

Fulton Hogan Egis Operations & Maintenance

WestConnex - M4 East Project

Ambient Air Quality and Weather Monitoring

Validated Report

1st November 2021 – 30th November 2021

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Executive Summary

The WestConnex - M4 East Project connects Sydney's west and south-west with the Sydney Airport and the Port Botany precinct. It comprises two new three-lane tunnels of approximately 5.5km that feature various ventilation plant and equipment and air quality monitors to ensure pollutants do not exceed the targets and limits set by the Minister's Conditions of Approval.

M4 East air quality is monitored by hundreds of sensors and measures various pollutants across three main areas:

- *Ambient air* - air quality in the areas around the M4 tunnels
- *Ventilation* - air quality around the ventilation stacks
- *In Tunnel* - air quality inside the tunnels and portals (entrances to the tunnel)

This Monthly Ambient Air Quality Monitoring Report details ambient air measurements. It is part of the commitment to the Minister and the community to report air quality measurements in real time (raw data as the measurements occur) as well as validated reports. It is important to re-publish the data in reports because the raw data needs to be checked and collated by approved air quality experts and 'translated' into a format that is easy to understand and can be interpreted by both experts and lay people.

This report details results at one external ambient air quality monitoring station located at Haberfield Public School between 1st November 2021 and 30th November 2021.

Report Summary

Air quality sensors and related equipment were operating for the full month although there were some instrumentation issues (called 'Exceptions') during this time.

The data capture was below the 95% goal for some parameters in this report as shown in Table 7. The low data capture ranged from 63.6% to 93.9% for the month.

There were no exceedance of the air quality goals at the WestConnex - M4 East Haberfield Public School Ambient Air Quality Monitoring station for the reporting month. Please refer to Table 8 in Section 5.2 – Air Quality Monthly Summary for further information.

The reasons for the exceptions are reported in Table 10 and were mainly due to equipment requiring adjustment.

1.0 Introduction

Ecotech Pty Ltd was commissioned by Fulton Hogan Egis Operations & Maintenance (FHEOM) to provide monitoring and data reporting for the WestConnex - M4 East Haberfield Public School ambient air quality and weather monitoring station, located as detailed in Table 1. Ecotech commenced data collection in December 2017.

This report presents the available data for November 2021.

The data presented in this report:

- Describes air quality measurements;
- Compares monitoring results;
- Has been quality assured;
- Complies with NATA accreditation requirements, where applicable.

2.0 Monitoring and Data Collection

2.1. Siting Details

WestConnex - M4 East Haberfield Public School station's location shows in Table 1 below.

Table 1: WestConnex M4 NSW East Haberfield Public School Station's Location

Site Name	Geographical Coordinates	Height Above Sea Level (m)
Haberfield Public School	33°52'45.70"S, 151°8'4.01"E	24

A siting audit to assess sites for compliance with *AS/NZS 3580.1.1:2016* has been completed at WestConnex - M4 East Haberfield Public School station on 24/11/21.



Figure 1: WestConnex - M4 East Haberfield Public School Station's Location

2.2. Monitored Parameters

Table 2 below details the parameters monitored and the instruments used at the WestConnex - M4 East Haberfield Public School Station. Appendix 1 defines any abbreviated parameter names used throughout the report.

Table 2: Parameters measured at the WestConnex - M4 East Haberfield Public School Station

Parameter Measured	Instrument and Measurement Technique	Elevation
CO	Ecotech Serinus 30 – NDIR gas filter correlation infrared photometry	2 m
NO, NO ₂ , NO _x	Ecotech Serinus 40 – gas phase chemiluminescence	2 m
PM _{2.5}	Met One BAM 1020 – Beta ray attenuation	2 m
PM ₁₀	Thermo – 1400 ab TEOM (Tapered Element Oscillating Microbalance)	2m
Differential Temperature (Elevation 2m)	Met One 062MP	2 m
Differential Temperature (Elevation 10m)	Met One 062MP	10 m
Wind Speed (Horizontal, elevation 10m)	Gill Windsonic Op3	10 m
Wind Direction (elevation 10m)	Gill Windsonic Op3	10 m
Sigma	Calculation	-

2.3. Data Collection Methods

Table 3 below shows the methods used for data collection.

Table 3: Methods

Parameter Measured	Data Collection Methods Used	Description of Method
NO, NO ₂ , NO _x	AS 3580.5.1 - 2011	Methods for sampling and analysis of ambient air - Method 5.1: Determination of oxides of nitrogen-Chemiluminescence method
CO	AS 3580.7.1 - 2011	Methods for sampling and analysis of ambient air. Method 7.1: Determination of carbon monoxide—Direct-reading instrumental method
PM ₁₀ (TEOM)	AS 3580.9.8-2008	Methods for sampling and analysis of ambient air. Method 9.8: Determination of suspended particulate matter - PM ₁₀ continuous direct mass method using a tapered element oscillating microbalance analyser.
PM _{2.5} (BAM 1020)	AS/NZS 3580.9.12-2013 ¹	Methods for sampling and analysis of ambient Air - Method 9.12: Determination of suspended particulate matter—PM _{2.5} beta attenuation monitors
Vector Wind Speed (Horizontal)	AS 2923-1987 ²	Methods for sampling and analysis of ambient air. Method 14: Meteorological monitoring for ambient air quality monitoring applications
Vector Wind Direction	AS 2923-1987 ³	Methods for sampling and analysis of ambient air. Method 14: Meteorological monitoring for ambient air quality monitoring applications
Sigma	AS 2923-1987 ³	Methods of sampling and analysis of ambient air. Method 14: Meteorological monitoring for ambient air quality monitoring applications
Atmospheric Temperature	USEPA (2000) EPA 454/R-99-005 ³	Methods for sampling and analysis of ambient air. Method 14: Meteorological monitoring for ambient air quality monitoring applications

¹ As approved by the Department of Planning and Environment on 8th September 2017.

² Superseded by AS/NZ 3580.14 2014 but specifically referenced in ministerial conditions.

³ Superseded by AS/NZ 3580.14 2014 but specifically referenced in ministerial conditions.

Note: Two different measurement techniques are used for monitoring PM₁₀ and PM_{2.5} at the WestConnex - M4 East Project Station. Studies conducted in Canada, the United States and other countries have found that the Tapered Element Oscillating Microbalance (TEOM) monitors can under report concentrations compared to the Beta Attenuation Monitors (BAM), especially when the air contains a large proportion of semi-volatile particulate matter, which may be the case during cooler seasons when the air contains less coarse dust and a greater proportion of semi-volatile organic compounds such as those associated with wood smoke. As a result, it is normal to see occasional periods where PM₁₀ < PM_{2.5} and this situation does not necessarily indicate a fault with either instrument.

2.3.1. Data Acquisition

Data acquisition is performed using a PC based WinAQMS logger (using WinAQMS® Version 2.0) situated at each of the monitoring sites. Each logger is equipped with a 3G modem for remote data collection. The recorded data is remotely collected from the Air Quality Monitoring Station (AQMS) loggers on a daily basis (using Airodis™ version 5.1) and stored at Ecotech's Environmental Reporting Services (ERS) department in Melbourne, Australia. Data samples are logged in 5-minute intervals.

2.4. Data Validation and Reporting

2.4.1. Validation

The Ecotech ERS department performs daily data checks to ensure maximum data capture rates are maintained. Any equipment failures are communicated to the responsible field engineers for urgent rectification. Ecotech ERS maintains two distinct databases containing non-validated and validated data respectively.

The validated database is created by duplicating the non-validated database and then flagging data affected by instrument faults, calibrations and other maintenance activities. The data validation software requires the analyst to supply a valid reason (e.g., backed by maintenance notes, calibration sheets etc.) in the database for flagging any data as invalid.

Details of all invalid or missing data are recorded in the Valid Data Exception Tables.

Validation is performed by the analyst, and the validation is reviewed. Graphs and tables are generated based on the validated five minutes and one-hour data as appropriate.

2.4.2. Reporting

Data is reported in one Microsoft Excel format file named:

- *WestConnex_M4_Haberfield School_ Monthly Data Report_ November 2021.xls*

Excel file consists of 5 worksheets:

1. Cover
2. 5 Minute Data
3. 1 Hour Data
4. 24-hour Data
5. Valid Data Exception Report

The data contained in this report is based on Australian Eastern Standard Time.

All averages are calculated from the five-minute and the one-hour data. Averages are based on a minimum of 75% valid readings within the averaging period. Where data capture is low for a particular parameter, summary values (e.g., monthly maximum and minimum) may be based on less than 75% valid samples. The reader should use caution when interpreting these values as they may not be representative of conditions for the entire sample period.

Averaging periods of eight hours or less are reported for the end of the period, i.e., the hourly average 02:00am is for the data collected from 1:00am to 2:00am. One-hour averages are calculated based on a clock hour. One day averages are calculated based on calendar days.

3.0 Air Quality Goals

The air quality goals and criteria for pollutants monitored at the WestConnex - M4 East Haberfield Public School station are based on SSI 6307 Planning Approval Condition E9. The air quality goals and criteria are shown in Table 4 below.

Table 4: WestConnex - M4 East Haberfield Public School Station - Air Quality Goals

Parameter	Time Period	Goal Level	Units
CO	8 hours (rolling, based on 1-hour averages)	9.0	ppm
NO ₂	1 hour	0.12	ppm
PM ₁₀	1 day	50	µg/m ³
	1 year	25	µg/m ³
PM _{2.5}	1 day	25	µg/m ³
	1 year	8	µg/m ³

Note:

This table includes all valid data points that exceed the defined air quality standards. The Ambient Air Quality NEPM includes a provision for excluding 1-day PM₁₀ or PM_{2.5} averages associated with “exceptional events” from the total exceedances of the Air Quality standard. The definition of an “exceptional event” is included below for reference. It is the responsibility of the end user of this data to evaluate whether any reported exceedances are associated with exceptional events and are eligible to be excluded from the exceedance total. Monitoring and reporting of exceedances during the operational project will be in accordance with the Planning Approval Conditions E10, E11 and E12.

As per the Ambient Air Quality NEPM, **Exceptional event** means a fire or dust occurrence that adversely affects air quality at a particular location, and causes an exceedance of 1 day average standards in excess of normal historical fluctuations and background levels, and is directly related to: bushfire; jurisdiction authorised hazard reduction burning; or continental scale windblown dust.

4.0 Calibrations and Maintenance

4.1. Units and Uncertainties

The uncertainties for each parameter have been determined by the manufacturer's tolerance limits of the equipment's parameters, and by the data collection standard method.

The reported uncertainties are expanded uncertainties, calculated using coverage factors which give a level of confidence of approximately 95%.

Table 5: Units and Uncertainties

Parameter	Units	Resolution	Uncertainty	Measurement Range ⁴
NO, NO _x (S40)	ppm	0.001 ppm	± (6% of reading + 0.011 ppm) k factor of 2.0	0 to 0.5 ppm LDL = 0.0004 ppm
NO ₂ (S40)	ppm	0.001 ppm	± (6% of reading + 0.011 ppm) k factor of 2.0	0 to 0.5 ppm LDL = 0.0004 ppm
CO (S30)	ppm	0.1 ppm	± (7% of reading + 0.8 ppm) k factor of 2.0	0 to 50 ppm LDL = 0.04 ppm
PM _{2.5} (BAM1020)	µg/m ³	1 µg/m ³	24Hr: ± (5.5% of reading + 4.0 µg/m ³) (in range 0 - 100 µg/m ³) Hr: ± (8% of reading + 8.0 µg/m ³) k factor of 2.0	0 to 1000 µg/m ³ LDL _{24hr} = 1.0 µg/m ³ LDL _{hr} = 4.8 µg/m ³
PM ₁₀ (TEOM)	µg/m ³	0.1 µg/m ³	± 5.0 µg/m ³ or 3.6% of reading, whichever is the greater K factor of 2.0	0 to 1 g/m ³ LDL = 5 µg/m ³
Vector Wind Speed	m/s	0.1 m/s	± 0.4 m/s or 2 % of reading, whichever is greater K factor of 2.0	0 to 30 m/s
Vector Wind Direction	Deg	1 deg	± 4 deg K factor of 2.0	0 to 360 deg <i>Starting threshold:</i> 0 m/s

⁴ Uncertainties may not be calculated based on the full measurement range. The max measurement range for gas analysers is defined as the full scale (FS=Span/0.8).

Parameter	Units	Resolution	Uncertainty	Measurement Range ⁴
Ambient Temperature	°C	0.1°C	± 0.6°C K factor of 2.0	-10°C to 50°C

4.2. Maintenance

4.2.1. Calibration & Maintenance Summary Tables

The last calibrations for the following parameters were performed on the indicated dates. Data supplied after this time is subject to further validation, to be performed at the next calibration cycle.

Note: Maintenance and calibration dates may differ, as calibrations may be less frequent than scheduled maintenance visits.

Table 6 indicates when the particulate and gas and meteorological equipment were last maintained/calibrated.

Table 6: M4 East Project Haberfield Public School Maintenance Table November 2021

Parameter	Date of Last Scheduled Maintenance	Maintenance Type ⁵	Date of Last Calibration	Calibration Cycle
NO, NO ₂ , NO _x	23/11/21	Yearly	23/11/21	Monthly
CO	23/11/21	Yearly	23/11/21	Monthly
PM ₁₀	24/11/21	Yearly	23/11/21	Yearly
PM _{2.5}	24/11/21	Yearly	19/11/21	Yearly
WS/WD/Sigma	23/11/21	Monthly	01/09/20 ⁶	2 Yearly
Differential Temperature 2m	11/11/21	Yearly	11/11/21	6 Monthly
Differential Temperature 10m	11/11/21	Yearly	26/05/11 (ID: 21-1452 OUT)	6 Monthly
			11/11/21 (ID: 20-0004 IN)	

⁵ Additional visits may have been made as required.

⁶ Wind sensor calibrated on 01/09/20 and installed at this site on 26/05/21.

5.0 Results

5.1. Data Capture

Valid data capture refers to the amount of valid data collected during the report period. It is based on 5-minute data, for gaseous and meteorological parameters and 1-hour data for particulate parameters.

The percentage of valid data captured is calculated using the following equation:

$$\text{Valid Data capture} = (\text{Reported air quality data} / \text{Total data}) \times 100\%$$

Where:

- Reported air quality data = Number of samples (instrument readings) which have been validated through a quality assured process and excludes all data errors, zero data collection due to calibration, equipment failures, planned and unplanned maintenance.
- Total data = Total number of samples (instrument readings) expected for the sampling period. Total data is calculated based on the same averaging period as “reported air quality data” and the duration of the corresponding report period. e.g., for 5-minute data collected over a month of 31 days, the total data would be equal to 12 (5-minute samples in an hour) x 24 (hours in a day) x 31 (days in a month) = 8928 samples.

Table 7 below displays data capture statistics for November 2021. **Bold** values in the table indicate data capture below 95%.

Details of all invalid or missing data affecting data capture are included in the Valid Data Exception Table, see section 6.0.

Table 7: Data Capture for WestConnex - M4 East Haberfield Public School Station

Parameter	Data Capture (%)
PM _{2.5}	95.3
PM ₁₀	89.2
CO	93.9
NO, NO ₂ , NO _x	95.7
WS, WD, Sigma	98.2
AT 2m	98.3
AT 10m	63.6

5.2. Air Quality Monthly Summary

Table 8 below includes a summary of any exceedances recorded at the WestConnex - M4 East Haberfield Public School Station during the reported period⁷.

Table 8: M4 East Project Haberfield Public School Exceedances Recorded for November 2021

Parameter	Time Period	Value of Exceedance	Date of Exceedance
NO ₂ (ppm)	1 hour	-	-
CO (ppm)	8-hour rolling	-	-
PM ₁₀ (µg/m ³)	24-hour	-	-
	Annual ⁸	-	-
PM _{2.5} (µg/m ³)	24-hour	-	-
	Annual ⁹	-	-

⁷ Exceedances are based on the decimal places reported.

⁸ Insufficient data to report annual average in 2021, any exceedances will be included in December 2021 report.

⁹ Insufficient data to report annual average in 2021, any exceedances will be included in December 2021 report.

5.3. Tabulated data

5.3.1. Annual average

Table 9 displays monthly averages of the PM_{2.5} and PM₁₀ parameters collected at WestConnex - M4 East Haberfield Public School ambient air monitoring station for 2021. Averages shown are for the 2021 calendar year, up to the current reported month. Table requires at least 75% valid data to display a monthly average. Footer values are based on all available data for 2021 rather than the average of individual months. This gives an indication of performance against the annual objectives.

Table 9: PM₁₀ and PM_{2.5} averages at the WestConnex M4 East Ambient Air Monitoring Station 2021

Month	Haberfield school	
	PM ₁₀ (µg/m ³)	PM _{2.5} (µg/m ³)
Jan-21	-	-
Feb-21	-	-
Mar-21	16.2	4.9
Apr-21	19.0	10.5
May-21	14.4	8.5
Jun-21	8.7	16.6
Jul-21	11.5	8.1
Aug-21	14.5	8.8
Sep-21	15.1	6.1
Oct-21	16.5	5.9
Nov-21	14.0	4.1
Average	15.0	7.3

5.4. Graphic Representations

This section displays graphs of the pollutants and meteorological parameters monitored at the WestConnex - M4 East Haberfield Public School station for November 2021. The graphs are based on validated 5 minutes or 1-hour data as appropriate.

CO 8-Hour (Rolling, based on 1-Hour Averages)

November 2021

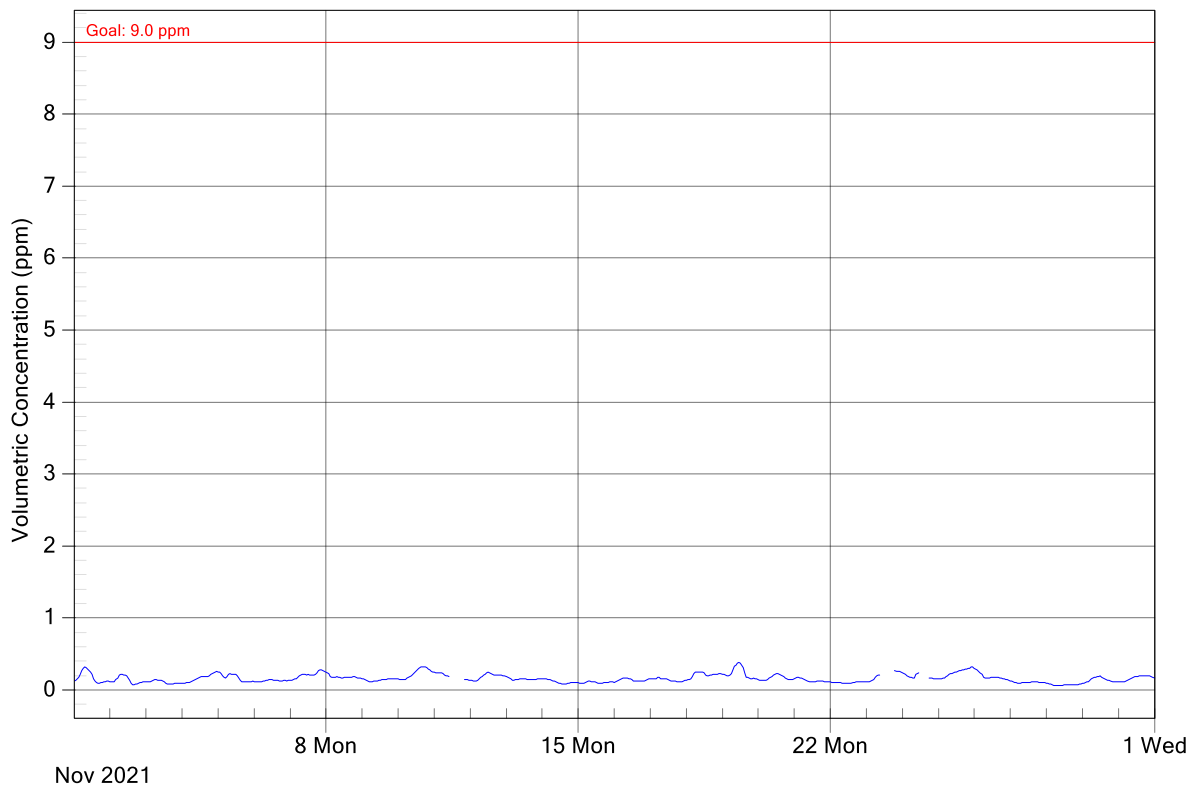


Figure 2: M4 East Haberfield Public School Station - CO 8-Hour Rolling Graph for November 2021

NO₂ 1-Hour Averages

November 2021

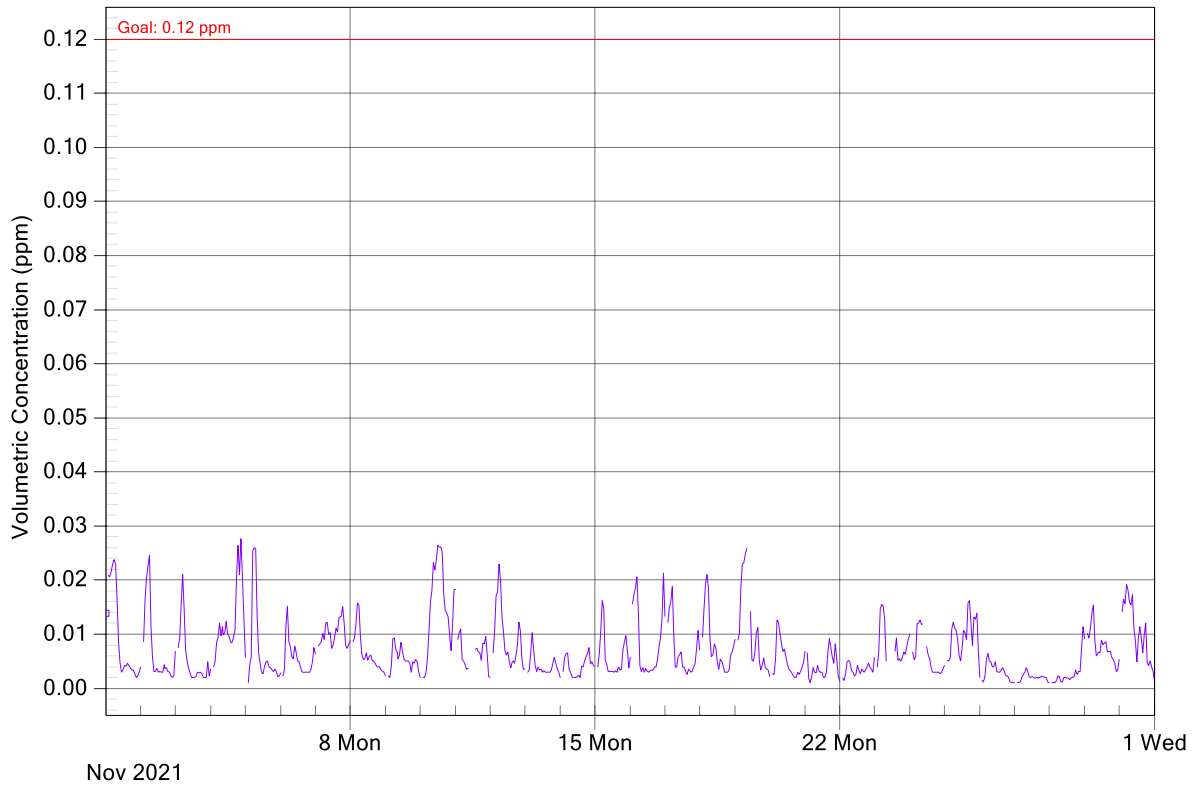


Figure 3: M4 East Haberfield Public School Station - NO₂ 1-Hour Averages Graph for November 2021

PM₁₀ 24-Hour Averages

November 2021

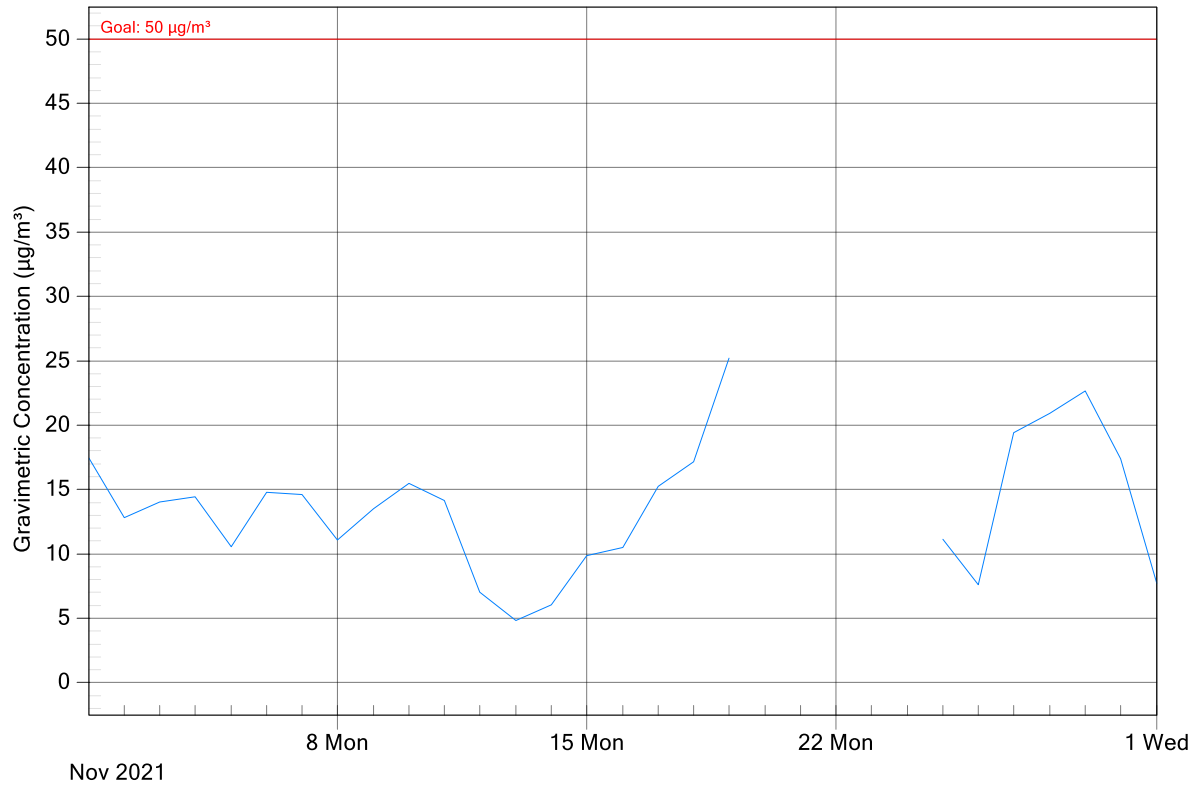


Figure 4: M4 East Haberfield Public School Station - PM₁₀ 24-Hour Averages Graph for November 2021

PM_{2.5} 24-Hour Averages

November 2021

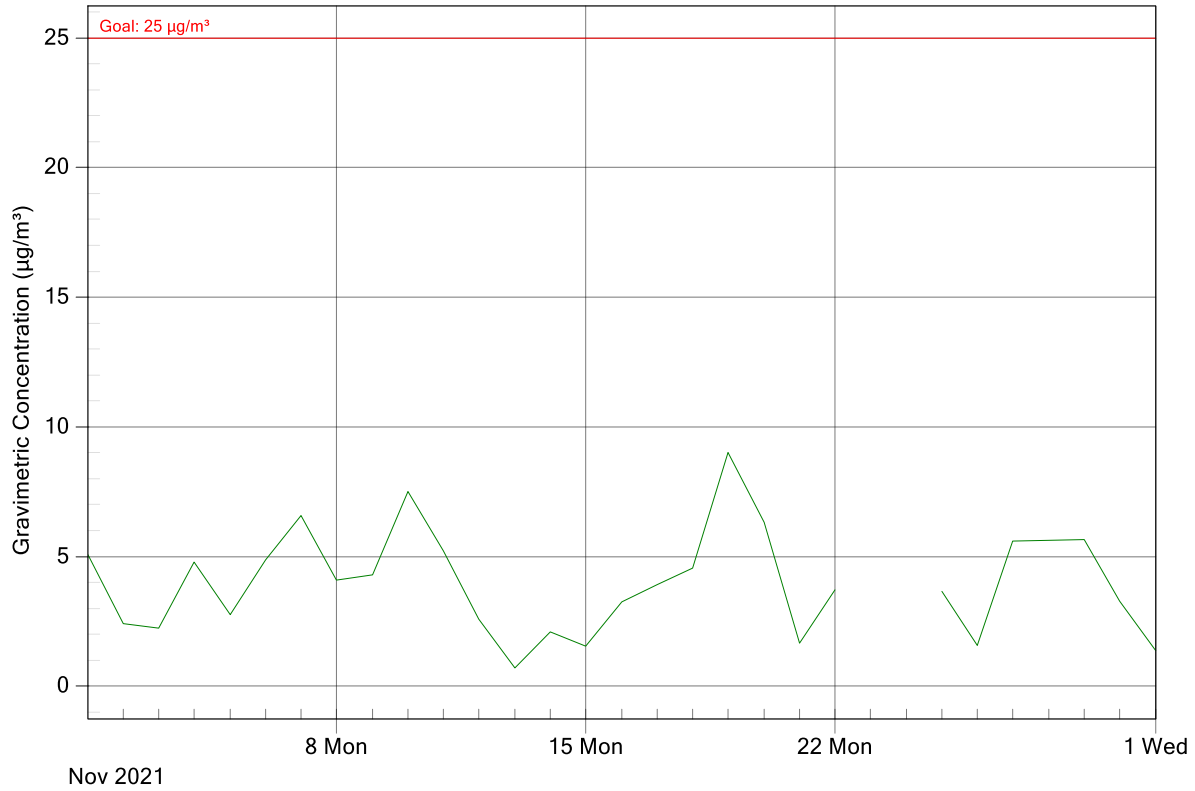
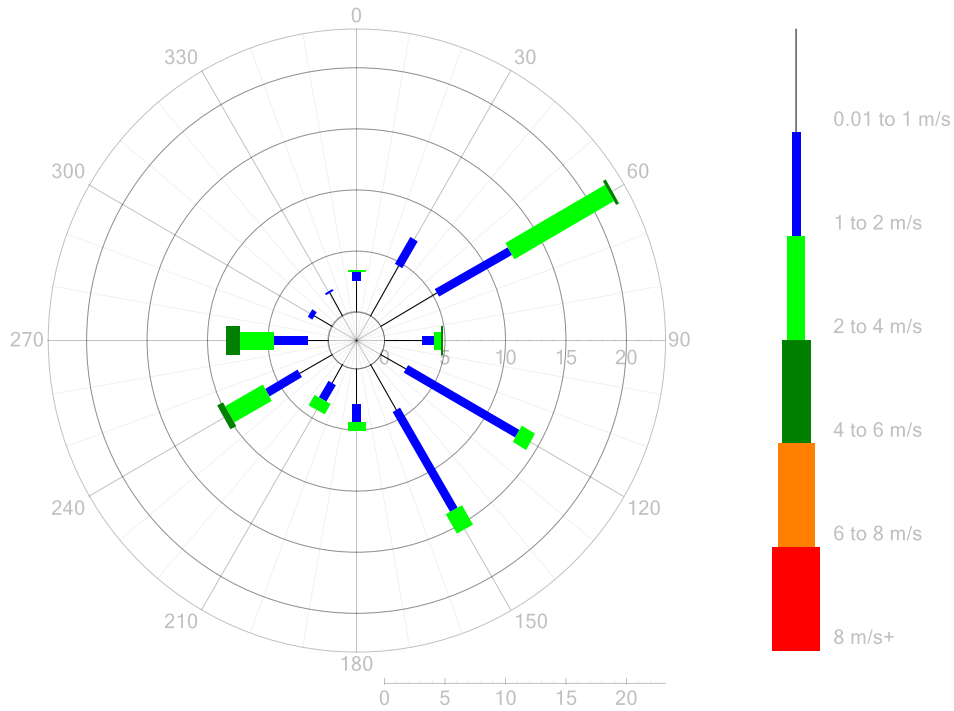


Figure 5: M4 East Haberfield Public School Station - PM_{2.5} 24-Hour Averages Graph for November 2021

Haberfield Public School - Wind Rose (1-Hour Averages)

Wind Rose

November 2021



0.1% calm
98.2% valid data present

Figure 6: Haberfield Public School – Wind Rose for November 2021

6.0 Valid Data Exception Tables

Table 10 below details all changes made to the raw data set during the validation process. An explanation of reasons given in the table can be found in Appendix 2.

Table 10: Haberfield Public School Valid Data Exception Table

Start Date	End Date	Reason	Change Details	User Name	Change Date
31/10/21 01:15	24/11/21 10:05	Intermittent linear offsets applied as required to correct unstable baseline <i>A values range from -0.15 to +0.10 ppm and B values range from -0.30 to +0.20 ppm</i>	CO	DL	14/12/21
01/11/21 00:00	11/11/21 09:45	Instrument fault	AT 10m	DL	14/12/21
01/11/21 00:45	30/11/21 01:20	Automatic span and zero checks, once daily from 00:45 to 01:15 followed by instrument stabilisation	CO, NO, NO ₂ , NO _x	DL	14/12/21
01/11/21 21:35	30/11/21 23:35	Intermittent data transmission errors	CO	DL	14/12/21
01/11/21 23:45	30/11/21 23:50	Background checks, once daily for 5 to 10 minutes followed by instrument stabilisation	CO	DL	14/12/21
07/11/21 03:40	26/11/21 23:40	Intermittent static offsets applied as required to correct unstable baseline <i>Values range from -0.05 ppm to +0.10 ppm</i>	CO	DL	14/12/21
11/11/21 09:00	11/11/21 14:35	Non-scheduled maintenance - Wind sensor zero check performed and AT 10m sensor swapped out (Instrument ID: 21-1452 OUT, 20-0004 IN)	All parameters	DL	14/12/21
19/11/21 09:00	19/11/21 12:25	Scheduled yearly maintenance (1 st Visit) - BAM instrument calibrations followed by instrument stabilisation	All parameters	DL	14/12/21
19/11/21 19:25	23/11/21 07:55	Intermittent unrealistic data - Possible moisture interferences	PM ₁₀	DL	14/12/21
23/11/21 08:00	23/11/21 13:55	Scheduled yearly maintenance (2 nd Visit) - Instrument calibrations followed by instrument stabilisation	All parameters	DL	14/12/21
23/11/21 14:00	24/11/21 09:55	Zero check performed	PM ₁₀ , PM _{2.5}	DL	14/12/21
24/11/21 10:00	24/11/21 12:15	Scheduled yearly maintenance (3 rd Visit) - Zero filter removed followed by instrument stabilisation	All parameters	DL	14/12/21

7.0 Report Summary

- Percentage availability for most parameters was above 95%, except for AT 10m sensor due to instrument fault, PM₁₀ due to noisy data, and CO due to several maintenance visits throughout the reporting month.
- Refer to Table 7 and Table 10 for details.
- There were no exceedance of the air quality goals at the WestConnex - M4 East Haberfield Public School Ambient Air Quality Monitoring Station for the reporting month. Please refer to Table 8 in Section 5.2 – Air Quality Monthly Summary for further information.

Appendix 1 - Definitions & Abbreviations

ERS	Environmental Reporting Services
AQMS	Air Quality Monitoring Station
AQM	Air Quality Monitor
BAM	Beta Attenuation Monitors
TEOM	Tapered Element Oscillating Microbalance
°	Degrees (True North)
K	Kelvin
LDL	Lower Detectable Limit
µg/m ³	Micrograms per cubic metre at standard temperature and pressure (0°C and 101.3 kPa)
AT	Ambient Temperature
calm	Wind conditions where the wind speed is below the operating range of the wind sensor
CO	Carbon monoxide
mg/m ³	Milligrams per cubic metre at standard temperature and pressure (0°C and 101.3 kPa)
mm	Millimeters
NO	Nitric oxide
NO ₂	Nitrogen dioxide
NO _x	Oxides of nitrogen
PM ₁₀	Particulate less than 10 microns in equivalent aerodynamic diameter
PM _{2.5}	Particulate less than 2.5 microns in equivalent aerodynamic diameter

ppb	Parts per billion
ppm	Parts per million
RH	Relative Humidity
WD	Vector Wind Direction
WS	Vector Wind Speed

Appendix 2 - Explanation of Exception Table

Automatic filter tape advance refers to the movement of the filter paper by the analyser to an unused spot.

Automatic background check refers to when analyser samples zero air and measures the level of the concentration voltage. This voltage is taken as the zero signal level and this value is subtracted from any subsequent readings as an active zero compensation. This is the analyser's fine zero measurement.

Automatic span/zero check. The E-Sampler is programmed to perform a zero calibration check whereby air is passed through filter element, removing particulates, before entering the sensor in the analyser. Data is invalidated when these checks occur.

Beta count failure refers to a fault in the functioning of the EBAM. A one minute beta count was less than the maximum acceptable counts during operation.

Calibration check outside tolerance refers to when the calibration values are outside the tolerance limits set for the precision check.

Calibration correction factor applied to data refers to an offset or multiplier applied to the data. This operation may be performed for a number of reasons including: (a) when a clear trend / drift outside the tolerance limit can be demonstrated by repeated operation precision checks, (b) when a correction is required on previously logged data due to a calibration check being outside the allowable tolerance

Commissioning refers to the initial setup and calibration of the instrument when it is first installed. For some instruments there may be a stabilisation period before normal operation commences.

Data transmission error refers to a period of time when the instrument could not transmit data. This may be due to interference, or a problem with the phone line or modem.

Equipment malfunction/instrument fault refers to a period of time when the instrument was not in the normal operating mode and did not measure a representative value of the existing conditions.

Gap in data/data not available refers to a period of time when either data has been lost or could not be collected.

Instrument Alarm refers to an alarm produced by the instrument. A range of alarms can be produced depending on how operation of the instrument is being affected.

Instrument out of service refers to a lack of data due to an instrument being shut down for repair, maintenance, or factory calibration.

Linear offset or multiplier refers to when an offset or multiplier has been applied between two points where the values of the offset or multiplier are different and the correction is interpolated between the two points.

Logger error refers to when an error occurs and instrument readings are not correctly recorded by the logger.

Maintenance refers to a period of time when the logger/instrument was switched off due to maintenance.

Overnight span/zero out of tolerance refers to when the span/zero reading measured by the analyser during an automatic precision check falls outside of the expected concentration limits.

Overnight zero out of tolerance refers to when the automatic zero reading measured by the analyser falls outside the expected limits.

Power Interruption refers to no power to the station therefore no data was collected at this time.

Remote Calibration refers to when a technician remotely connects to the station and manually performs a span check.

Static offset or multiplier refers to when a single offset or multiplier has been applied to the data between two points either to increase or decrease the measured value.

Tape break refers to the breaking of the EBAM/BAM sample tape during operation.

Warm up after power interruption refers to the startup period of an instrument after power has been restored.