Northern Territory Ambient Air Quality Monitoring Report 2020

Compliance with the National Environment Protection (Ambient Air Quality) Measure

ntepa Northern Territory Environment Protection Authority

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Acronyms	Full form
AAQ NEPM	National Environment Protection (Ambient Air Quality) Measure
ABS	Australian Bureau of Statistics
AQMS	Air Quality Monitoring Station
BoM	Bureau of Meteorology
CBD	Central Business District
CO	Carbon monoxide
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEPWS	Department of Environment, Parks and Water Security
EWG	Expert Working Group (NEPC)
FDMS	Filter Dynamics Measurement System (used by the TEOM)
GRUB	Generally representative upper bound (AQMS)
KTC	Katherine Town Council
NAFI	North Australian Fire Information
NASA	National Aeronautics and Space Administration (USA)
NATA	National Association of Testing Authorities
NEPC	National Environment Protection Council
NO/ NO_2/ NO_x	Nitric oxide/ Nitrogen dioxide/ Oxides of nitrogen
NT	Northern Territory
NT EPA	Northern Territory Environment Protection Authority
O_3	Ozone
PM_{10}	Particulate matter with aerodynamic diameter less than or equal to 10 μm
$PM_{2.5}$	Particulate matter with aerodynamic diameter less than or equal to 2.5 μm
ppm	Parts per million by volume
PRC	Peer Review Committee (NEPC)
SA2	Statistical Area Level 2
SO_2	Sulfur dioxide
TEOM	Tapered element oscillating microbalance
$\mu g/m^3$	Micrograms per cubic metre referenced to a temperature of 0 degrees Celsius and an absolute pressure of 101.325 kilopascals
μm	Micrometres (10^{-6} metres)
WMPCA	Waste Management and Pollution Control Act 1998

Contents

1 Summary

This report presents Northern Territory air quality monitoring data for the 2020 calendar year and assesses them against the requirements for *National Environment Protection (Ambient Air Quality) Measure* (AAQ NEPM).

During 2020, the Northern Territory Environment Protection Authority (NT EPA) operated three designated ambient air quality monitoring stations in the Darwin region. These stations, located at Palmerston, Winnellie and Stokes Hill measure and report real-time data on the concentrations of six AAQ NEPM air pollutants: sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), photochemical oxidants as ozone (O_3), and particulate matter with sizes of 10 micrometres or less (PM_{10}) and 2.5 micrometres or less ($PM_{2.5}$).

In September 2020, the Katherine Town Council commissioned an air quality monitoring station at Katherine under a performance agreement with the NT EPA. This station monitors PM_{10} and $PM_{2.5}$ and results have been reported here although there was insufficient data to assess compliance with the AAQ NEPM. Meteorological instruments for measuring parameters such as wind speed and direction, ambient temperature and relative humidity are located at the sites.

Assessment of goal compliance: Between 1 January and 31 December 2020, all the designated ambient air quality monitoring stations in the Darwin region complied with the AAQ NEPM goal for NO_2, SO_2, and O_3 by not recording any exceedances of the AAQ NEPM standards for these air pollutants. No exceedances of CO were recorded, but insufficient CO data was collected at the some stations. As explained below, although some exceedances of short-term standards were recorded for PM_{10} and $PM_{2.5}$, all the stations were compliant with the AAQ NEPM goals. The number of recorded exceedances in 2020 was much less than the numbers recorded in recent years.

Carbon monoxide: During 2020, although no exceedances of the 8-hour rolling average standard for CO were recorded at any of the stations, compliance with the AAQ NEPM was not demonstrated at Palmerston and Stokes Hill stations due to low data recovery rates (less than 75%) in the 2nd and 3rd quarters, caused by CO instrument downtime. AAQ NEPM goal for CO was demonstrated only at Winnellie.

Nitrogen dioxide: The AAQ NEPM goal for NO_2 was met in 2020, since there were no exceedances of the 1-hour or 1-year NO_2 standards.

Sulfur dioxide: The AAQ NEPM goal for SO_2 was met in 2020, since there were no recorded exceedances of the SO_2 1-hour, 1-day or 1-year standards.

Ozone: During 2020 no exceedances of the 1-hour average O_3 standard or the 4-hour rolling average O_3 standard were recorded at any of the stations – all the stations met the AAQ NEPM goal for ozone.

PM_{10}: To comply with the AAQ NEPM goal for particulates as PM_{10}, no exceedance of the 1-day average standard of 50 $\mu g/m^3$ is allowed, unless determined as an exceptional event, and there must be no exceedance of the 1-year average standard. Palmerston recorded one exceedance, Stokes Hill recorded no exceedances and Winnellie recorded one exceedance of the 1-day standard, but these exceedances were linked to smoke from bushfires, which are exceptional events. The PM_{10} 1-year averages of 18.3, 17.8 and 16.9 $\mu g/m^3$ at Palmerston, Stokes Hill and Winnellie, respectively, were below the AAQ NEPM standard of 25 $\mu g/m^3$.

No exceedances of the PM_{10} 1-year average standard of 25 $\mu g/m^3$ occurred at any of the stations in 2020.

Katherine did not record any exceedances, but did not achieve the 75% data capture rates required in each quarter to demonstrate compliance.

$PM_{2.5}$: To comply with the AAQ NEPM goal for particulates as $PM_{2.5}$, no exceedances of the 1-day average standard of 25 $\mu g/m^3$ is allowed, unless determined as an exceptional event, and there must be no exceedance of the 1-year average standard. During 2020, all exceedances of the $PM_{2.5}$ 1-day standard (7 at Palmerston, 4 at Stokes Hill and 7 at Winnellie) were linked to smoke from bushfires, which are classified as exceptional events. The $PM_{2.5}$ 1-year averages of 7.0, 6.4 and 6.5 $\mu g/m^3$ at Palmerston, Stokes Hill and Winnellie, respectively, were below the AAQ NEPM standard of 8 $\mu g/m^3$.

Katherine recorded one exceedance of the 1-day average $PM_{2.5}$ standard. This was caused by an exceptional event; however, insufficient data was recorded there to demonstrate compliance with the AAQ NEPM goal for $PM_{2.5}$.

It is now a requirement by the AAQ NEPM that jurisdictions should report population exposure for particles as $PM_{2.5}$. Using a simplified approach, a population-weighted annual average $PM_{2.5}$ concentration of 6.7 $\mu g/m^3$ was estimated for the Greater Darwin Region in 2020.

2 Background

The Department of Environment, Parks and Water Security (DEPWS) provides services to the Northern Territory Environment Protection Authority (NT EPA), which is responsible for implementing the *National Environment Protection (Ambient Air Quality) Measure* (AAQ NEPM) in the Northern Territory through the provisions of the *Waste Management and Pollution Control Act 1998* (WMPCA) and the *National Environment Protection Council (Northern Territory) Act 1994*.

Clause 18 of the *National Environment Protection (Ambient Air Quality) Measure* (AAQ NEPM) requires jurisdictions to submit a report on their compliance with the AAQ NEPM for each calendar year. The content of the jurisdictional report is prescribed in clause 17 of the AAQ NEPM.

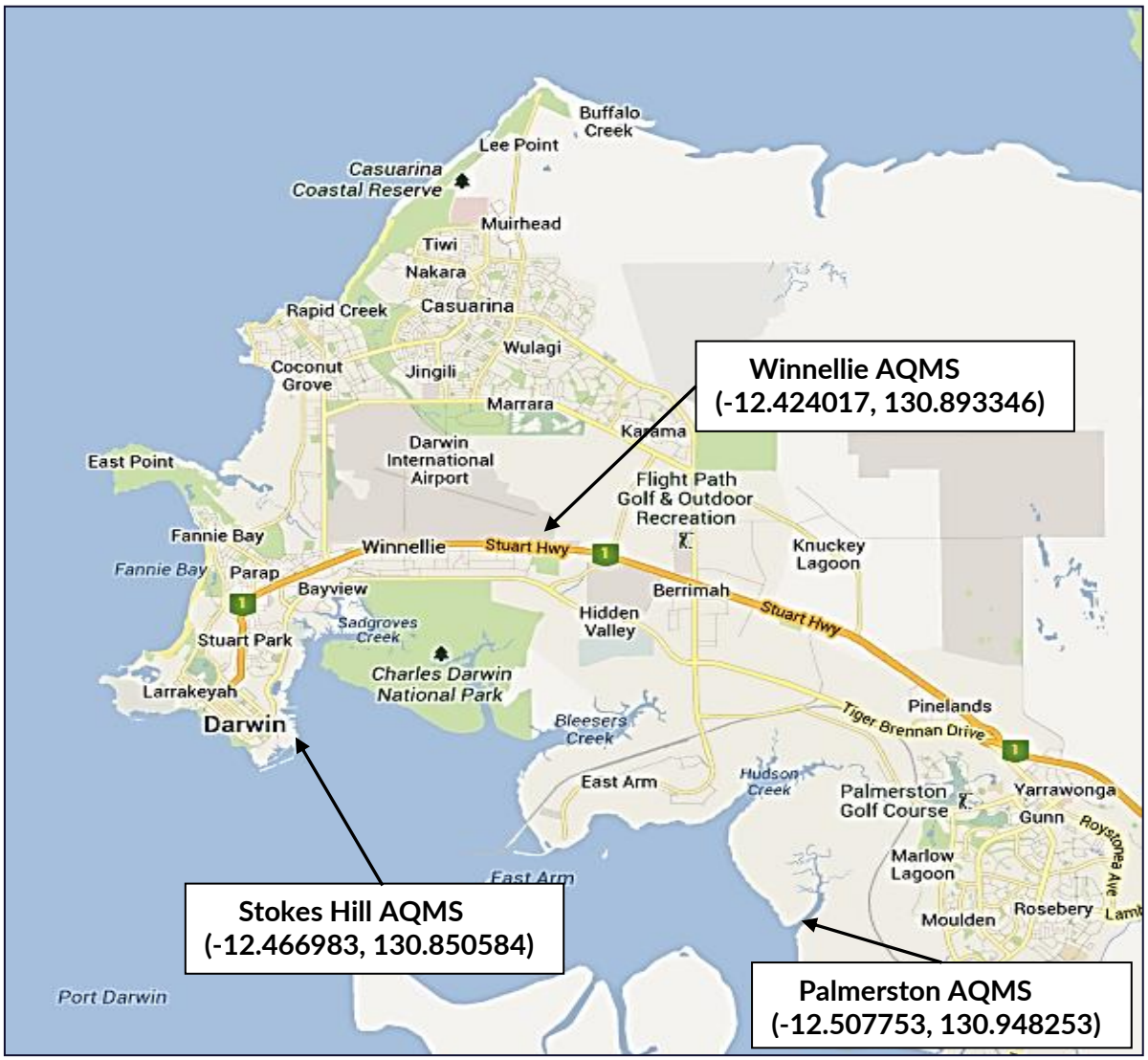

Figure 1a: Locations of Palmerston, Winnellie and Stokes Hill Air Quality Monitoring Stations (AQMS) in the Greater Darwin Region

Consistent with the reporting period defined in the AAQ NEPM, this report covers the calendar year ending on 31 December 2020 for data collected from the Northern Territory Environment Protection Authority (NT EPA) monitoring stations located at Palmerston, Winnellie and Stokes Hill (Figure 1a) and from the Katherine Town Council station located in Katherine (Figure 1b). The report is based on Technical Papers No. 8 - Annual Reports (PRC 2002) and No. 5 - Data Collection and Handling (PRC 2001) which detail the format and data requirements of the Annual Report. It is a technical report to the National Environment Protection Council (NEPC) and supplements the annual summary report provided each year by each jurisdiction under the *National Environment Protection Council Act 1994* on the overall implementation of the AAQ NEPM.

This technical report, *Northern Territory Ambient Air Quality Monitoring Report 2020 - Compliance with the National Environment Protection (Ambient Air Quality) Measure*, is available on the NT EPA website at https://ntepa.nt.gov.au/your-environment/air-quality/ambient-air-quality-reports.

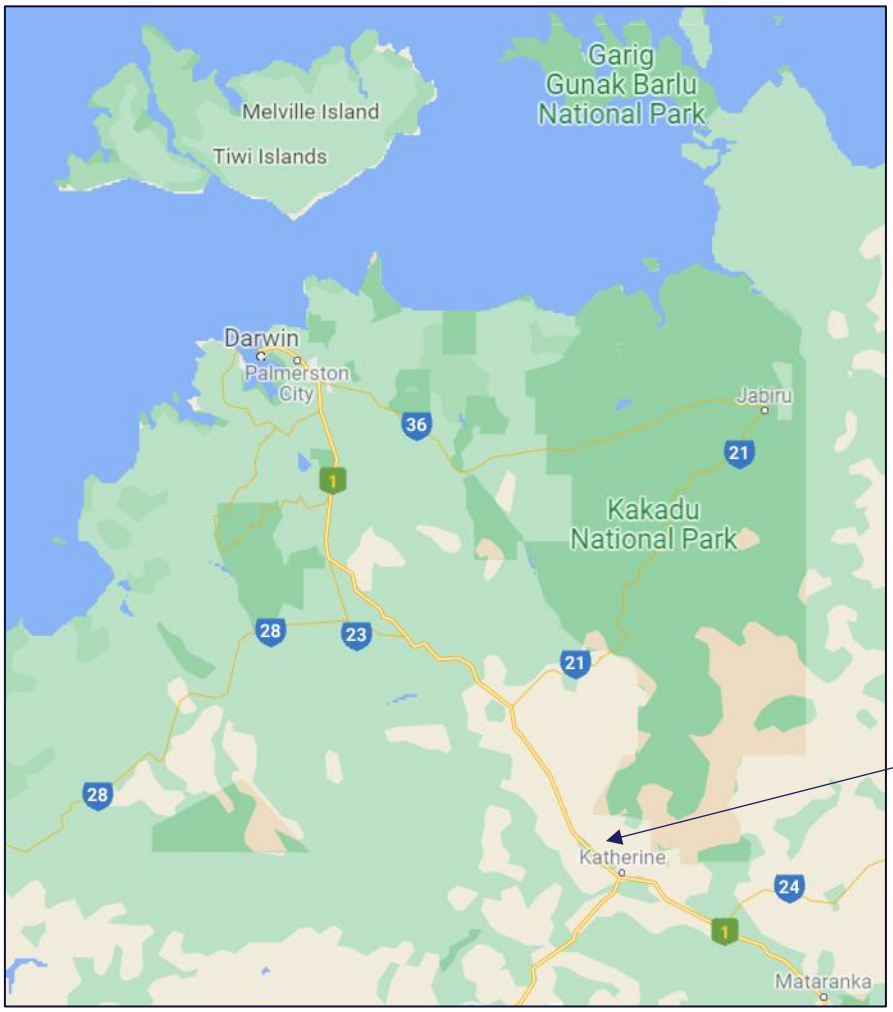

Figure 1b. Katherine AQMS is operated by Katherine Town Council

3 Overview of the 2020 AAQ NEPM monitoring network and activities

3.1 Monitoring requirements

The results of air quality monitoring in 2000-2001 were used to determine the monitoring requirements for the Northern Territory over the longer term and included in an approved monitoring plan (NTG, 2001). This monitoring identified fine particles from landscape fires affecting the Darwin region as the primary air pollutant of concern in the Northern Territory. Analysis of the 2000-2001 data against the AAQ NEPM standards indicated that nitrogen oxides, sulfur dioxide, carbon monoxide, ozone and lead aerosols were not a cause for concern in the Darwin/Palmerston region or regional population centres (Gras *et al*., 2001).

Since the initial monitoring, the population and industrial activities in Darwin have increased and more detailed monitoring of airborne pollutants is required. The establishment and operation of a comprehensive air quality monitoring system for the Darwin region commenced in 2010. This was completed in July 2012 allowing for monitoring of all pollutants identified in the AAQ NEPM with the exception of lead. Monitoring for lead was not deemed necessary as there are no significant sources close to populated areas in the region and the sale of unleaded petrol ceased in 2002.

The network of ambient air quality monitoring stations comprises of three stations in the Greater Darwin Region (Figure 1a) and one located at Katherine (Figure 1b). A performance monitoring station located near Palmerston has been operational since the beginning of 2011; a long-term trend monitoring station located at the Bureau of Meteorology (BoM) site in Winnellie has been operational since the second half of 2012; Stokes Hill started operating in May 2017; and the latest station Katherine was commissioned in September 2020.

3.2 Current monitoring stations for the purposes of this report

Winnellie air quality monitoring station (AQMS) meets requirements as a generally representative upper bound (GRUB) station. It is located between Darwin's northern suburbs and Darwin CBD, the two most densely populated areas in the Northern Territory (Figure 1a). The station consists of an air-conditioned instrument shed, which houses all instrumentation. Ambient air is continuously analysed for ozone (O_3), sulphur dioxide (SO_2), carbon monoxide (CO) and oxides of nitrogen (NO_x) concentrations by various instruments which are connected to a single gas-sampling manifold protruding through the station roof. NO_x is measured as the sum of nitrogen dioxide (NO_2) and nitric oxide (NO) concentrations. Air for particulate sampling is drawn through a separate mast attached to the station roof. The mast is fitted with

appropriate size selection inlets to sample specific particle size ranges (i.e., PM_{10} which are particles with aerodynamic diameters of 10 μm or less and $PM_{2.5}$ which are particles with aerodynamic diameters of 2.5 μm or less). Sampled air is drawn into a dichotomous tapered element oscillating microbalance (TEOM) instrument that provides near real-time PM_{10} and $PM_{2.5}$ concentrations in ambient air. Meteorological data is obtained from BoM instruments located at the site.

The Palmerston AQMS has been located to provide information on airborne pollutants, which may be moving from industrial sites in the middle harbour to populations in the Palmerston area. This station meets all siting and instrumentation requirements for reporting under the AAQ NEPM. It is located in light bushland approximately 4km south-west of Palmerston (Figure 1a). The station houses the same gas and particulate sampling instruments as Winnellie, but has meteorological instruments.

Stokes Hill AQMS (Figure 1a) is located about 1 km southeast of the CBD on the Darwin Waterfront and meets all siting and instrumentation requirements for reporting under the AAQ NEPM. This station was established to monitor potential air quality impacts from industrial development and increased shipping traffic in Darwin Harbour. The station houses similar gas and particulate sampling instruments as the other stations and has instruments for collection of meteorological data.

In September 2020, Katherine Town Council (KTC) commissioned the Katherine AQMS (Figure 1b) to monitor particulates in air, as part of a performance agreement with the NT EPA. The station only measures the concentrations of PM_{10} and $PM_{2.5}$ and various meteorological parameters.

Instrumentation and siting details for all stations are shown in Tables 1 and 2 in subsection 3.3.

3.3 Determination of exposed population for performance monitoring stations

Two areas within the Northern Territory exceed or are close to the population threshold of 25,000 required for establishing at least one performance air quality monitoring in the areas as required by the AAQ NEPM. These are the Greater Darwin region (137,000) and Alice Springs (25,000).

The major air pollutant of concern for Darwin and Palmerston is particulate matter from bushfire smoke in the Dry Season (May - October). Prevailing winds during the Dry Season are south-easterly to easterly, causing the population of the region to be frequently exposed to particulate pollution from relatively small fires in local bushland and more distant large-scale savannah fires.

Monitoring for particulates has been conducted at several sites in the Darwin/Palmerston region since 2002. From 2012, monitoring was conducted at two sites, whilst monitoring at the third site commenced

in 2017. A new station was established in Katherine in 2020. Results from simultaneous monitoring have shown that aside from spikes attributable to local fire events, particulate levels are reasonably uniform across the region on a seasonal basis. This was supported by the 2020 data: $PM_{2.5}$ annual average levels were 7.0, 6.4 and 6.5 $\mu g/m^3$ at Palmerston, Stokes Hill and Winnellie, respectively. As industrial development increases, divergence in particulate and other pollutant levels may occur between sites.

Table 1: Summary of station siting in compliance with AS/NZS 3580

Station	Location Category	Height above ground	Clear Sky Angle	Unrestricted airflow of 360°	20m from trees	No boilers/ incinerators nearby	Minimum distance from road or traffic
Winnellie AQMS	Bushland	Yes	Yes	Yes	Yes	Yes	Yes
Palmerston AQMS	Bushland	Yes	Yes	Yes	Yes	Yes	Yes
Stokes Hill AQMS	Coastal	Yes	Yes	Yes	Yes	Yes	Yes
Katherine AQMS	Bushland	Yes	Yes	Yes	Yes	Yes	Yes

No monitoring was undertaken in the Alice Springs region during the reporting period. The NT EPA intends to conduct monitoring of particulates in Alice Springs and other regional centres such as Tennant Creek in future years.

Table 1 shows that all the stations were sited in compliance with the requirements for Australian Standard AS/NZS 3580.1.1:2007 (Methods for sampling and analysis of ambient air – Guide to siting air monitoring equipment); and Table 2 lists the status of instruments located at the stations.

The anemometer is on a 10m mast at Palmerston; and on a 5m mast at Stokes Hill (the base of the mast is 5m from the ground). Meteorological data for Winnellie Station is sourced from BoM instruments located at the site. Environics Multi-Gas Calibrator/Diluter instruments and Environics Zero Air generators are located at the stations for conducting daily automatic zero/span checks and remote calibrations of the gas analysers. Katherine AQMS uses a Tapered Element Oscillating Microbalance (TEOM) model 1405DF which has a Filter Dynamics Measurement System (FDMS) to measure PM_{10} and $PM_{2.5}$. The FDMS unit measures and accounts for evaporative losses and does not require application of a correction factor to account for the loss of volatiles from the filter paper in the instrument. The TEOMs at the other stations do not operate with FDMS units.

Table 2: Air quality and meteorological instruments at ambient air quality stations

Parameter	Data available from	Data available to	Current Instrument	Sampling frequency
PM_{10}	01/01/11 (Palmerston) 18/07/12 (Winnellie) 03/07/17 (Stokes Hill) 02/09/20 (Katherine)	present	TEOM 1405D TEOM 1405D TEOM 1405D TEOM 1405DF	continuous
$PM_{2.5}$	01/01/11 (Palmerston) 18/07/12 (Winnellie) 03/07/17 (Stokes Hill) 02/09/20 (Katherine)	present	TEOM 1405D TEOM 1405D TEOM 1405D TEOM 1405DF	continuous
SO_2	01/01/11 (Palmerston) 18/07/12 (Winnellie) 05/05/17 (Stokes Hill)	present	Thermo Model 43i	continuous
NOx, NO, NO_2	01/01/11 (Palmerston) 18/07/12 (Winnellie) 05/05/17 (Stokes Hill)	present	Thermo Model 42i	continuous
O_3	01/01/11 (Palmerston) 18/07/12 (Winnellie) 05/05/17 (Stokes Hill)	present	Thermo Model 49i	continuous
CO	01/01/11 (Palmerston) 18/07/12 (Winnellie) 05/05/17 (Stokes Hill)	present	Thermo Model 48i	continuous
Wind direction	01/01/12 (Palmerston) 05/05/17 (Stokes Hill) 02/09/20 (Katherine)	present	RM Young, 2D ultra-sonic anemometer model 85000	continuous
Wind speed	01/01/12 (Palmerston) 04/05/17 (Stokes Hill) 02/09/20 (Katherine)	present	RM Young, 2D ultra-sonic anemometer model 85000	continuous
Sigma Theta	05/05/17 (Stokes Hill) 02/09/20 (Katherine)	present	RM Young, 2D ultra-sonic anemometer model 85000	continuous
Temperature	01/01/12 (Palmerston) 05/05/17 (Stokes Hill) 02/09/20 (Katherine)	present	RM Young, model 41382LC TEOM sensor TEOM sensor	continuous
Relative Humidity	01/01/12 (Palmerston) 05/05/17 (Stokes Hill) 02/09/20 (Katherine)	present	RM Young, model 41382LC TEOM sensor TEOM sensor	continuous
Atmospheric Pressure	01/01/12 (Palmerston) 05/05/17 (Stokes Hill) 02/09/20 (Katherine)	present	RM Young, model 61302v TEOM sensor TEOM sensor	continuous

Parameter	Data available from	Data available to	Current Instrument	Sampling frequency
Solar Radiation	01/01/12 (Palmerston)	present	Middleton Solar Pyranometer, model EQ08	continuous
Rainfall	01/01/12 (Palmerston)	present	RM Young, Tipping Bucket Rain Gauge	continuous

3.4 Monitoring during the reporting period

Palmerston, Winnellie and Stokes Hill stations monitor the same suite of air pollutants. Except for the carbon monoxide monitor at Palmerston and Stokes Hill, most of the instruments (including meteorological instruments) at these stations provided valid data for more than 75% of the time during the reporting period. Katherine only monitors particulates, and as it was commissioned in September, did not provide sufficient data to enable assessment of compliance with the AAQ NEPM.

3.5 Changes to the approved monitoring plan

No changes were made to the approved monitoring plan this year.

3.6 Unresolved issues

There are no unresolved issues in the reporting period.

3.7 Status of NATA accreditation

All data collection and validation processes were conducted by a National Association of Testing Authorities (NATA) accredited contractor who used Australian Standard methods/instruments for monitoring the air pollutants (Table 3), as prescribed in Clause 16 of the AAQ NEPM.

Table 3: Australian Standards and monitoring instruments used for air pollutant monitoring

Pollutant	Standard	Title	Instruments used
Carbon monoxide	AS3580.7.1	Ambient Air – Determination of Carbon Monoxide – Direct Reading Instrument Method	Gas filter correlation/ infra-red analyser
Nitrogen dioxide	AS3580.5.1	Ambient Air – Determination of Oxides of Nitrogen – Chemiluminescence Method	Gas-phase chemiluminescence analyser
Photochemical oxidant (ozone)	AS3580.6.1	Ambient Air – Determination of Ozone – Direct Reading Instrument Method	Non-dispersive ultra-violet analyser
Sulfur dioxide	AS3580.4.1	Ambient Air – Determination of Sulfur Dioxide – Direct Reading Instrument Method	Pulsed fluorescence analyser
Particles as PM_{10}	AS3580.9.8	Determination of Suspended Particulate Matter – PM_{10} continuous direct mass method using a TEOM	Tapered element oscillating microbalance (TEOM) dichotomous air monitor
Particles as $PM_{2.5}$	AS/NZS 3580.9.13	Determination of Suspended Particulate Matter – $PM_{2.5}$ continuous direct mass method using a TEOM	Tapered element oscillating microbalance (TEOM) dichotomous air monitor

3.8 Methods other than physical monitoring

No other methods were used in the reporting period.

4 Assessment of compliance with the AAQ NEPM standards and goals

A goal of the National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM) is to achieve the existing National Environment Protection Standards shown in Table 4 below (Schedule 2 of the AAQ NEPM). It is noted that the AAQ NEPM was varied in May 2021; however, all references to the AAQ NEPM in this document will be to the February 2016 version, which was current when data was collected in 2020.

Table 4: Ambient Air Quality NEPM Standards (February 2016 version)

Pollutant	Averaging period	Maximum concentration standard	Maximum allowable exceedances
Carbon monoxide	8 hour	9.0 ppm	1 day a year
Nitrogen dioxide	1 hour	0.12 ppm	1 day a year
	1 year	0.03 ppm	None
Photochemical oxidants (as ozone)	1 hour	0.10 ppm	1 day a year
	4 hours	0.08 ppm	1 day a year
Sulfur dioxide	1 hour	0.20 ppm	1 day a year
	1 day	0.08 ppm	1 day a year
	1 year	0.02 ppm	None
*Particles as PM_{10}	1 day	50 µg/m^3	None
	1 year	25 µg/m^3	None
*Particles as $PM_{2.5}$	1 day	25 µg/m^3	None
	1 year	8 µg/m3	None

**For the purpose of reporting compliance against PM_{10} and $PM_{2.5}$ 1-day average standards, monitoring data that has been determined as being directly associated with an exceptional event (such as bushfires) are excluded.*

The following tables (Table 5 to Table 10) summarise compliance with the standards and goals of the AAQ NEPM. Data availability (quarterly and annually), the number of days when standards were exceeded, the annual mean (where an annual standard exists) and an assessment of compliance are given for each pollutant. Pollutant concentrations are plotted in the corresponding figures (Figure 2 to Figure 9).

A station's performance is assessed as complying with the AAQ NEPM (i.e. 'Met') for a pollutant if the data availability was at least 75% for each quarter and the number of exceedances was no more than the "Maximum allowable exceedances" specified in Table 4.

Performance is assessed as not complying with the AAQ NEPM (i.e. 'Not Met') if the number of exceedances was more than the "Maximum allowable exceedances" specified in Table 4 for a pollutant. If there was insufficient data (less than 75% availability in any quarter of the year) then performance is assessed as 'Not Demonstrated' (ND), even if there were no exceedances recorded.

4.1 Carbon monoxide compliance

Table 5: 2020 compliance summary for CO in the Northern Territory

AAQ NEPM Standard

9.0 ppm (8-hour average)

Region/ Performance monitoring station	Data Availability Rates (% of Days)					Number of exceedances (days)	Performance against the standard and goal
	Q1	Q2	Q3	Q4	Annual		
Palmerston	93	57	25	96	67	0	Not demonstrated
Stokes Hill	98	46	28	96	67	0	Not demonstrated
Winnellie	77	100	75	98	84	0	Met

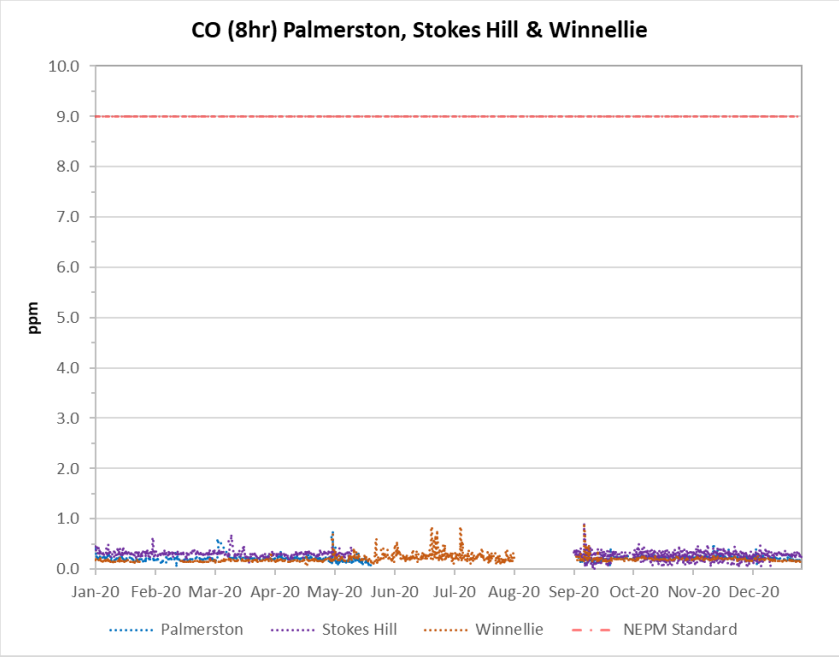

Figure 2: Carbon monoxide 8-hour averages 2020

During 2020, no exceedance of the carbon monoxide (CO) standard was recorded; however, compliance with the AAQ NEPM goal for CO was only demonstrated at Winnellie. During the second and third quarters, Palmerston and Stokes Hill did not meet the 75% data capture criteria for each quarter required to demonstrate compliance.

4.2 Nitrogen dioxide compliance

Table 6: 2020 compliance summary for NO_2 in the Northern Territory

AAQ NEPM Standard

0.12 ppm (1-hour average)

0.03 ppm (1-year average)

Region/ Performance monitoring station	Data Availability Rates (% of Days)					Number of exceedances (days)	Annual mean (ppm)	Performance against the standard and goal	
	Q1	Q2	Q3	Q4	Annual			1h	1y
Palmerston	88	92	91	82	88	0	0.0026	Met	Met
Stokes Hill	87	96	96	92	93	0	0.0019	Met	Met
Winnellie	95	95	92	95	94	0	0.0026	Met	Met

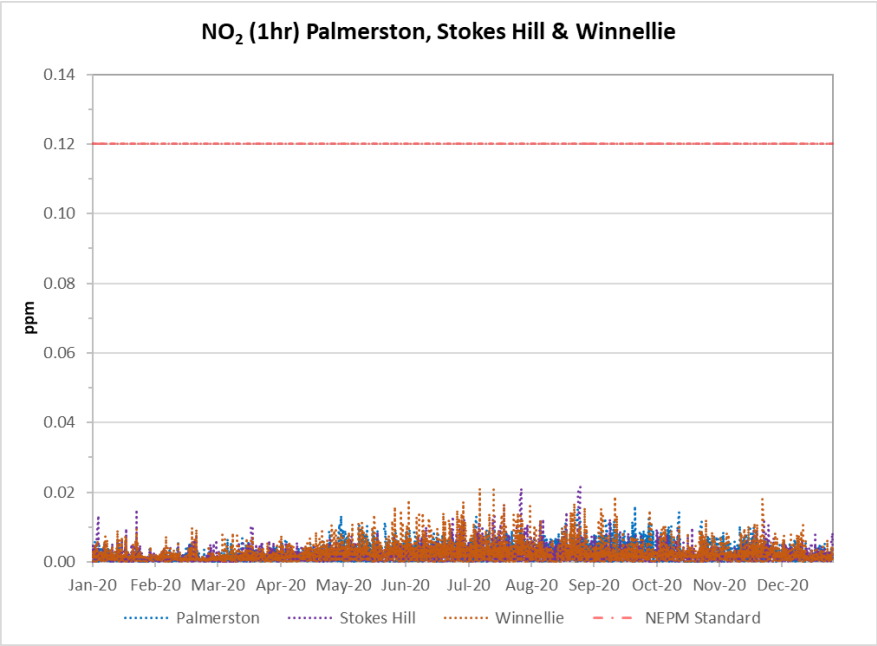

Figure 3: Nitrogen dioxide 1-hour averages 2020

In 2020, no exceedances of the nitrogen dioxide (NO_2) 1-hour and 1-year standards were recorded in the Darwin region. Compliance with the AAQ NEPM goal for NO_2 was met at all sites.

4.3 Ozone compliance

Table 7: 2020 compliance summary for O_3 in the Northern Territory

AAQ NEPM Standard

0.10 ppm (1-hour average)

0.08 ppm (4-hour average)

Region/ Performance monitoring station	Data Availability Rates (% of Days)					Number of exceedances (days)		Performance against the standard and goal	
	Q1	Q2	Q3	Q4	Annual	1h	4h	1h	4h
Palmerston	96	96	95	94	95	0	0	Met	Met
Stokes Hill	96	91	93	92	93	0	0	Met	Met
Winnellie	96	95	75	95	88	0	0	Met	Met

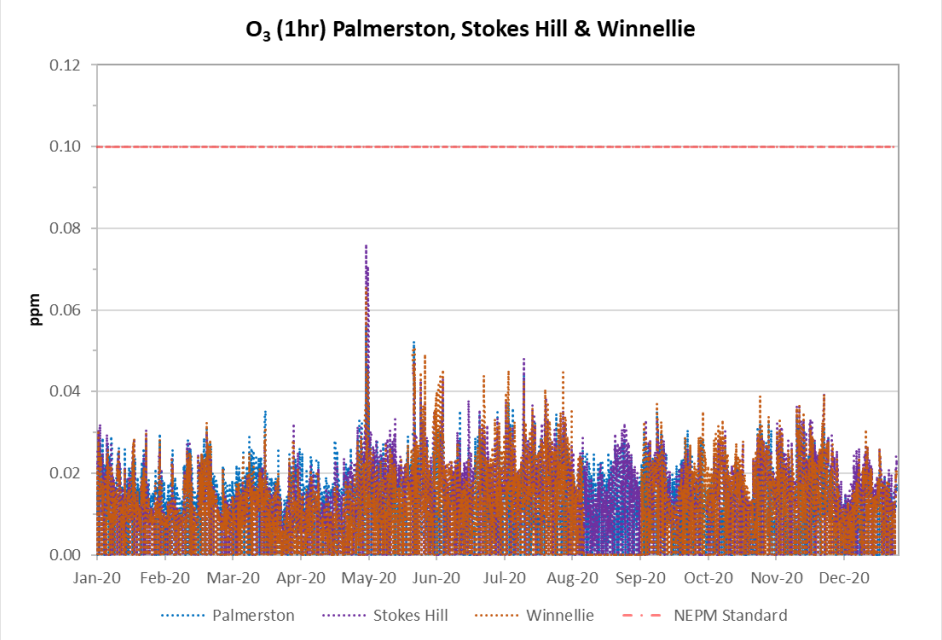

Figure 4: Ozone 1-hour averages 2020

During 2020, no exceedance of the ozone (O_3) 1-hour average standard or 4-hour rolling average standard was recorded in the Darwin region. Compliance with the AAQ NEPM O_3 goal was demonstrated at all sites.

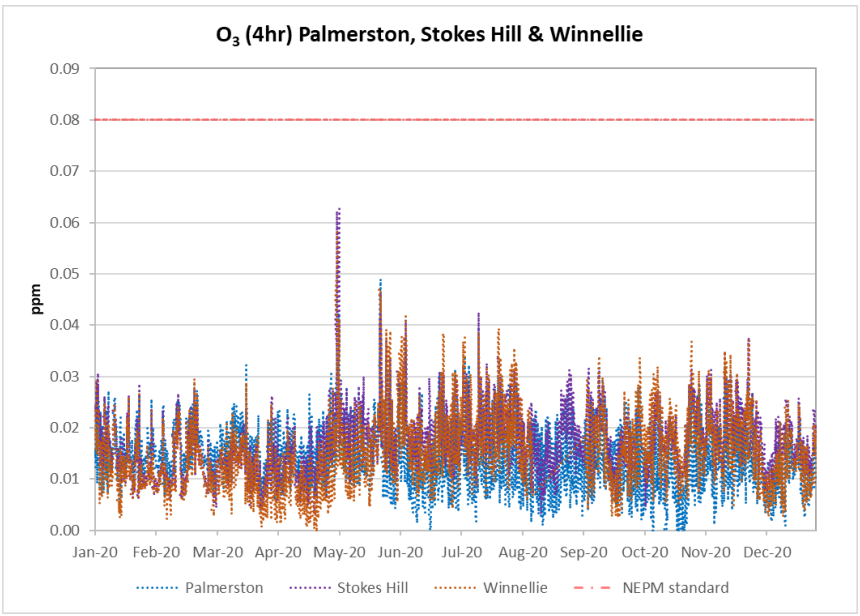

Figure 5: Ozone 4-hour averages 2020

4.4 Sulfur dioxide compliance

Table 8: 2020 compliance summary for SO_2 in the Northern Territory

Region/ Performance monitoring station	Data Availability Rates (% of Days)					Number of exceedances (days)		Annual mean (ppm)	Performance against the standard and goal		
	Q1	Q2	Q3	Q4	Annual	1h	24h		1h	24h	1y
								AAQ NEPM Standard			
								0.20 ppm (1-hour average)			
								0.08 ppm (1-day average)			
								0.02 ppm (1-year average)			
Palmerston	91	92	91	90	91	0	0	0.00048	Met	Met	Met
Stokes Hill	91	95	84	92	91	0	0	0.00052	Met	Met	Met
Winnellie	96	87	84	85	88	0	0	0.00062	Met	Met	Met

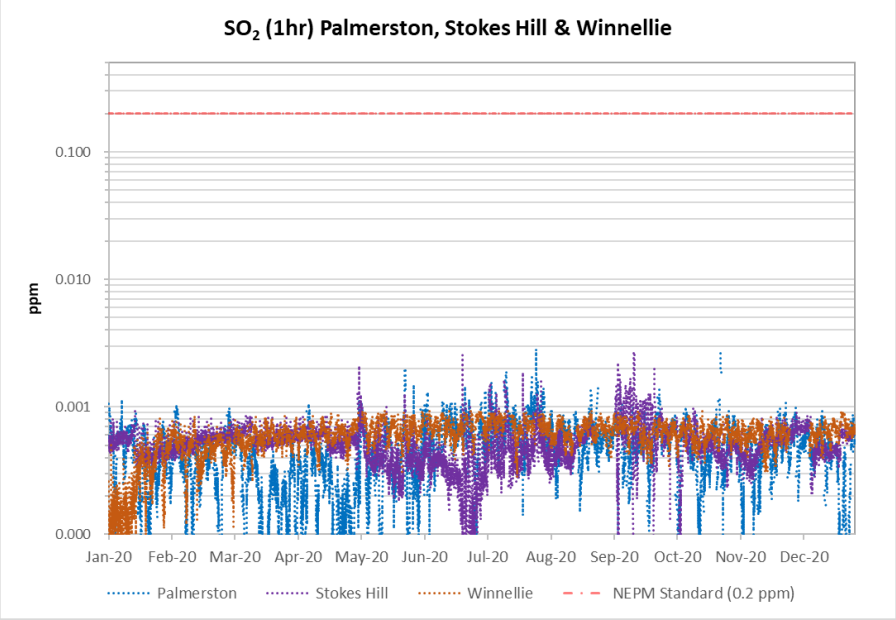

Figure 6: Sulfur dioxide 1-hour averages 2020 (concentration is on a logarithmic scale)

During 2020, no exceedances of the sulfur dioxide (SO_2) 1-hour, 1-day or 1-year standards were recorded in the Darwin region. Compliance with the AAQ NEPM goal for SO_2 was demonstrated at all sites.

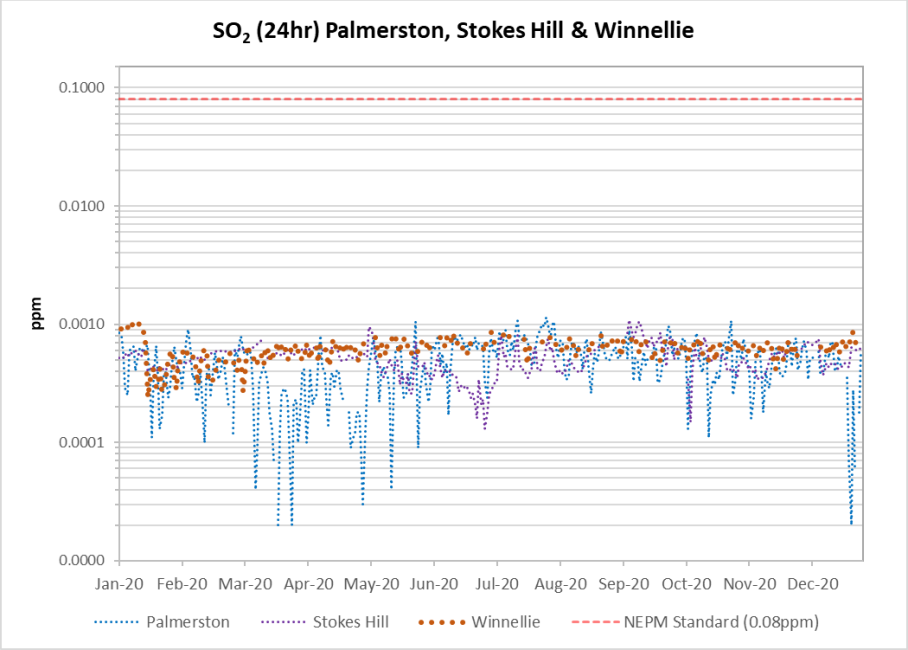

Figure 7: SO_2 1-day averages 2020 (concentration is on a logarithmic scale)

4.5 Particulates (PM_{10}) compliance

Table 9: 2020 compliance summary for PM_{10} in the Northern Territory

AAQ NEPM Standard

50 µg/m³ (1-day average)

25 µg/m³ (1-year average)

Region/ Performance monitoring station	Data Availability Rates (%)					Number of exceedances (days)	Annual average (µg/m³)	Performance against the standard and goal	
	Q1	Q2	Q3	Q4	Annual			24h	1y
Katherine									
Katherine	-	-	16	87	26	0	13.6	ND	ND
Darwin									
Palmerston	87	100	100	98	96	1	18.3	Met	Met
Stokes Hill	100	100	100	93	96	0	17.8	Met	Met

Winnellie	100	100	97	96	98	1	16.9	Met	Met

ND – Not demonstrated as insufficient data (less than 75%) was captured during one or more quarters of the year (station was commissioned in September 2020).

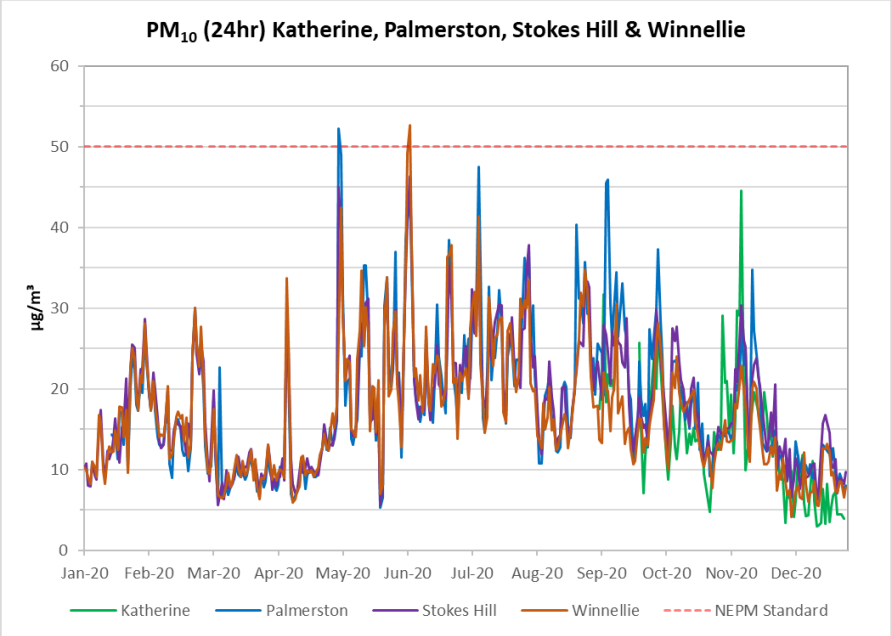

Figure 8: PM_{10} 1-day averages 2020

During 2020, only two exceedances of the PM_{10} 1-day standard were recorded, and these exceedances were attributed to exceptional events such as smoke from small-scale local bush/grass fires or more distant large-scale savannah fire activity such as hazard reduction burns. The AAQ NEPM excludes monitoring data associated with exceptional events for reporting compliance against PM_{10} and $PM_{2.5}$ 1-day average standards. In addition, since annual averages were all below the 1-year standard, compliance with the AAQ NEPM goal for PM_{10} was demonstrated at all the Darwin sites.

The amount of data collected at Katherine was not sufficient to demonstrate compliance with the AAQ NEPM; however, no exceedances of the PM_{10} standards were recorded there.

The AAQ NEPM defines an exceptional event as:

…. 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.

4.6 Particulates ($PM_{2.5}$) compliance

Table 10: 2020 compliance summary for $PM_{2.5}$ in the Northern Territory

AAQ NEPM Standard

25 µg/m³ (1-day average)

8 µg/m³ (1-year average)

Region/ Performance monitoring station	Data Availability Rates (%)					Number of exceedances (days)	Annual average µg/m³	Performance against the standard and goal	
	Q1	Q2	Q3	Q4	Annual			24h	1y
Katherine									
Katherine	-	-	16	87	26	1	7.8	ND	ND
Darwin									
Palmerston	87	100	100	98	96	7	7.0	Met	Met
Stokes Hill	100	100	100	93	96	4	6.4	Met	Met
Winnellie	100	100	97	96	98	7	6.5	Met	Met

ND – Not demonstrated as insufficient data (less than 75%) was captured during one or more quarters of the year (station was commissioned in September 2020).

Fewer exceedances of the $PM_{2.5}$ 1-day standard were recorded in 2020, than in previous years. These exceedances were all attributed to exceptional events such as smoke from small-scale local bush/grass fires or more distant large-scale savannah fire activity such as hazard reduction burns. 1-year averages were all below the AAQ standard at all the stations.

The amount of data collected at Katherine was not sufficient to demonstrate compliance with the AAQ NEPM; only one exceedance of the $PM_{2.5}$ standard was recorded, and this was attributed to an exceptional event.

With the exception of the Katherine station where compliance was not demonstrated, all the other sites complied with the AAQ NEPM goal for $PM_{2.5}$ since their annual averages did not exceed the 1-year average standard.

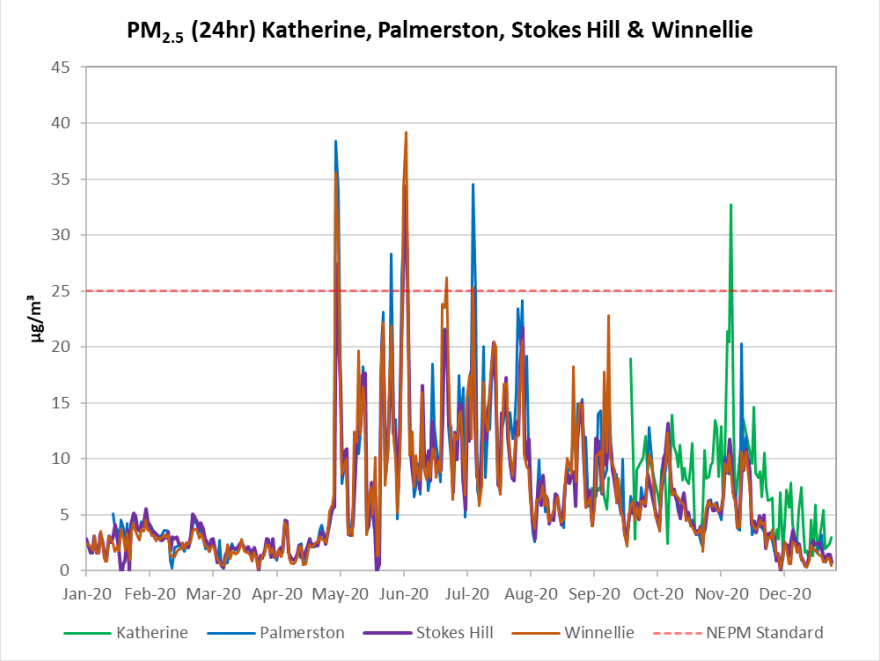

Figure 9: $PM_{2.5}$ 1-day averages 2020

5 Analysis of air quality data

Annual summary statistics for 2020 are presented in this section. The AAQ NEPM states that short-term standards should not be exceeded on more than one day for CO, NO_2, O_3 and SO_2 or on any day for PM_{10} and $PM_{2.5}$ (except when caused by exceptional events such as bushfires). Figures 2, 3, 6 & 7 in the previous section, show that levels of CO, NO_2 and particularly SO_2 were significantly below the AAQ NEPM standards, and there were no exceedances recorded.

In this section, data availability is presented as the number of valid days; this value represents the number of days during the year when at least 75% of averaging periods during the day had valid data.

There must be a minimum of 75% data availability in any averaging period for the data to be reported against the corresponding AAQ NEPM standard. For example, the 4-hour ozone AAQ NEPM standard is based on four-hour rolling averages. A valid 4-hour rolling average is calculated as the average of the valid one-hour averages over the preceding 4 hours - when at least three of those hours (75%) had valid data. In the case of the carbon monoxide 8-hour rolling average, the minimum number of valid hours required for averaging is six.

5.1 Carbon monoxide statistics

Table 11: 2020 summary statistics for daily peak 8 hour CO

AAQ NEPM Standard

9.0 ppm (8-hour average)

Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date/hour)	2nd highest (ppm)	2nd Highest (date/hour)
Palmerston	244	0.75	3 May 02:00	0.57	5 Mar 01:00
Stokes Hill	242	0.89	10 Sep 09:00	0.68	11 Mar 12:00
Winnellie	306	0.91	10 Sep 09:00	0.85	8 Jul 07:00

CO levels at all the stations were substantially below the CO 8-hour rolling average standard during the year. The highest event, recorded at Winnellie (0.91 ppm, 9am on 10 September 2020) was about 10% of the AAQ NEPM standard.

5.2 Nitrogen dioxide statistics

Table 12: 2020 summary statistics for daily peak 1 hour NO_2 in the Northern Territory

AAQ NEPM Standard

0.12 ppm (1-hour average)

Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date/hour)	2nd highest (ppm)	2nd Highest (date/hour)
Palmerston	350	0.016	25 Sep 08:00	0.015	28 Aug 00:00
Stokes Hill	352	0.022	28 Aug 22:00	0.021	30 Jul 22:00
Winnellie	357	0.021	10 Jul 08:00	0.021	17 Jul 08:00

NO_2 levels were below the AAQ NEPM 1-hour NO_2 standard of 0.12 ppm. The highest recorded reading (0.022 ppm) was recorded at Stokes Hill at 10pm on 28 August 2020, and was only slightly higher than the highest peak recorded at Winnellie.

5.3 Ozone statistics

Table 13: 2020 summary statistics for daily peak 1 hour O_3 in the Northern Territory

AAQ NEPM Standard

0.10 ppm (1-hour average)

Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date/hour)	2nd highest (ppm)	2nd Highest (date/hour)
Palmerston	363	0.056	2 May 18:00	0.052	24 May 16:00
Stokes Hill	354	0.076	2 May 18:00	0.071	3 May 16:00
Winnellie	332	0.065	2 May 19:00	0.051	24 May 22:00

There were no exceedances of the 1-hour or 4-hour O_3 standards at any of the monitoring sites. The highest peak of 0.076 ppm and second highest peak 0.071 ppm were both recorded at Stokes Hill on 2nd and 3rd May respectively. Other stations also recorded high ozone levels on these days and on 24 May 2020. These event days were characterised by high daily maximum temperatures (27 - 35 °C), low wind speeds (2 - 4 m/s) and high solar radiation (~900 W/m^2, maximum). The stations also recorded high particulate levels from bushfire smoke on those days.

Table 14: 2020 summary statistics for daily peak 4 hour O_3 in the Northern Territory

AAQ NEPM Standard

0.08 ppm (4-hour average)

Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date/hour)	2nd highest (ppm)	2nd Highest (date/hour)
Palmerston	363	0.049	24 May 19:00	0.045	2 May 21:00
Stokes Hill	354	0.063	3 May 20:00	0.062	2 May 21:00
Winnellie	332	0.059	2 May 22:00	0.047	25 May 01:00

5.4 Sulfur dioxide statistics

SO_2 levels in the Darwin region were substantially below the AAQ NEPM 1-hour and 1-day SO_2 standards. The highest recorded 1-hour reading was at Palmerston (0.0028 ppm) at 6pm on 28 July. The highest daily average SO_2 concentration was also recorded at Palmerston (0.0012 ppm) on 29 July 2020.

Table 15: 2020 summary statistics for daily peak 1 hour SO_2 in the Northern Territory

AAQ NEPM Standard

0.20 ppm (1-hour average)

Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date/hour)	2nd highest (ppm)	2nd Highest (date/hour)
Palmerston	363	0.0028	28 Jul 18:00	0.0026	27 Oct 03:00
Stokes Hill	347	0.0027	14 Sep 16:00	0.0026	22 Jun 15:00
Winnellie	327	0.0009	3 May 09:00	0.0009	15 May 07:00

Table 16: 2020 summary statistics for 24 hour SO_2 in the Northern Territory

	AAQ NEPM Standard
	0.08 ppm (1-day average)

Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date)	2nd highest (ppm)	2nd Highest (date)
Palmerston	364	0.0012	29 Jul	0.0011	15 Jul
Stokes Hill	348	0.0011	8 Sep	0.0011	13 Sep
Winnellie	327	0.0010	8 Jan	0.0010	11 Jan

5.5 Particulates statistics

The highest PM_{10} event (52.7 μg/m^3) in Darwin was recorded at Winnellie on 5 June 2020 (Table 17); the other Darwin stations recorded high PM_{10} levels on this day, but did not exceed the 24-hour AAQ NEPM. The next highest PM_{10} level was recorded at Palmerston (52.3 μg/m^3) on 2 May 2020. Katherine AQMS had not been commissioned during those months. The plume responsible for the highest PM_{10} event had elevated levels of $PM_{2.5}$, but very low levels of other combustion products such as carbon monoxide or oxides of nitrogen. This suggests a dust plume, which was wide spread over the Greater Darwin Region; however, there is no evidence that a dust storm occurred in Darwin on that day. The second highest PM_{10} event recorded at the stations had plumes associated with smoke events and contained substantial levels of $PM_{2.5}$ (see also Appendix A: Particulates Events for 2020). Although these PM_{10} levels exceeded the AAQ standard, they are considered as exceptional events since they are associated with natural events such as smoke from bushfires.

The highest $PM_{2.5}$ concentration (39.2 μg/m^3) was recorded at Winnellie on 5 June 2020, and the next highest (38.4 μg/m^3) was recorded at Palmerston on 2 May; these and the other high peaks shown in Table 18 all exceeded the AAQ NEPM standard. These exceedances and others were due to bushfire activity, which the AAQ NEPM classifies as exceptional events. High fine particle levels are typical of the Darwin airshed during the Dry season.

Since all exceedances of particulate standards were attributed to exceptional events, particulate levels complied with the AAQ NEPM 1-day standards for particulates.

Table 17: 2020 summary statistics for 24 hour PM_{10} in the Northern Territory

AAQ NEPM Standard

50 µg/m^3 (1-day average)

Region/Performance monitoring station	Number of valid days	Highest (µg/m^3)	Highest (date)	2nd highest (µg/m^3)	2nd Highest (date)
Katherine	95	44.6	11 Nov	31.7	6 Sep
Palmerston	352	52.3	2 May	48.9	3 May
Stokes Hill	359	46.3	5 Jun	44.9	2 May
Winnellie	359	52.7	5 Jun	49.2	4 Jun

Table 18: 2020 summary statistics for 24 hour $PM_{2.5}$ in the Northern Territory

AAQ NEPM Standard

25 µg/m^3 (1-day average)

Region/Performance monitoring station	Number of valid days	Highest (µg/m^3)	Highest (date)	2nd highest (µg/m^3)	2nd Highest (date)
Katherine	95	32.7	11 Nov	21.4	9 Nov
Palmerston	352	38.4	2 May	34.5	8 Jul
Stokes Hill	360	34.3	5 Jun	28.9	4 Jun
Winnellie	359	39.2	5 Jun	35.6	2 May

6 Analysis of exceedances and population exposure

This section will analyse exceedance events that occurred during 2020, and were recorded at the ambient air quality monitoring stations.

6.1 Particulates exceedances

Particulates generated by vegetation burning are the primary air pollutants in the Darwin region. This results in significant variation in air quality between the Dry (May-October) and the Wet (November-April). In general, air quality was excellent during the Wet, but poor during the Dry of 2020. Averaged daily levels of $PM_{2.5}$ across all the Darwin stations over the six months of the Dry was 10 $\mu g/m^3$; compared to 3 $\mu g/m^3$ during the Wet. The elevated $PM_{2.5}$ levels during the Dry are unavoidable and people with respiratory or cardiopulmonary issues may be impacted. $PM_{2.5}$ annual average concentration across all Darwin stations for 2020 was 7 $\mu g/m^3$, which is less than the AAQ NEPM standard of 8 $\mu g/m^3$. The $PM_{2.5}$ annual average across all Darwin stations for 2019 was 9 $\mu g/m^3$.

The 1-day standard for $PM_{2.5}$ had multiple exceedances in 2020 (Figure 9). There were 7 exceedances of the 1-day standard at Palmerston station, but the annual limit was not exceeded. Winnellie station also recorded 7 exceedances of the 1-day standard and did not exceed the annual limit. Stokes Hill station Winnellie recorded only 4 exceedances of the 1-day standard and likewise did not exceed the annual limit. Only one exceedance was recorded at Katherine. During the period of 3 June to 6 June 2020, each of the Darwin stations recorded three consecutive days when the $PM_{2.5}$ 1-day standard was exceeded (see Appendix A: Particulates events for 2020).

The AAQ NEPM 1-day standard for PM_{10} was exceeded on only 2 days: Palmerston recorded one day of exceedance; and Winnellie recoded another day of exceedance; no exceedance was recorded at Stokes Hill and the annual PM_{10} limit was not exceeded at any of the stations. As explained in previous sections of this report, since the $PM_{2.5}$ and PM_{10} exceedances were caused by natural events such as bushfire activity, they are considered exceptional events under the AAQ NEPM.

Tables 19 - 24 show dates and inferred causes of particulate exceedances for all stations.

Table 19: 2020 PM_{10} exceedances of 24-hour AAQ NEPM standard at Palmerston

Date	PM_{10} ($\mu g/m^3$)	Inferred Cause
2-May	52.3	smoke

Table 20: 2020 PM_{10} exceedances of 24-hour AAQ NEPM standard at Winnellie

Date	PM_{10} ($\mu g/m^3$)	Inferred Cause
5-Jun	52.7	smoke

Table 21: 2020 $PM_{2.5}$ exceedances of 24-hour AAQ NEPM standard at Katherine

Date	PM_{10} ($\mu g/m^3$)	Inferred Cause
11-Nov	32.7	smoke

Table 22: 2020 $PM_{2.5}$ exceedances of 24-hour AAQ NEPM reporting level at Palmerston

Date	$PM_{2.5}$ ($\mu g/m^3$)	Inferred Cause
2-May	38.4	smoke
3-May	34.0	smoke
29-May	28.3	smoke
3-Jun	26.4	smoke
4-Jun	30.0	smoke
5-Jun	33.4	smoke
8-Jul	34.5	smoke

Table 23: 2020 $PM_{2.5}$ exceedances of 24-hour AAQ NEPM reporting level at Stokes Hill

Date	$PM_{2.5}$ ($\mu g/m^3$)	Inferred Cause
2-May	27.4	smoke
4-Jun	28.9	smoke
5-Jun	34.3	smoke
6-Jun	26.3	smoke

Table 24: 2020 $PM_{2.5}$ exceedances of 24-hour AAQ NEPM reporting level at Winnellie

Date	$PM_{2.5}$ (µg/m^3)	Inferred Cause
2-May	35.6	smoke
3-May	29.0	smoke
4-Jun	34.3	smoke
5-Jun	39.2	smoke
6-Jun	25.3	smoke
25-Jun	26.2	smoke
8-Jul	25.3	smoke

Smoke from burning vegetation contains PM_{10} and $PM_{2.5}$, Figures 10 - 12 show the close relationship between these parameters at all stations during the Dry Season.

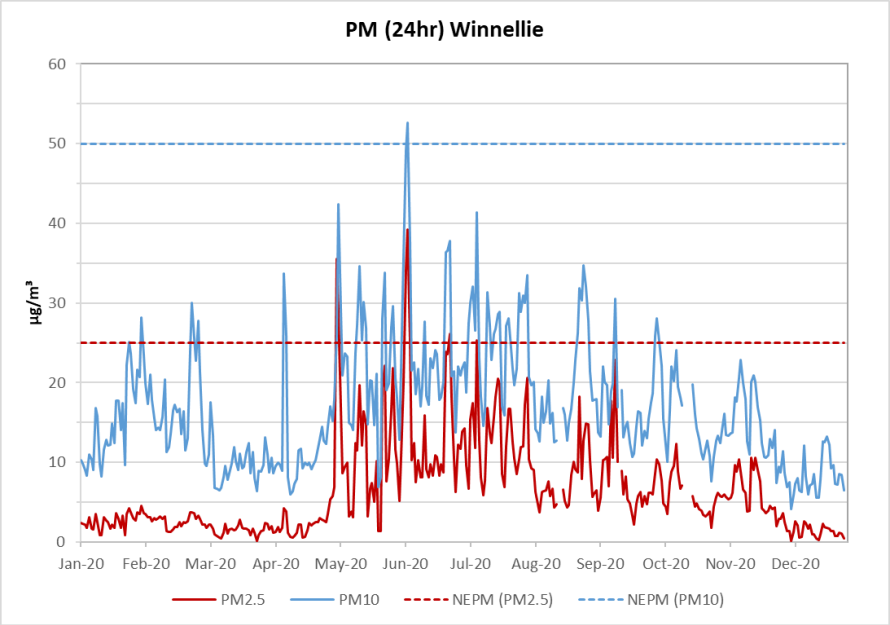

Figure 10: Particulates concentration at Winnellie AQMS 2020

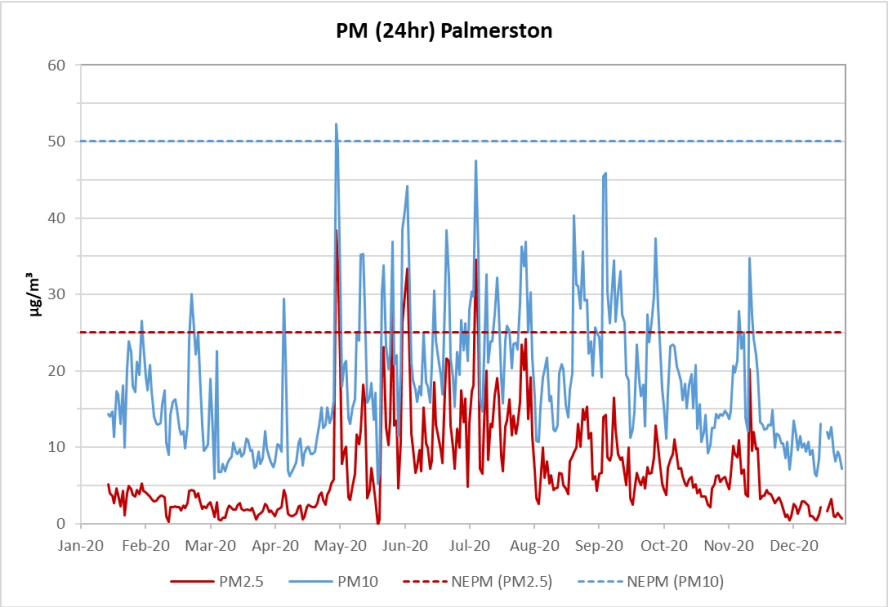

Figure 11: Particulates concentration at Palmerston AQMS 2020

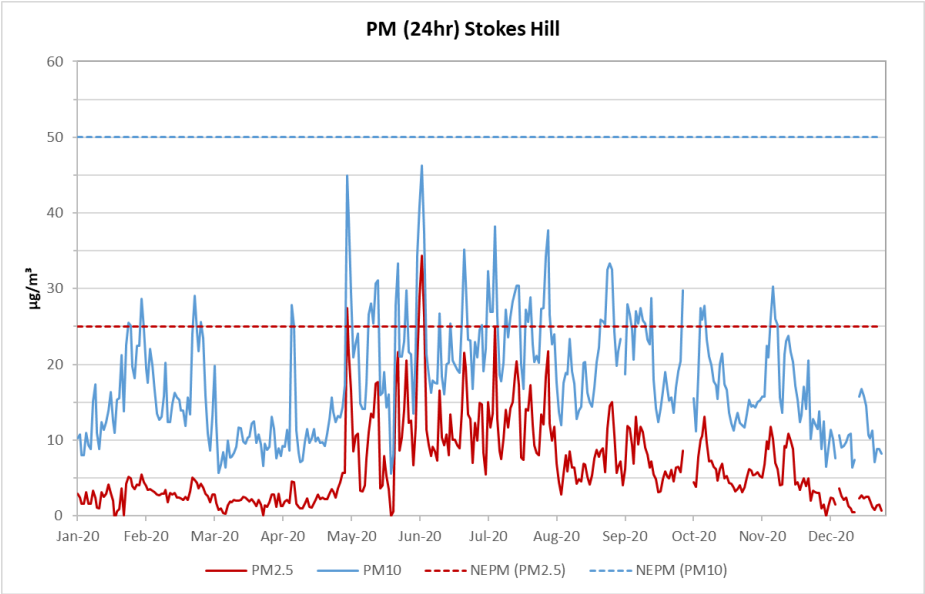

Figure 12: Particulates concentration at Stokes Hill AQMS 2020

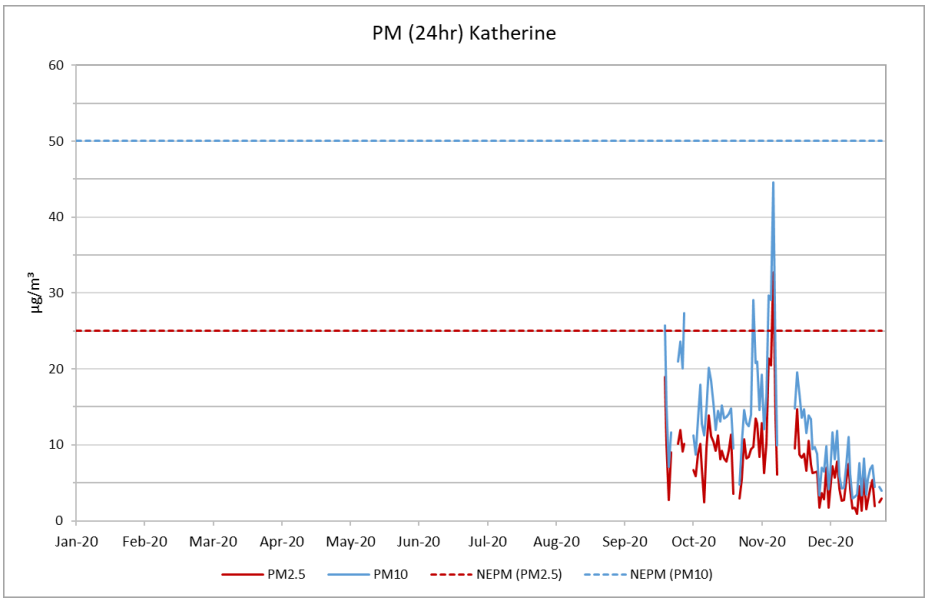

Figure 13: Particulates concentration at Katherine AQMS 2020

6.2 Population exposure to $PM_{2.5}$

It is a requirement of the AAQ NEPM as amended in 2016, for participating jurisdictions to evaluate and report population exposure to particles as $PM_{2.5}$ annually from June 2018.

A simplified approach (EWG 2017) which outputs a single value was used to determine the population-weighted annual average $PM_{2.5}$ concentration for the Greater Darwin Region.

Statistical Area Level 2 (SA2) areas in the Greater Darwin Region and their respective populations were identified from the Australian Bureau of Statistics (ABS) Population Data for 2016 (ABS 2016). SA2 is an area defined in the Australian Statistical Geography Standard and is usually based on officially gazetted State/Territory suburbs and localities.

An annual average $PM_{2.5}$ concentration was calculated for each of the three air quality monitoring stations: Stokes Hill, Winnellie and Palmerston, using available 1-hour average data. These values were assigned to each of the identified SA2 areas based on their proximity to the nearest station. It was assumed that people living in the SA2 areas of Darwin City, Fannie Bay - The Gardens, Larrakeyah and Stuart Park would be exposed to $PM_{2.5}$ levels represented by concentrations measured at Stokes Hill AQMS; all other Darwin SA2 areas would be exposed to $PM_{2.5}$ levels measured at Winnellie AQMS; and people living in SA2 areas in Palmerston would be exposed to $PM_{2.5}$ levels measured at Palmerston AQMS.

The population-weighted annual average $PM_{2.5}$ concentration was calculated by multiplying the annual average $PM_{2.5}$ concentration for each SA2 with the corresponding population of the SA2; then summing the products calculated for each SA2, and dividing by the total population across all identified SA2s.

The 2020 population-weighted annual average $PM_{2.5}$ concentration for the Greater Darwin Region was estimated to be 6.7 $\mu g/m^3$. (See Appendix B for details of the calculations.)

7 Data analysis and trends

Tables 25 to 28 in this section compare the number of particulates exceedances in the NT over a longer period in accordance with AAQ NEPM technical requirements. This comparison is of limited utility in providing an accurate indication of particulate trends as different sampling techniques have been used since monitoring began in 2002; also TEOM and Partisol instruments have not been located consistently throughout the sampling period. The Partisol dichotomous sampler which measured both PM_{10} and $PM_{2.5}$ was normally operating at Charles Darwin University in Casuarina and was collocated with a TEOM which measured PM_{10}.

7.1 Trends in historical particulate data

Issues with historical data include:

- 2004 - Data collection for this year did not commence until the second quarter.
- 2004 & 2005 - TEOM was located in Palmerston at the Charles Darwin University Palmerston campus.
- 2006 - TEOM data availability was below 75% for each quarter so Partisol data was used.
- 2009 – Dust produced from local construction activity in close proximity to the station required that exceedances for a period over the Dry be removed as they were not necessarily representative of air quality in the larger air shed.
- 2010 - There was significant downtime with the Partisol and TEOM instruments.
- 2011 – Validated data available from Palmerston AQMS from 1 January (PM_{10} & $PM_{2.5}$ now measured with a dichotomous TEOM).
- 2012 – Winnellie AQMS started operating on 18 July (PM_{10} & $PM_{2.5}$ measured with a dichotomous TEOM).
- 2016 - Data has not been analysed.
- 2017 - Stokes Hill AQMS started operating in May; TEOM data was only available from July.
- 2020 – Katherine AQMS started operating in September.

During the Wet of 2013, the Palmerston TEOM was offline for a number of months resulting in inadequate data collection for NEPC reporting. As the TEOM was operational for most of the Dry, when particulates are an issue, 2013 data from Palmerston is still useful when considering longer term trends in particulates.

Table 25: Casuarina 24-hour PM_{10} & $PM_{2.5}$ Trends (2004 -2010)

Year	*PM_{10}			**$PM_{2.5}$		
	Data Availability (%)	Number of Exceedances	Max Concentration ($\mu g/m^3$)	Data Availability (%)	Number of Exceedances	Max Concentration ($\mu g/m^3$)
2004	*69*	*1*	*54*	60	5	37
2005	98	2	63	98	5	58
2006	97	0	44	97	5	30
2007	95	0	45	-	-	-
2008	97	1	65	72	2	32
2009	90	0	50	87	1	26
2010	78	1	54	62	2	30

*TEOM data (but Partisol dichotomous PM_{10} data used for 2006)
**$PM_{2.5}$ data from Partisol dichotomous Sampler

Table 26: 24-hour PM_{10} Trends (2011-2020)

Year	Palmerston			Winnellie			Stokes Hill			Katherine		
	Data Availability (%)	Number of Exceedances	Max Concentration ($\mu g/m^3$)	Data Availability (%)	Number of Exceedances	Max Concentration ($\mu g/m^3$)	Data Availability (%)	Number of Exceedances	Max Concentration ($\mu g/m^3$)	Data Availability (%)	Number of Exceedances	Max Concentration ($\mu g/m^3$)
2011	96	3	92	-	-	-	-	-	-	-	-	-
2012	91	23	70	-	-	-	-	-	-	-	-	-
2013	49	1	72	76	3	58	-	-	-	-	-	-
2014	82	2	52	86	3	73	-	-	-	-	-	-
2015	94	3	61	99	5	107	-	-	-	-	-	-
2017	96	7	59	84	2	54	49	0	48	-	-	-
2018	97	5	143	92	5	78	89	6	64	-	-	-
2019	99	10	85	94	15	85	99	11	95	-	-	-
2020	96	1	52	98	1	53	98	0	46	26	0	45

Table 27: 24-hour $PM_{2.5}$ Trends (2011-2020)

Year	Palmerston			Winnellie			Stokes Hill			Katherine		
	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m³)	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m³)	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m³)	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m³)
2011	2696	15	77	-	-	-	-	-	-	-	-	-
2012	91	23	44	-	-	-	-	-	-	-	-	-
2013	49	6	56	76	5	34	-	-	-	-	-	-
2014	82	12	37	86	9	45	-	-	-	-	-	-
2015	94	7	40	99	10	78	-	-	-	-	-	-
2017	96	10	42	84	6	41	49	1	28	-	-	-
2018	97	15	112	92	19	57	89	13	44	-	-	-
2019	99	21	63	94	17	49	99	20	43	-	-	-
2020	96	7	38	98	7	39	96	4	34	26	1	33

Table 28: Averaged Particulates Key Metrics 2004-2020 (across all historic & current monitoring locations)

	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m³)
PM_{10}	86	4	67
$PM_{2.5}$	84	9	46

Trend data for the 2004 to 2020 period is presented in Figures 14 to 19. This data shows that there is no clear trend in $PM_{2.5}$ or PM_{10} in the Darwin region over the period. There was a large drop in the number of exceedances and the maximum concentrations recorded at all the stations in 2020. Population of the greater Darwin region has increased from approximately 105,000 in 2004 to ~140,000 in 2020 showing a clear upward trend in population. The lack of a relationship between population and particulate levels further demonstrates that the majority of particulate matter in the Darwin airshed derives from natural sources.

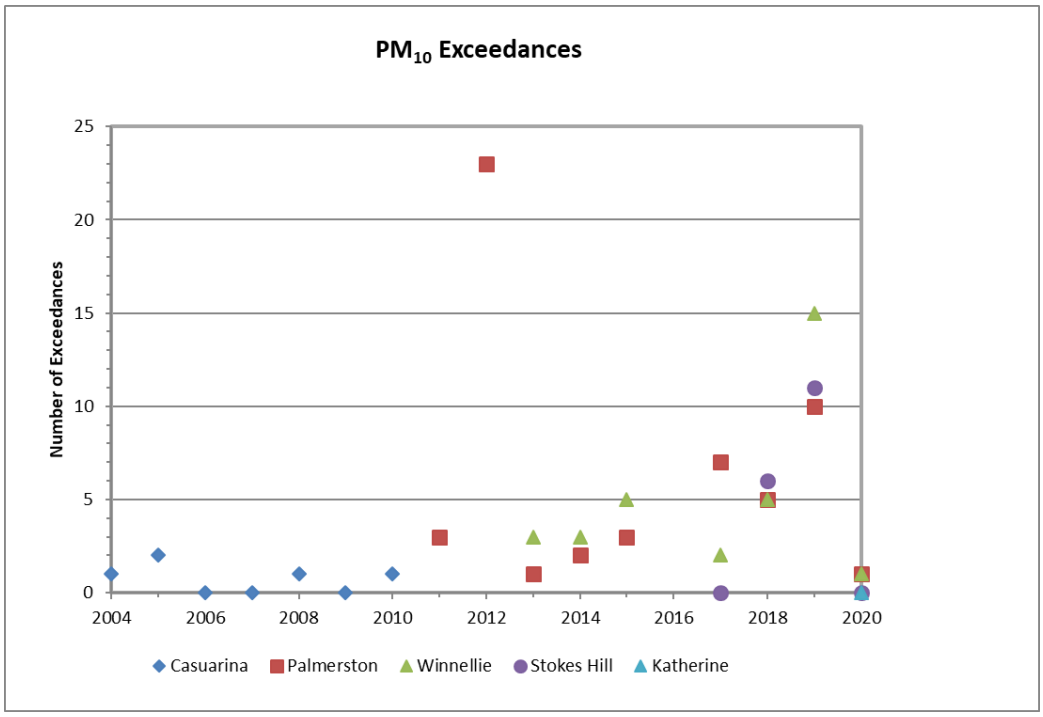

Figure 14: Historical PM_{10} exceedances of 24-hour AAQ NEPM

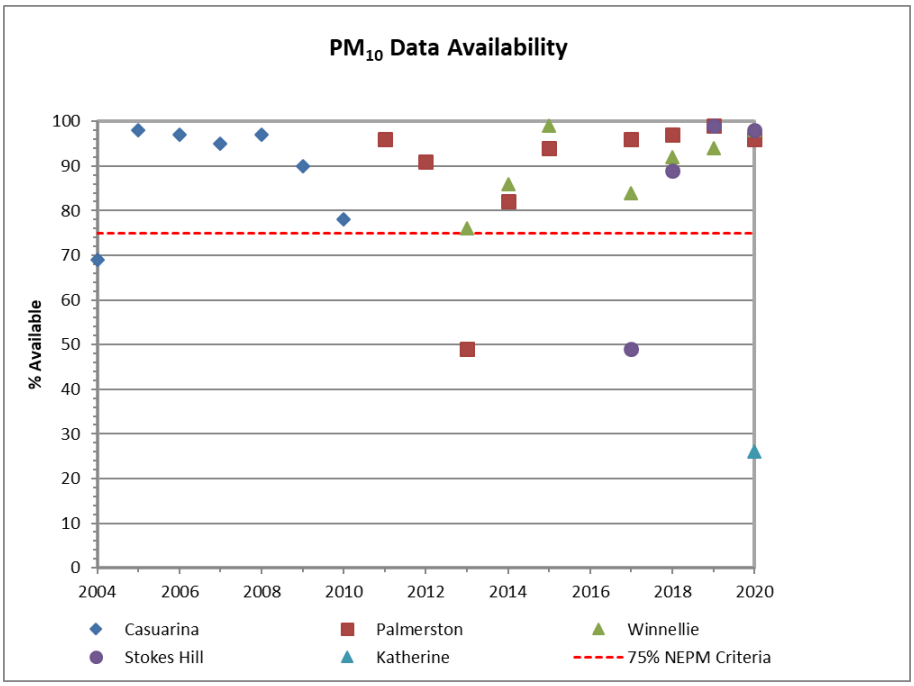

Figure 15: Historical PM_{10} data availability

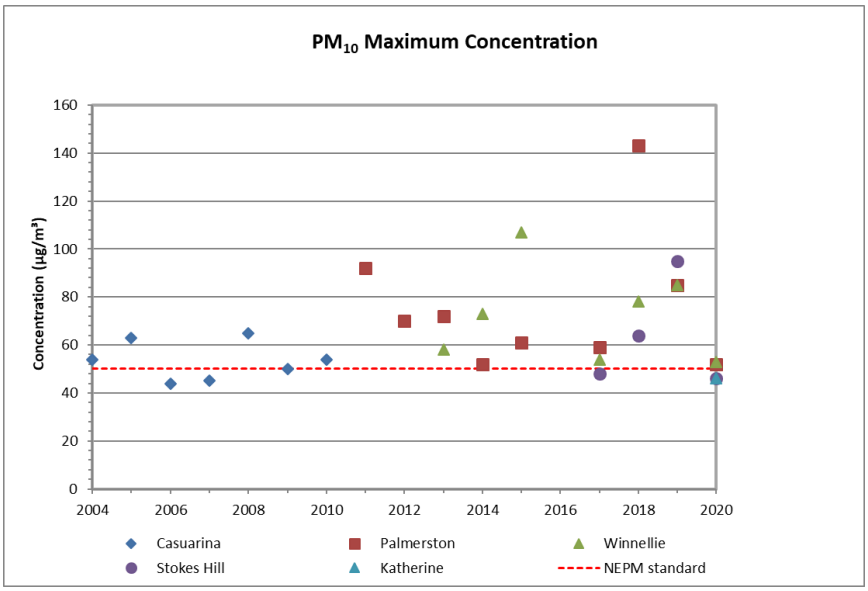

Figure 16: Historical maximum 24-hour PM_{10} concentrations

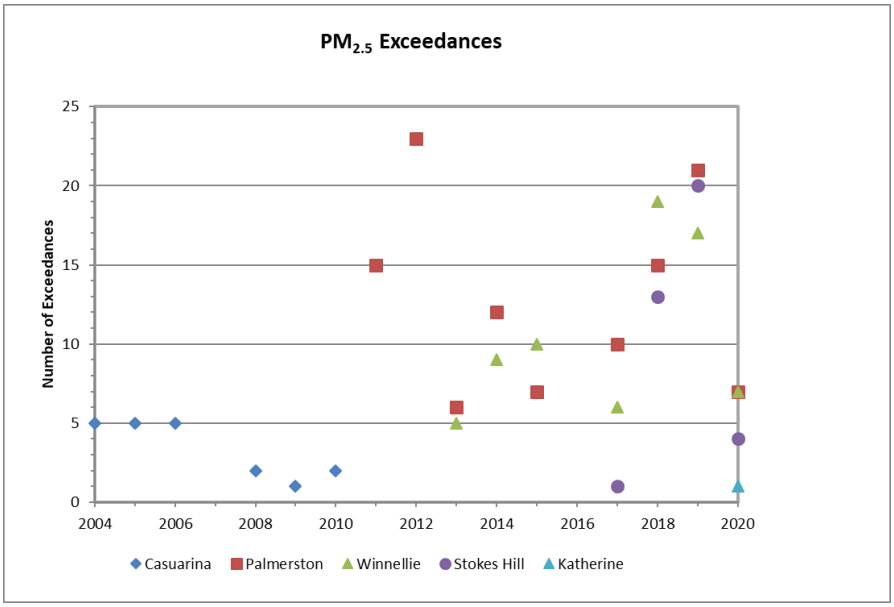

Figure 17: Historical $PM_{2.5}$ exceedances of 24 hour AAQ NEPM

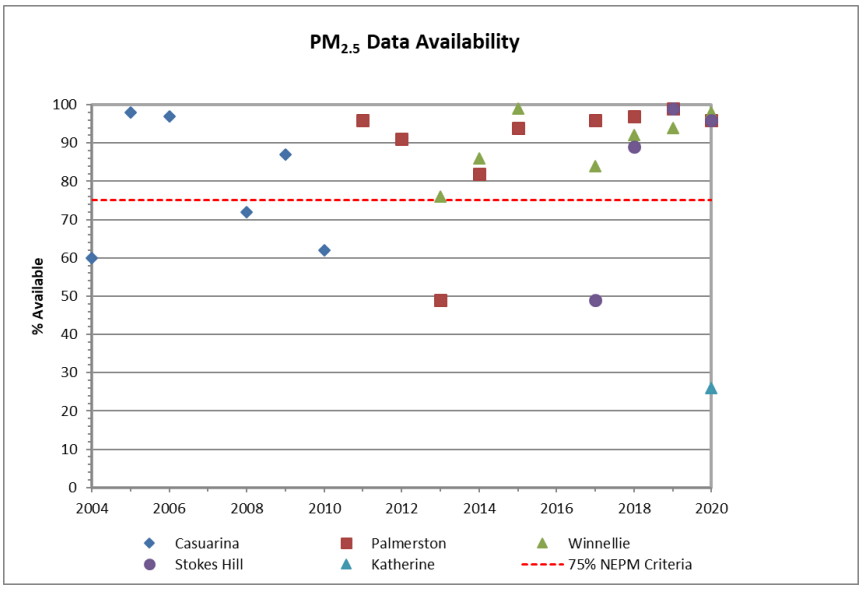

Figure 18: Historical $PM_{2.5}$ data availability

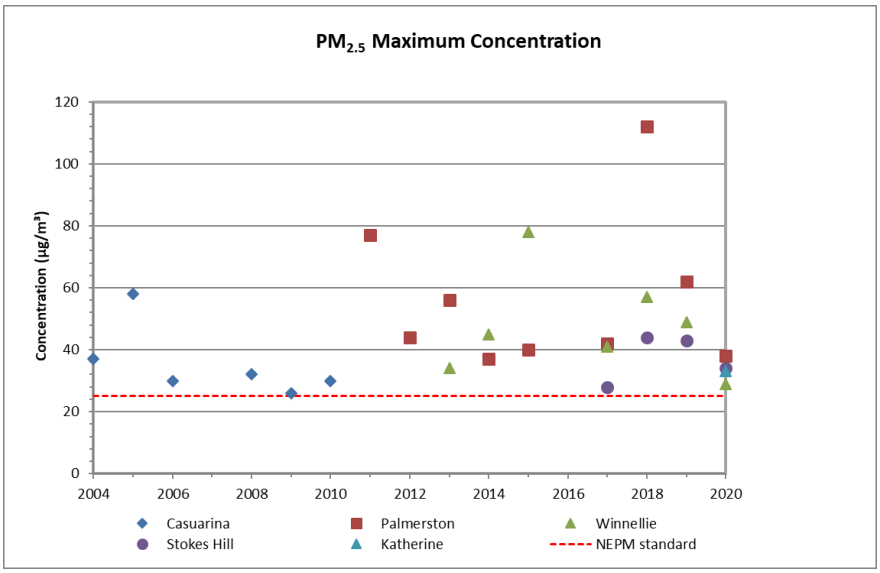

Figure 19: Historical $PM_{2.5}$ 24-hour maximum concentrations

7.2 Trends in fire-scar data

In the Darwin region, exceedances of the particulate standards are generally caused by smoke from burning vegetation. This connection has been made based on analysis of monitoring data, satellite imagery and observation of visible smoke on days when particulate standards have been exceeded.

Fire-scar data (NAFI 2021) provides information on areas burnt in Northern Australia. Fire-scar data obtained for a region with a radius of 50km (~800,000 ha), centred at McMinns Lagoon (southeast of Darwin) showed that a total of 38.5% of the area was burnt in 2020. A relationship was observed between the monthly area burnt and the monthly averaged $PM_{2.5}$ concentrations measured at the stations. Figure 20 shows that the monthly $PM_{2.5}$ concentrations increased sharply with area burnt in May. Although $PM_{2.5}$ levels peaked in June - July at all the stations (13 -15 µg/m^3), and the area burnt peaked in July (16%), there was a general decline in both parameters after July.

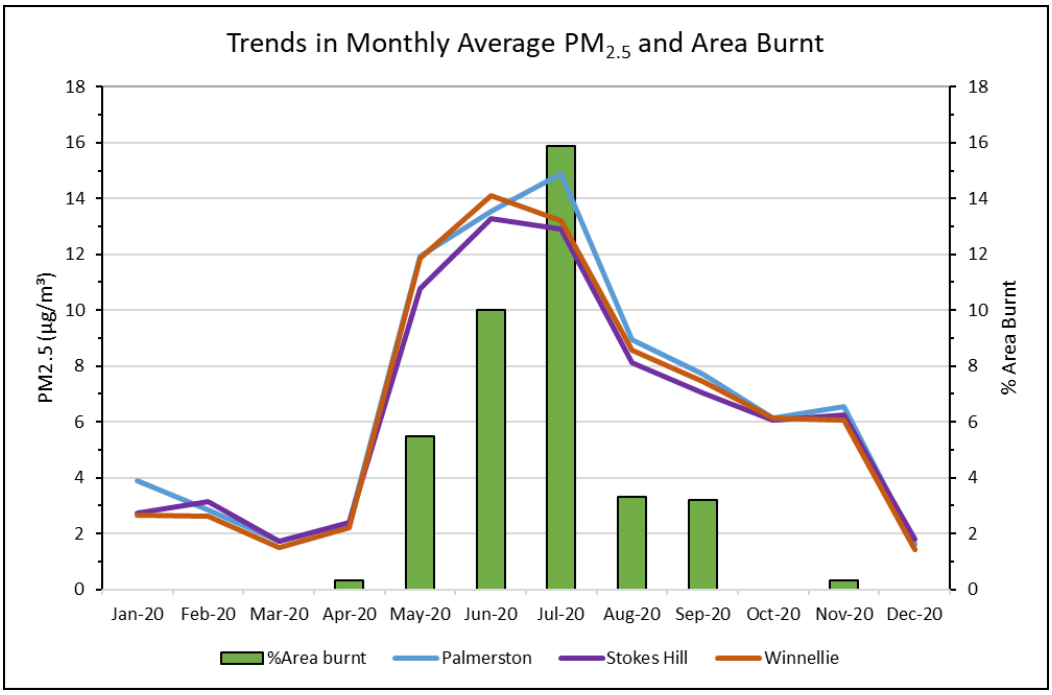

Figure 20: Comparison of $PM_{2.5}$ levels with Area Burnt (50 km radius from McMinns Lagoon)

Historical fire-scar data does not depict a clear long-term relationship between area burnt and particulate levels at the monitoring stations. The total area burnt is not the only key driver of particulate impacts on Darwin, other factors such as the timing of burns in relation to meteorological conditions such as wind-speed/direction and temperature inversions play a significant part in total particulate impacts on population centres.

Analysis of historical fire activity data and particulate monitoring shows that fires greater than 150 km from Darwin are rarely linked to exceedances of the 1-day average AAQ NEPM standards for particulate in the Darwin Region. However, the picture in Figure 21 shows that smoke from fires burning in areas to the east of Pine Creek, 150 - 300 km from Darwin, on 4 June 2020, could have affected air quality in the Darwin region. On that day and the following two days, all the air quality monitoring stations in Darwin recorded $PM_{2.5}$ levels at or above the AAQ NEPM standard (see Appendix A).

Figure 21: Large-scale fire events impacting the Top End on 4 June 2020 (Source: NASA Worldview)

These fires are due to controlled burns, unintended fires or arson. Controlled burns present some opportunity for managing particulates. Unintended fires can be reduced by pre-emptively burning areas with high fuel loads during favourable meteorological condition which will result in smoke being directed away from population centres.

Extending the monitoring of particulates to other regional centres in the NT will contribute towards development of NT Government air quality policy and may provide the basis for the development of management strategies aimed at reducing the impact of particulates on urban populations in the future. Various projects have been proposed to utilise citizen science based low cost sensors to measure particles in air at remote areas of the Territory.

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Appendix A: Particulates events for 2020

A pollution event for particulates occurs when the daily average concentration measured at any of the air quality monitoring stations exceeds any of the AAQ NEPM standards for particulates – 25 µg/m³ for $PM_{2.5}$ and 50 µg/m³ for PM_{10}. (**Red** – $PM_{2.5}$ exceedances; **Blue** – PM_{10} exceedances)

	Particulates Concentration (µg/m³)							
	Katherine		Palmerston		Stokes Hill		Winnellie	
Date	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10
2-May	n/a	n/a	38.4	52.3	27.4	44.9	35.6	26.0
3-May	n/a	n/a	34.0	48.9	21.6	39.4	29.0	42.5
29-May	n/a	n/a	28.3	36.9	20.5	29.8	21.9	29.6
3-Jun	n/a	n/a	26.4	38.5	20.3	34.4	20.0	35.7
4-Jun	n/a	n/a	30.0	41.0	28.9	41.0	34.3	49.2
5-Jun	n/a	n/a	33.4	44.1	34.3	46.3	39.2	52.7
6-Jun	n/a	n/a	25.0	35.1	26.3	37.3	25.3	37.7
25-Jun	n/a	n/a	21.3	32.1	19.6	30.9	26.2	37.8
8-Jul	n/a	n/a	34.5	47.5	24.9	38.2	25.3	41.4
11-Nov	32.7	44.6	11.0	27.8	10.1	30.3	8.9	22.9
Exceedances	**1**	**0**	**7**	**1**	**4**	**0**	**7**	**1**

Appendix B: Population-weighted $PM_{2.5}$ exposure

A simplified approach was used to calculate a single population-weighted annual average $PM_{2.5}$ concentration for the Greater Darwin Region

SA2 CODE[1]	SA2_NAME_2016	Population[2] (P_i)	$PM_{2.5}$ ($\mu g/m^3$) (C_i)	$C_i \times P_i$
71001	Darwin Airport	18	6.5	117
71002	Darwin City	6464	6.4	41369.6
71003	East Point	14	6.5	91
71004	Fannie Bay - The Gardens	3351	6.4	21446.4
71005	Larrakeyah	3729	6.4	23865.6
71006	Ludmilla - The Narrows	2545	6.5	16542.5
71007	Parap	2747	6.5	17855.5
71008	Stuart Park	4149	6.4	26553.6
71009	Woolner - Bayview - Winnellie	2821	6.5	18336.5
71010	Alawa	2127	6.5	13825.5
71011	Anula	2369	6.5	15398.5
71012	Berrimah	1277	6.5	8300.5
71013	Brinkin - Nakara	3581	6.5	23276.5
71014	*Buffalo Creek	0	6.5	0
71015	Charles Darwin	0	6.5	0
71016	Coconut Grove	3050	6.5	19825
71017	East Arm	13	6.5	84.5
71018	Jingili	1757	6.5	11420.5
71019	Karama	4944	6.5	32136
71020	Leanyer	4578	6.5	29757
71021	Lyons (NT)	4799	6.5	31193.5
71022	Malak - Marrara	4549	6.5	29568.5
71023	Millner	2548	6.5	16562
71024	Moil	2000	6.5	13000
71025	Nightcliff	3853	6.5	25044.5
71026	Rapid Creek	3282	6.5	21333
71027	Tiwi	2562	6.5	16653
71028	Wagaman	2162	6.5	14053
71029	Wanguri	1876	6.5	12194
71030	Wulagi	2435	6.5	15827.5
71031	Howard Springs	6981	7.0	48867
71032	*Humpty Doo	8711	7.0	60977
71033	*Koolpinyah	25	7.0	175
71034	Virginia	3292	7.0	23044
71035	*Weddell	4527	7.0	31689
71036	Bakewell	3069	7.0	21483
71037	Driver	2884	7.0	20188
71038	Durack - Marlow Lagoon	4287	7.0	30009
71039	Gray	3288	7.0	23016

SA2 CODE[1]	SA2_NAME_2016	Population[2] (P_i)	$PM_{2.5}$ ($\mu g/m^3$) (C_i)	C_i x P_i
71040	Moulden	2959	7.0	20713
71041	Palmerston - North	4231	7.0	29617
71042	Palmerston - South	3069	7.0	21483
71043	Rosebery - Bellamack	6678	7.0	46746
71044	Woodroffe	3233	7.0	22631
Greater Darwin Region Population (P_T)		136834		
$PM_{2.5}$ Population Exposure ($\mu g/m^3$)		**6.7**		

*These suburbs were "Not in any Significant Urban Area" for 2016 census, but have been included in the analysis.

[1]SA2 – ABS Statistical Areas Level 2 are normally designed around whole gazetted suburbs

[2]Population from ABS 2016 census for the SA2 area

$$\boldsymbol{Population\ Exposure} = \sum_i \frac{C_i \times P_i}{P_T}$$

C_i = annual average $PM_{2.5}$ concentration at each suburb

P_i = population at each suburb

P_T = total population in Greater Darwin Region

Annual average $PM_{2.5}$ concentration measured at Winnellie AQMS – 6.5 $\mu g/m^3$

Annual average $PM_{2.5}$ concentration measured at Stokes Hill AQMS – 6.4 $\mu g/m^3$

Annual average $PM_{2.5}$ concentration measured at Palmerston AQMS – 7.0 $\mu g/m^3$