Pollution Reduction Program (PRP) 4 - Particulate Emissions from Coal Trains

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Prepared by:		**Authorised by:**	
Name:	Michelle Manditch	Name:	Yvonne Scorgie
Title:	Senior Environmental Scientist	Title:	Senior Manager
Signature:		Signature:	
Date:	28/9/12	Date:	28/9/12

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Pollution Reduction Program 4 (PRP4) Particulate Emissions from Coal Trains outlined within ARTC's Environment Protection Licence (EPL3142) requires the implementation of a pilot monitoring program to determine whether coal trains and rail transport generally are contributing to ambient particulate levels along the Hunter Valley rail network. Key requirements of the program were:

1. Determine whether loaded coal trains operating on the Hunter Valley rail network are a source of particulate matter emission.
2. Determine whether loaded coal trains operating on the Hunter Valley rail network are a larger cause or source of particulate matter emissions than unloaded coal trains or other trains on the network.

A monitoring program was conducted in accordance with the Work plan PRP4 Coal Dust from Locomotive Loads dated November 2011. The purpose of the study did not include compliance monitoring or health impact assessment; hence the results of this study should not be used as a tool for such assessments.

The pilot monitoring program comprised the use of a light scattering laser photometer (OSIRIS instrument) for continuous measurement of airborne concentrations of TSP (total suspended particulates), PM_{10} (particulate matter with an equivalent aerodynamic diameter of 10 micrometres) and $PM_{2.5}$ (particulate matter with an equivalent aerodynamic diameter of 2.5 micrometres).

Particulate matter concentration monitoring was undertaken at two locations, namely Scholey Street Junction, Mayfield, and a site off Raymond Terrace Drive, Metford. Monitoring devices were positioned in proximity to the track to capture particle emissions from passing trains. Monitoring was undertaken during the period 13 February 2012 to 20 March 2012. Train movement data recorded during the period of particulate matter monitoring were collated and the data paired in time to facilitate joint analysis.

TSP, PM_{10} and $PM_{2.5}$ concentrations measured to coincide with train passes were statistically analysed by train type, accounting for loaded coal trains, unloaded coal trains, passenger trains, freight trains and 'no train' passes. There was a greater degree of confidence in the results obtained for the Metford site as compared to the Mayfield site due to limitations with the Mayfield train movement data set.

Results from the pilot monitoring program are presented in the report. Conclusions reached in respect of the key PRP4 requirements are as follows:

- **PRP4 Requirement: Determine whether loaded coal trains operating on the Hunter valley rail network are a source of particulate matter emission.**

At the Mayfield site, the TSP and PM_{10} concentrations recorded coinciding with all trains, including loaded coal, unloaded coal, freight and passenger were statistically greater than the 'no train' dataset. The $PM_{2.5}$ concentrations recorded coinciding with passenger and freight train categories only were statistically greater than the 'no train' dataset. The statistical technique (ISO20988:2007) shows that all train types are a source of TSP and PM_{10} on the rail network at Mayfield and only freight and passenger trains for $PM_{2.5.}$

At the Metford monitoring station, the TSP, PM_{10} and $PM_{2.5}$ concentrations recorded coinciding with all trains, including loaded coal, unloaded coal, freight and passenger were statistically greater than the 'no train' data set. The statistical technique (ISO20988:2007) shows that all train types are a source of TSP, PM_{10} and $PM_{2.5}$ on the rail network at Metford. The analysis of $PM_{2.5}$ is confounded by the longer atmospheric residence time of fine particles.

The difference in average concentrations when comparing loaded coal to the 'no train' dataset at Mayfield show that the loaded coal trains increase the concentration in the rail corridor on average by 3.3 µg/m³ for TSP, 2.2 µg/m³ for PM_{10} and 0.5 µg/m³ for $PM_{2.5}$. It is anticipated that these concentration differences may be greater if more accurate train movement data was available for this site.

At Metford, the difference in average concentrations when comparing loaded coal to the 'no train' dataset show that the loaded coal trains increase the concentration in the rail corridor by 7.1 µg/m³ for TSP, 4.8 µg/m³ for PM_{10} and 1.2 µg/m³ for $PM_{2.5}$.

- **PRP4 Requirement: Loaded coal trains operating on the Hunter Valley rail network are a larger cause or source of particulate matter emissions than unloaded coal trains or other trains on the network.**

At the Mayfield monitoring site, there were no statistical differences in concentrations across all particulate size fractions when examining the concentration ranges between the upper and lower confidence level concentrations (i.e. uncertainties) of all train types. This result shows that at Mayfield, loaded coal trains are not a statistically different source of particulate matter when compared to other train types. It is anticipated that the use of more accurate train movement data for this site may alter the conclusion.

At the Metford monitoring site, maximum concentrations were recorded to coincide with passenger trains for all particle size fractions. Based on the average, median and 95th percentile and confidence limits around the average concentration, it is concluded that concentrations coinciding with loaded and unloaded coal train passes at Metford are statistically higher for PM_{10} than concentrations recorded during passenger train passes. The $PM_{2.5}$ concentrations that were recorded to coincide with freight, unloaded coal and loaded coal are statistically higher than concentrations recorded during passenger train passes. There was no statistical difference for TSP when comparing the coal trains to passenger trains. Concentrations for loaded and unloaded coal train passes were however comparable to freight train passes across all particle size fractions. There was no statistical difference for TSP, PM_{10} and $PM_{2.5}$ concentrations coincided with loaded coal train passes compared to unloaded coal train passes when examining the confidence limits around the average concentrations between these train types. The $PM_{2.5}$ analysis may have been confounded by the longer atmospheric residence time (Friedlander, 1977) of fine particles.

1 Introduction

Pollution Reduction Program 4 (PRP4) Particulate Emissions from Coal Trains outlined within ARTC's Environment Protection Licence (EPL3142) requires the implementation of a pilot monitoring program to determine whether coal trains and rail transport generally are contributing to ambient particulate levels along the Hunter Valley rail network. Environ Australia Pty Ltd (ENVIRON) has undertaken a monitoring program in accordance with the Work plan PRP4 Coal Dust from Locomotive Loads dated November 2011.

This report documents the results of the pilot monitoring program.

1.1 Pollution Reduction Program Requirements

The requirements of the PRP 4 as specified within EPL3142 are as follows:

4A Action

The licensee will implement a monitoring program to determine whether:

- Loaded coal trains operating on the Hunter Valley rail network are a source of particulate matter emission; and
- Loaded coal trains operating on the Hunter Valley rail network are a larger cause or source of particulate matter emissions than unloaded coal trains or other trains on the network (and by inference contributing to ambient particulate levels).

4B Action

The licensee will submit a detailed work plan for a pilot monitoring program to the EPA for approval. The pilot monitoring program must include the following elements:

1. The use of real time particulate monitoring devices, such as a light scattering laser photometer, to determine in real time levels of TSP (total suspended particulates), PM_{10} and $PM_{2.5}$.
2. The installation of particulate monitoring devices at a minimum of two locations along the Hunter Valley rail network, including, unless otherwise agreed by EPA one location representative of an urban area between Warabrook and Islington. The locations will need to be chosen to capture the movements of loaded coal trains and at a minimum, unloaded coal trains, but preferably freight trains, grain trains and passenger trains as well.
3. The monitoring of the following information in the vicinity of the chosen locations:
   - Train type, direction and speed, loaded or unloaded (not for the background monitor); and
   - Meteorological conditions (including wind speed and wind direction)
4. The particulate monitoring devices will be positioned at an appropriate distance from the track to adequately capture particulate emissions from passing trains.

4C Action

The pilot program, in accordance with the approved monitoring work plan, will be implemented for a period of one month to determine the efficacy of the monitoring program and whether further monitoring is required.

1.2 Monitoring Locations

The two air quality monitoring locations selected during the work plan development were as follows (**Figure 1**):

- Scholey Street Junction, Mayfield (382024.66E, 6358109.21S), and
- The wayside monitor off Raymond Terrace Drive, Metford (369917.88E, 6374557.31S).

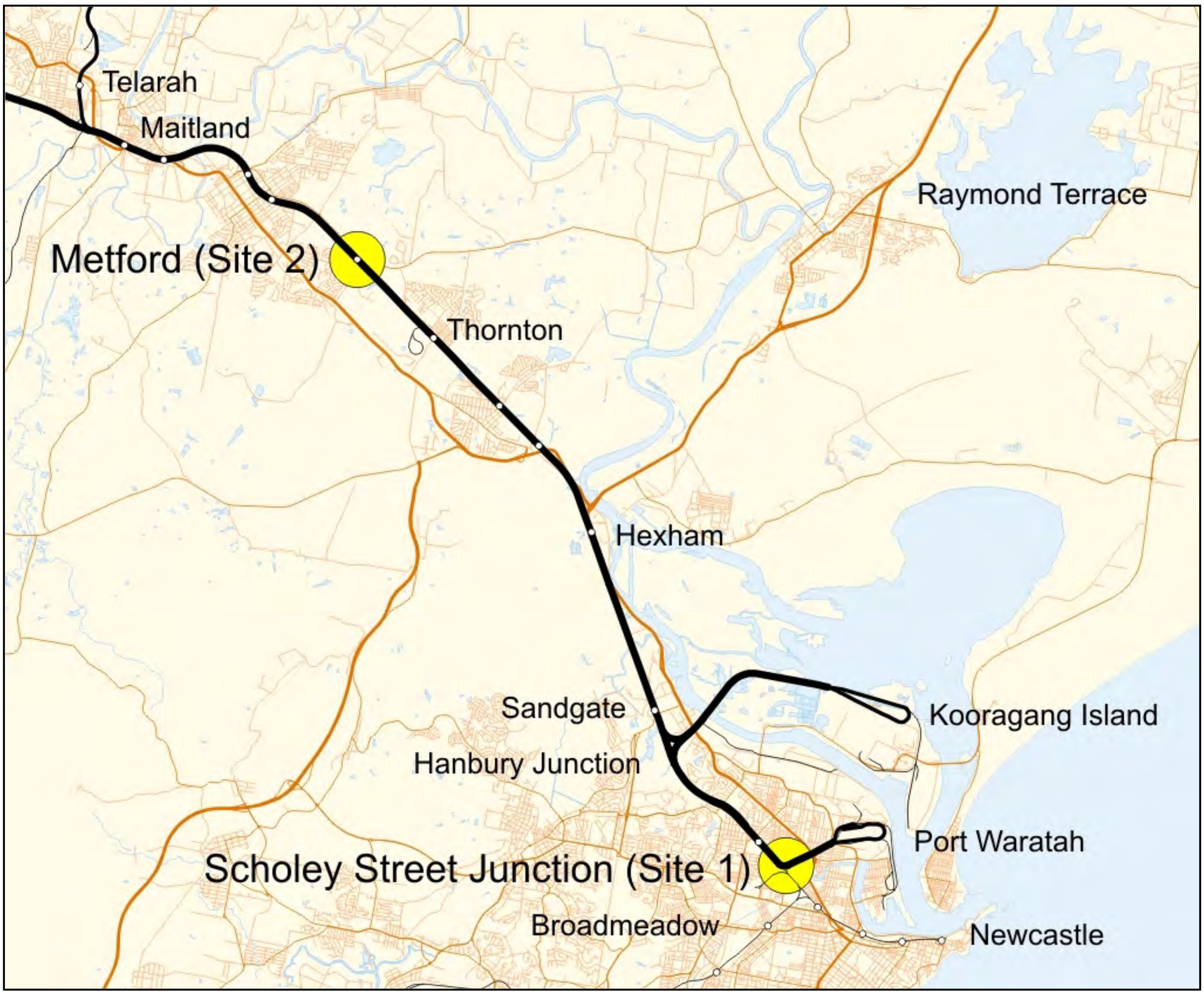

Figure 1: Lower Hunter rail network and monitoring locations (Although the NCIG rail loop is not depicted in this figure, coal train traffic to and from this terminal was measured at the Metford monitoring site.)

1.3 Pilot Program

1.3.1 Monitors Deployed

The OSIRIS instrument was used for the air quality pilot program. The OSIRIS instrument is a light scattering laser photometer that continuously indicates TSP, PM_{10} and $PM_{2.5}$. A laser light scattering photometer was approved for use by the NSW EPA for the PRP due to its fast response time to concentration changes and small size making it suitable for deployment in the rail corridor.

This instrument is not a compliance monitor as it does not satisfy the requirements of the USEPA for Federal Reference or Equivalence Method. As a result the results obtained are not suitable for comparison against National Environmental Protection Measure (NEPM) ambient air quality standards.

1.3.2 Siting of Monitoring Equipment

The OSIRIS and the accompanying cup and vane anemometer were mounted at 4m elevation above the track height. The monitoring equipment was located at a horizontal distance of approximately 3 metres from the nearest tracks at both sites (**Figure 5**, **Figure 6**). The position of the monitor was selected after a preliminary screening check on the concentration profile of particulates with elevation. The elevation of 4m was chosen as the height for the monitor as maximum concentrations of PM_{10} were recorded at this height during the pass by of coal trains. The risk of vandalism to the equipment was also a primary consideration; this elevation gave some protection against the possibility of vandalism.

1.3.3 Duration of Monitoring

The monitoring equipment was installed and data logging commenced at Mayfield on 13 February with the Metford site started on 14 February 2012, hence complying with the due date for the PRP of 15 February 2012. The monitoring program concluded on 20 March 2012 with the period equal to thirty five days.

1.3.4 Data Capture and Averaging Period

Data capture rates for the particulates monitoring at both stations was 100%.

Data logging frequency of the air quality monitors was initially set to 60 seconds then altered to 30 seconds to improve the time resolution.

The data logging frequency was selected due to memory capacity of the OSIRIS instrument. The preferred system became unavailable for hire at the time of the commencement of monitoring. This system would have enabled upload of results to the internet with a larger data storage capacity. If the preferred monitoring system was available, a data logging frequency of 10 -15 seconds may have been implemented for the program.

A more frequent data logging period for air quality data may alter the overall concentrations recorded for the trains, particularly in the case of passenger trains due to their short pass by period when compared to the other train categories. There may be improved accuracy to the concentrations assigned to trains with a more frequent data logging period. The data logging frequency was however adequate to capture changes in concentrations coinciding with train passes as illustrated in **Figure 2**, **Figure 3** and **Figure 4**

A selection of typical concentration profiles are provided to display the change in particulate concentration over time as a train passes the monitoring station. The data supplied for the approach and departure periods of the train is short due to the frequency of the trains

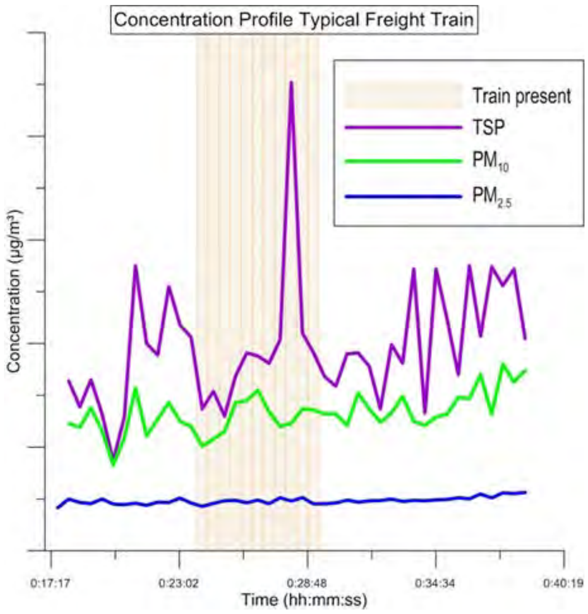

Figure 2: Concentration time series profiles – typical freight train

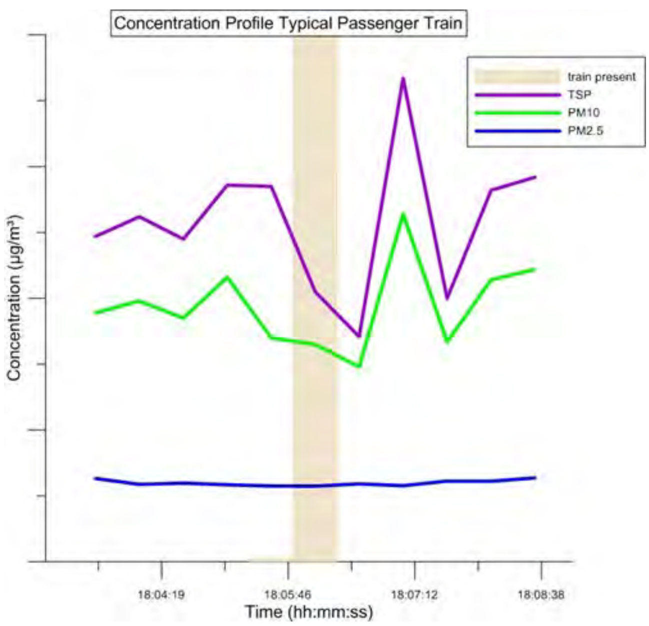

Figure 3: Concentration time series profiles – typical passenger train

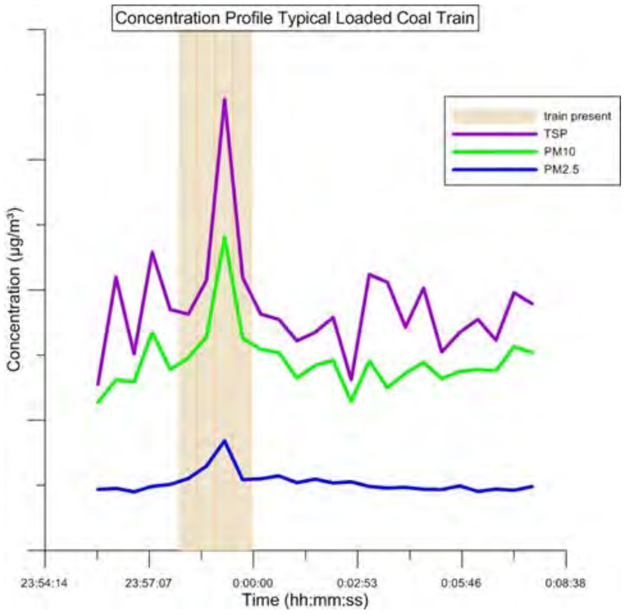

Figure 4: Concentration time series profiles – typical loaded coal train

1.3.5 Limitations and Assumptions

Program limitations and assumptions are listed in Section 5.

1.3.6 Assessment Methodology

Train movement data recorded during the period of particulate matter monitoring were collated and the data paired in time to facilitate joint analysis.

Mayfield Site - pairing of datasets:

1. Train type was determined from the 4Trak data supplied. Details used were Train ID and Locomotive ID.

2. Direction of travel was used to determine if a coal train was loaded or unloaded.

3. 4Trak is a GPS technology system that provided times when the train reached a 'location point'. There were points 500m either side of the Mayfield monitor. This data was to the nearest minute only. An average speed between the two points was assumed to determine the time when the train was at the air quality monitor (arrival time). Efforts to improve the 4Trak data set to a more frequent and accurate time at the 'location points' were not successful. The arrival time was rounded either up or down to match the logging interval of the air quality monitor. This limitation of the train movement system may have resulted in a misalignment of air quality data to the relevant train movement. Refer to Limitation 5.1.11.

4. The two data sets were paired together.

5. Pass by time for each train was determined in seconds using the average length of each train type as recorded at Metford. This pass by time was rounded either up or down to correspond to the logging interval of the air quality monitor. The number of air quality data points (TSP, PM_{10} and $PM_{2.5}$ concentrations) that equal the pass by time was averaged and allocated to that train. For example, a fast passenger train may be assigned one data point only and a coal train may have ten data points averaged to achieve a concentration that corresponds to that train being present.

6. To allow for limited atmospheric dispersion under low wind speed conditions, the averaging period was extended when the wind speed was less than 2m/s, refer to Assumption 5.2.7.

Metford Site - pairing of data sets:

1. The wayside monitor at Metford provided train movement data. The train type was provided by this system.

2. Direction of travel was determined from the train line data provided by the wayside monitor. Loaded and unloaded coal trains were differentiated according to the direction of travel.

3. The wayside monitor provided data on train arrival at the monitoring station, speed and the length of the train. This data was used to determine the time that the train left the vicinity monitoring station. A pass by time to the nearest second was calculated for each train.

4. The train arrival time at the monitor was rounded either up or down to match the nearest data logging interval of the air quality monitor.

5. The two data sets were paired together. The number of air quality data points (TSP, PM_{10} and $PM_{2.5}$ concentrations) that equal the pass by time was averaged and allocated to that train. For example, a fast passenger train may be assigned one data point only and a coal train may have ten data points averaged to achieve a concentration that corresponds to that train being present.

6. To allow for limited atmospheric dispersion under low wind speed conditions, the averaging period was extended when the wind speed was less than 2m/s, refer to Assumption 5.2.7.

Figure 5: Scholey Street Junction, Mayfield monitoring site

Figure 6: Adjacent wayside monitor, Metford monitoring site

2 Mayfield Air Quality Results

2.1 Train Movement Data

Train data for the two stations was recorded by two different mechanisms. At the Mayfield site, measurement of train data was via a system called 4Trak. 4Trak utilises GPS technology to detect the trains' presence at a point either side of the monitoring station and hence calculate its average speed through the area.

Train type was determined from using either the Train ID number or the Locomotive code, with trains identified as loaded coal, loaded coal, unknown, passenger or freight.

Additional 4Trak markers were set up to the south, east and north of the Mayfield site. The purpose of these markers was to determine the direction of the train travel and subsequently whether it was a loaded or unloaded coal train.

The 4Trak point to the north of Mayfield was used to determine the direction of train travel and hence whether it was a loaded or unloaded coal train.

2.2 Train Movements

Data on the total number of train movements is summarised in **Table 1**. The total of all types of trains that passed the monitoring station during the study period is provided. This data is further broken down into the number of single pass by movements (i.e. one train only passes the monitor at a point and time) and multiple pass by movements (more than one train passes the monitor).

Train movement data was further divided into four time categories for examination of the numbers of trains that passed the monitor at the varying periods of the day and week during the study. The categories are:

- Weekdays day(07:00 AM to 06:59PM)
- Weekdays night(07:00PM to 06:59AM)
- Weekends day(07:00AM to 06:59PM)
- Weekends night(07:00PM to 06:59AM)

The total number of trains per category is provided together with the average number per day.

Table 1: Number of train movements (% of total) at Mayfield site 14 February to 19 March 2012

Total number of trains	3 578 (100%)				
Multiple pass by (% of total)	1 991 (56%)				
Single pass by (% of total)	1 588 (44%)				
Time Period	**Train Type**				
	All Trains	**Passenger**	**Coal**	**Freight**	**Unknown**
Total of Weekday Day	1702 (48%)	896 (25%)	355 (10%)	446 (12%)	5 (0%)
Total of Weekday Night	1141 (32%)	389 (11%)	346 (10%)	394 (11%)	12 (0%)
Total of Weekend Night	328 (9%)	84 (2%)	124 (3%)	120 (3%)	0 (0%)
Total of Weekend Day	406 (11%)	153 (4%)	120 (3%)	133 (4%)	0 (0%)
Total per train type	3578 (100%)	1522 (42.5%)	945 (26%)	1094 (31%)	17 (0.5%)
Average per Weekday Day	340	179	71	89	1
Average per Weekday Night	228	78	69	79	2
Average per Weekend Day	81	31	24	27	0
Average per Weekend Night	66	17	25	24	0

Categorisation of the train movement data shows that 44% of the train movements were single pass bys at Mayfield with 1588 train movements in this category. These train movements formed the basis for further analysis.

The number of passenger trains per day is at a maximum for the weekday day periods (07:00AM to 06:59PM). The majority of coal train movements occurred in the day time period on weekdays.

2.3 Trains Assessed

The number of single pass by train type that passed the Mayfield monitor are summarised in **Table 2**. Only known train types were included in the analysis.

Table 2: Number of single pass by trains at Mayfield site 14 February to 19 March 2012

Total	Coal Number (%of singles)		Passenger Number (%of singles)	Freight Number (%of singles)
1588	Loaded	Unloaded	898 (56.6%)	405 (25.6%)
	101(6.4%)	178 (11.3%)		

To allow for differentiation of emissions from each train type only air quality data that was recorded during the pass by of a single train was assessed as detailed in the Work plan Section 6.5 and Limitation 7.1.8.

As a result of the slower train speeds at Mayfield compared to Metford, there are less single pass bys to assess for the coal trains. This is most noticeable for the loaded coal trains due to their slow speed in the vicinity of the Mayfield monitoring station on approach to Port Waratah Carrington coal loader.

2.4 Particulate Matter Concentration by Train Type

Particulate data associated with multiple pass bys was summarised into one category for statistical analysis. There are two or more trains present during a multiple pass by. Similarly, particulate matter concentration data recorded to coincide with single pass bys was analysed statistically. These train movements were broken down into categories of loaded coal, unloaded coal, freight and passenger trains for statistical assessment as shown in **Table 3**.

Whereas the maximum concentrations recorded are presented in the table, 5^{th} and 95^{th} percentile values are given to indicate the data range, indicating potential outliers. Differences in concentrations measured during loaded coal train passes compared to concentrations recorded for other train types are given in **Table 4**.

The study period was five weeks long and took place during the late summer to early autumn seasons of 2012. The data obtained is an indication of the concentrations that would be measured under the meteorological conditions typical of a later summer/autumn period in the lower Hunter region. This data can be treated as a sample for a larger data population by calculating confidence limits around the average or mean value. Upper and lower limits of 95% confidence levels are included in **Table 3** for examination of any statistical difference between the train categories. A statistical difference occurs where there is no overlap in the concentration range between the upper and lower confidence limits of the train categories. The purpose of the PRP is to compare individual train types, so comparison is only made between the single pass bys and not multiple pass bys. For the Mayfield monitoring site, there were no statistical differences in concentrations across all particulate size fractions when examining the concentrations range between the upper and lower confidence level concentrations.

Differences in average, median, 95th percentile and maximum concentrations by train type are illustrated for TSP, PM_{10} and $PM_{2.5}$ in **Figure 7**, **Figure 8** and **Figure 9** respectively.

Maximum particulate matter concentrations during train passes tended to coincide with calm or low wind speed conditions, or alternatively occurred during periods when the wind direction put the monitoring station directly downwind of the rail track. Maximum TSP, PM_{10} and $PM_{2.5}$ concentrations recorded during the program coincided with passenger train passes. This data may however be skewed by the large number of passenger trains measured (898 trains) compared to the number of coal trains (279 trains) and freight trains (405 trains). The 95th percentile concentrations were more comparable across train types.

Average TSP and PM_{10} concentrations coinciding with loaded coal train passes were measured to be marginally higher than concentrations coinciding with passenger train passes. Average particulate concentrations for loaded coal trains and freight trains were within 1% of each other for all particle size fractions. Average $PM_{2.5}$ concentrations were comparable across train types, being negligibly lower for loaded coal trains. Average concentrations coinciding with unloaded coal train passes were lower than concentrations associated with freight and passenger trains for all particle size fractions.

Median particulate matter concentrations were recorded to be similar but slightly lower than average concentrations for all train types. Median TSP and PM_{10} concentrations coinciding with loaded coal train passes were measured to be marginally higher than concentrations coinciding with other train types, however median $PM_{2.5}$ concentrations were comparable across train types (**Table 3**, **Figure 7**, **Figure 8**, **Figure 9**).

By way of summary, the monitoring at Mayfield provided mixed results. Whereas maximum concentrations were recorded to coincide with passenger and freight trains, average and median TSP and PM_{10} concentrations coinciding with loaded coal train passes were marginally higher (less than 1 µg/m^3) than concentrations coinciding with other train types. Average and median $PM_{2.5}$ concentrations were comparable across train types.

Table 3: Mayfield – particulate concentrations by train type (µg/m³)

	TSP					PM_{10}					$PM_{2.5}$				
	Multiple pass bys (c)	Loaded Coal	Unloaded Coal	Other		Multiple pass bys	Loaded Coal	Unloaded Coal	Other		Multiple pass bys	Loaded Coal	Unloaded Coal	Other	
				Freight	Passenger				Freight	Passenger				Freight	Passenger
Average	20.4	21.4	19.9	21.2	20.6	15.4	16.2	15.2	16.1	15.7	6.2	6.4	6.3	6.5	6.5
Standard deviation	10.4	10.2	8.8	10.9	12.7	7.4	7.5	6.3	8.0	9.0	3.2	3.3	3.0	1.4	3.7
Upper Confidence level on Average (95%)	20.8	23.4	21.2	22.3	21.5	15.7	17.6	16.1	16.8	16.3	6.4	7.0	6.8	6.8	6.8
Lower Confidence level on Average (95%)	19.9	19.4	18.6	20.2	19.8	15.1	14.7	14.3	15.3	15.1	6.1	5.7	5.9	6.1	6.3
Median	18.9	21.0	19.8	19.4	18.1	14.7	16.1	14.8	14.9	14.3	5.6	5.7	5.8	5.8	5.9
5^{th} percentile	7.6	7.4	8.6	7.9	6.9	5.9	5.7	6.7	6.4	5.3	2.2	2.3	2.4	2.4	2.0
95^{th} percentile	38.2	39.3	37.1	40.9	43.8	28.7	30.1	24.9	30.2	31.3	12.4	12.8	11.9	12.6	12.8
Number of trains assessed	1990	101[(a)]	178[(a)]	405	898	1990	101	178	405	898	1990	101	178	405	898
Maximum concentration	89.8	53.6	59.4	82.1	99.6	53.1	42.2	46.9	66.6	69.8	25.6	17.3	18.5	24.6	29.6
Date Time of maximum	15/3/12 07:28	3/3/12 15:06	3/3/12 19:08	3/3/12 17:46	25/2/12 12:21	4/3/12 19:06	3/3/12 18:51	3/3/12 19:08	3/3/12 17:46	3/3/12 18:34	4/3/12 19:06	3/3/12 15:06	3/3/12 19:08	4/3/12 18:36	4/3/12 19:21
Wind speed at maximum[(b)]	Calm	1.7	2.3	Calm	1.9	1.0	1.7	2.3	0.8	Calm	1.0	1.7	2.3	1.4	0.5

Wind direction at maximum	Calm	NE	NE	Calm	E	NE	NE	NE	E	Calm	NE	NE	NE	E	NE

(a) Loaded trains approaching Port Waratah Carrington coal loader generally travel at lower speeds due to their queuing to enter the port and hence are more likely to coincide with freight or passenger train passes. Consequently, a significantly lesser number of single pass bys by loaded coal trains were recorded compared to unloaded coal trains.

(b) Calm conditions are defined as periods with wind speeds lower than 0.5 m/s.

(c) Air quality concentrations of all multiple train pass by movements are included in the category. There are two or more trains of any type present at the monitoring station for this category.

Table 4: Mayfield – particle concentrations coinciding with loaded coal trains compared to concentrations coinciding with other train passes and no train dataset

	Differences in TSP Concentrations between Coal Trains and Other Train Types (µg/m³)(a)				Differences in PM_{10} Concentrations between Coal Trains and Other Train Types (µg/m³)(a)				Differences in $PM_{2.5}$ Concentrations between Coal Trains and Other Train Types (µg/m³)(a)			
	Unloaded Coal	Freight	Passenger	No train dataset(b)	Unloaded Coal	Freight	Passenger	No train dataset (b)	Unloaded Coal	Freight	Passenger	No train dataset (b)
Average	1.5	0.2	0.8	3.3	1.0	0.1	0.5	2.2	0.1	-0.1	-0.1	0.5
Median	1.2	1.6	2.9	4.6	1.3	1.2	1.8	3.1	-0.1	-0.1	-0.2	0.4
95th Percentile	2.2	-1.6	-4.5	3.1	5.2	-0.1	-1.2	3.4	0.9	0.2	0.0	1.3
Maximum concentration	-5.8	-28.5	-46.0	-62.1	-4.7	-24.4	-27.6	-16.0	-1.2	-7.3	-12.3	-5.0

(a) Positive (negative) values indicate concentrations recorded to coincide with coal trains are higher (lower) than concentrations measured during other train pass bys.

(b) Positive (negative) values indicate concentrations recorded to coincide with coal trains are higher (lower) than the statistical data set for the 'no train' data.

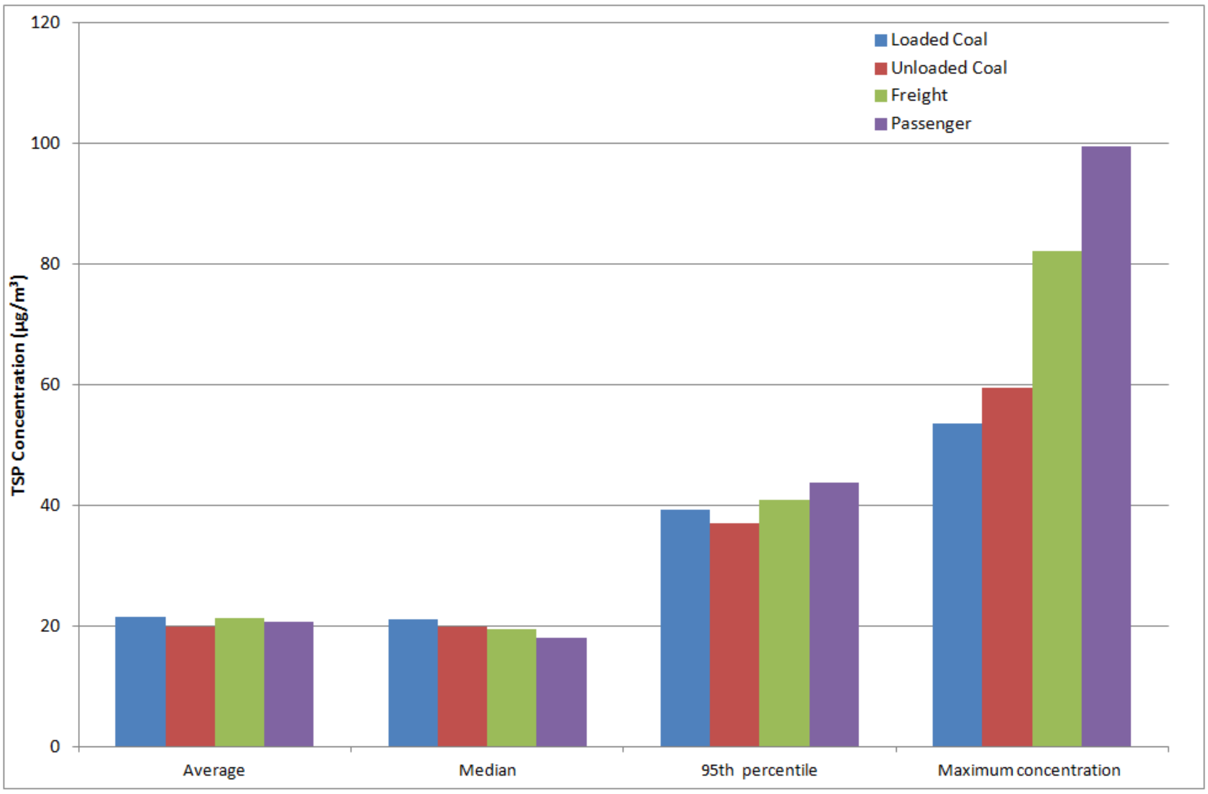

Figure 7: Mayfield – Comparison of TSP Concentrations by Train Type

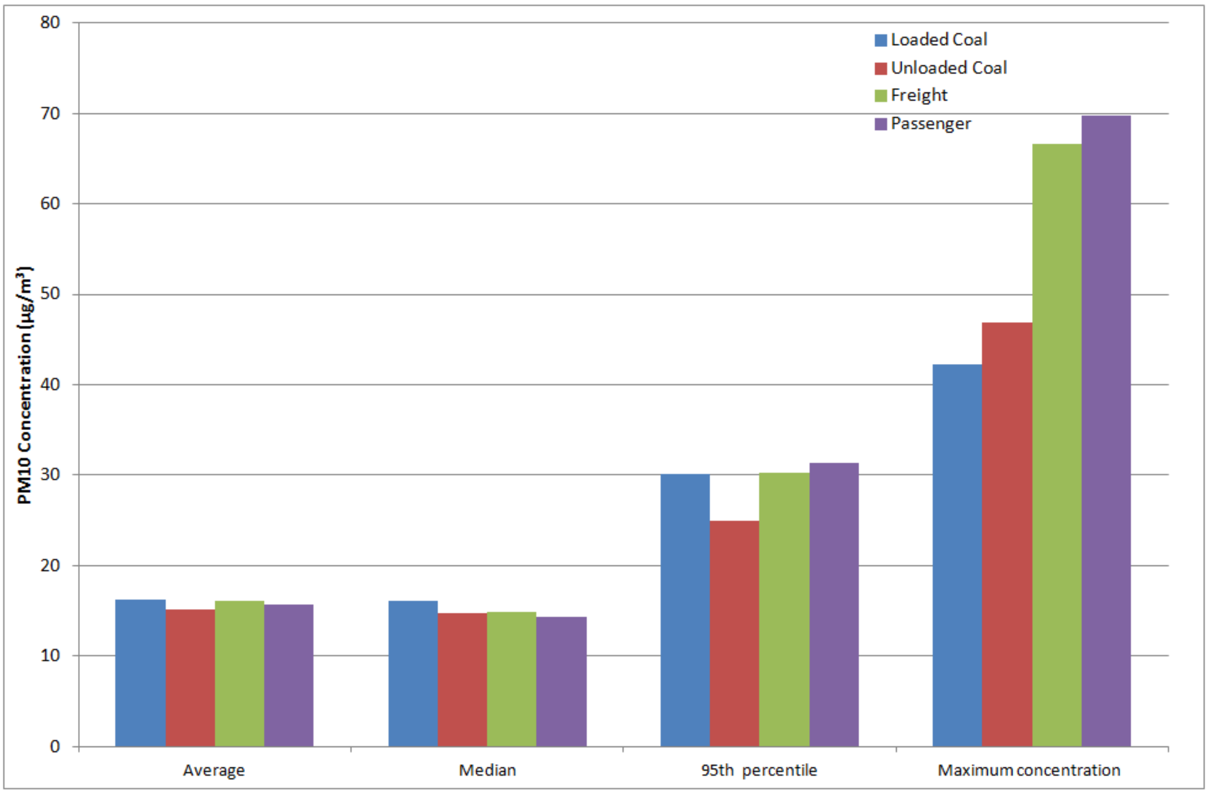

Figure 8: Mayfield – Comparison of PM_{10} Concentrations by Train Type

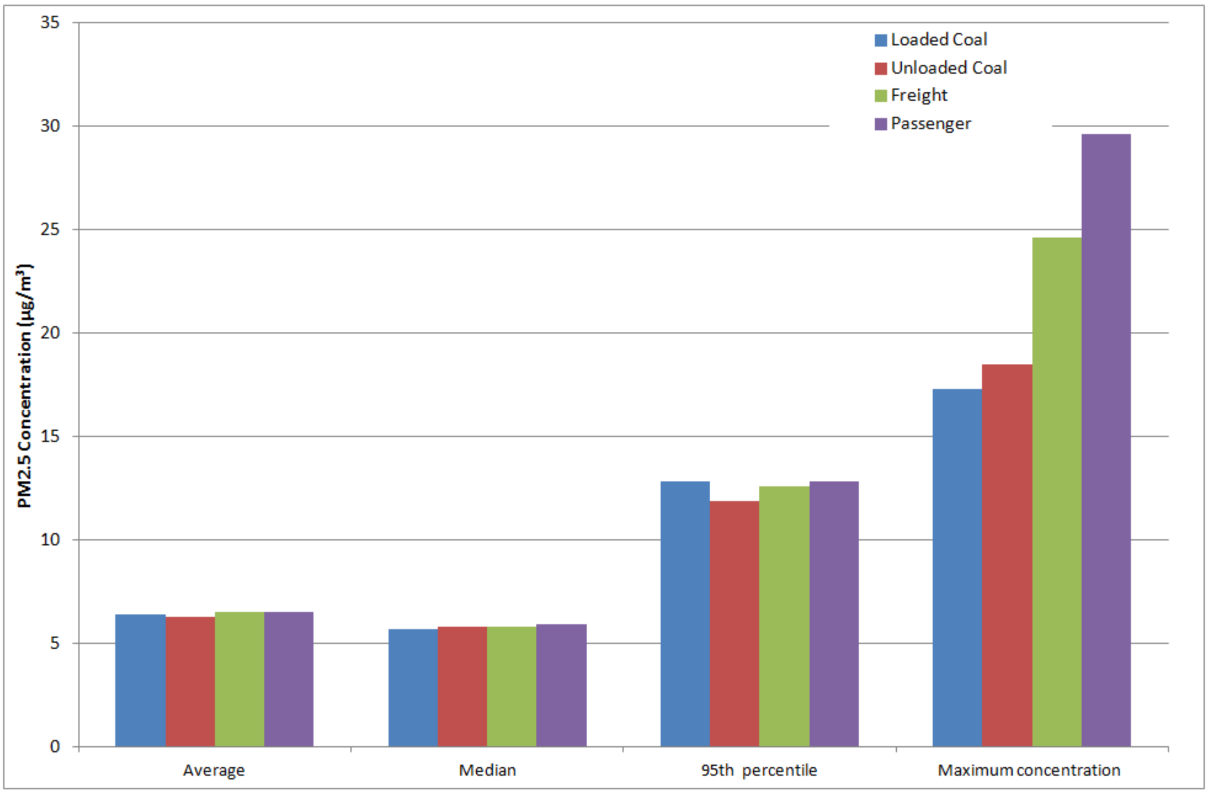

Figure 9: Mayfield – Comparison of $PM_{2.5}$ Concentrations by Train Type

2.5 Ambient Concentrations for ‘No Train’ Periods

A separate ‘no train’ dataset was prepared by removing data from the database that corresponded to a train being present. As there were limitations in accurately matching the train movement data set to the air quality monitoring data set for the Mayfield site, additional data on either side of each train was also removed from this dataset to ensure that a more accurate ‘no train’ dataset was achieved. The amount of data removed was determined by the conditions.

This data is provided to provide an indication of the background ambient air concentration in the rail corridor and allow comparison to the concentrations recorded as coinciding with each train type.

A statistical summary of the ‘no train’ data set is provided in Table 5.

Table 5: Mayfield – no train present dataset (µg/m3)

	TSP	PM_{10}	$PM_{2.5}$
Average	18.1	14.0	5.9
Sample Standard deviation	9.6	6.7	2.9
Upper Concentration level on Average (95% CL)	18.3	14.1	6.0
Lower Concentration level on Average (95%CL)	18.0	13.9	5.9
Median	16.4	13.0	5.3
5th percentile	6.1	4.7	1.5
95th percentile	36.2	26.7	11.5

Examination of the no train dataset against each train type was performed to determine if there were any statistical differences between the datasets. Each bar in the Figures corresponds to a train type. **Figure 10** shows the upper concentration, lower concentration that corresponds to a statistically expanded uncertainty at a confidence level of 95% with the average value shown in the centre of the bar.

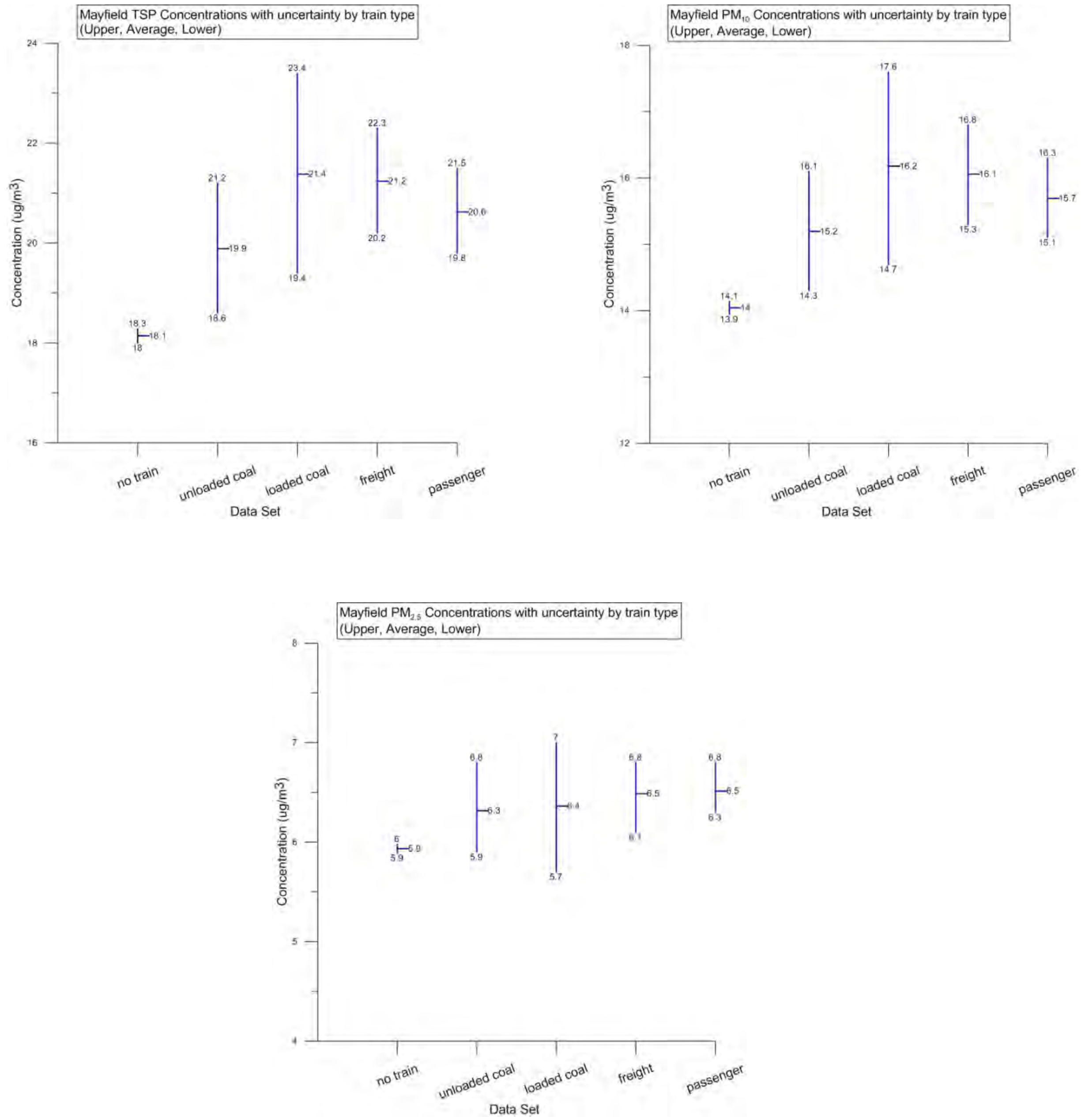

Figure 10: Mayfield – TSP, PM_{10}, $PM_{2.5}$ Particulate Concentrations with upper and lower concentration limits given by train type and with the 'no train' data set

As all train datasets illustrated in **Figure 10** have some overlap, and as such are regarded as having no statistical difference in TSP, PM_{10} or $PM_{2.5}$ concentrations between the train types. The 'no train' dataset has minimal variance in concentrations compared to the train datasets. All train types are a source of TSP and PM_{10} at Mayfield as the average concentrations with expanded uncertainty are greater than the no train dataset. Freight and passenger train concentrations recorded to coincide with the pass by do not overlap with the no train dataset for $PM_{2.5}$ concentrations, hence these two train groups are a source of $PM_{2.5}$

concentrations at Mayfield. Concentrations of $PM_{2.5}$ recorded to coincide with the unloaded and loaded coal trains were not statistically different to the no train dataset and appear to not be a source of $PM_{2.5}$ at this site. The analysis of $PM_{2.5}$ is confounded by the longer atmospheric residence time (Friedlander, 1977) of fine particles.

2.6 Variations in Concentration with Train Speed

Particulate emissions were classified into speed categories of less than 5km/hr, 5km/hr to less than 30km/hr, 30km/hr to less than 60km/hr, 60km/hr to less than 90km/hr and greater than 90km/hr.

Table 6 summarises the concentrations under varying train speed for all single train pass-bys. **Figure 11**, **Figure 12** and **Figure 13** comprise box-and-whisker plots summarising median, 25th percentile and 75th percentile concentrations by train type and speed. Where the data set is small, the whisker for the minimum and maximum values does not differ from the upper and/or lower quartiles and is displayed as coinciding.

Marginally higher median $PM_{2.5}$ concentrations were measured to coincide with slow (<5km/hr) passes by loaded and unloaded coal trains (**Figure 13**).

No statistical difference trends were however evident when comparing particle concentrations with train speed categories.

Table 6: Mayfield – particulate matter concentrations (µg/m^3) classified by train speed

Train speed	<5km/hr			5 to 30km/hr			30 to <60km/hr			60 to <90km/hr			>90 km/hr		
	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP	PM10	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Average	21.1	16.0	6.5	20.3	15.5	6.5	21.3	16.0	6.4	18.9	15.1	6.6	18.0	13.7	5.8
Standard deviation	11.1	8.1	3.5	11.8	8.5	3.6	13.1	8.9	3.5	8.1	6.7	3.3	8.8	5.5	2.5
Median	19.5	14.9	5.9	18.1	14.7	5.9	18.5	14.3	5.7	20.5	15.9	6.3	16.2	13.2	6.0
5th Percentile	7.9	6.2	2.3	6.9	5.2	1.9	7.3	6.0	2.3	4.6	4.2	1.6	8.4	6.4	2.3
95th Percentile	40.9	30.3	12.7	41.1	30.3	13.1	45.7	32.0	12.6	28.5	23.6	11.7	33.9	22.2	9.1
Maximum concentration(a)	88.5	69.8	25.7	92.5	66.6	29.6	99.6	67.4	24.9	36.7	30.2	13.6	34.1	24.0	10.2
Number of trains	593	593	593	643	643	643	309	309	309	28	28	28	15	15	15

(a) The maximum concentration may be due to any train type.

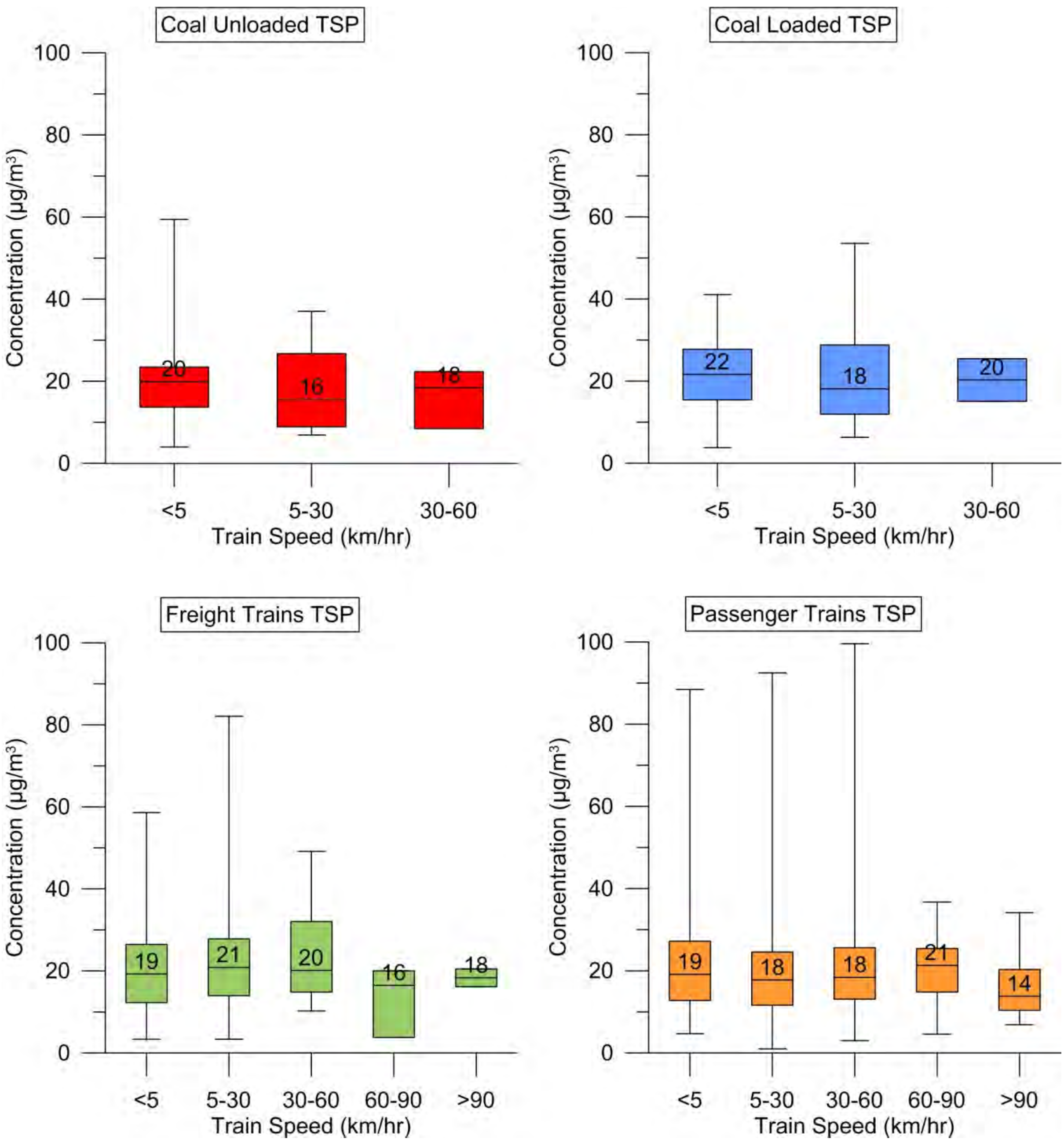

Figure 11: Mayfield TSP by train speed

Box and whisker plots are used in the report to graphically summarise the data sets established. The upper bar or 'whisker' in these plots equates to the maximum concentrations recorded, and the lower whisker reflects the minimum concentration. The upper edge of the coloured box provides the 75th percentile value, and the lower edge of the box the 25th percentile value. The line drawn across the coloured box is the median concentration value. Where only a small data set exists the whiskers are drawn as coinciding with the 25th and 75th percentile values.

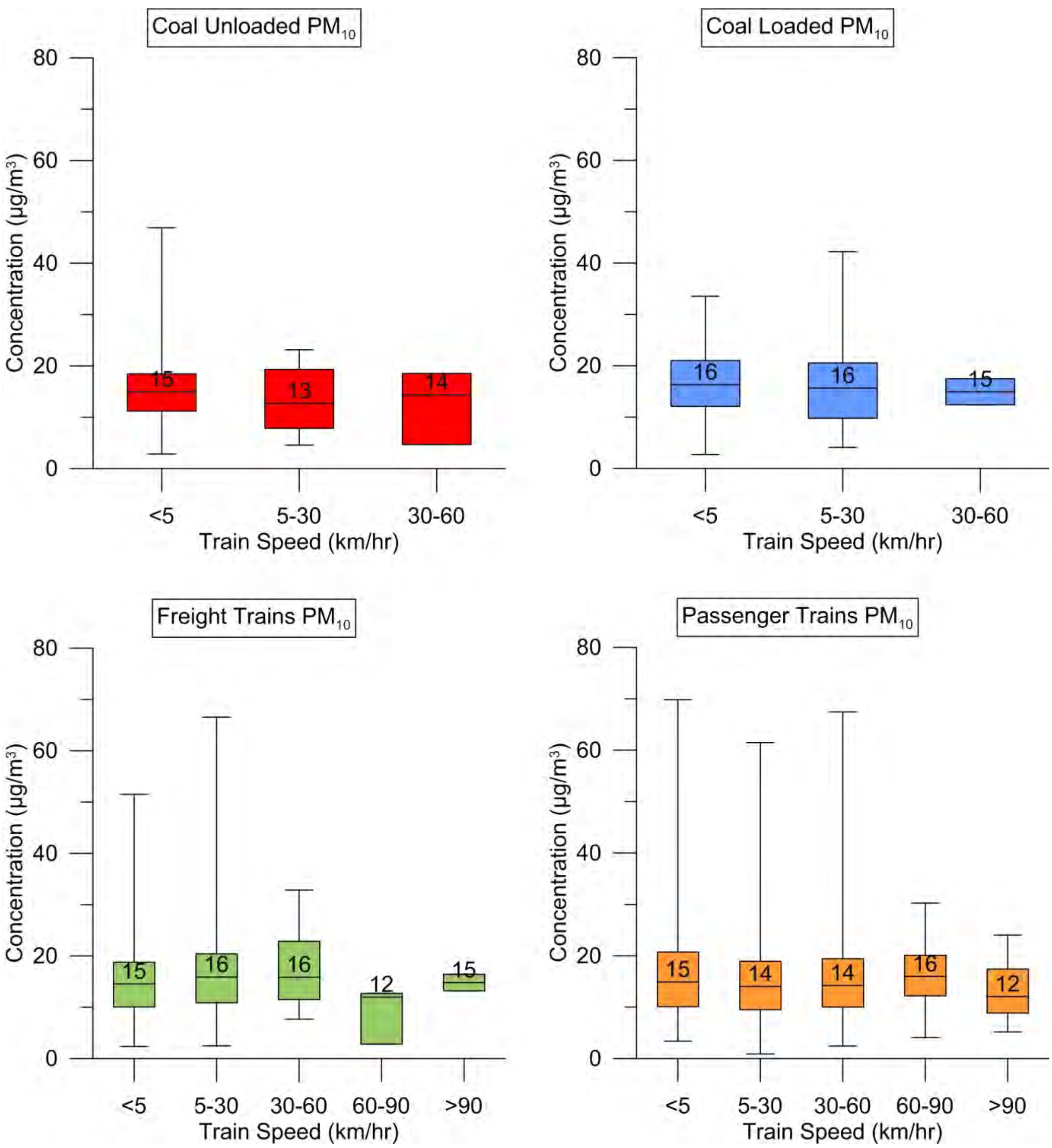

Figure 12: Mayfield PM_{10} by train speed

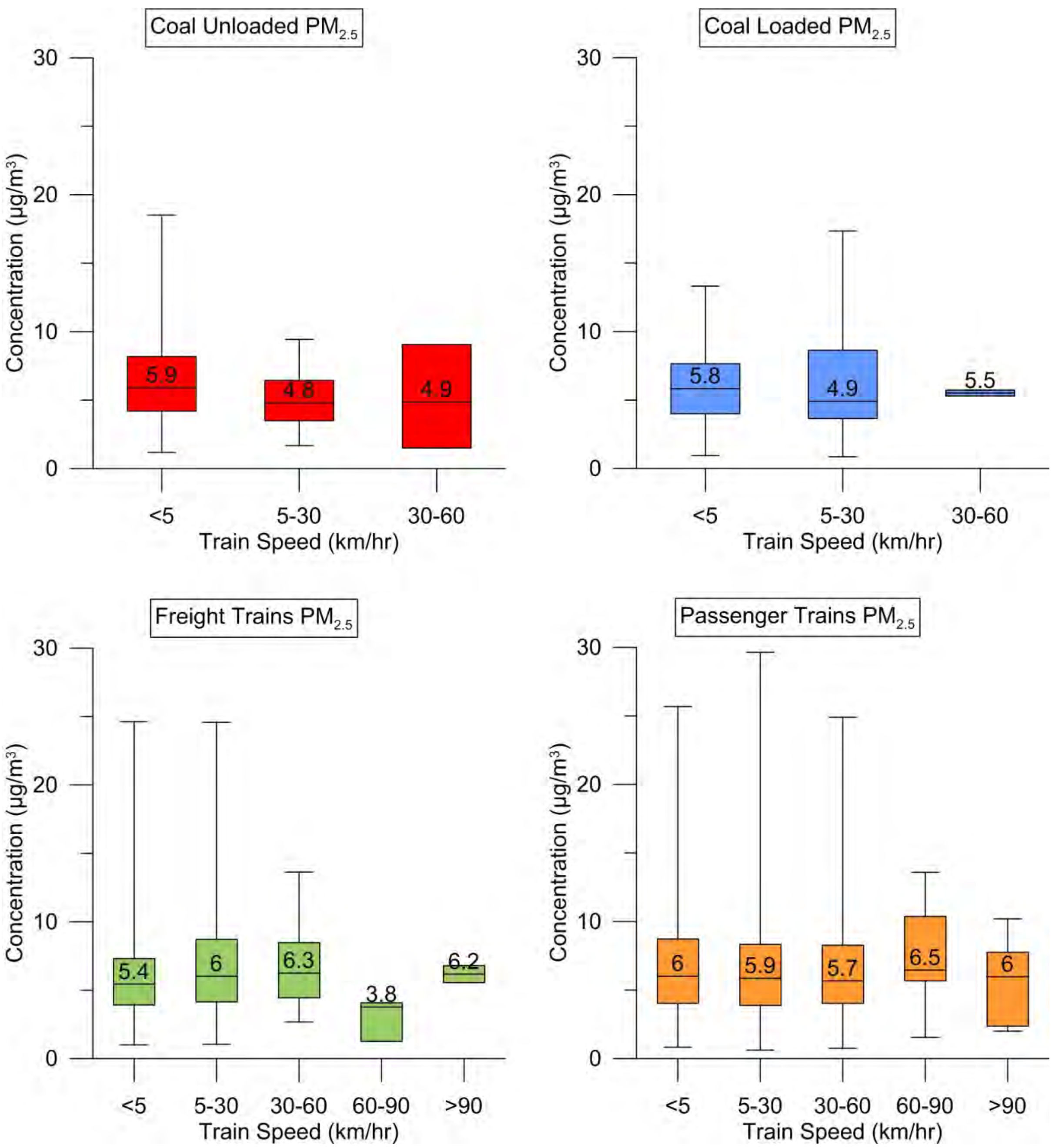

Figure 13: Mayfield $PM_{2.5}$ by train speed

2.7 Potential Influence of Meteorology

2.7.1 Wind Direction

Wind speed and wind direction was measured at each site with the same logging frequency as the air quality data. The anemometer was placed at the same elevation as the air quality monitor. The Mayfield monitoring station is surrounded by rail track on all sides. The train line from Country to Port Waratah runs from 315 degrees bearing through to 90 degrees bearing relative to the position of the air quality monitor. The track from City to Country runs from 140 degrees through to 310 degrees bearing. The track from Port Waratah to City makes up the remainder of the triangle. Particulate matter concentration pollution rose plots are shown in **Figure 14**, **Figure 15** and **Figure 16** for TSP, PM_{10} and $PM_{2.5}$ respectively. Due to the monitoring station being surrounded by and in close proximity to rail tracks, the potential to distinguish trends in concentration by wind direction is limited.

The number of elevated points for the passenger group of trains is related to the greater number of these trains (898) compared to the number of unloaded coal trains (178) and loaded coal trains (101) plotted. Concentrations of particulates in the rail corridor are impacted by the wind direction with higher concentrations measured when the wind direction transports train emissions towards the monitor when the train is at its closest point to the monitor. As there were more passenger train movements available for assessment during the study than coal trains there is a greater probability that a passenger train will be present when the wind direction is at the optimal position to transport particulate emissions to the air quality monitor.

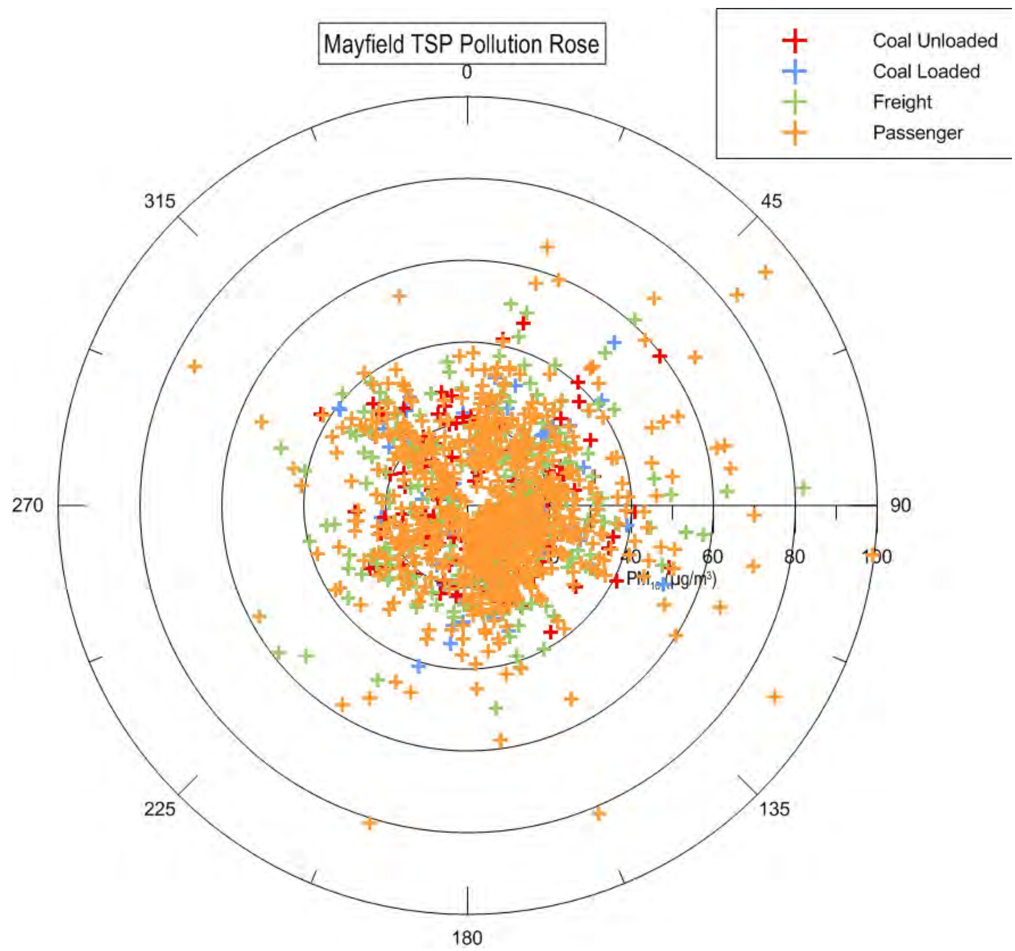

Figure 14: Mayfield TSP Pollution Rose

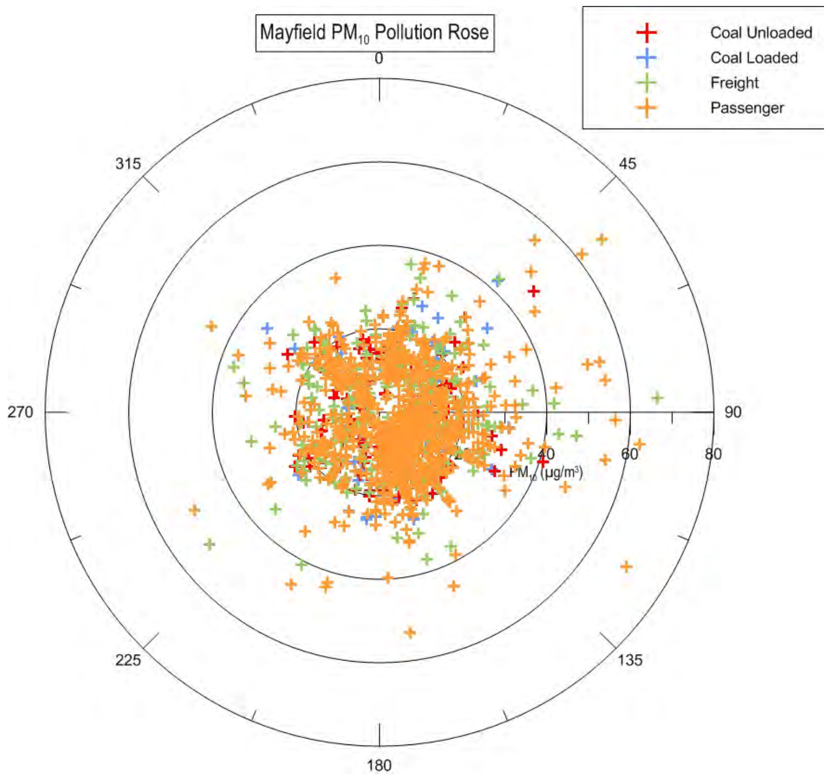

Figure 15: Mayfield PM_{10} Pollution Rose

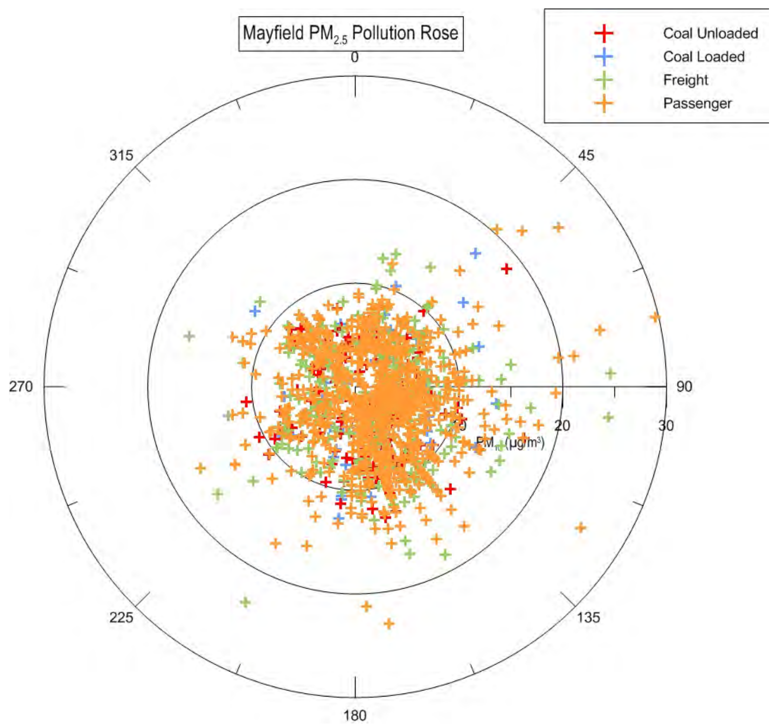

Figure 16: Mayfield $PM_{2.5}$ Pollution Rose

2.7.2 Wind Speed

The concentrations of TSP, PM_{10} and $PM_{2.5}$ were plotted against ambient wind speed to assess whether a relationship exists between these parameters. Increases in ambient wind speed may give rise to increases in dust entrainment from coal trains, but may also enhance the atmospheric dispersion potentials. Data is provided for all trains **Table 7** with scatter plots for each train type given in **Figure 18**, **Figure 19** and **Figure 20**.

Average and median TSP and PM_{10} concentrations were measured to decrease with increased ambient wind speed across train types, including loaded and unloaded coal trains. Trends between average $PM_{2.5}$ concentrations were less significant and consistent across ambient wind speed classes and train types.

Table 7: Mayfield – particulate matter concentrations classified by ambient wind speed

Ambient wind speed (m/s)	TSP (µg/m³)					PM_{10} (µg/m³)					$PM_{2.5}$ (µg/m³)				
	<0.5 m/s	0.5 to <1 m/s	1 to <2 m/s	2 to <5 m/s	5 to <10 m/s	<0.5 m/s	0.5 to <1 m/s	1 to <2 m/s	2 to <5 m/s	5 to <10 m/s	<0.5 m/s	0.5 to <1 m/s	1 to <2 m/s	2 to <5 m/s	5 to <10 m/s
Average	25.1	23.8	21.6	16.4	15.2	17.9	18.0	16.5	13.2	12.1	6.1	6.8	6.6	6.5	7.2
Standard deviation	12.2	14.2	11.7	8.7	6.0	8.4	10.9	8.3	6.6	3.9	3.0	4.4	3.5	3.6	2.7
Median	23.2	21.1	19.8	15.2	14.6	16.7	15.8	15.1	12.4	12.1	5.4	5.9	6.0	6.0	7.3
5th Percentile	8.7	9.3	8.6	6.4	8.2	7.0	6.7	6.8	4.9	5.5	2.6	2.8	2.3	1.7	2.0
95th Percentile	47.8	49.2	41.8	30.3	24.7	33.7	36.7	31.5	23.6	19.9	12.1	14.2	13.0	12.5	10.5
Maximum concentration(a)	81.3	88.5	99.6	62.5	32.5	51.5	69.8	62.6	53.3	21.6	17.1	29.6	24.6	24.2	13.5
Number of trains	347	199	450	569	23	347	199	450	569	23	347	199	450	569	23

(a) The maximum concentration may be due to any train type.

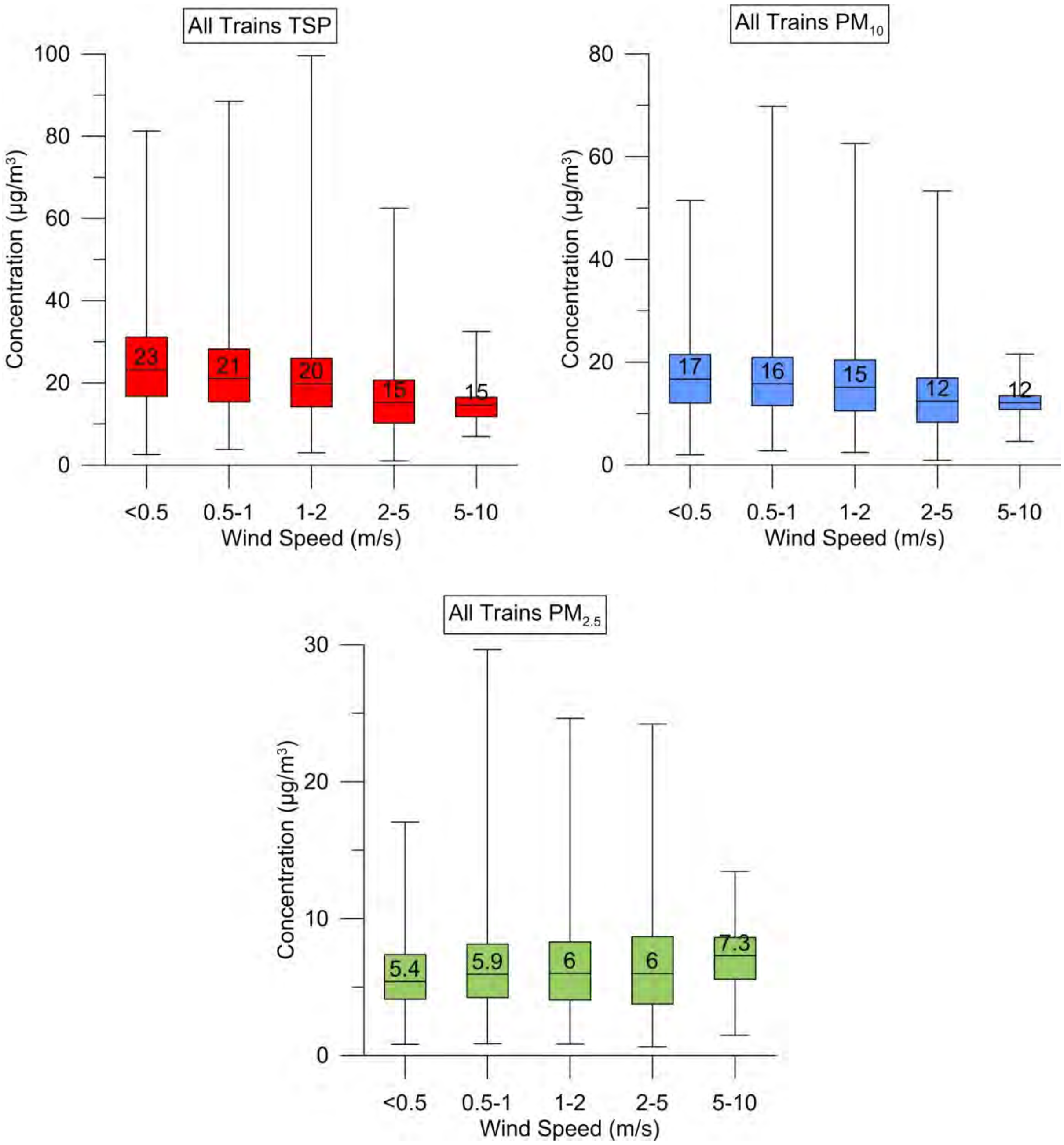

Figure 17: Mayfield – particulate concentrations by ambient wind speed (all train types)

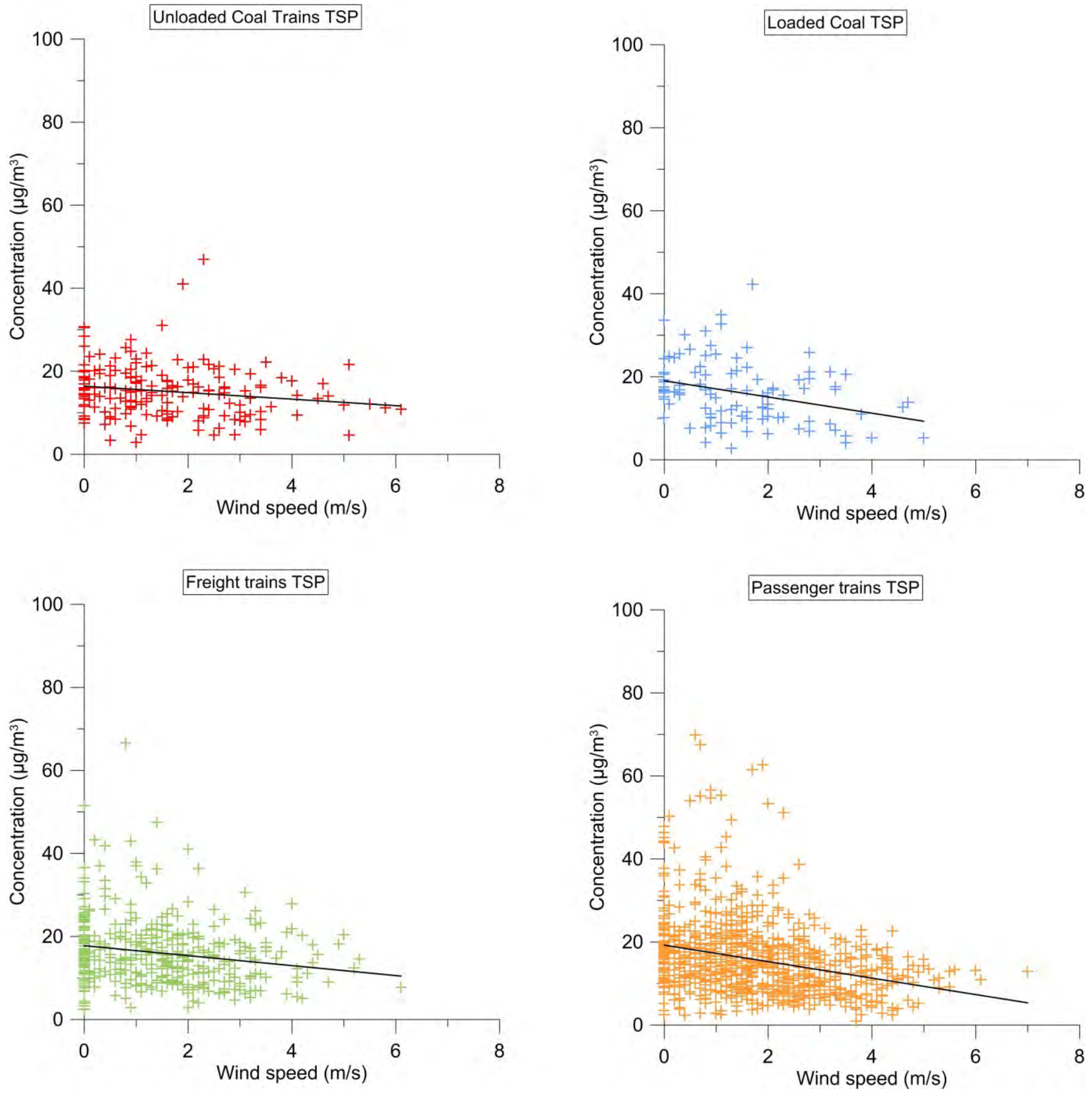

Figure 18: Mayfield TSP concentrations by ambient wind speed and train type

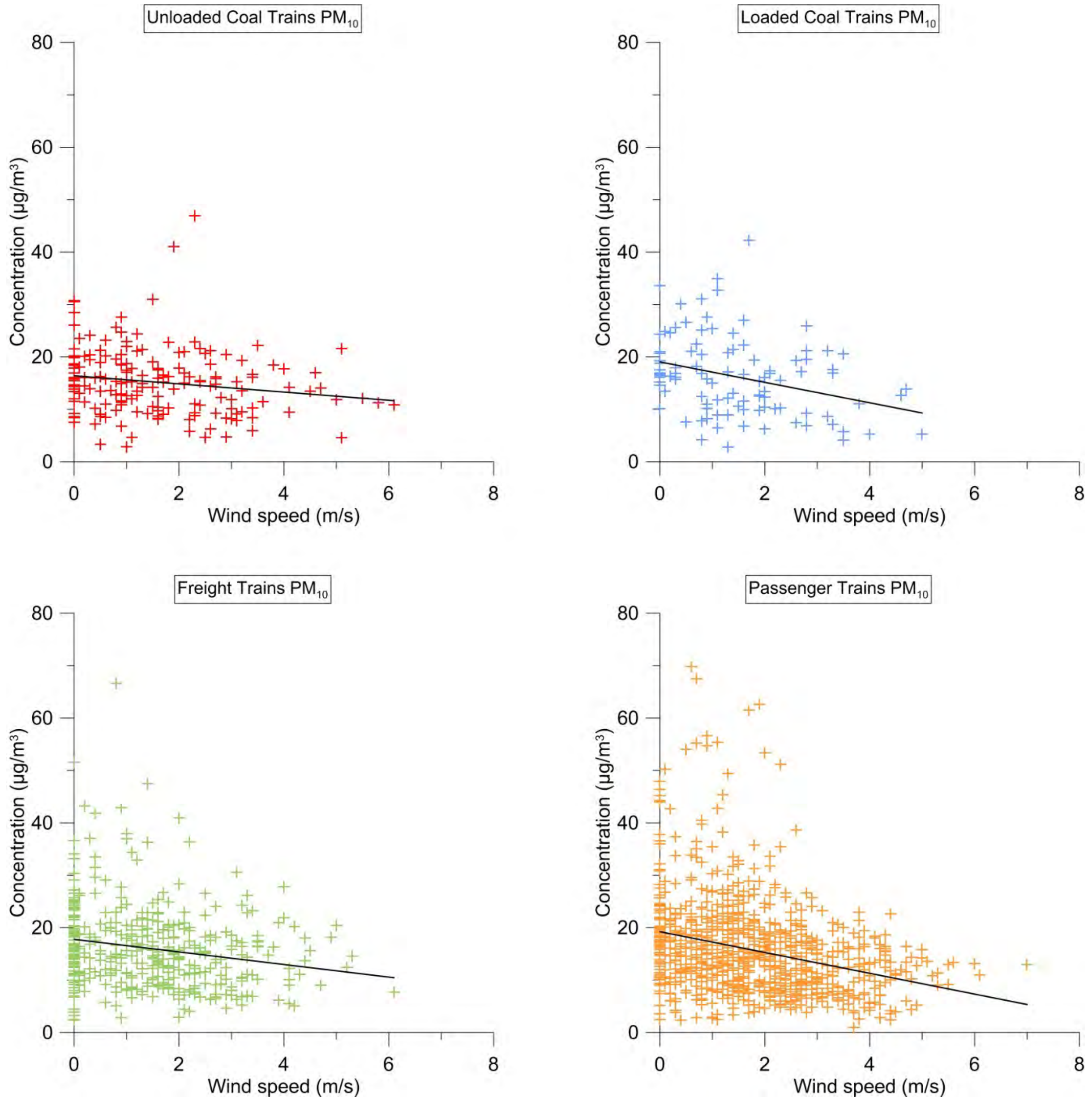

Figure 19: Mayfield PM_{10} concentrations by ambient wind speed and train type

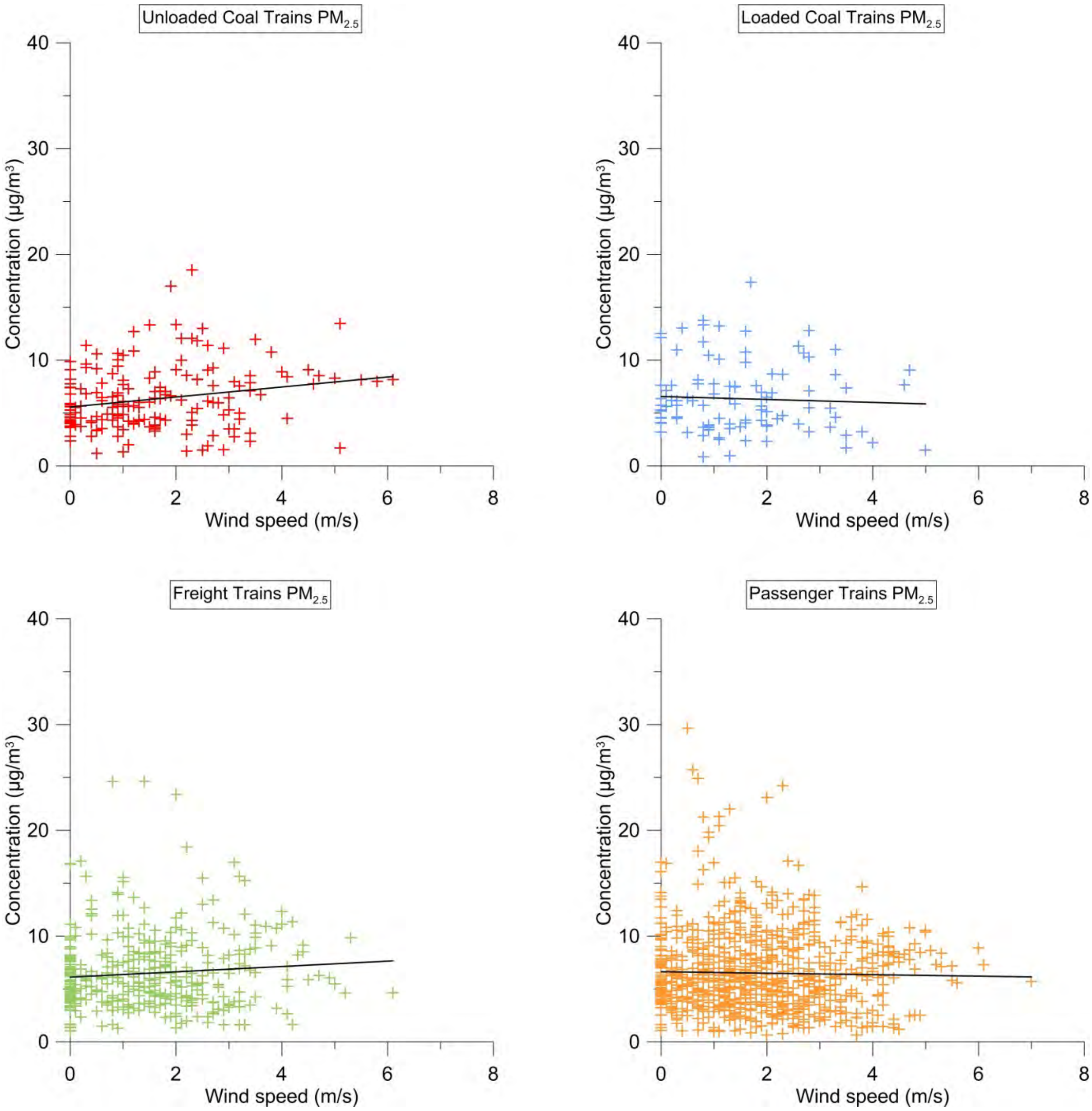

Figure 20: Mayfield $PM_{2.5}$ concentrations by ambient wind speed and train type

3 Metford Air Quality Results

3.1 Train Movement Data

The position of the second monitoring station was selected due to the presence of a wayside train logger. The wayside system provided data on train type, the line the train was travelling on, train speed, length of the train and arrival time to the nearest second.

The information of the line in use was used to determine if a coal train was loaded or unloaded. Trains on the Up Coal line were deemed to be loaded and those on the Down Coal line were unloaded.

The data for the arrival time, speed and length of a train allowed for calculation of a pass by time. Air quality data that corresponded to the pass by time was allocated to each train being assessed.

3.2 Train Movements

Data on the total number of train movements is summarised in **Table 8**.The total of all types of trains that passed the monitoring station during the study period is provided. This data is further broken down into the number of single pass by movements (i.e. one train only passes the monitor at a point and time) and multiple pass by movements (more than one train passes the monitor).

Train movement data was further divided into four time categories for examination of the numbers of trains that passed the monitor at the varying periods of the day and week during the study. The categories are:

- Weekdays day(07:00 AM to 06:59PM)
- Weekdays night(07:00PM to 06:59AM)
- Weekends day(07:00AM to 06:59PM)
- Weekends night(07:00PM to 06:59AM)

The total number of trains per category is provided together with the average number per day.

Table 8: Number of train movements (% of total) at Metford site 14 February to 20 March 2012

Total number of trains	5346 (100%)				
Multiple pass by (% of total)	546 (10%)				
Single pass by (% of total)	4800 (90%)				
Time Period	**Train Type**				
	All Trains	**Passenger**	**Coal**	**Freight**	**Unknown**
Total of Weekday Day	2455 (46%)	1517 (28%)	675 (13%)	173 (3%)	90 (2%)
Total of Weekday Night	1637 (31%)	738 (14%)	700 (13%)	124 (2%)	75 (1%)
Total of Weekend Day	706 (13%)	290 (5%)	319 (6%)	69 (1%)	28 (1%)
Total of Weekend Night	548 (10%)	187 (3%)	284 (5%)	50 (1%)	27 (1%)
Total per train type	5346 (100%)	2732 (51%)	1978 (37%)	416 (8%)	220 (4%)
Average per Weekday Day	491	303	135	35	18
Average per Weekday Night	327	148	140	25	15
Average per Weekend Day	141	58	64	14	6
Average per Weekend Evening	110	37	57	10	5

Categorisation of the train movement data shows that 90% of the train movements were single pass bys at Metford with 4800 train movements in this category. These train movements formed the primary basis for further analysis.

The number of passenger trains per day is at a maximum for the weekday day periods (07:00 AM to 06:59 PM). Coal train movements per day show little difference between the day and night periods, with more train movements per day noted to have occurred on weekdays.

3.3 Trains Assessed

The number of single pass by train type that passed the Metford monitoring site are summarised in **Table 9**. Only known train types were included in the analysis.

Table 9: Number of single pass by trains at Metford site, 14 February to 20 March 2012

Total	Coal		Passenger	Freight
4621	Loaded	Unloaded	2596 (54%)	376 (8%)
	765 (16%)	884 (18%)		

To enable particulate matter concentration data to be analysed by train type, only air quality data recorded during the passage of a single train was assessed, as detailed in the Work plan Section 6.5 and Limitation 7.1.8.

3.4 Particulate Matter Concentration by Train Type

Particulate matter concentration data recorded to coincide with multiple pass bys was summarised into one category for statistical analysis. Similarly, particulate matter concentration data recorded to coincide with single pass bys were further classified by train type, namely loaded coal, unloaded coal, freight and passenger trains, for statistical analysis (**Table 10**).

Whereas the maximum concentrations recorded are presented in the table, 5^{th} and 95^{th} percentile values are given to indicate the data range, indicating potential outliers. Differences in concentrations measured during loaded coal train passes compared to concentrations recorded for other train types are given in **Table 11**.

The study period took place over five weeks during the late summer to early autumn seasons of 2012. The data obtained is therefore indicative of the concentrations that would be measured under the meteorological conditions typical during a late summer/autumn period in the Hunter region. This data can be treated as a sample for a larger data population by calculating confidence limits around the average or mean value. Upper and lower limits at 95% confidence level are included for examination of any statistical differences between the train categories. A statistical difference occurs where there is no overlap in the concentration range between the upper and lower concentration limits of the train categories. The purpose of the PRP is to compare individual train types, so comparison are only made between single pass bys and not multiple pass bys. For the Metford monitoring site, the only statistical difference in concentrations was in the PM_{10} particulate size fraction. The concentrations of PM_{10} recorded to coincide with the loaded and unloaded coal trains were found to be statistically greater than those recorded to coincide with the passenger trains.

Differences in average, median, 95^{th} percentile and maximum concentrations by train type are illustrated for TSP, PM_{10} and $PM_{2.5}$ in **Figure 21**, **Figure 22** and **Figure 23** respectively.

Table 10: Metford – particulate concentrations (µg/m^3) by train type

	TSP					PM_{10}					$PM_{2.5}$				
	Multiple pass bys (b)	Loaded Coal	Unloaded Coal	Other		Multiple pass bys	Loaded Coal	Unloaded Coal	Other		Multiple passbys	Loaded Coal	Unloaded Coal	Other	
				Freight	Passenger				Freight	Passenger				Freight	Passenger
Average	33.9	30.8	29.6	31.2	28.8	22.1	20.7	20.0	20.6	18.6	6.3	5.9	6.0	6.0	5.3
Sample Standard deviation	40.2	18.3	21.5	35.4	31.7	18.8	11.9	11.9	17.0	14.8	3.6	3.4	3.4	3.6	3.2
Upper Confidence on Average (95%)	37.2	32.1	31.0	34.7	30.0	23.6	21.5	20.7	22.3	19.2	6.6	6.2	6.2	6.4	5.4
Lower Confidence on Average (95%)	30.5	29.5	28.2	27.6	27.6	20.5	19.8	19.2	18.8	18.0	6.0	5.7	5.8	5.7	5.2
Median	27.5	27.1	25.8	26.1	23.5	19.0	18.8	17.7	18.3	15.8	5.7	5.1	5.3	5.4	4.6
5th Percentile	12.7	11.3	11.0	11.2	10.4	8.7	7.5	7.3	6.7	6.9	2.3	1.8	1.9	1.6	1.6
95th Percentile	67.0	63.5	58.9	61.1	57.6	42.6	40.2	38.8	39.7	36.2	12.7	11.7	12.0	12.0	10.9
Number of trains	546	765	884	376	2596	546	765	884	376	2596	546	765	884	376	2596
Maximum concentration	783	234	450	634	983	338	234	193	273	411	25.5	28.1	26.0	29.0	43.6
Date Time of	1/3/12	16/2/1	1/3/12	1/3/12	1/3/1	1/3/12	16/2/12	1/3/12	1/3/12	1/3/12	20/2/12	16/2/12	19/3/12	19/3/12	13/3/1

maximum	14:42	2 02:01	14:16	18:44	2 14:06	14:42	02:01	14:16	18:44	14:06	04:33	02:01	03:27	05:00	2 15:00
Wind speed at maximum	4.2	0.5	5.3	5.0	4.6	4.2	0.5	5.3	5.0	4.6	2.5	0.5	Calm[(a)]	Calm[(a)]	1.4
Wind direction at maximum	NW	SW	WNW	NW	NW	NW	SW	WNW	NW	NW	N	SW	Calm[(a)]	Calm[(a)]	S

(a) Calm conditions are defined as periods with wind speeds below 0.5 m/s.

Air quality concentrations of all multiple train pass by movements are included in the category. There are two or more trains of any type present at the monitoring station for this category.

Table 11: Metford – particle concentrations coinciding with loaded coal trains compared to concentrations coinciding with other train passes

	Differences in TSP Concentrations between Coal Trains and Other Train Types (µg/m³)[(a)]				Differences in PM_{10} Concentrations between Coal Trains and Other Train Types (µg/m³)[(a)]				Differences in $PM_{2.5}$ Concentrations between Coal Trains and Other Train Types (µg/m³)[(a)]			
	Unloaded Coal	**Freight**	**Passenger**	**No train data set(b)**	**Unloaded Coal**	**Freight**	**Passenger**	**No train data set (b)**	**Unloaded Coal**	**Freight**	**Passenger**	**No train dataset (b)**
Average	1.2	-0.4	2.0	7.1	0.7	0.1	2.1	4.8	-0.1	-0.1	0.6	1.2
Median	1.3	1.0	3.6	5.8	1.1	0.5	3.0	4.5	-0.2	-0.3	0.5	1.1
95th Percentile	4.6	2.4	5.9	17.3	1.4	0.5	4.0	10.2	-0.3	-0.3	0.8	2.3
Maximum concentration	-216.0	-400.0	-749.0	-352	41.0	-39.0	-177.0	-82	2.1	-0.9	-15.5	-29.1

(a) Positive (negative) values indicate concentrations recorded to coincide with coal trains are higher (lower) than concentrations measured during other train pass bys.
(b) Positive (negative) values indicate concentrations recorded to coincide with coal trains are higher (lower) than the concentrations in the 'no train' dataset.

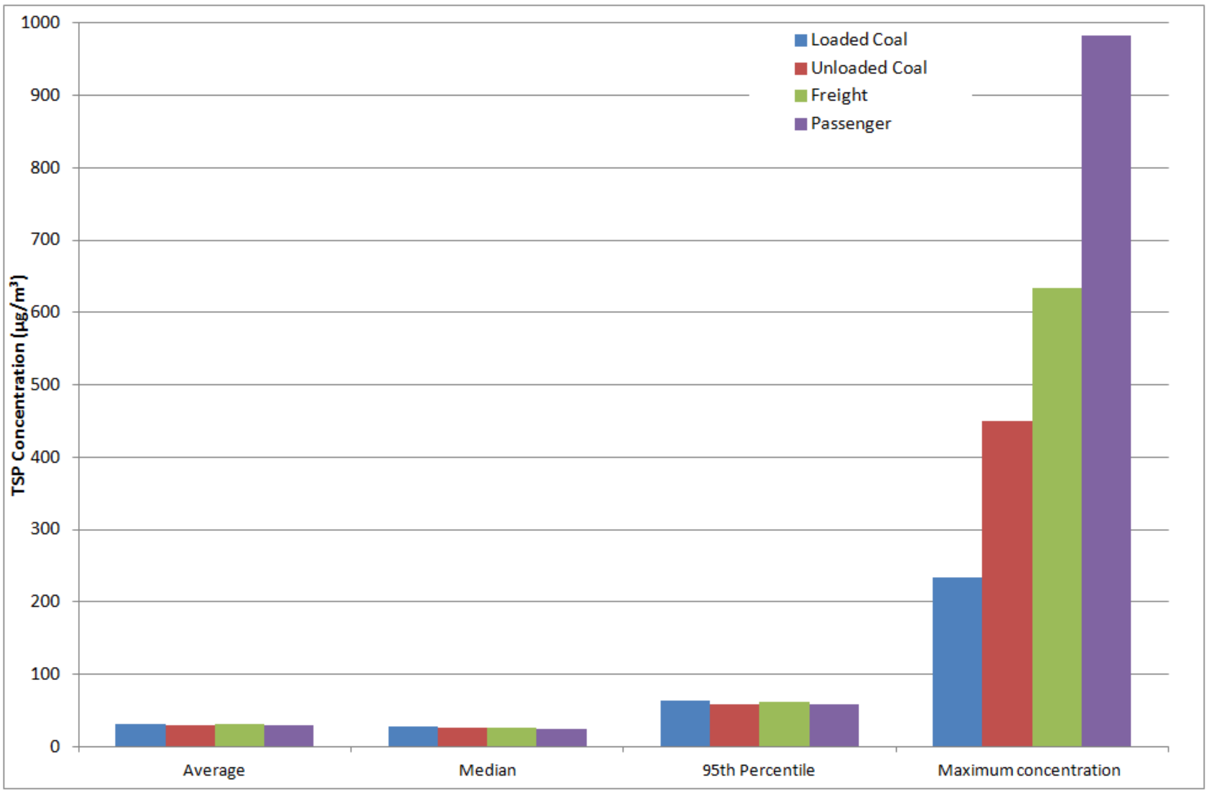

Figure 21: Metford – Comparison of TSP Concentrations by Train Type

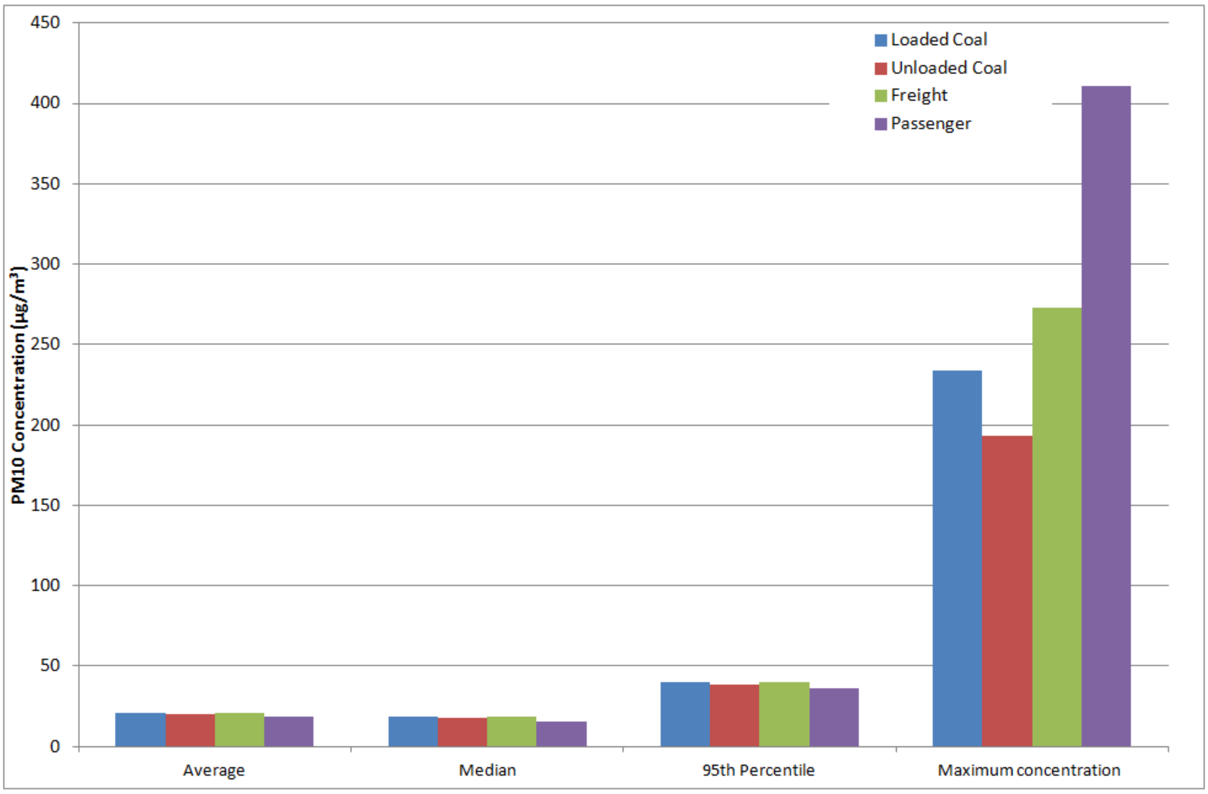

Figure 22: Metford – Comparison of PM_{10} Concentrations by Train Type

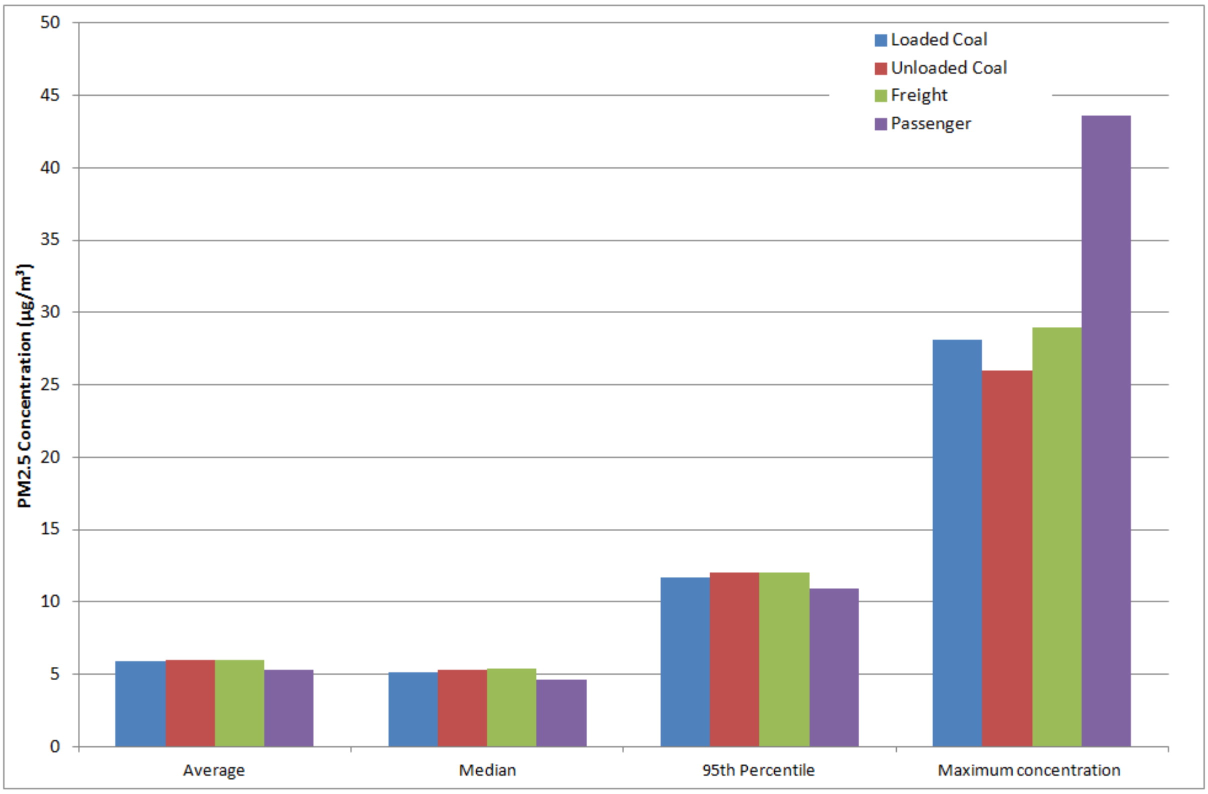

Figure 23: Metford – Comparison of $PM_{2.5}$ Concentrations by Train Type

Maximum TSP, PM_{10} and $PM_{2.5}$ concentrations recorded during the program coincided with passenger train passes. This data may however be skewed by the large number of passenger trains measured (2596 trains) compared to the number of coal trains (1649 trains) and freight trains (376 trains).

Maximum particulate matter concentrations during train passes tended to coincide with calm or low wind speed conditions, or alternatively occurred during periods when the wind direction put the monitoring station directly downwind of the rail track (**Table 10**).

Average and median TSP, PM_{10} and $PM_{2.5}$ concentrations measured to coincide with loaded and unloaded coal trains were higher than the concentrations recorded to coincide with passenger train pass bys.

Average particle concentrations coinciding with both loaded and unloaded coal trains were lower than or equal to the average measured concentrations for freight trains passes, across all particle size fractions.

Based on the combined consideration of average, median and 95th percentile concentrations, it is concluded that concentrations coinciding with loaded and unloaded coal train passes are higher than concentrations recorded during passenger train passes. Concentrations for loaded and unloaded coal train passes where however comparable to freight train passes across particle size fractions.

The only statistical difference in concentrations was that noted for the PM_{10} and $PM_{2.5}$ particulate size fraction when comparisons of average concentrations including expanded measurement uncertainties at a 95% confidence level were made. The concentrations of PM_{10} recorded to coincide with the loaded and unloaded coal trains were found to be statistically greater than those recorded to coincide with the passenger trains. The concentrations of $PM_{2.5}$ recorded to coincide with the loaded, unloaded coal and freight trains were found to be statistically greater than those recorded to coincide with the passenger trains.

3.5 Ambient Concentrations for 'No Train' Periods

A separate 'no train' dataset was prepared by removal of data from the database that corresponded to a train being present.

This data was prepared to provide an indication of the background ambient air concentration in the rail corridor and allow comparison with concentrations recorded as coinciding with each train type.

A statistical summary of the 'no train' data set is provided in Table 12.

Table 12: Metford – no train present dataset (µg/m^3)

	TSP	PM_{10}	$PM_{2.5}$
Average	23.7	15.9	4.7
Sample Standard deviation	13.2	7.9	2.7
Upper Concentration level on Average (95% CL)	23.8	16.0	4.7
Lower Concentration level on Average (95%CL)	23.6	15.8	4.7
Median	21.3	14.3	4.0
5th percentile	8.9	6.4	1.5
95th percentile	46.2	30.0	9.4

Examination of the 'no train' dataset against each train type was performed to determine if there were any statistical differences between the datasets. Each bar in the Figures corresponds to a train type. **Figure 24** shows the upper and lower concentrations corresponding to a confidence level of 95% with the average concentration value given in the centre of the bar.

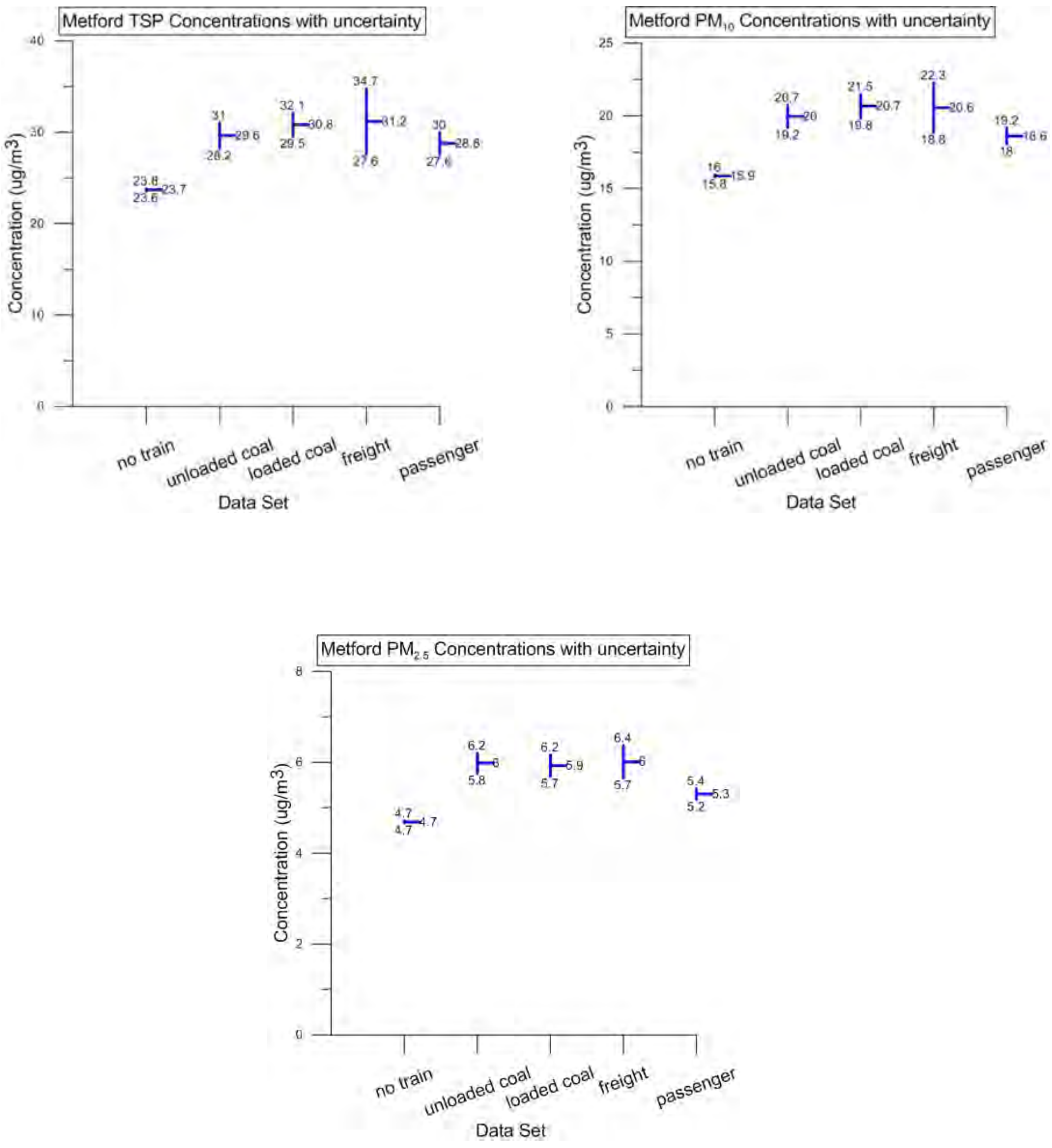

Figure 24: Metford – TSP, PM_{10}, $PM_{2.5}$ Particulate Concentrations with upper and lower concentration limits given by train type and for the with 'no train' data set

As the TSP datasets in **Figure 24** have some overlap for the train type data they are regarded as having no statistical difference between train types. The TSP 'no train' dataset has minimal variance in concentrations compared to the train datasets and does not overlap with the train datasets. The PM_{10} concentrations that were recorded to coincide with passenger trains are statistically different to those of the coal trains, including both loaded and unloaded. As there is no overlap for the TSP, PM_{10} and $PM_{2.5}$ 'no train' data compared to the train datasets, this indicates that the trains have an impact on the ambient air in terms of TSP , $PM_{10.}$and $PM_{2.5}$.

The $PM_{2.5}$ concentrations that were recorded to coincide with passenger trains are statistically different to those of the freight trains and the coal trains, including both loaded and unloaded. The analysis of $PM_{2.5}$ may be confounded by the longer atmospheric residence time of fine particles.

Concentrations measured to coincide with loaded coal train pass bys were higher than the 'no train' concentrations for the average, median and 95th percentile TSP, PM_{10} and $PM_{2.5}$ concentrations. The maximum concentrations for the 'no train' data set were greater than the loaded coal, This would be due to comparison of a single 30 second data point for 'no train' periods being compared to averaged data points that corresponded to train pass by intervals. The comparison of maximum concentrations is therefore not considered a good indicator of trends.

3.6 Variations in Concentration with Train Speed

Particulate emissions were classified into speed categories of less than 5km/hr, 5km/hr to less than 30km/hr, 30km/hr to less than 60km/hr, 60km/hr to less than 90km/hr and greater than 90km/hr. There were no coal trains passing by the Metford monitoring station during the monitoring period with speeds of greater 90 km/hr.

Table 13 summarises the measured particle concentrations coinciding with varying train speed classes for all single train pass-bys. This data is further disaggregated in **Figure 25**, **Figure 26** and **Figure 27** into individual train types. The Box and whisker plots provided in these figures enable comparisons in median, 25th percentile and 75th percentile concentrations measured to coincide with different train types and speeds.

No significant trends were noted when comparing particulate matter concentrations with train speed across train types and particle size fractions. An increase in TSP concentrations coinciding with loaded coal train passes with increases in train speed was noted; however the significance of this trend is uncertain. Average TSP concentrations of 24 $\mu g/m^3$, 27 $\mu g/m^3$ and 34 $\mu g/m^3$ were measured to coincide with loaded coal train speeds in the ranges of less than 30km/hr, 30km/hr to 60km/hr, and 60km/hr to 90km/hr respectively.

Peak particulate matter concentrations measured across train types tended to coincide with higher train speed classes. Such peaks could be due to dust entrainment from wagons (in the case of coal trains) or from the track due to trains travelling at higher speeds.

Table 13: Metford – particulate matter concentrations (µg/m^3) by train speed class												
Train speed	**<30km/hr**			**30 to <60km/hr**			**60 to <90km/hr**			**>90 km/hr**		
	TSP	**PM_{10}**	**$PM_{2.5}$**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**TSP**	**PM10**	**$PM_{2.5}$**	**TSP**	**PM_{10}**	**$PM_{2.5}$**
Average	26.7	18.5	5.6	30.0	20.1	5.9	30.3	19.8	5.7	28.5	18.5	5.3
Standard deviation	11.9	83	2.9	16.9	10.8	3.4	37.8	17.5	3.4	25.5	12.5	3.2
Median	23.0	15.3	5.4	26.3	18.2	5.1	24.8	16.8	4.9	23.6	15.9	4.6
5th Percentile	13.2	9.7	2.0	11.2	7.2	1.8	10.6	6.9	1.7	10.4	7.1	1.6
95th Percentile	50.6	33.2	10.9	63.2	39.9	11.7	58.9	38.4	11.7	58.8	36.1	10.7
Maximum concentration (a)	55.4	39.2	13.3	125	81.2	28.1	983	411	33.1	479	211	43.6
Number of trains	68	68	68	912	912	912	2353	2353	2353	1289	1289	1289

(a) The maximum concentration may be due to any train type.

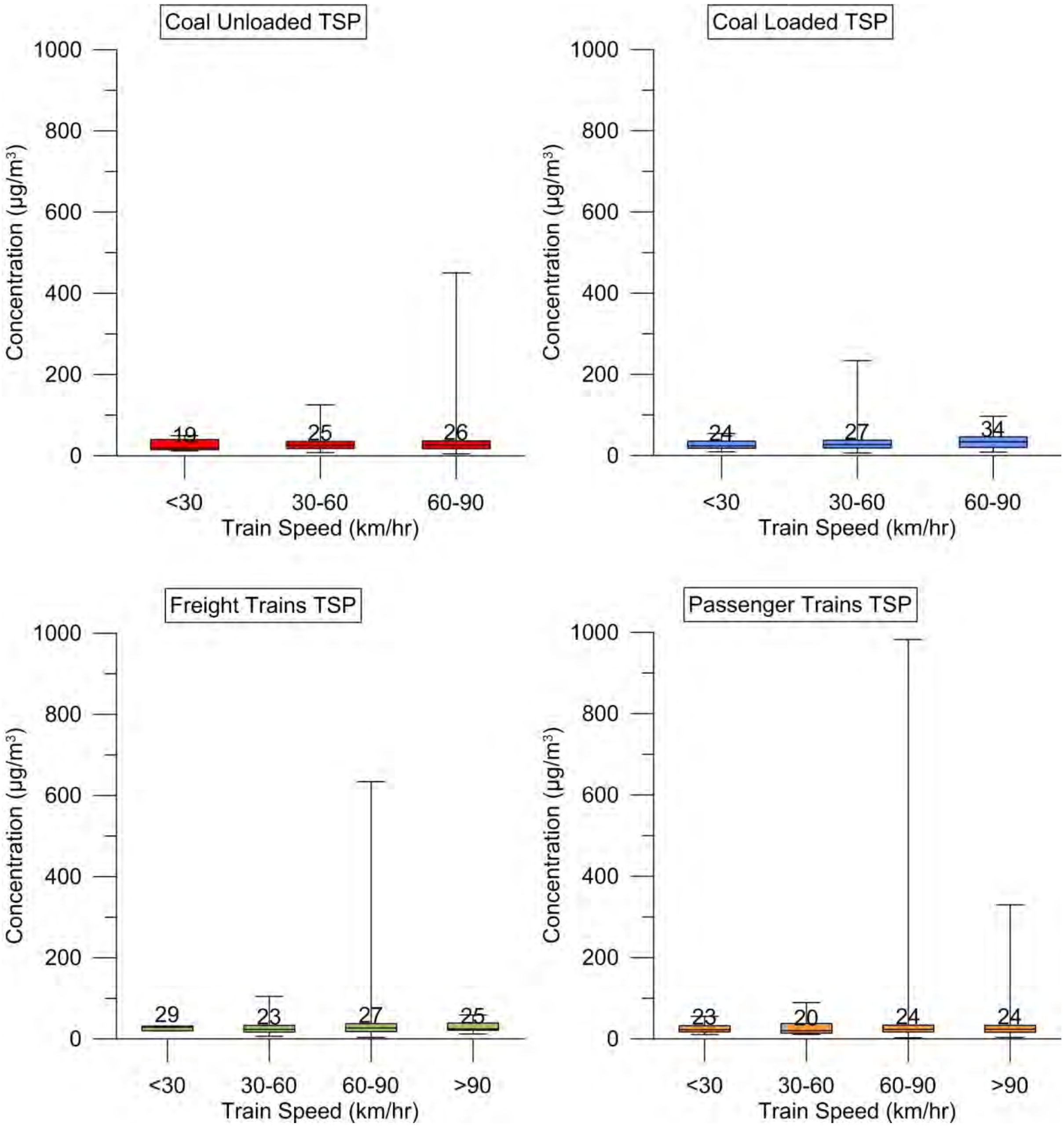

Figure 25: Metford TSP by train speed

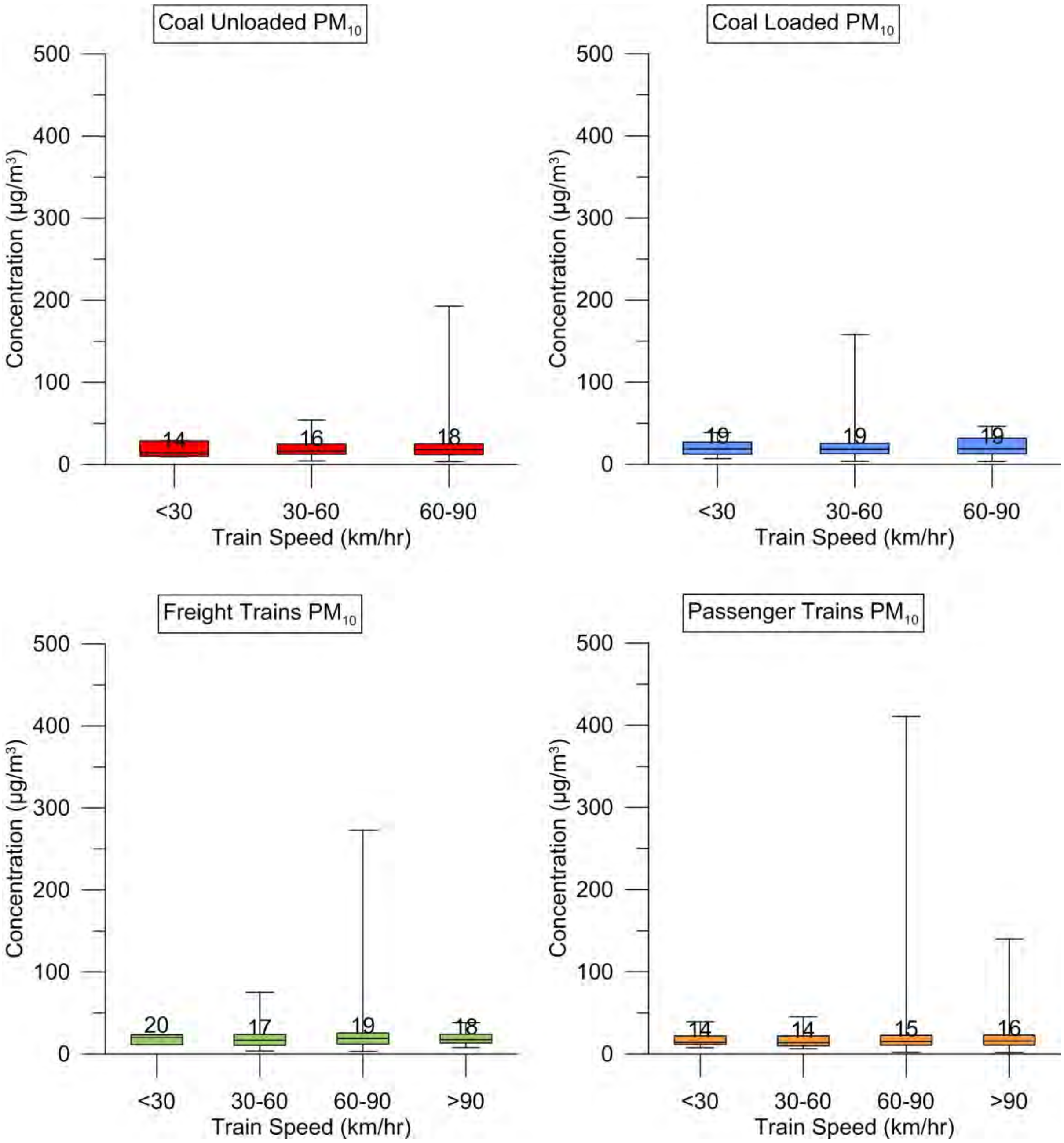

Figure 26: Metford PM_{10} by train speed

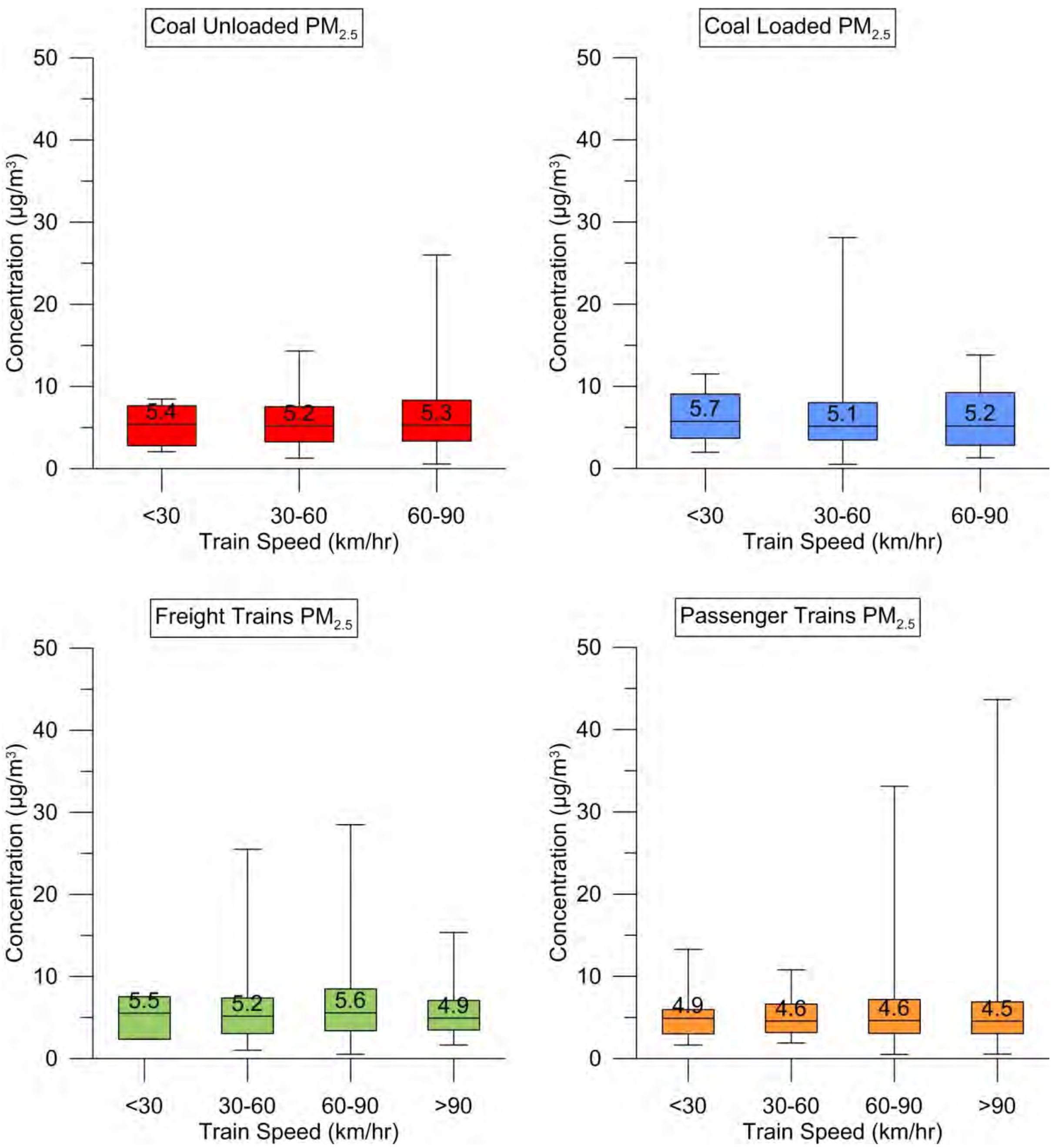

Figure 27: Metford $PM_{2.5}$ by train speed

3.7 Potential Influence of Meteorology

3.7.1 Wind Direction

Wind speed and wind direction was measured at each site with the same logging frequency as the air quality data. The anemometer was placed at the same elevation as the air quality monitor. The train line runs city to country from 140 to 315 degrees bearing relative to the position of the air quality monitor.

Particulate matter concentration pollution rose plots are shown in **Figure 28**, **Figure 29** and **Figure 30**. Maximum concentrations were measured to coincide with periods during which the wind was blowing from the train line to the monitor. It is however noted that an industrial premises is located immediately on the other side of the rail track. During the monitoring period demolition works was occurring at the premises.

The number of elevated points for the passenger group of trains is related to the greater number of these trains (2596) compared to the number of unloaded coal trains (884) and loaded coal trains (765) plotted. Concentrations of particulates in the rail corridor are impacted by the wind direction with higher concentrations measured when the wind direction transports train emissions towards the monitor when the train is at its closest point to the monitor. As there were more passenger train movements available for assessment during the study than coal trains there is a greater probability that a passenger train will be present when the wind direction is at the optimal position to transport maximum particulate emissions to the air quality monitor.

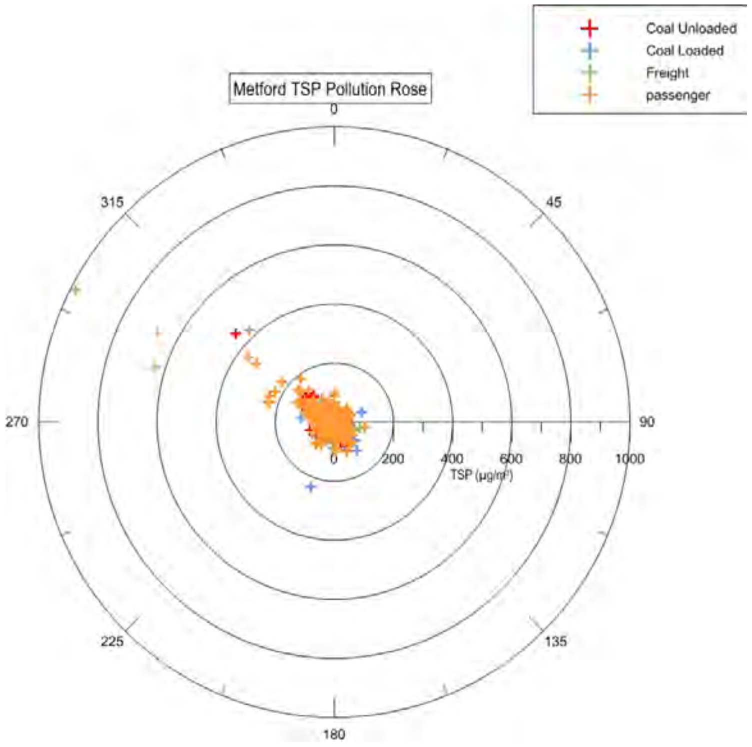

Figure 28: Metford TSP Pollution Rose

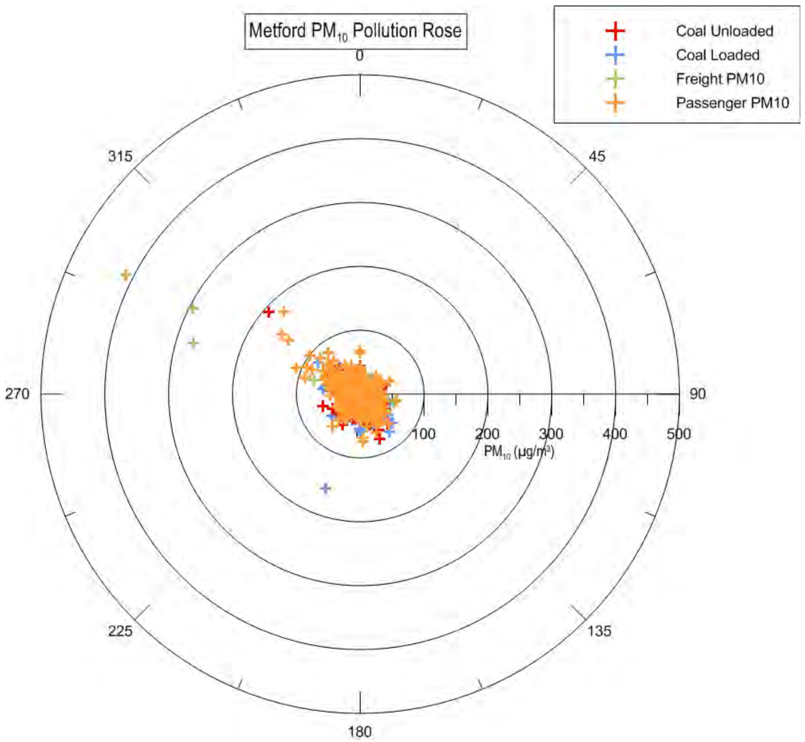

Figure 29: Metford PM_{10} Pollution Rose

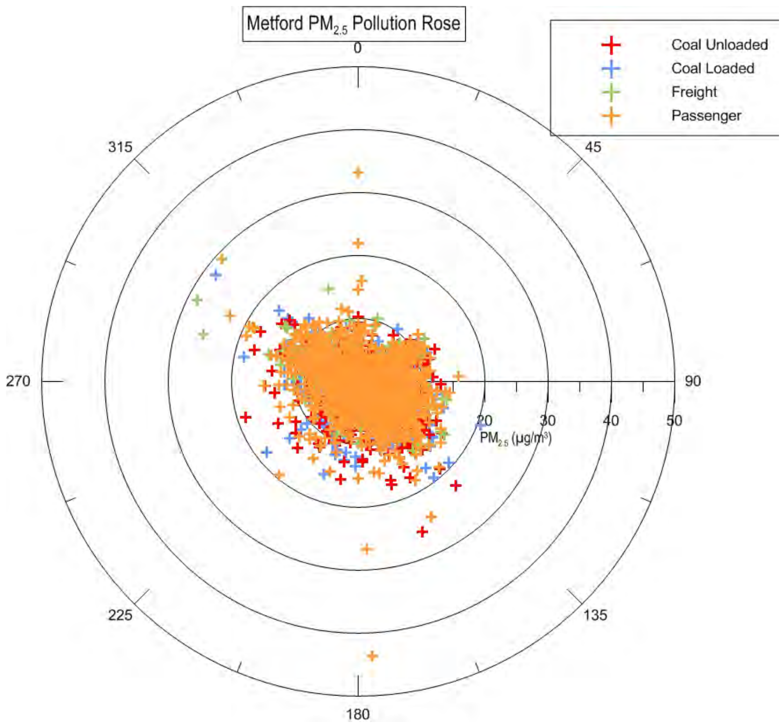

Figure 30: Metford $PM_{2.5}$ Pollution Rose

3.7.2 Wind Speed

The concentrations of TSP, PM_{10} and $PM_{2.5}$ were plotted against ambient wind speed to assess whether a relationship exists between these parameters. Increases in ambient wind speed may give rise to increases in dust entrainment from coal trains, but may also enhance the atmospheric dispersion potentials. Data is provided for all trains in **Table 14** with scatter plots by train type given in **Figure 32**, **Figure 33** and **Figure 34**.

Lower median particulate matter concentrations were recorded to coincide with higher wind speeds (**Table 14**).

No clear trends were identified when plotting TSP and PM_{10} concentrations by ambient wind speed class, for any train types (**Figure 32**, **Figure 33**). Peaks in TSP and PM_{10} concentrations tended to coincide with higher wind speed bands. It is however of note that such peaks tended to coincide with passenger train pass-bys (**Figure 32**, **Figure 33**).

$PM_{2.5}$ concentrations tended to be lower for higher ambient wind speeds across train types, including coal trains (**Figure 34**). Peaks in $PM_{2.5}$ concentrations tended to coincide with low and moderate ambient wind speeds in most cases.

Table 14: Metford – particulate matter concentrations by ambient wind speed class

Ambient wind speed (m/s)	TSP (µg/m³)					PM_{10} (µg/m³)					$PM_{2.5}$ (µg/m³)				
	<0.5 m/s	0.5 to <1 m/s	1 to <2 m/s	2 to <5 m/s	5 to <10 m/s	<0.5 m/s	0.5 to <1 m/s	1 to <2 m/s	2 to <5 m/s	5 to <10 m/s	<0.5 m/s	0.5 to <1 m/s	1 to <2 m/s	2 to <5 m/s	5 to <10 m/s
Average	30.8	28.4	28.7	28.4	39.2	20.7	19.4	19.3	17.9	21.1	6.0	6.0	6.0	4.8	3.9
Standard deviation	16.0	17.2	17.3	41.3	94.1	10.8	10.6	10.2	18.2	39.8	3.4	3.3	3.5	2.9	2.8
Median	27.9	24.7	25.3	22.1	17.8	18.9	17.5	17.6	14.5	12.3	5.4	5.3	5.3	3.9	3.1
5th Percentile	19.3	17.6	17.5	15.8	14.4	12.7	11.9	11.8	10.7	9.8	3.7	3.8	3.6	2.7	2.5
95th Percentile	38.8	35.5	34.2	31.1	26.1	26.7	24.9	34.2	34.2	21.0	7.9	8.0	8.1	6.3	4.3
Maximum concentration (a)	134	224	185	983	670	93.9	99.3	84.6	411	295	33.1	28.1	43.6	20.5	18.8
Number of trains	1725	498	869	1389	141	1725	498	869	1389	141	1725	498	869	1389	141

(a) The maximum concentration may be due to any train type.

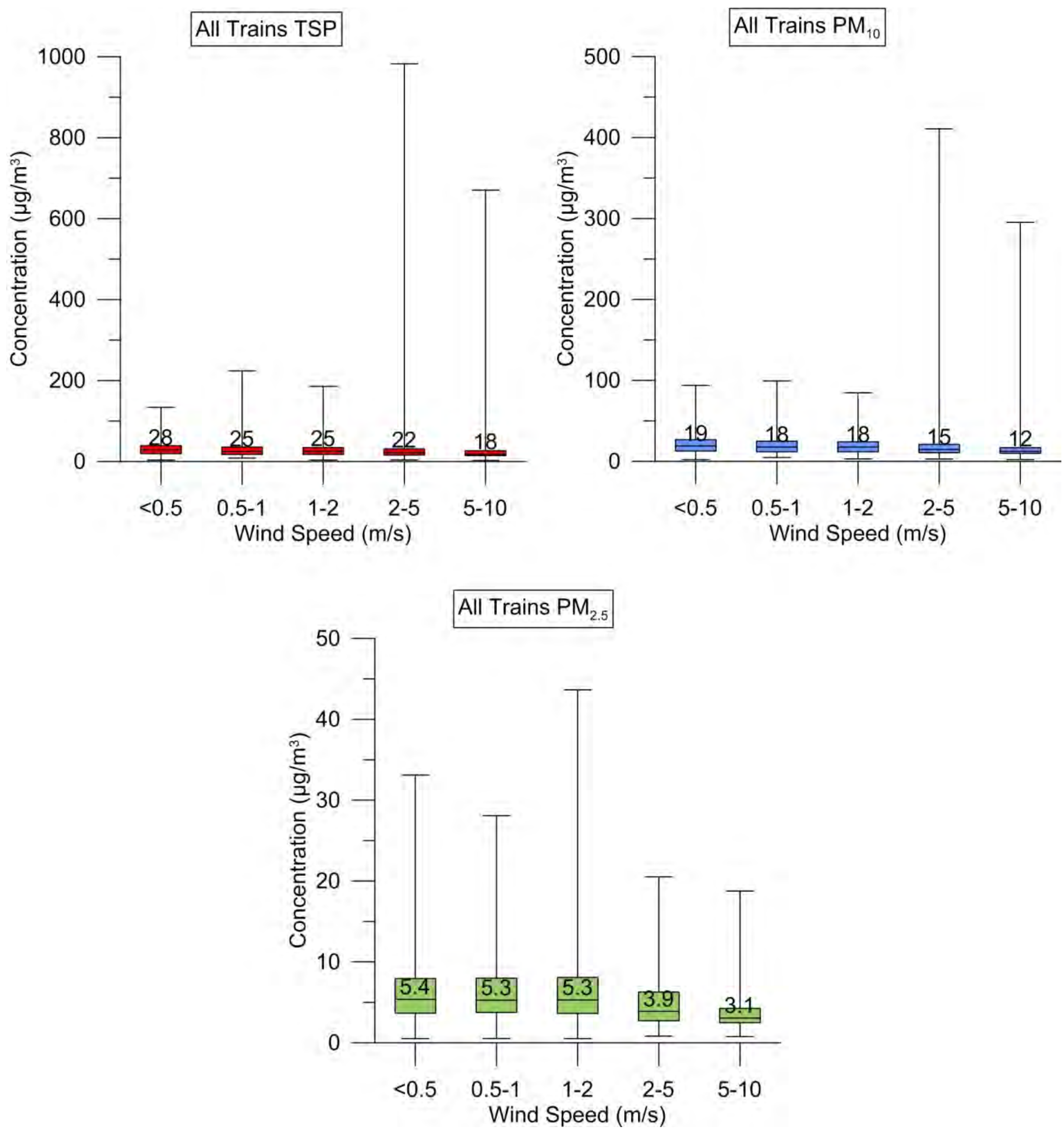

Figure 31: Metford – particulate matter concentrations by ambient wind speed class (all train types)

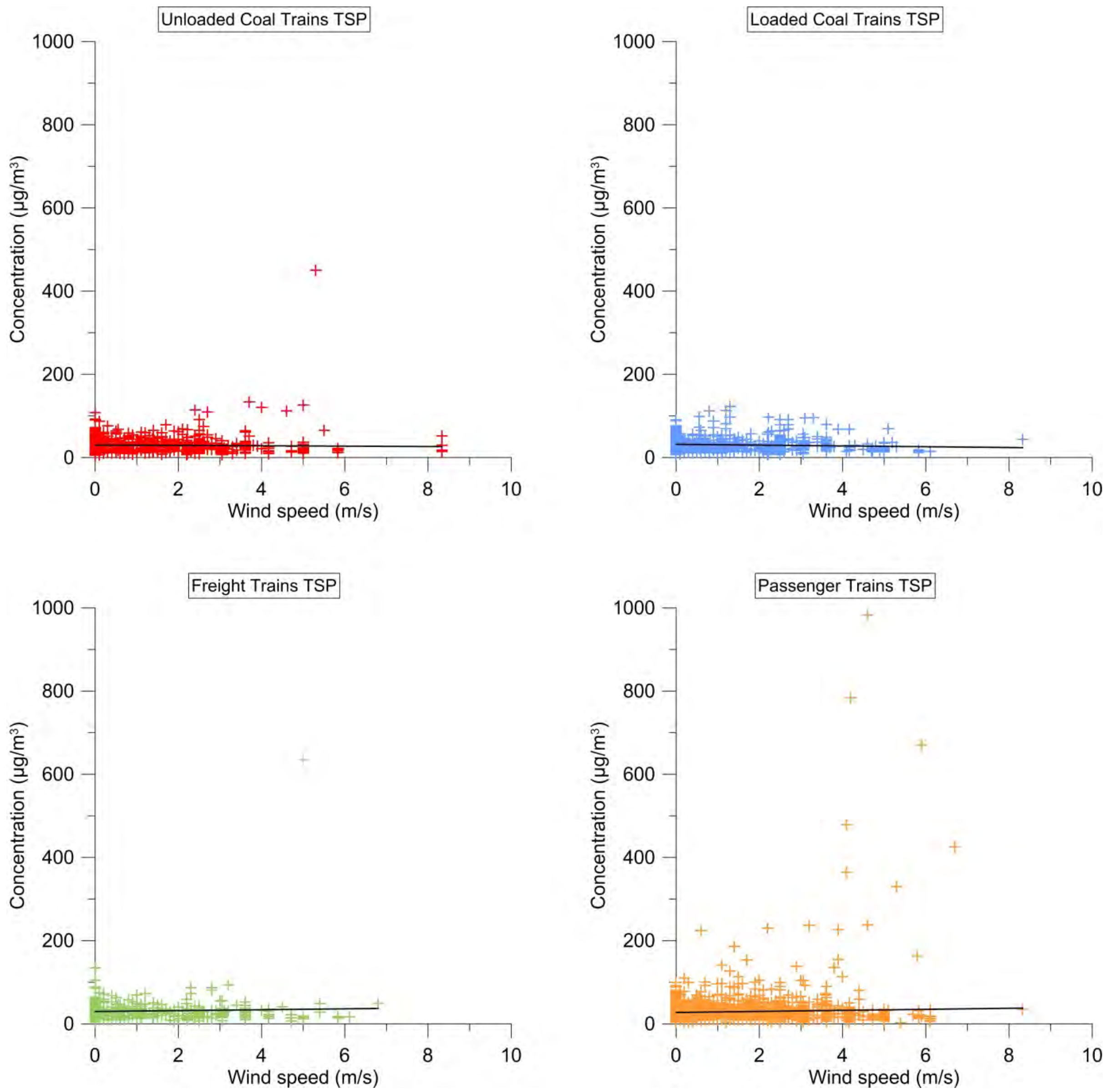

Figure 32: Metford - TSP concentrations by ambient wind speed class and train type

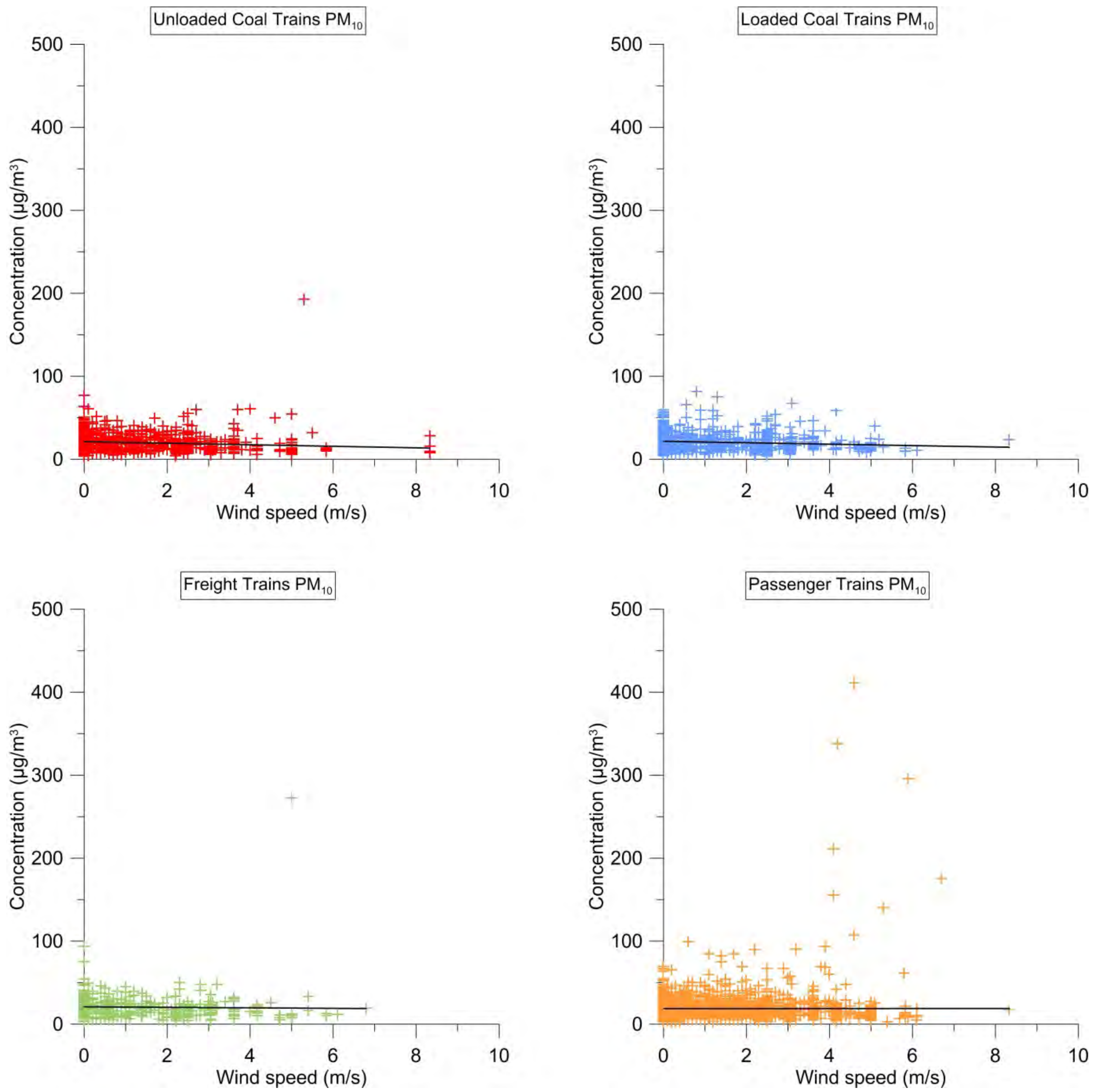

Figure 33: Metford - PM_{10} concentrations by ambient wind speed class and train type

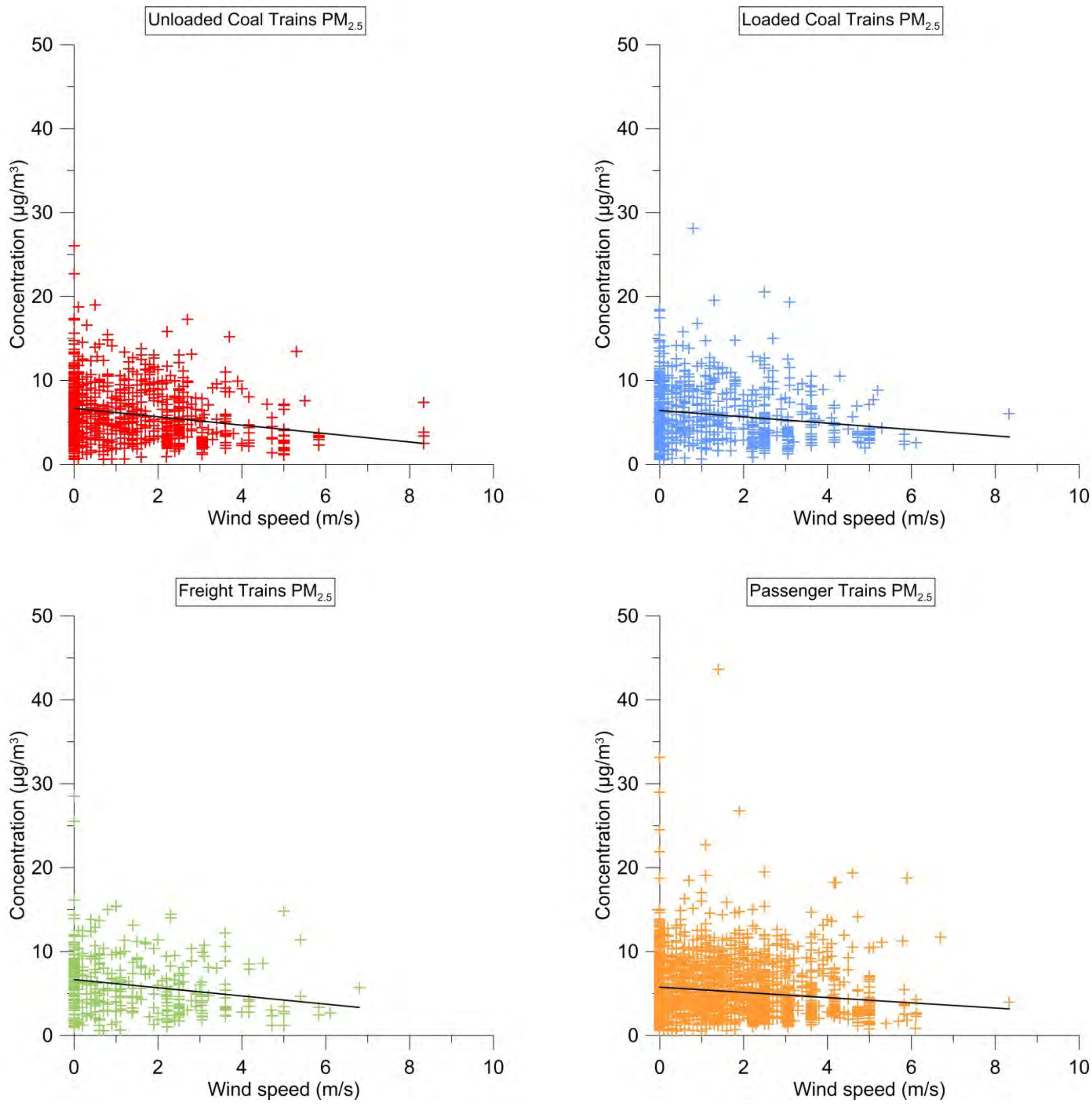

Figure 34: Metford - $PM_{2.5}$ concentrations by ambient wind speed class and train type

4 Comparison with Regional Air Quality Measurements

Average particulate matter concentration data for the period of monitoring is compared to concentrations recorded concurrently at Office of Environment and Heritage (OEH) air quality compliance monitors located in the region (**Table 15**). Tapered Elemental Oscillating Microbalance (TEOM) instruments are deployed at the OEH monitoring stations.

As the OSIRIS instrument is not a compliance monitor, the data is provided for information purposes only and should not be used for assessment of compliance with ambient air quality guidelines. The data should not be compared to the Air Quality NEPM or used for any health impact assessments as this was not an objective of the monitoring program. A monitoring program designed for compliance assessment against NEPM air quality standards or for health impact assessment would require different monitors to be employed together with compliance meteorological stations and the micro-siting of the monitors at locations where extended community exposures are likely to occur.

Table 15: ARTC pilot study measurements compared to OEH regional measurements

	Concentration by Site (µg/m³)				
	Metford	**Mayfield**	**Beresfield OEH**	**Wallsend OEH**	**Newcastle OEH**
$PM_{2.5}$	5.5	6.6	4.4	3.6	No data
PM_{10}	18.7	15.8	16.4	13.6	15.5

Despite differences in the monitoring methods deployed, PM_{10} and $PM_{2.5}$ concentrations measured during the program are comparable with levels measured at the OEH air quality monitoring stations referenced. Continuous monitoring of TSP is not included in the suite of parameters measured at the OEH monitoring stations, and is therefore not provided in the table.

5 Program Limitations and Assumptions

5.1 Limitations

Limitations of the pilot program include:

5.1.1 Sampling of the TSP size fraction may be inaccurate and result in an underestimate of the concentration of TSP in ambient air. The sampler may be effective in sampling only up to the particulates of aerodynamic diameter PM_{15}.

5.1.2 At Metford the particulate monitor was located at distances from the coal and main lines that are not equal.

5.1.3 At Scholey Street the train monitoring system does not identify which track a train is travelling on, making it impossible to determine the exact distance between a specific train pass and the monitoring station.

5.1.4 Train lines are bi-directional; a coal train travelling in an up direction could be unloaded, and vice versa. However this is expected to be a rare occurrence.

5.1.5 Locomotives are used for numerous train types and is a limitation of the 4TRAK system used for the Scholey Street monitoring site. ARTC estimate that between 10% and 20% of locomotives are used for multiple cargoes. Identification data for these locomotives were sought at the commencement of the pilot program . To improve the confidence in the process of identification of the cargoes from the locomotive identification code, those locomotives used for multiple cargoes were eliminated from the study. Preference was given to the air quality data measured during the pass of locomotives that are dedicated to a single cargo.

5.1.6 At Metford, a train type is not recorded if the train is travelling less than 30km/h. Train type was determined in these instances from the line that is was travelling on and the train length.

5.1.7 Trains that pass-by other trains were not included in the analysis.

5.1.8 Trains that cannot be confidently identified were eliminated from the assessment of single train types.

5.1.9 The air quality monitor logging intervals were set at a frequency of 60 seconds and later altered to 30 seconds. These values were selected after recording pass-by times of trains during attended monitoring and were also influenced by the memory capacity of the monitor. Shorter logging intervals may have resulted in higher particulate concentrations being allocated to some train. Further discussion is provided in Section 1.3.4.

5.1.10 At Metford the train speed recorded at the position of the wayside monitor and train length was used to determine the pass-by time. If a train was accelerating or decelerating this may have resulted in the actual pass-by time being different to the calculated pass-by time.

5.1.11 At Mayfield, it was not possible to determine the time taken for the train to pass the monitoring station from the data logged on train movements as the entire train, including locomotives and wagons, is logged as passing the marker points at the same time. The coal trains are also varying lengths, therefore train speed data could not be used to assist in determining the exact pass-by time. Approximations for pass-by time were used in interpreting the monitoring program results. The average train length, as measured at Metford for each train type category, was used in the calculation of the pass-by time for each train at Mayfield. The 4TRAK system was less accurate than desired for the arrival and departure times of the trains into the air quality monitor zone. These arrival and departure points, or ‘markers’, were established 500m either side of the Mayfield air quality station. Average speed between the two points was used in calculating the time that the train reached the air quality monitor, i.e. the midpoint between the two markers.

5.1.12 Wind speed and direction for the first week of the program for Metford was obtained from the Bureau of Meteorology (BoM).

5.1.13 Residual particulate concentration may be present at the monitoring station after a train has passed.

5.2 Assumptions

Assumptions used in the monitoring program include:

5.2.1 The average train length measured at Metford for passenger, freight and coal trains was assumed to be applicable to the respective train types for the Mayfield site.

5.2.2 Pass-by time was estimated at the Mayfield site based on average train lengths measured at Metford (refer to Assumption 5.2.1) and the train speed.

5.2.3 Work trains and engine only movements were excluded from the analysis.

5.2.4 The train type at Scholey Street was recorded from a combination of the locomotive and train identification codes and by the direction the train moves.

5.2.5 At Metford, the train type was also identified from the track it is travelling on. It may be the case that a loaded coal train travelling on a down direction track is recorded as being unloaded and an unloaded coal train travelling on an up direction track is recorded as being loaded.

5.2.6 Speed of the locomotive recorded by the 4TRAK system at the Scholey Street Triangle is an average between two points.

5.2.7 Dispersion of particulates during low wind speed conditions is limited. A factor of three was applied to the pass-by times at both sites to extend the averaging time for each train when the wind speed was less than 2m/s in an effort to allow for limited dispersion. This factor was calculated after examination of the air quality results during low wind speed conditions. For example, a train that may have 5 minutes of data coinciding with its movement if wind speed is greater than 2 m/s will have 15 minutes of data averaged if the wind speed is less than 2 m/s. There may still be a residual concentration of particulates in the rail corridor due to this train in some instances.

6 Conclusions

PRP4 Requirement: Determine whether loaded coal trains operating on the Hunter valley rail network are a source of particulate matter emission.

To address this requirement, a 'no train' data set was prepared for each site. The measurement uncertainties of the average concentrations were calculated at a 95% confidence limit. At the Mayfield site, there was a statistical difference between the 'no train data' and the concentrations recorded to coincide with all of the train categories, including loaded coal, unloaded coal, freight and passenger for TSP and PM_{10}. When examining $PM_{2.5}$ and the 'no train data' there was only a statistical difference for the freight and passenger train types. The statistical technique shows that all trains are a source of TSP and PM_{10} and that only passenger and freight trains are a source of $PM_{2.5}$ on the rail network at Mayfield. This conclusion may be impacted if the time resolution of the Mayfield 4Trak train movement data system and the air quality data logging system were improved as higher concentrations due to all trains may be recorded. At the Metford monitoring station, the TSP, PM_{10} and $PM_{2.5}$ concentrations recorded coinciding with all trains, including loaded coal, unloaded coal, freight and passenger were statistically greater than the 'no train' data set. The statistical technique shows that all trains are a source of TSP, PM_{10} and $PM_{2.5}$ on the rail network at Metford. The analysis of $PM_{2.5}$ is confounded by the longer atmospheric residence time (Friedlander, 1977) of fine particles.

The difference in average concentrations when comparing loaded coal to the 'no train' dataset at Mayfield show that the loaded coal trains increase the concentration in the rail corridor on average by 3.3 µg/m³ for TSP, 2.2 µg/m³ for PM_{10} and 0.5 µg/m³ for $PM_{2.5}$. It is anticipated that these concentration differences may be greater if more accurate train movement data was available for this site.

At Metford, the difference in average concentrations when comparing loaded coal to the 'no train' dataset show that the loaded coal trains increase the concentration in the rail corridor by 7.1 µg/m³ for TSP, 4.8 µg/m³ for PM_{10} and 1.2 µg/m³ for $PM_{2.5}$.

PRP4 Requirement: Loaded coal trains operating on the Hunter Valley rail network are a larger cause or source of particulate matter emissions than unloaded coal trains or other trains on the network.

The monitoring at Mayfield provided mixed results. Maximum concentrations were recorded to coincide with passenger and freight trains for all particle size fractions. Average and median TSP and PM_{10} concentrations coinciding with loaded coal train passes were marginally higher (less than 1 µg/m³ higher) than concentrations coinciding with other train types. Slightly higher TSP and PM_{10} concentrations coincided with loaded coal train passes compared to unloaded coal train passes. Average and median $PM_{2.5}$ concentrations were comparable across train types. There were no statistical differences in concentrations across all particulate size fractions when examining the concentration ranges between the upper and lower confidence level concentrations (i.e. uncertainties) of all train types. This result shows that at Mayfield, loaded coal trains are not a statistically greater source of particulate matter when compared to other train types. It is anticipated that the use of more accurate train movement data for this site may alter the conclusion.

At the Metford monitoring site, maximum concentrations were recorded to coincide with passenger trains for all particle size fractions. Based on the average, median and 95th percentile and confidence limits around the average concentration, it is concluded that concentrations coinciding with loaded and unloaded coal train passes are statistically higher for PM_{10} than concentrations recorded during passenger train passes. The $PM_{2.5}$ concentrations that were recorded to coincide with freight, unloaded coal and loaded coal are statistically higher than concentrations recorded during passenger train passes. The analysis of $PM_{2.5}$ may be confounded by the longer atmospheric residence time of fine particles. There was no statistical difference for TSP, PM_{10} and $PM_{2.5}$ concentrations coincided with loaded coal train passes compared to unloaded coal train passes when examining the confidence limits around the average concentrations between these train types. Concentrations for loaded and unloaded coal train passes were however comparable to freight train passes across particle size fractions.

There was a greater degree of confidence in the results obtained for the Metford site as compared to the Mayfield site due to limitations with the Mayfield train movement data set. There were limitations with the pilot study as outlined in Section 5.1; these would be addressed in any further monitoring studies.

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