45	0.19	0.05	5.6	0.20	0.28	0.04
46	0.17	0.05	5.1	0.21	0.30	0.04
47	0.13	0.05	3.8	0.20	0.26	0.03
48	0.13	0.05	3.6	0.17	0.24	0.03
49	0.13	0.05	3.6	0.18	0.23	0.03
50	0.13	0.05	3.6	0.18	0.25	0.03
51	0.11	0.04	3.3	0.15	0.20	0.02
52	0.12	0.04	3.5	0.15	0.19	0.02
53	0.13	0.04	3.7	0.15	0.19	0.02
54	0.13	0.04	3.7	0.15	0.20	0.02
55	0.12	0.04	3.6	0.14	0.17	0.02
56	0.12	0.04	3.6	0.13	0.17	0.02
57	0.12	0.03	3.5	0.11	0.13	0.01
58	0.15	0.04	4.1	0.18	0.20	0.02
59	0.22	0.07	5.7	0.38	0.33	0.08
60	0.13	0.05	3.5	0.18	0.18	0.03
61	0.39	0.10	10.8	0.44	0.55	0.14
62	0.37	0.10	10.7	0.40	0.48	0.11
63	0.33	0.09	9.4	0.00	0.40	0.00
64	0.24	0.07	6.3	0.30	0.36	0.06
65	0.12	0.04	3.5	0.11	0.13	0.02
66	0.10	0.02	2.7	0.10	0.12	0.01
67	0.20	0.04	5.6	0.14	0.13	0.02
68	0.12	0.03	3.1	0.09	0.16	0.02
69	0.19	0.04	5.7	0.13	0.18	0.03

Table 7-2: Predicted maximum ground-level concentrations in 2027

Receptors	EPA criteria CO 30 (mg/m^3)	CO 10 (mg/m^3)	NO_2 246 (µg/m^3)	NO_2 62 (µg/m^3)	PM_{10} 50 (µg/m^3)	PM_{10} 30 (µg/m^3)
1	0.21	0.06	4.6	0.05	0.18	0.01
2	0.20	0.05	4.7	0.24	0.18	0.03
3	0.15	0.05	3.4	0.17	0.27	0.04
4	0.21	0.05	5.1	0.11	0.18	0.02
5	0.21	0.05	4.9	0.10	0.18	0.02
6	0.22	0.05	5.2	0.11	0.17	0.02
7	0.21	0.05	5.1	0.10	0.17	0.02
8	0.22	0.05	5.1	0.10	0.17	0.02
9	0.22	0.05	5.1	0.10	0.21	0.01
10	0.22	0.05	5.4	0.10	0.18	0.01
11	0.22	0.04	5.3	0.09	0.15	0.01
12	0.37	0.07	8.7	0.14	0.24	0.02
13	0.32	0.06	7.6	0.11	0.20	0.02
14	0.33	0.06	7.7	0.10	0.20	0.01
15	0.28	0.05	6.6	0.09	0.18	0.01
16	0.28	0.05	6.7	0.09	0.17	0.01
17	0.19	0.04	4.4	0.07	0.12	0.01
18	0.16	0.04	3.9	0.18	0.15	0.02
19	0.14	0.04	3.2	0.14	0.14	0.01
20	0.22	0.06	5.4	0.26	0.24	0.04
21	0.21	0.06	5.1	0.24	0.21	0.03
22	0.25	0.08	5.9	0.39	0.36	0.07
23	0.33	0.06	7.9	0.11	0.20	0.02
24	0.28	0.05	6.6	0.09	0.18	0.01
25	0.30	0.05	7.2	0.09	0.18	0.01
26	0.16	0.03	3.7	0.05	0.10	0.01
27	0.17	0.03	4.0	0.08	0.10	0.01
28	0.38	0.07	8.5	0.33	0.27	0.05
29	0.18	0.04	4.0	0.20	0.17	0.02
30	0.23	0.04	5.1	0.18	0.14	0.02
31	0.28	0.09	7.1	0.30	0.30	0.06
32	0.29	0.08	6.8	0.26	0.24	0.05
33	0.30	0.08	7.2	0.26	0.25	0.04
34	0.32	0.08	7.7	0.27	0.28	0.05

Receptors	EPA criteria					
	CO		NO_2		PM_{10}	
	30 (mg/m^3)	10 (mg/m^3)	246 (µg/m^3)	62 (µg/m^3)	50 (µg/m^3)	30 (µg/m^3)
35	0.38	0.07	9.1	0.23	0.27	0.04
36	0.40	0.07	9.3	0.22	0.31	0.04
37	0.41	0.07	9.7	0.23	0.33	0.05
38	0.27	0.05	6.5	0.20	0.23	0.03
39	0.46	0.08	10.7	0.29	0.43	0.06
40	0.29	0.06	7.1	0.22	0.27	0.03
41	0.31	0.06	7.5	0.25	0.34	0.04
42	0.33	0.06	8.1	0.26	0.30	0.04
43	0.27	0.05	6.5	0.20	0.22	0.03
44	0.30	0.06	7.4	0.24	0.30	0.04
45	0.27	0.07	6.8	0.25	0.28	0.04
46	0.25	0.07	6.2	0.26	0.31	0.05
47	0.19	0.07	4.6	0.24	0.29	0.04
48	0.18	0.07	4.4	0.21	0.26	0.03
49	0.18	0.07	4.4	0.21	0.25	0.03
50	0.18	0.07	4.3	0.21	0.25	0.03
51	0.16	0.06	4.0	0.18	0.20	0.02
52	0.17	0.06	4.2	0.19	0.20	0.02
53	0.18	0.06	4.4	0.19	0.20	0.02
54	0.19	0.06	4.5	0.18	0.22	0.02
55	0.18	0.05	4.3	0.17	0.18	0.02
56	0.18	0.06	4.3	0.16	0.19	0.02
57	0.19	0.05	4.3	0.13	0.14	0.01
58	0.22	0.06	5.0	0.21	0.20	0.02
59	0.32	0.10	7.0	0.44	0.33	0.08
60	0.19	0.07	4.2	0.21	0.20	0.03
61	0.57	0.15	13.0	0.51	0.58	0.15
62	0.55	0.14	12.8	0.47	0.53	0.12
63	0.49	0.13	11.4	0.43	0.45	0.10
64	0.36	0.10	7.8	0.35	0.38	0.06
65	0.18	0.05	4.2	0.13	0.14	0.02
66	0.15	0.03	3.3	0.12	0.11	0.01
67	0.30	0.06	6.7	0.16	0.15	0.02
68	0.18	0.05	3.9	0.11	0.16	0.02
69	0.30	0.06	6.8	0.15	0.20	0.03

7.2 Carbon monoxide

7.2.1 Predicted impacts

Table 7-1 and **Table 7-2** show that the highest predicted one hour average carbon monoxide concentrations along the proposed highway are 0.39 milligrams per cubic metre and 0.57 milligrams per cubic metre in 2017 and 2027, respectively. Both these concentrations occurred at residences to the east of Berry. The maximum predicted eight hour average carbon monoxide concentration is approximately 0.10 milligrams per cubic metre and 0.15 milligrams per cubic metre in 2017 and 2027 respectively. These values are well below their respective EPA criteria of 30 milligrams per cubic metre (one hour) and 10 micrograms per cubic metre (eight hour).

These results are of the same order as those presented for the existing alignment in **Table 4-2** for distances 30 metres from the highway. This is not surprising given that even though traffic volumes have increased, the vehicles are spread further across four lane widths instead of two. Also, although no specific future improvements in emissions technology have been incorporated in the modelling, the vehicle mix is considered and in 2017 and 2027, the vehicle fleet would have a lower percentage of older, more inefficient vehicles.

7.2.2 Cumulative impacts

Based on the data presented in **Table 4-1**, the maximum one hour average carbon monoxide concentration is 10.6 milligrams per cubic metre. Therefore, the cumulative impact with the maximum predicted one hour average concentration of 0.39 milligrams per cubic metre at the most affected residence, is 11 milligrams per cubic metre. The cumulative eight hour average carbon monoxide concentration is estimated to be 5.4 milligrams per cubic metre [5.3 milligrams per cubic metre + 0.1 milligrams per cubic metre]. It is therefore unlikely that the EPA one hour average impact assessment criteria of 30 milligrams per cubic metre would be exceeded due to emissions from the proposed highway. Concentrations at residences further from the highway would be lower.

It should be noted, that the existing air quality data presented in **Table 4-1** includes emissions from the current sources in the area including the existing highway. Therefore, simply summing the maximum modelled concentration and maximum measured background concentration would result in a very conservative assessment of cumulative impacts. However, it has been shown that even this conservative approach does not result in an exceedance of the EPA criteria.

7.3 Oxides of nitrogen

7.3.1 Introduction

Estimating nitrogen dioxide concentrations is more complicated than estimating carbon monoxide concentrations. As discussed in Section 3.2, nitrogen oxides are initially emitted as a mixture of nitric oxide and other oxides of nitrogen, which are oxidised to nitrogen dioxide. At the point of emission the mixture is generally about five per cent nitrogen dioxide by mass. However, while the maximum concentrations of total oxides of nitrogen generally occur during peak hour, this is not necessarily the case for nitrogen dioxide. The monitoring program undertaken by RMS (RTA, 1997) indicates that during peak hour the percentage nitrogen dioxide at 10 metres from the highway edge is likely to be about five per cent. The conversion rate from nitric oxide to nitrogen dioxide at other times of the day may be significantly higher than this although the total oxides of nitrogen levels may be significantly lower than peak hour levels. It is therefore necessary to assume some intermediate value for a worst-case assessment.

Data from the air quality monitoring program (RTA, 1997) indicates that at 10 metres from the highway, a conversion rate of 15 per cent by weight is conservative (ie an overestimate). At distances of between 20 metres and 60 metres from the kerbside, the 20 per cent conversion rate appears to be appropriate. There are no monitoring data for the kerbside location in the present study, but it is considered that a 15 per cent conversion rate at 10 metres is likely to still be conservative. Given that the nearest residences are 20-30 metres or more from the highway, a rate of 20 per cent would be appropriate. However, for this study a 100 per cent conversion rate has been used to show that, even at this rate, levels would remain below the air quality criteria.

7.3.2 Predicted impacts

Table 7-1 and **Table 7-2** show that the highest predicted one hour and annual average concentrations of nitrogen dioxide, are 10.8 micrograms per cubic metre and 0.4 micrograms per cubic metre (2017) and 13.0 micrograms per cubic metre and 0.5 micrograms per cubic metre (2027), respectively. These are well within the EPA assessment criteria and are also lower than those predicted for the existing alignment, for reasons already discussed in Section 7.2.1.

7.3.3 Cumulative impacts

As summarised in **Table 4-1** the maximum measured nitrogen dioxide concentrations in the area were 166 micrograms per cubic metre (one hour average) and 31 micrograms per cubic metre (annual average). It should be remembered that these were maximum values over an 11 year monitoring period and most values were much lower, so adding model predictions to these is a very conservative method of assessment. However, even when using this conservative method, the nitrogen dioxide values remain below EPA criteria.

7.4 Particulate matter

7.4.1 Predicted impacts

Table 7-1 and **Table 7-2** show that the highest predicted 24 hour average PM_{10} concentrations contributed by emissions from the project alone are 0.55 micrograms per cubic metre and 0.58 micrograms per cubic metre in 2017 and 2027, respectively, at the nearest residential receptor. The maximum predicted annual average concentrations contributed by emissions from the project alone are approximately 0.14 micrograms per cubic metre and 0.15 micrograms per cubic metre in 2017 and 2027 respectively. These values are well below their respective EPA criteria of 50 micrograms per cubic metre and 30 micrograms per cubic metre respectively. These predicted PM_{10} concentrations are not significant increases to the emission levels from the existing highway and are not likely to result in adverse impacts on air quality at residences.

When comparing these PM_{10} results with those for the existing alignment, as shown in **Table 4-2**, it can be seen that PM_{10} values are predicted to be lower following completion of the project. Given the extremely variable nature of 24 hour PM_{10} measurements due to local sources, these increases are unlikely to be detectable.

7.4.2 Cumulative impacts

In the case of particulate matter, there would be exceedances of the 24 hour assessment criteria from time to time, as background levels on occasions are already close to or in exceedance of the goal (as can be seen from the data presented in **Table 4-1**). This is due to the fact that 24 hour levels can be greatly affected by local dust generating activities near the monitor, and may be quite high when levels not far away are much lower. These measurements can also be influenced by more regional phenomenon such as dust storms which is indeed the case for some of the excessive levels.

Also, the 24 hour average values presented in **Table 4-1** are the maximum values over the whole year, and may have occurred on a single day while the majority of readings were well below these.

If the logic that there should be no exceedances of impact assessment criteria is followed, no project could be approved on the basis of particulate emissions given that the goals are already exceeded on occasion. In the case of a relatively rural area such as for this project, these exceedances are often caused by local dust generating activities and are usually short lived. In these circumstances it is useful to consider the degree to which the project on its own compromises the impact assessment criteria.

The approach adopted in this report has been to consider first the case of adding the maximum predicted to the median background. If this approach shows exceedances, the degree to which the predicted concentrations of pollutants make up the relevant impact assessment criteria has been considered.

Based on the data presented in **Table 4-1**, the median 24 hour average PM_{10} concentration is 63 micrograms per cubic metre. This exceeds the EPA impact assessment criteria of 50 micrograms per cubic metre without the inclusion of the predicted concentrations due to the project. The maximum predicted 24 hour average concentration of 0.55 micrograms per cubic metre represents less than one per cent of the EPA assessment criteria. This percentage is approximately the same in 2027. It is therefore unlikely that the goal would be exceeded due to the small contribution from the proposed upgrade.

Based on the data presented in **Table 4-1**, the median annual PM_{10} concentration is 17 micrograms per cubic metre. Therefore, the cumulative impact with the maximum predicted annual average concentration of 0.15 micrograms per cubic metre is 17.2 micrograms per cubic metre at the nearest residences. This is well below the EPA annual average criteria of 30 micrograms per cubic metre.

8 Construction impacts

Dust would be generated from earthworks associated with the construction of the proposed highway and the total amount of dust would depend on the silt and moisture content in the soil and the types of activities being carried out.

There are a number of activities involved in the construction process but the main sources would be blasting, the use of excavators, front-end loaders and dump trucks, as well as wind erosion from exposed areas.

8.1 Earth moving operations

In order to estimate what emissions may be expected in an area where drilling and blasting would occur, emissions have been calculated on information provided by AECOM and are summarised in **Table 8-1**. It has been assumed that the construction would occur over a 39 month period. Blasting, however, has been assumed to occur only at the beginning of construction for the first 24 months.

There would be other sources of dust such as vehicle movement on unsealed roads (an estimate for which has been made in **Table 8-1**), but these are not as easily quantifiable due to the highly variable distances travelled. The use of a water cart would assist to substantially reduce these emissions.

Table 8-1: Estimated dust emissions due to earthworks

Source/activity	Intensity	Emission factor[5]	Total dust emissions
Site setup and excavation (Time period – 39 months)			
Blasting	300 blasts	14 kg/blast[6]	4200 kg
Excavators on material	441,100 t[7]	0.0022 kg/t	970 kg
Front-end loaders moving material	441,100 t	0.0022 kg/t	970 kg
Haulage	441,100 t	0.0139 kg/t[8]	6130 kg
Surface area exposed to wind erosion	8 ha	0.4 kg/ha/h	91,100 kg
Total (over a 39 month period)			103,370 kg
Average annual emission			31,800 kg/y

t = tonne
kg = kilogram
kg/t = kilogram per tonne
kg/blast = kilogram per blast
kg/y = kilogram per year
kg/ha/h = kilogram per hectare per hour

[5] *Using equations from US EPA, 1995 and updates.*

[6] *Assuming 1600 square metres blasts and 150 blasts per year (300 total blasts over construction period).*

[7] *Assuming a density of 2.3 tonnes per bank cubic metre (used to convert cubic metres into tonnes for use with emission factors). Bank cubic metre refers to the amount of material when it is in the ground.) for the 192,000 cubic metres of rock to be excavated through Toolijooa Ridge.*

[8] *This assumes a truck capacity of about 36 tonne, travelling approximately 500 metres on unsealed/watered roads.*

Dust emissions of this scale are unlikely to cause any adverse impacts at the nearest residential areas. As a comparison, there are major dust producing industries such as quarries which emit dust at rates significantly greater than this and still comply with both health and nuisance long-term criteria. There may be short-term nuisance impacts at locations adjacent to the construction site and these would generally occur on days where wind speeds are elevated.

8.2 Wind erosion from proposed ancillary facilities

A simple modelling study was undertaken to estimate the impacts of wind erosion emissions from proposed ancillary facilities on sensitive receptors. It was assumed that all sites would be stockpile compounds and that all stockpiles were 50 per cent exposed at all times over a 12 month period, and subject to wind erosion 24 hours per day. This is a conservative (ie worst case) estimate as it is more likely that construction would occur in phases and therefore not all stockpiles would be active simultaneously for the whole year.

Predictions were made using a modified version of the United States Environment Protection Agency (USEPA) Industrial Source Complex model, namely ISCMOD[9], at sensitive receptors (residences) along the proposed route. Both maximum 24 hour and annual average PM_{10} concentrations were predicted as well as annual average total suspended particulates (TSP) concentrations and dust deposition levels. As discussed in Section 3.3, the maximum 24 hour and annual average PM_{10} criteria are 50 micrograms per cubic metre and 30 micrograms per cubic metre, respectively, and the annual average criterion for TSP is 90 micrograms per cubic metre.

In addition to this, airborne dust also has the potential to cause nuisance effects by depositing on surfaces, and deposition criteria are set to protect against these nuisance impacts (NSW DEC, 2005). The maximum acceptable increase in dust deposition over the existing dust levels from an amenity perspective is two grams per square metre per month. So for the project alone, the incremental criterion is two grams per square metre per month and for total deposition (including background) is four grams per square metre per month.

Modelling results for both concentration and deposition are shown in contour plots from **Figures 8-1** to **Figure 8-4**, and show that none of these annual concentration criteria are predicted to be exceeded due to wind erosion from the stockpile compounds along the alignment route. The highest predicted annual average PM_{10} level at any of the sensitive receptors was estimated to be approximately six micrograms per cubic metre, while the maximum predicted annual average TSP concentration at these receptors was 12 micrograms per cubic metre. These predictions are both well below their respective goals of 30 micrograms per cubic metre and 90 micrograms per cubic metre and are likely to remain so even when adding in a conservative background level.

Dust deposition predictions at a single residence (indicated as a red cross) showed an annual average level of three grams per square metre per month as a result of the project. This is an exceedance of the incremental criterion. However, this is unlikely to occur in reality given the conservative assumptions made about the wind erosion occurring from all stockpile compounds simultaneously for the entire year. Also, and perhaps more importantly, it should be noted that no dust mitigation measures (discussed in Section 9) have been incorporated into the modelling. With these measures in place, particularly at times of elevated wind speeds, emissions are likely to be lower than those modelled and within the criterion. Predictions at all other sensitive receptors remained well below the incremental criterion of two grams per square metre per month. It is also unlikely that the cumulative criterion would be exceeded at this receiver.

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[9] *ISCMOD has been accepted for use in NSW by the EPA*

Predictions of 24 hour PM_{10} concentrations at almost all of the sensitive receptors were below 10 micrograms per cubic metre. One residence (identified with a red cross on **Figure 8-1)** is predicted to experience a maximum 24 hour PM_{10} concentration of 38 micrograms per cubic metre, which is below 50 micrograms per cubic metre criteria. Further review of results at that particular residence showed that there were only two days in the year where predictions were above 20 micrograms per cubic metre, and that the 90^{th} percentile 24 hour average PM_{10} level was very low at four micrograms per cubic metre.

This low 90^{th} percentile indicates that these higher values are infrequent and likely to be the result of winds blowing directly from the stockpile towards that particular receptor for a number of hours within the 24 hour period. Again, it should also be noted that mitigation measures have not been incorporated into the modelling, and on a 24 hour basis these can reduce ground level concentrations significantly. The implementation of the standard and best practice mitigation measures, discussed further in Section 9 is more than likely to be able to manage both the long-term deposition and short-term PM_{10} impacts.

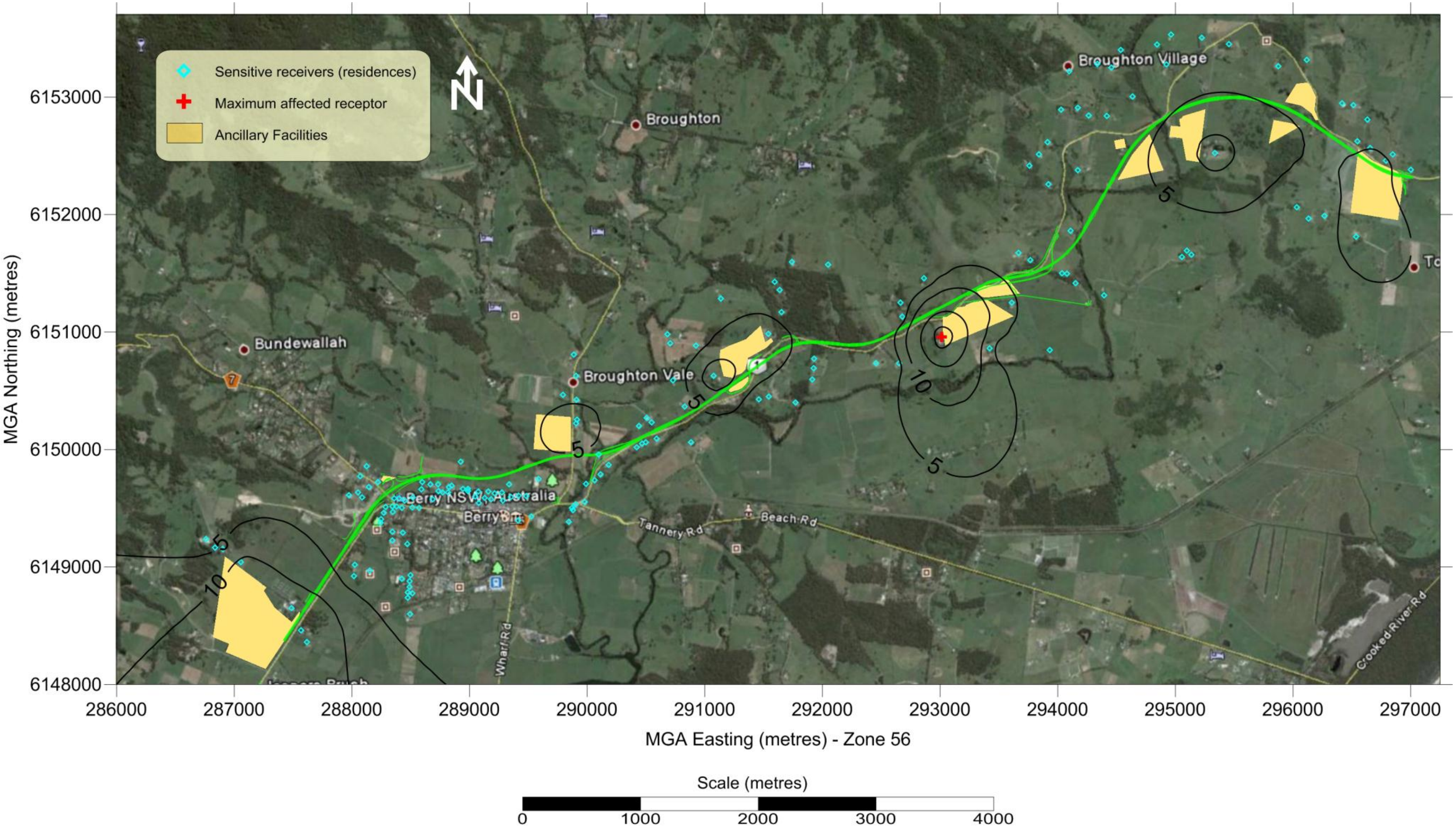

Figure 8-1: Predicted maximum 24 hour average PM10 concentrations (unmitigated) due to wind erosion from the potential ancillary facilities locations (µg/m3)

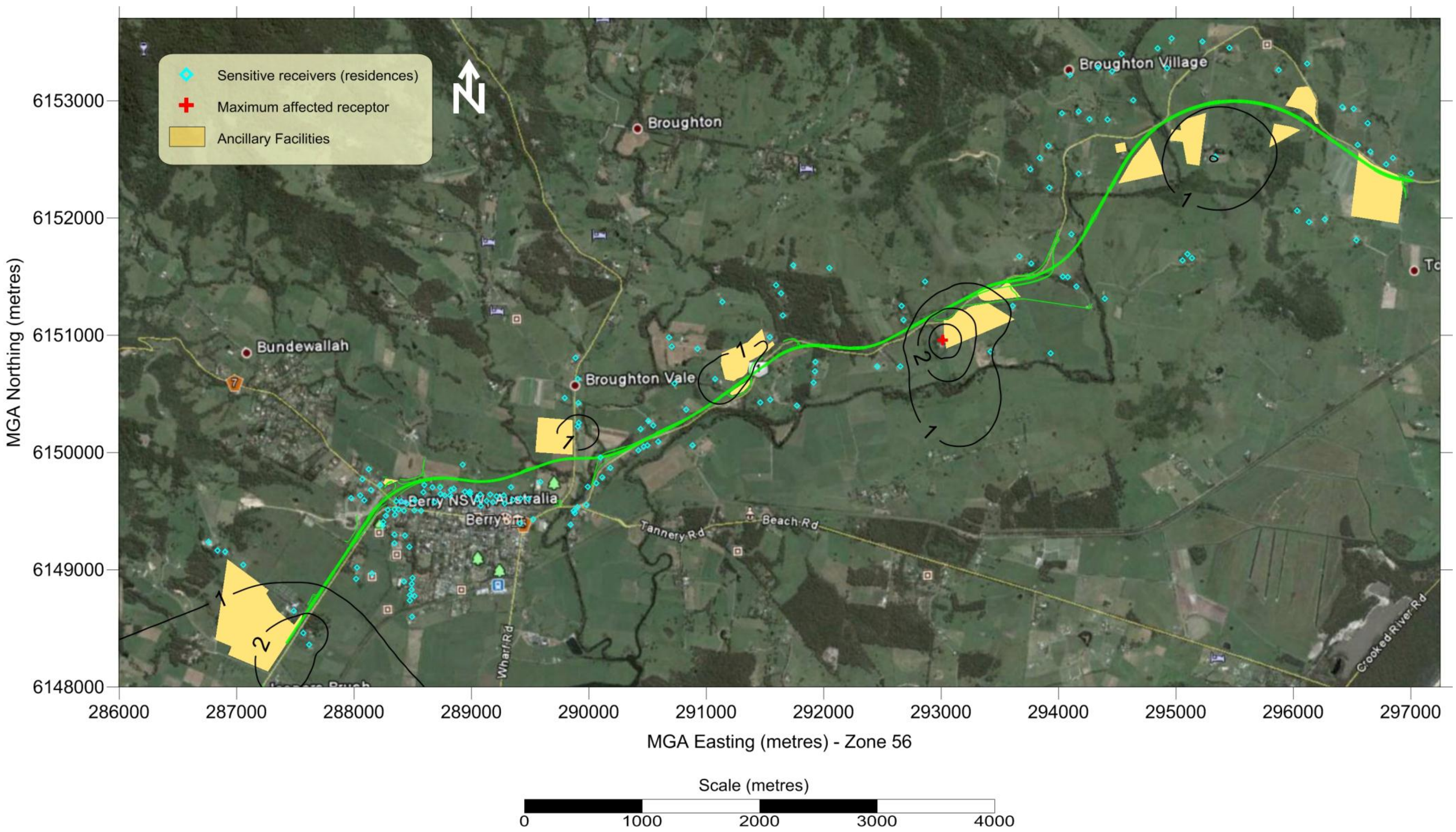

Figure 8-2: Predicted annual average PM10 concentrations (unmitigated) due to wind erosion from the potential ancillary facilities locations (µg/m3)

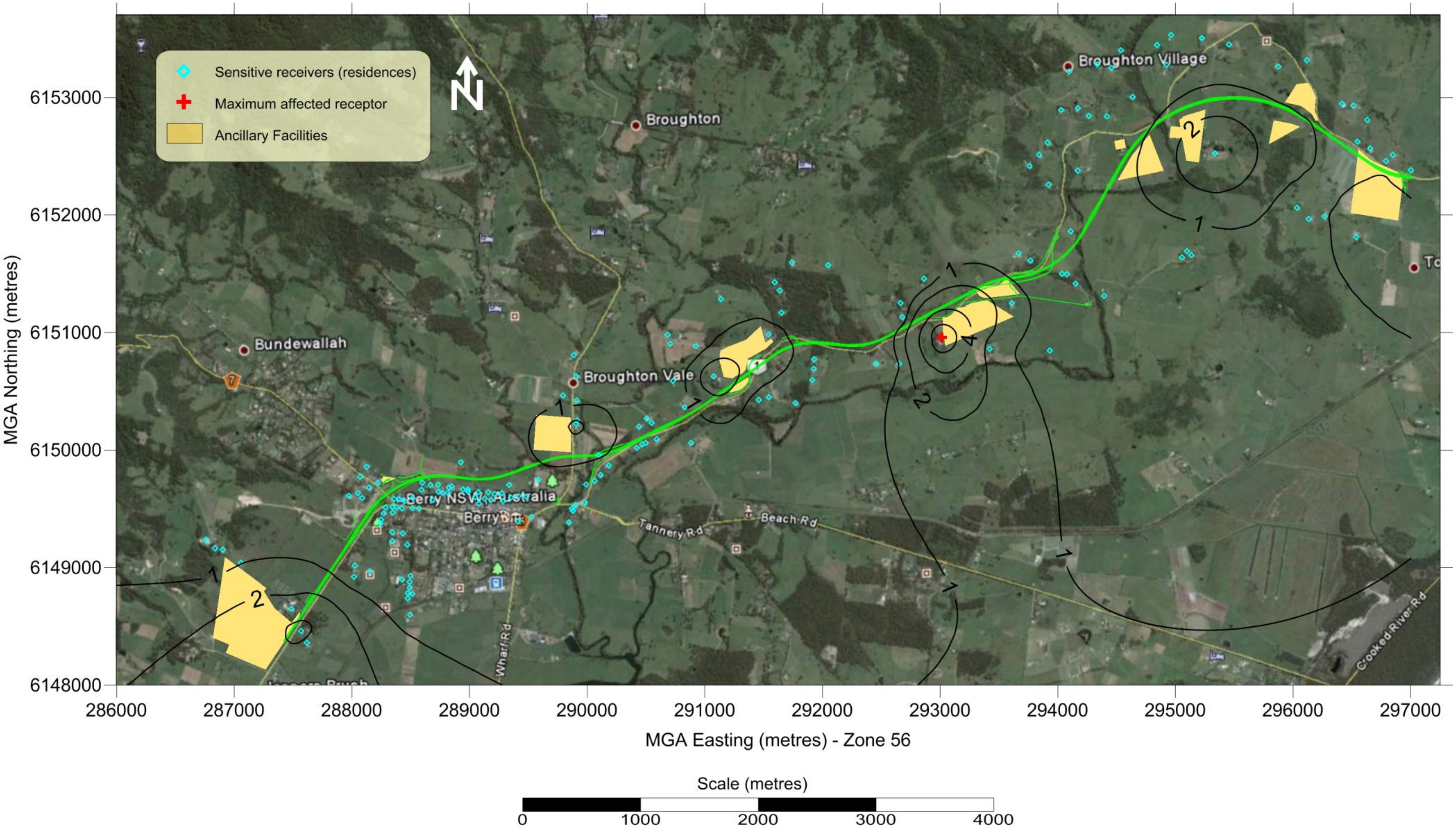

Figure 8-3: Predicted annual average TSP concentrations (unmitigated) due to wind erosion from the potential ancillary facilities locations (µg/m3)

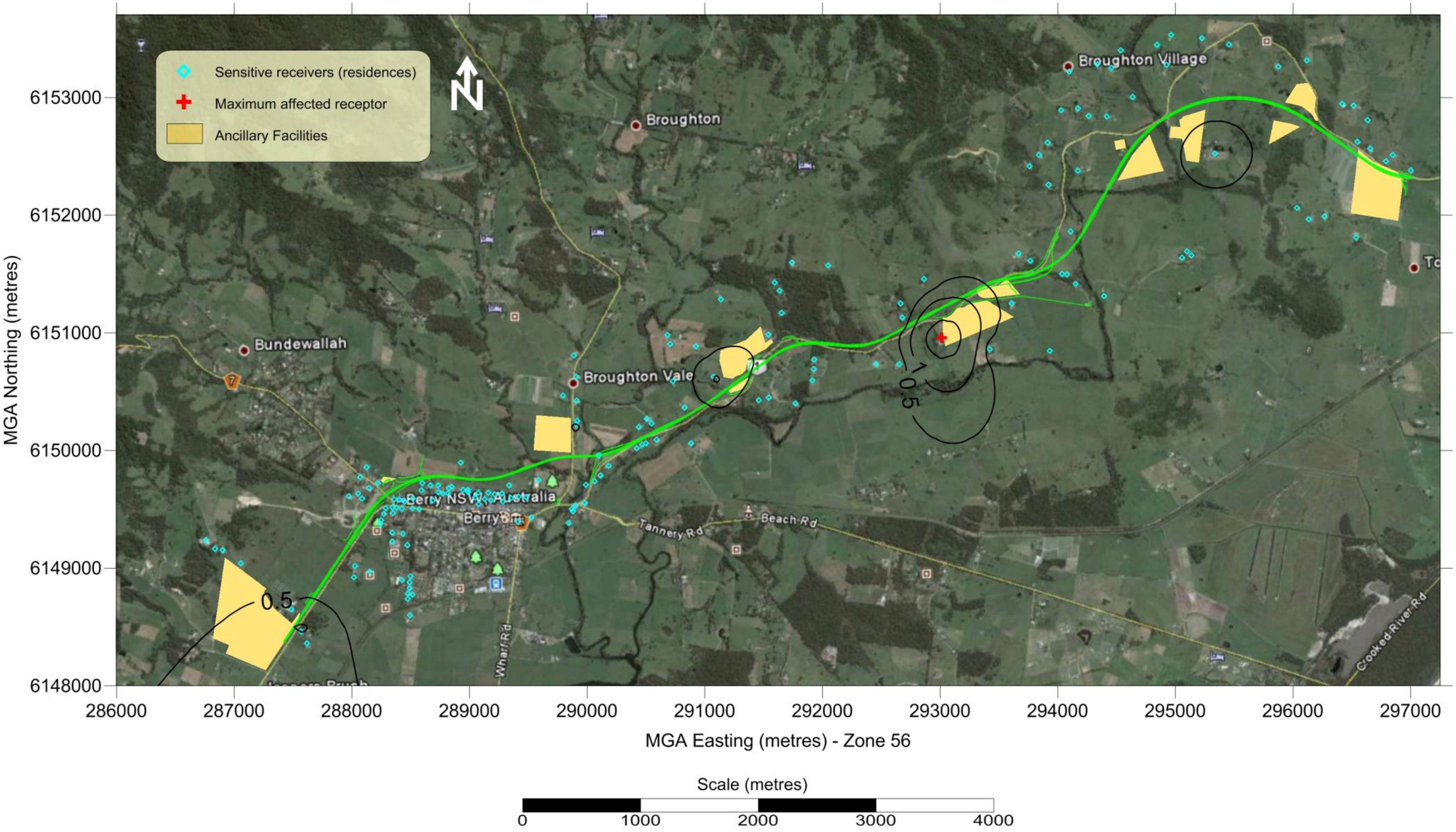

Figure 8-4: Predicted annual average dust deposition (unmitigated) due to wind erosion from the potential ancillary facilities locations (g/m2/month)

9 Dust mitigation and management

The EPA has reviewed the environmental hazards associated with construction/excavation sites and prepared a general document containing safeguards to protect the environment during such activities. Many of these safeguards relate to controlling water pollution and runoff. However, these procedures frequently assist in the control of air pollution. The recommendations of the EPA include mitigation measures such as:

- Watering of haul roads and sealing of roads, where possible.
- Maintenance of all trucks entering and leaving the site in accordance with the manufacturer's specification to comply with all relevant regulations. Fines may be imposed on vehicles that do not comply with smoke emission standards.
- Truck movement controlled on-site and restricted to designated roadways.
- Truck wheel washes or other dust removal procedures installed to minimise transport of dust off-site.
- If necessary, modification of construction activities during periods of high wind.
- Watering / revegetating of stockpiles and exposed areas.

It may be necessary to carry out dust monitoring at sensitive receptors during construction to determine compliance with dust deposition goals currently noted by the EPA and summarised in **Table 9-1** below. The interpretation of these goals is that the maximum total dust deposited should be no more than four grams per square metre per month over a twelve-month period. This total includes ambient levels already present in the area. The project alone should not contribute more than an additional two grams per square metre per month to this total, as indicated by the maximum increase listed in **Table 9-1**.

Table 9-1: EPA criteria for dust fallout

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

An air quality management plan (AQMP) for the proposed works is also recommended as part of an overall construction environmental management plan. The general principles of the AQMP are listed below.

- All disturbed areas would be stabilised as soon as practicable to prevent or minimise windblown dust.
- All unsealed trafficable areas would be kept sufficiently damp during working hours to minimise windblown or traffic generated dust emissions.
- Water sprays, sprinklers and water carts would be employed if needed to adequately dampen stockpiles, work areas and exposed soils to prevent the emission of dust from the site.
- Stockpiles and handling areas would be maintained in a condition that minimises windblown or traffic generated dust. Areas that may be inaccessible by water carts would be kept in a condition which minimises windblown or traffic generated dust using other means, such as alternative soil treatment or reduction of wind through use of windbreaks.

- All equipment for dust control would be kept in good operating condition. The equipment would be operable at all times with the exception of shutdowns required for maintenance. Construction equipment would be properly maintained to ensure exhaust emissions comply with the *Protection of the Environment Operations Act 1997.*
- Silt would be removed from behind filter fences and other erosion control structures on a regular basis, so that collected silt would not become a source of dust.
- Any dust, soil or mud deposited on public roads by subcontractors construction activities and vehicle movements would be removed immediately and disposed of appropriately.

10 Conclusions

The Caline series of dispersion models was used to predict concentrations of carbon monoxide, nitrogen dioxide and PM_{10} due to emissions from the project. The model was used to predict pollutant concentrations from vehicle emissions at the nearest residential receptors.

Predictions of ground-level concentrations from the existing alignment were also used to determine the potential changes due to the project. It was determined that the predictions for the project in 2017 and 2027 were generally lower than those for the existing alignment. The predicted concentrations of carbon monoxide, nitrogen dioxide, and PM_{10}, were found to be within the relevant EPA air quality standards.

Dust impacts associated with construction were also analysed using both qualitative and quantitative techniques. Emissions for drilling and blasting areas were calculated and determined to be minimal and not likely to result in adverse concentration or deposition impacts. Some preliminary modelling was undertaken for wind erosion emissions from stockpile compounds and assumed that all stockpile compounds are fully exposed simultaneously and all year. These were conservative assumptions and the modelling determined that there were unlikely to be any long-term PM_{10} or TSP adverse impacts at any of the sensitive receptors along the proposed alignment.

Dust deposition and short-term PM_{10} predictions indicated that although there may be impacts at one residence, these are unlikely and could be avoided or controlled by implementing standard and best practice management and mitigation measures as outlined in Section 9.

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Appendix A

Joint wind speed, wind direction and stability class frequency tables for the Gerroa Tip - 2000

STATISTICS FOR FILE: C:\Jobs\G2B\Met\Ger00_rev1.AUS
MONTHS: All
HOURS : All
OPTION: Frequency

PASQUILL STABILITY CLASS 'A'
Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000343	0.002862	0.001603	0.000114	0.000000	0.000000	0.000000	0.000000	0.004922
NE	0.001717	0.003320	0.002633	0.000572	0.000000	0.000000	0.000000	0.000000	0.008242
ENE	0.000916	0.001717	0.000229	0.000000	0.000000	0.000000	0.000000	0.000000	0.002862
E	0.001030	0.001030	0.000458	0.000000	0.000000	0.000000	0.000000	0.000000	0.002518
ESE	0.001145	0.000916	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.002175
SE	0.001030	0.003892	0.000916	0.000000	0.000000	0.000000	0.000000	0.000000	0.005838
SSE	0.002976	0.007784	0.002976	0.000458	0.000000	0.000000	0.000000	0.000000	0.014194
S	0.002633	0.006296	0.004235	0.001717	0.000000	0.000000	0.000000	0.000000	0.014881
SSW	0.002060	0.009272	0.006410	0.001832	0.000000	0.000000	0.000000	0.000000	0.019574
SW	0.003434	0.008585	0.004579	0.001259	0.000000	0.000000	0.000000	0.000000	0.017857
WSW	0.002976	0.011103	0.005266	0.000916	0.000000	0.000000	0.000000	0.000000	0.020261
W	0.004922	0.011905	0.010417	0.006410	0.000000	0.000000	0.000000	0.000000	0.033654
WNW	0.002060	0.006868	0.006983	0.004808	0.000000	0.000000	0.000000	0.000000	0.020719
NW	0.001946	0.002633	0.000687	0.000000	0.000000	0.000000	0.000000	0.000000	0.005266
NNW	0.000801	0.001145	0.000572	0.000229	0.000000	0.000000	0.000000	0.000000	0.002747
N	0.001145	0.001259	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.002518
CALM									0.003434
TOTAL	0.031136	0.080586	0.048191	0.018315	0.000000	0.000000	0.000000	0.000000	0.181662

MEAN WIND SPEED (m/s) = 2.74
NUMBER OF OBSERVATIONS = 1587

PASQUILL STABILITY CLASS 'B'
Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000687	0.001832	0.001946	0.000458	0.000000	0.000000	0.000000	0.000000	0.004922
NE	0.000687	0.005723	0.016598	0.014423	0.000000	0.000000	0.000000	0.000000	0.037431
ENE	0.000572	0.003205	0.007326	0.006181	0.000000	0.000000	0.000000	0.000000	0.017285
E	0.000229	0.001145	0.001488	0.000458	0.000000	0.000000	0.000000	0.000000	0.003320
ESE	0.000572	0.001374	0.000458	0.000000	0.000000	0.000000	0.000000	0.000000	0.002404
SE	0.001717	0.006181	0.001145	0.000000	0.000000	0.000000	0.000000	0.000000	0.009043
SSE	0.002633	0.003663	0.000687	0.000229	0.000000	0.000000	0.000000	0.000000	0.007212
S	0.001030	0.006067	0.002175	0.000458	0.000000	0.000000	0.000000	0.000000	0.009730
SSW	0.001717	0.001946	0.000916	0.000000	0.000000	0.000000	0.000000	0.000000	0.004579
SW	0.000801	0.001374	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.002289
WSW	0.002862	0.005037	0.000343	0.000114	0.000000	0.000000	0.000000	0.000000	0.008356
W	0.004006	0.013851	0.002060	0.000343	0.000000	0.000000	0.000000	0.000000	0.020261
WNW	0.001488	0.003205	0.003892	0.000916	0.000000	0.000000	0.000000	0.000000	0.009501
NW	0.000458	0.000687	0.000343	0.000114	0.000000	0.000000	0.000000	0.000000	0.001603
NNW	0.000343	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000343
N	0.000458	0.000458	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000916
CALM									0.001374
TOTAL	0.020261	0.055746	0.039492	0.023695	0.000000	0.000000	0.000000	0.000000	0.140568

MEAN WIND SPEED (m/s) = 3.02
NUMBER OF OBSERVATIONS = 1228

PASQUILL STABILITY CLASS 'C'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000114	0.000229	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000343
NE	0.000114	0.003320	0.004579	0.003434	0.000000	0.000000	0.000000	0.000000	0.011447
ENE	0.000343	0.003205	0.004006	0.004579	0.000000	0.000000	0.000000	0.000000	0.012134
E	0.000458	0.003892	0.004121	0.001488	0.000000	0.000000	0.000000	0.000000	0.009959
ESE	0.000801	0.008242	0.004121	0.000229	0.000000	0.000000	0.000000	0.000000	0.013393
SE	0.001488	0.003320	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.004922
SSE	0.001259	0.000801	0.000572	0.000000	0.000000	0.000000	0.000000	0.000000	0.002633
S	0.000229	0.000687	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000916
SSW	0.000229	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000229
SW	0.000229	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000229
WSW	0.000916	0.000229	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001145
W	0.003549	0.006754	0.000229	0.000000	0.000000	0.000000	0.000000	0.000000	0.010531
WNW	0.003434	0.002747	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.006296
NW	0.000916	0.000229	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.001259
NNW	0.000343	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000343
N	0.000000	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000114
CALM									0.001946
TOTAL	0.014423	0.033768	0.017972	0.009730	0.000000	0.000000	0.000000	0.000000	0.077839

MEAN WIND SPEED (m/s) = 2.71

NUMBER OF OBSERVATIONS = 680

PASQUILL STABILITY CLASS 'D'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000916	0.000572	0.005037	0.000916	0.000114	0.000000	0.000000	0.000000	0.007555
NE	0.001832	0.003091	0.016827	0.006410	0.007212	0.000229	0.000000	0.000000	0.035600
ENE	0.001603	0.001145	0.001946	0.001145	0.000458	0.000000	0.000000	0.000000	0.006296
E	0.000458	0.000801	0.000916	0.000000	0.000572	0.000000	0.000000	0.000000	0.002747
ESE	0.000343	0.000572	0.001374	0.000000	0.000114	0.000000	0.000000	0.000000	0.002404
SE	0.000229	0.000114	0.000687	0.000000	0.000000	0.000000	0.000000	0.000000	0.001030
SSE	0.000114	0.000000	0.000229	0.000000	0.000000	0.000000	0.000000	0.000000	0.000343
S	0.000000	0.000000	0.002747	0.001259	0.000114	0.000000	0.000000	0.000000	0.004121
SSW	0.000000	0.000000	0.002747	0.001374	0.000114	0.000000	0.000000	0.000000	0.004235
SW	0.000114	0.000000	0.001832	0.001030	0.000000	0.000000	0.000000	0.000000	0.002976
WSW	0.000458	0.000114	0.003549	0.001145	0.000000	0.000000	0.000000	0.000000	0.005266
W	0.009615	0.013851	0.014766	0.009158	0.004464	0.000343	0.000114	0.000000	0.052312
WNW	0.027816	0.020604	0.005838	0.003434	0.002289	0.000114	0.000114	0.000000	0.060211
NW	0.008814	0.001374	0.000801	0.000114	0.000114	0.000000	0.000000	0.000000	0.011218
NNW	0.004808	0.000114	0.000229	0.000000	0.000000	0.000000	0.000000	0.000000	0.005151
N	0.002747	0.000114	0.000343	0.000000	0.000000	0.000000	0.000000	0.000000	0.003205
CALM									0.006525
TOTAL	0.059867	0.042468	0.059867	0.025984	0.015568	0.000687	0.000229	0.000000	0.211195

MEAN WIND SPEED (m/s) = 2.96

NUMBER OF OBSERVATIONS = 1845

PASQUILL STABILITY CLASS 'E'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.004006	0.004006	0.001488	0.000000	0.000000	0.000000	0.000000	0.000000	0.009501
NE	0.004464	0.011790	0.000801	0.000000	0.000000	0.000000	0.000000	0.000000	0.017056
ENE	0.001603	0.003777	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.005495
E	0.001145	0.001030	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002175
ESE	0.000343	0.001145	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001488
SE	0.000000	0.000343	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000343
SSE	0.000343	0.000458	0.000801	0.000000	0.000000	0.000000	0.000000	0.000000	0.001603
S	0.000114	0.000343	0.001145	0.000000	0.000000	0.000000	0.000000	0.000000	0.001603
SSW	0.000229	0.000916	0.002289	0.000000	0.000000	0.000000	0.000000	0.000000	0.003434
SW	0.000229	0.001374	0.001374	0.000000	0.000000	0.000000	0.000000	0.000000	0.002976
WSW	0.003320	0.005151	0.002633	0.000000	0.000000	0.000000	0.000000	0.000000	0.011103
W	0.015797	0.048077	0.003320	0.000000	0.000000	0.000000	0.000000	0.000000	0.067193
WNW	0.021864	0.018086	0.000916	0.000000	0.000000	0.000000	0.000000	0.000000	0.040865
NW	0.012134	0.001832	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.014080
NNW	0.004350	0.000916	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.005380
N	0.004235	0.000687	0.000229	0.000000	0.000000	0.000000	0.000000	0.000000	0.005151
CALM									0.007898
TOTAL	0.074176	0.099931	0.015339	0.000000	0.000000	0.000000	0.000000	0.000000	0.197344

MEAN WIND SPEED (m/s) = 1.79

NUMBER OF OBSERVATIONS = 1724

PASQUILL STABILITY CLASS 'F'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.005266	0.008814	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.014080
NE	0.006525	0.009730	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.016255
ENE	0.002633	0.001717	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004350
E	0.001603	0.000572	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002175
ESE	0.002289	0.002289	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004579
SE	0.001717	0.001946	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003663
SSE	0.001603	0.002633	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004235
S	0.001145	0.001374	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002518
SSW	0.002747	0.004693	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.007440
SW	0.004235	0.007440	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.011676
WSW	0.006410	0.014995	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.021406
W	0.010646	0.019918	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.030563
WNW	0.012935	0.008585	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.021520
NW	0.011447	0.002747	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.014194
NNW	0.005952	0.001374	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.007326
N	0.008013	0.003892	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.011905
CALM									0.013507
TOTAL	0.085165	0.092720	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.191392

MEAN WIND SPEED (m/s) = 1.54

NUMBER OF OBSERVATIONS = 1672

ALL PASQUILL STABILITY CLASSES

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.011332	0.018315	0.010073	0.001488	0.000114	0.000000	0.000000	0.000000	0.041323
NE	0.015339	0.036973	0.041438	0.024840	0.007212	0.000229	0.000000	0.000000	0.126030
ENE	0.007669	0.014766	0.013622	0.011905	0.000458	0.000000	0.000000	0.000000	0.048420
E	0.004922	0.008471	0.006983	0.001946	0.000572	0.000000	0.000000	0.000000	0.022894
ESE	0.005495	0.014538	0.006067	0.000229	0.000114	0.000000	0.000000	0.000000	0.026442
SE	0.006181	0.015797	0.002862	0.000000	0.000000	0.000000	0.000000	0.000000	0.024840
SSE	0.008929	0.015339	0.005266	0.000687	0.000000	0.000000	0.000000	0.000000	0.030220
S	0.005151	0.014766	0.010302	0.003434	0.000114	0.000000	0.000000	0.000000	0.033768
SSW	0.006983	0.016827	0.012363	0.003205	0.000114	0.000000	0.000000	0.000000	0.039492
SW	0.009043	0.018773	0.007898	0.002289	0.000000	0.000000	0.000000	0.000000	0.038004
WSW	0.016941	0.036630	0.011790	0.002175	0.000000	0.000000	0.000000	0.000000	0.067537
W	0.048535	0.114354	0.030792	0.015911	0.004464	0.000343	0.000114	0.000000	0.214515
WNW	0.069597	0.060096	0.017743	0.009158	0.002289	0.000114	0.000114	0.000000	0.159112
NW	0.035714	0.009501	0.002060	0.000229	0.000114	0.000000	0.000000	0.000000	0.047619
NNW	0.016598	0.003549	0.000916	0.000229	0.000000	0.000000	0.000000	0.000000	0.021291
N	0.016598	0.006525	0.000687	0.000000	0.000000	0.000000	0.000000	0.000000	0.023810
CALM									0.034684
TOTAL	0.285027	0.405220	0.180861	0.077724	0.015568	0.000687	0.000229	0.000000	1.000000

MEAN WIND SPEED (m/s) = 2.40

NUMBER OF OBSERVATIONS = 8736

FREQUENCY OF OCCURENCE OF STABILITY CLASSES

- A : 18.2%
- B : 14.1%
- C : 7.8%
- D : 21.1%
- E : 19.7%
- F : 19.1%