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LVAMN Inc.

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Executive Summary

Overview

Ecotech operated and maintained the Jeeralang Hill and Rosedale South rural air monitoring stations on behalf of the Latrobe Valley Air Monitoring Network Incorporated (LVAMN) during 2015. Ecotech conducted Quality Assurance checks on the monitoring data in accordance with NATA procedures, and provided monthly monitoring data and reports to Jacobs and LVAMN, setting out details such as equipment and monitoring specifications and data capture rates.

The purpose of this report is to provide an independent review of Ecotech's LVAMN 2015 air quality monitoring data acquired from the Jeeralang Hill and Rosedale South stations, with a focus on data interpretation.

Sulfur Dioxide

In 2015, the *State Environment Protection Policy (Ambient Air Quality)* ('SEPP(AAQ)') objectives and goals for hourly average sulfur dioxide (SO_2) were met for 99.98% of the time at Jeeralang Hill and for all hours at Rosedale South. The 24-hour objectives were met throughout the year at both stations.

At Jeeralang Hill air quality monitoring station there were two exceedences of the *SEPP(AAQ)* objective for hourly average SO_2 (200 ppb), on the same day, which means there were no exceedences of the goal that allows for one day of exceedences per year. The four highest hourly average SO_2 concentrations at Jeeralang Hill occurred during the early morning hours on four days: 4/12/15 5:00-7:00 (338 ppb and 207 ppb); 29/12/15 3:00-4:00 (194 ppb); 11/3/15 3:00-4:00 (173 ppb); and 1/1/15 3:00-4:00 (171 ppb). These maxima occurred during easterly winds with low wind speeds of approximately 2-3 m/s. These and other higher SO_2 concentrations were most likely due to plumes from coal fuelled power stations intercepting high ground in the Strzelecki Ranges, including at Jeeralang Hill.

At Rosedale South there were no exceedences of the objectives and goal for SO_2. The highest hourly average SO_2 concentrations at Rosedale South occurred on 29/12/2015 11:00-13:00 (153 ppb and 172 ppb); and 5/12/15 11:00-12:00 (66 ppb).

At Jeeralang Hill, the median hourly average SO_2 concentration was 1.4 ppb; data capture was 94.4%.

At Rosedale South, the median hourly average SO_2 concentration was 1.9 ppb; data capture was 95.1%.

An Air Quality Index based on the SO_2 concentrations indicated that air quality was 'good' or better for 99.88% and 99.98% of the time at Jeeralang Hill and Rosedale South respectively.

Nitrogen Dioxide

In 2015, oxides of nitrogen (NO_x) measurements including nitrogen dioxide (NO_2) were undertaken at Jeeralang Hill and Rosedale South. There were no recorded exceedences of the SEPP(AAQ) objective or goals for maximum hourly average nitrogen dioxide (NO_2, 120 ppb), at the two sites.

At Jeeralang Hill, the median hourly average NO_2 concentration was 0.9 ppb. The highest hourly average NO_2 concentration was 45 ppb; data capture was 94.9%.

At Rosedale South, the median hourly average NO_2 concentration was 1.7 ppb, the highest hourly average NO_2 concentration recorded was 21 ppb; data capture was 95.1%.

Further analysis of the NO_x data was undertaken by investigating the ratios between the NO_2 and NO_x concentrations (NO_2/NO_x). Lower values of NO_2/NO_x can be indicative of local NO_x sources in cases where some NO has had insufficient time to convert to NO_2. The data showed that as NO concentrations increased the NO_2/NO_x ratios decreased, typical of NO_x emissions from road vehicle traffic for example. The median NO_2/NO_x ratio was approximately 40% for NO_x concentrations greater than 20 ppb at Jeeralang Hill and

Rosedale South. There was an upwards trend in NO_2/NO_x as NO concentrations decreased, indicative of NO_x that had been in the atmosphere for longer periods allowing more time for NO_2 to form.

Ozone

There were no exceedences of SEPP(AAQ) objectives or goals for ozone (O_3). In 2015, at Jeeralang Hill, the median hourly and 4 hourly average O_3 concentrations were 22 ppb. The highest hourly average O_3 concentration was 70 ppb (although data capture was 65.2% only).

At Rosedale South, the median hourly average and rolling 4-hourly average O_3 concentration was 21 ppb. The highest hourly average O_3 concentration 69 ppb and data capture 95.1%.

Further analysis of the NO_2 and O_3 results at Jeeralang Hill and Rosedale South indicated higher NO_x levels at Jeeralang Hill contributed to smaller O_3 concentrations there. Higher O_3 levels were recorded at Rosedale South, which is more distant from the Latrobe Valley's main NO_x sources.

Particulate Matter

The very good correlation between the Particulate Matter 10 (PM_{10}) measurements at Jeeralang Hill and Rosedale South in 2015 indicated that for the majority of days the PM_{10} was due to regional influences, rather than local sources; there was a similar finding for the previous year; see Jacobs (2016b). Data capture rates for hourly average PM_{10} were high: at Jeeralang Hill (95.9%), and Rosedale South (99.0%).

The SEPP(AAQ) objective for PM_{10} is the 24-hour average, 50 µg/m^3. The objective was met on all but one of the 344 daily averages obtained for Jeeralang Hill and for all the 358 daily averages obtained for Rosedale South. The single exceedence of 50 µg/m^3 was detected at Jeeralang Hill (2/4/2015; 52 µg/m^3) – this was likely due to planned burning. The SEPP(AAQ) goal of not more than 5 exceedences of this objective, was achieved at both sites.

Local Visual Distance (Rosedale South)

In 2015, in situ nephelometer measurements of the atmospheric scattering coefficient (B_{sca}) were obtained at Rosedale South. Results for B_{sca} were used to calculate Local Visual Distance (LVD) in accordance with a Victorian Government procedure set out in the *State Environment Protection Policy, The Air Environment* (VG, 1982). According to the Rosedale South measurements and calculations, the SEPP(AAQ) visibility minimum of 20 km was exceeded for a total of 18 hours in 2015, on five days (31/3/15, 1/4/15, 4/4/15, and 12-13 June). Therefore, there were 2 exceedences of the 3-day goal with visibility deemed acceptable for 99.8% of the hourly measurements in 2015. A review of planned burns and previous studies of visibility undertaken in the Latrobe Valley indicated it was likely that all the exceedences detected in 2015 were due to smoke from planned burns or other fires.

Summary of Results

A summary of results for each of the air pollutants and objectives with respect to the SEPP(AAQ) ambient air quality standards and goals is set out in the table below. In the right-hand columns of the table, results are provided for maximum concentrations (ppb) and exceedences of the goals for exceedences [days per year], for Jeeralang Hill and Rosedale South.

Indicator	Statistic & averaging period	Objective	Goal (Exceedence)	Jeeralang Hill [Exceedences of Goal]	Rosedale South [Exceedences of Goal]
SO_2	Max. 1 hour	200 ppb	1 day/year	338 ppb [0]	172 ppb [0]
	Max. daily	80 ppb	1 day/year	46 ppb [0]	20 ppb [0]
	Annual	20 ppb	None	3.8 ppb [0]	3.0 ppb [0]
O_3	Max. 1 hour	100 ppb	1 day/year	70 ppb [0]	69 ppb [0]
	Max. 4 hour	80 ppb	1 day/year	67 ppb [0]	66 ppb [0]

Indicator	Statistic & averaging period	Objective	Goal (Exceedence)	Jeeralang Hill [Exceedences of Goal]	Rosedale South [Exceedences of Goal]
NO_2	Max. 1 hour	120 ppb	1 day/year	45 ppb [0]	21 ppb [0]
	Annual	30 ppb	None	2.2 ppb [0]	2.2 ppb [0]
Particles as PM_{10}	Max. 24 hour	50 µg/m^3	5 days/year	52 µg/m^3 [0]	46 µg/m^3 [0]
Local Visual Distance	Minimum 1 hour	20 km	3 days/year	N/A	9.1km [2 days]

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to provide data interpretation for Ecotech's 2015 ambient air quality monitoring data for LVAMN, in accordance with the scope of services set out in the contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client (if any) and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

Some of the data obtained in 2015 from the LVAMN Jeeralang Hill and Rosedale South monitoring stations were unable to be validated due to a variety of technical problems and the causes were detailed in Ecotech's 2015 monthly reports. Any further data removed from the analysis by Jacobs are described in this report. The main assumption of this review was that all the ambient air monitoring data provided by Ecotech were of sufficient accuracy for data interpretation.

This report has been prepared on behalf of, and for the exclusive use of, Jacobs's Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

1. Introduction

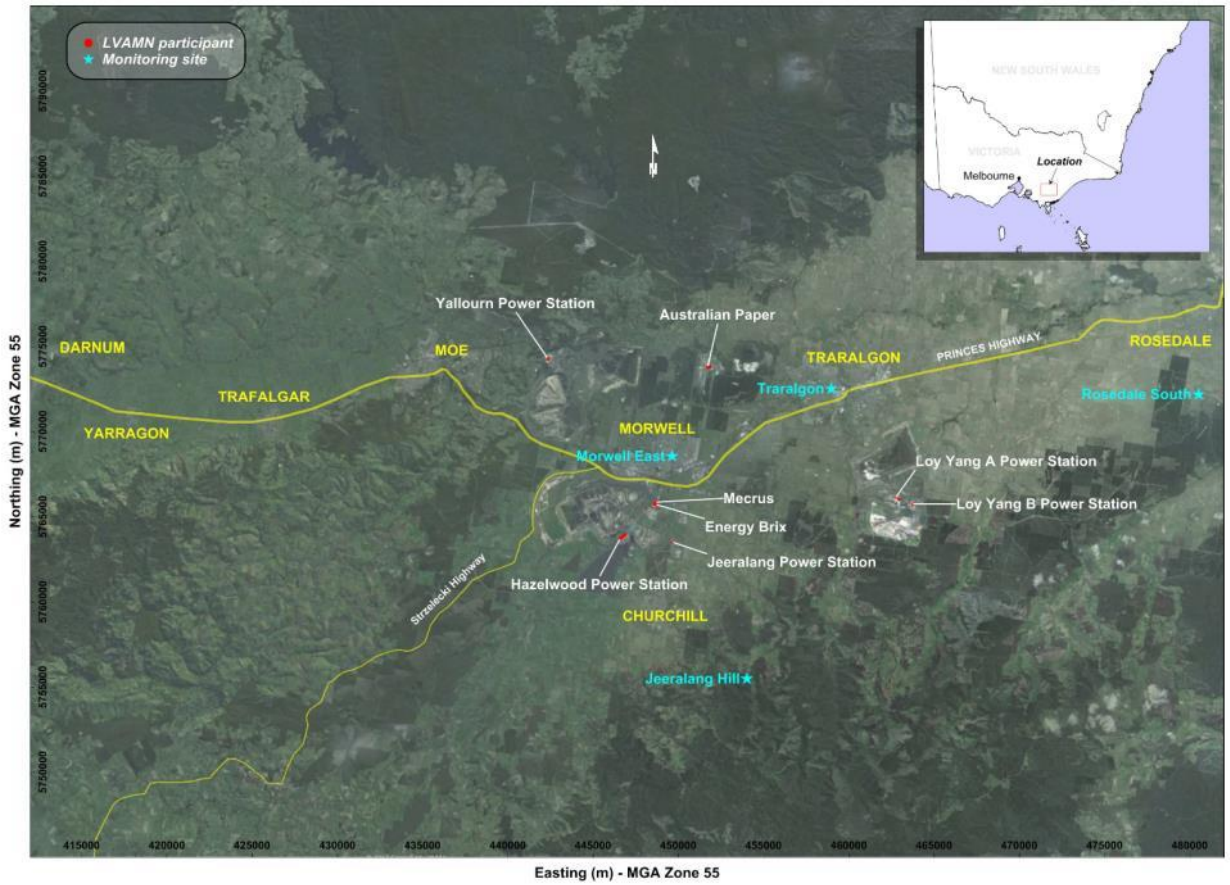
The Latrobe Valley Air Monitoring Network (LVAMN) has undertaken ambient air quality monitoring in the Latrobe Valley since the 1980s. CSIRO (1989) provides a summary of the air quality monitoring undertaken in the Latrobe Valley in the 1980s, and associated studies. Aurecon (2012) reviews some statistics for monitoring data acquired over 1980–2011. In addition, LVAMN calendar year annual summary reports have historically been produced; e.g., Jacobs (2016a) and Jacobs (2016b) provide the 2013 and 2014 reports; see LVAMN (2016).

Commencing in 2012, Ecotech Pty Ltd was commissioned by LVAMN Incorporated to provide monitoring and data reporting for the LVAMN stations Jeeralang Hill and Rosedale South. The Ecotech monitoring station locations for calendar year 2015 were unchanged from 2014 (Jacobs, 2016b) and included:

- Jeeralang Hill, a rural site in the Strzelecki Ranges approximately 11 km southeast of Hazelwood Power Station and 13.5 km southwest of Loy Yang Power Stations.
- Rosedale South, a rural site south of the town of Rosedale approximately 5 km south of the Rosedale township and 19 km east-north-east of Loy Yang Power Station.

A map of the Latrobe Valley is provided in **Figure 1-1** showing the locations of towns and the larger industrial facilities; i.e. those of the LVAMN participants, and four monitoring stations used for collecting information on air quality and meteorological conditions. The Traralgon and Morwell East stations, operated by Victoria's Environment Protection Authority (EPA), are also shown, but data from these stations were not analysed for this report.

Figure 1-1 Map of Latrobe Valley and Locations of Air Quality Monitoring Stations



1.1 Ecotech Monthly Reports

The monthly air monitoring reports for 2015 are detailed in the series of reports; Ecotech (2015a–2015k) and Ecotech (2016). The reports include details such as:

- Monitoring equipment, methods, and measured parameters.
- Data collection methods and compliance with monitoring standards.
- Data capture rates and key statistics for the measurement parameters.
- Recording of measured exceedences of ambient air quality standards and levels.

1.2 Purpose of this Report

The purpose of this report was to interpret the 2015 ambient air monitoring data from the Ecotech-operated LVAMN sites, Jeeralang Hill and Rosedale South, by comparing the data to relevant air quality objectives and goals. While auditing of measurement data quality is not in the scope of works for this report, data quality checks were undertaken during the data interpretation task.

The Ecotech measurement parameters reviewed for this report focus on the air pollutants for which objectives and goals are listed in the Victoria Government (VG) *State Environment Protection Policy (Ambient Air Quality)* ('SEPP(AAQ)'; or VG, 1999); i.e., sulfur dioxide (SO_2); nitrogen dioxide (NO_2); ozone (O_3); particulate matter comprising particles with aerodynamic diameters less than 10 microns (µm) in size (PM_{10}); and visibility reducing particles measured as Local Visual Distance (LVD).

It is noted the *State Environment Protection Policy (Air Quality Management)* ('SEPP(AQM)', or VG, 2001), varied the SEPP(AAQ) by removing the 8-hour average standards for O_3.

A 2016 variation to the SEPP(AAQ) introduced stronger air quality standards for particles (VG, 2016). These new standards were not applicable to the data analysed for this report, which were collected in 2015.

1.3 Abbreviations & Definitions

Abbreviation	Definition
Aerosols	For the purpose of this report, an aerosol is a suspension of liquid or solid particles in a gas with particle diameters in the range 0.001 micron to 100 micron; e.g., Poschl (2005).
AQI	Air Quality Index
CO	Molecular formula for carbon monoxide
CPF	Conditional Probability Function
DELWP	Department of Environment, Land, Water and Planning
EPA	Environment Protection Authority (Victoria)
LVAMN	Latrobe Valley Air Monitoring Network
LVAVS	Latrobe Valley Aerosol/Visibility Study
µm	micron (thousandth of a millimetre)
m/s	Metres per second
NEPC	National Environment Protection Council
NEPM	National Environment Protection (Ambient Air Quality) Measure
NO	Molecular formula for nitric oxide
NO_2	Molecular formula for nitrogen dioxide
NO_x	Oxides of nitrogen
O_3	Molecular formula for ozone

Abbreviation	Definition
Photochemical smog	Photochemical or 'summer' smog is a mixture of gases and particles, with ozone (O_3) being a significant component; e.g., EPA (2007). Ozone forms in the atmosphere from emissions of air pollutants such as NO_x, CO and hydrocarbons, in the presence of sunlight (hence 'photochemical' smog). In Melbourne, the most significant source of these O_3-forming pollutants is road vehicle traffic, and the most common weather pattern associated with summer smog involves light morning winds followed by afternoon sea breezes (EPA, 2007). Less is known about photochemical smog in the Latrobe Valley. Melbourne's photochemical smog would be transported into the Latrobe Valley during some meteorological conditions. Also, bushfires and controlled burns in the Latrobe Valley would lead to raised O_3 levels there.
$PM_{2.5}$	Particulate Matter 2.5; particulate matter comprising particles with aerodynamic diameters less than 2.5 microns (µm) in size
PM_{10}	Particulate Matter 10; particulate matter comprising particles with aerodynamic diameters less than 10 microns (µm) in size
SEPP(AAQ)	State Environment Protection Policy (Ambient Air Quality) (VG, 1999); the 25 February 2016 variation to the SEPP(AAQ) is noted.
SEPP(AQM)	State Environment Protection Policy (Ambient Quality Management) (VG, 2001)
SO_2	Molecular formula for sulfur dioxide
USEPA	United States Environmental Protection Agency
VG	Victoria Government

2. Objectives and Goals

2.1 SEPP(AAQ) Objectives and Goals

A purpose of the SEPP(AAQ) was to adopt National Environment Protection Council (NEPC) objectives and goals set out in the *National Environment Protection (Ambient Air Quality) Measure* (NEPM) (NEPC, 2003). The SEPP(AAQ) (1999) objectives and goals used to review the air quality monitoring data for this report are listed in **Table 2-1**, without the 8-hour average O_3 standards in accordance with the more recent SEPP(AQM).

Table 2-1 SEPP(AAQ) 1999 Objectives and Goals Used in this Report

Environmental Indicator	Averaging Period	Objective	Goal (exceedences)*
NO_2 (maximum conc.)	1 hour	120 ppb	1 day/year
	1 year	30 ppb	None
O_3 (maximum conc.)	1 hour	100 ppb	1 day/year
	4 hours#	80 ppb	1 day/year
SO_2 (maximum conc.)	1 hour	200 ppb	1 day/year
	1 day	80 ppb	1 day/year
	1 year	20 ppb	None
Particles as PM_{10}	1 day	50 µg/m^3	5 days/year
Visibility reducing particles (minimum visual distance)	1 hour	20 km	3 days/year

*Goals are maximum allowable exceedences of objective.

#Rolling 4-hour average based on 1 hour averages.

"Day" and "Year" mean “calendar day” and “calendar year”.

2.2 Note on 2016 Ambient Air Quality Standards

The national NEPM was updated in 2016 with new standards for particles (NEPC, 2016). Subsequently the Victorian Government adopted the same standards by a variation to the SEPP(AAQ) (VG, 2016); these are listed in **Table 2-2**. While these new standards weren’t applicable for the 2015 data analysed for this report, they are listed here for future reference.

Table 2-2 New National and Victorian Ambient Air Quality Standards for Particles

Environmental Indicator	Averaging Period	Objective	Goal (exceedences)*
Particles as PM_{10}	1 day	50 µg/m^3	Nil
	Annual	20 µg/m^3	Nil
Particles as $PM_{2.5}$	1 day	25 µg/m^3	Nil
	Annual	8 µg/m^3	Nil

3. Measured Parameters

3.1 Sulfur Dioxide

The most significant sources of sulfur dioxide (SO_2) emissions in the Latrobe Valley are the brown coal-fuelled power stations, and the Maryvale Paper Mill. As a result the highest SO_2 concentrations detected at the LVAMN monitoring stations can be attributed to, primarily, SO_2 emissions from these sources.

3.2 Oxides of Nitrogen

Oxides of nitrogen (NO_x) emissions produced by the burning of fuels; e.g., by road vehicle fleets associated with cities and larger towns including on the M1 Freeway, bushfires and planned burns, and power stations, comprise mostly nitric oxide (NO), and smaller amounts of NO_2. In the atmosphere, NO may be oxidised to NO_2 by the reaction with ozone (O_3): $O_3 + NO \rightarrow NO_2 + O_2$.

3.3 Ozone

The significant source of ozone (O_3) in the atmosphere is the photolysis of NO_2 in sunlight involving ultraviolet photons ($h\nu$) with wavelengths less than 424 nanometres by the pair of reactions: (1) $NO_2 + h\nu \rightarrow NO + O$; and (2) $O + O_2 \rightarrow O_3$.

Information about sources and concentrations of NO_x and reactive hydrocarbons are important for understanding the formation of photochemical O_3. In the Latrobe Valley, local sources of NO_x and hydrocarbons would include the power stations, road vehicle traffic including on the M1 Freeway, and 'natural' sources of hydrocarbons such as forested areas. Also, air pollution transported into the Latrobe Valley from the Melbourne airshed would affect the Latrobe Valley's O_3 levels.

3.4 Particulate Matter

Potential local sources of small airborne particles as Particulate Matter 10 (PM_{10}) and Particulate Matter 2.5 ($PM_{2.5}$) in the Latrobe Valley include: controlled burning and bushfires; open cut coal mining and wheel generated dust on unpaved roads; domestic wood heaters and open fireplaces, road vehicle traffic on the M1 Freeway (locomotives would be a minor source), and industry. Measurements of PM_{10} in the Latrobe Valley would also include some components transported from outside the region, such as sea salt aerosols from Bass Strait and beyond.

3.5 Local Visual Distance

Air pollution can affect amenity by forming a visibility-reducing haze, caused by light scattering by small particles in the atmosphere (aerosols). The sources of such aerosols are similar to those for particulate matter e.g. open cut coal mining; domestic wood heaters and open fireplaces; planned burns and bushfires; and photochemical smog. In humid conditions, fog and mist (essentially low cloud), also reduce visibility. The SEPP(AAQ) sets out an objective for minimum visibility of 20 km. In Victoria, compliance with the visibility objective is determined by nephelometer measurements of light scattering properties of ambient air conditioned to a relative humidity of 70%. The Victorian Government Gazette No. 120 (VG, 1982), sets out the following equation for determination of the Local Visual Distance (LVD) from a nephelometer-measured parameter:

$$LVD = 47 \times (10{,}000 \times B_{sca})^{-1},$$

where B_{sca} is the atmospheric light scattering coefficient (units m^{-1}), measured by an integrating nephelometer; e.g., using a scattering coefficient of 4.7×10^{-5} m^{-1}, the calculated LVD is 100 km. The Ecotech results for LVD were calculated from measurements of B_{sca} by an Aurora 1000 Nephelometer at the Rosedale South monitoring station; e.g., see Ecotech (2015a).

4. Ecotech LVAMN Operations 2015

4.1 Overview

This section sets out the results of the interpretation of measurements of air pollutants and meteorological parameters undertaken at Jeeralang Hill and Rosedale South in 2015. Further details about equipment, specifications and data capture may be found in the monthly reports Ecotech (2015a) through to Ecotech (2015k), and Ecotech (2016). Some of the monitoring data acquired in 2015 from Rosedale South and Jeeralang Hill were invalidated due to a variety of technical non-compliances; the causes were detailed in the Ecotech monthly reports.

4.2 Ecotech LVAMN Data Capture for In Situ Measurements

A statistical summary of the hourly average data for the air pollutants and wind parameters measured at Jeeralang Hill for 2015 is provided in **Table 4-1**, and similarly for Rosedale South in **Table 4-2**.

The minimum data capture requirement of 80% was not met for ozone at Jeeralang Hill. The reason for this was the O_3 analyser failed its multi-point calibration during 3-monthly maintenance on 26/02/2015. Further testing by Ecotech between 13/03/2015 and 02/04/2015 determined the cause to be instrument malfunction. As such the O_3 data recorded between 27/11/2014 and 02/04/2015 were marked as invalid (Ecotech, 2015d).

Table 4-1 Summary of Jeeralang Hill Monitoring Data for 2015 (Hourly Averages)

Parameter (units)	No. of hourly average records	Data Capture 2015
SO_2 (ppb)	8267	94.4%
NO (ppb)	8312	94.9%
NO_2 (ppb)	8312	94.9%
NO_x (ppb)	8312	94.9%
O_3 (ppb)	5709	65.2%
PM_{10} ($\mu g/m^3$)	8403	95.9%
WS_a (m/s)	8623	98.4%
WD_b (deg)	8623	98.4%
$\sigma\theta_c$ (deg)	8623	98.4%

a. Wind Speed; b. Wind Direction; c. Sigma-theta, or standard deviation of the horizontal wind direction.

Table 4-2 Summary of Rosedale South Monitoring Data for 2015 (Hourly Averages)

Parameter (units)	No. of hourly average records	Data Capture 2015
SO_2 (ppb)	8333	95.1%
NO (ppb)	8328	95.1%
NO_2 (ppb)	8328	95.1%
NO_x (ppb)	8328	95.1%
O_3 (ppb)	8163	93.2%
PM_{10} ($\mu g/m^3$)	8673	99.0%
WS_a (m/s)	8699	99.3%
WD_b (deg)	8699	99.3%
$\sigma\theta_c$ (deg)	8699	99.3%
LVD_d (km)	8445	96.4%

a. Wind Speed; b. Wind Direction; c. Sigma-theta, or standard deviation of the horizontal wind direction; d. Local Visual Distance

Wind roses were created from the wind speed and direction data for 2015; see **Appendix C.1** (Jeeralang Hill); and **Appendix C.2** (Rosedale South).

The wind patterns for 2015 were very similar to those reported for 2014 (see Jacobs, 2016b). In summary, at Jeeralang Hill light south-westerly winds are dominant throughout most of the year. Stronger easterly winds are dominant in the summer months and the first two months of autumn.

At Rosedale South, south-southwesterly winds are dominant throughout the year, with lighter easterly winds having more of an influence in the summer months.

5. LVAMN Results 2015

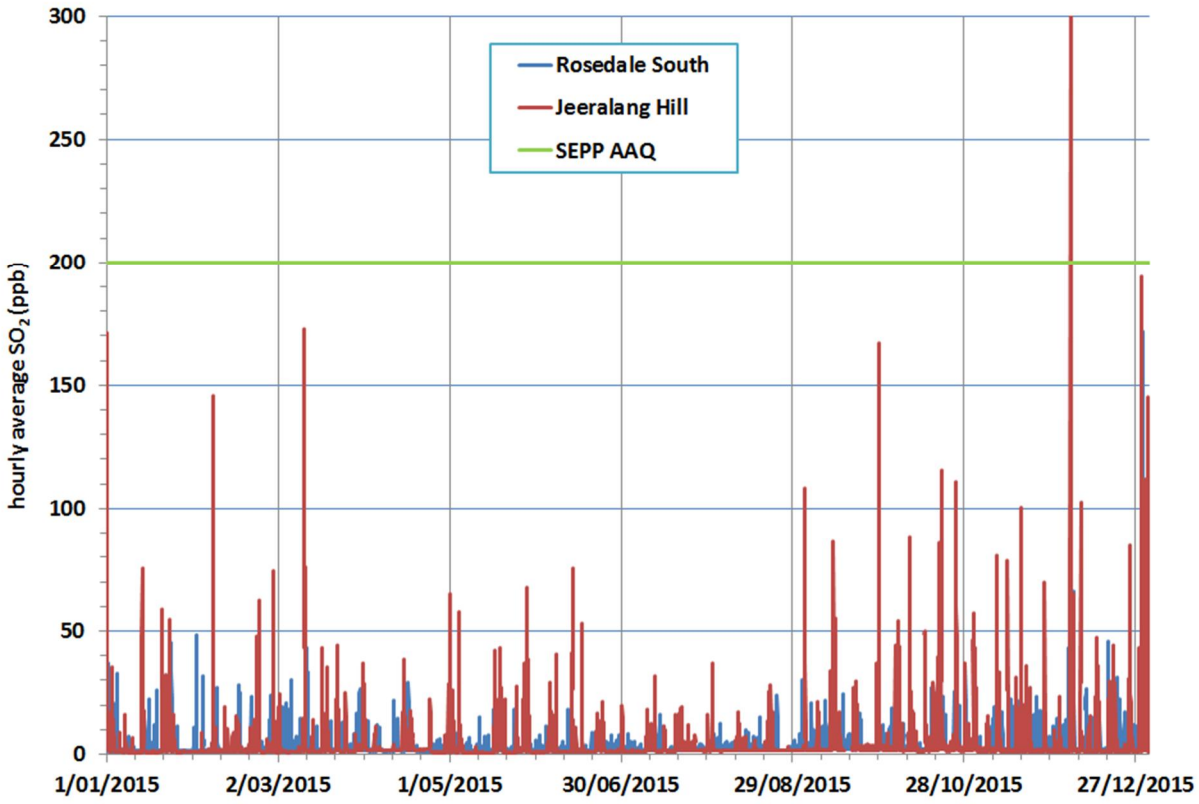
5.1 Overview

This section provides the results of data interpretation for the LVAMN air monitoring data acquired in 2015 at the air monitoring stations Jeeralang Hill and Rosedale South. Ecotech's reported 1-hour and 24-hour averages were based on a minimum of 80% valid readings within the averaging period. The same fraction was adopted for the calculations undertaken for this report.

5.2 Sulfur dioxide – Jeeralang Hill and Rosedale South

The LVAMN 2015 results for hourly average SO_2 concentrations (ppb) measured at Jeeralang Hill and Rosedale South are provided in **Figure 5-1**.

Figure 5-1 LVAMN Results for Hourly Average SO_2 Concentration (ppb)



A summary of results of the analysis of the hourly average SO_2 concentrations acquired from Jeeralang Hill in 2015 is set out in **Table 5-1**. Daily averages were calculated for days where 80% of hourly average data were available for that day.

Table 5-1 Summary of Results: Jeeralang Hill SO_2 Concentrations

Parameter	Hourly Averages	Daily Averages	Annual Average
Number of records	8267	354	1
Total records possible	8760	365	1
Data capture	94.4%	97.0%	100%
Median	1.4 ppb	1.7 ppb	–
Annual average	3.8 ppb	3.7 ppb (avg. of 24h avgs.)	3.8 ppb

Parameter	Hourly Averages	Daily Averages	Annual Average
70th percentile	1.8 ppb	3.5 ppb	–
Maximum	338 ppb	46 ppb	–
SEPP(AAQ) Objective	200 ppb	80 ppb	20 ppb
Percentage of time Objective met (of measured data)	99.98%	100%	100%
Exceedences of Objective	2 hours on 1 day	0	0
SEPP(AAQ) Goal	Exc. 1 day/year	Exc. 1 day/year	No exceedences
Exceedences of Goal	0	0	0

The five highest hourly average SO_2 concentrations at Jeeralang Hill occurred during morning hours on four days: 4/12/15 5:00-7:00 (338 ppb and 207 ppb); 29/12/15 3:00-4:00 (194 ppb); 11/3/15 3:00-4:00 (173 ppb); and 1/1/15 3:00-4:00 (171 ppb). These maxima occurred during easterly winds with low wind speeds of approximately 2-3 m/s; i.e., a similar result to the previous two years (Jacobs, 2016a; Jacobs, 2016b). The higher SO_2 concentrations observed at Jeeralang Hill are indicative of plume strikes on higher ground in the Strzelecki Ranges due to emissions from coal-fired power stations.

A summary of results of the analysis of the hourly average SO_2 concentrations acquired at Rosedale South in 2015 is set out in **Table 5-2**.

Table 5-2 Summary of Results: Rosedale South SO_2 Concentrations

Parameter	Hourly Averages	Daily Averages	Annual Average
Number of records	8333	357	1
Total records possible	8760	365	1
Data capture	95.1%	97.8%	100%
Median	1.9 ppb	2.2	–
Annual average	3.0 ppb	3.0 ppb (avg. of 24h avgs.)	3.0 ppb
70th percentile	2.2 ppb	3.0 ppb	–
Maximum	172 ppb	19.6 ppb	–
SEPP(AAQ) Objective	200 ppb	80 ppb	20 ppb
Percentage of time Objective met (of measured data)	100%	100%	100%
Exceedences of Objective	0	0	0
SEPP(AAQ) Goal	Exc. 1 day/year	Exc. 1 day/year	No exceedences
Exceedences of Goal	0	0	0

The three highest hourly average SO_2 concentrations at Rosedale South occurred on 29/12/2015 11:00-13:00 (153 ppb and 172 ppb); and 5/12/15 11:00-12:00 (66 ppb). Inspection of the SO_2 and wind data on these days indicated that sometimes high SO_2 concentrations observed at Jeeralang Hill could be followed by high SO_2 concentrations at Rosedale South approximately 6-9 hours later.

In 2015 the SEPP(AAQ) goals for exceedences of the SO_2 objectives were met at Jeeralang Hill and Rosedale South.

5.3 Air Quality Indices from SO_2 Concentrations

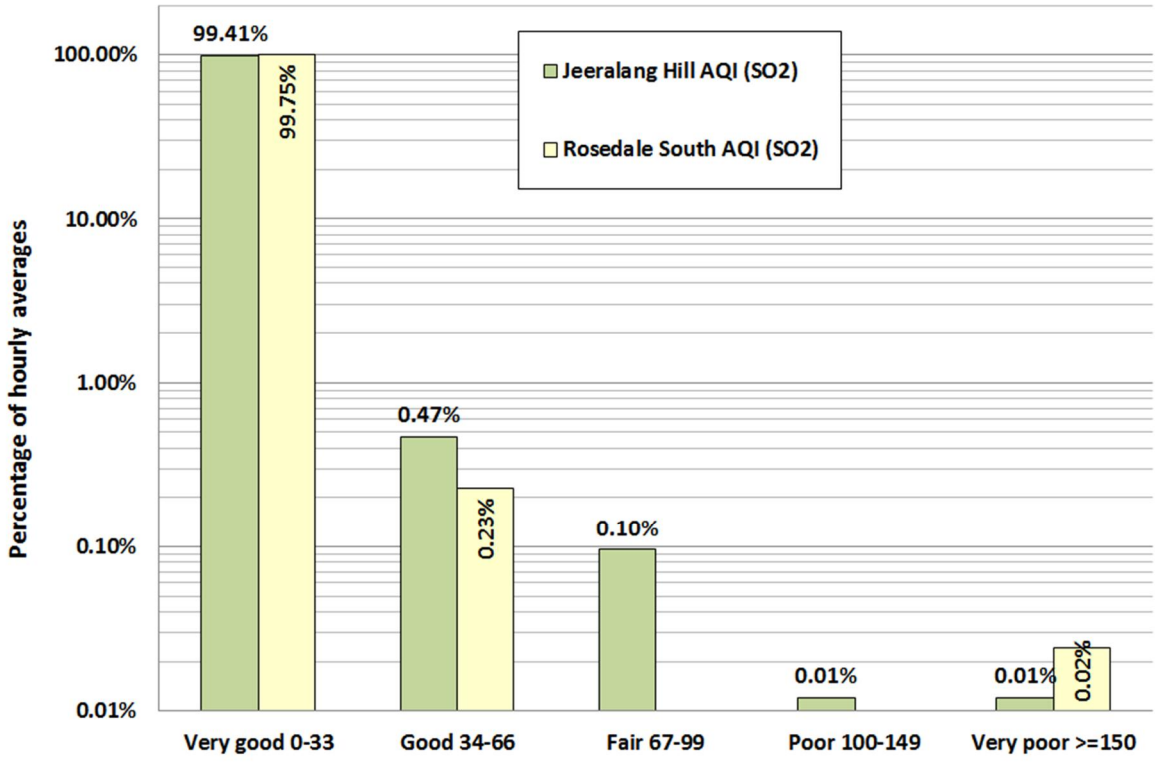
Air Quality Indices (AQI) based on EPA Victoria procedures were calculated using the Jeeralang Hill and Rosedale South hourly average SO_2 data. The AQI is a concentration expressed as a percentage of the

relevant air quality standard; in this case, maximum hourly average 200 ppb. The Jeeralang Hill and Rosedale South SO_2 results are provided as frequency distributions in **Figure 5-2** (logarithmic plots).

Inspection of **Figure 5-2** clearly demonstrates that air quality due to SO_2 at Jeeralang Hill and Rosedale South was very good for the majority of the time; i.e., more than 99% of the time for both locations.

As expected, overall, air quality as indicated by hourly average SO_2 was slightly worse at Jeeralang Hill due to the proximity of the coal fuelled power stations and the higher elevation being more susceptible to plume strikes. The elevation of Jeeralang Hill is 510 metres above sea level; and Rosedale South 52 metres above sea level.

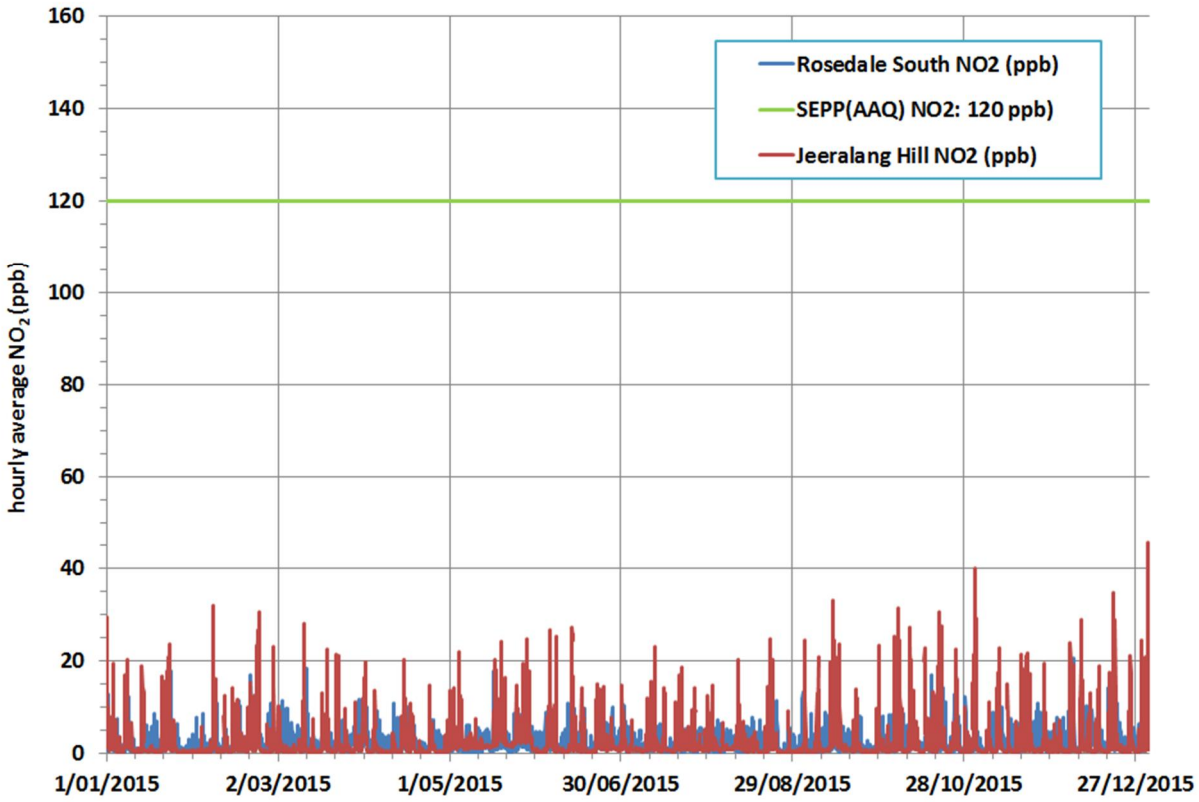
Figure 5-2 Frequency Distributions of Air Quality Indices as Logarithmic Plot – Hourly Average SO_2



5.4 Oxides of Nitrogen – Jeeralang Hill and Rosedale South

The results for hourly average nitrogen dioxide (NO_2) concentrations (ppb) are provided in **Figure 5-3**. There were no exceedences of the SEPP(AAQ) objective of 120 ppb for maximum hourly NO_2 concentration at either location.

Figure 5-3 LVAMN Results for Hourly Average NO_2 Concentration (ppb)



A summary of results of the analysis of the Jeeralang Hill hourly average NO_2 concentrations is set out in **Table 5-3**. There were no exceedences of the SEPP(AAQ) objectives and goals for NO_2.

Table 5-3 Summary of Results: Jeeralang Hill NO_2 Concentrations

Parameter	Hourly Averages	Annual Average
No. records	8312	1
Total possible	8760	1
Data capture	94.9%	100%
Median	0.9 ppb	–
Annual average	2.2 ppb	2.2 ppb
70th percentile	1.6 ppb	–
Maximum	45 ppb	–
SEPP(AAQ) Objective	120 ppb	30 ppb
Percentage of time Objective met	100%	100%
Exceedences of Objective	0	0
SEPP(AAQ) Goal	Exc. 1 day/year	No exceedences
Exceedences of Goal	0	0

A statistical summary for all the NO_x components measured at Jeeralang Hill is provided in **Table 5-4**.

Table 5-4 Statistical Summary for All NO_x Components – Jeeralang Hill

Air Pollutant	Median Conc. (ppb)	Average Conc. (ppb)	70th Percentile Conc. (ppb)	Maximum Conc. (ppb)
NO	0.2	1.1	0.4	131
NO_2	0.9	2.2	1.6	45
NO_x	1.0	3.3	2.0	155

A summary of results of the analysis of the Rosedale South hourly average NO_2 concentrations is set out in **Table 5-5**. There were no exceedences of the SEPP(AAQ) objectives and goals for NO_2.

Table 5-5 Summary of Results: Rosedale South NO_2 Concentrations

Parameter	Hourly Averages	Annual Average
No. records	8328	1
Total possible	8760	1
Data capture	95.1%	100%
Median	1.7 ppb	–
Annual average	2.2 ppb	2.2 ppb
70th percentile	2.5 ppb	–
Maximum	21 ppb	–
SEPP(AAQ) Objective	120 ppb	30 ppb
Percentage of time Objective met	100%	100%
Exceedences of Objective	0	0
SEPP(AAQ) Goal	Exc. 1 day/year	No exceedences
Exceedences of Goal	0	0

A statistical summary for all the NO_x components measured at Rosedale South is provided in **Table 5-6**.

Table 5-6 Statistical Summary for All NO_x Components – Rosedale South

Air Pollutant	Median Conc. (ppb)	Average Conc. (ppb)	70th Percentile Conc. (ppb)	Maximum Conc. (ppb)
NO	0.3	0.7	0.6	29
NO_2	1.7	2.2	2.5	21
NO_x	2.0	2.9	3.1	49

5.5 Analysis of NO_2/NO_x Ratios

Analysis of the NO_x data was undertaken by investigations of the ratios between the NO_2 and NO_x concentrations (NO_2/NO_x). Lower values of NO_2/NO_x can be indicative of local NO_x sources, in cases where some NO has had insufficient time to convert to NO_2.

A select few of the NO_x data were used in this analysis, primarily to remove large numerical errors associated with small measured quantities. Data were selected by the following steps: (1) Negative and zero results for NO_x concentrations were removed; (2) NO_2/NO_x ratios greater than unity and less than or equal to zero were removed; and (3) NO concentrations less than 1 ppb were removed. The resulting NO_2/NO_x ratios are listed in **Table 5-7**.

Table 5-7 Summary of Calculated NO_2/NO_x Ratios for 2015

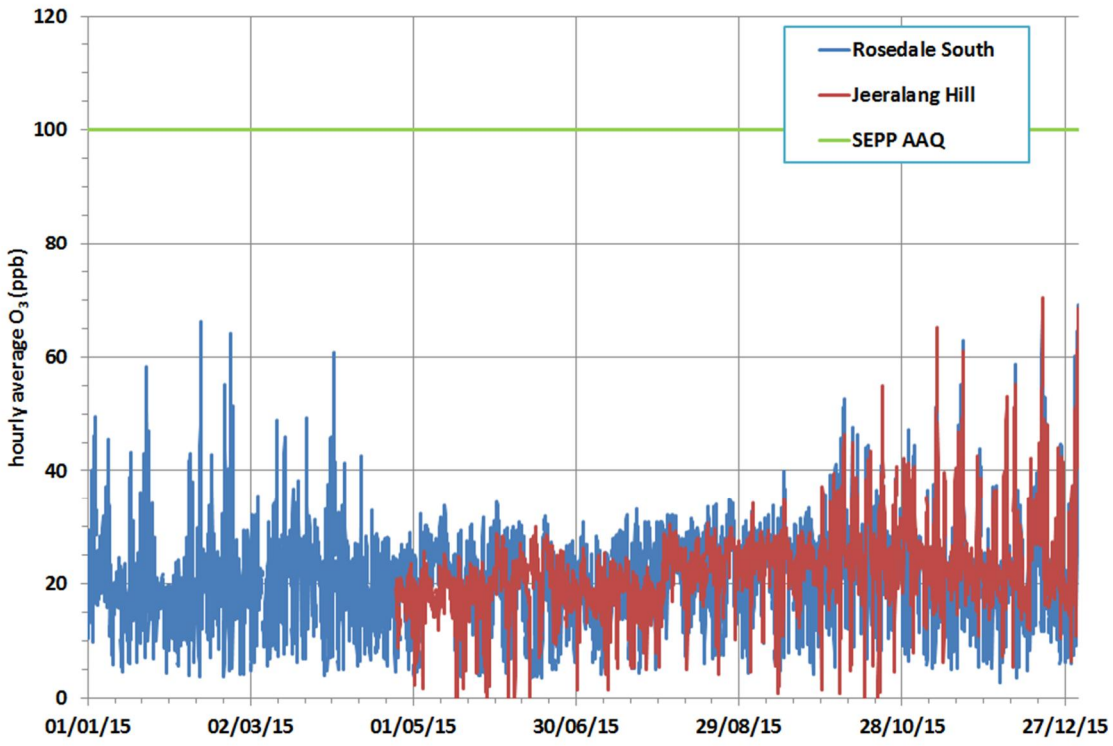
NO Range (ppb)	Median NO_2/NO_x Ratio	No. Hourly Records	Percentage of Hourly Data Used for Ratio
Jeeralang Hill			
1 ≤ [NO] < 5	64%	939	72%
5 ≤ [NO] < 10	57%	189	14%
10 ≤ [NO] < 20	51%	92	7.0%
[NO] ≥ 20	37%	87	6.7%
Rosedale South			
1 ≤ [NO] < 5	63%	1460	88%
5 ≤ [NO] < 10	51%	157	9.5%
10 ≤ [NO] < 20	47%	34	2.1%
[NO] ≥ 20	40%	2	0.1%

Inspection of the results listed in **Table 5-7** indicates that as the NO concentrations increase the NO_2/NO_x ratios decreases, which is typical of NO_x emissions from the combustion of fossil fuels; e.g., due to road vehicle traffic. The NO_2/NO_x ratios ranged between 15% and 23% for the three NO concentrations greater than 100 ppb (all from Jeeralang Hill). There was an upwards trend in the NO_2/NO_x ratios as the NO concentrations decreased, indicative of NO_x that has been in the atmosphere for longer periods, allowing more time for NO_2 to form. These results for NO_2/NO_x are very similar to those determined for 2014; see Jacobs (2016b).

5.6 Ozone – Jeeralang Hill and Rosedale South

The Jeeralang Hill and Rosedale South results for hourly average O_3 concentrations (ppb) are provided in **Figure 5-4**. The results are shown with the SEPP(AAQ) hourly average objective (100 ppb); all the hourly O_3 data were less than the objective. (Data capture was detailed in **Section 4.2**).

Figure 5-4 Ecotech LVAMN Results for Hourly Average O_3 Concentration (ppb)



Summaries of results of the analysis of the hourly average O_3 concentrations are set out in **Table 5-8** (Jeeralang Hill); and Rosedale South (**Table 5-9**). The measured O_3 concentrations were less at Jeeralang Hill; this is investigated in some further detail in the next section.

Table 5-8 Summary of Results: Jeeralang Hill O_3 Concentrations

Parameter (Jeeralang Hill)	1h average	4h rolling average
No. records	5709	5918
Total possible	8760	8757
Data capture	65.2%	67.6%
Median (ppb)	22	22
Annual average (ppb)	23	23
70th percentile (ppb)	25	25
Maximum (ppb)	70	67
SEPP(AAQ) Objective (ppb)	100	80
Percentage of time Objective met	100%	100%
Exceedences of Objective	0	0
SEPP(AAQ) Goal	Exc. 1 day/year	Exc. 1 day/year
Exceedences of Goal	0	0

Note: VG (2001) varied VG (1999) by removing the 8-hour average objectives for O_3.

Table 5-9 Summary of Results: Rosedale South O_3 Concentrations

Parameter (Rosedale South)	1h average	4h rolling average
No. records	8330	8680
Total possible	8760	8757
Data capture	95.1%	99.1%
Median (ppb)	21	21
Annual average (ppb)	21	21
70th percentile (ppb)	25	25
Maximum (ppb)	69	66
SEPP(AAQ) Objective (ppb)	100	80
Percentage of time Objective met	0	0
Exceedences of Objective	Exc. 1 day/year	Exc. 1 day/year
SEPP(AAQ) Goal	0	0
Exceedences of Goal	0	0

Note: VG (2001) varied VG (1999) by removing the 8-hour average objectives for O_3.

In 2015 the SEPP(AAQ) goals for the O_3 objectives were met at Jeeralang Hill and Rosedale South.

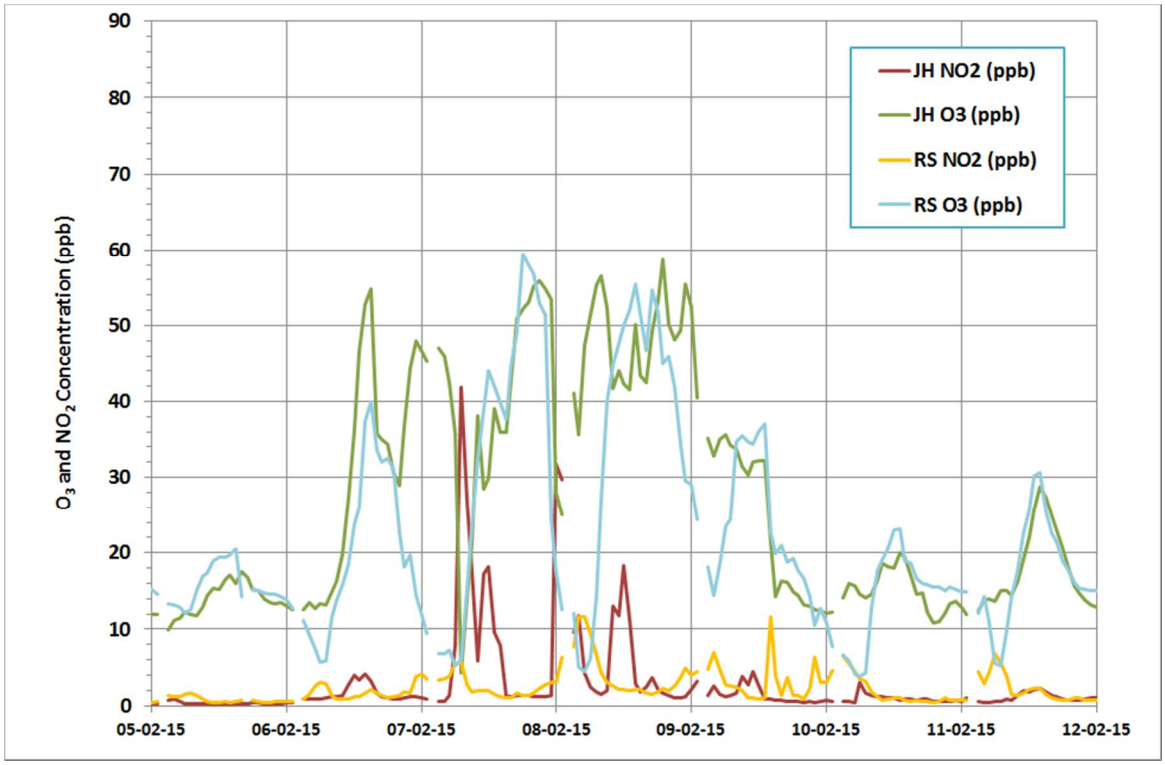
5.7 Products of Photolysis – O_3 and NO_2

This section provides a sample of results for concurrent hourly average O_3 and NO_2 concentrations. (Monitoring of NO_2 at Jeeralang Hill commenced in 2014; see Jacobs, 2016b). In general, the NO_2 concentrations at Jeeralang Hill and Rosedale South were low and variable, and there was clear evidence of photolysis occurring at both sites, with several well defined O_3 peaks occurring around midday during the summer; e.g., the hourly average data for the period 5/2/15–12/2/15 are shown in **Figure 5-5**. The NO_2 present earlier in the mornings would have provided the oxygen for formation of O_3, in sunlight (see **Section 3.2** and **Section 3.3**). Pulses of

NO_2 in the mornings, perhaps due to road vehicle traffic emissions, reduce O_3 levels at those times. Some of the O_3 concentrations measured at Jeeralang Hill and Rosedale South matched very well indicating the homogeneity of the photochemical smog across the Latrobe Valley region, at those times.

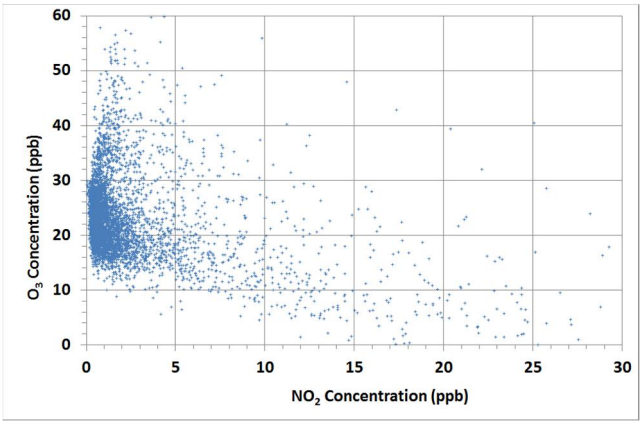
The hourly average O_3 and NO_2 data pairs are shown in **Figure 5-6** as scatter plots for Jeeralang Hill (left), and Rosedale South (right). The plots show different relationships between the data for the two sites. In summary, in 2015 larger amounts of fresher NO_x emissions at Jeeralang Hill meant that O_3 was less dominant there, whereas the smaller amounts of NO_x at Rosedale South meant that O_3 formation was more dominant at that site. These results are similar to those from the previous year's data (Jacobs, 2016b).

Figure 5-5 Example of O_3 and NO_2 Measurements at Jeeralang Hill and Rosedale South: 5/2/15–12/4/15

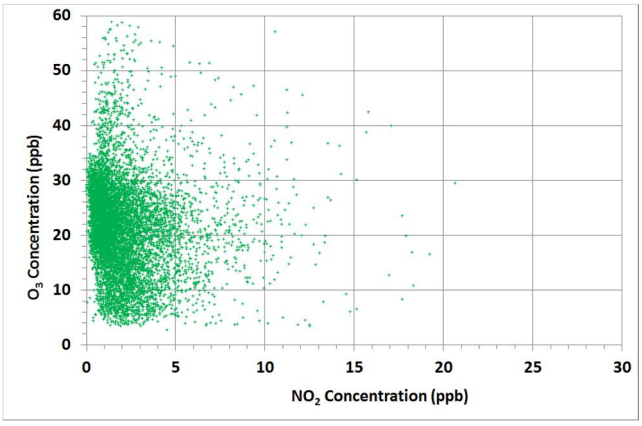


Note: Relevant SEPP (AAQ) Objectives are 100 ppb (O_3) and 120 ppb (NO_2).

Figure 5-6 Hourly Average O_3 and NO_2: Jeeralang Hill (left) and Rosedale South (right)



Jeeralang Hill; O_3 less dominant

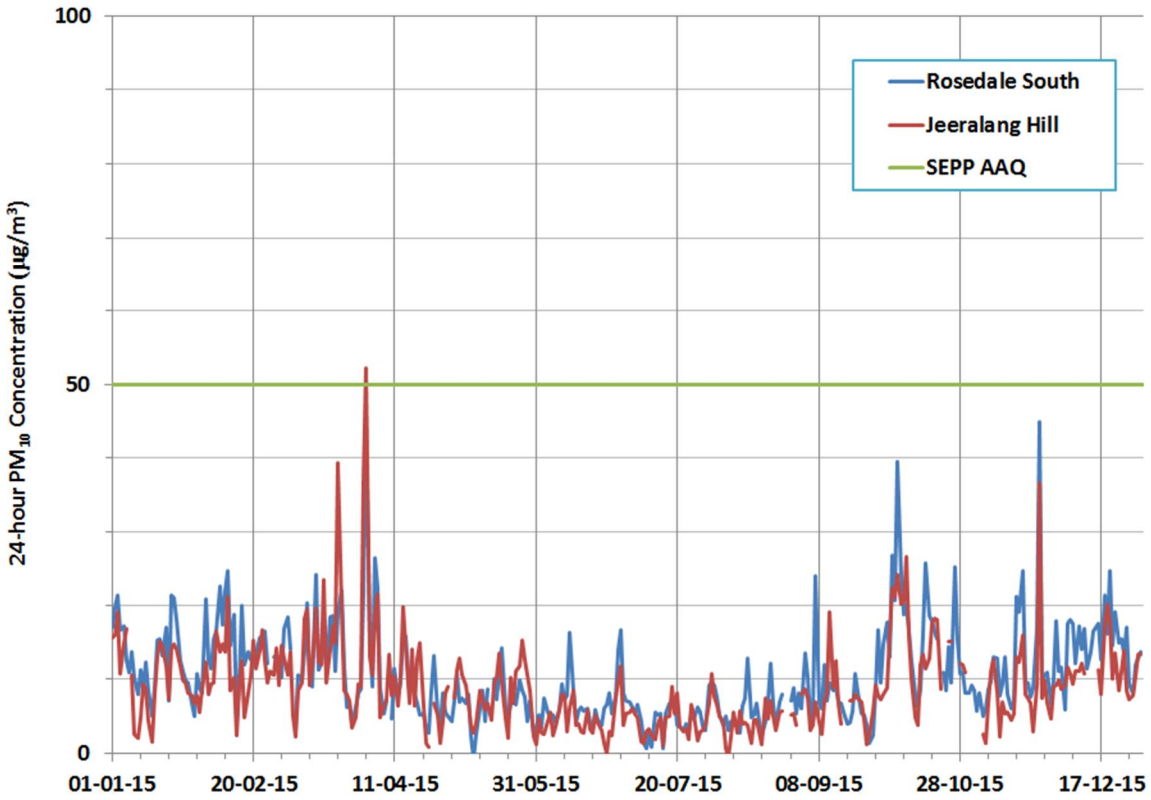


Rosedale South; O_3 more dominant

5.8 Particulate Matter as PM_{10} – Jeeralang Hill and Rosedale South

The Jeeralang Hill and Rosedale South results for daily average PM_{10} concentrations (µg/m^3) are provided in **Figure 5-7**; the relevant SEPP(AAQ) objective is also shown (50 µg/m^3). Inspection of **Figure 5-7** indicates there is an excellent correlation between the 24 hour average PM_{10} data (linear correlation coefficient, 0.81; in the previous year the result was almost the same; 0.82). This means that most of the variations in PM_{10} concentrations were characteristic of the atmospheric conditions in the Latrobe Valley region, not local sources such as stacks.

Figure 5-7 LVAMN Results for 24-Hour Average PM_{10} Concentration (µg/m^3)



A summary of results for PM_{10} data acquired at Jeeralang Hill and Rosedale South is set out in **Table 5-10**. One exceedence of the SEPP(AAQ) 24-hour average objective of 50 µg/m^3 was detected at Jeeralang Hill (2/4/2015; 52 µg/m^3). It is likely that this exceedence and days of higher PM_{10} concentrations during March-April 2015 were due to a planned burning program conducted by the Department of Environment, Land, Water and Planning (DELWP), and Parks Victoria (DELWP, 2015). In any case the SEPP(AAQ) goal of not more than 5 exceedences (i.e. 5 days) of this objective, was achieved at Jeeralang Hill and Rosedale South.

Table 5-10 Summary of Results for PM_{10} Concentrations (µg/m^3) – Jeeralang Hill and Rosedale South

Parameter	Jeeralang Hill	Rosedale South
No. of hourly averages	8403	8673
Data capture (hourly data)	95.9%	99.0%
Median of hourly averages	7 µg/m^3	8 µg/m^3
Annual average of hourly averages	9 µg/m^3	11 µg/m^3
70th percentile of hourly averages	11 µg/m^3	12 µg/m^3
Maximum hourly average	212 µg/m^3	320 µg/m^3
No. of daily averages	344	358

Parameter	Jeeralang Hill	Rosedale South
Maximum daily average	52 µg/m^3	46 µg/m^3
SEPP(AAQ) Objective	50 µg/m^3	50 µg/m^3
Percentage of time Objective met	99.7%	100%
Exceedences of Objective	1	0
Days of exceedences and values (µg/m3)	2/4/2015 (52)	N/A
SEPP(AAQ) Goal	Exceedences 5 days per year	Exceedences 5 days per year
Exceedences of Goal	0	0

5.9 Local Visual Distance (Rosedale South)

In this section units of per metre (m^{-1}) are used for the nephelometer light scattering coefficient (B_{sca}) in accordance with the procedure set out in VG (1982); see **Section 3.5**. It is noted the current Australian/New Zealand Standard (AS/NZS) 3580.12.1:2015, *Methods for sampling and analysis of ambient air Method 12.1: Determination of light scattering—Integrating nephelometer method*, employs units of 'inverse Megametre' for the scattering coefficient. However the AS/NZS 3580.12.1:2015 does not support estimates for visual distance.

As a first step in the analysis of the Rosedale South nephelometer data, results for hourly average B_{sca} (m^{-1}) were calculated using the VG (1982) procedure, using as input the Ecotech estimates for hourly average LVD. A statistical summary of these calculated values of B_{sca} is provided in **Table 5-11**. Again using the VG (1982) procedure, values for LVD were calculated for the statistical results in column 2 in the table; these are listed in column 3.

The days of exceedences were: 31/3/15 (1 hour); 1/4/15 (10 hours); 12/6/15 (3 hours); and 13/6/15 (1 hour). The exceedences in March-April were probably due to planned burns; e.g., see DELWP (2015). The reasons for the exceedences detected on 12-13 June could not be determined at the time of writing. However it is likely they were due to smoke particles also. The Latrobe Valley Aerosol/Visibility Study (LVAVS), undertaken in 1986-1988, determined that low visibility days were due to biomass burning; e.g., Ayers et al. (1990). The findings of LVAVS ruled out the coal-fuelled power stations as a cause of breaches of the SEPP(AAQ) standard for LVD in the Latrobe Valley, instead implicating planned burning as the cause.

Table 5-11 Summary of results for calculated B_{sca} and their LVD; Rosedale South 2015

Statistic	B_{sca} (m^{-1})	Calculated LVD (km)
Number of hourly averages	8445 (96.4% of year)	8445 (96.4% of year)
Maximum hourly average B_{sca}	5.2×10^{-4} m^{-1}	9.1 km
70th percentile hourly average B_{sca}	4.4×10^{-5} m^{-1}	107 km
Median hourly average B_{sca}	3.7×10^{-5} m^{-1}	127 km
Minimum hourly average B_{sca} ca	2.1×10^{-5} m^{-1}	221 km

A summary of results for the hourly average Ecotech results for LVD is provided in **Table 5-12**. Again, values for B_{sca} (m^{-1}) calculated using the VG (1982) procedure, are shown alongside.

Table 5-12 Summary of results for Ecotech Results for LVD and their Calculated B_{sca}; Rosedale South 2015

Statistic	LVD (km)	Calculated B_{sca} (m^{-1})
Number of hourly averages	8445 (96.4% of year)	N/A
Maximum hourly average LVD	221 km	2.1×10^{-5} m^{-1}
70th percentile hourly average LVD	144 km	3.3×10^{-5} m^{-1}
Median hourly average LVD	127 km	3.7×10^{-5} m^{-1}

Statistic	LVD (km)	Calculated B_{sca} (m^{-1})
Minimum hourly average LVD	9.1 km	5.2×10^{-4} m^{-1}
Number of exceedences of the minimum hourly average LVD; 20 km	18 (0.2% of annual hours), occurring on 5 days	N/A
Exceedences of goal (not >3 days)	2 (days)	N/A

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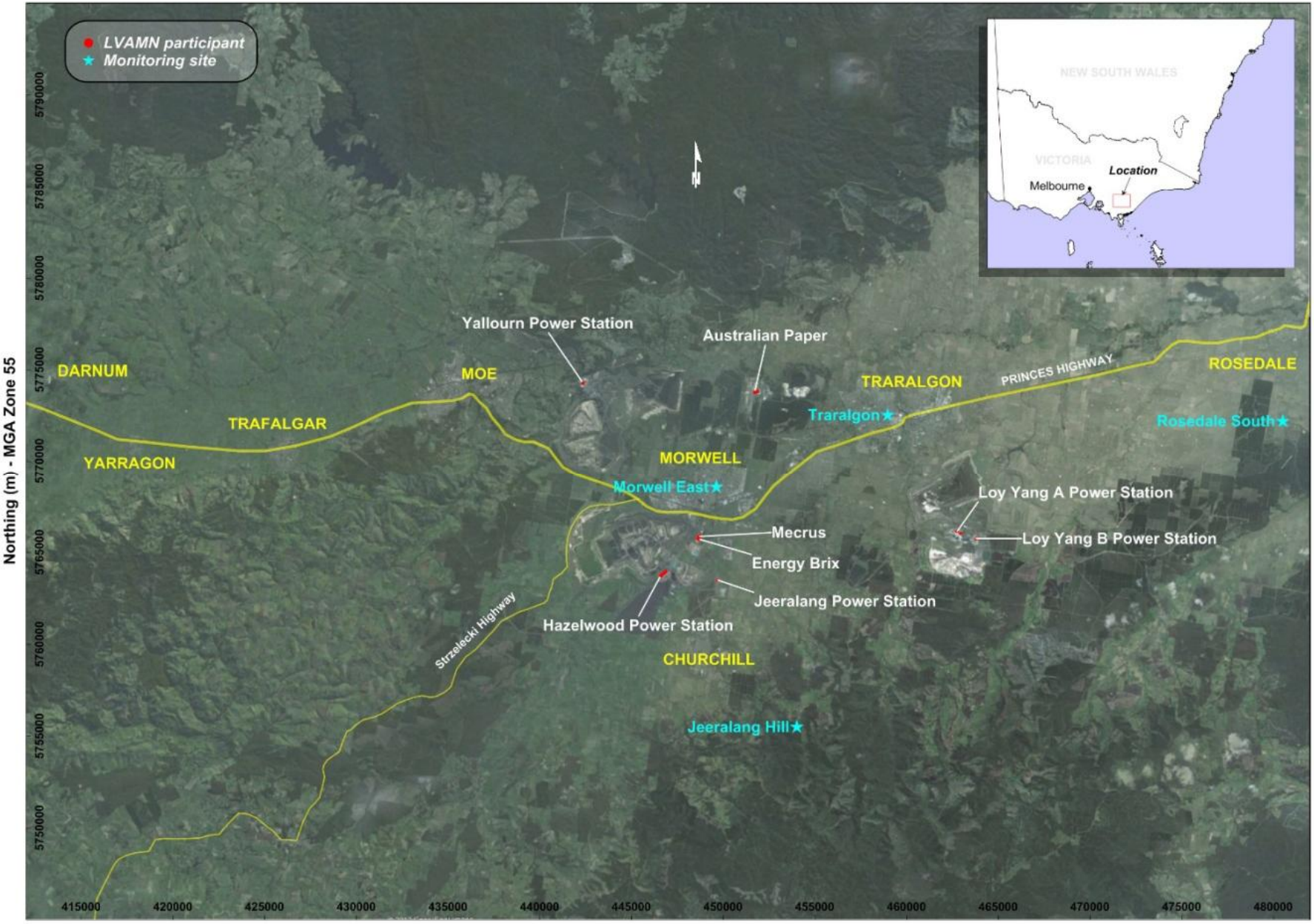
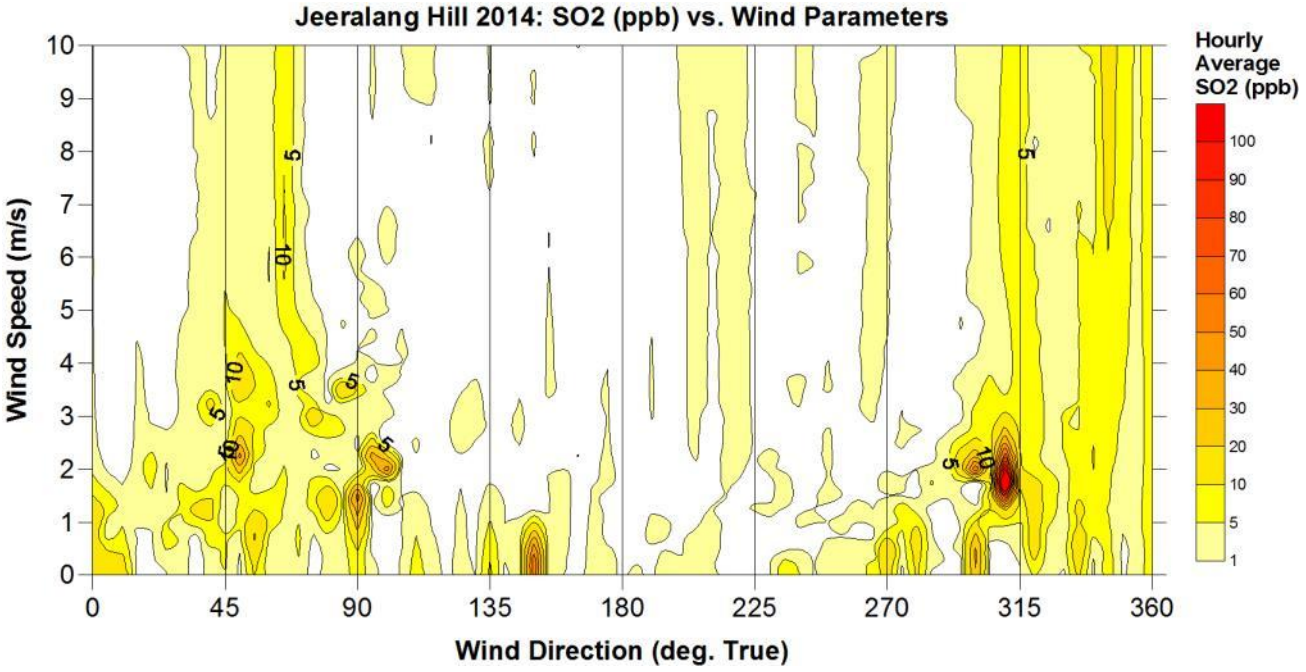
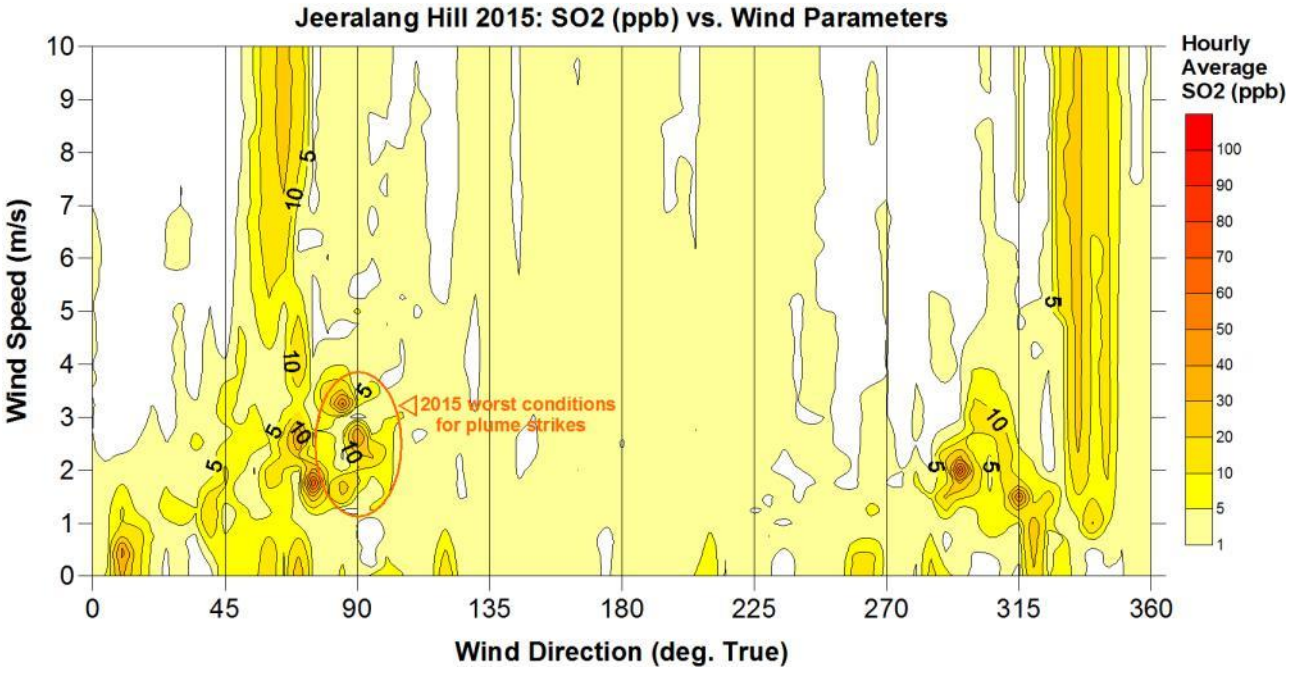
Appendix A. Map of Latrobe Valley


LVAMN participant
Monitoring site
NEW SOUTH WALES
VICTORIA
Location
Melbourne
Yallourn Power Station
Australian Paper
DARNUM
MOE
TRARALGON
PRINCES HIGHWAY
ROSEDALE
Traralgon★
Rosedale South★
TRAFALGAR
YARRAGON
MORWELL
Morwell East★
Loy Yang A Power Station
Loy Yang B Power Station
Mecrus
Energy Brix
Jeeralang Power Station
Hazelwood Power Station
Strzelecki Highway
CHURCHILL
Jeeralang Hill★
Northing (m) - MGA Zone 55
Easting (m) - MGA Zone 55
5790000
5785000
5780000
5775000
5770000
5765000
5760000
5755000
5750000
415000
420000
425000
430000
435000
440000
445000
450000
455000
460000
465000
470000
475000
480000

Appendix B. Jeeralang Hill 2014-2015: SO_2 and Winds

The SO_2-wind maps for 2014 (Jacobs, 2016b) and 2015 (this report) were created from hourly average SO_2 concentrations measured at Jeeralang Hill in 2014-2015, versus concurrent hourly average wind direction, and wind speed. The results illustrated highlight the complexity of air pollutant dispersion in the Strzelecki Ranges of the Latrobe Valley (refer to **Figure 1-1**). In 2015 at Jeeralang Hill, the highest SO_2 concentrations occurred after several hours of light easterly winds.

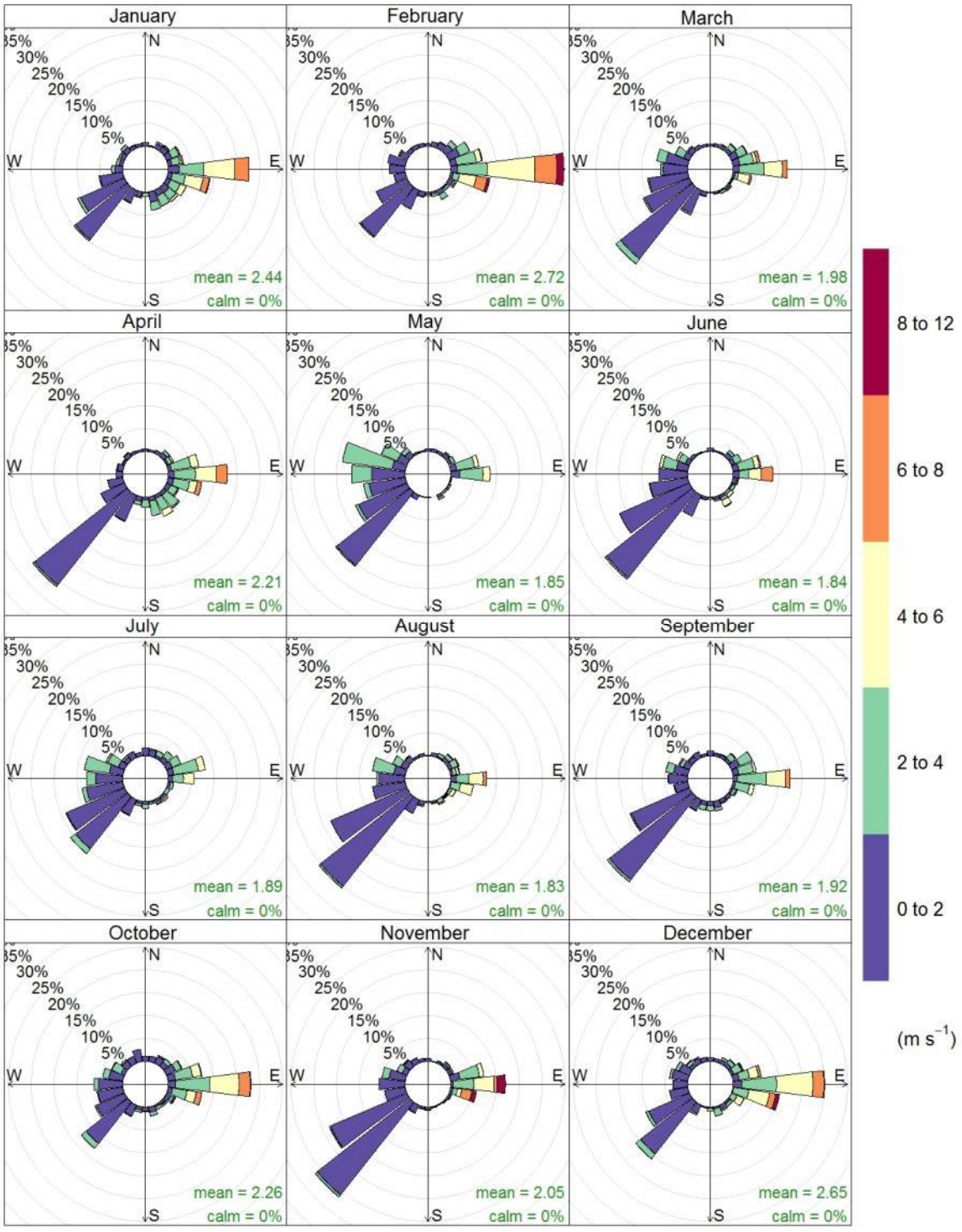




Appendix C. Wind Roses

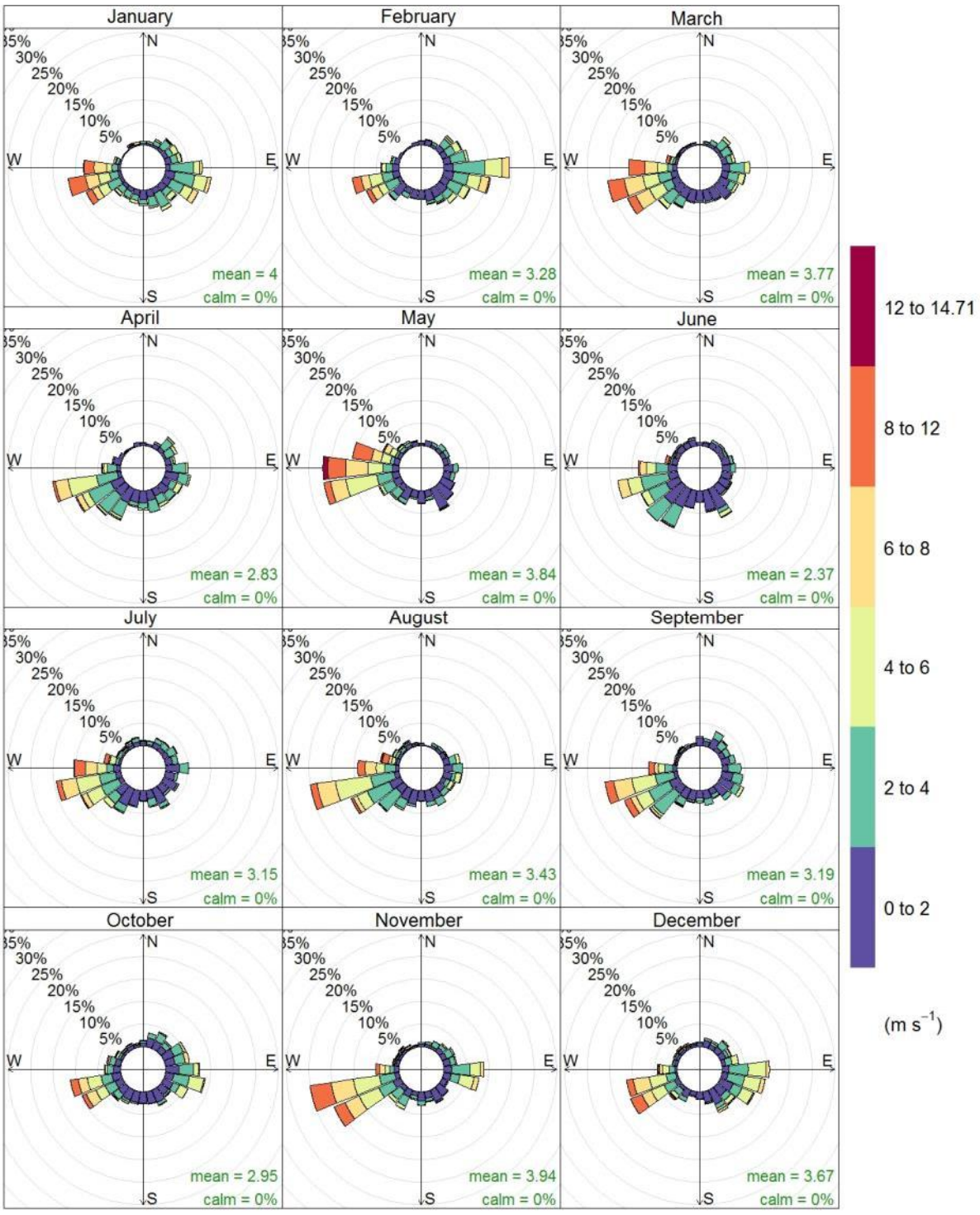
C.1 Jeeralang Hill 2015 Wind Roses

The Jeeralang Hill 2015 monthly wind rose plots were created using 8623 records of hourly average wind speed and wind direction data (for data capture see **Section 4.2**).



C.2 Rosedale South 2015 Wind Roses

The Rosedale South 2015 monthly wind rose plots were created using 8699 records of hourly average wind speed and wind direction data (for data capture see **Section 4.2**).



Frequency of counts by wind direction (%)