Proposed Katherine to Gove Gas Pipeline
Draft Environmental Impact Statement

Appendix G

Air Quality Assessment

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Katherine to Gove Gas Pipeline: Environmental Impact Study

Air Quality Assessment

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04-Apr-13

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KATHERINE TO GOVE GAS PIPELINE: ENVIRONMENTAL IMPACT STUDY
AIR QUALITY ASSESSMENT

SYNOPSIS

An investigation into the air quality impacts from the construction and operation of the proposed Katherine to Gove Gas Pipeline Project (KGGP Project) was conducted utilising the pollution dispersion modelling software TAPM v4.0.5 and Ausplume v6.0. The pollutants of potential concern which were assessed included particulate matter of various size distributions (PM_{10} and TSP) during the construction phase and oxides of nitrogen (NO_X as NO_2), carbon monoxide (CO) and photochemical smog as evidenced by ozone (O_3) during the operational phase. The modelling results were compared against the National Environment Protection (Ambient Air Quality) Measure.

Modelling for the construction phase of the project predicted that the PM_{10} ambient ground-level concentration (GLC) footprint could potentially impact the Wallaby Beach sensitive receptor. Modelling for the operational phase of the project predicted that human health impacts would be minimal due to the remoteness of the emission sources and the magnitude of the emissions.

It is recommended that a Dust Management Plan is developed for the construction phase of the project detailing methods to minimise and/or manage impacts appropriately.

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KATHERINE TO GOVE GAS PIPELINE: ENVIRONMENTAL IMPACT STUDY
AIR QUALITY ASSESSMENT

Rev	Description	Originator	Reviewer	WorleyParsons Approval	Date	Client Approval	Date
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B	Issued for Client Review	G Hickson	A Campbell	A J Wood	13-Mar-13		
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1	Re-Issued for Use	A Boladz	A Hanly	A J Wood	04-Apr-13		

CONTENTS

Glossary 1

1 Introduction 3

1.1 Project Overview and Scope of Work 3

1.2 Limitations 4

2 Existing Environment 5

2.1 Climate and Meteorology 5

2.1.1 Katherine / Tindal RAAF Base 5

2.1.2 Gove Airport 15

2.2 Surrounding Land Use and Terrain 24

2.3 Existing Ambient Air Quality 24

3 Pollutants of Potential Concern and Legislation 26

3.1 Pollutants of Potential Concern 26

3.1.1 Airborne Particulates 26

3.1.2 Oxides of Nitrogen (NO_X) 26

3.1.3 Carbon Monoxide (CO) 27

3.1.4 Photochemical Smog (As Evidenced by Ozone, O_3) 27

3.2 Legislative Assessment Criteria 27

3.2.1 National Environment Protection (Ambient Air Quality) Measure 27

3.2.2 Vegetation Impacts 28

3.2.3 Adopted Assessment Criteria 28

3.3 Sensitive Receptors 28

4 Emissions Inventory 30

4.1 Emission Sources – Construction Phase 30

4.1.1 General Assumptions 30

4.1.2 Summary 32

4.1.3 Dry Depletion / Particle Scavenging 32

4.1.4 Construction Traffic 33

4.2 Emission Sources – Operational Phase 34
4.2.1 Background Emission Sources 35
5 Modelling Method 38
5.1 Modelling Approach 38
5.2 Model Definition 38
5.2.1 Construction Phase Dispersion Modelling 38
5.2.2 TAPM v4.0.5 – Meteorology and Operational Phase Dispersion 45
5.3 Meteorological Model Validation 47
5.3.1 Wind Speed and Direction 47
5.3.2 Temperature 50
5.3.3 Discussion 51
6 Modelling Results 52
6.1 Construction Phase 52
6.1.1 Ambient PM_{10} Concentrations 52
6.1.2 Vegetation Impacts 54
6.1.3 Construction Traffic Impacts 55
6.1.4 Dust Management / Mitigation Measures 55
6.2 Operational Phase 56
6.2.1 Oxides of Nitrogen (NO_X as NO_2) 56
6.2.2 Carbon Monoxide (CO) 59
6.2.3 Photochemical Smog (as Ozone, O_3) 60
7 Conclusions and Recommendations 63
7.1 Construction Phase 63
7.1.1 Construction Traffic Impacts 63
7.2 Operational Phase 63
8 References 64

GLOSSARY

AED	Aerodynamic Equivalent Diameter
AWS	Automated Weather Station
BoM	Bureau of Meteorology
CO	Carbon Monoxide
CSIRO	Commonwealth Scientific and Industrial Research Organisation
°C	degrees Celsius
EETM	Emission Estimation Technique Manual
EPBC Act	Environment Protection and Biodiversity Conservation Act
EIS	Environmental Impact Statement
g	grams
GLC	Ground-level Concentration
hPa	hectoPascals
h	Hour
KGGP	Katherine to Gove Gas Pipeline
K	Kelvin
kg	kilograms
km	kilometres
kPa	kiloPascals
MSLP	Mean Sea Level Pressure
m	metres
mAHD	metres Australian Height Datum
µm	micrometres
NEPC	National Environment Protection Council
AAQ NEPM	National Environment Protection (Ambient Air Quality) Measure
NPI	National Pollutant Inventory
NSW	New South Wales
NO_2	Nitrogen Dioxide
NT	Northern Territory
NTEPA	Northern Territory Environmental Protection Agency
NO_X	Oxides of Nitrogen
SO_X	Oxides of Sulfur
O_3	Ozone
$PM_{2.5}$	Particulate Matter with AED of 2.5 µm or less
PM_{10}	Particulate Matter with AED of 10 µm or less
ppb	Parts Per Billion
ppm	Parts Per Million
POPC	Pollutant of Potential Concern
ROW	Right of Way
RAAF	Royal Australian Air Force
R_{smog}	Smog Reactivity

SO_2	Sulfur Dioxide
TEOM	Tapered Element Oscillating Microbalance
TAPM	The Air Pollution Model
TSP	Total Suspended Particulates
VKT	Vehicle Kilometres Travelled
VOCs	Volatile Organic Compounds

1 INTRODUCTION

Pacific Aluminium (a business unit of Rio Tinto) owns and operates a bauxite mine and alumina refinery at Gove, 650 kilometres (km) east of Darwin in north east Arnhem Land, Northern Territory. The Gove mine and refinery produce high grade alumina which is then shipped to other locations for smelting and further processing.

Power and steam for the Gove Refinery and mining operations are currently generated from imported fuel oil. In order to reduce fuel oil consumption and improve operating costs at the Refinery, it is proposed to provide the facility with natural gas as an alternative fuel source. The lower cost natural gas will help underpin the long term operating viability of the Refinery.

The Katherine to Gove Gas Pipeline (KGGP) is proposed to deliver natural gas from the existing NT Amadeus Gas Pipeline at a point approximately 20 km south of Katherine, to the Gove Refinery. The KGGP would be a high pressure, steel pipeline approximately 603 km long with a nominal diameter of 300mm and a design operating life of 50 years. It will also include above ground facilities at specific locations along the route such as metering facilities, scraper stations, mainline valves and a compressor station. The supplied gas from the Amadeus Pipeline is sales quality so no additional processing of gas would be required. The pipeline would be constructed within a 30 m wide construction corridor and would include supporting infrastructure such as temporary work camps and equipment access tracks to facilitate construction activities.

1.1 Project Overview and Scope of Work

WorleyParsons has been engaged by Pacific Aluminium to undertake an air assessment to consider and address potential environmental impacts of the air emissions from the project during its construction and operation stages in accordance with Sections 4.9 and 6.8.3 of the EIS Guidelines.

The scope of the assessment undertaken by WorleyParsons was developed to address the EIS Guidelines and included:

- Desktop review of any available literature for air quality issues for the region in the public domain;
- Identification of all relevant statutory and company-specific guidelines / regulations and assessment criteria;
- Identification of all relevant human health and environmental dust sensitive receptors in the region;
- Identify any alternative operating scenarios that may need to be assessed;
- Generation of appropriate meteorological dataset(s) via the use of the CSIRO-developed model TAPM;
- Refinement of the generated dataset(s) via the incorporation of observed meteorological data from the nearest weather station(s) obtained from the Bureau of Meteorology (BoM);

- Development of an emissions inventory identifying the major sources of airborne particulate matter and chemical pollutants based upon information obtained through the desktop review and provided by the client about proposed construction and operational methods;
  - Note: In the absence of available specific emissions information for the project, the emissions inventory would primarily be calculated via the National Pollutant Inventory (NPI) Emission Estimation Technique Manuals (EETMs).
- Identification of any pollutant emission sources that may need to be considered in the modelling and which are in the vicinity of the project site, but external to the project (i.e. background dust levels);
  - Note: Background pollutant levels will only be considered where the information is freely available to the public or is provided by the client.
- Atmospheric dispersion modelling of dust impacts via the use of TAPM and the EPA Victoria-developed steady-state Gaussian plume dispersion model AUSPLUME v6.0;
- Completion of the report (this report), which will include;
  - Predicted impacts, including contour plots of anticipated ground-level pollutant concentrations across the region and at identified sensitive receptors;
  - Predicted compliance against relevant State and Federal Acts, regulations, guidelines and policies; and
  - Recommendations for any additional air quality management methods required.

1.2 Limitations

This report is not to be used for any reason other than its intended purpose. This assessment was conducted via the use of computer simulation software packages and therefore is subject to any inherent limitations associated with the software. This assessment depends on model input information provided by a third party, in this case Alcan Gove. The accuracy of the input information and hence the results of the assessment are based upon best available information at the time. Any assumptions undertaken for this assessment in the estimation of pollutant emissions are stated in this report. Should the final design and/or equipment selection result in material change, further analysis and subsequent communication with the NTEPA may be required.

2 EXISTING ENVIRONMENT

The following section describes the existing environmental factors that influence pollution dispersion in the relevant airshed. A diagram of the proposed pipeline alignment and associated infrastructure is provided in **Appendix A**. These factors include: climatic conditions; the surrounding land use and terrain; and the existing ambient air quality in the region.

2.1 Climate and Meteorology

The climatic data presented in the following sections is based on the long-term meteorological observations made at two Automated Weather Stations (AWS): the Tindal RAAF Base (located approximately 14 km east southeast of Katherine and 10.5 km north northeast of the western-most end of the pipeline alignment); and the Gove Airport (located at the eastern-most end of the pipeline alignment, approximately 17 km southeast of the Alcan Refinery). AWS data has been sourced from the Bureau of Meteorology (BoM, 2013a and 2013b). Relevant observations to pollutant dispersion modelling are:

- Wind Speed and Wind Direction;
- Temperature;
- Precipitation;
- Relative Humidity; and
- Mean Sea Level Pressure.

2.1.1 Katherine / Tindal RAAF Base

The Tindal RAAF Base AWS (AWS Number: 014932) observational dataset was reported from 3rd March 2002 3:00 pm to 25th February 2013 12:00 pm (BoM, 2013a). The availability of the dataset is 95.84% with 3,822 incomplete hours over the approximately 11 year observational period.

2.1.1.1 Wind Speed and Direction

The wind speed and direction are the most important meteorological data in relation to pollutant dispersion modelling as it is the primary factor dictating the behaviour of a plume. The long-term annual and quarterly wind roses for the Tindal RAAF Base AWS (2002-2013) are presented in **Figure 2-1**.

The prevailing winds for each quarter are:

- **Quarter 1 (January – March)**: Low to moderate speed (0.5 – 8 m/s) blowing from the northwest and southeast.
- **Quarter 2 (April – June)**: High proportion of winds blowing from the south-eastern arc of low to moderate speed (0.5 – 8 m/s).
- **Quarter 3 (July – September)**: High proportion of winds blowing from the south-eastern arc of low to moderate speed (0.5 – 8 m/s).
- **Quarter 4 (October – December)**: Low to moderate speed (0.5 – 8 m/s) blowing from the northwest and southeast.

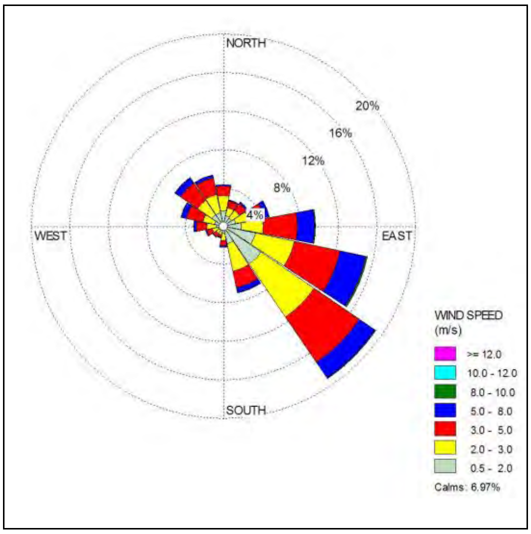
These prevailing wind trends shows two distinctly different behaviours, roughly aligned with the ‘wet’ and ‘dry’ monsoonal seasonal variation.

The long-term wind class frequency distribution for the Tindal RAAF Base AWS is presented in **Figure 2-2**. This histogram is for the full year span for all data, 2002 to 2013. Primary observations for this dataset are listed below:

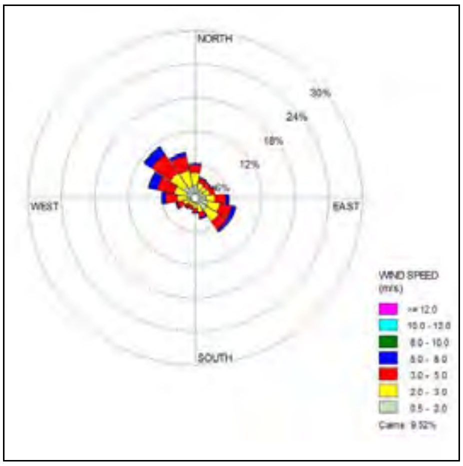
- Very similar frequencies exist for wind speed categories: 0.5 – 2 m/s; 2 – 3 m/s; and 3 – 5 m/s.
- 82% of all wind speeds recorded occur within the range of 0.5 – 5 m/s.
- 7.3% of winds recorded fall below 0.5 m/s and are designated as ‘calms’.
- >1% of all winds recorded are above 8.0 m/s.

Figure 2-1 Tindal RAAF Base AWS Long-Term Wind Roses (2002-2013)

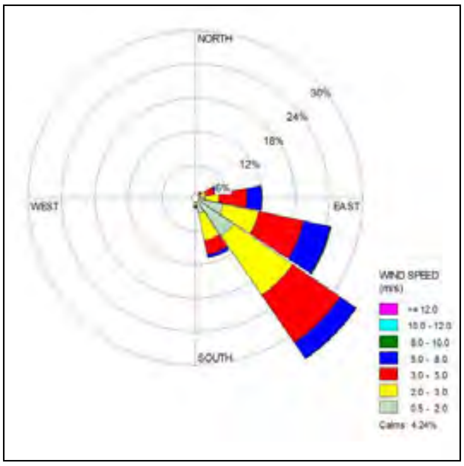
Full Year



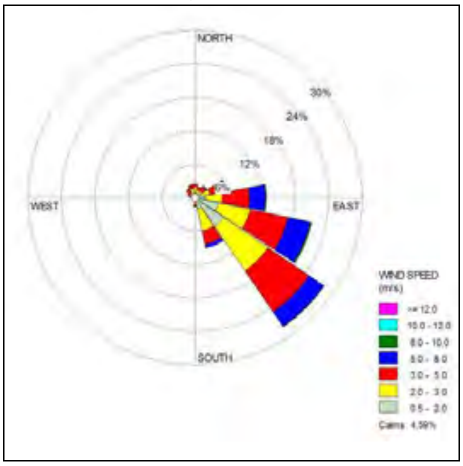
Quarter 1



Quarter 2



Quarter 3



Quarter 4

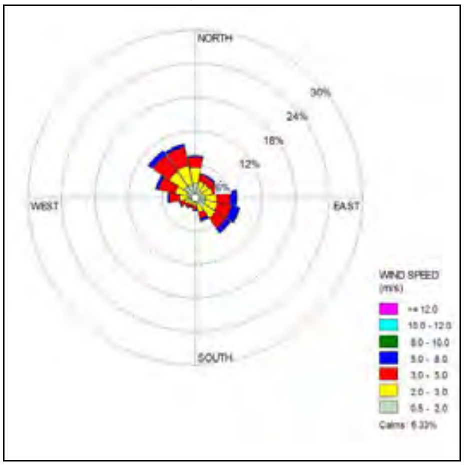
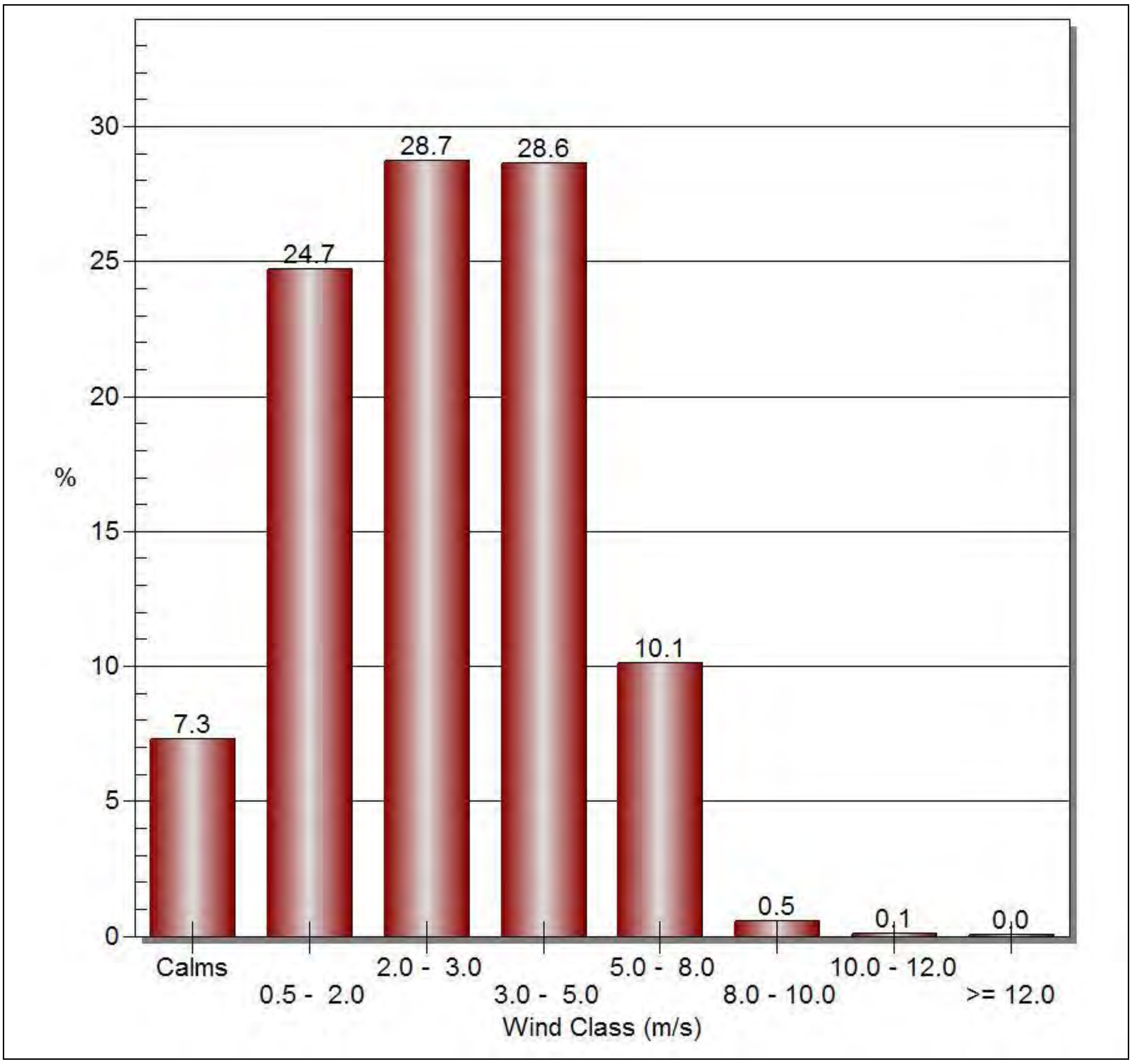


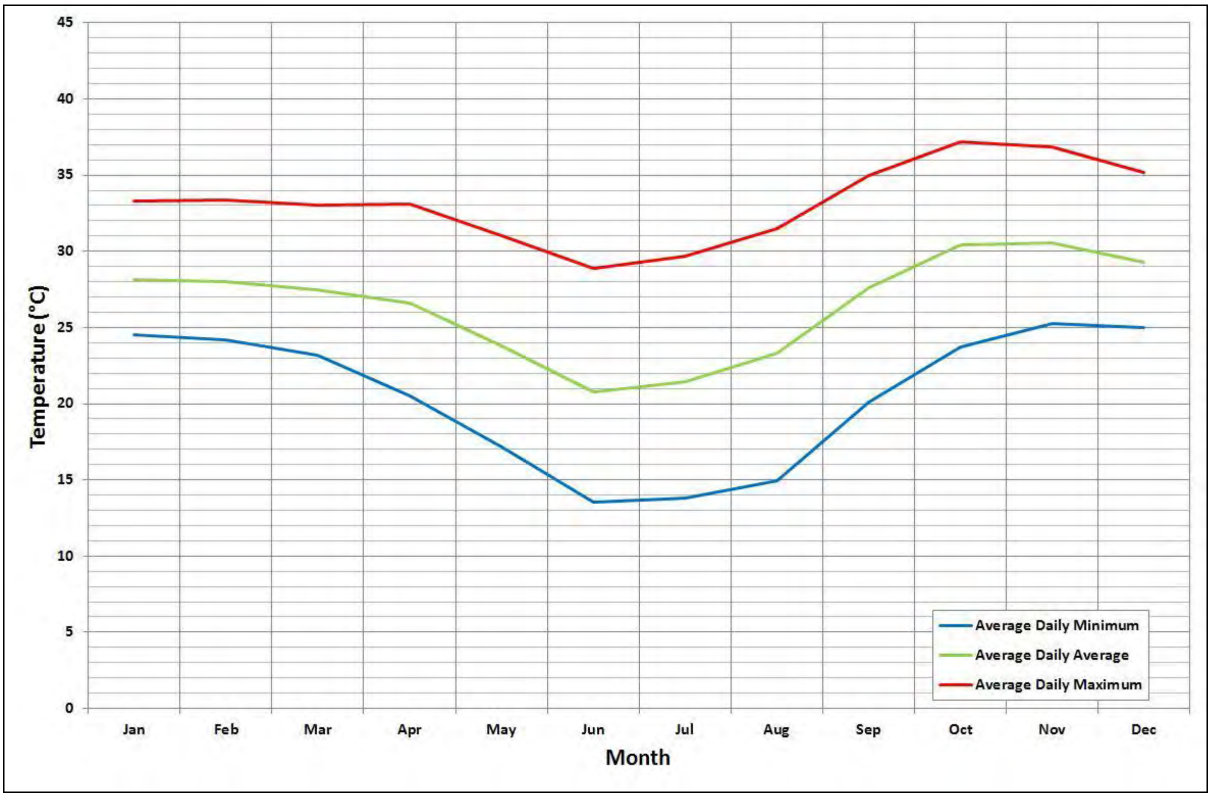
Figure 2-2 Tindal RAAF Base AWS Long-Term Wind Class Frequency Distribution (2002-2013)



2.1.1.2 Temperature

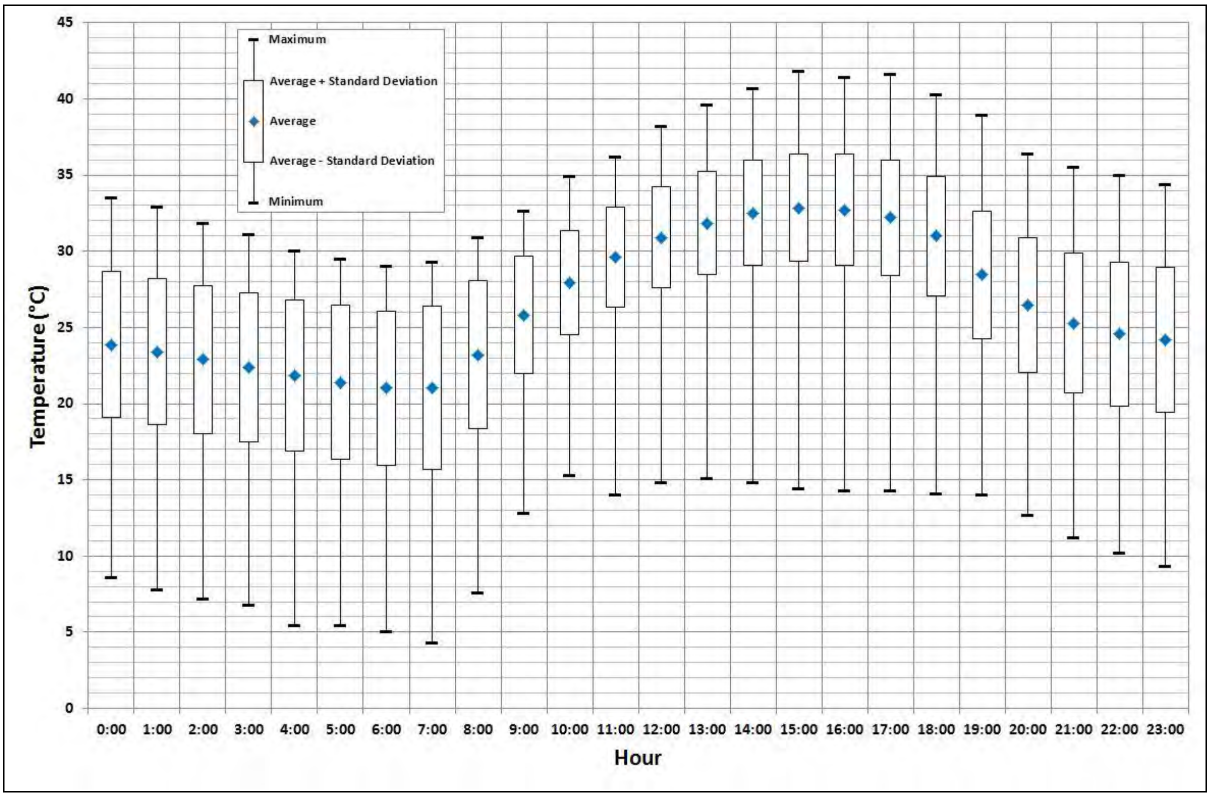
The long-term average daily temperature trends per month are presented in **Figure 2-3**. It is apparent that the October-November period is the warmest of the year with average maximum temperatures around 37°C and average minimum temperatures around 24-25°C. The June-July period is the coolest with average maximum temperatures around 29°C and average minimum temperatures around 13-14°C.

Figure 2-3 Tindal RAAF AWS Long-Term (2002-2013) Annual Temperature Profile



The long-term daily temperature profile is presented in **Figure 2-4**. The extreme observed temperatures range between 4°C and 42°C; however, the average hourly temperatures range between 21°C and 33°C. This behaviour is indicative of a stable tropical climate, observed over a longer timeframe.

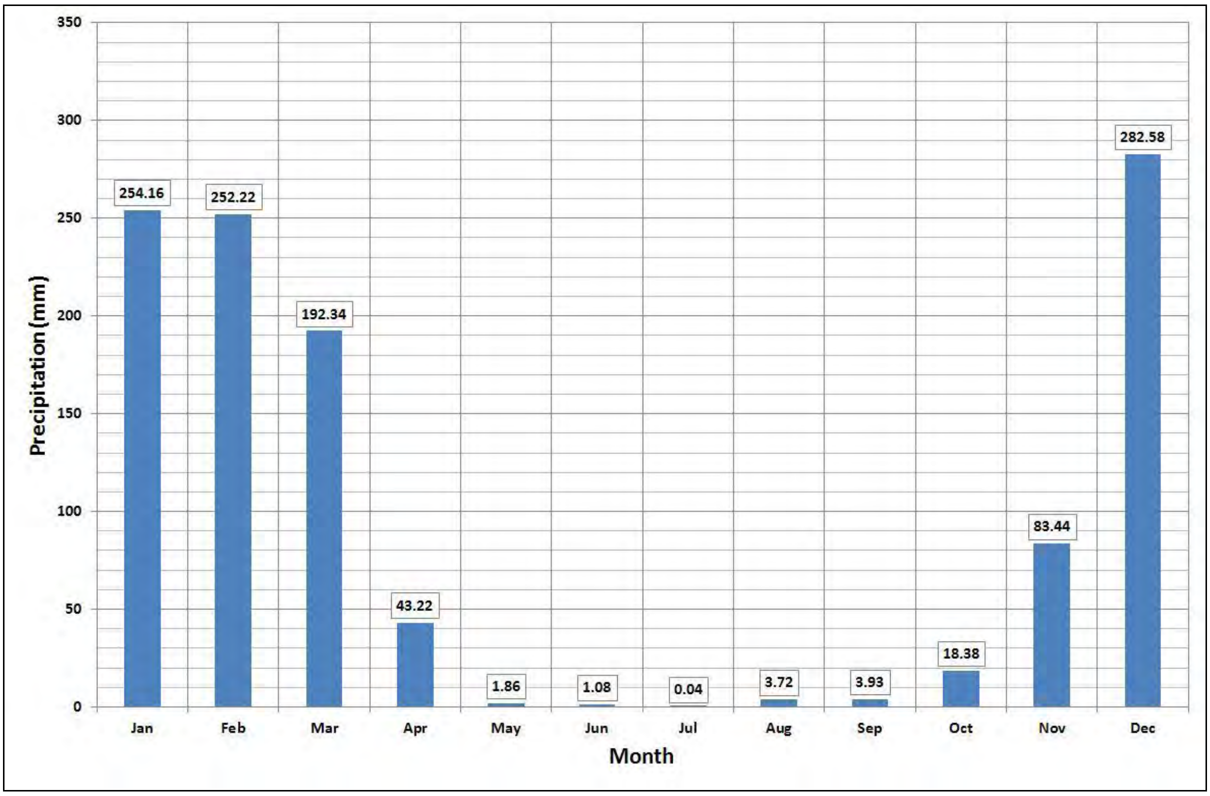
Figure 2-4 Tindal RAAF AWS Long-Term (2002-2013) Daily Temperature Profile



2.1.1.3 Precipitation

The average monthly precipitation recorded at the Tindal RAAF AWS is presented in **Figure 2-5**. It is apparent that the December to March period is when a majority of the rainfall is recorded over the year with greater than 85% of the total rainfall occurring in this period. This meteorological behaviour is very typical of a tropical monsoonal wet and dry seasonal variation.

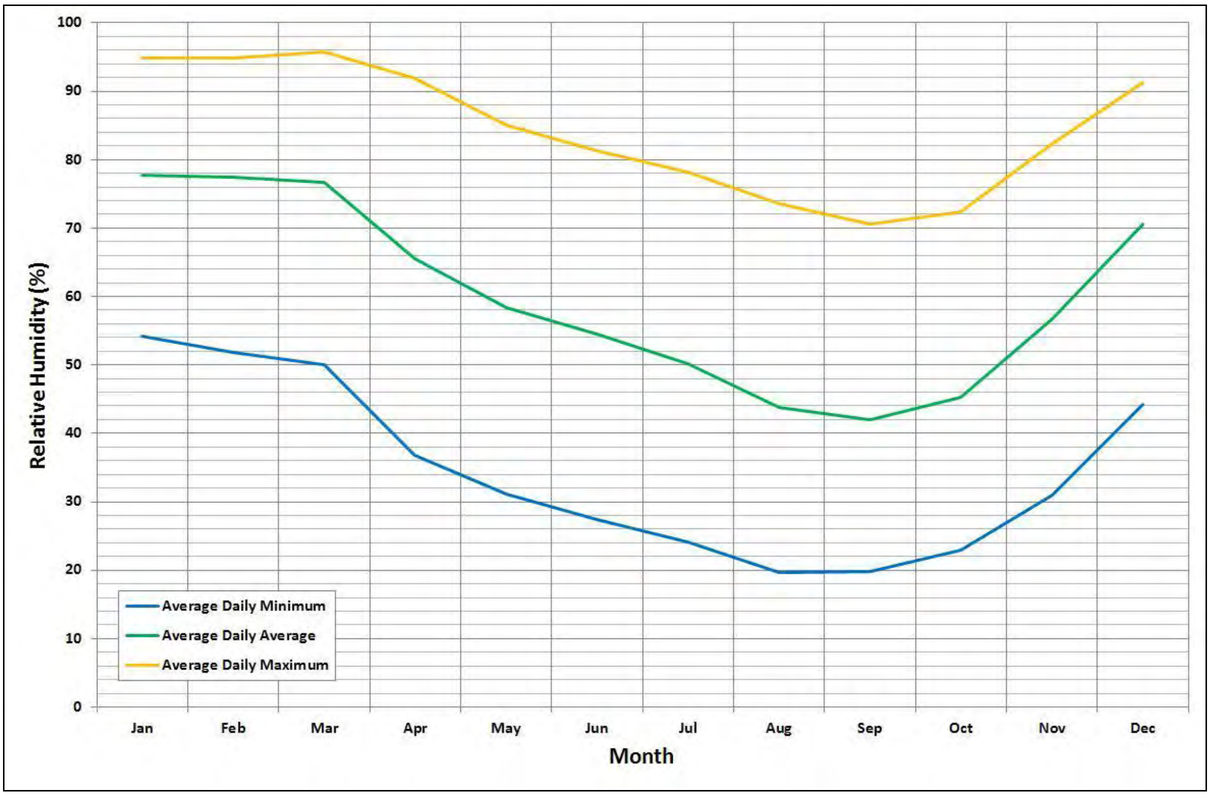
Figure 2-5 Tindal RAAF AWS Long-Term (2002-2013) Average Monthly Precipitation



2.1.1.4 Relative Humidity

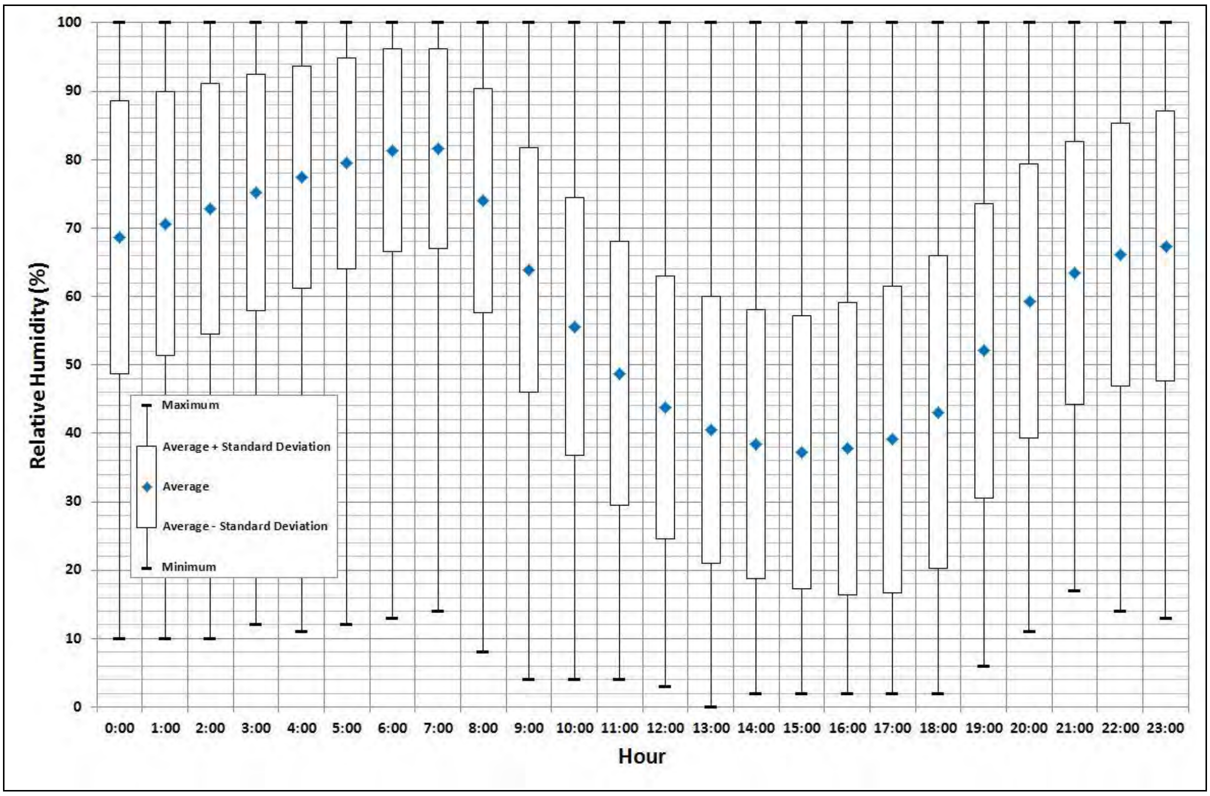
The long-term average daily relative humidity trends per month are presented in **Figure 2-6**. The greatest average daily humidity occurs during the January-March period with average maximum values around 95% and average minimum values around 52-54%. The lowest humidity period is during the months of August to October with average maximum values marginally above 70% and average minimum values at 20%. Similar to the precipitation, this behaviour follows a tropical monsoonal wet and dry seasonal variation.

Figure 2-6 Tindal RAAF AWS Long-Term (2002-2013) Annual Relative Humidity Profile



The long-term daily relative humidity profile is presented in **Figure 2-7**. Rapid increases and decreases in humidity are apparent throughout the typical daily profile. The maximum average humidity occurs at 7:00 am after a steady rise over the night hours. The minimum average humidity occurs at 3:00 pm with lower values occurring during the afternoon hours. It is important to note that the humidity ranges from very low (less than approximately 10-20%) to saturated (100%) during any hour of the day.

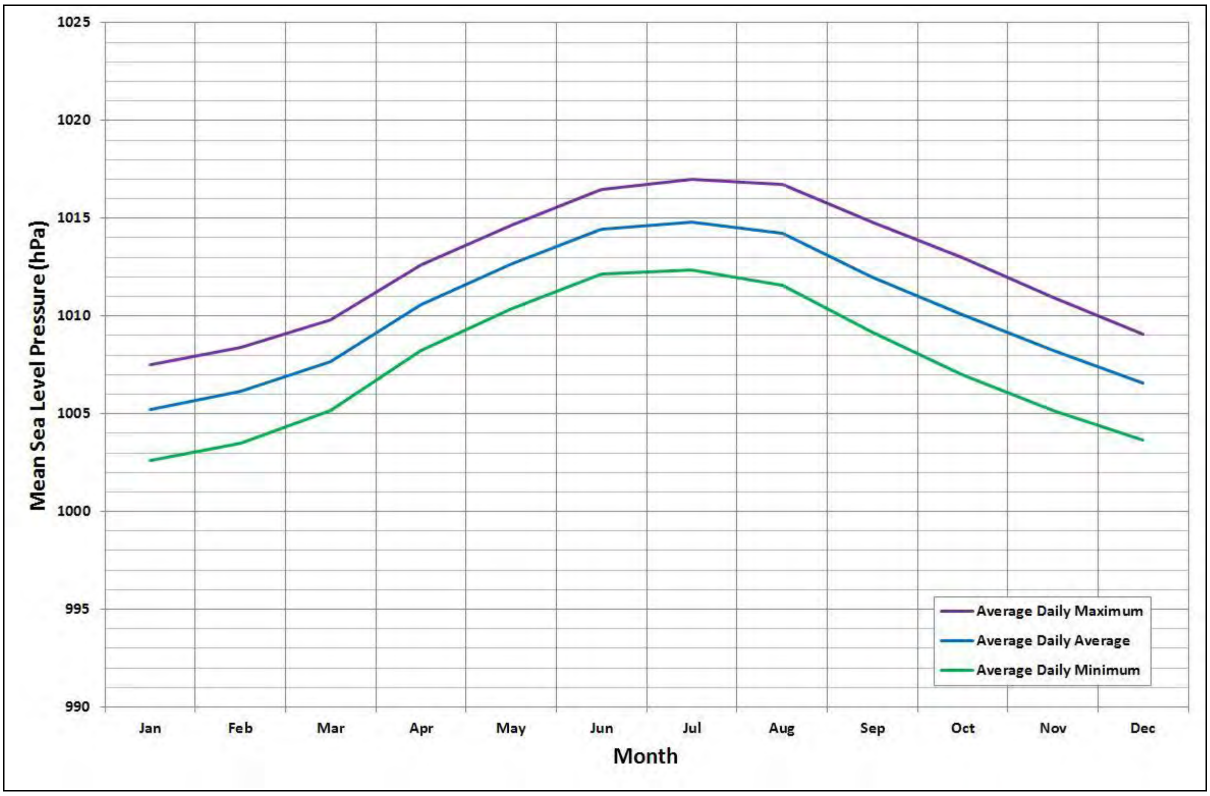
Figure 2-7 Tindal RAAF AWS Long-Term (2002-2013) Daily Relative Humidity Profile



2.1.1.5 Mean Sea Level Pressure

The long-term average daily mean sea level pressure (MSLP) trends per month are presented in **Figure 2-8**. The maximum average daily MSLP occurs during the months of June to August with average daily maximum values around 1017 hPa. The minimum average daily MSLP occurs in January with average daily minimum values less than 1003 hPa. This trend follows with the monsoonal seasonal variation and corresponds well with the annual precipitation trends.

Figure 2-8 Tindal RAAF AWS Long-Term (2002-2013) Annual Mean Sea Level Pressure Profile



2.1.2 Gove Airport

The Gove Airport AWS (AWS Number: 014508) observational dataset was reported from 28th August 2002 4:00 pm to 25th February 2013 12:00 pm (BoM, 2013b). No data was reported for the period from 21st February 2006 to 31st December 2006, inclusive. Hence, taking into account the incomplete hours within the main data, the dataset is 86.93% complete over the approximately 10.5 year observational period.

2.1.2.1 Wind Speed and Direction

The long-term annual and quarterly wind roses for the Gove Airport AWS (2002-2013) are presented in **Figure 2-9**.

The prevailing winds for each quarter are:

- **Quarter 1 (January – March)**: Moderate to high speed (3 – 10 m/s) winds blowing from the northwest.
- **Quarter 2 (April – June)**: High proportion of moderate to high speed (3 – 10 m/s) winds blowing from the south-eastern arc.
- **Quarter 3 (July – September)**: High proportion of moderate to high speed (3 – 10 m/s) winds blowing from the south-eastern arc.
- **Quarter 4 (October – December)**: Moderate speed (3 – 8 m/s) winds blowing in an approximately even distribution from northern to eastern arc.

Similar to the Tindal RAAF Base AWS measurements, there appears to be two distinct seasonal variations corresponding with the monsoonal 'wet' and 'dry' periods.

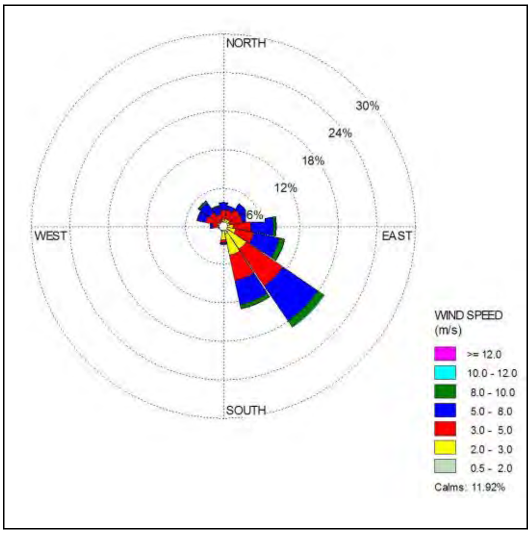
The long-term wind class frequency distribution for the Gove Airport AWS is presented in **Figure 2-10**. This histogram is for the full year span for all data, 2002 to 2013. Primary observations for this dataset are listed below:

- There is an increased proportion of higher speed winds (5 – 8 m/s and 8 – 10 m/s) compared to the Tindal RAAF Base AWS.
- Subsequently there are decreased proportions of lower speed winds, particularly in the 0.5 – 2 m/s range.
- There is also an increased proportion of 'calms' with wind speeds below 0.5 m/s.

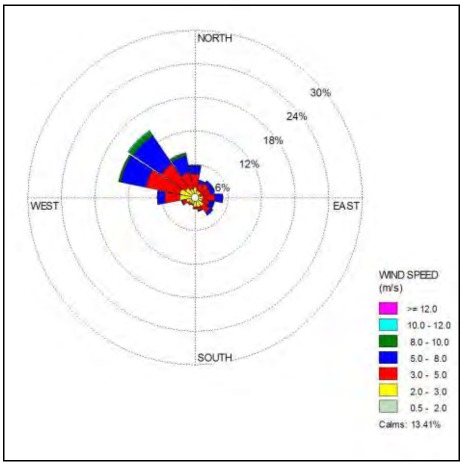
These trends are typical of a more coastal region where onshore/offshore diurnal variations are common.

Figure 2-9 Gove Airport AWS Long-Term Wind Roses (2002-2013)

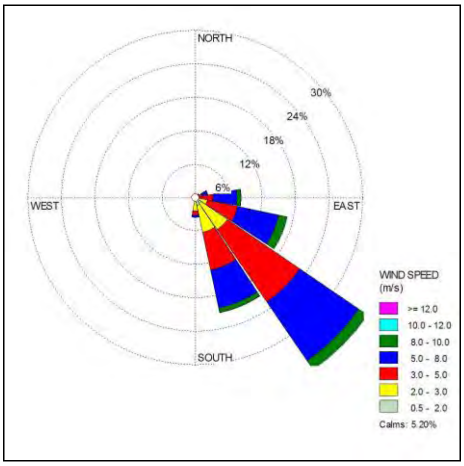
Full Year



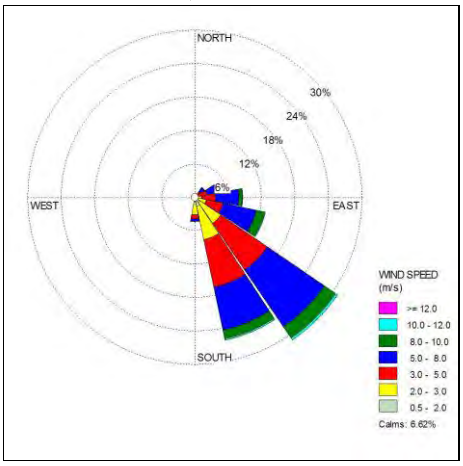
Quarter 1



Quarter 2



Quarter 3



Quarter 4

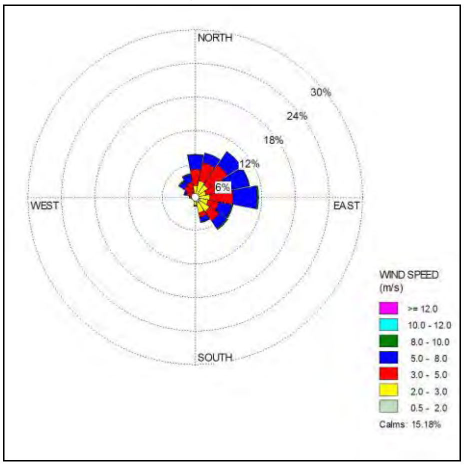
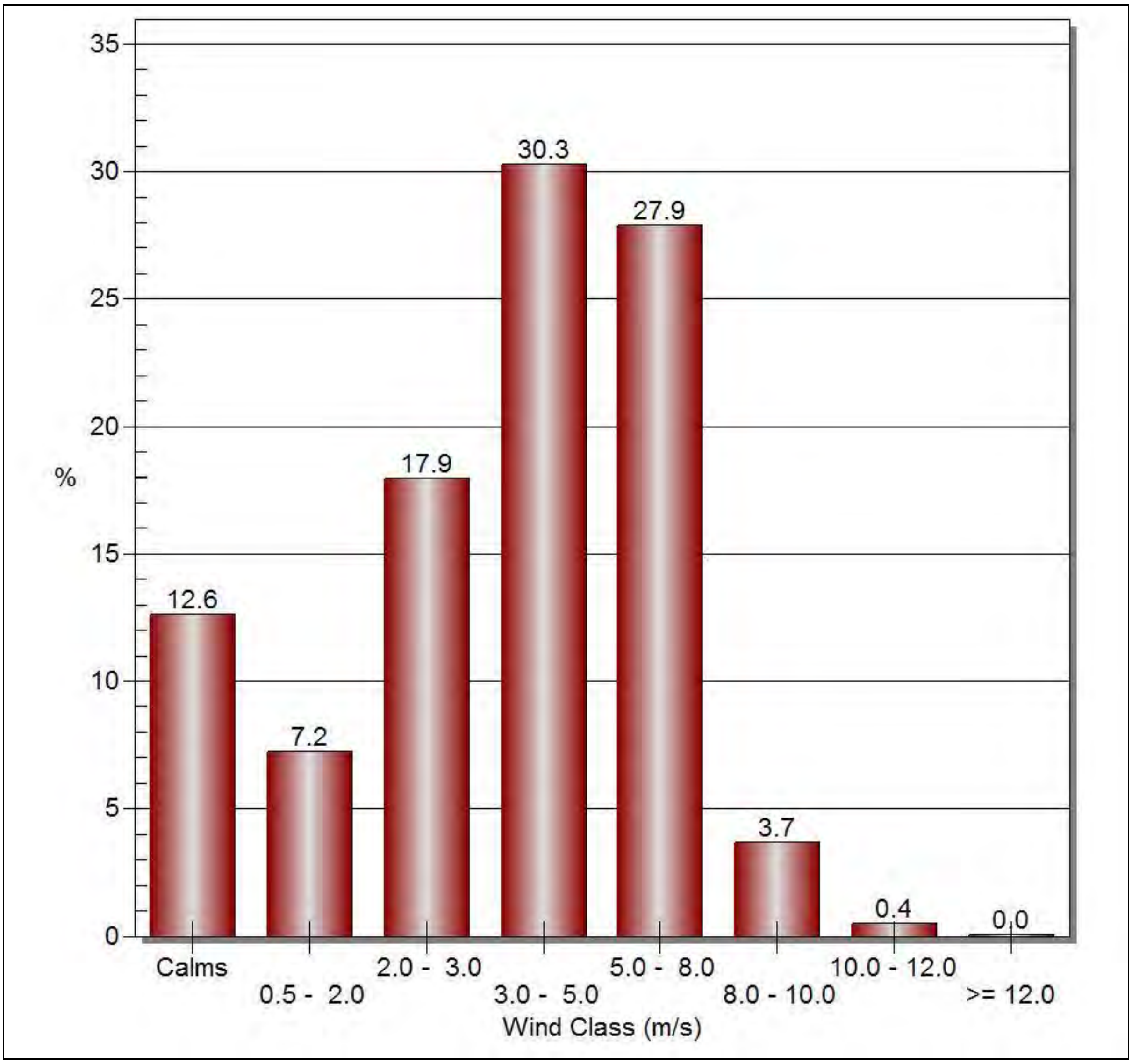


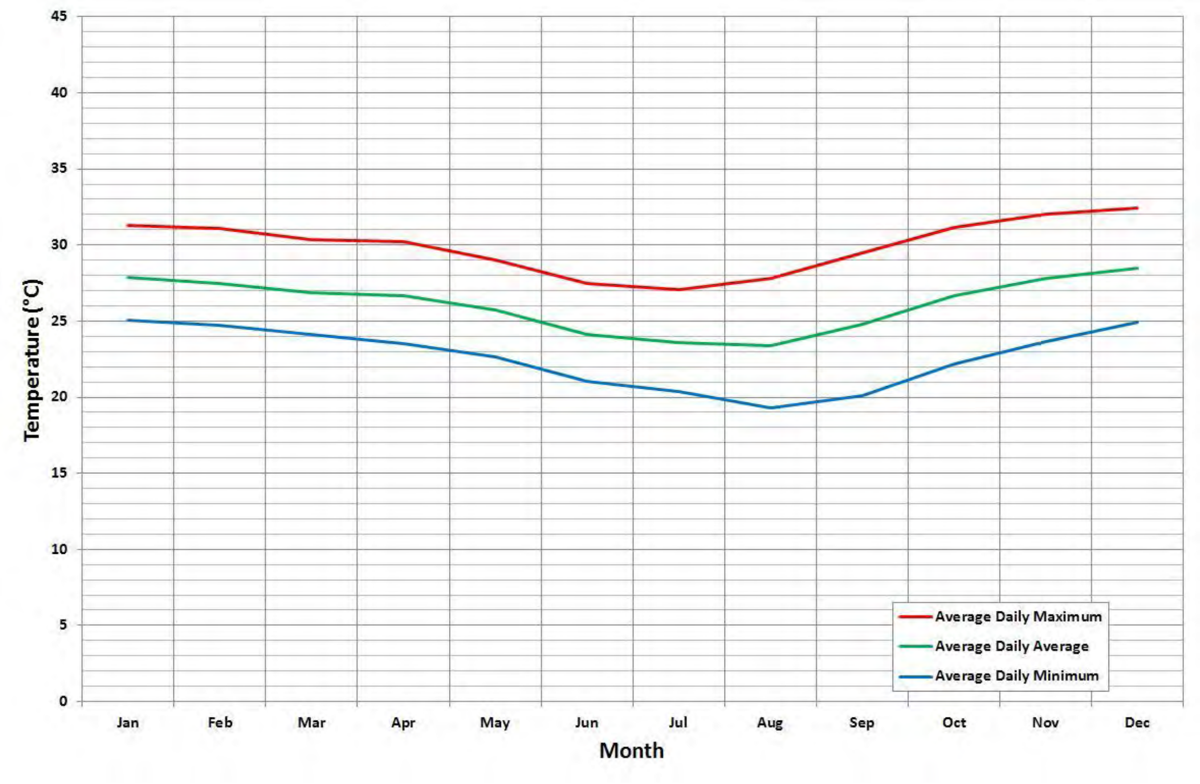
Figure 2-10 Gove Airport AWS Long-Term Wind Class Frequency Distribution (2002-2013)



2.1.2.2 Temperature

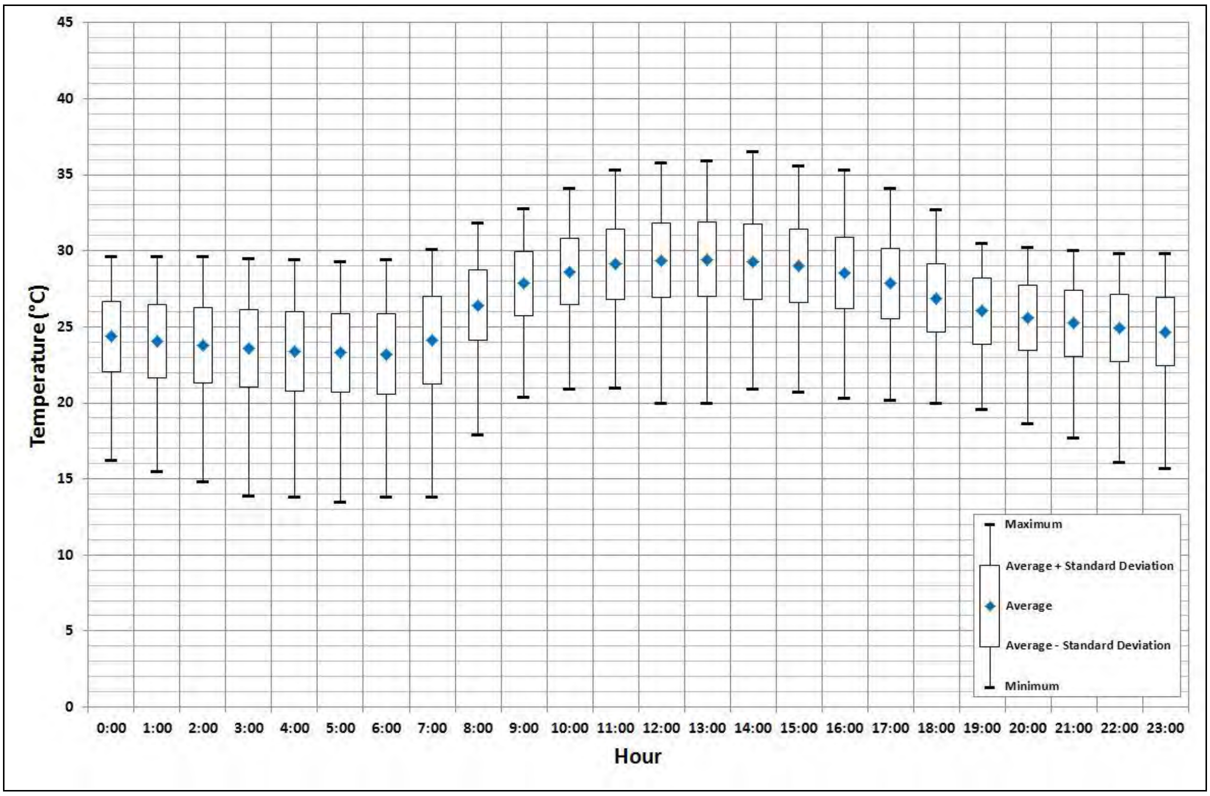
The long-term average daily temperature trends per month are presented in **Figure 2-11**. The December-January period is the warmest across the year with average daily maximum temperatures between 31°C and 33°C. August is the coolest month with average daily minimum temperatures around 19°C. The Gove Airport AWS recorded a smaller variation between average daily maximum and average daily minimum as well as a smaller overall variation between the annual maximum and minimum than the Tindal RAAF AWS. This is likely due to the coastal location of the Gove Airport AWS.

Figure 2-11 Gove Airport AWS Long-Term (2002-2013) Annual Temperature Profile



The long-term daily temperature profile is presented in **Figure 2-12**. The daily profile reflects the smaller daily temperature variation than the Tindal RAAF AWS with values ranging between approximately 13.5°C and 36.5°C.

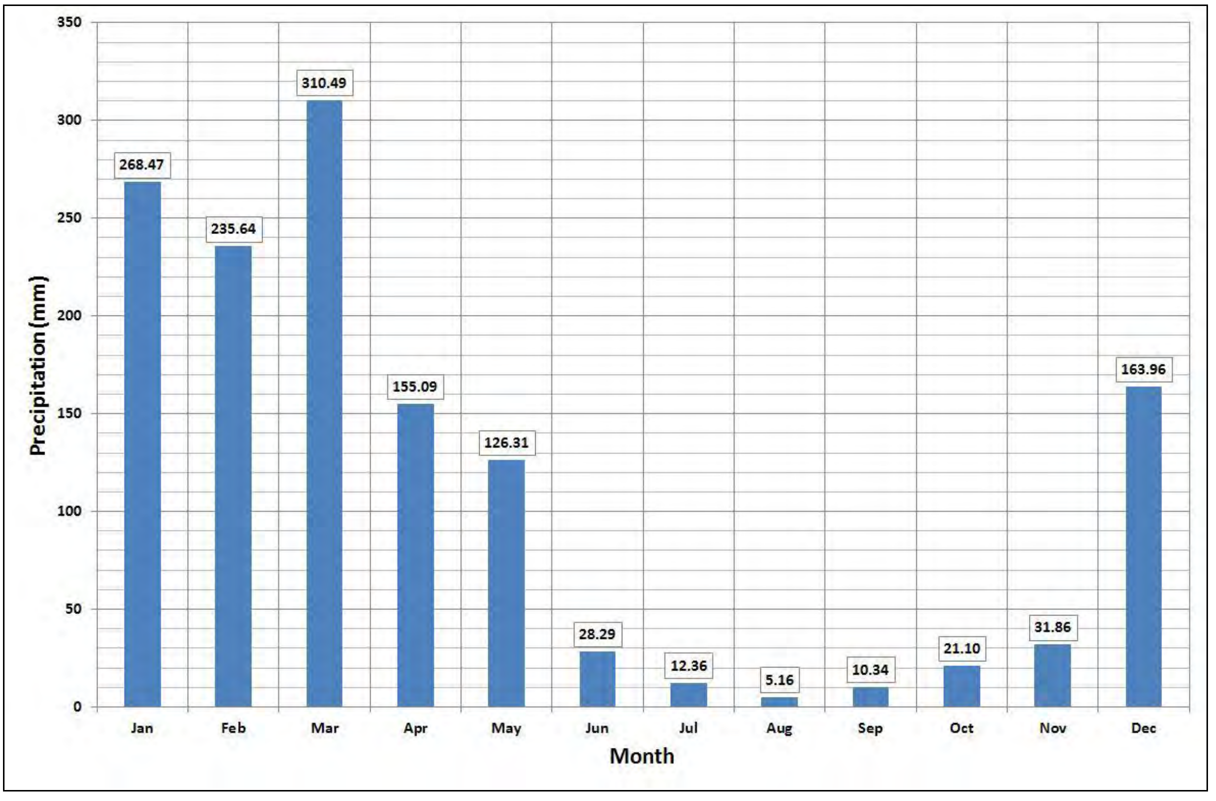
Figure 2-12 Gove Airport AWS Long-Term (2002-2013) Daily Temperature Profile



2.1.2.3 Precipitation

The average monthly precipitation recorded at the Gove Airport AWS is presented in **Figure 2-13**. The rainfall follows a similar monsoonal 'wet' and 'dry' seasonal variation, however there is increased rainfall observed in April and May and decreased rainfall in November and December when compared to the Tindal RAAF AWS. This implies that the onset of the 'wet' season is shifted approximately a month later in the year.

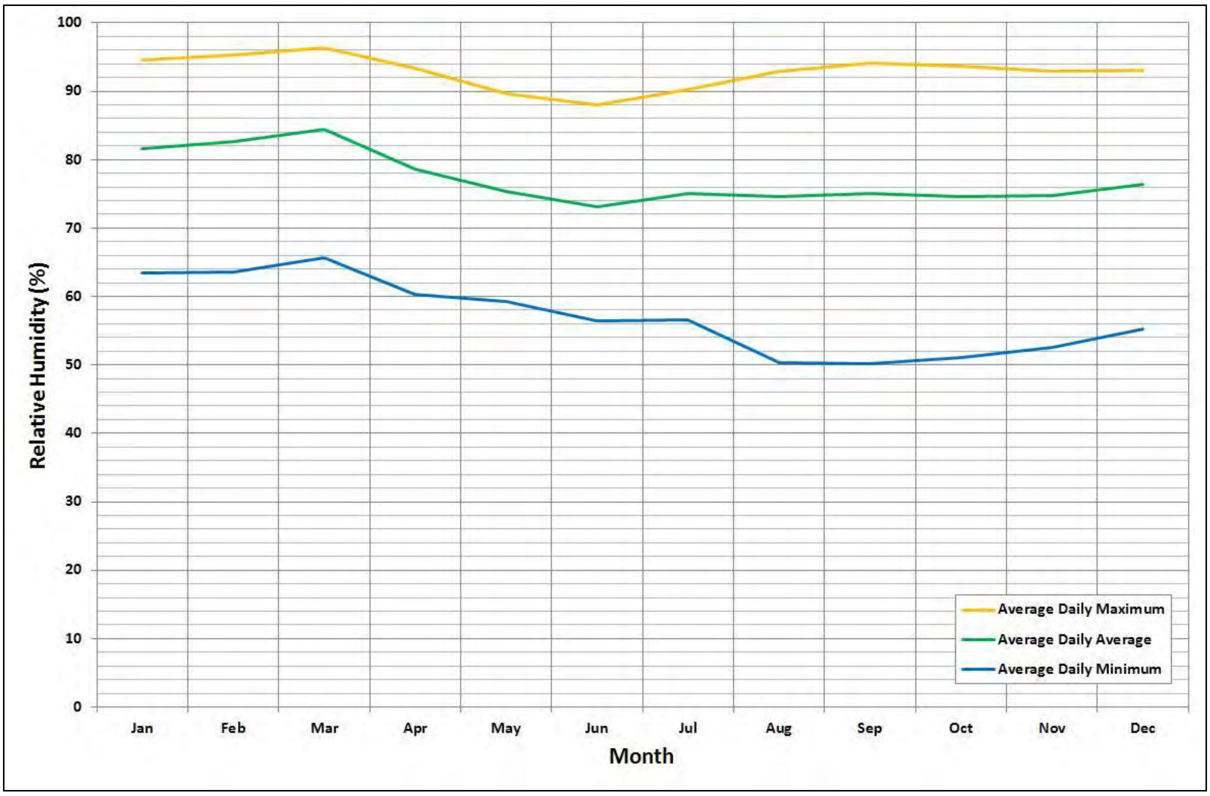
Figure 2-13 Gove Airport AWS Long-Term (2002-2013) Average Monthly Precipitation



2.1.2.4 Relative Humidity

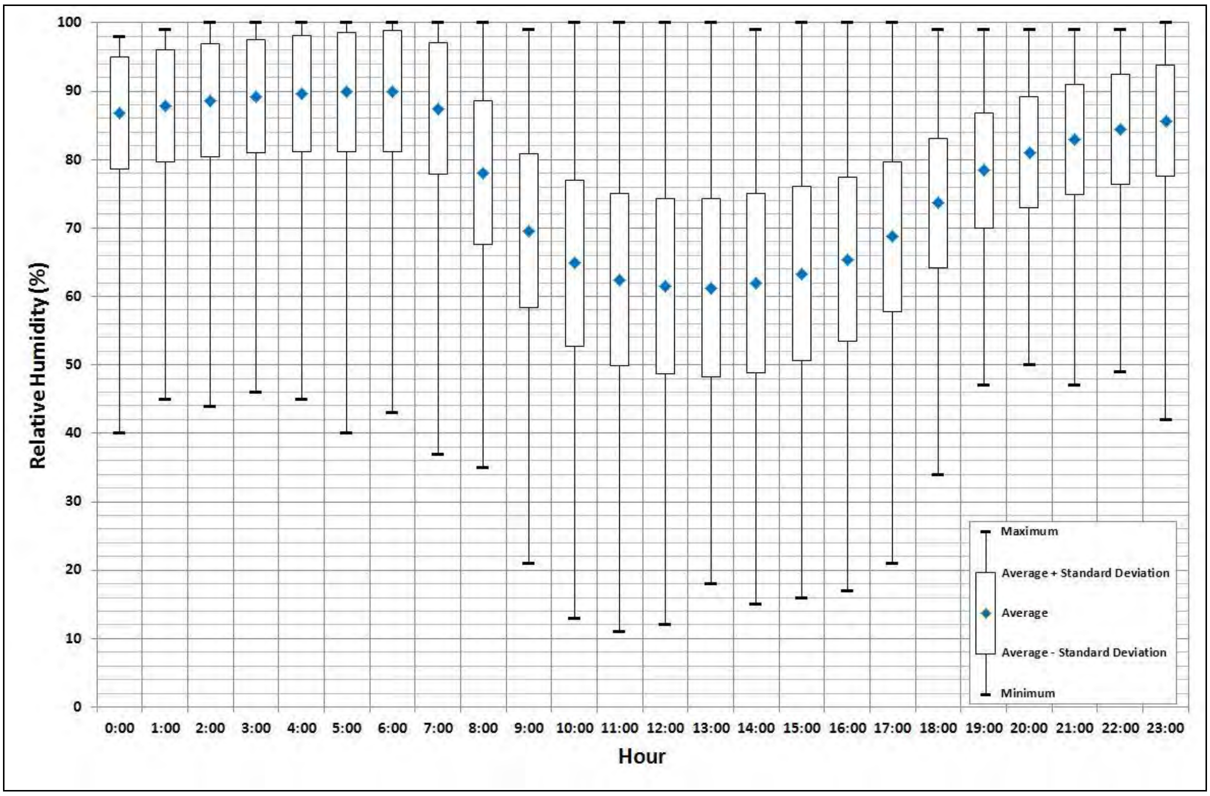
The long-term average daily relative humidity trends per month are presented in **Figure 2-14**. It is apparent that the humidity does not change significantly, with high values occurring consistently throughout the year. A slight reduction in the average daily maximum and daily average humidity is observed in June, with a reduction in the average daily minimum occurring during the August-September period.

Figure 2-14 Gove Airport AWS Long-Term (2002-2013) Annual Relative Humidity Profile



The long-term daily relative humidity profile is presented in **Figure 2-15**. This profile shows a more consistently high humidity on average throughout the day with average maximum humidity reaching approximately 90% and average minimum humidity occurring at 1:00 pm with approximately 61%. Note that all hours across the daily profile have a recorded maximum relative humidity either at or near saturation (100%), but the minimum humidity recorded for each hour are higher than what was recorded at the Tindal RAAF AWS.

Figure 2-15 Gove Airport AWS Long-Term (2002-2013) Daily Relative Humidity Profile

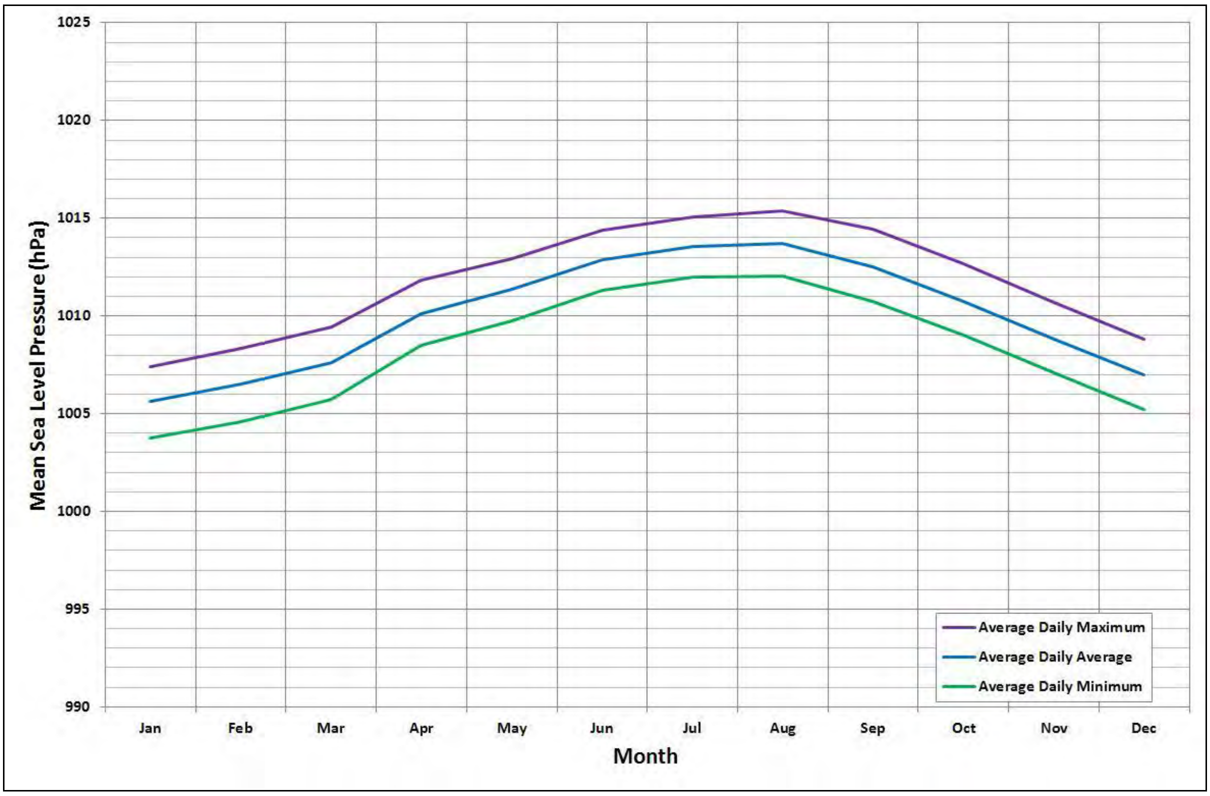


2.1.2.5 Mean Sea Level Pressure

The long-term average daily MSLP trends per month are presented in **Figure 2-16**. Similar trends are observed in comparison to the Tindal RAAF AWS with the following exceptions:

- The variation between the average daily maximum and average daily minimum is less;
- The overall maximum MSLP occurs in August, a month later than the Tindal RAAF AWS; and
- The average daily average MSLP is approximately 1 hPa lower.

Figure 2-16 Gove Airport AWS Long-Term (2002-2013) Annual Mean Sea Level Pressure Profile



2.2 Surrounding Land Use and Terrain

The surrounding land use is primarily open grassland and woodlands with some rural properties along the alignment. The alignment is located in an extremely sparsely populated region and as such there are little anthropogenic sources of pollutants in the immediate vicinity of the pipeline. Details of the anthropogenic sources, as listed by the National Pollutant Inventory (NPI) are provided in **Section 2.3**.

The terrain varies along the alignment ranging from an elevation of up to 220 m Australian Height Datum (mAHD) down to sea level. There are little significant topographical features (natural or man-made) that would significantly influence the local wind flows (i.e. mountain ranges/valleys or high rise buildings/canyons). Hence, for dispersion modelling purposes, the local region (i.e. within 20 km of the pipeline alignment) can be considered a flat plane and thus terrain effects are typically ignored.

2.3 Existing Ambient Air Quality

Ambient air quality monitoring data was not publically available in the vicinity of the proposed pipeline alignment. The NTEPA lists the nearest ambient air quality monitoring facilities to be in the Darwin/Palmerston region which measures the following parameters:

- Particulate matter (both PM_{10} and $PM_{2.5}$) via a dichotomous Tapered Element Oscillating Microbalance (TEOM);
- Carbon Monoxide (CO);
- Oxides of Nitrogen (NO_X, NO and NO_2);
- Ozone (O_3); and
- Sulfur Dioxide (SO_2).

It has been identified by the NTEPA that the primary source of particulate matter observed at the Darwin/Palmerston monitoring facilities are bushfires. Bushfire emissions are sporadic and difficult to characterise by their nature. For the purpose of assessing construction impacts, bushfires are considered to be an abnormal event. The modelling considers the “normal” case during construction and assumes no bushfires are occurring in the vicinity of the construction area.

For this assessment, the minimum distance between the proposed pipeline alignment and the air quality monitors for the Darwin/Palmerston region is 280 km. Hence the monitoring results are not relevant to this assessment. Therefore background concentrations, other than the default 0.5 ppb (R_{smog}) and 20 ppb (O_3) used by TAPM v4.0.5 are not incorporated. To compensate for this, major anthropogenic sources of pollutants have been modelled directly.

The National Pollutant Inventory (NPI) website (http://www.npi.gov.au/index.html) lists the local facilities relevant to this assessment. These sources are listed in **Table 2-1**:

- 'F' signifies only fugitive sources of the pollutant;
- 'P' signifies only point sources of the pollutant; and
- 'F P' signifies both fugitive and point sources of the pollutant.

Details of the emissions are provided in **Section 4.2**.

Table 2-1 Background Sources of Air Emissions (NPI, 2013a)

Facility Name		Air Pollutant Emissions					
		CO	NO_X	PM_{10}	$PM_{2.5}$	SO_2	VOCs
Katherine Depot		–	–	–	–	–	F
Katherine Waste Transfer Station		F	F	F	F	F	F
Tindal Airport – Shell Refuelling Facility		–	–	–	–	–	F
Northern Cement Ltd – Mataranka Lime		F P	F P	F P	F	F P	F
Gapuwiyak (Lake Evella) Community Power Station		P	P	P	P	P	F P
Gove Airport – BP Australia Pty Ltd		–	–	–	–	–	F
Alcan Gove Pty Ltd	Gove Mine site	F P	F	F	F	F	F
	Gove Refinery	F P	F P	F P	F P	P	F P

3 POLLUTANTS OF POTENTIAL CONCERN AND LEGISLATION

3.1 Pollutants of Potential Concern

The pollutants of potential concern (POPCs) identified for this assessment are as follows:

- For the construction phase of the project:
    - Airborne particulate matter with an aerodynamic equivalent diameter (AED) of 10 µm or less (PM_{10}); and
    - Deposited Total Suspended Particulates (TSP).
- For the operational phase of the project:
    - Oxides of nitrogen (NO_X as nitrogen dioxide, NO_2);
    - Carbon monoxide (CO); and
    - Photochemical smog (as evidenced by ozone, O_3).

3.1.1 Airborne Particulates

Airborne particulates are differentiated by size, chemical composition and derivation. This report is concerned with dust generated from activities associated with the construction of the pipeline, specifically the ambient size ranges. These include total suspended particulate (TSP) and particulate matter with an aerodynamic equivalent diameter (AED) of 10 µm or less (PM_{10}).

Particles less than 10µm, while not a strict marker, are generally accepted as the respirable threshold. PM_{10} can settle in the bronchi and can lead to exacerbation of respiratory conditions, with a causal link also suggested to increased plaque deposition in the arteries (Cohen *et. al.,* 2005).

PM_{10} have also been shown to affect environmental impacts through deposition of particulate on leaf surfaces, which reduces photosynthetic potential. Further, particulate matter with an AED of 2.5 µm or less ($PM_{2.5}$) has been shown to settle in the stomatal openings of leaf surfaces, inhibiting gas exchange (Prajapati, 2012).

3.1.2 Oxides of Nitrogen (NO_X)

Low levels of nitrogen oxides can cause adverse effects in humans which consist of: irritation of the eyes, nose, throat and lungs. This can lead to coughing, shortness of breath, tiredness and nausea. A build-up of fluid in the lungs can also occur 1-2 days after exposure. Acute exposure to nitrogen oxides can cause rapid burning, spasms and swelling of tissues in the throat and upper respiratory tract, reduced oxygenation of tissues, a build-up of fluid in the lungs and possible death. Environmentally, high levels of nitrogen oxides can damage roots and leaves of vegetation. Nitrogen dioxide is an acrid reddish-brown toxic gas and is the damaging component of photochemical smog.

An increase in nitrogen oxides in the atmosphere can cause an increase in acidity of rain, acting as a catalyst for the oxidation of sulfur dioxide into sulfur trioxide and subsequent conversion into sulfuric acid. This can cause follow-on damage to biological ecosystems (NPI, 2013b).

3.1.3 Carbon Monoxide (CO)

Carbon monoxide affects the amount of Greenhouse Gas found in the atmosphere, which is linked to global warming. In humans, exposure to low levels of carbon monoxide (200 ppm for 2-3 hours) can cause headaches, dizziness, light-headedness and fatigue. Exposure to high levels (400 ppm) can cause convulsions, collapse, loss of consciousness and death. Carbon monoxide can also lead to long term health effects such as heart disease, damage to the nervous system and can cause birth defects. The same effects of carbon monoxide on humans have also been observed in animals.

3.1.4 Photochemical Smog (As Evidenced by Ozone, O_3)

Photochemical smog is a combination of several airborne pollutants including various volatile organic compounds (VOCs), oxides of nitrogen, ozone, nitrates and aldehydes. Depending on the composition, VOCs can cause irritation of the eyes, nose and throat, headaches, loss of coordination, nausea, and damage to the liver, kidneys and central nervous system. Some VOCs have been suspected to cause cancer in humans as well as animals. VOCs are the causative agent in photochemical smog.

As the chemical constituents of photochemical smog are balanced by a reversible titration reaction, when simulated via computer modelling software, it is evidenced by the presence of ozone concentrations above the predefined background levels. Long term exposure to ozone has been shown to increase risk of death from respiratory illness and lung disease.

3.2 Legislative Assessment Criteria

This section discusses the relevant legislative and assessment criteria that relate to the air quality impacts of the project.

3.2.1 National Environment Protection (Ambient Air Quality) Measure

The National Environment Protection Council (NEPC) defines national-level environmental standards for environmental assessment purposes. The National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM) was first produced under Section 20 of the *NEPC (Northern Territory) Act 1994* (NT). It was later amended in July 2003 to incorporate additional reporting standards (NEPC, 2003). The goal of the AAQ NEPM was for the ambient air quality standard to be achieved, at the monitoring stations it is assessed at, within ten years of its implementation. This period ended in 2008. In July 2010 the NEPC released a discussion paper on Air Quality Standard and a series of public consultation meetings were held. The review of this public discussion was released in September 2011.

The NTEPA has adopted the AAQ NEPM (2003) standards as their general air quality objectives for human health across the territory.

3.2.2 Vegetation Impacts

Vegetation impacts are primarily associated with the deposition of particulate matter onto the leaf surface and decreasing the ability for the plant life to photosynthesise sunlight. Although assessment of dust deposition is not strictly required by the EIS, it is considered good practice to investigate the impacts from all construction emissions. Currently the Northern Territory does not have specific assessment criteria related to dust deposition; therefore a qualitative assessment has been conducted for this investigation.

3.2.3 Adopted Assessment Criteria

The following relevant air quality assessment criteria in **Table 3-1** have been adopted for this assessment.

Table 3-1 Adopted Air Quality Assessment Criteria

Pollutant	Averaging Period	Maximum Concentration	Maximum Allowable Exceedences Goal
Human Health Criteria			
Carbon monoxide (CO)	8 hours	11,244 μ/m^3	1 day a year
Nitrogen dioxide (NO_2)	1 hour	120 ppb	1 day a year
	1 year	30 ppb	none
Photochemical oxidants (as ozone, O_3)	1 hour	100 ppb	1 day a year
	4 hours	80 ppb	1 day a year
Sulfur dioxide (SO_2)	1 hour	200 ppb	1 day a year
	24 hours	80 ppb	1 day a year
	1 year	20 ppb	none
Particles (as PM_{10})	24 hours	50 μg/m^3	5 days a year
Vegetation Criteria	Qualitative Assessment		

Note: Concentrations are expressed at Standard Conditions (Temperature = 0°C, Pressure = 101.325 kPa)

It is important to note however that the NEPM criteria for photochemical oxidants (as ozone) do not strictly apply in the context of the project as they are based on urban areas with high vehicle usage.

Sulfur dioxide has not been modelled as it is assumed that the Gas fuel will have zero sulfur content.

3.3 Sensitive Receptors

Two classifications of sensitive receptor have been identified for this assessment: human health; and vegetation. **Table 3-2** lists the human health receptors identified in this assessment. The primary factor identifying these locations is the presence of dwellings in which humans will reside for extended periods of time and hence will be impacted upon by chronic exposure to the POPCs.

Vegetation receptors are identified as any vegetated area outside the construction corridor. The locations of the sensitive receptors relative to the pipeline alignment are presented in **Appendix A**.

Table 3-2 Sensitive Receptors

Receptor	Centroid Coordinates			Distance of Centroid from Pipeline Alignment (km)	Alignment Chainage (km)
	Zone	Easting (m)	Northing (m)		
Single Dwellings	53	224947	8383536	1.6	12
	53	227525	8384144	2.16	15
	53	228276	8384704	2.63	16
	53	228212	8385265	3.21	16
Barunga	53	270037	8393154	8.14	58
Camp 1	53	284421	8391303	4.76	72
Beswick	53	296833	8390078	2.14	86
Camp 2	53	386431	8440220	0.59	193
Dwellings	53	402214	8447576	3.44	210
Camp 3	53	456169	8511830	3.92	294
Dwellings	53	551081	8574959	5.59	409
Camp 4	53	576748	8596151	1.38	446
Camp 5	53	667828	8621685	0.93	547
Single Dwelling	53	673632	8630243	1.48	559
Nhulunbuy	53	693350	8652300	2.35	594
Wallaby Beach	53	686354	8652160	0.23	600
Gunyangara	53	685609	8648961	3	601
Single Dwellings	53	685111	8648141	3.95	601
	53	684695	8648199	3.94	601
	53	684748	8647629	4.48	601
Galupa	53	683865	8651560	0.85	602.5

4 EMISSIONS INVENTORY

This section discusses the calculated emissions parameters for both the construction and operational phases of the project.

4.1 Emission Sources – Construction Phase

Particulate emissions have been calculated using the emission factor method detailed in the *National Pollutant Inventory* (NPI) *Emission Estimation Technique Manual* (EETM) *for Mining Version 3.1* (NPI, January 2012). This EETM details various excavation and earthmoving activities that commonly occur during construction activities for the installation of pipelines.

The generalised equation to determine particulate emissions to air from earthmoving activities is as follows:

$$E_i(kg/yr) = [A_{t/h} \times OP_{h/yr}] \times EF_{i\,(kg/t)} \times \left[1 - \frac{CE_i}{100}\right] \qquad \textbf{Equation 4-1}$$

Where:

E_i (kg/yr)	=	Emission rate of pollutant i, in kg/yr;
$A_{t/h}$	=	Activity rate, in t/h;
$OP_{h/yr}$	=	Operating hours, in h/yr;
$EF_{i\,(kg/t)}$	=	Uncontrolled emission factor of pollutant i, in kg/t; and
CE_i	=	Overall control efficiency for pollutant i, in %.

4.1.1 General Assumptions

General assumptions made to facilitate calculation the emission rates of various construction activities are as follows:

- Indicative construction schedule obtained from *Draft Environmental Impact Statement – Trans Territory Underground Pipeline – Wadeye to Gove in the Northern Territory* (Alcan, 2004):
  - Operation work hours are 7:00 am to 5:30 pm;
  - Construction work is limited to within the monsoonal ‘dry’ season (April – November) totalling 183 working days;
- Soil density = 1.5 t/m^3; and
- Construction corridor = 30 m wide x 1 km long (for modelling purposes, details in **Section 5.2.1**).
- No dust emission mitigation controls are in place.

Activities considered emission sources in the modelling include:

- Bulldozer operation;
- Grader operation;
- Haul Trucks dumping overburden;
- Trencher (bucket and wheel) operation;
- Excavator operation;
- Padding Machine operation;
- Wheel-generated dust from vehicle movements within the Right of Way (ROW) (both light and heavy vehicles); and
- Wind Erosion from stockpiles.

Blasting has not been included in the modelling. Although explosives may be used to assist in the excavation of rock material during the construction of the pipeline, the explosive yields to be used are not large enough to be calculated using the NPI EETM methods. In addition, the method of blasting to be employed is shallow rock fracturing, as opposed to bench blasting conducted in mining operations. Hence the particulate emissions from these activities are likely to be low.

Both Wheel Generated Dust and Wind Erosion sources have control factors associated with their respective emissions. As water sprays have been included in the modelling for the unpaved roads and stockpiles, a control factor of 50% has been applied in accordance with (NPI, January 2012).

Particulate emissions relating to vehicular traffic for construction purposes outside the ROW have not been included in the modelling for the following reasons:

- The spatial scale of the project;
- The availability of data relating to vehicle-generated dust specific to the project conditions; and
- Limitations of the dispersion model to appropriately characterise vehicular emissions.

To compensate, a qualitative assessment of dust impacts from vehicular traffic outside the construction ROW has been conducted.

For full details on the calculation methods for each construction activity, refer to **Appendix C**.

4.1.2 Summary

A summary of the individual emission source emission rates is provided in **Table 4-1**.

Table 4-1 Dust Emissions Summary

Emission Source	PM_{10} Emission Rate when in Operation (g/s)	TSP Emission Rate when in Operation (g/s)
Bulldozer (Clear and Grade)	0.063	0.289
Bulldozer (Padding and Backfill)	0.063	0.289
Bulldozer (Restoration)	0.063	0.289
Grader (Clear and Grade)	0.013	0.030
Grader (Padding and Backfill)	0.013	0.030
Grader (Restoration)	0.013	0.030
Haul Truck (Dumping)	2.500	7.143
Trencher Operation	0.328	0.702
Excavator (Trenching)	0.952	1.984
Excavator (Tie-ins and Road Crossings)	0.952	1.984
Padding Machine Operation	0.328	0.702
LV-Wheel Generated (Clear and Grade)	0.042	0.121
LV-Wheel Generated (Trenching)	0.042	0.121
LV-Wheel Generated (Padding and Backfill)	0.042	0.121
Haul Truck (Wheel Generated)	0.245	0.890
Semi-trailer (Wheel Generated)	0.245	0.890
Flatbed (Trenching) (Wheel Generated)	0.030	0.086
Flatbed (Welding) (Wheel Generated)	0.030	0.086
Wind Erosion	Variable	Variable
TOTAL EMISSIONS	**5.966 + Wind Erosion**	**15.787 + Wind Erosion**

4.1.3 Dry Depletion / Particle Scavenging

Plumes of particulate matter suspended in the atmosphere are subject to deposition onto the ground surface due to gravitational settling. This is known as the dry depletion of a particulate matter plume. The rate in which the particles settle is dependent on the particle size. The Ausplume v6.0 steady-state Gaussian plume model, employed to simulate the dispersion of the particulate matter plumes during the construction phase of the project, uses an algorithm to 'tilt' the plumes toward the ground to mimic the gravitational settling of particles. As particles reach ground level they are deposited out of the plume, altering the concentration of particles in the plume, making the distribution no longer Gaussian in nature.

Particle scavenging is the 'picking up' of particulate matter already deposited onto the ground surface by the wind. This has the effect of slightly increasing the quantity of airborne particulate matter further downwind from the source, increasing the distance in which the resulting plume can travel. Similar to dry depletion, this phenomenon is dependent on the particle size in question.

The particle size distribution used for this assessment is based upon investigations into particulate matter generation in the Pilbara region of Western Australia, as this is analogous to the general conditions experienced in the northern region of the Northern Territory. The values were sourced from (SKM, 2011) and are listed in **Table 4-2**.

Table 4-2 Particle Size Distribution by Weight (SKM, 2011)

Particle Size Midpoint (µm)	Mass Fraction	
	PM_{10}	TSP
1	0.31	0.11
4	0.26	0.09
7	0.23	0.08
9	0.20	0.07
12	–	0.13
19	–	0.13
26	–	0.13
35	–	0.13
45	–	0.13

Wet deposition is the removal of particulate matter from a plume by precipitation. To ensure a conservative estimate of the potential impacts from the construction activities, wet deposition has not been included in the simulations.

4.1.4 Construction Traffic

The majority of access points for construction traffic to the pipeline are via roads with current low traffic volumes or with no data available on the traffic volumes, the most utilised roads used by construction traffic that pass significant potential sensitive receptors will be:

- Stuart Highway through Katherine.

The highest recorded traffic flow (2011) along the section of Stuart Highway that will be used by construction traffic and passes through Katherine was 2,282 vehicles per day. The anticipated construction traffic volume along the route will be an additional 65 vehicles per day.

- Central Arnhem Road passing Barunga.

The highest recorded traffic flow (2011) along the section of Central Arnhem Road that will be used by construction traffic was 157 vehicles per day. The anticipated construction traffic volume along the route will be as high as an additional 281 vehicles per day.

- Melville Bay Road through Nhulunbuy.

There are currently no existing traffic counts for Melville Bay Road which is a local name for Central Arnhem Road. The nearest traffic count data (2011) is for Central Arnhem Road intersection with Dhupuma Road which is 66 vehicles per day. It is assumed that as Melville Bay Road is located near to an urban area that it would have a greater traffic flow than this. The anticipated construction traffic volume along this route will be 145 vehicles per day.

Due to the current low traffic volumes, it is inappropriate to estimate emissions of pollutants or particulate matter via the methods adopted for the sources listed in **Section 4.1**. Therefore, quantitative modelling of particulate matter impacts from these activities cannot be undertaken. Hence, a qualitative assessment of the impacts has been conducted. Refer to **Section 6.1.3** for the results.

4.2 Emission Sources – Operational Phase

During the operational phase of the gas pipeline, the primary source of POPCs identified in **Section 3.1** is combustion exhaust from the gas turbine operating the King River compressor station (Chainage: 23.5 km). The gas turbine has been nominally chosen as a Caterpillar Solar Taurus 70 engine; employing the *SoLoNOx™* dry, low NO_X emissions technology. As specifics regarding the design of the compressor station have not been finalised at the time of writing, emissions information has been determined from publically available information and previous experience of gas turbine design. For the purpose of this assessment, it is assumed that no post combustion emission mitigation is installed.

Relevant data provided in the engineering specification sheet and publically available sources include:

- Exhaust Volumetric Flow Rate: 96,775 kg/h;
- Exhaust Temperature: 505°C (~778 K);
- Exhaust Emissions:
    - NO_X = 25 ppm(V);
    - CO = 50 ppm(V); and
    - Unburned Hydrocarbons (VOCs) = 25 ppm(V).

Emissions parameters supplied to TAPM v4 are listed in **Table 4-3**. These estimates are based on the known fuel and combustion characteristics with no post combustion controls. The proposed natural gas fuel is a relatively clean-burning fuel with negligible SOx or particulate air emissions expected. CO2 and water are the major combustion by-products. NOx is produced during combustion from the oxidation of Nitrogen present in the inlet air.

Table 4-3 Proposed Compressor Station Gas Turbine Emission Parameters

Source		Units	Solar Taurus 70 Engine GT001	Comments
Mode[1]		–	0	
Coordinates	**Easting**	m	236343	Centroid of plant location
	Northing	m	8383161	
Stack Height		m	22.5	Assumed values
Stack Radius		m	1.58	
Buoyancy Enhancement Factor[2]		–	1	
NO / NO_X Ratio		–	0.9	
FPM / APM Ratio[3]		–	1	
Exit Velocity		m/s	7.58	Calculated value
Exhaust Temperature		K	778	Vendor data
Emission Rates	**APM**	g/s	0	Negligible particulate emissions
	NO_X	ppm(V)	25	g/s emissions calculated from ppm(V)
		g/s	0.735	
	SO_2	g/s	0	Gas fuel – zero sulfur content
	VOCs	ppm(V)	25	R_{smog} value calculated from VOC emissions
	R_{smog}[4]	g/s	0.0025	
	CO	ppm(V)	50	g/s emissions calculated from ppm(V)
		g/s	1.303	

Note: 1 – Mode (-1 = Off, 0 = Eulerian Transport, 1 = Eulerian and Lagrangian Transport).
2 – Buoyancy Enhancement Factor (1 = No enhancement – conservative estimate).
3 – FPM = Fine Particulate Matter ($PM_{2.5}$), APM = All Particulate Matter (PM_{10}).
4 – Smog Reactivity [R_{smog}] = 0.0067 [VOCs] (Hurley, October 2008).

4.2.1 Background Emission Sources

Emissions information for existing sources was sourced from the NPI website (NPI, 2013a). Background emissions were separated into: point sources representing exhaust stacks; and area sources representing various fugitive pollutant emissions. **Table 4-4** summarises the total emissions for both fugitive and point sources relevant to this investigation. Emissions information provided to TAPM v4 for dispersion modelling is listed in **Table 4-5** for point sources and **Table 4-6** for area sources.

Table 4-4 Summary of NPI Emissions Search (NPI, 2013a)

Facility	Substance	Fugitive Air Emissions 2010/2011 (kg/year)	Point Source Air Emissions 2010/2011 (kg/year)
Katherine Depot	Total VOCs	11,000	–
Katherine Waste Transfer Station	CO	280	–
	NO_X	340	–
	PM_{10}	46	–
	$PM_{2.5}$	44	–
	SO_2	0.34	–
	Total VOCs	2,200	–
Tindal Airport Shell Refuelling Facility	Total VOCs	1,800	–
Gapuwiyak (Lake Evella) Community Power Station	CO	–	11,000
	NO_X	–	52,000
	PM_{10}	–	3,700
	$PM_{2.5}$	–	3,600
	SO_2	–	12
	Total VOCs	–	3,800
Gove Airport – BP Australia Pty Ltd	Total VOCs	46	3,800
Alcan Gove Pty Ltd – Gove Mine site	CO	66,000	560
	NO_X	190,000	–
	PM_{10}	210,000	–
	$PM_{2.5}$	13,000	–
	SO_2	130	–
	Total VOCs	15,000	–
Alcan Gove Pty Ltd – Gove Refinery	CO	70,000	420,000
	NO_X	160,000	2,800,000
	PM_{10}	230,000	110,000
	$PM_{2.5}$	13,000	73,000
	SO_2	–	39,000,000
	Total VOCs	110,000	91,000

Table 4-5 Background Emissions – Point Sources (NPI, 2013a)

Source		Mode[1]	Coordinates		Stack Height (m)	Stack Radius (m)	Buoyancy Enhancement Factor[2]	NO/NO_X Ratio	FPM/APM Ratio[3]	Exit Velocity (m/s)	Temperature (K)	Emission Rates (g/s)				
			Easting (m)	Northing (m)								APM[3]	NO_X	SO_2	R_{smog}[4]	CO
Northern Cement Ltd – Mataranka Lime		0	293690	8343050	30	1	1	0.9	1	5	573	0.729325	0.123668	0.01966	–	11.09843
Gapuwiyak (Lake Evella) Community Power Station		0	586930	8617900	10	1.2	1	0.9	0.972973	8	778	0.117326	1.648909	0.000381	0.000807	0.348808
Alcan Gove Pty Ltd	Gove Mine site	0	700030	8643735	6	0.2	1	0.9	0	10	773	–	–	–	–	0.017757
	Gove Refinery	0	683490	8652020	100	4	1	0.9	0.663636	30	973	1.162692	29.59581	412.2273	0.006444	4.439371
		0	683490	8651965	100	1.3	1	0.9	0.663636	30	973	1.162692	29.59581	412.2273	0.006444	4.439371
		0	683490	8651930	100	1.5	1	0.9	0.663636	30	973	1.162692	29.59581	412.2273	0.006444	4.439371

Note: 1 – Mode (-1 = Off, 0 = Eulerian Transport, 1 = Eulerian and Lagrangian Transport).
2 – Buoyancy Enhancement Factor (1 = No enhancement – conservative estimate).
3 – FPM = Fine Particulate Matter ($PM_{2.5}$), APM = All Particulate Matter (PM_{10}).
4 – Smog Reactivity [R_{smog}] = 0.0067 [VOCs] (Hurley, October 2008).

Table 4-6 Background Emissions – Area Sources (NPI, 2013a)

Source			Mode[1]	Coordinates (m)						NO/NO_X Ratio	FPM/APM Ratio[2]	Emission Rates (g/s)				
				X_0	Y_0	H_0	X_1	Y_1	H_1			APM[2]	NO_X	SO_2	R_{smog}[3]	CO
Katherine Depot			0	203055	8400315	0	203120	8400400	3	0.9	0	–	–	–	0.002337	–
Katherine Waste Transfer Station			0	202560	8393975	0	202585	8394010	4	0.9	0.957	0.001459	0.010781	0.00001	0.000467	0.008879
Tindal Airport – Shell Refuelling Facility			0	215920	8393980	0	216020	8394080	4	0.9	0	–	–	–	0.000382	–
Northern Cement Ltd – Mataranka Lime			0	293615	8342905	0	294035	8343125	5	0.9	0.013	0.272704	0.044394	0.00003	0.000104	0.015221
Gapuwiyak (Lake Evella) Community Power Station			0	586915	8617875	0	586970	8617920	4	0.9	0	–	–	–	0.000010	–
Gove Airport – BP Australia Pty Ltd			0	698125	8642870	0	698190	8642920	5	0.9	0	–	–	–	0.000637	–
Alcan Gove Pty Ltd	Gove Mine site	Pollutants	0	699900	8643720	0	700160	8644150	8	0.9	0	–	6.02486	0.004122	0.003187	2.092846
		Dust	0	696500	8638500	0	704200	8645000	10	0.9	0.062	6.659056	–	–	–	–
	Gove Refinery		0	682900	8651450	0	684150	8652400	15	0.9	0.057	7.293252	5.073567	–	0.02337	2.219685

Note: 1 – Mode (-1 = Off, 0 = Eulerian Transport, 1 = Eulerian and Lagrangian Transport).
2 – FPM = Fine Particulate Matter ($PM_{2.5}$), APM = All Particulate Matter (PM_{10}).
3 – Smog Reactivity [R_{smog}] = 0.0067 [VOCs] (Hurley, October 2008).

5 MODELLING METHOD

The following section details the modelling method undertaken for this assessment. The investigation was conducted in a staged manner:

1. Generate local meteorological conditions using the CSIRO-developed, three-dimensional prognostic meteorological model The Air Pollution Model (TAPM) version 4.0.5.
2. Using observed meteorological data obtained from the Bureau of Meteorology (BoM, 2013a and 2013b); adjust the generated data to more accurately represent the local meteorology.
3. Validate the adjusted meteorological dataset against the actual observations.
4. Using the validated meteorological data, conduct the pollutant and dust dispersion modelling to predict the air quality impacts generated by the project, via TAPM v4.0.5 for the pollutants and via the EPA Victoria-developed, steady-state Gaussian dispersion model Ausplume v6.0 for the particulate matter.
5. Process the model output datasets for comparison against the relevant assessment criteria.
6. For the pollutant impacts, generate a series of ground-level concentration (GLC) isopleth contour plots to present the pollutant concentration trends. For particulate matter, determine the impact ‘footprint’ for the construction phase of the project and what effect will this have on the sensitive receptors.

5.1 Modelling Approach

Airborne emissions from construction activities do not follow the conventional archetype of an emission ‘point source’ or ‘volume source’ for dispersion modelling purposes. This is because the physical locations of the emission sources change as the construction activities progress along the alignment. To compensate for the different nature of the construction phase emission sources, a representative ‘segment’ modelling approach was adopted. Details of the model definition are provided in the following sections.

5.2 Model Definition

This section details the configuration settings provided to the modelling software to conduct this assessment.

5.2.1 Construction Phase Dispersion Modelling

As stated in **Section 5.1** the ambient particulate matter impacts have been modelled by simulating the construction activities over a segment of pipeline. This segment represents all the construction phase operations relevant to air quality impacts, from initial excavation to restoration.

The nominated segment is 1 km in length and is represented by 11 volume sources evenly distributed along the segment (nominally oriented north-south). Each source has the same emission rate to represent the activities being evenly distributed along the segment.

Particulate dispersion was conducted using three sets of meteorological data, tailored to determine the predicted impact footprint of the construction activities downwind:

1. TAPM-generated data for the King River Compressor Station;
2. The King River Compressor Station dataset with the wind directions set to 270°True (westerly); and
3. The King River Compressor Station dataset with the wind directions set to 0°True (northerly).

The TAPM-generated dataset for the King River Compressor Station was used as it is a plausible representation of meteorological phenomena that can be encountered along the pipeline alignment (Refer to **Section 5.3** for details).

However, this assessment is investigating the impact from a representative segment of construction activities and over the entirety of the pipeline alignment the orientation of the alignment changes relative to the wind direction (i.e. near to Katherine the orientation is west-east, then progresses to southwest-northeast, then to south-north and finally to east-west near the Gove refinery). Therefore the TAPM-generated dataset may not identify the 'worst case' meteorological conditions at every point along the alignment.

To account for this, the two other meteorological datasets were included to represent the worst possible case for particulate matter dispersion:

- The perpendicular (westerly) orientation to ensure maximum displacement of particulate matter; and
- The parallel (northerly) orientation to determine the combined effects of all sources at the ends of the construction corridor.

These simulations aid in identifying the maximum potential impact footprint from the construction activities and adopt a level of conservatism desirable in this type of assessment.

To ensure the impact footprint is not significantly overestimated, the standard deviation of the wind direction during the hour, known as sigma-theta ($\sigma\theta$), is preserved from the TAPM-Generated dataset. This parameter spreads the plume out and increases dispersion, decreasing the downwind concentrations.

As the impact footprint is relative to the pipeline segment, the spatial units are set to a relative grid with the origin centred about the centre of the segment.

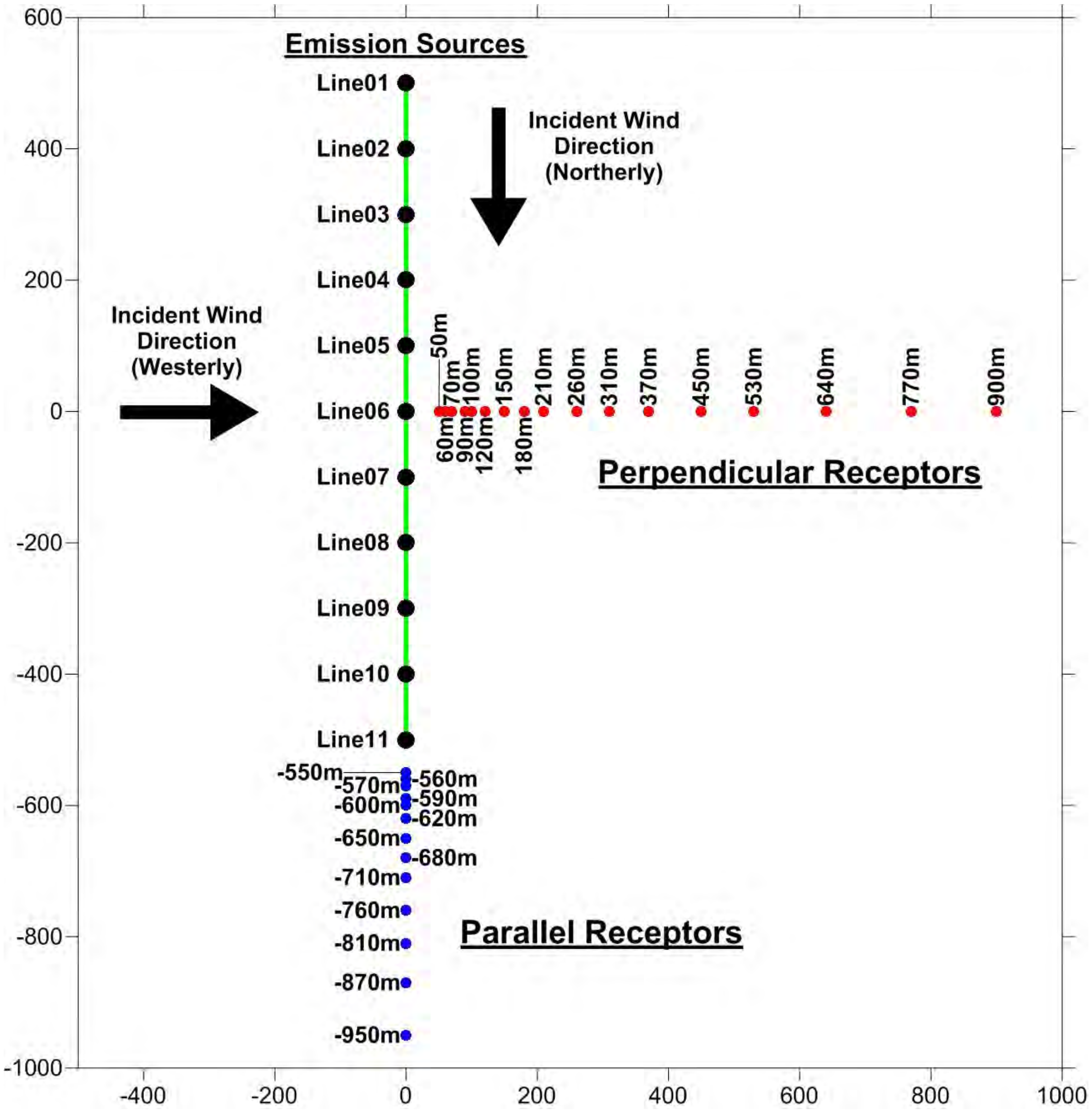
The emission source parameters are summarised in **Table 5-1** and a conceptual diagram of the sources and receptors is provided in **Figure 5-1**.

Table 5-1 Ausplume Volume Source Parameters

Source ID	Coordinates (m)			Horizontal Spread (m)	Height (m)	Vertical Spread (m)	Emission Rates (g/s)	
	X	Y	Z				PM_{10}	TSP
Line01	0	500	0	25	6	1.5	0.542 + WE	1.435 + WE
Line02	0	400	0	25	6	1.5	0.542 + WE	1.435 + WE
Line03	0	300	0	25	6	1.5	0.542 + WE	1.435 + WE
Line04	0	200	0	25	6	1.5	0.542 + WE	1.435 + WE
Line05	0	100	0	25	6	1.5	0.542 + WE	1.435 + WE
Line06	0	0	0	25	6	1.5	0.542 + WE	1.435 + WE
Line07	0	-100	0	25	6	1.5	0.542 + WE	1.435 + WE
Line08	0	-200	0	25	6	1.5	0.542 + WE	1.435 + WE
Line09	0	-300	0	25	6	1.5	0.542 + WE	1.435 + WE
Line10	0	-400	0	25	6	1.5	0.542 + WE	1.435 + WE
Line11	0	-500	0	25	6	1.5	0.542 + WE	1.435 + WE

Note: WE = Variable Wind Erosion emissions

Figure 5-1 Conceptual Diagram of Emission Sources and Receptors



5.2.1.1 Ausplume v6.0 – Model Configuration

The following configuration settings were provided to Ausplume v6.0 to conduct the dust dispersion modelling:

Simulation

- Meteorological Data File:
  - General Dispersion: TAPM-generated data for the King River Compressor Station;
  - Perpendicular Dispersion: As above with wind directions set to 270°True (i.e. westerly); and
  - Parallel Dispersion: As above with wind directions set to 0°True (i.e. northerly).
- Emission Rate Units: g/s;
- Concentration Units: μg/m^3;
- Conversion Factor: 1,000,000;
- Background Level = 0 μg/m^3;
- Output: Concentration;
- Dry Depletion Effects Enabled; and
- Terrain Effects: Ignore.

Source Information

- Emissions data: All Volume sources, as per **Section 4.1** and listed in **Table 5-1**; and
- No source grouping.

Receptors

- Discrete receptor locations: Linear distributions as per **Table 5-2**.

Table 5-2 Discrete Receptor Locations (Relative Coordinates)

Receptor Number	TAPM-Generated Met Data and Perpendicular Dispersion Relative Coordinates (m)		TAPM-Generated Met Data and Parallel Dispersion Relative Coordinates (m)		Receptor Height Above Ground
	X	Y	X	Y	
1	50	0	0	-550	2.0
2	60	0	0	-560	2.0
3	70	0	0	-570	2.0
4	90	0	0	-590	2.0
5	100	0	0	-600	2.0
6	120	0	0	-620	2.0
7	150	0	0	-650	2.0
8	180	0	0	-680	2.0
9	210	0	0	-710	2.0
10	260	0	0	-760	2.0
11	310	0	0	-810	2.0
12	370	0	0	-870	2.0
13	450	0	0	-950	2.0
14	530	0	0	-1,030	2.0
15	640	0	0	-1,140	2.0
16	770	0	0	-1,270	2.0
17	900	0	0	-1,400	2.0
18	1,100	0	0	-1,600	2.0
19	1,300	0	0	-1,800	2.0
20	1,600	0	0	-2,100	2.0
21	2,000	0	0	-2,500	2.0
22	2,500	0	0	-3,000	2.0
23	3,000	0	0	-3,500	2.0
24	4,000	0	0	-4,500	2.0
25	5,500	0	0	-6,000	2.0
26	8,000	0	0	-8,500	2.0
27	10,000	0	0	-10,500	2.0
28	12,500	0	0	-13,000	2.0
29	15,000	0	0	-15,500	2.0

Averaging Times

- Averaging periods:
  - PM_{10} GLC: 24-hours; and
  - TSP GLC: 24-hours.

Outputs

- Print every concentration/deposition (Text file output); and

Dispersion Curves

- Horizontal for sources <100 m = Sigma Theta;
- Vertical for sources <100 m = Pasquill Gifford;
- Horizontal for sources >100 m = Briggs Rural;
- Vertical for sources >100 m = Briggs Rural;
- Adjustment for Wind Direction Shear = None;
- Adjusted PG Curves for Roughness both Horizontally and Vertically; and
- Enhanced Plume Buoyancy both Horizontally and Vertically.

Plume Rise

- Gradual Plume Rise = On;
- Stack Tip Downwash = On;
- Disregard Temperature Gradients in Met File = Off;
- Partial Penetration of Elevated Plumes = Off;
- Entrainment Coefficients = Adiabatic (0.6) and Stable (0.6); and
- Temperature Gradients as per **Table 5-3** below.

Table 5-3 Temperature Gradients

Wind Speed Category	Stability Category					
	A	B	C	D	E	F
1	0.000	0.000	0.000	0.000	0.020	0.035
2	0.000	0.000	0.000	0.000	0.020	0.035
3	0.000	0.000	0.000	0.000	0.020	0.035
4	0.000	0.000	0.000	0.000	0.020	0.035
5	0.000	0.000	0.000	0.000	0.020	0.035
6	0.000	0.000	0.000	0.000	0.020	0.035

Wind Speed Categories

Table 5-4 Upper Bounds for Wind Speed Categories

1	2	3	4	5	6
1.54	**3.09**	**5.14**	**8.23**	**10.80**	**>10.80**

Wind Profile Exponents

- Wind Profile Exponent Scheme = Irwin Rural; and
- Disregard Exponents in the Meteorological File = Off.

Land Use

- Surface Roughness = 0.1 m (Flat Rural).

Miscellaneous Parameters

- Include Building Wake Effects = No;
- Default Decay Coefficient = 0.0;
- Anemometer Height = 10 m;
- Sigma Theta Averaging Period = 60 minutes;
- Met. Site Roughness Height = 0.1 m;
- Smooth Stability Class Changes = Off;
- Convective Plume Rise = Off;
- Stability Class Adjustments = None; and
- Building Wake Algorithm = PRIME.

5.2.2 TAPM v4.0.5 – Meteorology and Operational Phase Dispersion

TAPM v4.0.5 generates site-specific meteorological data by referencing several databases provided by the CSIRO: terrain elevation; vegetation/land use and soil type; sea-surface and deep soil temperatures; and synoptic-scale meteorological analyses. TAPM is able to predict meteorological events at a mesoscale (20 km – 200 km) and a local scale (approximately 200 m) by solving the fundamental fluid dynamics equations (Hurley, October 2008).

The following configuration settings were provided to TAPM v4.0.5 to generate the site specific meteorological dataset:

- Model Grid Centre Coordinates: clat = 14° 36.5’ South and clon = 132° 35’ East
- Local Coordinates: cx = 239670mE and cy = 8383610mN
- A 31 point x 31 point, 4-layer nested grid domain with the following grid spacing respectively: 30 km; 10 km; 3 km; and 1 km.
- 25 vertical grid levels with 20 levels stored in the output file.
- Date range: 29 December 2007 to 31 December 2008 allowing for 3 days of ‘spin-up’ simulation time for the model to adequately define time-dependent boundary conditions.
- Default sea-surface and deep soil temperature data.

- Default Australian terrain height database as supplied by Geoscience Australia on a 9-second (approximately 300 m) grid spacing.
- Meteorological observational data from the Tindal RAAF Base AWS and the Gove Airport AWS for the same period (BoM, 2013a and 2013b) with a 50 km radius of influence and 0.75 data quality indicator.

The additional pollution dispersion configuration settings provided to TAPM v4.0.5 are listed below:

- Both pollutant (with chemistry and deposition) and tracer runs were defined:
    - Chemistry runs: APM / FPM; NO_X / NO_2; SO_2 and O_3.
    - Tracer runs: CO.
- Pollutant sub-grid: 224670mE – 254670mE; 8368610mN – 8398610mN; 500 m x 500 m spacing (i.e. 61 point x 61 point grid).
- Prognostic pollutant concentration variance equation = On.
- 1 model level to mix surface emissions.
- pH of liquid water = 4.5.
- Refer to **Section 4.2** for details of emission sources.
- Eulerian calculations only (no Lagrangian calculations enabled).
- All remaining options are set to their default values.

5.3 Meteorological Model Validation

A comparison of the resulting meteorological data from the model was made against the long-term averages of the observations made at the Tindal RAAF Base AWS in order to validate the model.

5.3.1 Wind Speed and Direction

The wind roses for the full year and quarterly datasets for the TAPM-generated (2008) and the long-term Tindal RAAF Base AWS (2002-2013) measurements are compared in **Figure 5-2** and the wind speed frequency distribution histograms are compared in **Figure 5-3**. The following observations have been made:

- Overall, the TAPM-generated dataset shows a good correlation with observed seasonal wind trends;
- TAPM underestimates the proportion of winds blowing from the southeast direction for the second and third quarters;
- TAPM overestimates the proportion of winds blowing from the south-southeast direction for the second and third quarters;
- TAPM under predicts the frequency of ‘calms’ by 3.7%; and
- TAPM over predicts the frequency of 2 – 3 m/s wind speeds.

The potential result of the differences between the TAPM-generated dataset and the long-term observations made at the Tindal RAAF Base AWS is an overestimation of ground-level concentrations of pollutants north of the sources, however; the discrepancies between the datasets are small and are unlikely to significantly alter the conclusions of the modelling.

Figure 5-2 Full Year and Quarterly Wind Roses for TAPM-Generated (2008) and Tindal RAAF Base AWS (2002-2013)

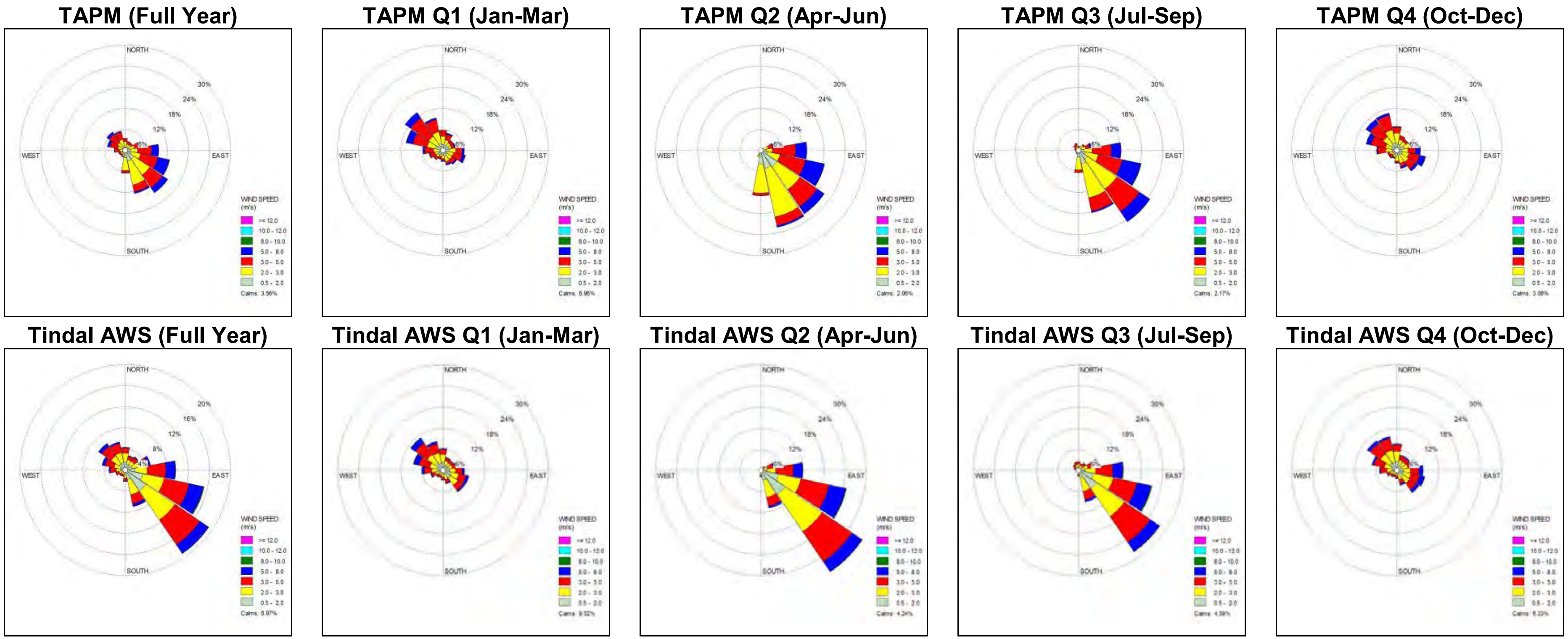
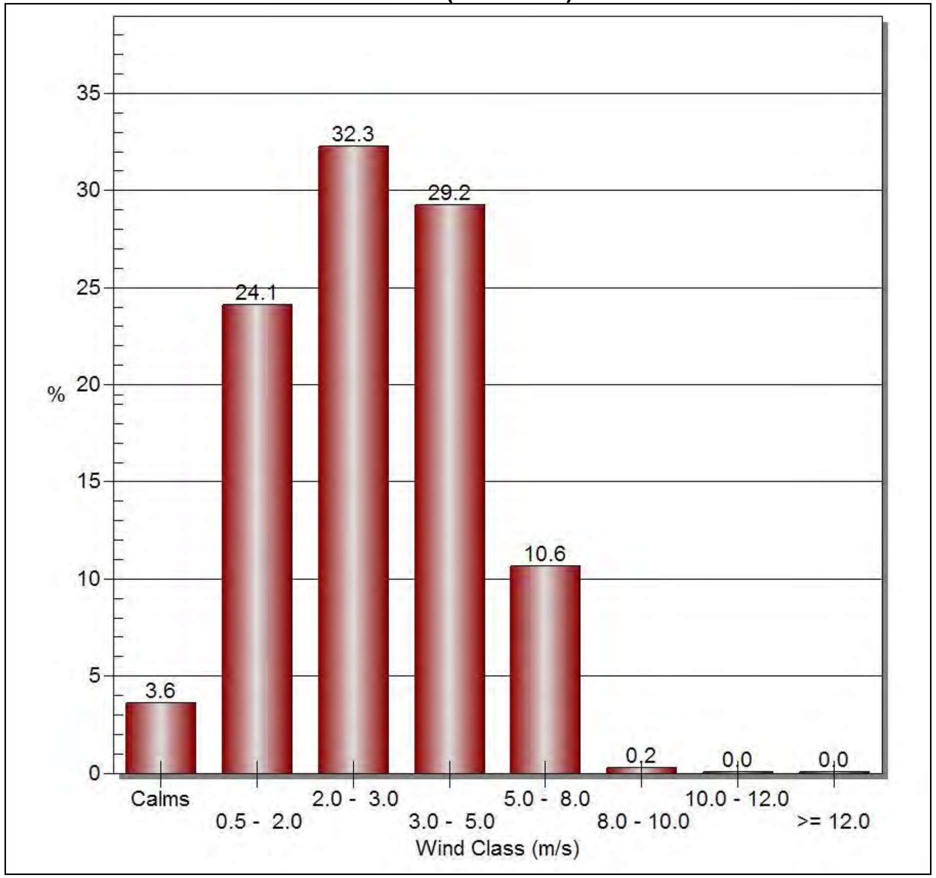
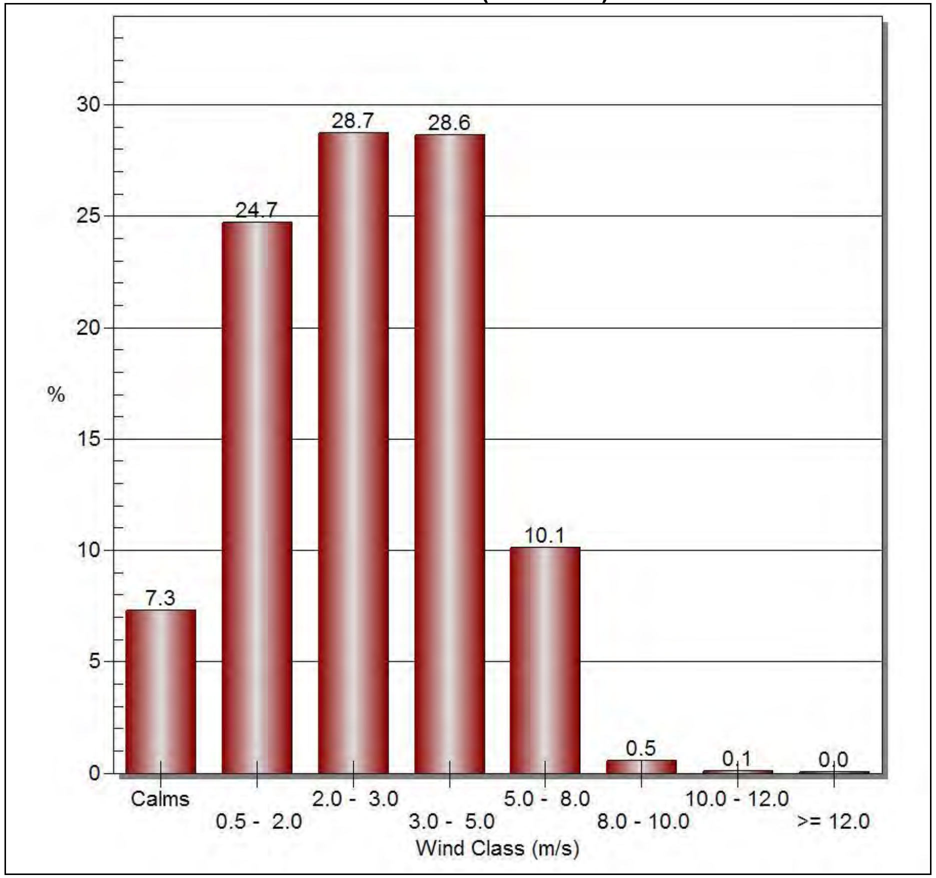


Figure 5-3 Wind Speed Frequency Distribution Histograms for TAPM-Generated (2008) and Tindal RAAF Base AWS (2002-2013)

TAPM (Full Year)



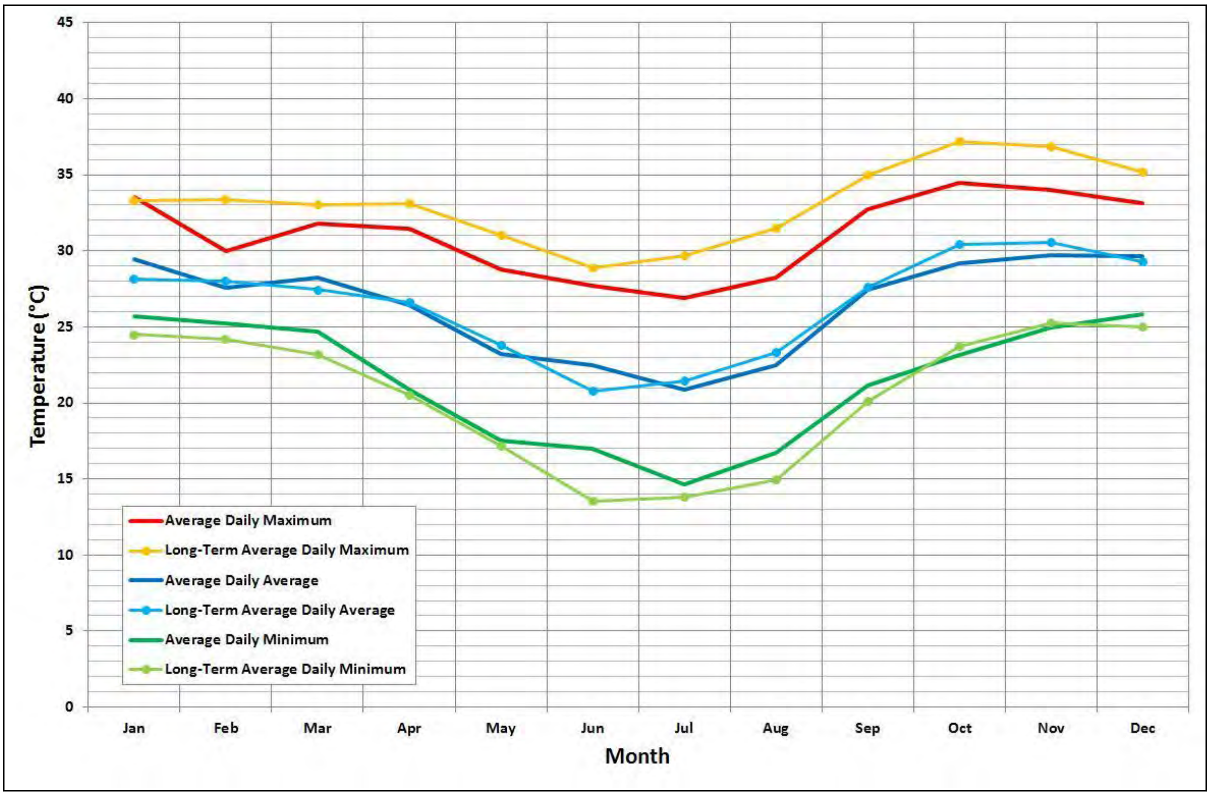
Tindal AWS (Full Year)



5.3.2 Temperature

The modelled average daily maximum, average daily average and average daily minimum temperatures per month is presented in **Figure 5-4** versus the long-term average measurements reported at the Tindal RAAF Base AWS. It is apparent that TAPM v4.0.5 under-predicts the average daily maximum temperature by up to 3°C. Both the average daily average and average daily minimum temperatures are reasonably well predicted. This results in TAPM v4.0.5 temperature data being less extreme in their variation in comparison to what was reported at the Tindal RAAF Base AWS between 2002 and 2013.

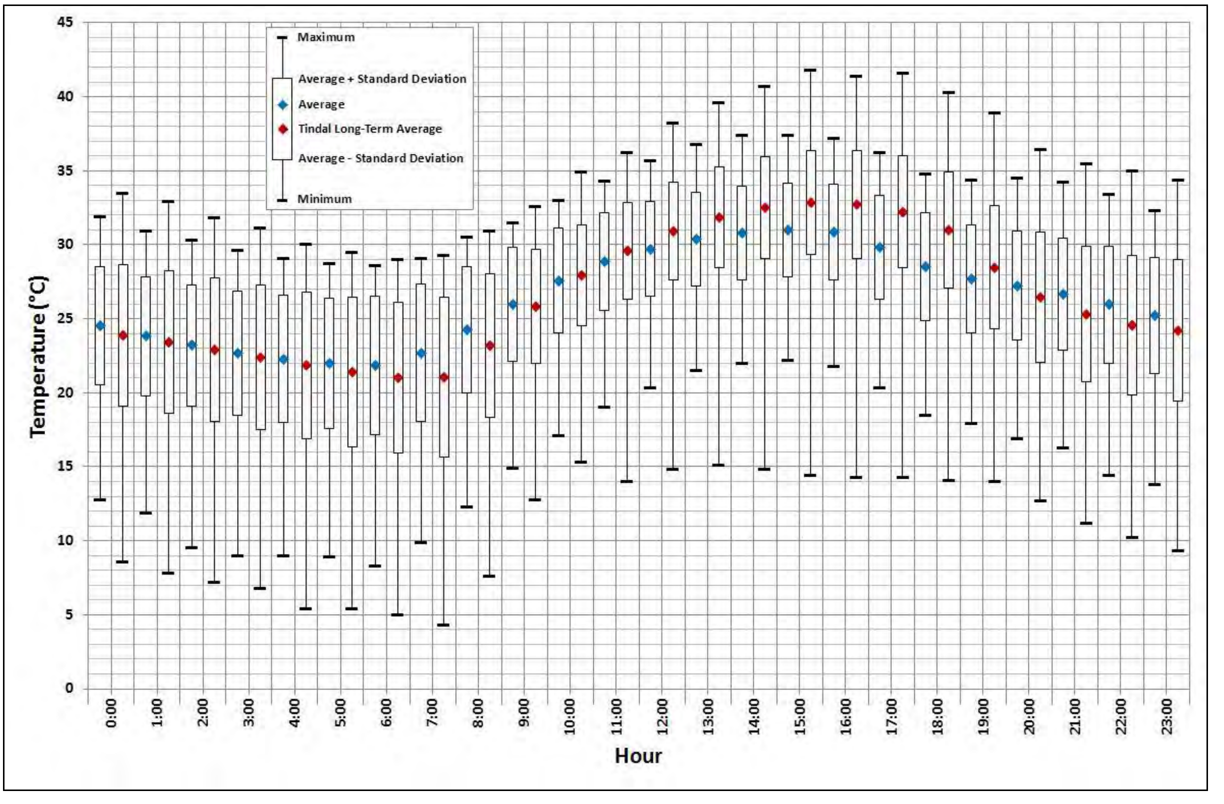
Figure 5-4 Annual Temperature Profile – Generated Data vs. Long-Term Measurements



A comparison of the daily temperature profiles is presented in **Figure 5-5**. This further shows that the TAPM-generated dataset is less extreme in variation than the Tindal RAAF Base AWS dataset. Both maximum and minimum temperatures are 1-2°C greater and less respectively compared to the TAPM-generated data.

It is important to note however, that the variations between the maximum and minimum temperatures are minimal in the context of pollutant dispersion modelling and are unlikely to significantly affect the modelling results.

Figure 5-5 Daily Temperature Profile – Generated Data vs. Long-Term Measurements



5.3.3 Discussion

The TAPM-generated dataset shows a reduced frequency of more 'extreme' values for both wind speeds and temperature. TAPM has a known tendency to predict less extreme meteorological conditions than what is observed at local AWSs. In general, this can err on the side of conservatism, as extreme wind speeds have a tendency to increase dispersion and lower ground-level concentrations of pollutants.

The differences between the TAPM-generated and observed datasets are small in comparison and are unlikely to significantly alter the conclusions of the dispersion modelling. Hence, the TAPM-generated dataset is considered acceptable for its intended purpose.

6 MODELLING RESULTS

6.1 Construction Phase

This section presents the results of the Ausplume v6.0 dispersion modelling for the construction phase of the project.

6.1.1 Ambient PM_{10} Concentrations

Based on the results of the simulation, with increasing distance downwind from the construction activities, there is increased dispersion of particulate matter resulting in decreased ground-level concentrations and decreased numbers of exceedences of the assessment criterion. Therefore the construction impact footprint is defined as the distance downwind from the alignment in which the activities comply with the assessment criterion. The assessment criterion allows a maximum of 5 exceedences of the limit per year to remain compliant with the AAQ NEPM goals.

The perpendicular receptor results are presented in **Figure 6-1**. The plot shows a measure of the number of exceedences of the assessment criterion versus the distance downwind from the emission sources. The purpose of the plot is to identify the distance downwind where the number of exceedences falls below the compliance threshold, defining the impact footprint boundary. Both the TAPM-Generated meteorological dataset and the perpendicular wind dataset are shown. It is apparent that the perpendicular wind dataset produces a higher number of exceedences of the assessment criterion than the TAPM-generated meteorological dataset and therefore produces a larger impact footprint. This is to be expected as the perpendicular winds represent the conditions for maximum particulate transport, hence the worst possible case scenario.

The probable buffer distances perpendicular downwind from the alignment beyond which compliance with the AAQ NEPM goals are achieved are as follows:

- Realistic Maximum Footprint = 240 m; and
- Worst Case Maximum Footprint = 370 m.

The parallel receptor results are presented in **Figure 6-2**. Similar trends are observed to the perpendicular winds; however, the difference between the realistic maximum and worst case maximum footprints is more pronounced. Note that the realistic maximum footprint for the parallel winds is less than the realistic maximum footprint for the perpendicular winds.

The probable buffer distances parallel downwind from the alignment beyond which compliance with the AAQ NEPM goals are achieved are as follows:

- Realistic Maximum Footprint = 170 m; and
- Worst Case Maximum Footprint = 620 m.

A diagram of the potential realistic and maximum footprints for ambient PM_{10} GLCs about the pipeline alignment is presented in **Appendix B**.

Figure 6-1 Number of Exceedences versus Distance Downwind for Perpendicular Receptors

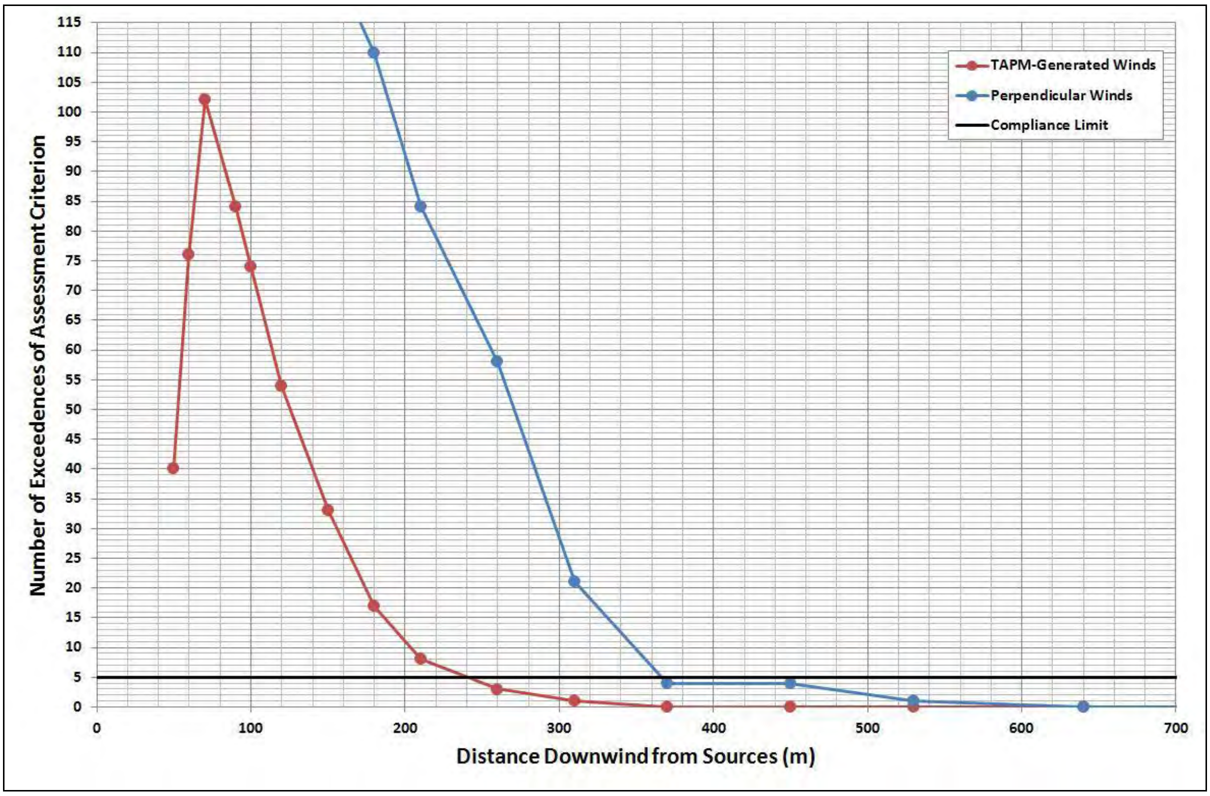
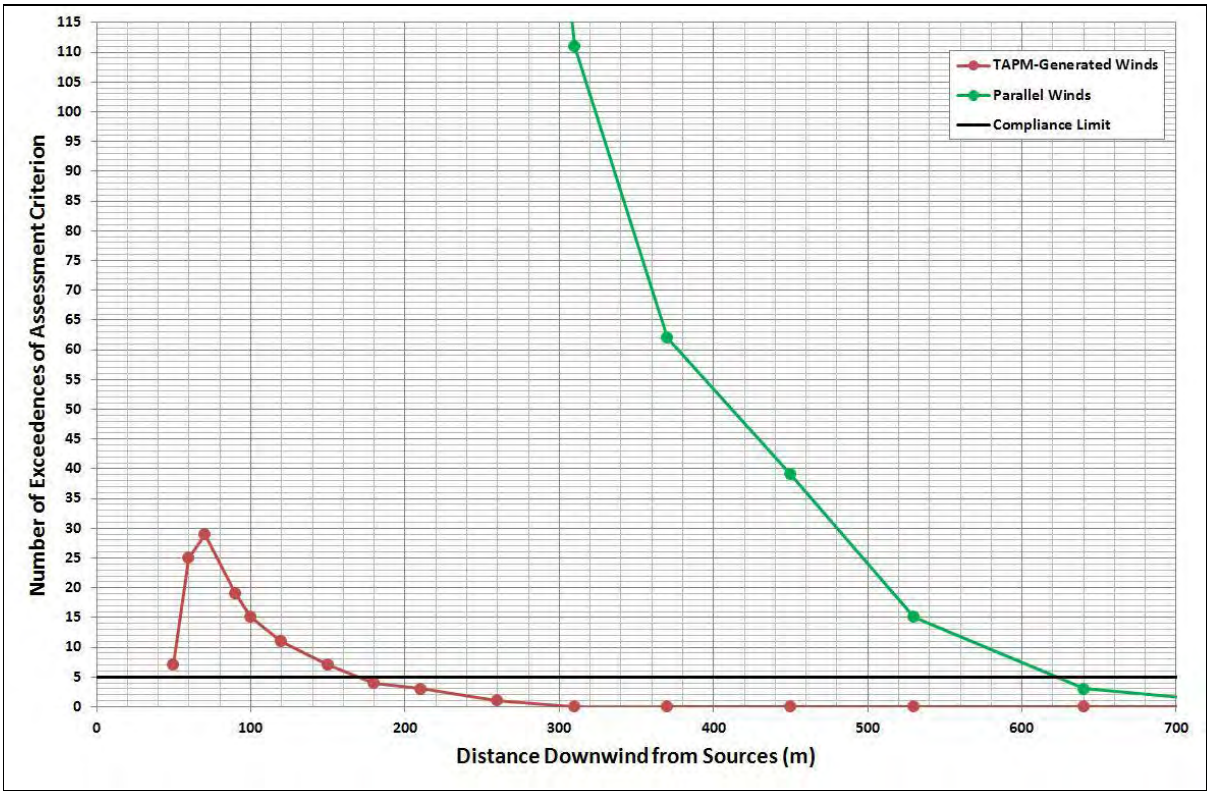


Figure 6-2 Number of Exceedences versus Distance Downwind for Parallel Receptors



There is one sensitive receptor, Wallaby Beach, which falls within the area of the predicted impact footprints. This receptor has the potential to be impacted by ambient GLCs of PM_{10}.

There is a low probability that construction activities will coincide with meteorological conditions that facilitate production of high GLCs of PM_{10}. This is due to the dust-generating activities being localised, short-term and transient in nature. To manage the potential impact, it is recommended that a Dust Management Plan for the construction phase is developed.

The Dust Management Plan should detail the methods to minimise dust generation and/or manage the dust-generating activities to minimise the impacts. Some examples of dust management and mitigation measures are provided in **Section 6.1.4**.

6.1.2 Vegetation Impacts

Qualitatively, it is likely that the risk presented to vegetation health from the increase in deposition of particulate matter from construction activities is low, due to the following reasons:

- Construction activities are not long-term sources of emissions reducing the total quantity of dust generated;
- The proposed excavation activities are significantly smaller in scale in comparison with activities commonly associated with vegetation impacts from deposited dust (e.g. open cut mines);

- The physical locations of the emission sources change as construction activities progress along the alignment, moving away from previously affected areas;
- The construction activities are not scheduled to occur at night, during times when meteorological conditions are often at their worst for pollutant dispersion purposes; and
- The impact footprint is likely to be on a similar order to the PM_{10} ambient concentration impacts which are very small distance scales in comparison to the project.

6.1.3 Construction Traffic Impacts

The following qualitative assessment of particulate matter from vehicular traffic associated with the construction phase of the project focusses on the locations identified in **Section 4.1.4**.

An important factor in the uncertainty of the assessment is the lack of background particulate matter monitoring in the Arnhem Land region, refer to **Section 2.3**. Therefore, there is no baseline data to be able to make a comparison against during construction.

- Stuart Highway through Katherine.

The highest recorded traffic flow in 2011 was 2,282 vehicles per day. With an anticipated increase of 65 vehicles per day associated with the pipeline construction, the increase in particulate matter impacts is likely to be minimal.

- Central Arnhem Road passing Barunga.

The highest recorded traffic flow in 2011 was 157 vehicles per day. With an anticipated increase of 281 vehicles per day associated with the pipeline construction, it is expected that emissions of particulate matter will increase significantly. However, as particulate emissions from moving vehicles are short-duration events from the point of view of a receptor and the duration of when this region will be affected is short-term, it is unlikely that adverse impacts will be encountered.

- Melville Bay Road through Nhulunbuy.

As there is no definitive record of traffic volume in this region, the proportion of increase in particulate emissions cannot be categorically stated. However, as the estimated increase in vehicle traffic is significantly less than the anticipated amount for the Barunga region (145 vehicles per day) it is unlikely adverse impacts will occur, due to similar reasons as above.

6.1.4 Dust Management / Mitigation Measures

The recommended Dust Management Plan to be developed should target aspects of the project that are likely to produce the greatest quantity of dust to provide the most effective management and mitigation measures.

Some examples of dust management and/or mitigation measures that can be implemented in the Dust Management Plan are listed below:

- Monitoring of current and projected weather patterns during the construction phase to predict the occurrence of adverse conditions conducive to high dust generation;

- Scheduling of construction activities known to generate high levels of dust to avoid adverse weather conditions;
- Minimisation of land clearing, when practicable, to reduce the area of land susceptible to wind erosion;
- Watering of unsealed roads, potentially with a crusting agent, to reduce wheel-generated dust from vehicle traffic;
- Watering of all non-active stockpiles or covering with an impermeable layer to reduce wind erosion emissions;
- Watering of excavated material prior to major handling to ensure high moisture content and reduce available particulate matter;
- Minimisation of haul truck overburden dump drop heights (e.g. use of chutes or stockpile 'benching'); and
- Minimisation of heavy vehicle traffic (e.g. graders and haul trucks), particularly traffic moving overburden, to reduce disturbance of low moisture material.

6.2 Operational Phase

This section presents the results of the TAPM v4.0.5 dispersion modelling for the operational phase of the project.

6.2.1 Oxides of Nitrogen (NO_X as NO_2)

The 1-hour averaged 99.9th percentile NO_2 ground-level concentration (GLC) trends, centred about the King River Compressor Station source, are presented in **Figure 6-3**. The maximum GLC across the entire modelling domain is 1 ppb, which is well below the assessment criterion of 120 ppb.

The annual average NO_2 GLC trends across the modelling domain are presented in **Figure 6-4**. Similarly, the maximum concentration over the modelling domain (0.19 ppb) is well below the assessment criterion of 30 ppb.

Hence the human health impact from NO_2 during the operation of the King River Compressor Station is minimal.

Figure 6-3 1-hour Averaged 99.9th Percentile NO_2 Ground Level Concentrations (ppb)

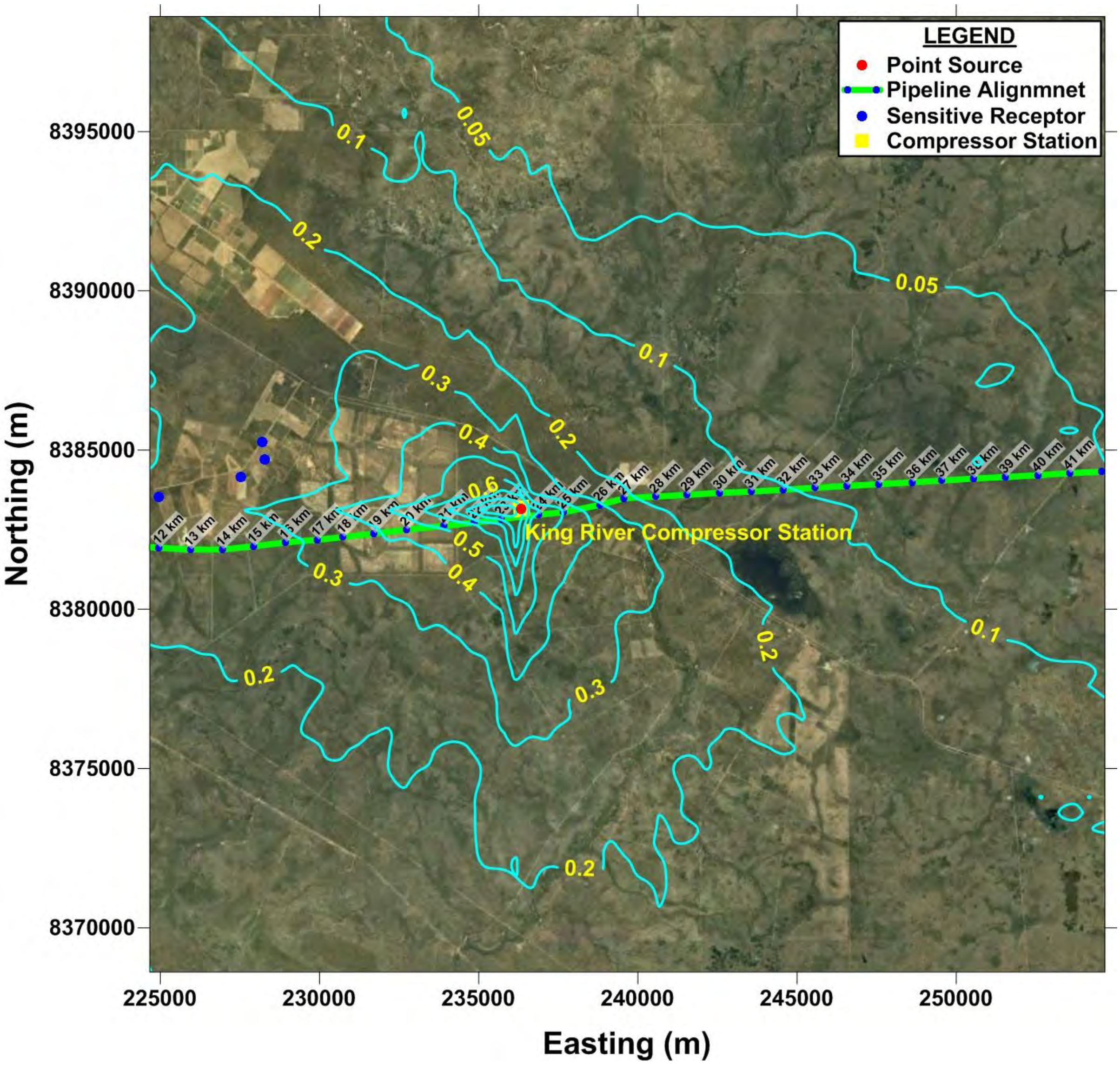
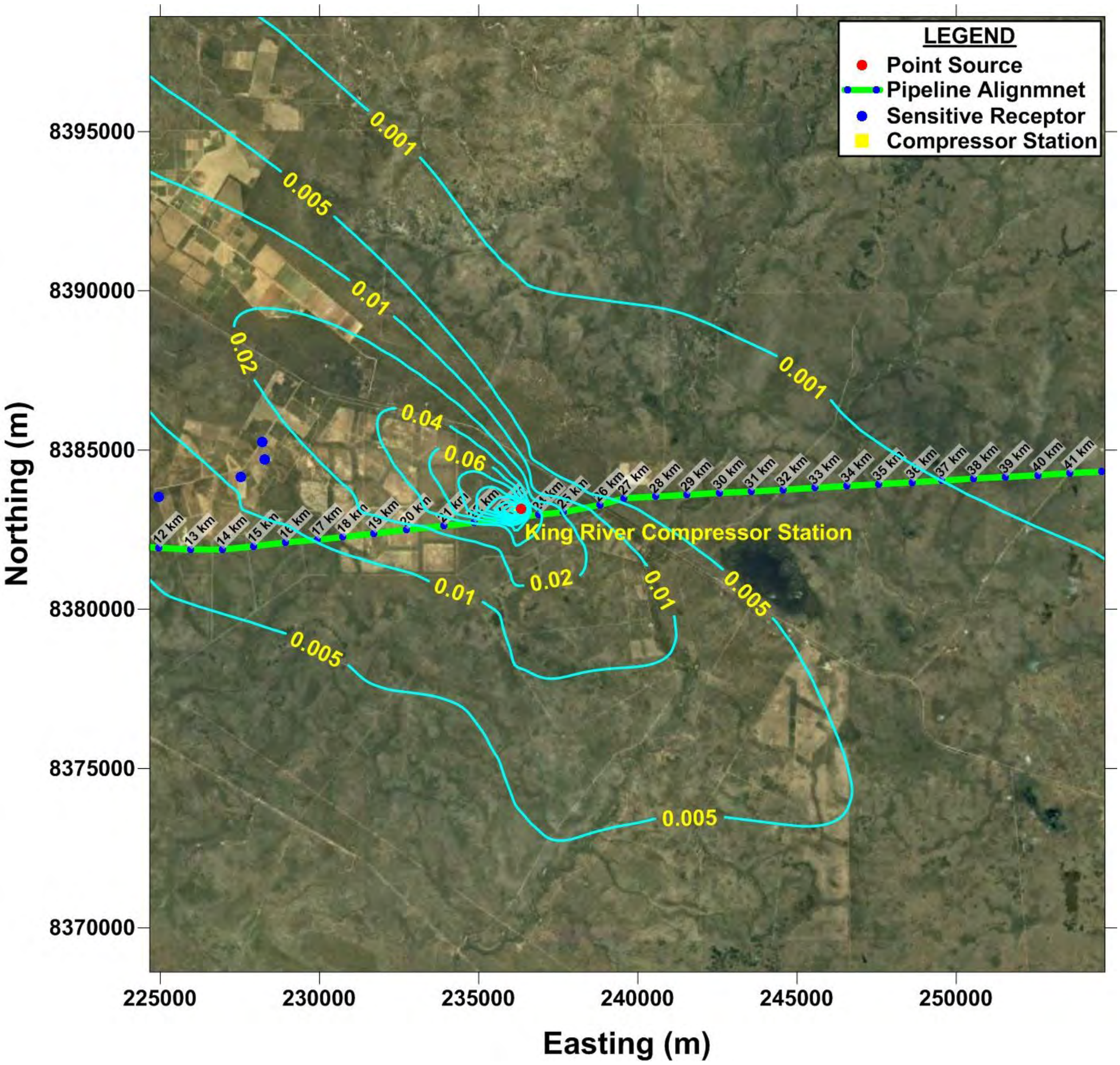


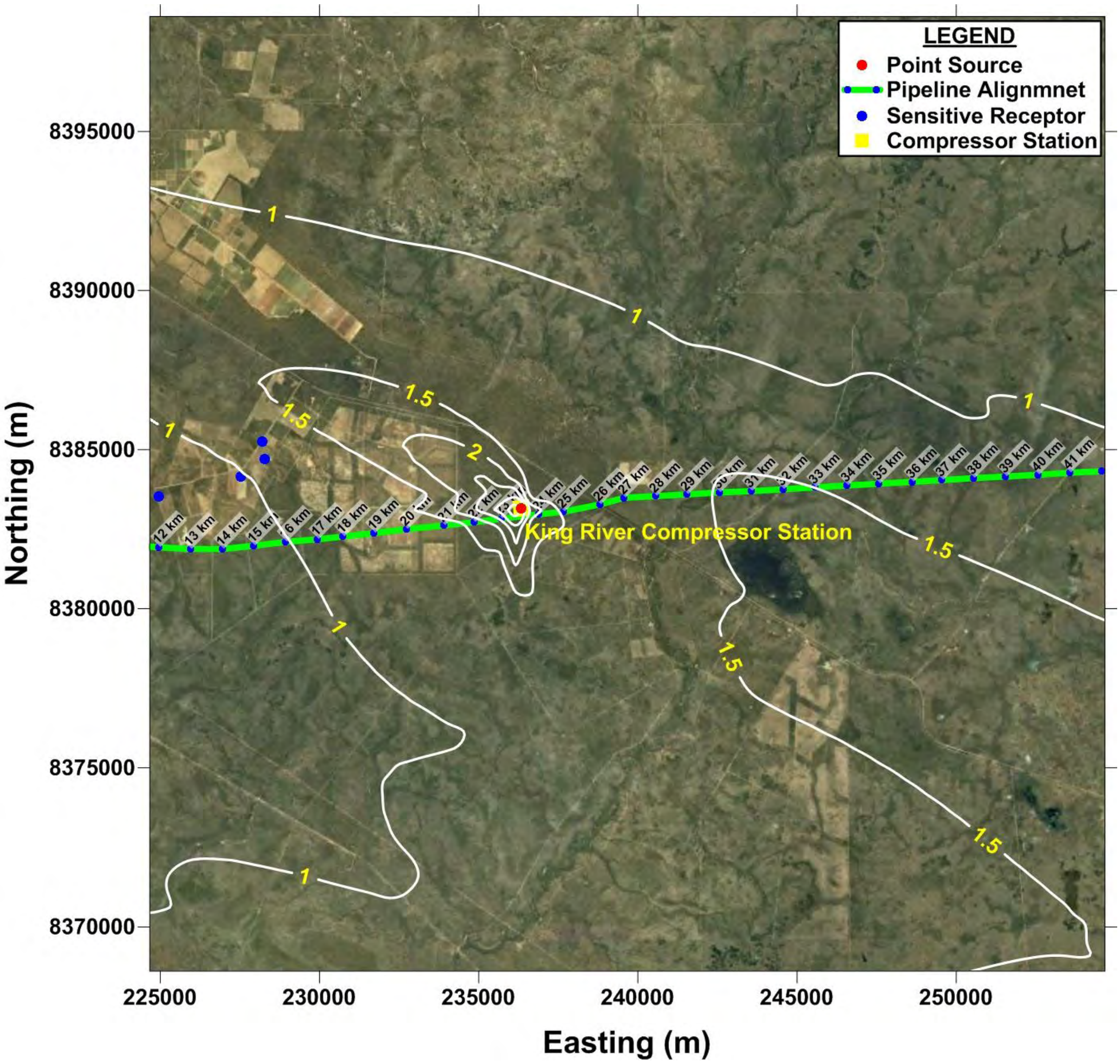
Figure 6-4 Annual Averaged NO_2 Ground Level Concentrations (ppb)



6.2.2 Carbon Monoxide (CO)

The 8-hour averaged maximum CO GLC trends, centred about the King River Compressor Station are presented in **Figure 6-5**. The maximum GLC across the modelling domain is 3.82 µg/m^3. In comparison to the CO assessment criterion of 11,244 µg/m^3, the maximum impact is four orders of magnitude lower. Hence the impact from CO from the operation of the King River Compressor Station is minimal.

Figure 6-5 8-hour Averaged Maximum CO Ground Level Concentrations (µg/m3)



6.2.3 Photochemical Smog (as Ozone, O_3)

The 99.9th percentile 1-hour and maximum 4-hour averaged O_3 GLC trends across the modelling domain are presented in **Figure 6-6** and **Figure 6-7** respectively. The maximum averaged GLCs across the domain are 18.93 ppb and 19.00 ppb respectively. These are lower than the background concentration of 20 ppb supplied to TAPM v4.0.5. This local minimum about the emission source occurs due to the balanced titration reaction between several pollutant constituents including: NO_X; VOCs; and O_3. The background ozone near the compressor station is being consumed in the reaction to convert NO to NO_2 in the presence of VOCs. As there is a higher concentration of NO in the immediate vicinity of the source, more O_3 is being consumed and therefore produces a local minimum concentration.

Both maximum GLCs are below their respective assessment criteria (1-hour averaged: 100 ppb and 4-hour averaged: 80 ppb). Hence, the impact from O_3 from the operation of the King River Compressor Station is minimal.

Figure 6-6 1-hour 99.9th Percentile Averaged O_3 Ground Level Concentrations (ppb)

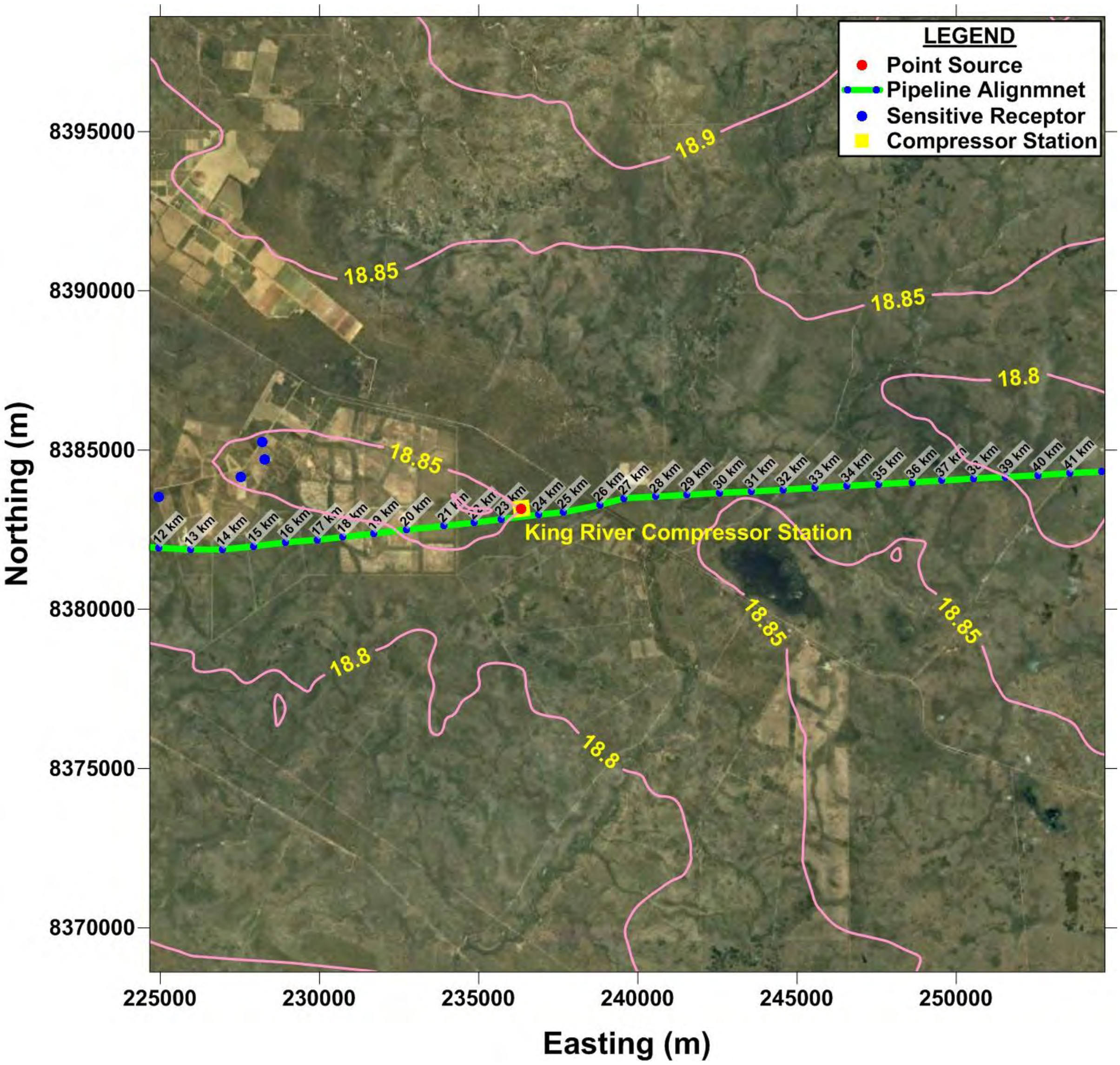
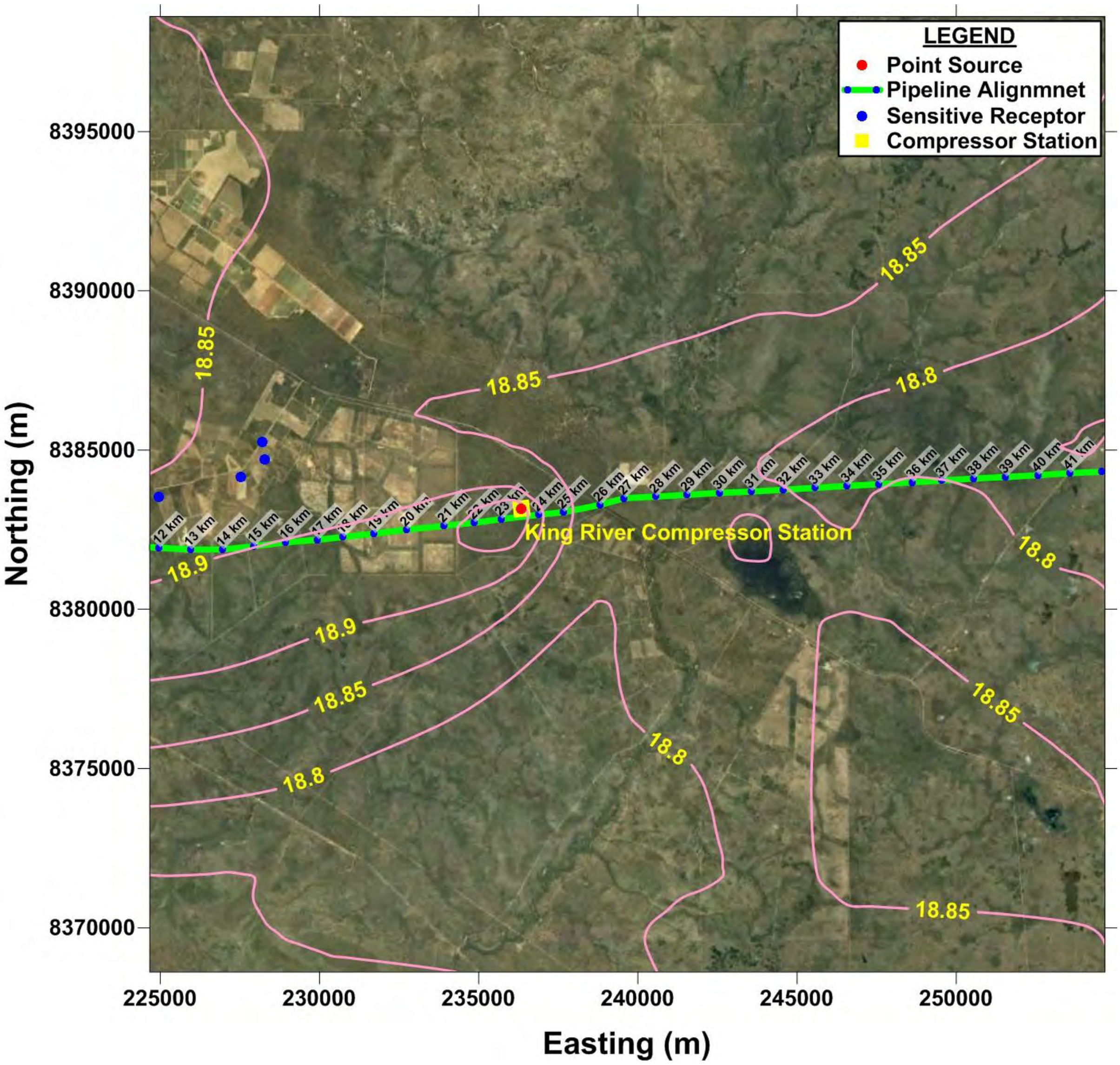


Figure 6-7 4-hour Maximum Averaged O_3 Ground Level Concentrations (ppb)



7 CONCLUSIONS AND RECOMMENDATIONS

This section presents the conclusions and recommendations based on the modelling results.

7.1 Construction Phase

The ambient PM_{10} ground-level concentration footprint from the construction of the Katherine to Gove Gas Pipeline is predicted to have the potential to impact the Wallaby Beach sensitive receptor. The deposition of TSP also has the potential to impact local vegetation.

For PM_{10} GLCs, the impacts are likely to be localised, short-term and transient and hence the risk presented to human health and vegetation by these impacts is low.

To manage the potential impact, it is recommended that a Dust Management Plan for the construction phase is developed. The Dust Management Plan should detail the methods to minimise dust generation and/or manage the dust-generating activities to minimise the impacts. Examples of management and mitigation measure that could be implemented are provided in **Section 6.1.4**.

7.1.1 Construction Traffic Impacts

In relation to the impacts from the increased level of ambient particulate matter resulting from the increased vehicular traffic associated with the construction, it is likely that ambient concentrations will increase significantly near the Barunga region. However, as particulate emissions from moving vehicles are short-duration events from the point of view of a receptor and the duration of when regions will be affected is short-term, it is unlikely that adverse impacts will be encountered. Numeric analysis cannot be performed at this stage due to a lack of ambient particulate monitoring in the Arnhem Land region.

7.2 Operational Phase

The predicted impacts from the POPCs emitted by the proposed King River Compressor Station during operation of the Katherine to Gove Gas Pipeline project are all well below their relevant assessment criteria. Taking into account, both the low impacts and the large distances to the nearest human health receptors, the operation of the pipeline is considered to present minimal risk to human health.

It is recommended that the turbine running the compressor station is specified and operated such that POPC emissions are minimised. This will ensure impacts and therefore human health risks are also minimised in turn.

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Appendix A – Location of Pipeline and Sensitive Receptors

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Appendix B – Potential 24-Hour Averaged PM_{10} GLC Impact Footprint during Construction Phase

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Appendix C – Particulate Emissions Calculation Methods

Bulldozer Operation

The emission factors used for bulldozers operating on excavated material was adopted from the NPI EETM for Mining v3.1 (NPI, January 2012) and is presented below:

$$EF_{TSP} = 2.6 \times \frac{s^{1.2}}{M^{1.3}} \qquad EF_{PM_{10}} = 0.34 \times \frac{s^{1.5}}{M^{1.4}}$$

Where:

EF_{TSP} = Uncontrolled emission factor for TSP, in kg/t;
s = Silt content, in %;
M = Moisture content, in %; and
EF_{PM10} = Uncontrolled emission factor for PM_{10}, in kg/t.

Assumptions

- Silt content = 7%; and
- Moisture content = 2%.

Grader Operation

The emission factors used for graders levelling cleared land was adopted from the NPI EETM for Mining v3.1 (NPI, January 2012) and is presented below:

$$EF_{TSP} = 0.0034 \times S^{2.5} \qquad EF_{PM_{10}} = 0.0034 \times S^{2.0}$$

Where:

EF_{TSP} = Uncontrolled emission factor for TSP, in kg/VKT;
EF_{PM10} = Uncontrolled emission factor for PM_{10}, in kg/VKT; and
S = Mean vehicle speed, in km/h.

Assumptions

- Grader vehicle speed = 5 km/h; and
- Grader VKT = 6 km/day (Corridor Width (30 m) x Corridor Length (1 km) / Blade length (5 m))

Haul Truck Dumping

The emission factors used for haul trucks dumping excavated material was adopted from the NPI EETM for Mining v3.1 (NPI, January 2012) and is presented below:

$$EF_{TSP} = 0.012 \qquad EF_{PM_{10}} = EF_{TSP} \times {}^{PM_{10}}/_{TSP}$$

Where:

EF_{TSP} = Uncontrolled emission factor for TSP, in kg/t;
EF_{PM10} = Uncontrolled emission factor for PM_{10}, in kg/t and
PM_{10}/TSP = Ratio of PM_{10} to TSP.

Assumptions

- The ratio of PM_{10} to TSP is 0.35. Values obtained from **Table 4-2**.

Trencher Operation (Bucket and Wheel)

The emission factors used for operation of a bucket and wheel trencher for excavation was adopted from the miscellaneous transfer equation in from the NPI EETM for Mining v3.1 (NPI, January 2012) and is presented below:

$$EF_{TSP} = 0.74 \times 0.0016 \times \frac{(U/2.2)^{1.3}}{(M/2)^{1.4}} \qquad EF_{PM_{10}} = 0.35 \times 0.0016 \times \frac{(U/2.2)^{1.3}}{(M/2)^{1.4}}$$

Where:

EF_{TSP} = Uncontrolled emission factor for TSP, in kg/t;
EF_{PM10} = Uncontrolled emission factor for PM_{10}, in kg/t;
U = Mean wind speed, in m/s; and
M = Moisture content, in %.

Assumptions

- Mean wind speed = 6 m/s (Obtained from BoM website for Gove Airport over 2012).

Excavator Operation

The emission factors used for an excavator operating on overburden was adopted from the NPI EETM for Mining v3.1 (NPI, January 2012) and is presented below:

$$EF_{TSP} = 0.025 \qquad EF_{PM_{10}} = 0.012$$

Where:

EF_{TSP} = Uncontrolled emission factor for TSP, in kg/t; and
EF_{PM10} = Uncontrolled emission factor for PM_{10}, in kg/t.

Padding Machine Operation

The emission factors used for operation of the padding machine was adopted from the miscellaneous transfer equation in the NPI EETM for Mining v3.1 (NPI, January 2012), as per the Excavator Operation.

Wheel Generated Dust

The emission factors used to determine the wheel-generated dust from light and heavy vehicles were adopted from the NPI EETM for Mining v3.1 (NPI, January 2012) and are presented below:

Light Vehicles:

$$EF_{TSP} = 1.69 \times \frac{(s/12) \times (S/48)^{0.3}}{(M/0.5)^{0.3}} - 0.0013 \qquad EF_{PM_{10}} = 0.51 \times \frac{(s/12) \times (S/48)^{0.5}}{(M/0.5)^{0.2}} - 0.0013$$

Heavy Vehicles:

$$EF_{TSP} = \frac{0.4536}{1.6093} \times 4.9 \times \left(\frac{s}{12}\right)^{0.7} \times \left(\frac{W \times 1.1023}{3}\right)^{0.45} \qquad EF_{PM_{10}} = \frac{0.4536}{1.6093} \times 1.5 \times \left(\frac{s}{12}\right)^{0.9} \times \left(\frac{W \times 1.1023}{3}\right)^{0.45}$$

Where:

EF_{TSP}	=	Uncontrolled emission factor for TSP, in kg/VKT;
EF_{PM10}	=	Uncontrolled emission factor for PM_{10}, in kg/VKT;
s	=	Silt content, in %;
S	=	Mean light vehicle speed, in km/h;
M	=	Moisture content, in %; and
W	=	Heavy vehicle gross mass, in t.

Assumptions

- Silt content = 7%;
- Mean light vehicle speed = 50 km/h;
- Moisture content = 2%;
- Heavy vehicle gross mass: Haul truck (loaded) = 46 t; and Semi-trailer (loaded) = 46 t;
- Light Vehicle VKT = 7 km/day; and
- Heavy Vehicle VKT: Haul truck = 10 km/day; and Semi-trailer = 10 km/day.

Wind Erosion

Wind erosion was estimated using the refinement of the emission estimation equations proposed in *Improvement of NPI Fugitive Particulate Matter Emission Estimation Techniques* (SKM, 2005). The equation is listed below:

$$PM_{10}(g/m^2/s) = \begin{cases} k\left[WS^3 \times \left(1 - \dfrac{WS_0^{\ 2}}{WS^2}\right)\right] & if\ WS > WS_0 \\ 0 & if\ WS < WS_0 \end{cases}$$

Where:

$PM_{10}(g/m^2/s)$	=	Uncontrolled emission rate for PM_{10}, in $g/m^2/s$;
k	=	Constant (2.5×10^{-6});
WS	=	Wind speed, in m/s; and
WS_0	=	Wind speed threshold (6 m/s).

Assumptions

- Wind speeds taken from TAPM-generated hourly meteorological dataset; and
- Stockpile area = 4,000 m^2.