Report

Warrah Ridge Rearing Layer Farm – Odour and Dust Assessment

Pace Farm Pty Ltd

Job: 21-132

Date: 15 October 2021

Astute Environmental Consulting

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1 INTRODUCTION

Astute Environmental Consulting ("Astute") was engaged by PSA Consulting on behalf of Pace Farm Pty Ltd ("Pace") to perform an odour and dust assessment of the proposed Warrah Ridge Rearing Layer located at Warrah Ridge on the Liverpool Plains, in New South Wales.

1.1 Background

Pace proposes to submit a Development Application for a Free Range Rearing Farm on land described as Lot 2 on DP556635 ("the site"). The site will be known as Warrah Ridge Farm and will consist of four sheds with 62,000 birds per shed for a total of 248,000 birds. The sheds are described as toe to toe and will be 115 m long and 20 m wide.

The proposed farm is situated in the north west corner of the Lot adjacent to Inverkip Road as presented in Figure 1-1, with the sheds coloured green.

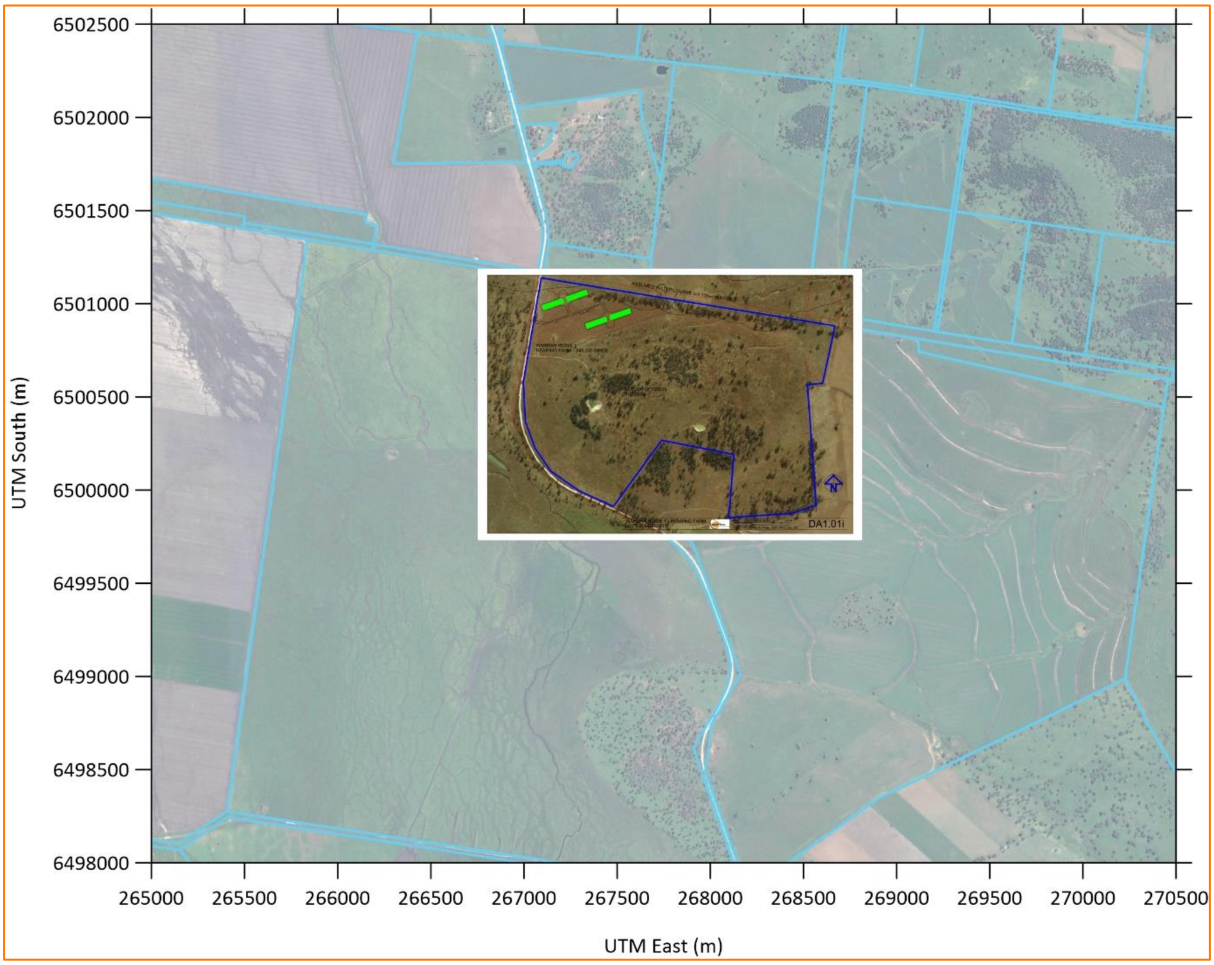


Figure 1-1: Proposed Farm and Surrounding Area (Source: Pace Farms)

1.2 Scope of Work

The scope of work for the assessment included:

- Obtaining information about the proposed sheds;
- Analysing regional weather data;

- Analysing on site weather data;
- Modelling meteorology for the area using TAPM/CALMET;
- Estimating dust emissions based on data in Poultry CRC (2011);
- Predicting odour dispersion using CALPUFF; and
- Preparing a report.

The modelling methodology used is summarised in Figure 1-2.

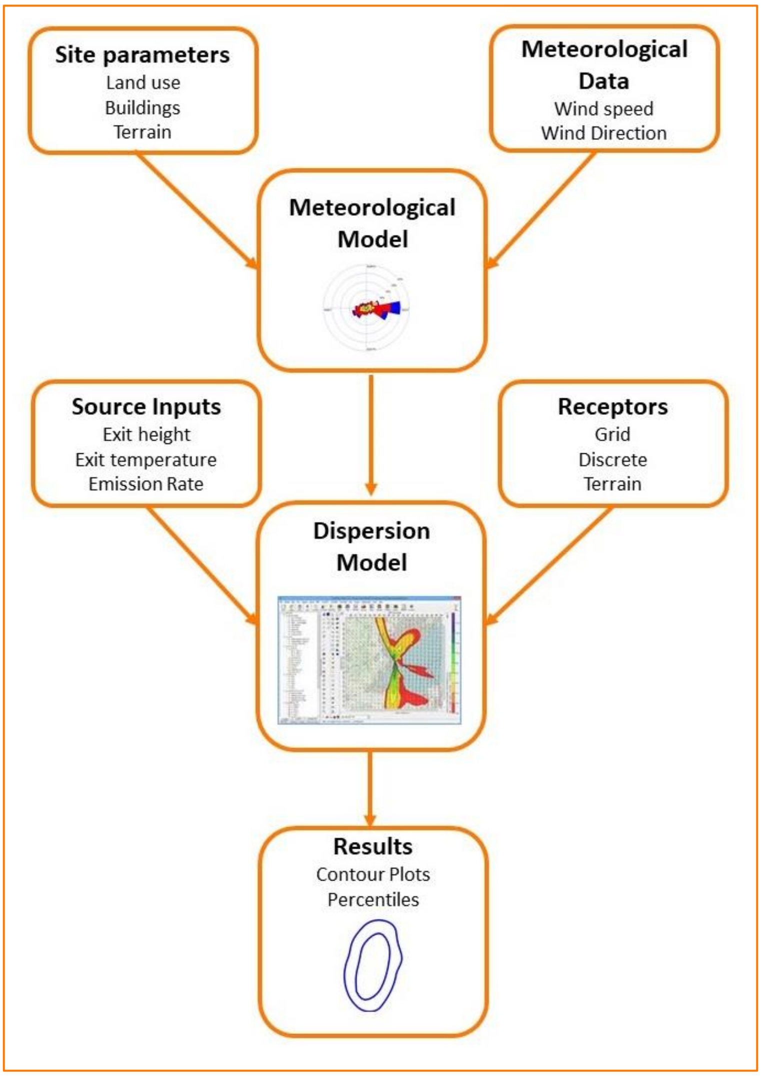


Figure 1-2: Modelling Methodology

2 ASSESSMENT CRITERIA

2.1 Odour

The odour criteria used in New South Wales are detailed in the Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (NSW EPA, 2016)[1]. For a complex mixture of odorants (i.e. odour measured as odour units), the criterion is selected based on the population density in an area. This is based on the concept that as population density increases, the number of people who may be sensitive to an odour increases. The criteria are summarised in Table 2-1.

Table 2-1: Impact Assessment Criteria from NSW EPA (2016)

Population of affected Community	Impact assessment criterion for complex mixtures of odorous air pollutants (ou)
Urban (≥~2000) and/or schools and hospitals	2.0
~500	3.0
~125	4.0
~30	5.0
~10	6.0
Single rural residence (≤~2)	7.0

Whilst no specific guidance is provided in the Approved Methods, the approach often suggested by NSW EPA for setting the odour criterion for a site is as follows:

- Model the site using standard methods;
- Prepare a contour plot showing the $C_{99\ 1sec}$ = 2 ou contour;
- Count the existing houses/dwellings within the 2 ou contour and include any proposed dwellings within the 2 ou contour;
- Calculate the average population per dwelling based on the average data from the most recent Census data;
- Based on the total population and then determine the criterion to be used based on Equation 7.2 in the Approved Methods.

This is discussed further in Section 5 below.

2.2 Particulate Matter

The Approved Methods (NSW EPA, 2016) also specifies the air quality assessment criteria relevant for assessing impacts from dust-generating activities. For this assessment, particulate matter less than 10 micrometres (PM_{10}) was included as the assessment parameter for dust emissions. PM_{10} is the size fraction that is generally the limiting dust parameter from poultry farms as it is generated by normal activities in the sheds (as opposed to combustion sources). This means that if the PM_{10} criteria are met, there is minimal risk of exceedances of dust deposition or particulate matter less than 2.5 micrometres ($PM_{2.5}$).

[1] "The Approved Methods"

Particulate matter criteria relevant to the proposed modification are detailed in Table 2-2.

Table 2-2: Particulate Matter Impact Criteria (NSW EPA, 2016)

Pollutant	Averaging Period	Concentration (µg/m^3)
PM_{10}	24-hour maximum	50
	Annual mean	25

3 MODELLING METHODOLOGY

3.1 Representative year

The selection of a representative meteorological year for dispersion modelling is important. Typically, a single year of data is included in an assessment.

Critical meteorological factors for air quality assessments include wind speed and temperature. These need to be assessed against long term data to determine which year is most similar to the average conditions rather than simply selecting a modelling year at random. However, for sites where local data (including on-site data) is used, and the emissions are independent of factors that vary can significantly year to year (i.e. rainfall) the selection of a representative year is not considered as significant as for a site where no local data is available.

In accordance with NSW EPA (2016) five years of meteorological data was analysed from the nearest BoM Station (which is located at the Tamworth Airport approximately 60 km to the northeast of the farm) from 2013 to 2017 to capture the recent data.

The Mann-Whitney U test for large sample sizes was also used to analyse the data for wind speed, temperature and relative humidity, as they often show a clear diurnal cycle. The box and whisker plot used above compares the dataset by year, rather than by hour. The null hypothesis for the U test is there is no significant difference between an individual year and the long-term average values. A summary of the best performing years (ranked 1 to 5) for the data period (2013 to 2017) is presented in Table 3-1. As expected, there was variability between the years.

Table 3-1: Representative year data for Tamworth BoM 2013-2017

Rank (best to last)	Temperature	Wind Speed	Relative Humidity
1	2017	**2014**	2017
2	2016	2013	2013
3	2013	2016	**2014**
4	**2014**	2015	2016
5	2015	2017	2015

The year 2014 was selected as the most representative with priority given to wind speed, the key meteorological parameter in dispersing odour and dust. Furthermore, 2014 was the most complete dataset for both the Tamworth BOM station and Tamworth NSW EPA station.

3.2 TAPM

TAPM (version 4), is a three-dimensional meteorological and air pollution model developed by CSIRO. The model is a prognostic model which uses synoptic-scale data to predict hourly meteorology in the area modelled. Details about TAPM can be found in the TAPM user manual (Hurley, 2008a) and details of the model development and underlying equations can be found in Hurley (2008b). Details of validation studies performed for TAPM are also available and include Hurley et. al. (2008c).

TAPM v4 predicts meteorological data including wind speed and direction in an area using a series of fluid dynamics and scalar transport equations (Hurley, 2008b) and it has both prognostic meteorological and air pollution (dispersion) components. The benefit of using TAPM is that key meteorological aspects including the influence of terrain induced flows are predicted both locally and regionally.

The TAPM default land use database was further refined to include more agricultural and cropping land with some scattered low density bushland within the 1 km modelling domain. The default and adjusted land-use files are presented in Figure 3-1. The TAPM setup is summarised in Table 3-2 and is consistent with good practice and the requirements in NSW EPA (2016).

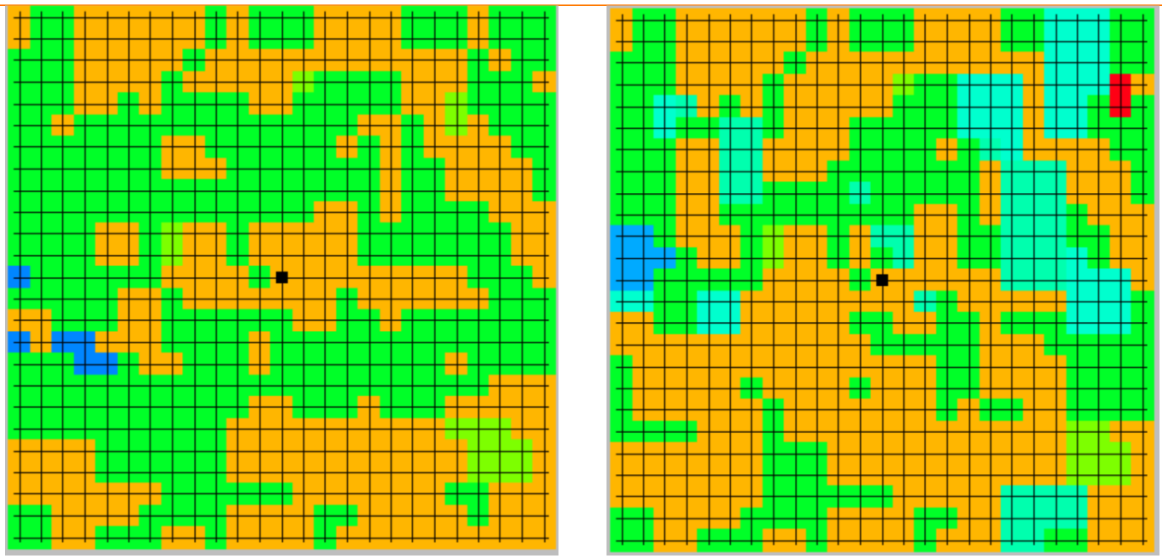


Figure 3-1: Default TAPM (left) and Adjusted Land use (right) for the Site

3.3 CALMET

CALMET is the meteorological pre-processor to CALPUFF and generates wind fields which include slope flows, terrain effects, and can incorporate factors including terrain blocking. CALMET uses meteorological inputs in combination with land use and terrain information for the modelling domain to predict a three-dimensional meteorological grid (which includes wind speed, direction, air temperature, relative humidity, mixing height, and other variables) for the area (domain) to be modelled in CALPUFF.

A 20 km x 20 km domain with a terrain resolution of 100 m was modelled with the centre of the domain to the northeast of the site. A terrain resolution of 30 m was used throughout the domain and was initially taken from the SRTM dataset using CALPUFF view. This was then converted to a 100 m resolution for the model runs.

Land use was initially based on the Australia Pacific Global Land Cover Characterisation (GLCC) dataset at 1km resolution. The land use was then manually edited at 100 m resolution based on a recent aerial photograph of the area using Google Earth Pro and CALPUFF View.

Key inputs used in TAPM and CALMET are summarised below in Table 3-2.

Table 3-2: TAPM and CALMET Setup

Model	Parameter	Value
TAPM (v 4.0.5)	Number of grids (spacing)	30km, 10km, 3km, 1km
	Number of grid points	25 x 25 x 25 (vertical)
	Year of analysis	2014
	Centre of analysis	31°35'00" South (latitude), 150°33'30" East (longitude)
	Meteorological data assimilation	N/A
CALMET (v 6.334)	Meteorological grid domain	20km x 20km
	Meteorological grid resolution	0.10km
	South-west corner of domain	X = 258.000 km, Y = 6493.500 km
	Surface meteorological stations	N/A
	Upper air meteorological data	N/A
	3D Windfield	m3D from TAPM (1km) input as in initial guess in CALMET
	Year of analysis	2014
	Terrad	4.0 km
	Cloud	4 - Gridded cloud cover from Prognostic Relative Humidity at all levels
	IKINE	1

Note: On site data was not modelled as there was no full year available for modelling. In lieu of this, and consistent with the Approved Methods we modelled a representative year. See also Section 5.1 below.

3.4 CALPUFF

CALPUFF (Exponent, 2011) is a US EPA regulatory dispersion model and is a non-steady state puff dispersion model that simulates the effects of varying meteorological conditions on the emission of pollutants. The model contains algorithms for near source effects including building downwash, partial plume penetration as well as long range effects such as chemical transformation and pollutant removal. CALPUFF is widely recognised as being the best model for odour studies as it handles light wind conditions and terrain effects better than simpler steady state models such as AUSPLUME and AERMOD. As such it is accepted as a regulatory model in all states of Australia.

CALPUFF simulates complex effects including vertical wind shear, coastal winds including recirculation and katabatic drift. The model employs dispersion equations based on a Gaussian distribution of puffs released within the model run, and it takes into account variable effects between emission sources.

Key inputs used in CALPUFF for the project are summarised below in Table 3-3.

Table 3-3: CALPUFF Setup

Model	Parameter	Value
CALPUFF (v 6.40)	Meteorological grid domain	20km x 20km
	Meteorological grid resolution	0.10km
	South-west corner of domain	X = 258.000 km, Y = 6493.500 km
	Method used to compute dispersion coefficients	2 - dispersion coefficients using micrometeorological variables
	Minimum turbulence velocity (Svmin)	0.2 m/s
	Building downwash included	No
	Default settings	All other CALPUFF defaults have been used in line with OEH (2011).

The proposed sheds will be tunnel ventilated and therefore have been represented as pseudo point sources at the fan end of the sheds. This means that each shed had a point source on the tunnel fan end of each shed with a diameter the same as the shed width. The vertical velocity in the point source was varied as a function of the maximum predicted ventilation rate to ensure that the momentum of the plume (and thus plume mass) was maintained. The vertical momentum was set to zero by using the 'rain hat' switch in CALPUFF. This ensures that the plume did not move vertically in the model but starts near ground level and disperses slowly from there. The shed exit temperature was assumed to be consistent with shed target temperatures.

Building wake has been shown to have a negligible effect on the predicted concentrations of low-level sources such as chicken sheds therefore building wake has not been included in the modelling.

3.5 Emissions Estimation

3.5.1 Farm Setup

The Warrah Ridge Farm 1 will consist of four sheds with 62,000 birds per shed for a total of 248,000 birds. The sheds are described as toe to toe and measure 115m x 20m. The site plan is presented in Figure 3-2.

Day old birds will be placed in the sheds and grown for 17 weeks, and then the sheds will be cleaned over a 3 week period before being restocked.

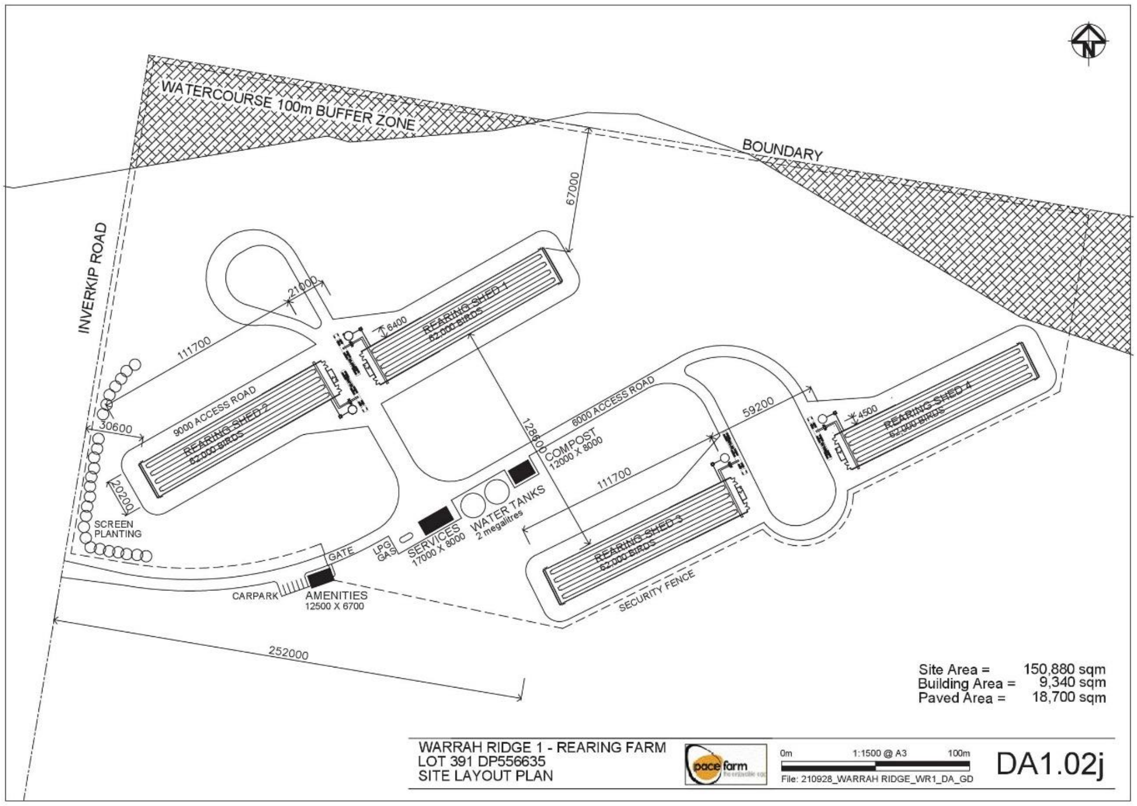


Figure 3-2: Warrah Ridge Farm (Source: Pace)

3.5.2 Odour

The odour emissions model of Ormerod and Holmes (2005) was used as the basis of this assessment. The methodology is referred to in the *Best Practice Guidance for the Queensland Poultry Industry - Plume Dispersion Modelling and Meteorological Processing* (PAEHolmes, 2011) and is widely used in Australia. The method is based on odour test data at a number of farms and uses a series of equations, which enable emissions to be predicted as a function of:

- the size and number of birds present;
- the stocking density of birds; and
- the ventilation rate, which varies by bird age and ambient temperature.

The odour emissions rate is predicted using the following equation (Ormerod & Holmes, 2005; PAEHolmes, 2011):

$$OER = 0.025 \times K \times A \times D \times V^{0.5}$$ **Equation 1**

Where ***OER*** = odour emission rate (ou/s), ***A*** = total shed floor area (m²), ***D*** = average bird density (in kg/m²), **V** is the ventilation rate in m³/s and **K** if the K factor.

The K factor is a scaling factor which is used to reflect the performance of a farm. For meat chicken farms, a K factor of 2 is commonly used. However it is recognised that layer/rearer farms are of a lower risk than meat chicken farms in terms of odour emissions and offensiveness of the odour.

The most recent data we have for layer rearer sheds indicates a K factor of 0.8 is appropriate. For conservatism, and test the model outputs, we have modelled the farm with K=0.8 and K=2.0. For the sheds, we have modelled a 17 week batch instead of a 7 to 8 week batch for meat chickens and have matched the rearer shed batch length with typical commercial layer growth rates.

Maximum shed ventilation rates were based on typical shed ventilation rates (~10 m^3/hr/bird at maximum). Table 3-4 shows the shed ventilation rate (% of maximum) as a function of temperature above target temperature based on PAEHolmes (2011).

Table 3-4: Calculated Shed Ventilation as Percentage of Maximum Ventilation

Bird Age (weeks)	1	2	3	4	5	6	7	≥8
Temperature (°C) above Target		**Ventilation Rate (Percent of maximum)**						
<1	1.3	2.5	5.1	7.6	9.8	11.5	17.0	17.0
1	1.3	12.5	12.5	25.0	25.0	25.0	25.0	25.0
2	1.3	25.0	25.0	37.5	37.5	37.5	37.5	37.5
3	1.3	37.5	37.5	50.0	50.0	50.0	50.0	50.0
4	1.3	37.5	37.5	50.0	50.0	50.0	50.0	50.0
6	1.3	37.5	37.5	62.5	75.0	75.0	75.0	75.0
7	1.3	37.5	37.5	62.5	75.0	75.0	87.5	100.0
8	1.3	62.5	62.5	62.5	75.0	75.0	100.0	100.0
9	1.3	62.5	62.5	87.5	100.0	100.0	100.0	100.0

An example profile for one shed is shown below in Figure 3-3.

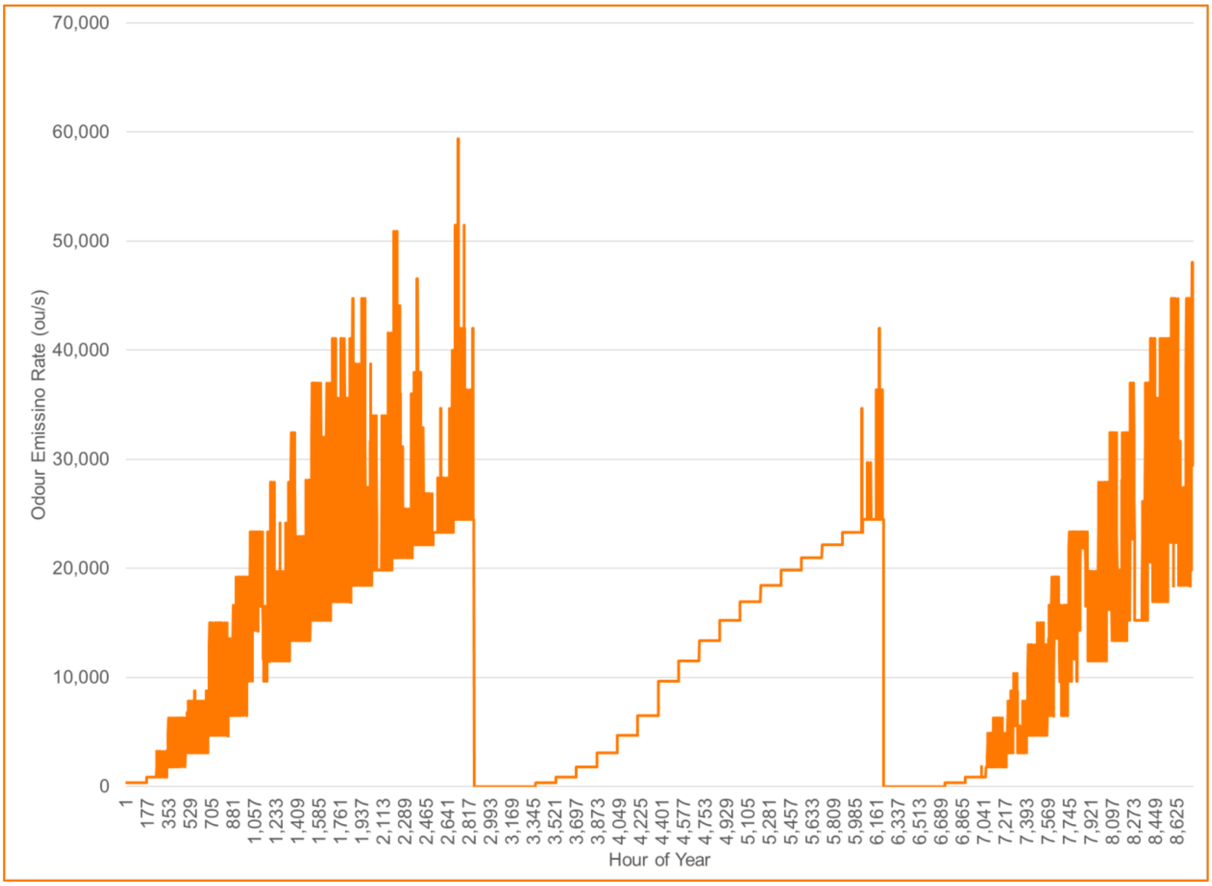


Figure 3-3 Example Layer Profile K=2 (62,000 birds)

3.5.3 Dust Emissions

The PM_{10} emission rates have been calculated using the relationship provided below in Figure 3-4 in conjunction with the ventilation rates mentioned in the previous two sections. The relationships were derived based on emission rate data from Poultry CRC (2011).

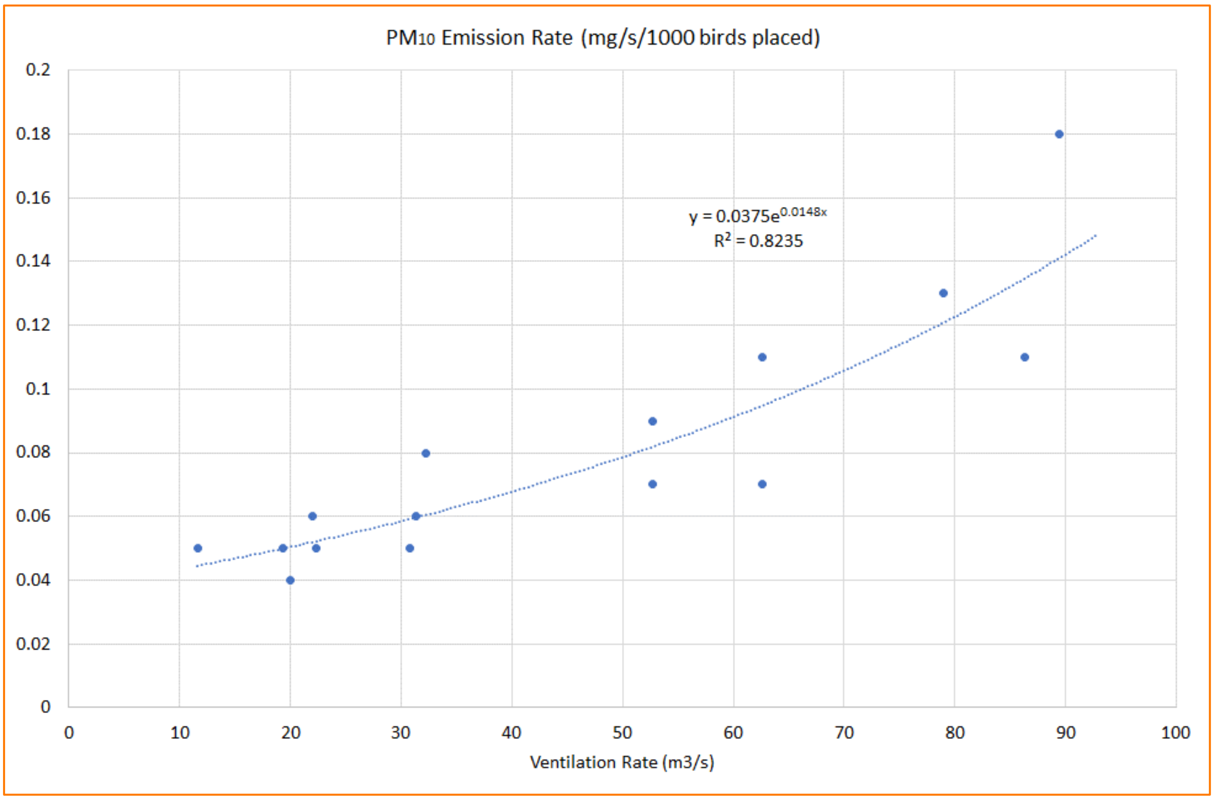


Figure 3-4 PM_{10} Emission Rate for Layers

3.6 Sensitive Receptors

Several sensitive receptors were identified during the modelling process. The location of the receptors as identified by spatial imagery are detailed below in Table 3-5.

Table 3-5: Identified Receptors (UTM m WGS84)

Number	Easting	Northing	Comments
SR1	266,836	6,505,647	
SR2	267,270	6,507,949	
SR3	269,248	6,507,453	
SR4	270,023	6,507,276	
SR5	270,172	6,506,560	
SR6	272,057	6,505,420	
SR7	271,000	6,504,783	
SR8	271,224	6,504,342	
SR9	272,079	6,503,039	
SR10	276,343	6,501,413	
SR11	277,737	6,500,880	
SR12	272,964	6,498,730	
SR13	273,419	6,495,632	
SR14	272,118	6,495,653	
SR15	269,836	6,497,477	
SR16	269,961	6,496,955	
SR17	270,005	6,496,344	
SR18	268,457	6,496,259	
SR19	264,124	6,497,489	
SR20	263,175	6,498,447	
SR21	266,821	6,501,972	
SR22	267,086	6,501,914	
SR23	267,412	6,501,993	
SR24	260,943	6,502,411	
SR25	266,500	6,503,704	Owned by Pace – Not sensitive
SR26	261,210	6,505,213	
SR27	261,709	6,505,129	
SR28	261,684	6,505,732	
SR29	261,843	6,507,371	
SR30	262,386	6,508,616	
SR31	261,478	6,509,034	
SR32	258,780	6,512,324	
SR33	263,327	6,512,117	
SR34	265,970	6,507,106	

3.7 On site Weather Station

Pace Farm commissioned Measurement Engineering Australia (MEA) to install and manage an onsite weather station. A summary of the details that have been provided to Astute are as follows;

- Station went live on the 15 December 2020 collecting valid data;
- Sensor is installed on a 9 m mast;

- A Gill 2D ultrasonic wind speed and direction sensor are positioned at 10 m from ground level;
- Air temperature and humidity sensor in sensor shelter located near ground level;
- Tipping bucket rain gauge on raised mount located adjacent to the weather station;
- Data is logged on a 15 minute period;
- A logger with remote telemetry with data uploading to MEA's Green Brain server;
- Wind speed and direction averaging is performed using vector averaging methods; and
- No information regarding averaging techniques or calibration standards have been provided.

Dispersion modelling assessments are conducted over a period of at least 12 months of continuous meteorological data. Due to the limited data available, the weather station observations haven't been assimilated in the TAPM or CALMET modelling methodology. At the time of writing the TAPM synoptic data has been released up until the end of August 2021.

A comparison of the basis of the modelling methodology presented in this report against the observational data is presented below in Section 5.1 which shows TAPM performs well at the site.

4 EXISTING ENVIRONMENT

The principal meteorological parameters that influence plume dispersion are wind direction, wind speed, atmospheric stability (turbulence) and atmospheric mixing height (height of turbulent layer). This section presents a summary of the key meteorological features

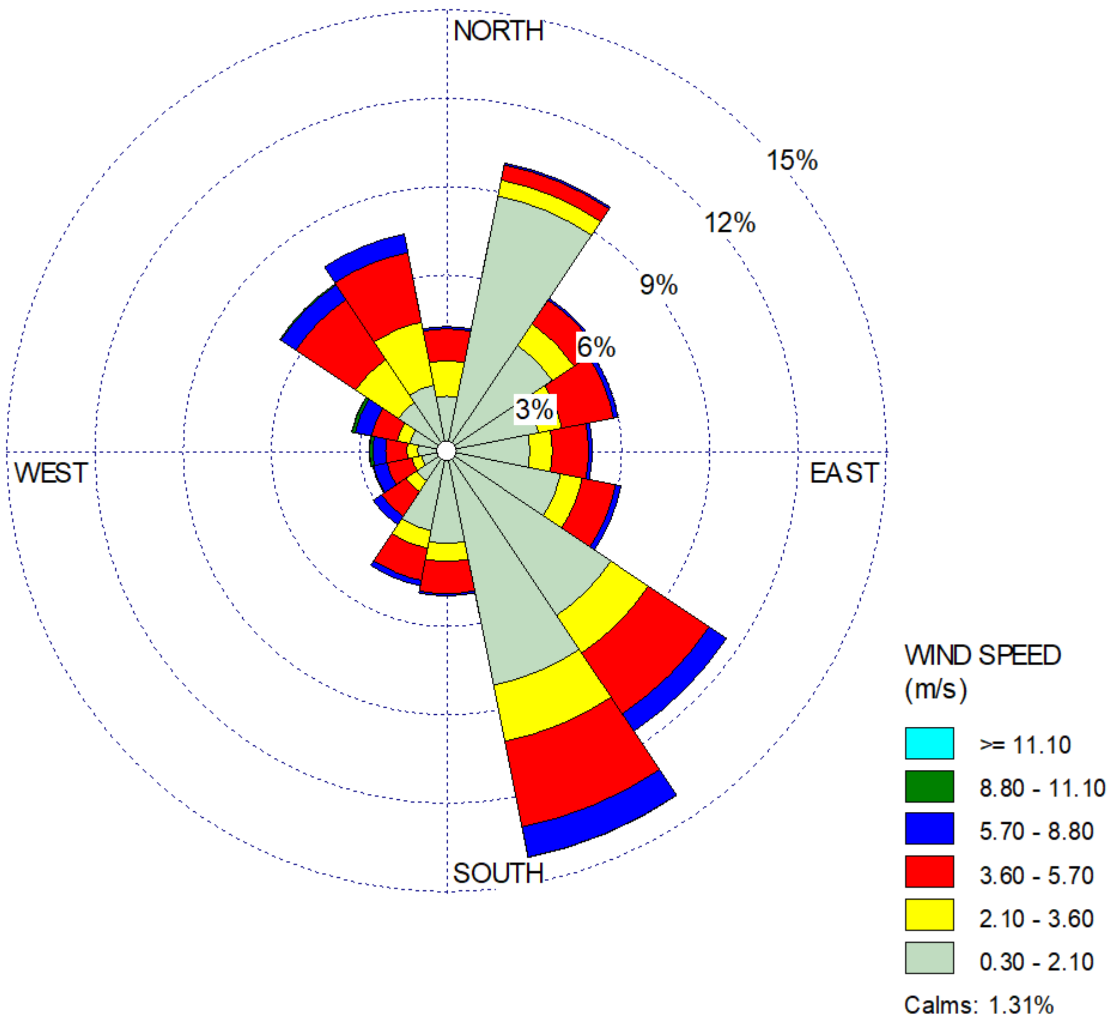
4.1 Metrological Data

4.1.1 Wind Speed and Direction

Wind roses are used to show the frequency of winds by direction and strength. The bars show the compass points (north, north-north-east, north-east etc) from which wind could blow. The length of each bar shows the frequency of winds from that direction and the different coloured sections within each bar show the wind speed categories and frequency of winds in those categories. In summary, wind roses are used to visually show winds over a period of time.

The wind roses below were created from data extracted from CALMET and are presented in Figure 4-1 and Figure 4-2. The annual wind rose (Figure 4-1) shows that the site is dominated by south easterly winds with a noticeable northerly component.

The wind roses show a low proportion of calm winds (~1%) with light winds over the year (up to 3 m/s) occurring ~67% of the time. The wind speed frequencies are summarised graphically in Figure 4-3.

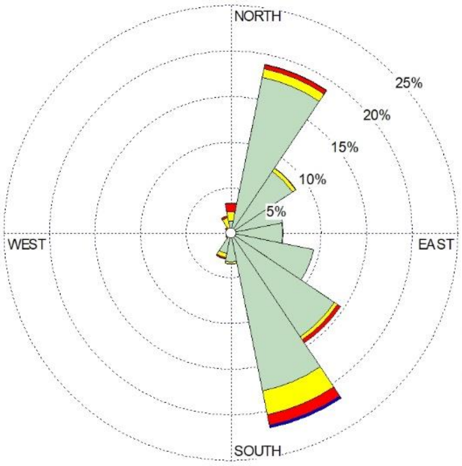


Location: Centre of domain	*Year:* 2014	*Data Source:* CALMET extract
Calm winds: 1.31 %	*Average wind speed:* 2.89 m/s	*Creator:* W. Shillito

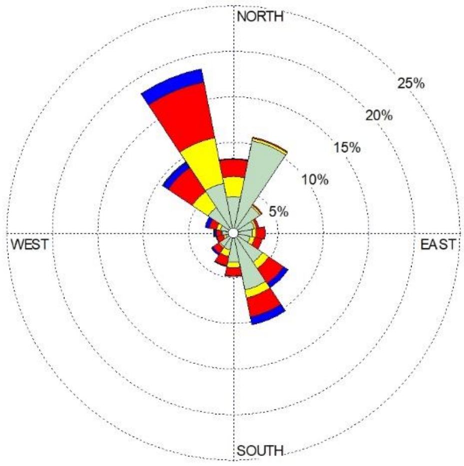
Figure 4-1: Annual Wind Rose for Centre of Domain[2]

[2] Approximately 2 km east of weather station location

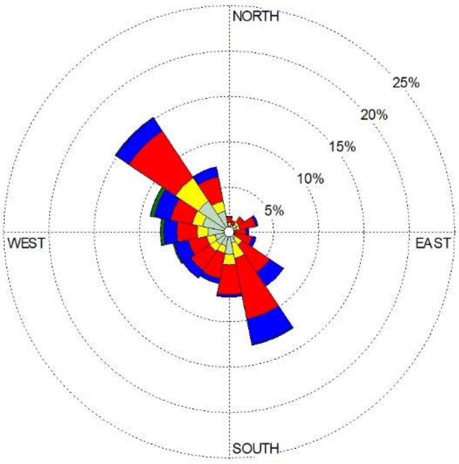
1 AM to 6 AM



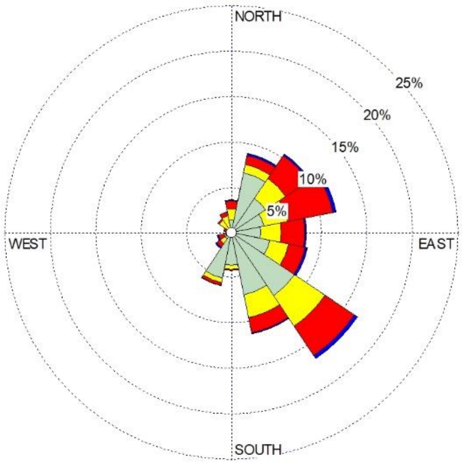
7 AM to 12 PM



1 PM to 6 PM



7 PM to 12 AM



Period	*Average wind speed (m/s)*	*Calm winds %*	WIND SPEED (m/s)
1 AM to 6 AM	1.6	1.4%	>= 11.10
7 AM to 12 PM	2.5	2.7%	8.80 - 11.10 5.70 - 8.80
1 PM to 6 PM	3.9	1.1%	3.60 - 5.70 2.10 - 3.60
7 PM to 12 AM	2.6	0.1%	0.30 - 2.10
Location: Centre of domain	*Year:* 2014	*Data Source:* CALMET extract	*Creator:* W. Shillito

Figure 4-2: Time of Day Wind Rose for the site

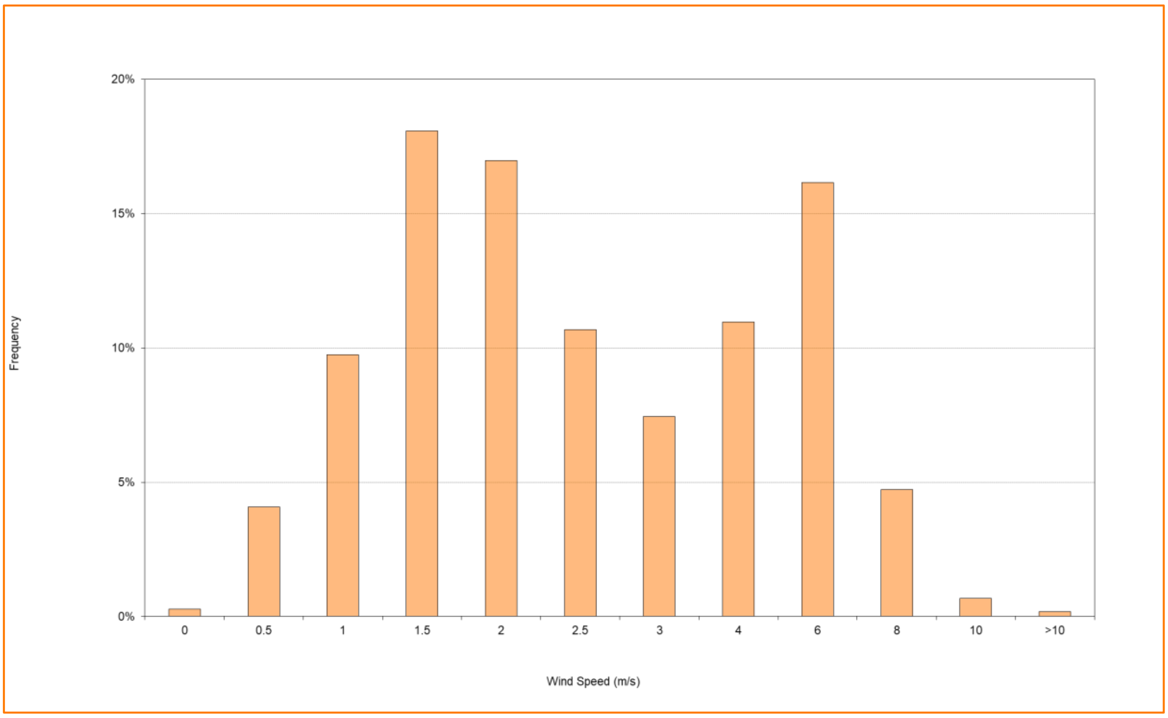


Figure 4-3 Wind Speed Frequency from CALMET

4.1.2 Atmospheric Stability

Atmospheric stability is a key factor in dispersion modelling and is used to describe turbulence in the atmosphere. Turbulence is an important factor in plume dispersion. Turbulence increases the width of a plume due to random motion within the plume. This changes the plume cross-sectional area (width and height of the plume), thus diluting or spreading the plume. As turbulence increases, the rate at which this occurs also increases. Limited or weak turbulence, therefore, does not dilute or diffuse the plume as much as strong turbulence, and leads to high downwind concentrations. This is often associated with low wind speeds (<0.3 m/s).

The Pasquill-Gifford stability scheme has been in use for many years to define turbulence in the atmosphere. The scheme uses stability classes from A to F[3]. Class A is highly unstable and at the other end of the scheme are class F conditions, which are very stable conditions that commonly occur at night and in the early morning. As noted above, under stable conditions, plumes do not disperse as well as during the day (unstable conditions) and these conditions can lead to impacts, especially for ground level sources.

Between Class A and Class F are stability classes which range from moderately unstable (B), through neutral (D) to slightly stable (E). Whilst classes A and F are most often associated with clear skies, class D is linked to sunset and sunrise, or cloudy and/or windy daytime conditions. Unstable conditions most often occur during the daytime and stable conditions are most common at night.

The stability classes predicted by CALMET for the Development Site are summarised in Figure 4-4. The data shows that E and F class stability occurs ~44% of the time. The frequency of D class

[3] Note that CALPUFF uses a more accurate micrometeorological scheme for turbulence.

stability (25%) is commonly seen in areas with winds above 2.5 m/s at night or site with a high frequency of cloudy days.

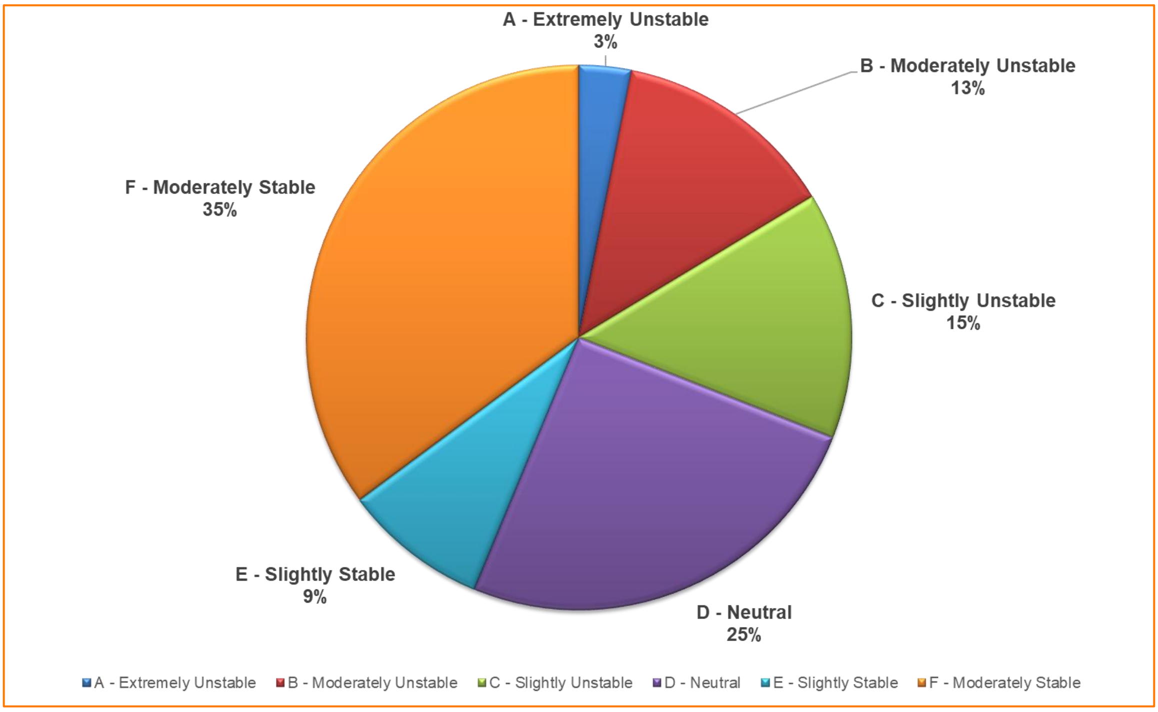


Figure 4-4: Atmospheric Stability

4.1.3 Atmospheric Mixing Height

The mixing height is the height of vertical mixing of air and suspended gases or particles above the ground. This height can be measured by the observation of the atmospheric temperature profile. A parcel of air rising from the surface of the Earth will rise at a given rate (called the dry-adiabatic lapse rate). As long as the parcel of air is warmer than the ambient temperature, it will continue to rise. However, once it becomes colder than the temperature of the environment, it will slow down and eventually stop (University of Michigan , 2004).

The mixing height is commonly referred to as an inversion layer. It is an important parameter when assessing air emissions as it defines the vertical mixing of a plume. This is because the air below the layer has restricted dispersion vertically and therefore the higher the mixing height, the more potential for dispersion.

The estimated variation of mixing height over time predicted at the site by CALMET is shown in Figure 4-5. The diurnal cycle is clear in this figure whereby at night the mixing height is normally relatively low and after sunrise, it increases as a result of heat associated with the sun on the Earth's surface. Overall, the estimated mixing height shown below is as expected.

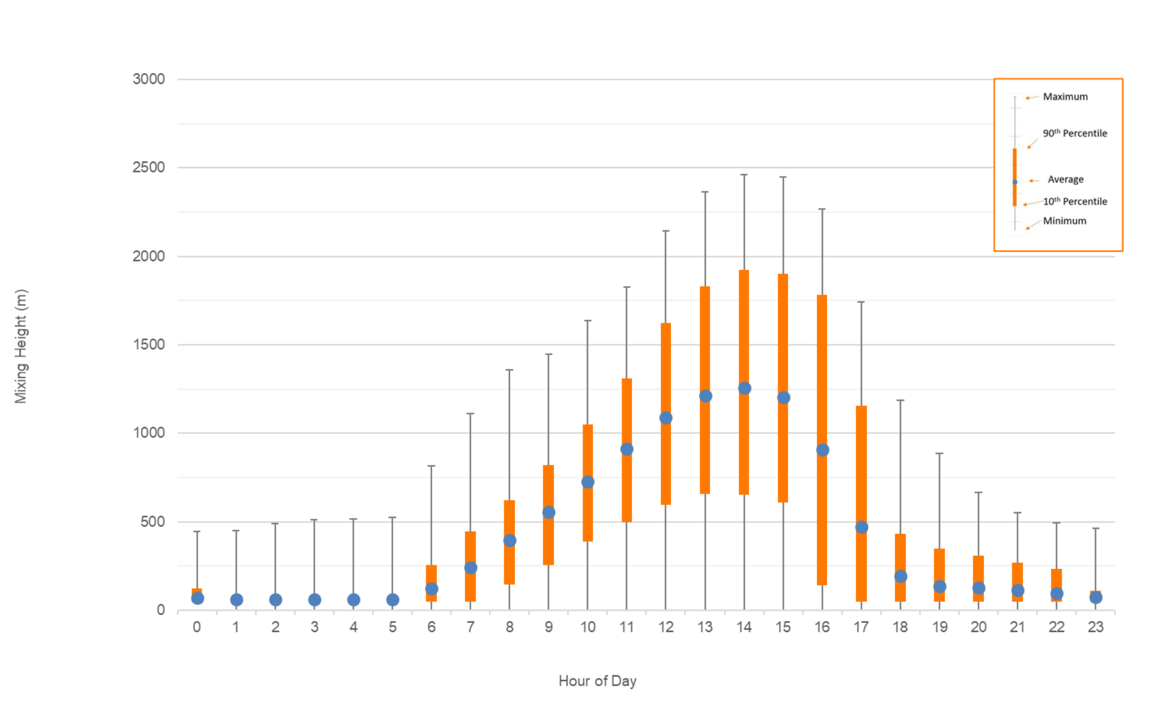


Figure 4-5: CALMET Extract – Predicted Mixing Heights

4.2 Background Air Quality Data

Existing air quality in the region is influenced by the following sources:

- Dust from agricultural activities (ploughing, harvesting, bailing);
- Wind erosion from exposed areas; and
- Wheel generated dust from unsealed rural roads.

The Office of Environment and Heritage (OEH) operates several monitoring stations throughout New South Wales. The closest monitoring station, being within the township of Tamworth, has been selected as the source of background data for the proposed modification. As there are numerous combustion sources within Tamworth including heavy vehicle traffic the measured concentrations would be higher than that typically expected at Warrah Ridge.

In accordance with the Approved Methods (NSW EPA, 2016) a level two assessment incorporating background data is as follows;

- Obtain ambient monitoring data that includes at least one year of continuous measurements and is contemporaneous with the meteorological data used in the dispersion modelling.
- At each receptor, add each individual dispersion model prediction to the corresponding measured background concentration (e.g. add the first hourly average dispersion model prediction to the first hourly average background concentration) to obtain hourly predictions of total impact.
- At each receptor, determine the 100th percentile (i.e. maximum) total impact for the relevant averaging period.

A statistical summary for the 2014 monitoring year (24 hour PM_{10}) is provided in Table 4-1. The ranked background 24 hour averaged data is shown in Figure 4-6.

Table 4-1 below shows that the average concentration was 15.8 µg/m^3 and the dataset as a whole was dominated by a small number of high values (with the second highest value being 39.2 µg/m^3). This is also shown clearly in Figure 4-6 and the use of the maximum background value would produce an unrealistic estimate of the expected maximum dust concentrations in the area as the long term maximums and 99th percentiles in the area were typically below this (NSW OEH, 2016).

Table 4-1: Statistical summary of Tamworth Monitoring Data

Parameter	PM_{10} 24 – hour
Monitoring period	01/01/2014 – 31/12/2014
Averaging period	24 hours
Number of validated measurements	363
Data capture	99.4%
Average	15.8 µg/m^3
Standard deviation	7.0 µg/m^3
Percentiles and Concentrations (µg/m^3)	
25th	11.0
50th	14.9
70th	18.1
90th	24.7
99th	36.2
3rd highest	37.4
2nd highest	39.2
Maximum	**66.6** (15/11/2014)
Annual Average	**15.8**

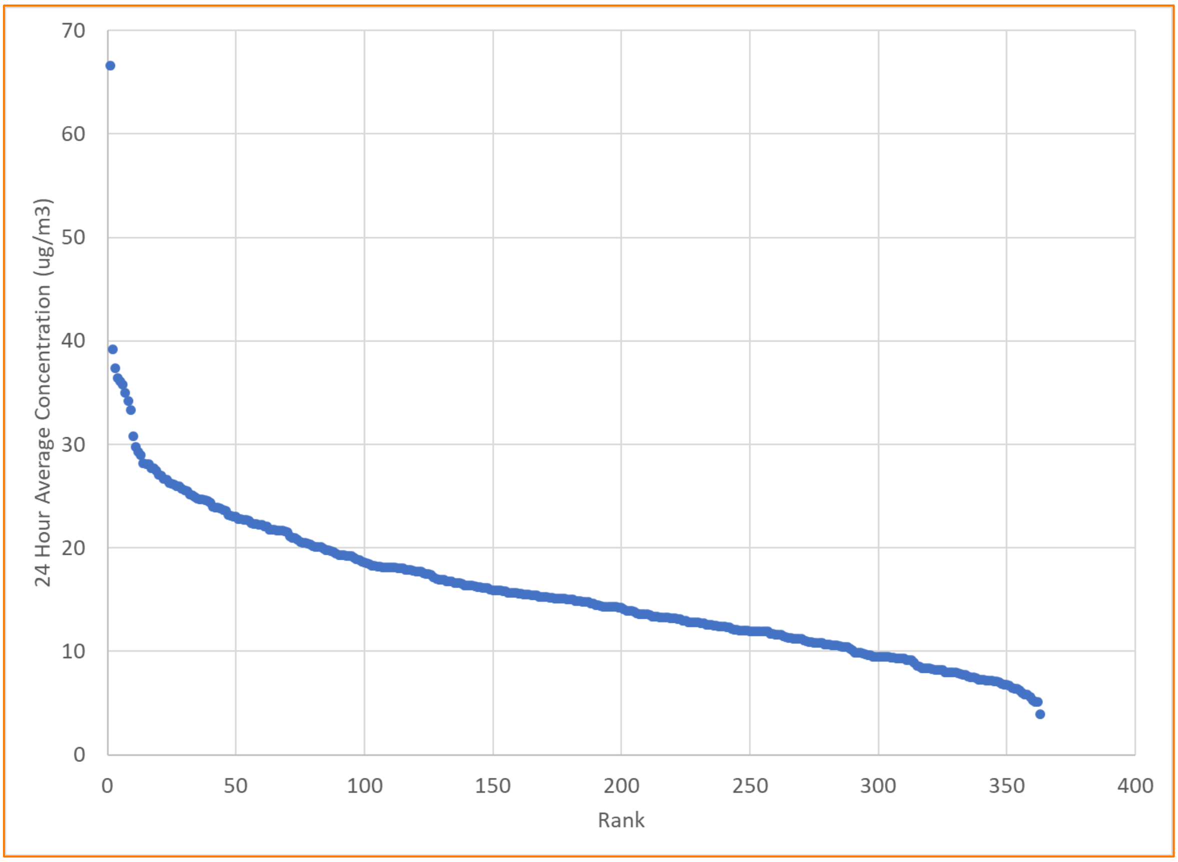


Figure 4-6: Ranked Background – 24 Hour Average PM_{10}

For the annual average PM_{10} background, a concentration of 15.8 µg/m^3 was used.

5 RESULTS

5.1 Meteorological Methodology Validation

Prior to selecting a modelling methodology, a TAPM run was made whereby data from the weather station was compared to a standard TAPM run prepared in line with the Approved Methods. The run was centred as close as practicable to the weather station location and was run from 16 December 2020 to 29 June 2021. This period was selected based on the TAPM synoptic data at the time. The paired hourly data from the weather station and TAPM for the same period from a 1 km grid were analysed using the methodology detailed in Emery et al. (2001) with the exception that daily wind direction analysis was also performed in line with Johnson (2019). Johnson recommended daily gross error checks for direction as opposed to hourly.

We also considered the work of Kemball-Cook et. al (2005) who proposed a series of benchmarks for model performance under complex conditions including areas with variable terrain heights and land uses. Kemball-Cook et al. suggested a gross error benchmark of ≤55° for wind direction and a bias benchmark of ≤10° for areas with complex features. These benchmarks were subsequently adopted in many studies including USEPA (2015)and USEPA (2020).

The American Meteorological Society (2012) defines complex terrain as “A region having irregular topography, such as mountains or coastlines. Complex terrain can also include variations in land use, such as urban, rural, irrigated, and unirrigated”.

The 15 minute weather station data was vector averaged for wind direction and arithmetically averaged for wind speed in line with USEPA (2000).

An analysis of the weather station and TAPM dataset[4] is presented in the following;

- Table 5-1: Wind Speed Statistics;
- Table 5-2: Wind Direction Statistics;
- Figure 5-1: TAPM Wind Rose Comparison; and
- Figure 5-2: Wind Speed Frequency.

Table 5-1: Wind Speed Statistics (1 km TAPM Grid)

Variable	Calculated Value	Criteria	Meets Criteria?
Bias	0.0	±0.5	Yes
RMSE	1.3	≤2	Yes
IO	0.8	≥0.6	Yes
SkillE	0.9	≤1	Yes
SkillR	0.9	≤1	Yes
SkillV	1.2	Close to 1	Yes

[4] Note the extract location for TAPM was taken near the weather station which is different to the centre of the CALMET grid.

Table 5-2: Wind Direction Statistics

Variable	Calculated Value	Criteria	Meets Criteria?
Bias (hourly)	6°	±10°	Yes
Gross Error (hourly)	48°	≤30° ≤55° (complex)	Yes for complex.
Bias (daily)	11°	±10	Yes
Gross Error (daily)	35°	≤30° ≤55° (complex)	Yes for complex.

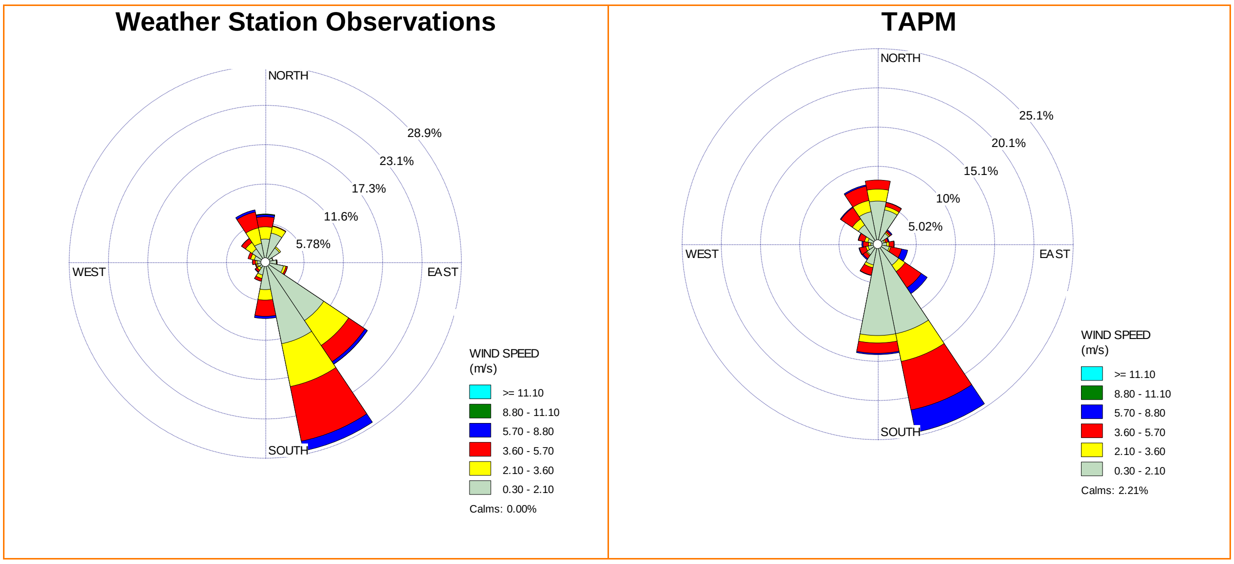


Figure 5-1: TAPM Wind Rose Comparison

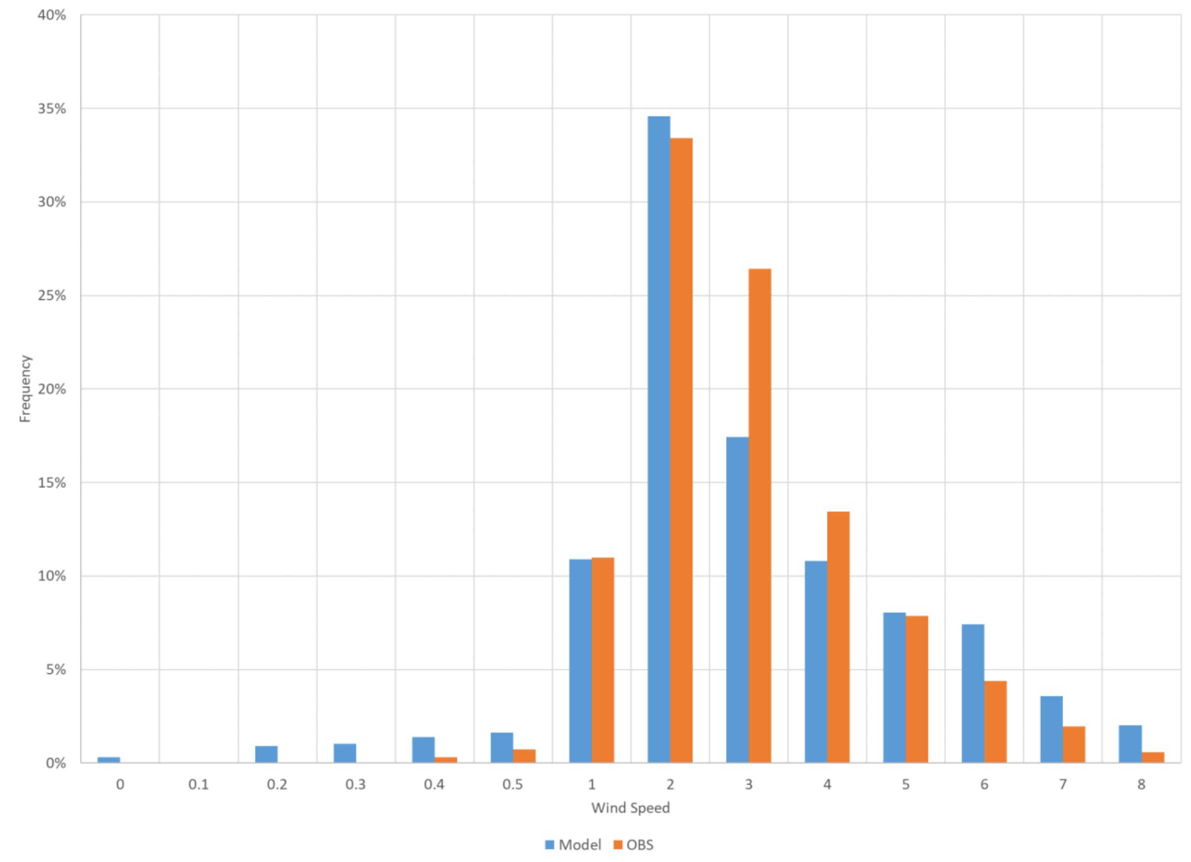


Figure 5-2: Wind Speed Frequency

A summary of the validation is as follow:

- The wind roses show that the observed data and TAPM data (1 km grid) were generally similar indicating the direction frequencies were similar;
- The wind speed statistics met the criteria for all variables considered indicating that the datasets were similar;
- The TAPM dataset had more calms (<0.3 m/s) than the observed data;
- Whilst the gross error metric was not met for flat conditions, for complex conditions it was met, which is consistent with the visual comparison of the two windroses;
- The higher frequency of southerly winds in the TAPM dataset would see larger contours towards the receptors to the north compared to the observed dataset.

When using the benchmarks above, Emery et. al. (2001) noted that the purpose of the benchmarks is not necessarily to give a passing or failing grade to any one particular application, but rather to put the results into context. In other words, by assessing a variety of benchmarks for wind speed and direction, the relative accuracy of the dataset as a whole can be assessed.

Considering the results in Table 5-1 and Table 5-2, and the wind roses in Figure 5-1, it was concluded that for dispersion modelling, the model TAPM v4 produces a dataset of a suitable quality for the area which is consistent with the good quality prognostic data requirement in OEH (OEH, 2011).

5.2 Odour

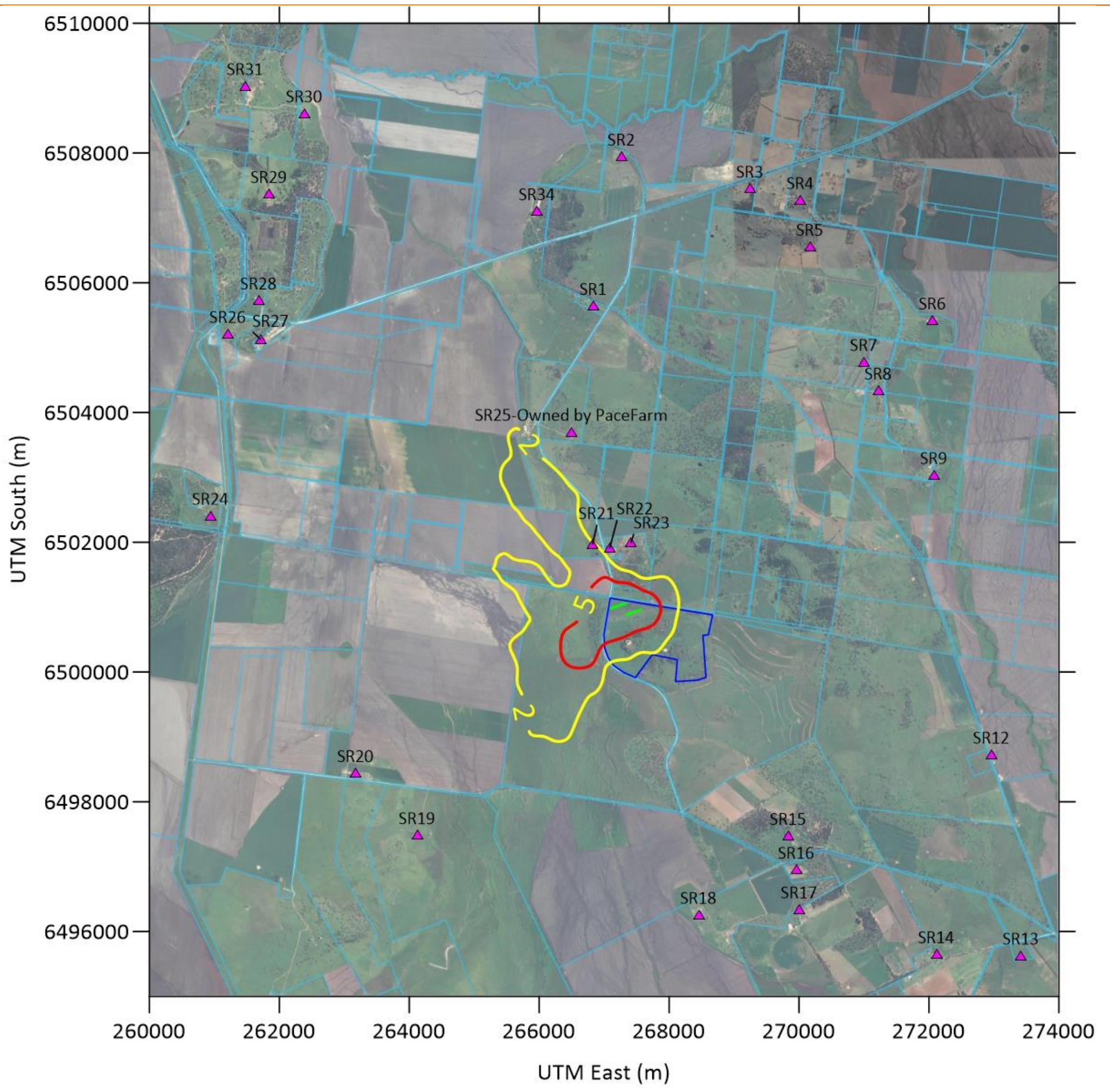
Predicted odour concentrations associated with the proposed farm based on the modelling and emissions estimation methodologies detailed above are shown below as follows:

- Figure 5-3: Predicted 1 second 99th Percentile Odour Concentrations K=2 ;
- Table 5-3: Predicted Receptor Concentrations K=2 ; and .
- Figure 5-4: Predicted 1 second 99th Percentile Odour Concentrations K=0.8.

As discussed in Section 2.1, the preferred method to determine the odour criterion is to count the existing houses within the 2 ou contour, calculate the total population, then determine the criterion to be used based on Equation 7.2 in the Approved Methods.

Figure 5-3 indicates that no existing houses are within the 2 ou contour, which means that under the EPA method an odour criterion of $C_{99\ 1sec}$ = 7 ou would apply. However, to ensure conservatism, and to be consistent with recent decisions made by the EPA, we have applied an odour criterion of 5 ou.

The predicted ground level 99th percentile 1 second concentrations for a K factor of 2 are predicted to comply with the 5 ou (and 7 ou) criterion for the proposed site. The highest predicted concentration is 2.1 ou at sensitive Receptor 21, located to the northwest of the poultry sheds. The predicted concentration is less than half the conservative 5 ou criterion. If a K factor of 0.8 ou is adopted, the predicted concentration at Receptor 21 would be 0.8 ou.



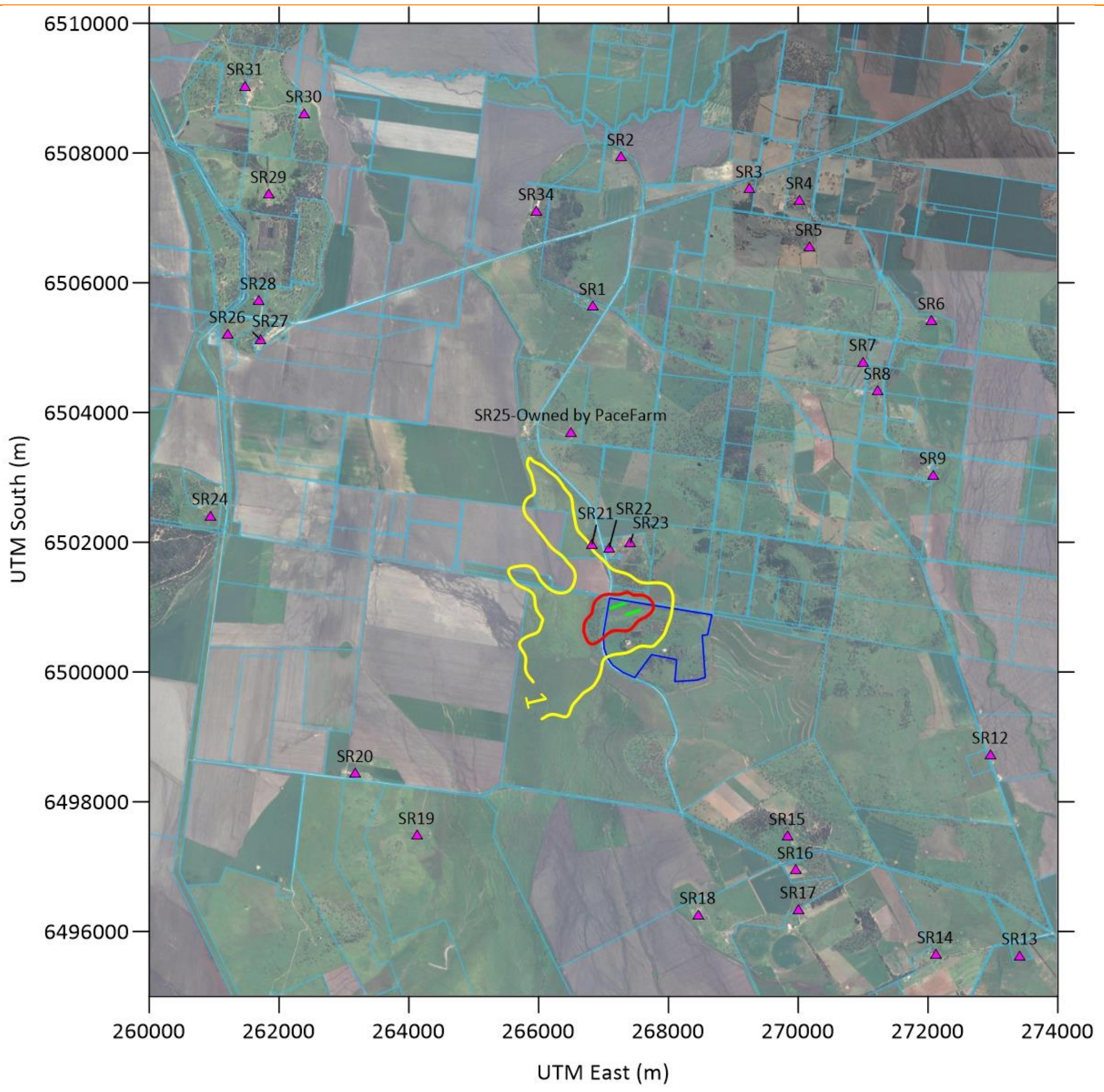
Species: Odour	Site: Warrah Ridge	Scenario: Proposed (K=2)	Averaging Period: 1 sec	Percentile: 99th
Criterion: 5 ou	Units: ou	Meteorology: 2014	Model: CALPUFF v 6.42	Author: G. Galvin

Figure 5-3: Predicted 1 second 99th Percentile Odour Concentrations K=2

Table 5-3: Predicted Receptor Concentrations K=2 ($C_{99.5\ 1hr}$)

Receptor Number	Odour concentration
SR 1	0.2
SR 2	0.1
SR 3	0.0
SR 4	0.0
SR 5	0.0
SR 6	0.0
SR 7	0.1
SR 8	0.1
SR 9	0.0
SR 10	0.0
SR 11	0.0
SR 12	0.0
SR 13	0.0
SR 14	0.1
SR 15	0.1
SR 16	0.1
SR 17	0.1
SR 18	0.3
SR 19	0.5
SR 20	0.4
SR 21	2.1
SR 22	1.3
SR 23	0.7
SR 24	0.2
SR 25	0.1
SR 26	0.0
SR 27	0.0
SR 28	0.0
SR 29	0.0
SR 30	0.1
SR 31	0.1
SR 32	0.0
SR 33	0.0
SR 34	0.0

Note: Grey highlighted receptors are owned by Pace Farm.



Species: Odour	**Site:** Warrah Ridge	**Scenario:** Proposed (K=0.8)	**Averaging Period:** 1 sec	**Percentile:** 99th
Criterion: 5 ou	**Units:** ou	**Meteorology:** 2014	**Model:** CALPUFF v 6.42	**Author:** G. Galvin

Figure 5-4: Predicted 1 second 99th Percentile Odour Concentrations K=0.8

5.3 Particulate Matter

Predicted particulate matter concentrations associated with the proposed site based on the modelling and emissions estimation methodologies are provided below.

The results are shown as follows:

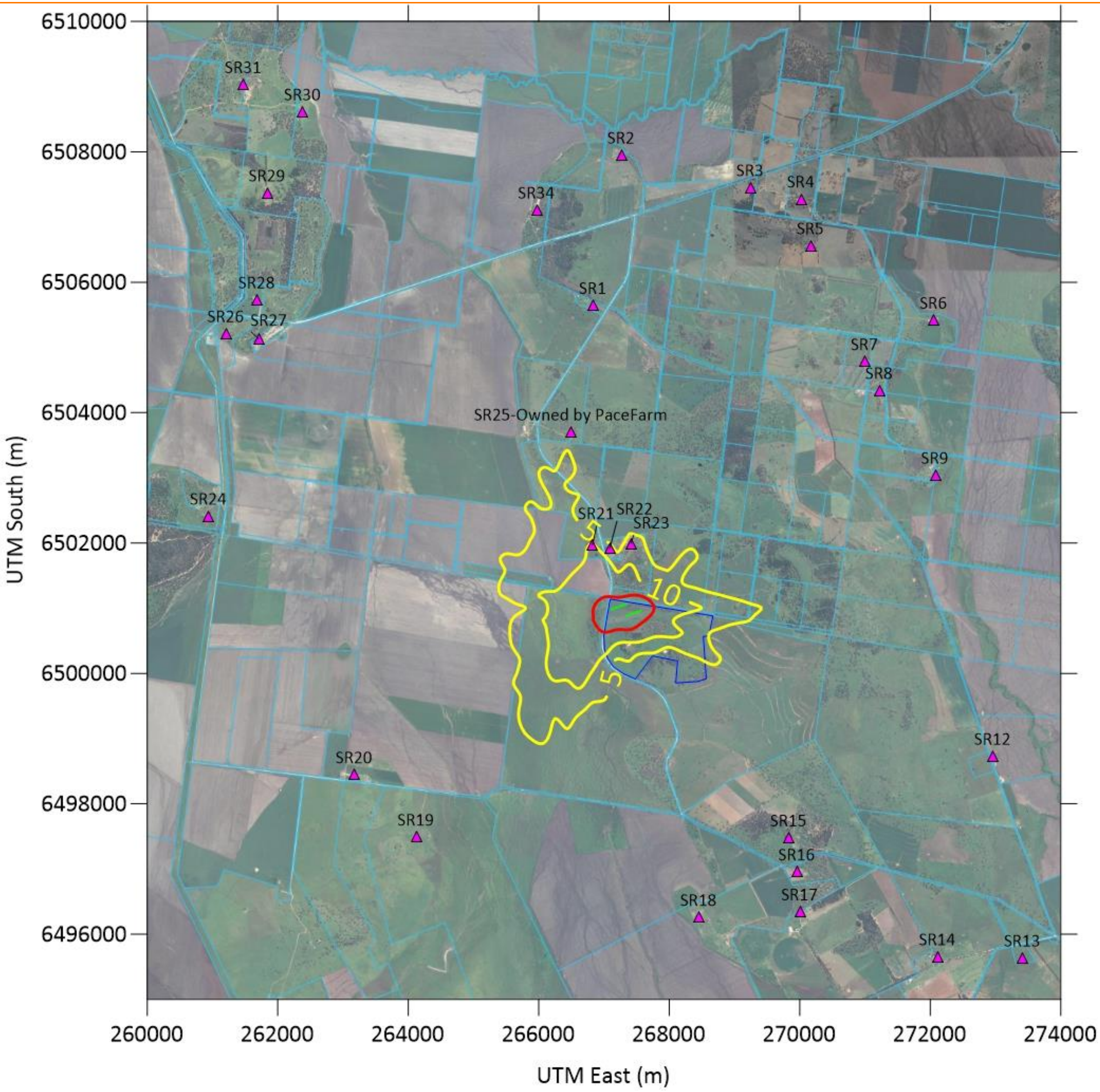
- Table 5-4 Predicted PM_{10} Concentrations for Sensitive Receptors in isolation;
- Figure 5-5: Predicted 24 hour maximum PM_{10} Concentrations –without background;
- Figure 5-6: Predicted 24 hour maximum PM_{10} Concentrations –with background; and
- Figure 5-7: Predicted Annual Average PM_{10} Concentrations – with background.

Note that for all figures the red contour shows the regulatory criterion. Areas outside of this contour are compliant with the criterion. The exception to this is Figure 5-6 where the whole domain exceeds the criterion as the maximum background value was above the criterion. This is analysed further in Section 5.4 below.

Table 5-4 Predicted PM_{10} Concentrations for Sensitive Receptors in isolation

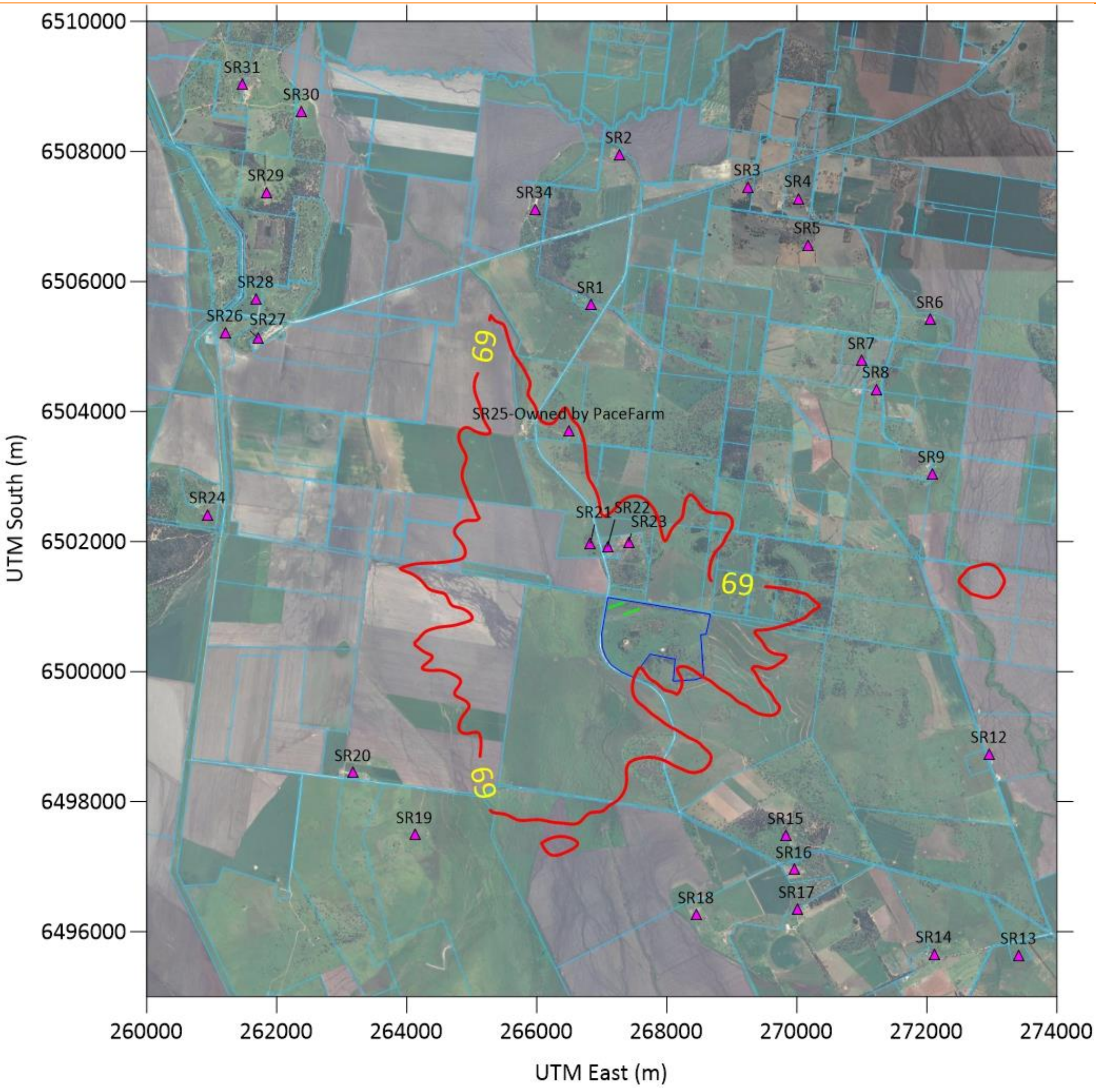
Receptor Number	Maximum PM_{10} 24 hour concentration in isolation (µg/m³)	Maximum PM_{10} 24 hour concentration with background (µg/m³)	PM_{10} Annual Average concentration in isolation (µg/m³)	PM_{10} Annual Average concentration with background (µg/m³)
SR 1	1.3	67.9	0.0	15.8
SR 2	0.4	67.0	0.0	15.8
SR 3	0.3	66.9	0.0	15.8
SR 4	0.2	66.8	0.0	15.8
SR 5	0.2	66.8	0.0	15.8
SR 6	0.5	67.1	0.0	15.8
SR 7	0.5	67.1	0.0	15.8
SR 8	0.7	67.3	0.0	15.8
SR 9	0.3	66.9	0.0	15.8
SR 10	0.2	66.8	0.0	15.8
SR 11	0.1	66.7	0.0	15.8
SR 12	0.3	66.9	0.0	15.8
SR 13	0.4	67.0	0.0	15.8
SR 14	0.8	67.4	0.0	15.8
SR 15	1.1	67.7	0.0	15.8
SR 16	0.8	67.4	0.0	15.8
SR 17	0.8	67.4	0.0	15.8
SR 18	0.9	67.5	0.0	15.8
SR 19	1.2	67.8	0.1	15.9
SR 20	1.3	67.9	0.0	15.8
SR 21	10.7	77.3	0.5	16.3
SR 22	5.3	71.9	0.3	16.1
SR 23	6.0	72.6	0.1	15.9
SR 24	1.3	67.9	0.0	15.8
SR 25	0.4	67.0	0.0	15.8
SR 26	0.3	66.9	0.0	15.8
SR 27	0.2	66.8	0.0	15.8
SR 28	0.2	66.8	0.0	15.8
SR 29	0.5	67.1	0.0	15.8
SR 30	0.5	67.1	0.0	15.8
SR 31	0.7	67.3	0.0	15.8
SR 32	0.3	66.9	0.0	15.8
SR 33	0.2	66.8	0.0	15.8
SR 34	0.1	66.7	0.0	15.8

Note: Grey highlighted receptors are owned by Pace Farm



Species:	Site:	Scenario:	Averaging Period:	Percentile:
PM_{10}	Warrah Ridge	Proposed	24 hour	Maximum in isolation
Criterion:	**Units:**	**Meteorology:**	**Model:**	**Author:**
50	µg/m^3	2014	CALPUFF v 6.42	W. Shillito

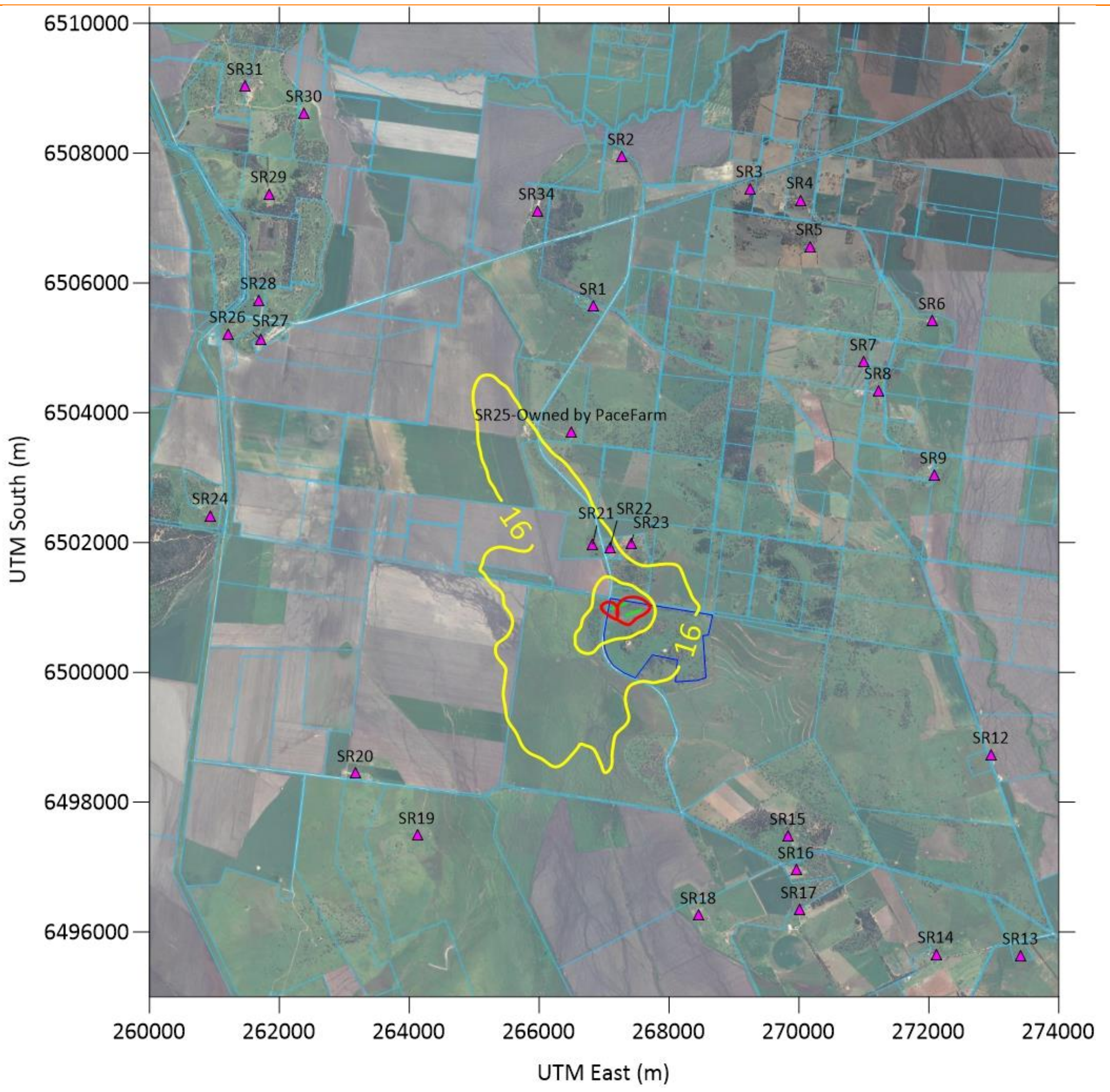
Figure 5-5: Predicted 24 hour maximum PM_{10} Concentrations –without background



Species: PM10	Site: Warrah Ridge	Scenario: Proposed	Averaging Period: 24 hour	Percentile: Maximum with background 66.6 µg/m3
Criterion: 50	**Units:** µg/m3	**Meteorology:** 2014	**Model:** CALPUFF v 6.42	**Author:** W. Shillito

Figure 5-6: Predicted 24 hour maximum PM_{10} Concentrations –with background[5]

[5] Note the maximum 24 hour PM_{10} was above the criterion and therefore produces highly conservative results. See further analysis in Section 5.4 below.



Species: PM10	**Site:** Warrah Ridge	**Scenario:** Proposed	**Averaging Period:** Annual Average	**Percentile:** Average with background of 15.8 µg/m^3
Criterion: 25	**Units:** µg/m^3	**Meteorology:** 2014	**Model:** CALPUFF v 6.42	**Author:** W. Shillito

Figure 5-7: Predicted Annual Average PM_{10} Concentrations – with background

5.4 Contemporaneous PM_{10} Results

As the maximum background concentration was above the criterion, we have performed a contemporaneous assessment where the hourly predicted PM_{10} concentrations at each receptor for each hour were added to the hourly background data from Tamworth. The 24-hour average concentration at each receptor for the year modelled was then calculated based on 24-hours of data.

The top 10 concentrations ranked by influence of the proposed site and influence of background concentrations from Tamworth are shown in each table below for the 5 most affected receptors (S19, SR20, SR21, SR22, SR23). The tables show that the highest background concentrations didn't occur at the same time as the highest predicted impacts.

The results show additional exceedances of the 24 hour PM_{10} are predicted to occur at any of the sensitive receptors.

Table 5-5: Top 10 Cumulative 24 Hour PM_{10} (µg/m3) – Receptor SR19

Ranked by Background				Ranked by Incremental Concentration			
Date	Measured	Predicted increment	Total	Date	Predicted increment	Measured Background	Total
15/11/2014	66.6	0.0	66.6	23/03/2014	1.3	9.5	10.9
3/01/2014	39.2	0.0	39.2	6/03/2014	1.0	14.4	15.3
7/10/2014	36.1	0.0	36.1	7/03/2014	0.9	11.4	12.3
27/10/2014	35.8	0.0	35.8	3/04/2014	0.7	15.8	16.4
23/11/2014	35.2	0.0	35.2	10/04/2014	0.6	19.8	20.4
31/10/2014	35.0	0.0	35.0	18/02/2014	0.5	13.1	13.6
3/11/2014	34.2	0.0	34.2	28/12/2014	0.5	3.9	4.3
5/11/2014	33.6	0.0	33.7	29/11/2014	0.4	11.6	12.0
13/02/2014	33.3	0.0	33.3	26/03/2014	0.4	7.1	7.5
30/10/2014	30.8	0.0	30.8	24/12/2014	0.4	11.2	11.6

Table 5-6: Top 10 Cumulative 24 Hour PM10 (µg/m3) – Receptor SR20

Ranked by Background				Ranked by Incremental Concentration			
Date	Measured	Predicted increment	Total	Date	Predicted increment	Measured Background	Total
15/11/2014	66.6	1.1	67.7	30/12/2014	10.7	16.3	27.0
3/01/2014	39.2	0.0	39.2	29/03/2014	7.2	8.0	15.2
7/10/2014	36.1	0.2	36.3	6/04/2014	4.4	8.4	12.8
27/10/2014	35.8	0.0	35.8	5/04/2014	4.3	11.9	16.2
23/11/2014	35.2	0.0	35.2	27/04/2014	3.8	15.9	19.7
31/10/2014	35.0	0.0	35.0	27/08/2014	3.5	8.2	11.7
3/11/2014	34.2	0.3	34.5	13/04/2014	3.0	8.2	11.2
5/11/2014	33.6	0.0	33.6	17/11/2014	3.0	13.7	16.7
13/02/2014	33.3	0.0	33.3	8/12/2014	3.0	14.8	17.7
30/10/2014	30.8	1.5	32.3	26/08/2014	2.5	9.3	11.8

Table 5-7: Top 10 Cumulative 24 Hour PM10 (µg/m3) – Receptor SR21

Ranked by Background				Ranked by Incremental Concentration			
Date	Measured	Predicted increment	Total	Date	Predicted increment	Measured Background	Total
15/11/2014	66.6	2.7	69.3	17/12/2014	5.3	26.1	31.4
3/01/2014	39.2	0.0	39.2	29/03/2014	4.4	8.0	12.4
7/10/2014	36.1	0.2	36.3	24/04/2014	3.2	23.1	26.3
27/10/2014	35.8	0.2	36.1	15/11/2014	2.7	66.6	69.3
23/11/2014	35.2	0.0	35.2	8/12/2014	2.6	14.8	17.4
31/10/2014	35.0	0.0	35.0	17/11/2014	2.5	13.7	16.1
3/11/2014	34.2	0.2	34.4	16/11/2014	2.0	22.3	24.3
5/11/2014	33.6	0.0	33.6	28/08/2014	1.9	8.3	10.2
13/02/2014	33.3	0.0	33.3	5/04/2014	1.9	11.9	13.8
30/10/2014	30.8	0.3	31.0	30/12/2014	1.9	16.3	18.2

Table 5-8: Top 10 Cumulative 24 Hour PM10 (µg/m3) – Receptor SR22

Ranked by Background				Ranked by Incremental Concentration			
Date	Measured	Predicted increment	Total	Date	Predicted increment	Measured Background	Total
15/11/2014	66.6	0.6	67.2	24/04/2014	6.0	23.1	29.1
3/01/2014	39.2	0.0	39.2	19/08/2014	1.4	9.1	10.6
7/10/2014	36.1	0.0	36.1	17/12/2014	1.1	26.1	27.2
27/10/2014	35.8	0.0	35.9	31/12/2014	0.9	21.6	22.5
23/11/2014	35.2	0.0	35.2	24/03/2014	0.9	7.9	8.8
31/10/2014	35.0	0.0	35.0	4/09/2014	0.8	13.2	14.0
3/11/2014	34.2	0.1	34.3	25/11/2014	0.8	10.9	11.7
5/11/2014	33.6	0.0	33.6	2/04/2014	0.8	14.9	15.7
13/02/2014	33.3	0.0	33.3	19/04/2014	0.7	25.6	26.2
30/10/2014	30.8	0.0	30.8	5/04/2014	0.6	11.9	12.5

Table 5-9: Top 10 Cumulative 24 Hour PM10 (µg/m3) – Receptor SR23

Ranked by Background				Ranked by Incremental Concentration			
Date	Measured	Predicted increment	Total	Date	Predicted increment	Measured Background	Total
15/11/2014	66.6	0.0	66.6	17/08/2014	1.5	6.4	7.9
3/01/2014	39.2	0.0	39.2	22/03/2014	1.0	8.4	9.4
7/10/2014	36.1	0.0	36.1	14/03/2014	0.7	11.9	12.6
27/10/2014	35.8	0.0	35.8	8/03/2014	0.6	7.2	7.7
23/11/2014	35.2	0.0	35.2	13/03/2014	0.6	15.2	15.8
31/10/2014	35.0	0.0	35.0	16/08/2014	0.5	7.5	8.0
3/11/2014	34.2	0.0	34.2	13/02/2014	0.5	33.3	33.8
5/11/2014	33.6	0.0	33.6	1/04/2014	0.5	14.9	15.3
13/02/2014	33.3	0.5	33.8	25/02/2014	0.4	9.5	9.9
30/10/2014	30.8	0.1	30.8	7/09/2014	0.3	7.3	7.7

6 CONCLUSION

The modelling presented in this report considers the proposed site and has been performed in accordance with the Approved Methods (NSW EPA, 2016). The assessment has used the K factor method of Ormerod & Holmes (2005) to determine odour emissions. The method was modified for layer rearer operations and included a batch length of 17 weeks. The modelling with a conservative K factor of 2 indicates that the proposed site would not lead to any exceedances of the odour criterion of 5 ou at the nearest sensitive locations. The modelling has also demonstrated that the risk associated with particulate matter is low as there will not be any additional exceedances at the receptors.

Therefore, based on the emission estimation methods used, the operation is unlikely to have impacts on the amenity and character of the locality.

Based on our assessment we recommend the development be approved and operated in line with current industry best practice.

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