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ENERGYAUSTRALIA YALLOURN EMISSIONS MONITORING PROGRAM - PARTICULATE MATTER REPORT

Prepared for	EnergyAustralia Yallourn Pty Ltd
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Executive Summary

HRL Technology Group (HRL) has prepared this document for EnergyAustralia Yallourn Pty Ltd (EAY) to report on the outcomes of a Particulate Matter (PM) Emissions Monitoring Program (PM Program) completed at Yallourn power station. As required by EPA Licence No. 10961 (EPA Licence):

LI_DA4.3 *You must establish and implement a program for a 12-month period to monitor the discharge to air, at discharge point(s) A1, A2a and A2b, of fine particles $PM_{2.5}$ and coarse particles PM_{10} to establish the 90th percentile annual frequency distribution. The results of this program must be made available to EPA on request and must be published to the publicly accessible website required by condition LI_DA4.2 by 31 March 2022.*

The PM Program prepared to comply with new licence condition LI_DA4.3 was developed to align with the guidance presented in EPA Publication 440.1 *Guide to Air Quality Sampling and Analysis* and the EPA deemed it was appropriate for the purpose of complying with condition LI_DA4.3.

Stack emission testing was conducted by a third-party specialist across all Yallourn Power Station licenced air emission discharge points (A1, A2a, and A2b). The PM program involved four separate emission testing campaigns between June 2021 and February 2022 resulting in a total of 25 separate tests being conducted. Testing occurred on 8 separate days spread over the 7-month period, which enabled testing to occur over a range of operating conditions and varying coal qualities that occur during routine power station operations. Testing conducted on Unit 3 and Unit 4 included sampling when an Electrostatic Dust Precipitator (EDP) zone was out of service for maintenance to assess the effects on particulate size distributions.

The PM_{10} stack emission testing results showed a good correlation with Total Particulate Matter (TPM) emissions. No clear difference was observed between test results for a specific Unit and/or Flue. Additionally, there was no clear difference observed in the PM_{10} relationship with TPM for operations when an EDP was out of service. Therefore, all data from the PM Program was combined and the resultant linear correlation suggests that at the time of the testing the average or best-fit PM_{10}:TPM concentration ratio was 0.4882. The maximum PM_{10}:TPM concentration ratio measured was 0.6047 (i.e. 24% higher than the average).

The $PM_{2.5}$ stack emission testing results showed a reasonably good correlation with TPM emissions, although much larger scatter (i.e. increasing divergence of measurements from the best-fit trendline with increasing TPM concentrations) is observed compared to the PM_{10} results. No clear difference was observed between test results for a specific Unit and/or Flue. Additionally, there was no clear difference observed in the $PM_{2.5}$ relationship with TPM for operations when an EDP was out of service. Therefore, all data from the PM Program was combined and the resultant linear correlation suggests that at the time of the testing the average or best-fit $PM_{2.5}$:TPM concentration ratio was 0.1624. The maximum $PM_{2.5}$:TPM concentration ratio measured was 0.2067 (i.e. 27% higher than the average).

No clear influences were observed in the correlations for factors such as Unit output or EDP zones in service, nor for the variation of coal quality that occurred over the PM Program. It is anticipated that measurement uncertainty contributes to variability in the results (particularly for $PM_{2.5}$, due to the smaller concentrations of the finer particulates).

Comparing the PM Program results to historically available stack emission testing results (consisting of limited testing conducted between Apr 2001 and Jan 2021) shows that:

- Much larger scatter is observed in the historic results when comparing the measured concentrations of PM_{10} and $PM_{2.5}$ with TPM.
- The average PM_{10}:TPM ratio for all historic test results is 0.4361, which is similar to the 0.4882 average ratio from the current PM monitoring.
- The maximum historic PM_{10}:TPM ratio was 0.9265, which is much higher than the maximum PM_{10}:TPM ratio of 0.6047 measured for the current PM monitoring.
- The average $PM_{2.5}$:TPM ratio for all historic test results is 0.2428, which is higher than the 0.1624 average ratio from the current PM monitoring.
- The maximum historic $PM_{2.5}$:TPM ratio was 0.7514, which is much higher than the maximum PM_{10}:TPM ratio of 0.2067 measured for the current PM monitoring.

The EPA has acknowledged the technological challenges of monitoring PM_{10}/$PM_{2.5}$ emissions in real-time. As such, the EPA supports the use of surrogate methods, together with stack testing, to achieve the expected EPA objective of establishing a rolling average real-time calculation of the 90th percentile annual frequency distribution of PM_{10}/$PM_{2.5}$ emissions, for compliance monitoring purposes. Estimates of 30-minute average Station PM_{10} and $PM_{2.5}$ mass emission rates were calculated by applying the average PM_{10}:TPM and $PM_{2.5}$:TPM concentration ratios (0.4882 and 0.1624) from the PM Program to 30-minute average total particle emissions data from the station Continuous Emissions Monitoring System (CEMS) for the 1 January 2020 to 17 February 2022 time period. The estimated 30-minute average Station PM_{10} and $PM_{2.5}$ mass emission rates were then used to calculate rolling annual 90th percentile PM_{10} and $PM_{2.5}$ emission rates. An example of the rolling annual 90th percentile TPM, PM_{10} and $PM_{2.5}$ emission rates for 1 January 2021 to 17 February 2022 is shown in Figure 1 below.

Figure 1: Example Annual Rolling 90th Percentile Emission Rates for Station TPM (continuously monitored) and PM_{10} and $PM_{2.5}$ estimated using correlations with TPM

Using the approach described above, the maximum annual rolling 90th percentile Station mass emission rates during the 1 January 2021 to 17 February 2022 time period were estimated as:

- TPM = 10,329 g/min;
- PM_{10} = 5,043 g/min; and
- $PM_{2.5}$ = 1,677 g/min.

Given that the PM Program could not cover all potential variability in PM emissions nor can variables affecting PM emissions such as coal quality and ash composition be monitored continuously, HRL understands that EAY will discuss the options for establishing a rolling annual 90th percentile mass emission rate for PM_{10} and $PM_{2.5}$ as a ratio of TPM with the EPA.

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1 Introduction

Yallourn power station is subject to Victorian Environment Protection Authority (EPA) Operating Licence No. 10961 (EPA Licence). Licence condition LI_DA4.3 requires EnergyAustralia Yallourn Pty Ltd (EAY):

LI_DA4.3 *You must establish and implement a program for a 12-month period to monitor the discharge to air, at discharge point(s) A1, A2a and A2b, of fine particles $PM_{2.5}$ and coarse particles PM_{10} to establish the 90^{th} percentile annual frequency distribution. The results of this program must be made available to EPA on request and must be published to the publicly accessible website required by condition LI_DA4.2 by 31 March 2022.*

HRL Technology Group (HRL) has prepared this document for EAY to report on the outcomes of the particulate matter monitoring program (PM Program) completed at Yallourn power station.

2 PM Program Methodology

EPA Publication 1322.9 *Licence Management* requires sampling and analysis to be conducted in accordance with EPA Publication 440.1 *Guide to Air Quality Sampling and Analysis*. The particulate matter monitoring program (PM Program) developed to address Licence condition LI_DA4.3 was prepared following guidance from EPA Publication 440.1 and was informed by available historic Yallourn analytical results.

The PM Program proposed by EAY included conducing stack emission testing on all licenced air emission discharge points (A1 – Stage 1, A2a – Unit 3, and A2b – Unit 4). The PM Program proposed that physical stack emission sampling would utilise the normal sampling location on each stack or flue which is utilised for routine annual Licence compliance monitoring.

EPA Publication 440.1 specifies Australian Standard 4323.2-1995 *Stationary Source Emissions - Determination of Total Particulate Matter - Isokinetic Manual Sampling - Gravimetric Method* for total particulate matter sampling but does not specify a method for PM_{10} or $PM_{2.5}$. In other Australian jurisdictions USEPA Method 201A *Determination of PM10 and PM2.5 Emissions from Stationary Sources (Constant Sampling Rate Procedure)* is specified as an approved method for fine particulate sampling from stationary sources. For the PM Program it was proposed that Total Particulate Matter (TPM) would be sampled using AS 4323.2 and that PM_{10} and $PM_{2.5}$ would be sampled using USEPA Method 201A. Testing for all three analytes would be conducted concurrently.

EAY submitted the proposed PM Program to the EPA on 16 September 2021. The EPA deemed the PM Program was appropriate for complying with new condition LI_DA4.3 and provided written feedback to EAY on 21 January 2022.

The PM program involved four separate emission testing campaigns between June 2021 and February 2022 resulting in a total of 25 separate tests being conducted. Testing occurred on 8 separate days spread over the 7-month period, which enabled testing to occur over a range of operating conditions and varying coal qualities that occur during routine power station operations. Testing conducted on Unit 3 and Unit 4 included sampling when an Electrostatic Dust Precipitator (EDP) zone was out of service for maintenance to assess the effects on particulate size distributions. Since the EAY licence

provides dispensation for Unit Start-up and Shut-down these situations were not considered in the experimental design.

EAY engaged a National Association of Testing Authorities (NATA) accredited specialist stack emission sampling and testing service provider (Ektimo Pty Ltd) to:

- Implement the physical sampling and testing aspects of the PM Program using NATA accredited methods and laboratories; and
- Prepare reports for each sampling and testing campaign.

All sampling and analysis were performed by Etkimo as outlined in Table 1 below.

Table 1: Sampling and analysis methods and associated NATA accreditation for PM Program

Parameter	Sampling Method	Analysis Method	Uncertainty*	NATA Accredited	
				Sampling	Analysis
Sampling points - Selection	AS 4323.1	NA	NA	✓	NA
Flow rate, temperature and velocity	ISO 10780	ISO 10780	8%, 2%, 7%	NA	✓
Moisture	USEPA Method 4	USEPA Method 4	8%	✓	✓
Molecular weight	NA	USEPA Method 3	not specified	NA	✓
Carbon dioxide and oxygen	USEPA Method 3A	USEPA Method 3A	13%	✓	✓
Total particulate matter	AS 4323.2	AS 4323.2	7%	✓	✓††
Particulate matter (PM_{10} and $PM_{2.5}$)	USEPA Method 201A	USEPA Method 201A	9%	✓	✓††

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* Uncertainties cited in this table are estimated using typical values and are calculated at the 95% confidence level (coverage factor = 2).

†† Gravimetric analysis conducted at the Ektimo Mitcham, VIC laboratory, NATA accreditation number 14601.

3 PM Program Results Summary & Assessment

A total of 25 tests were completed for TPM, PM_{10} and $PM_{2.5}$:

- Stage 1 (Discharge point A1):
  - June 2021 a total of 5 tests were conducted
  - February 2022 a total of 4 tests were conducted
- Unit 3 (Discharge point A2a):
  - July 2021 a total of 4 tests were conducted (2 per flue)
  - December 2021 a total of 4 tests were conducted (2 per flue)
- Unit 4 (Discharge point A2b):
  - December 2021 a total of 4 tests were conducted (2 per flue)
  - January 2022 a total of 4 tests were conducted (2 per flue)

3.1 PM_{10} and TPM Relationship

In Figure 2 stack test results for PM_{10} concentration are plotted against their corresponding TPM concentrations for all 25 data points across both Stage 1, Unit 3 (Flue 1 and Flue 2) and Unit 4 (Flue 1 and 2). The test data for all flues (Stage 1, Unit 3 (Flue 1 and Flue 2) and Unit 4 (Flue 1 and 2)) is observed to follow the same general trend.

The best-fit linear trendline shown in Figure 2 is for all testing data from the June 2021 – February 2022 testing campaigns combined and shows a good correlation overall. The resultant linear best-fit correlation (forced through zero) suggests that TPM emissions are made up of about 48.82% PM_{10} on average. The linear best-fit correlation that isn't forced through zero is noted to be very similar.

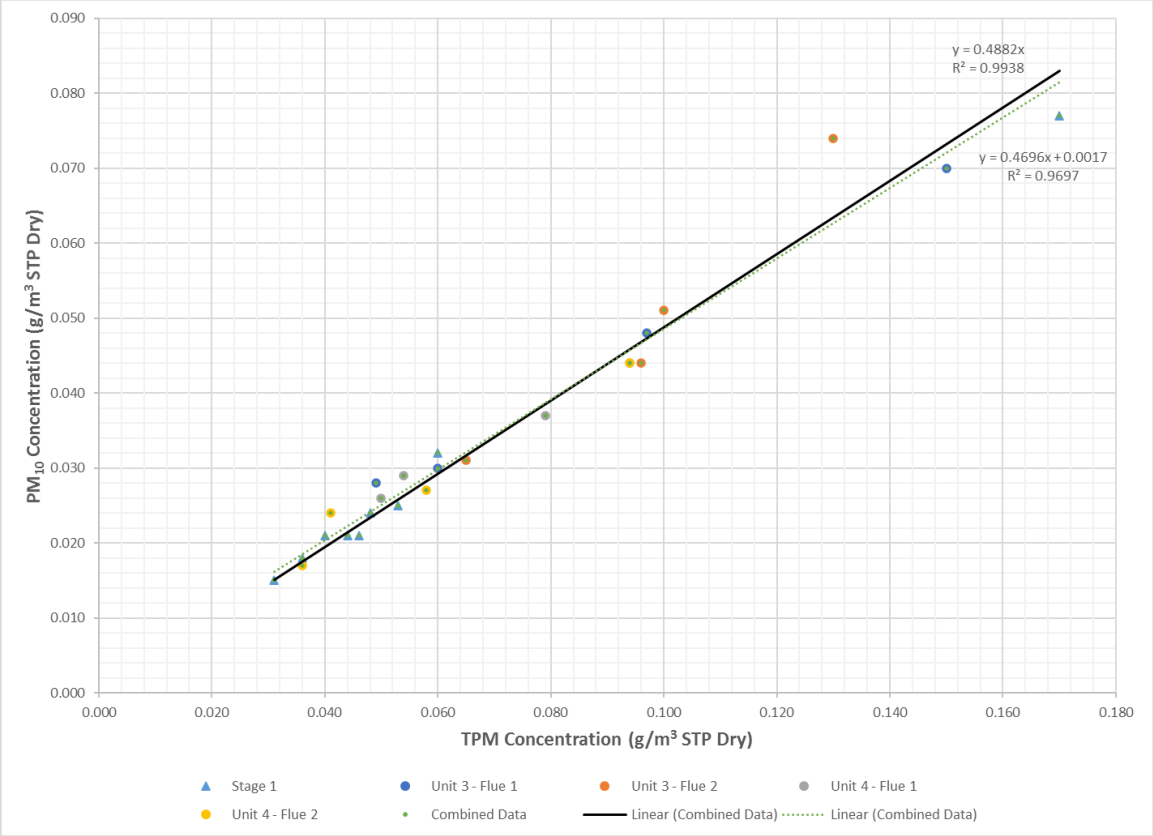

Figure 2: PM_{10} to TPM correlation with all Stage 1, Unit 3 and Unit 4 Test Data (Jun 21 – Feb 22)

The PM_{10} stack emission testing results show a good correlation with TPM emissions. No clear difference was observed between test results for a specific Unit and/or Flue. Additionally, there was no clear difference observed in the PM_{10} relationship with TPM for operations when an EDP was out of service. Therefore, all data from the PM Program was combined and the resultant linear correlation suggests that at the time of the testing the average PM_{10}:TPM concentration ratio was 0.4882. The maximum PM_{10}:TPM concentration ratio measured was 0.6047 (i.e. 24% higher than the average).

3.2 $PM_{2.5}$ and TPM Relationship

In Figure 3 stack test results for $PM_{2.5}$ concentration are plotted against their corresponding TPM concentrations for all 25 data points across both Stage 1, Unit 3 (Flue 1 and Flue 2) and Unit 4 (Flue 1 and 2). The test data for all flues (Stage 1, Unit 3 (Flue 1 and Flue 2) and Unit 4 (Flue 1 and 2)) is observed to follow the same general trend.

The best-fit linear trendline shown in Figure 3 is for all testing data from the June 2021 – February 2022 testing campaigns combined and shows a reasonably good correlation overall. The resultant linear best- fit correlation (forced through zero) suggests that TPM emissions are made up of about 16.24%

$PM_{2.5}$ on average. The linear best-fit correlation that isn't forced through zero is noted to be very similar.

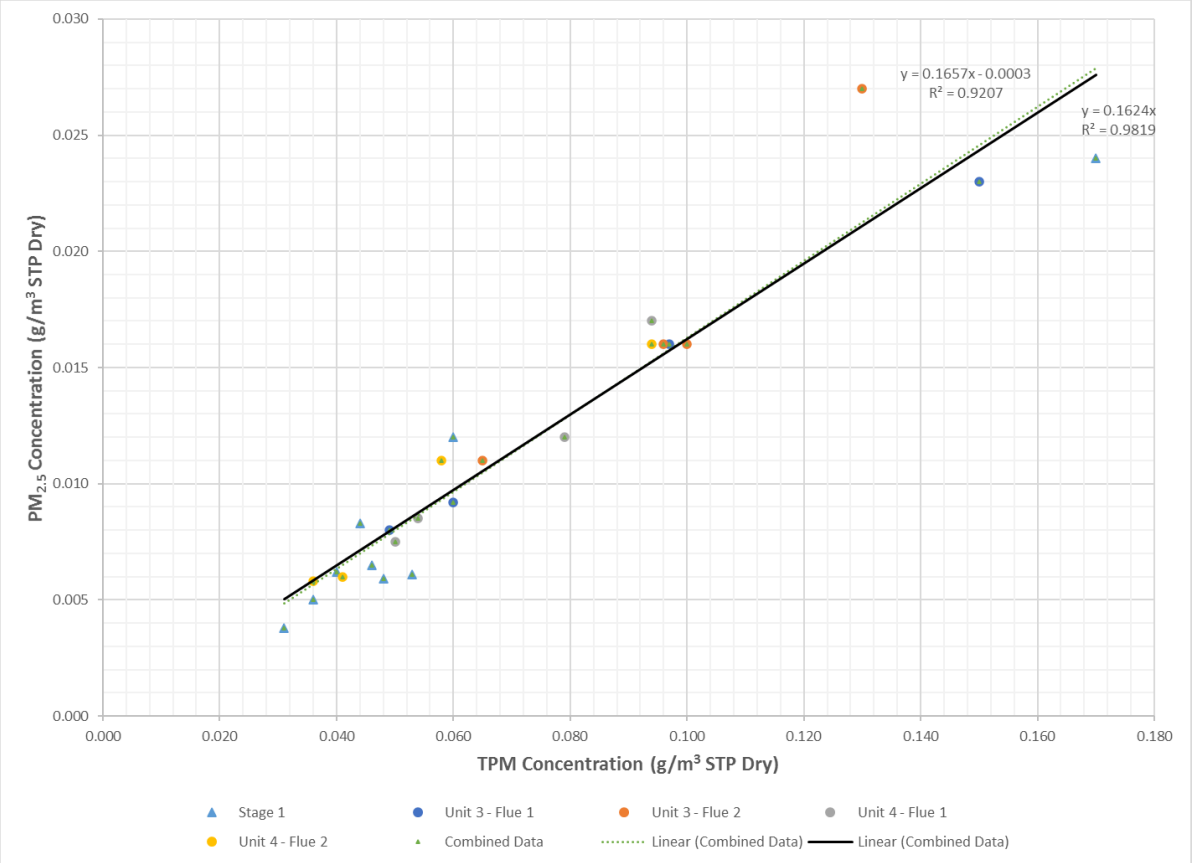

Figure 3: $PM_{2.5}$ to TPM correlation with all Stage 1, Unit 3 and Unit 4 Test Data (Jun 21 – Feb 22)

The $PM_{2.5}$ stack emission testing results show a reasonably good correlation with TPM emissions, although much larger scatter (i.e. increasing divergence of measurements from the best-fit trendline with increasing TPM concentrations) is observed compared to the PM_{10} results. No clear difference was observed between test results for a specific Unit and/or Flue. Additionally, there was no clear difference observed in the $PM_{2.5}$ relationship with TPM for operations when an EDP was out of service. Therefore, all data from the PM Program was combined and the resultant best-fit linear correlation suggests that at the time of the testing the average $PM_{2.5}$:TPM concentration ratio was 0.1624. The maximum $PM_{2.5}$:TPM concentration ratio measured was 0.2067 (i.e. 27% higher than the average).

No clear influences were observed in the correlations for factors such as Unit output or EDP zones in service, nor for the variation of coal quality that occurred over the PM Program. It is anticipated that measurement uncertainty contributes to variability in the results (particularly for $PM_{2.5}$, due to the smaller concentrations of the finer particulates).

Comparing the PM Program results to historically available stack emission testing results (consisting of limited testing conducted between Apr 2001 and Jan 2021) shows that:

- Much larger scatter is observed in the historic results when comparing the measured concentrations of PM_{10} and $PM_{2.5}$ with TPM.

- The average PM_{10}:TPM ratio for all historic test results is 0.4361, which is similar to the 0.4882 average ratio from the current PM monitoring.
- The maximum historic PM_{10}:TPM ratio was 0.9265, which is much higher than the maximum PM_{10}:TPM ratio of 0.6047 measured for the current PM monitoring.
- The average $PM_{2.5}$:TPM ratio for all historic test results is 0.2428, which is higher than the 0.1624 average ratio from the current PM monitoring.
- The maximum historic $PM_{2.5}$:TPM ratio was 0.7514, which is much higher than the maximum PM_{10}:TPM ratio of 0.2067 measured for the current PM monitoring.

3.3 Example Annual 90th Percentile Distributions

The EPA has acknowledged the technological challenges of monitoring PM_{10}/$PM_{2.5}$ emissions in real-time. As such, the EPA supports the use of surrogate methods, together with stack testing, to achieve the expected EPA objective of establishing a rolling average real-time calculation of the 90th percentile annual frequency distribution of PM_{10}/$PM_{2.5}$ emissions, for compliance monitoring purposes. Estimates of 30-minute average Station PM_{10} and $PM_{2.5}$ mass emission rates were calculated by applying the average PM_{10}:TPM and $PM_{2.5}$:TPM concentration ratios (0.4882 and 0.1624) from the PM monitoring program to 30-minute average total particle emissions data from the station Continuous Emissions Monitoring System (CEMS) for the 1 January 2020 to 17 February 2022 time period.

The estimated 30-minute average Station PM_{10} and $PM_{2.5}$ mass emission rates were used to calculate rolling annual 90th percentile PM_{10} and $PM_{2.5}$ emission rates. The resulting rolling annual 90th percentile TPM, PM_{10} and $PM_{2.5}$ emission rates for 1 January 2021 to 17 February 2022 is shown in Figure 4.

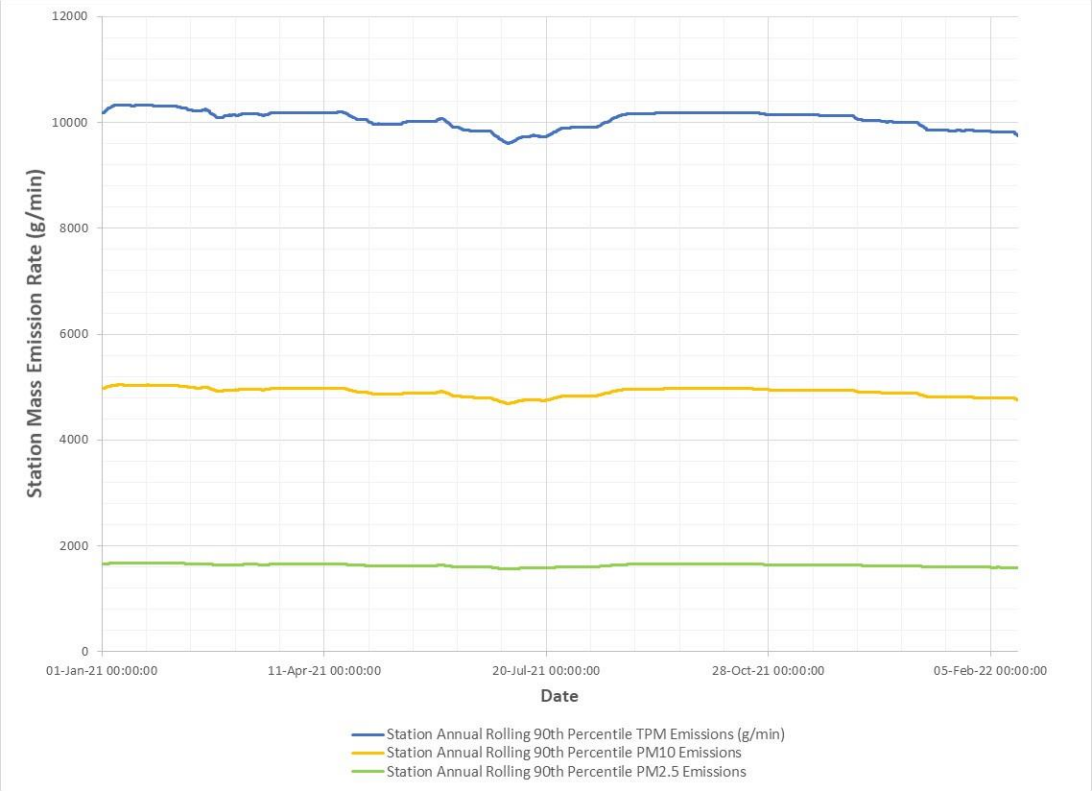

Figure 4: Example Annual Rolling 90th Percentile Emission Rates for Station TPM (continuously monitored) and PM_{10} and $PM_{2.5}$ estimated using correlations with TPM

The maximum annual rolling 90th percentile Station TPM mass emission rate during the time period was 10,329 g/min. The maximum annual rolling 90th percentile estimated Station PM_{10} mass emission rate during the time period was 5,043 g/min. The maximum annual rolling 90th percentile estimated Station $PM_{2.5}$ mass emission rate during the time period was 1,677 g/min.

The annual distribution of PM emissions for the 12-month period with the maximum annual rolling average 90th percentile TPM emission rate (10,329 g/min) is summarised in Table 2.

Table 2: Annual Distribution for maximum annual rolling average TPM emission rate during 1 Jan 2021 – 17 Feb 2022

	Station PM Mass Rate 30 min average without excess emission	Estimated Station PM_{10} (0.4882 x TPM)	Estimated Station $PM_{2.5}$ (0.1624 x TPM)
	g/min	g/min	g/min
Minimum	1,786	872	290
10th Percentile	3,832	1,871	622
20th Percentile	4,719	2,304	766
30th Percentile	5,655	2,761	918
40th Percentile	6,327	3,089	1,028
50th Percentile	6,922	3,380	1,124
60th Percentile	7,663	3,741	1,245
70th Percentile	8,438	4,119	1,370
80th Percentile	9,253	4,517	1,503
90th Percentile	**10,329**	**5,043**	**1,677**
95th Percentile	11,196	5,466	1,818
99th Percentile	12,767	6,233	2,073
Maximum	18,318	8,943	2,975

It should be noted that the annual rolling 90th percentile mass emission rates calculated above:

- An example based on a limited time period (e.g. annual rolling 90th percentile mass emission rates are for the 1 January 2021 to 17 February 2022 period only);
- Have been calculated assuming the average PM_{10}:TPM correlation (0.4882) and average $PM_{2.5}$:TPM correlation (0.1624) based on the test results from the PM Program.

However, ratios of PM_{10}:TPM and $PM_{2.5}$:TPM for specific tests from the PM Program, as well as historically available data, indicate that the ratios can be significantly higher than the average values. Given that the PM Program could not cover all potential variability in PM emissions nor can variables affecting PM emissions such as coal quality and ash composition be monitored continuously, HRL understands that EAY will discuss the options for establishing a rolling annual 90th percentile mass emission rate for PM_{10} and $PM_{2.5}$ as a ratio of TPM with the EPA.

4 References

The following Ektimo stack testing reports were referenced when preparing this report:

Ektimo Report No.	Report Title	Comment
R011072	Emission Testing Report, 90 Percentile Evaluation, EnergyAustralia – Yallourn Power Station	Testing included Stage 1 (5 tests), Unit 3 Flue 1 (2 tests) and Unit 3 Flue 2 (2 tests)
R012002	EnergyAustralia – Yallourn Pty Ltd, W3,W4 PM Testing, EPA Licence condition LI_DA4.3 Report	Testing included Unit 3 Flue 1 (2 tests), Unit 3 Flue 2 (2 tests), Unit 4 Flue 1 (2 tests) and Unit 4 Flue 2 (2 tests)
R012003	EnergyAustralia – Yallourn Pty Ltd, W1, W2 & W4 PM Testing, EPA Licence condition LI_DA4.3	Testing included Stage 1 (4 Tests), Unit 4 Flue 1 (2 tests) and Unit 4 Flue 2 (2 tests)