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REPORT

BOGGABRI PRP – IDENTIFICATION OF ADVERSE WEATHER CONDITIONS FOR OVERBURDEN HANDLING

Boggabri Coal Pty Limited

Job No: **8031**

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CONTENTS

1 INTRODUCTION

Boggabri Coal Pty Limited (Boggabri Coal) holds Environmental Protection Licence (EPL) 12407 for the Boggabri Coal Mine (Boggabri). Condition U2 (*Particulate Matter Control Best Practice Implementation - Disturbing and Handling Overburden under Adverse Weather Conditions)* requires Boggabri to alter or cease the use of equipment on overburden and the loading and dumping of overburden during adverse weather conditions. The licence must:

- Undertake daily visual dust level assessments, continuously record real-time PM_{10} levels and continuously measure and record real-time meteorological conditions, and
- Record changes to mining activities due to adverse weather conditions.

The purpose of this report is to define "adverse conditions" that may result in unacceptable dust levels beyond the site boundary. Trigger levels will be identified for these adverse conditions to inform a Trigger Action Response Plan (TARP) for overburden handling activities in critical locations.

1.1 Scope of Work

The following methodology is used to identify adverse conditions:

- Identify critical locations where overburden (OB) handling may result in elevated dust concentrations at or beyond the site boundary.
- Represent each location using two sources to simulate dozer and loading/unloading operations simultaneously occurring in one location. A TSP emission rate of 1,000,000 kg/y has been assumed, with loading and dumping emissions varying with wind speed according to the US EPA AP-42 emissions factor.
- Use a screening level atmospheric dispersion model to predict dust plume behaviour under various meteorological conditions (using site representative data).
- At boundary locations where the highest impacts are predicted, analyse the meteorological conditions that correspond to the highest 1-hour dust concentrations.
- Based on these "adverse" meteorological conditions, determine appropriate trigger values to inform a TARP.

2 METHODOLOGY

2.1 Critical locations

The locations of current OB activities are shown in **Figure 1** and were determined in consultation with Boggabri. Dust sources are released from the OB dump at the location shown and the resultant dust concentration predictions are made at each of the numbered boundary locations shown.

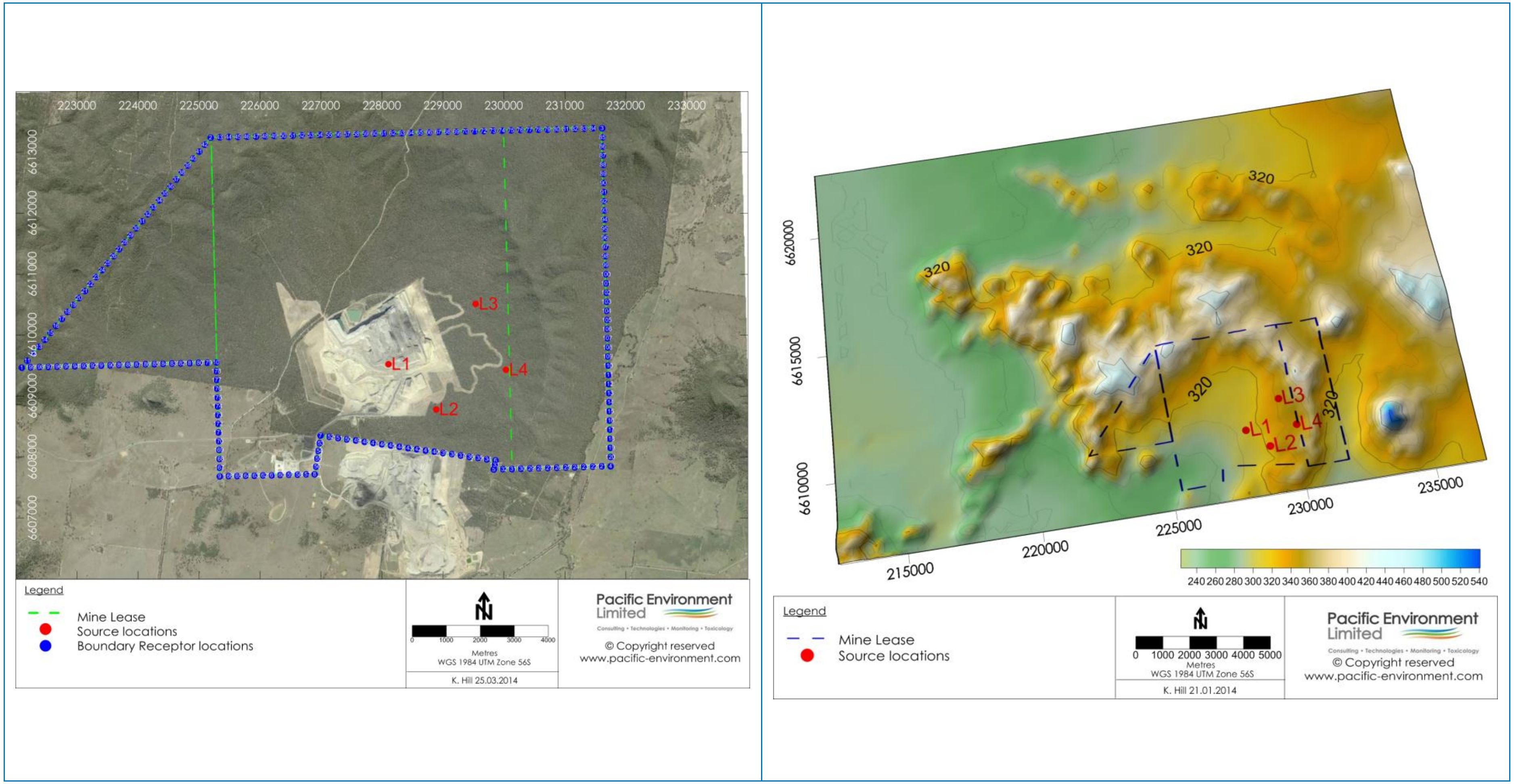

Figure 1: Overburden Activity Source Locations

2.2 Model Inputs

Overburden handling activities are assumed to include loading / unloading of OB, dozers operating on OB and wind erosion from the disturbed surfaces. Each activity is assumed to operate simultaneously and an emission rate for total suspended particulate (TSP) is assumed to be 3,000,000 kg/y from each source.

Adjustments are made to hourly emissions as follows:

- **Loading/dumping OB**. Emissions are assumed to be dependent on wind speed to account for wind dependency in the overburden handling emission factor equation and hourly emissions are adjusted for wind speed as follows (**US EPA, 1987**):

$$Emission_{adjusted} = Emission_{unadjusted} \times \left({}^{Hourly\ Wind\ Speed}/_{2.2}\right)^{1.3}$$

- **Dozers**. Emissions are independent of wind speed, as per the dozer emission factor equation.

By varying emissions in this way, "adverse conditions" will not only be influenced by the meteorological conditions under which dust disperses but also include those conditions under which higher emissions are generated at source (i.e. high wind speeds).

A meteorological modelling file was compiled using valid measured data from the Boggabri meteorological station from May 2012 to December 2013. The source and receptor heights took mine terrain into account. The scenarios modelled are as summarised in **Table 1**.

Table 1: Modelling Scenarios

Scenario ID	Elevation (m)	Distance from nearest boundary (m)	Comments for selection
L1	308	1,200	Highest dumping area located to the west of pit operations
L2	327	700	Elevated dumping area close to southern boundary
L3	343	2,100	Highest dumping area located to the east of pit operations
L4	340	1,500	Elevated dumping area close to eastern and southern boundaries

3 ANALYSIS OF MODELLING RESULTS

The location of the 10 highest TSP boundary predictions for each OB activity location were, as expected, at locations closest to or in a prevailing direction of the active OB areas. The ten boundary receptors for each OB location (shown in **Figure 2**) were selected for analysis of the meteorological conditions under which these high concentrations occur.

An hourly time series of predicted TSP concentrations at each of these top ten receptors was extracted for each scenario. The time series data were then normalised to enable the different scenarios to be directly compared with each other. The aim of normalisation of the predicted TSP concentrations across the scenarios was to enable identification of the scenarios (or locations) where the highest concentrations occur. In other words, the focus is on relative concentrations rather than actual concentrations.

Normalisation takes a large number of data sets that are on different scales and consolidates them to a single common scale. In this case, the activities were modelled with the same emissions and therefore the predicted levels at the receptors are not a reflection of actual levels which will be experienced, but rather how the results relate to one another. The concentrations determined from dispersion modelling have been normalised to the maximum predicted TSP concentrations for the parameter investigated (i.e. wind speed or wind direction). This enables all the data from the different scenarios to be compared on a scale of 0 to 1, across all scenarios. The plots therefore represent normalised levels not actual TSP concentrations.

It is important to note that the data were analysed separately based on wind speed and wind direction and therefore the graphs shown for wind speed and wind direction do not relate to each other.

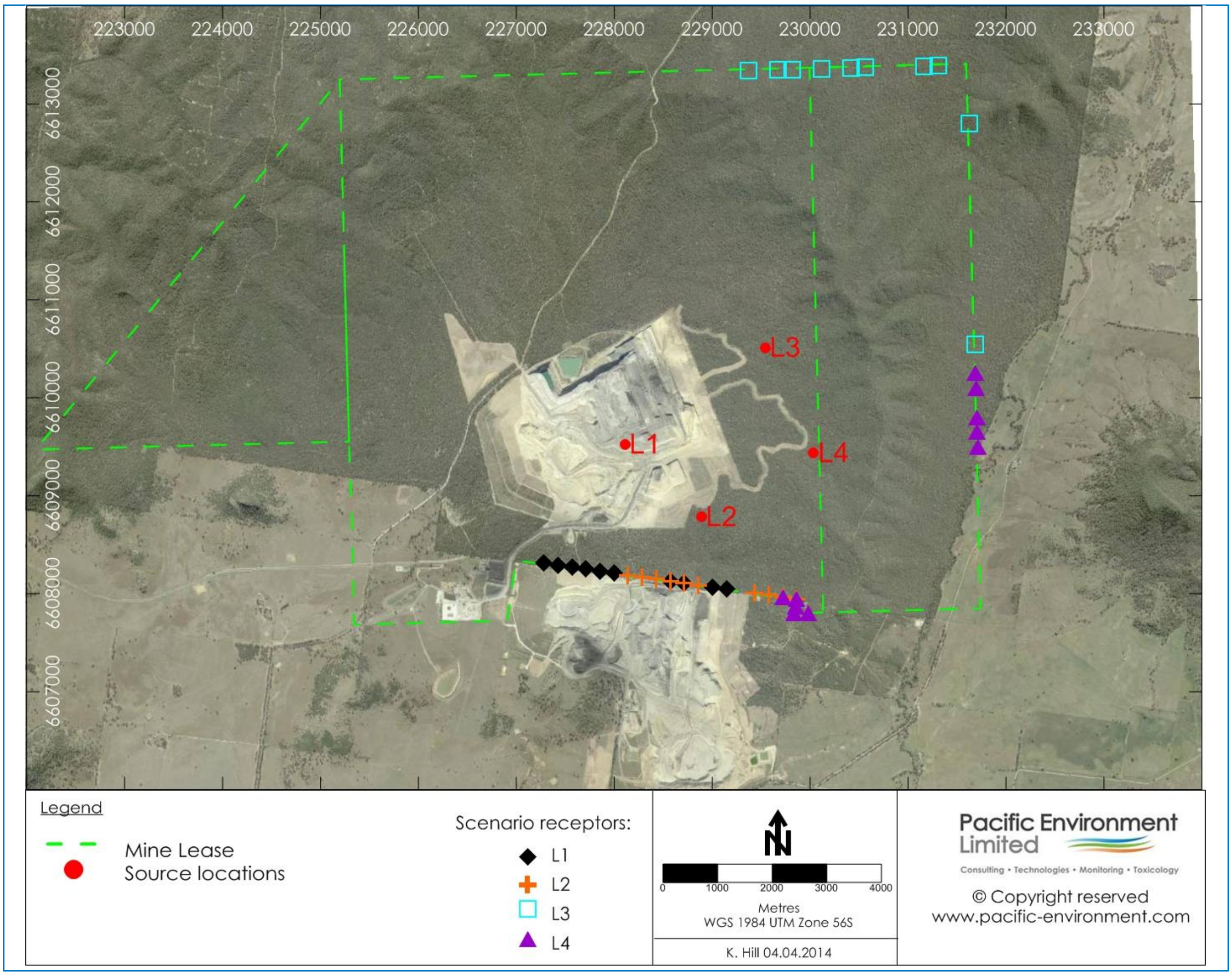

Figure 2: Location of highest boundary predictions for each OB activity location

3.1 Wind speed analysis

The normalised 1-hour TSP concentration for each hour of the year were averaged into a corresponding wind speed bin (at 0.1 m/s increments) and the results are presented in **Figure 3**, for the scenarios L1 to L4. Each line shows the hourly prediction (averaged by wind speed) for each of the 10 highest boundary receptors for each scenario, as identified in **Figure 2**.

The time series data were then normalised to enable the different scenarios to be directly compared with each other. The aim of normalising the predicted TSP concentrations across the scenarios was to enable identification of the scenarios (or locations) where the highest impacts occur relative to each other.

Location L2 shows the highest impact compared to the other locations. It is noted that locations L3 and L4 are an order of magnitude lower in normalised concentration compared to L1 and L2.

The analysis shows that the highest predicted TSP concentrations occur below 3 m/s for all scenarios. These higher concentrations generally occur at night when the atmosphere is stable and winds are lighter. At these times, it is not the emissions that are the issue, but rather dispersion conditions for those particles already airborne. In other words, emissions are lower for wind speed dependant sources, but dispersion conditions are less favourable.

It is noted that there are some spikes in TSP levels experienced at higher wind speeds (> 7 m/s), which are particularly noticeable for location L3, located near the centre of the mine lease boundary.

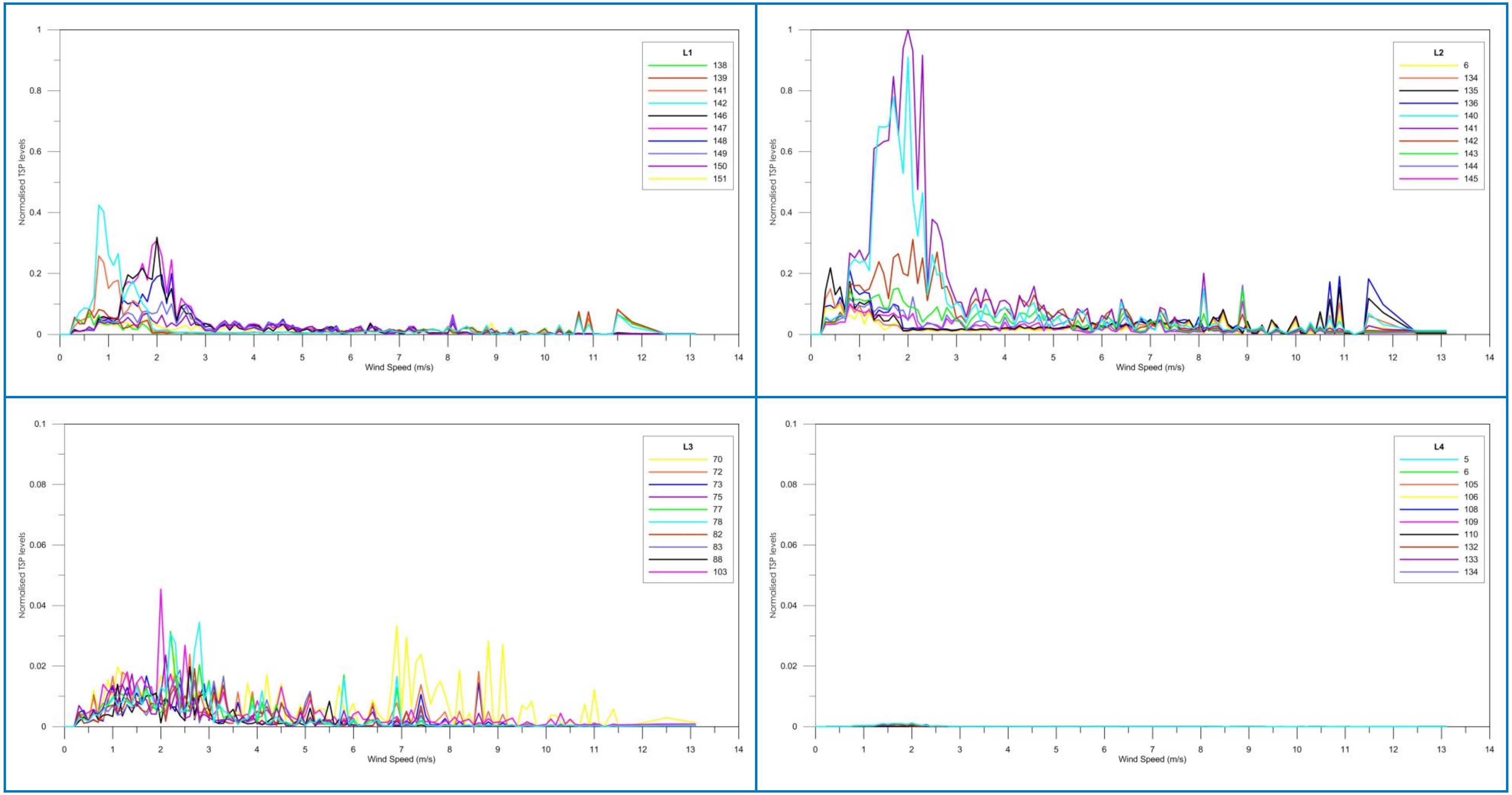

Figure 3: Normalised TSP concentrations by wind speed

3.2 Time of day analysis

An analysis of the 1-hour TSP concentrations by hour of the day is presented in **Figure 4**. This analysis has been carried out for L2, the highest predicted levels for the dump areas. A clear pattern is evident with higher concentrations at the boundaries during night-time conditions (approximately between 6 pm to 8 am). In addition, L3 was analysed to provide an indication of the time of day corresponding with the spikes at high wind speeds observed in **Figure 3**. The results indicate that this occurs at around 8 am to 10 am and would not necessarily be considered “adverse” based on the relatively low normalised dust concentration.

Hour of the day can be used as a surrogate for atmospheric stability, which is an indicator of turbulence or dispersive capacity. A descriptor of turbulence, known as Monin-Obukhov length (L), can be interpolated from the modelling files and used to describe whether conditions are unstable (enhanced dust dispersion) or stable (dust dispersion is suppressed). The inverse of Monin-Obukhov length (1/L) is plotted in **Figure 4** below the time of day analysis, showing highest concentration during stable conditions (when Monin-Obukhov length is positive). As expected, the hour of day analysis is consistent with the stable and unstable conditions observed in **Figure 3**.

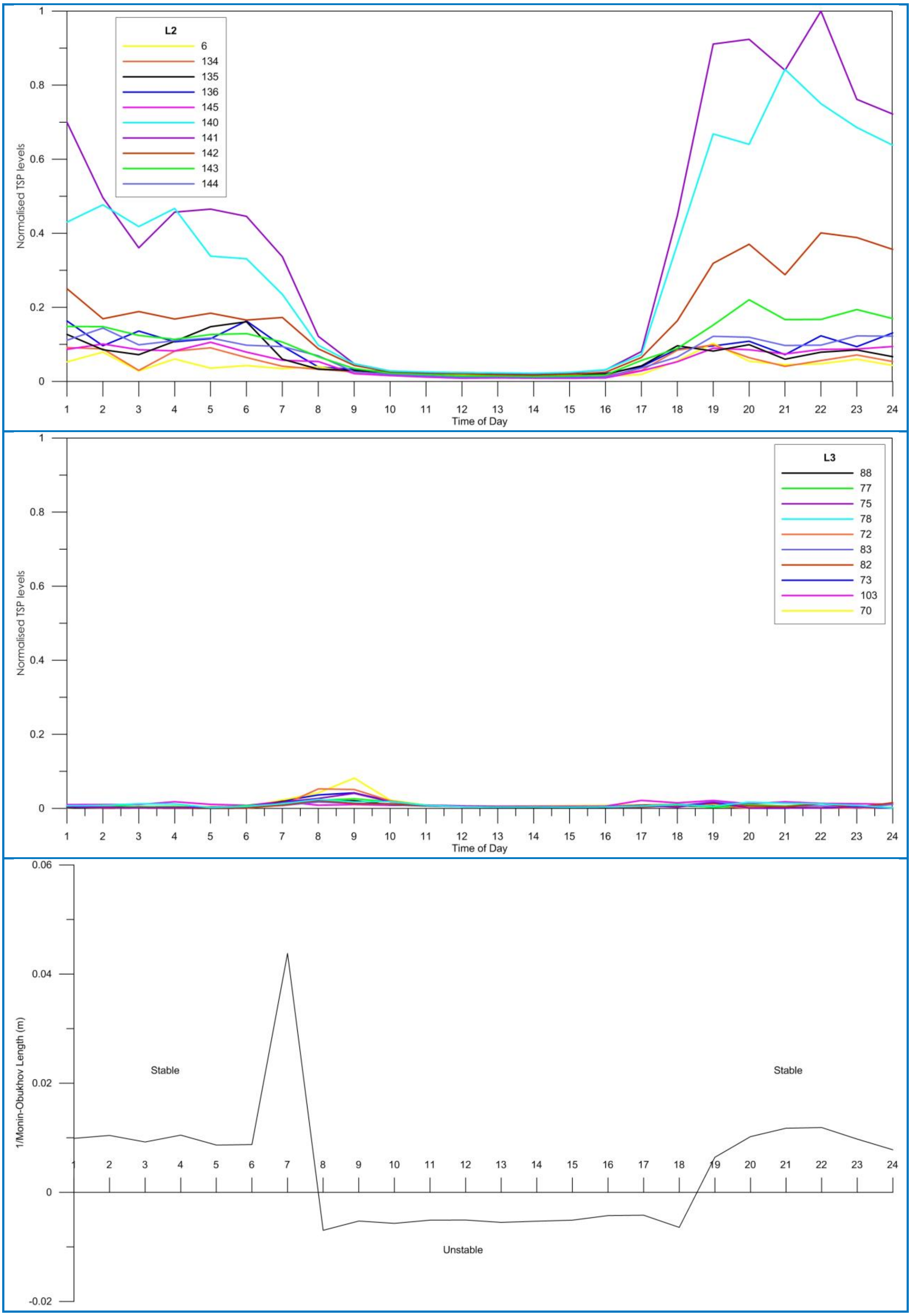

Figure 4: Normalised TSP concentrations and Monin-Obukhov length by hour of the day at L2 and L3

3.3 Wind direction analysis

Normalised TSP concentrations for scenarios L1 to L4 are plotted against wind direction for the same top 10 boundary receptors discussed previously (**Figure 5**). The wind directions which result in the highest relative TSP concentrations are clearly dependent on the location of the dump relative to the boundary. For example, for L1 and L2 where the relative concentrations are highest at the southern boundary, winds are nearly all between 315 – 45 degrees (northern quadrant).

Similarly, for L3 the winds which contribute to the highest levels at the northern and eastern boundary are from the southwestern quadrant. This is clearly what would be expected and so because the dumping areas are varied in terms of location, there will be different wind direction triggers for different dumps.

Similar to what was observed in the analysis of wind speed (**Figure 3**), the magnitudes of impact at L3 and L4 are small compared to L1 and L2. This indicates that locations L3 and L4 may not necessarily be considered "critical locations" based on the relatively low normalised dust concentration.

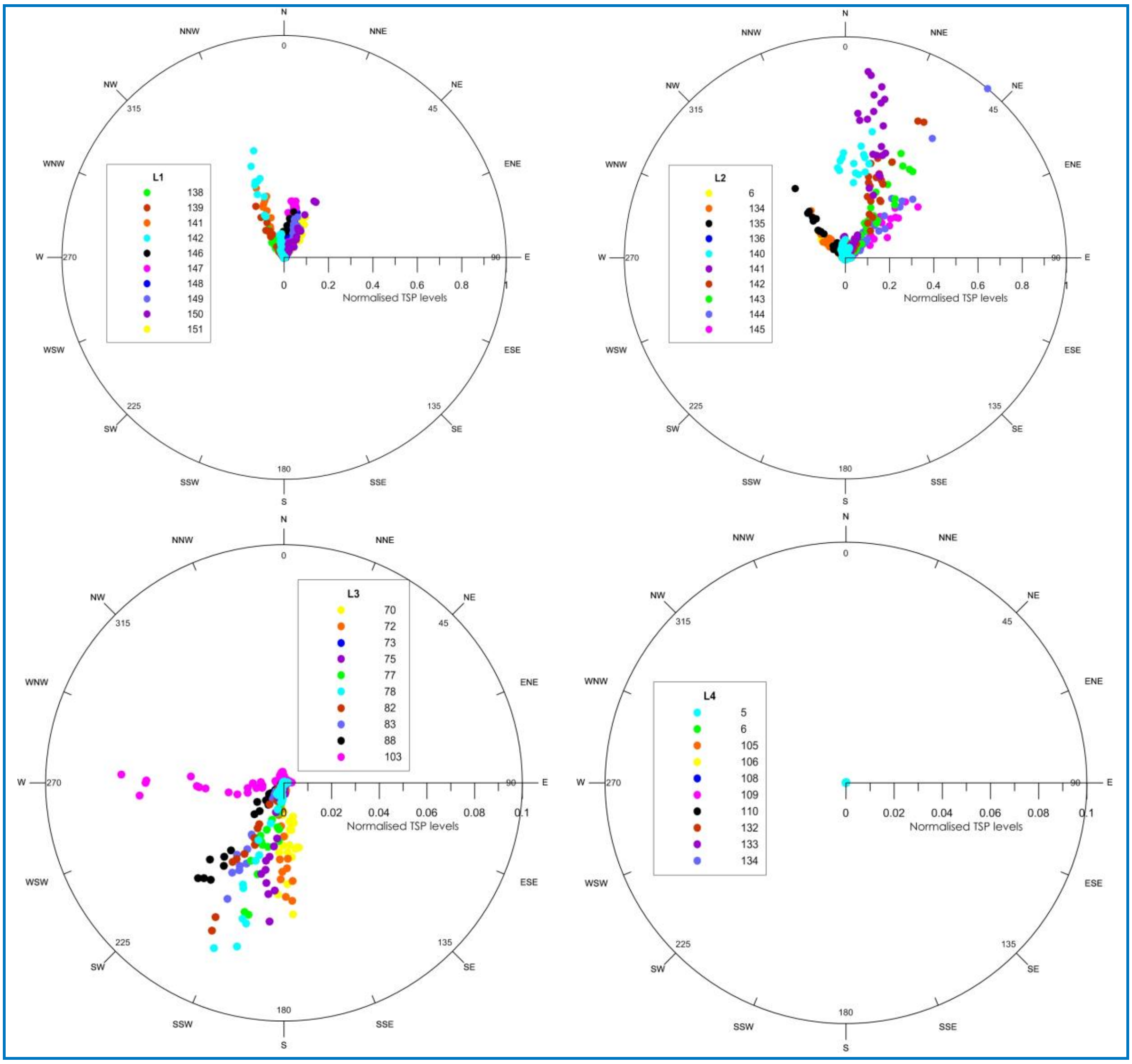

Figure 5: Normalised TSP concentrations against wind direction

4 DEVELOPMENT OF TRIGGER LEVELS

4.1 Meteorological Parameters

The results of modelling indicate that stable conditions (low winds during the night periods) have the highest impacts at the boundary receptors. Another indicator of stable conditions is the temperature difference with height. This temperature difference is known as the lapse rate. Similar to the Monin-Obukhov length discussed in **Section 3.2**, lapse rate provides an indication of whether conditions are unstable (enhanced dust dispersion) or stable (dust dispersion is suppressed).

During the day, the ground is heated by solar radiation and the temperature difference between the air at ground level and the air above usually decreases with height. Immediately after sunset, the ground loses heat rapidly cooling the air closest to it which then becomes denser than the air immediately above it. When this happens a 'temperature (or radiation) inversion' occurs and the temperature difference between the air near the ground and the air above increases with height. This constitutes stable atmospheric conditions.

During class F conditions when the atmosphere is stable and winds are light, dispersion of dust plumes is limited. Under these conditions plumes can remain relatively undiluted for considerable distances downwind.

The Boggabri meteorological station measures temperature at 2 m, 10 m and 52 m. The average temperature difference (2 m reading subtracted from the 52 m reading) is plotted by hour of the day (refer to **Figure 6**) and stable conditions occur when the temperature difference is positive (that is, warmer air aloft at 52 m). The time of day where the temperature difference is positive is generally from 6-7 pm to 7-8 am, depending on the time of sunrise and sunset. This corresponds with the Monin-Obukhov length plot in **Figure 4**.

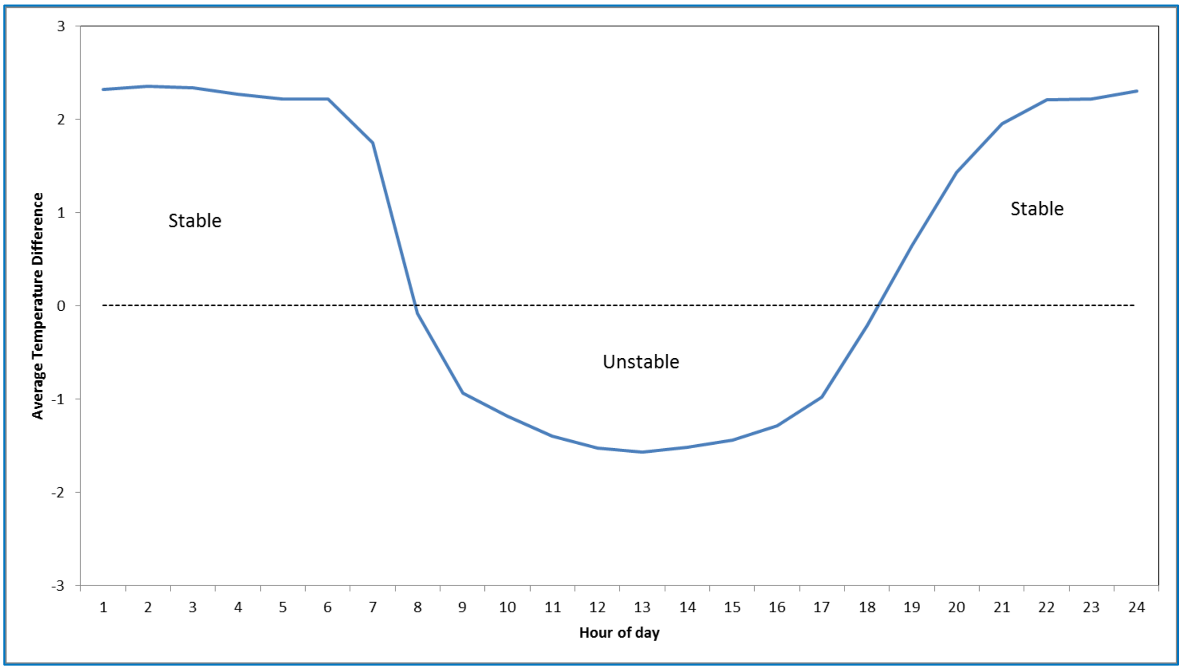

Figure 6: Temperature difference by hour of the day

Further analysis can be done comparing the lapse rate to wind speeds at the Boggabri meteorological station, as presented in **Figure 7**. This indicates that as wind speeds increase, the lapse rate decreases and as such the temperature inversion (atmospheric stability) weakens. The strongest positive temperature differences of more than 4°C generally occur when winds are below about 1.5 m/s.

There is no strong correlation between low winds speeds and temperature difference and wind speed alone is not a good indicator of stability. Low wind speeds can occur during both stable and unstable conditions.

In summary then, stronger inversions (greater than 4°C in 50 m) predominantly occur when winds are below 1.5 m/s, but just having a low wind speed does not necessarily mean there will be an inversion.

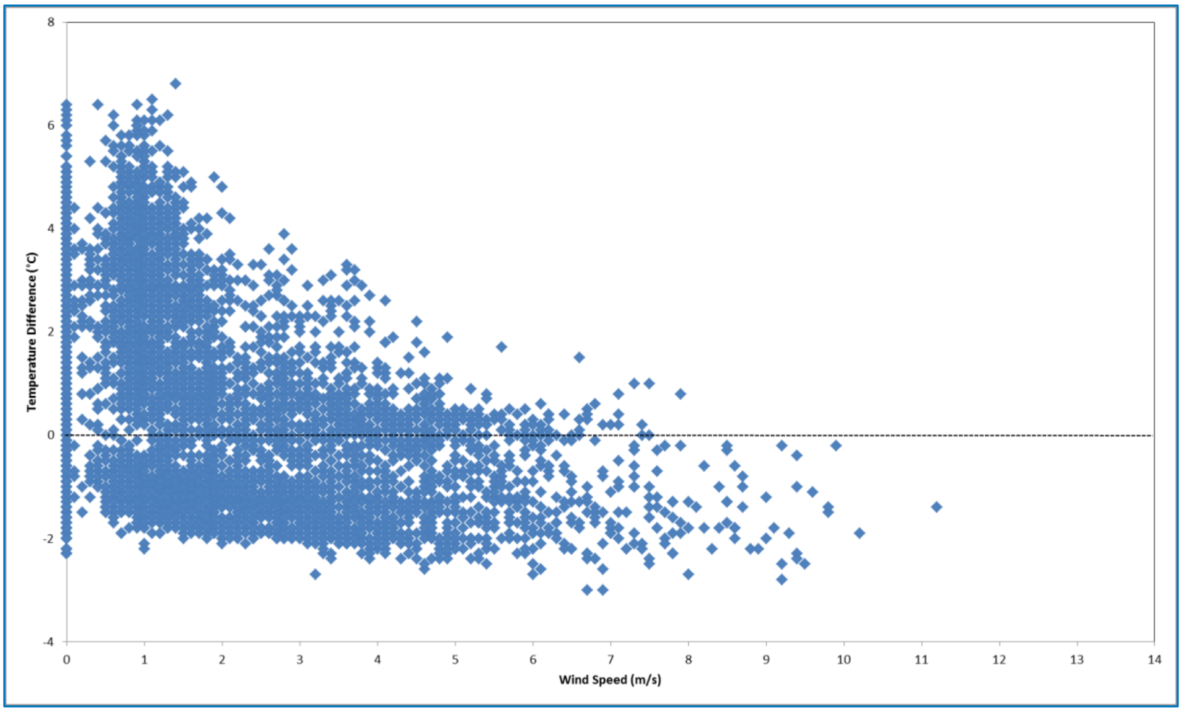

Figure 7: Temperature difference by wind speed

4.2 Trigger Levels

Based on the analysis presented above, adverse conditions for elevated dust levels beyond the site boundary are identified as stable conditions when wind speed is less than 1.5 m/s. Predicted concentrations were highest for scenario L1 and L2.

The pollution roses for the various OB areas (refer to **Figure 5**) identify that the wind directions where the highest concentrations at the boundary may occur, are from the northern quadrant (approximately 315° to 45°), due to OB activities at L1 and L2.

It is wind speed that is more critical in determining the level of emission from loading and dumping activities on OB dump areas, but the wind direction will determine where those emissions are transported to.

Given the relatively large distance from the mine lease boundary of the site to the relevant dumping locations, it is practical to perform a check for visible dust prior to implementation of the trigger levels. That is, staff should carry out a visual inspection of the active overburden dump areas and determine whether or not dust is excessive at the source and being transported towards the boundary. If dust impacts are observed, then the source should be mitigated immediately and activity ceased.

The above indicates that this level of investigation should suffice when wind speeds are less than 1.5 m/s. There will however be times under these wind speeds (< 1.5 m/s) and wind directions (e.g. northerlies) together with strong temperature inversions to warrant visual inspection and trigger of the TARP in accordance with the real-time management system. Details of the real-time management system are provided in **Section 4.3**.

The following trigger levels are therefore defined for the Boggabri TARP:

- Investigation Level:
    - Wind speed < 1.5 m/s
    - Wind direction from northern quadrant (approximately 315° to 45°)
    - Temperature difference (52m – 2 m) is greater than 4°C

4.3 Real-time Management System

Boggabri Coal Mine, Tarrawonga Coal Mine and Maules Creek Coal Mine (referred to hereafter as B-T-M) have developed a Precinct Air Quality Management Strategy that outlines how the B-T-M complex will undertake and achieve management of cumulative air quality outcomes.

The predictive and reactive air quality management system will include:

- A predictive component: using forecast weather data and dispersion modelling.
- A reactive component: using real-time meteorology, air quality monitoring and dispersion modelling.
- A non-steady state air quality dispersion model (that is capable of processing data at a sub-hourly time interval).
- Short term tiered trigger levels and notifications for managing potential impacts.
- A daily forecast report: providing information on temperature inversions, wind conditions at various heights, dust risk, and recommended control actions.

The real-time air quality management system will generate daily risk response reports which will:

- Provide forecast meteorological conditions for coming day
- Daily dust risk forecasts.
- Identify the level of risk (low, medium, high)
- Outline specific management actions or response.

Predictive and 'real-time' reactive triggers will be built into the system. Triggers will be initially set based on analysis of the available monitoring data. The nature of any trigger from a predictive system may vary from simple indicators risk of impacts for the next day through to a specific forecast value and list of actions needed to limit impacts to criteria (or a fair share of total criteria for cumulative impact control systems).

Initially predictive triggers will be set for typical meteorological conditions that are known to have adverse impacts on air quality due to dust generated during mining operations. Over time predictive triggers can be updated for conditions resulting in observed increases in dust impacts.

Reactive triggers will be set to alert operations when monitoring data for short term average periods indicate that the 24-hour air quality criteria may be breached at areas of relevant exposure. The real-time dust monitoring system will be used to trigger when controls need to be instigated. The real-time air quality monitoring allows relevant personnel to react when short term trigger levels are breached which are set at a level that allows proactive dust management (to control 24-hour and ultimately annual average impacts).

Associated with each trigger level (i.e. low, medium, high) is a response which will inform the course of action taken by the relevant personnel. These triggers and responses will be built into the real-time dust management system.

Corrective measures aim to minimise environmental impact in the event of an incident occurring by instigating an appropriate operational response. Corrective measures are instigated in response to visual inspection and when alerts are triggered by the predictive and real-time dust management system.

4.4 Analysis of the frequency of "adverse conditions"

The percentage occurrence of adverse conditions at Boggabri is presented in **Table 2**, based on a review of the meteorological data from May 2012 to February 2014. The frequency distribution of wind speeds is presented in **Figure 8** and the wind rose (**Figure 9**) shows the occurrence of wind speeds for different directions.

These plots and the data presented in **Table 2**, show that while the lower wind speeds are frequent, they are predominantly from the north and north-northwest. In other words, when the wind speed is such to activate a trigger, the wind will often be from the northern quadrant. This explains why scenario L2 resulted in higher relative concentrations at the boundary for both the wind speed and wind direction analyses.

The data in **Table 2** also shows that winds below 1.5 m/s (in any direction) occur 40.6 % of the time, and less than half of those (approximately 20.2% of the time) will be from the northern quadrant (between 315° and 45°). The percentage of time where the wind speeds are less than 1.5 m/s from the northern quadrant AND the temperature difference is greater than 4°, is approximately 4% of the time.

Table 2: Frequency distribution of wind speeds and direction

Wind Direction		Wind Speed (m/s)		
		< 1.5	1.5 - 10	>10
>=0 – 22.5	N	6.7%	5.4%	0.0%
>22.5 – 45	NNE	1.2%	1.5%	0.0%
>45 – 67.5	NE	0.6%	0.7%	0.0%
>67.5 – 90	ENE	0.6%	0.8%	0.0%
>90 – 112.5	E	0.7%	2.2%	0.0%
>112.5 – 135	ESE	1.2%	5.6%	0.0%
>135 – 157.5	SE	2.1%	8.1%	0.1%
>157.5 – 180	SSE	3.4%	7.0%	0.1%
>180 – 202.5	S	3.2%	2.8%	0.0%
>202.5 – 225	SSW	2.3%	2.9%	0.0%
>225 – 247.5	SW	1.8%	1.9%	0.0%
>247.5 – 270	WSW	1.6%	2.4%	0.0%
>270 – 292.5	W	1.5%	3.5%	0.0%
>292.5 – 315	WNW	1.6%	6.3%	0.0%
>315 – 337.5	NW	2.7%	3.9%	0.1%
>337.5 – 360	NNW	9.6%	4.4%	0.0%
Total	**All directions**	**40.6%**	**59.3%**	**0.2%**

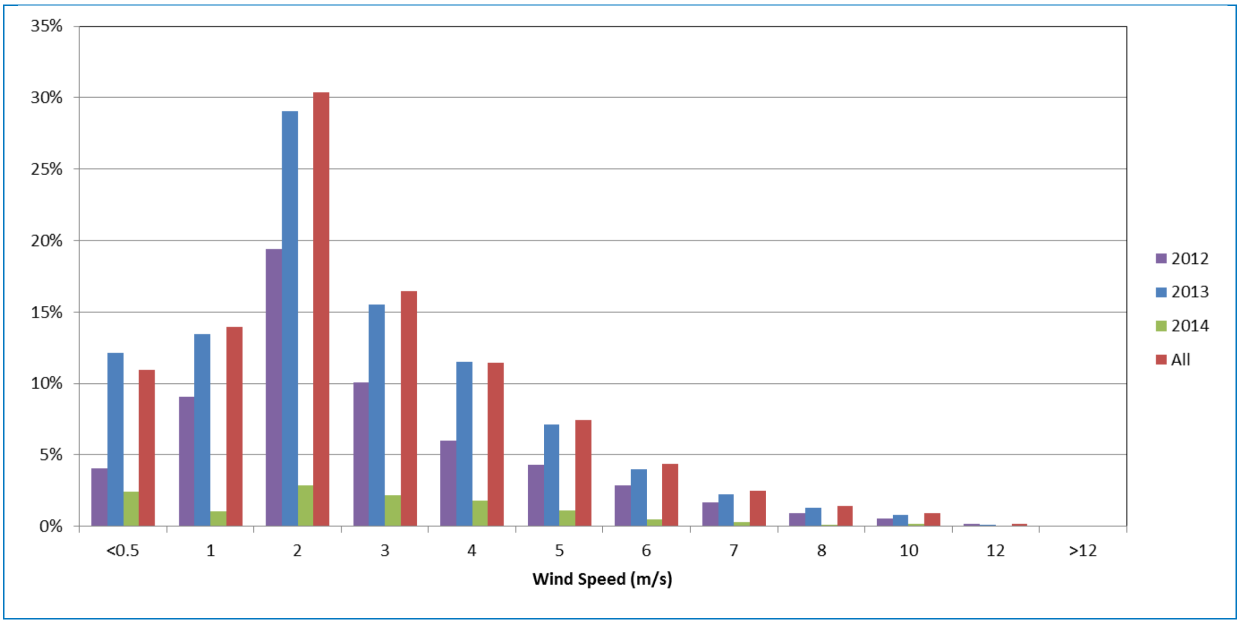

Figure 8: Frequency of wind speeds

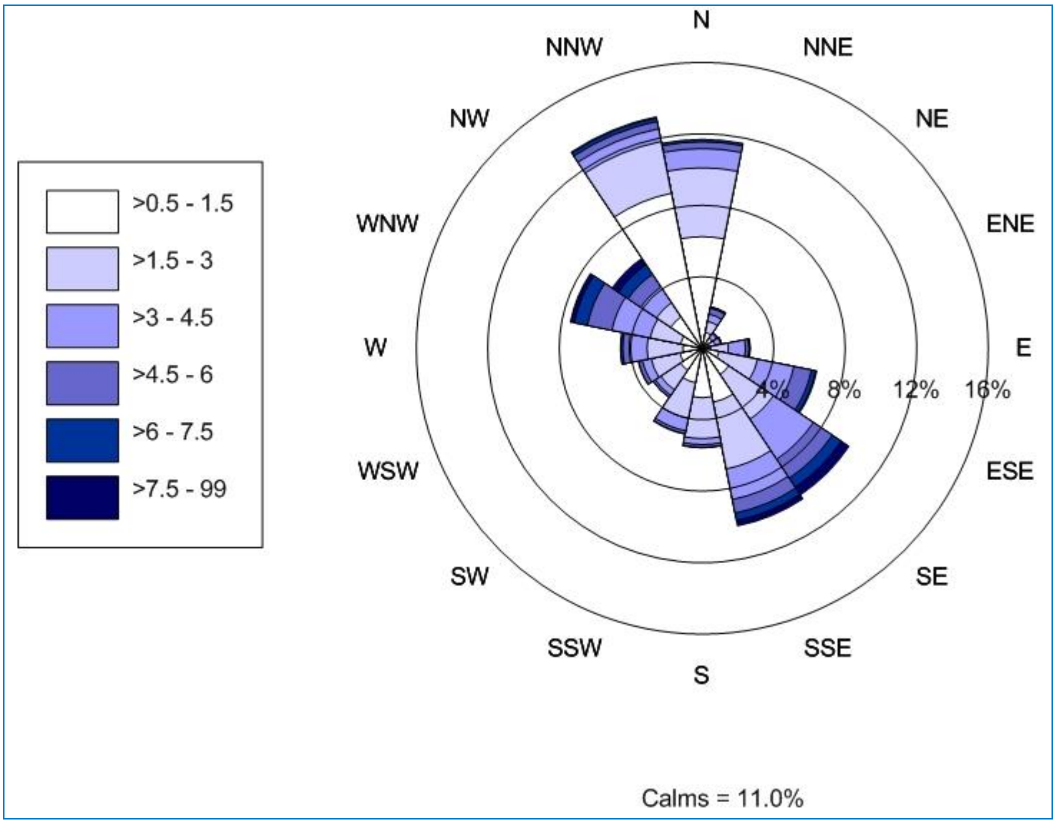

Figure 9: Windrose for all data from May 2012 to February 2014

5 SUMMARY

Based on the location of the existing and proposed overburden handling areas, trigger levels for 'adverse conditions' where there is potential for elevated dust impacts were developed using air dispersion modelling.

The trigger levels determined from air dispersion modelling provide an indication of the potential 'adverse conditions' that can result in elevated dust impacts. The air dispersion modelling for this report did not take into account rainfall or other control measures on site. Therefore, during the 'adverse conditions' identified, visual inspections of the operating conditions at the time will assist in determining if there are dust impacts. In addition, B-T-M has developed a Precinct Air Quality Management Strategy with predictive and reactive measures using air dispersion modelling and real-time monitoring to manage dust emissions from the B-T-M complex. The B-T-M Precinct Air Quality Management Strategy implemented in conjunction with the investigation level developed in this report will assist in minimising dust impacts from the Boggabri coal mine.

The critical locations and trigger levels developed are summarised in **Table 3**.

Table 3: Summary of Trigger Levels

	Trigger Level	Percentage Occurrence
Investigation Level	➢ Wind speed < 1.5 m/s ➢ Wind direction from northern quadrant (approximately 315° to 45°) ➢ Temperature difference (52m – 2m) is positive	4%

6 REFERENCES

US EPA (1985). Compilation of Air Pollutant Emission Factors, AP-42, Fourth Edition United States Environmental Protection Agency, Office of Air and Radiation Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina 27711.