Northern Territory Environment Protection Authority

Northern Territory Ambient Air Quality Monitoring Report 2018

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

September 2019

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1 Summary

This report presents Northern Territory air quality monitoring data for the 2018 calendar year and assesses them against the requirements for *National Environment Protection (Ambient Air Quality) Measure* (AAQ NEPM). Northern Territory Environment Protection Authority (NT EPA) operates three ambient air quality monitoring stations in the Darwin region. These stations 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 ($PM_{2.5}$).

This is the first year that the newest station, located at Stokes Hill and established in May 2017, has provided a whole calendar year of data to enable assessment of its 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.

Between 1 January and 31 December 2018, all the ambient air quality monitoring stations in the Darwin region showed no exceedances of the AAQ NEPM standards for SO_2 and NO_2. As explained below, although some exceedances of the short-term standards were recorded for CO, O_3, PM_{10} and $PM_{2.5}$, all the stations were compliant with the AAQ NEPM standards. Conversely, compliance with the long-term AAQ NEPM standard for $PM_{2.5}$ was not met at any of the stations.

Carbon monoxide: During 2018, there was only one exceedance of the 8-hour rolling average standard for CO, and this occurred at Winnellie. However, one exceedance day per year of the standard is permitted, so all the stations complied with the AAQ NEPM standard for carbon monoxide.

Ozone: To comply with the AAQ NEPM standard for 1-hour average ozone, one exceedance day per year is allowed. Ozone data recorded at the stations did not exceed this standard.

To comply with the AAQ NEPM standard for 4-hour rolling average ozone, one exceedance day per year of the standard is permitted. During 2018, there was only one exceedance of this standard, and this occurred on the same day at Palmerston and Stokes Hill.

PM_{10}: To comply with the 1-day AAQ NEPM standard for particulates as PM_{10}, no exceedances of the 1-day average standard of 50.0 $\mu g/m^3$ is allowed, unless determined as an exceptional event. Palmerston recorded five exceedances, Winnellie recorded five and Stokes Hill recorded

six, but as with previous years, these exceedances were linked to smoke from bushfires, which are exceptional events.

To comply with the 1-year AAQ NEPM standard for particulates as PM_{10}, the 1-year average must be less than 25.0 $\mu g/m^3$. All monitoring sites complied with this requirement.

$PM_{2.5}$: To comply with the 1-day AAQ NEPM standard for particulates as $PM_{2.5}$, no exceedances of the 1-day average standard of 25.0 $\mu g/m^3$ is allowed, unless determined to be an exceptional event. During 2018, all exceedances of the $PM_{2.5}$ standard (15 at Palmerston, 19 at Winnellie and 13 at Stokes Hill) were linked to smoke from bushfires, which are classified as exceptional events.

During 2018, none of monitoring sites complied with the $PM_{2.5}$ long-term AAQ NEPM standard. The $PM_{2.5}$ 1-year averages of 9.1, 8.7 and 8.3 $\mu g/m^3$ respectively at Winnellie, Palmerston and Stokes Hill were above the AAQ NEPM standard of 8.0 $\mu g/m^3$.

2 Background

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.

Consistent with the reporting period defined in the AAQ NEPM this report covers the calendar year ending on 31 December 2018 for data collected from the Northern Territory Environment Protection Authority (NT EPA) monitoring stations located at Palmerston, Winnellie and Stokes Hill (Figure 1). The report is based on Technical Papers No. 8 (Annual Reports) and No. 5 (Data Collection and Handling) 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, *Compliance with the National Environment Protection (Ambient Air Quality) Measure*, is available on the NT EPA website at https://ntepa.nt.gov.au.

3 Overview of the 2018 AAQ NEPM monitoring network and activities

Figure 1: Locations of Palmerston, Winnellie and Stokes Hill Air Quality Monitoring stations.

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. 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.

Since the initial monitoring, the population and industrial activities in Darwin have increased and more detailed monitoring of airborne pollutants is required. In 2010, the establishment and operation of a comprehensive air quality monitoring system for the Darwin region commenced.

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 in the Darwin Region comprises of three stations (Figure 1): a performance monitoring station located near Palmerston; a long-term trend monitoring station located at the Bureau of Meteorology (BoM) site in Winnellie; and a recently added station near Stokes Hill Wharf. The Winnellie station has been operational since the second half of 2012, the Palmerston station has been operational since the beginning of 2011 and the Stokes Hill station started operation in May 2017.

3.2 Current monitoring stations for the purposes of this report

The Winnellie station 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 1). The station consists of an air-conditioned instrument shed, which houses all instrumentation. Ambient air is analysed for nitrogen oxides (nitrogen dioxide and nitric oxide), ozone, sulfur dioxide and carbon monoxide via a single gas-sampling manifold. Air for particulate sampling is drawn from a separate mast attached to the station roof. Meteorological data is obtained from BoM instruments located on the same site.

The Palmerston station 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 1). The station houses the same gas and particulate sampling instruments as Winnellie, but has meteorological instruments.

Stokes Hill station (Figure 1) 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.

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 (April - 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. 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 2018 data: $PM_{2.5}$ annual average levels were 9.1, 8.7 and 8.3 $\mu g/m^3$ respectively for Winnellie, Palmerston and Stokes Hill. As industrial development increases divergence in particulate and other pollutant levels may occur between sites.

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 Katherine and Tennant Creek in future years.

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

Station	Location Category	Height above ground	Clear Sky Angle	Unrestricted airflow of 360º	20m from trees	No boilers/ incinerators nearby	Minimum distance from road or traffic
Winnellie DBE 1	Bushland	Yes	Yes	Yes	Yes	Yes	Yes
Palmerston DBE 2	Bushland	Yes	Yes	Yes	Yes	Yes	Yes
Stokes Hill DBE 3	Coastal	Yes	Yes	Yes	Yes	Yes	Yes

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.

Table 2: 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)	present	TEOM 1405D	continuous
$PM_{2.5}$	01/01/11 (Palmerston) 18/07/12 (Winnellie) 03/07/17 (Stokes Hill)	present	TEOM 1405D	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
Meteorology (mast height: 10 m)				
Wind direction	01/01/12 (Palmerston) 05/05/17 (Stokes Hill)	present	RM Young, 2D ultra-sonic anemometer model 85000	continuous
Wind speed	01/01/12 (Palmerston) 04/05/17 (Stokes Hill)	present	RM Young, 2D ultra-sonic anemometer model 85000	continuous

Sigma Theta	05/05/17 (Stokes Hill)	present	RM Young, 2D ultra-sonic anemometer model 85000	continuous
Temperature	01/01/12 (Palmerston) 05/05/17 (Stokes Hill)	present	RM Young, model 41382LC TEOM sensor	continuous
Relative Humidity	01/01/12 (Palmerston) 05/05/17 (Stokes Hill)	present	RM Young, model 41382LC TEOM sensor	continuous
Atmospheric Pressure	01/01/12 (Palmerston) 05/05/17 (Stokes Hill)	present	RM Young, model 61302v TEOM sensor	continuous
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

Meteorological data for Winnellie Station are sourced from BoM instruments located at the site.

3.4 Monitoring during the reporting period

Palmerston, Winnellie and Stokes Hill stations monitor the same suite of air pollutants. Almost all of the instruments (including meteorological instruments) at the three stations provided valid data for more than seventy-five per cent of the time during the reporting period. This is the first year that the newest station, located at Stokes Hill and established in May 2017, has provided a whole calendar year of data 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).

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 current National Environment Protection Standards shown in Table 4.

Table 4: Ambient Air Quality NEPM Standards

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	0.10ppm	1 day a year
	4 hours	0.08ppm	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 (5-10) 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.

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

Performance is assessed as not complying (i.e. 'Not Met') if there were exceedances and the number exceedances was more than the "Maximum allowable exceedances" specified in Table 4 above.

If there was insufficient data (less than 75% availability) then performance is assessed as 'Not Demonstrated' ('ND').

4.1 Carbon Monoxide

Table 5: 2018 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		
Winnellie	84	100	95	88	92	1	Met
Palmerston	75	92	98	84	91	0	Met
Stokes Hill	84	95	100	92	93	0	Met

During 2018, one exceedance of the carbon monoxide (CO) standard was recorded at Winnellie. However, compliance with the AAQ NEPM was demonstrated at all sites since one exceedance day is allowed for this standard.

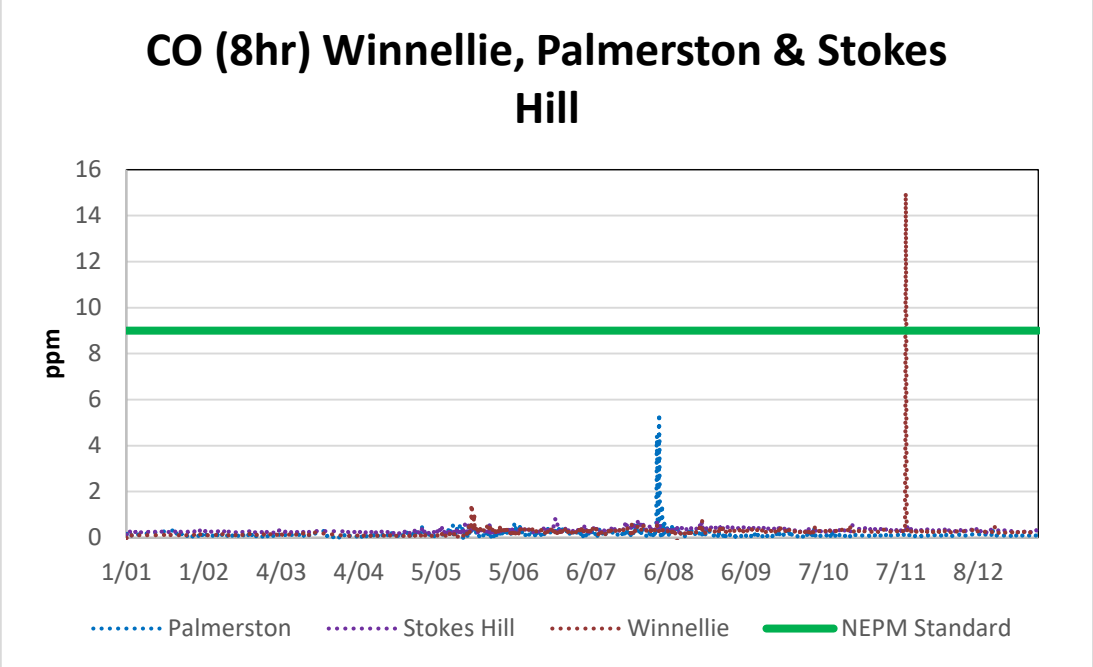

Figure 2: CO 8-hour average

4.2 Nitrogen Dioxide

Table 6: 2018 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
Winnellie	61	100	96	88	86	0	0.0017	Met	Met
Palmerston	93	98	100	95	96	0	0.0024	Met	Met
Stokes Hill	84	93	100	92	92	0	0.0020	Met	Met

In 2018, no exceedances of the nitrogen dioxide (NO_2) 1-hour and 1-year standards were recorded in the Darwin region. During the first quarter, Winnellie did not meet 75% data recovery to demonstrate compliance; however, due to the very low concentrations measured at the stations during that quarter, no exceedances are expected. Compliance with the AAQ NEPM for NO_2 was met at all sites.

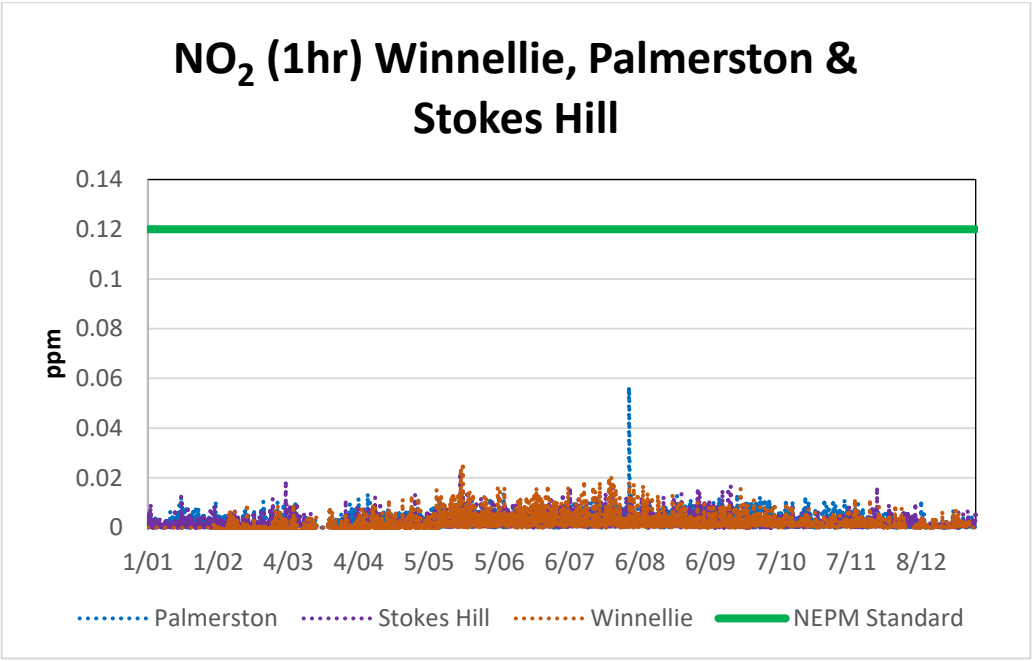

Figure 3: NO_2 1-hour average

4.3 Ozone

Table 7: 2018 compliance summary for Ozone 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	1 h	4 h	1h	4h
Winnellie	93	100	96	84	93	0	0	Met	Met
Palmerston	93	93	100	98	96	0	1	Met	Met
Stokes Hill	84	95	100	93	93	0	1	Met	Met

During 2018, no exceedance of the ozone (O_3) one-hour standard was recorded in the Darwin region.

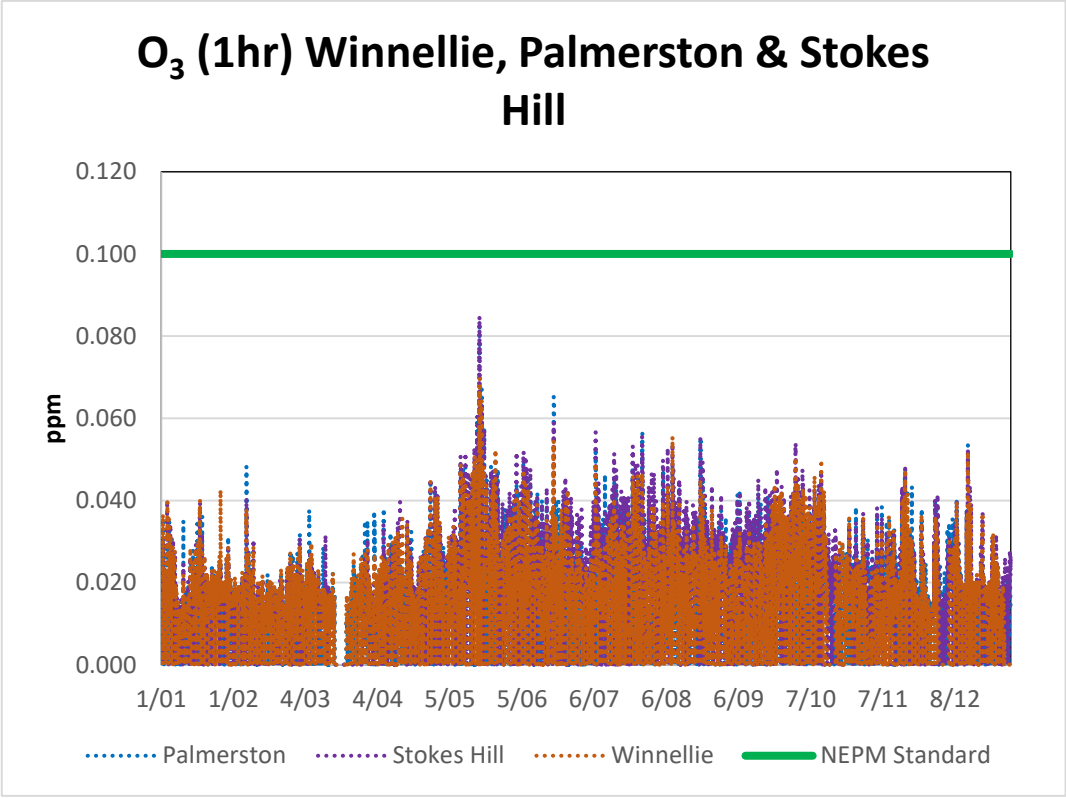

Figure 4: O_3 1-hour average

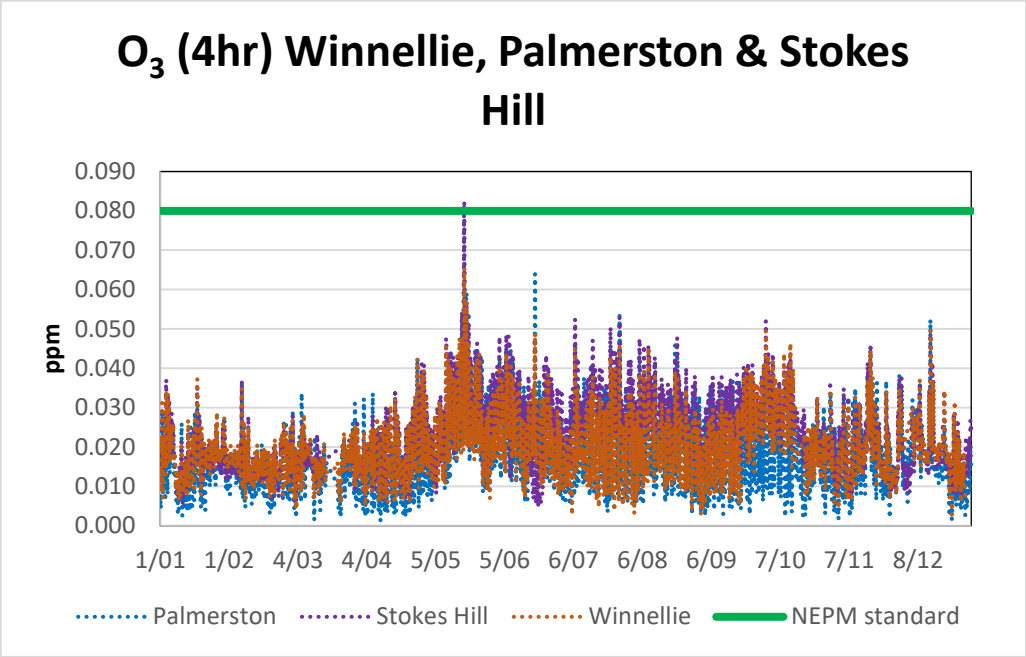

Figure 5: O_3 4-hour average

An exceedance of the ozone 4-hour rolling average standard was recorded at Palmerston and Stokes Hill on the same day. However, the AAQ NEPM allows one exceedance day for this standard. Compliance with the AAQ NEPM O_3 standard was demonstrated at all sites.

4.4 Sulfur Dioxide

Table 8: 2018 compliance summary for SO_2 in the Northern Territory

AAQ NEPM Standard

0.20 ppm (1-hour average)

0.08 ppm (1-day average)

0.02 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	24h		1h	24h	1y
Winnellie	93	100	95	88	94	0	0	0.00001	Met	Met	Met
Palmerston	93	91	100	98	95	0	0	0.00039	Met	Met	Met
Stokes Hill	84	95	100	92	93	0	0	0.00024	Met	Met	Met

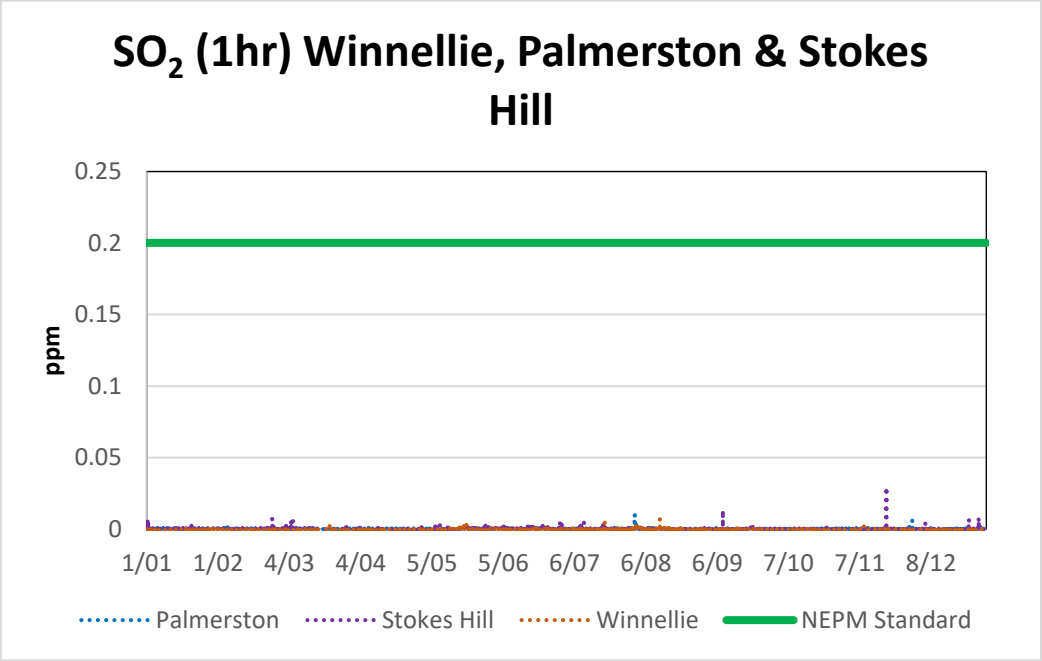

Figure 6: SO_2 1-hour average

During 2018, 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 for SO_2 was demonstrated at all sites.

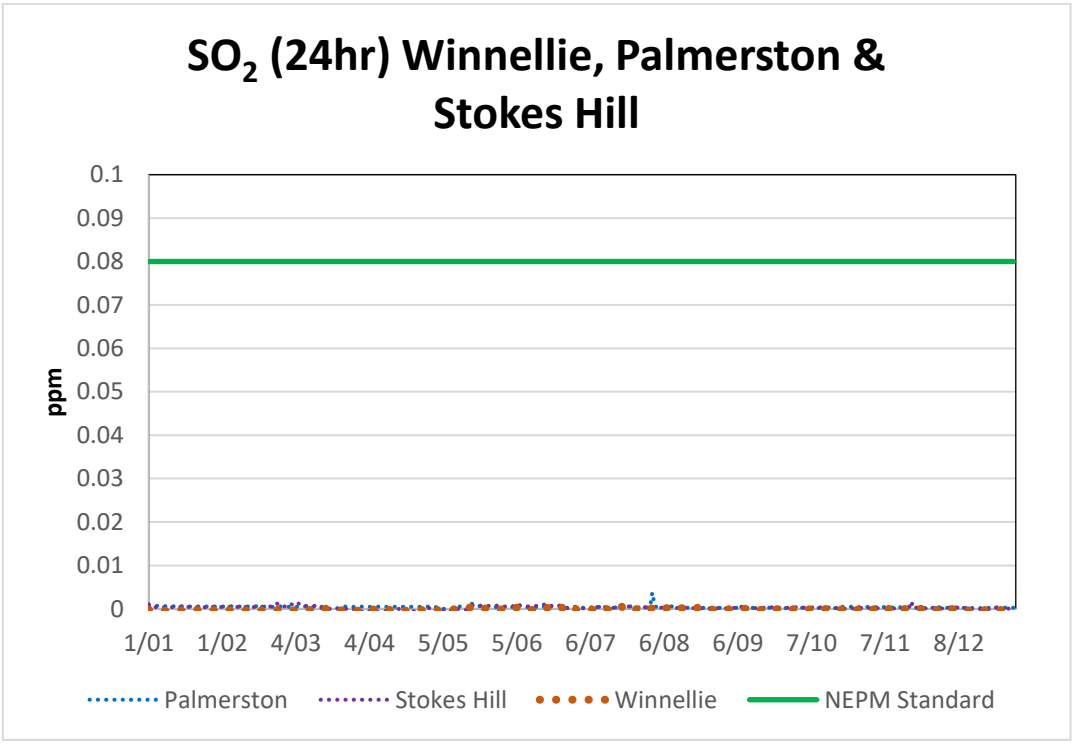

Figure 7: SO_2 1-day average

4.5 Particulates PM_{10}

Table 9: 2018 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 (% of Days)					Number of exceedances (days)	Annual average (µg/m³)	Performance against the standard and goal	
	Q1	Q2	Q3	Q4	Annual			24h	1y
Winnellie	84	97	100	89	92	5	13.3	Met	Met
Palmerston	93	97	98	100	97	5	19.7	Met	Met
Stokes Hill	81	85	93	95	89	6	22.6	Met	Met

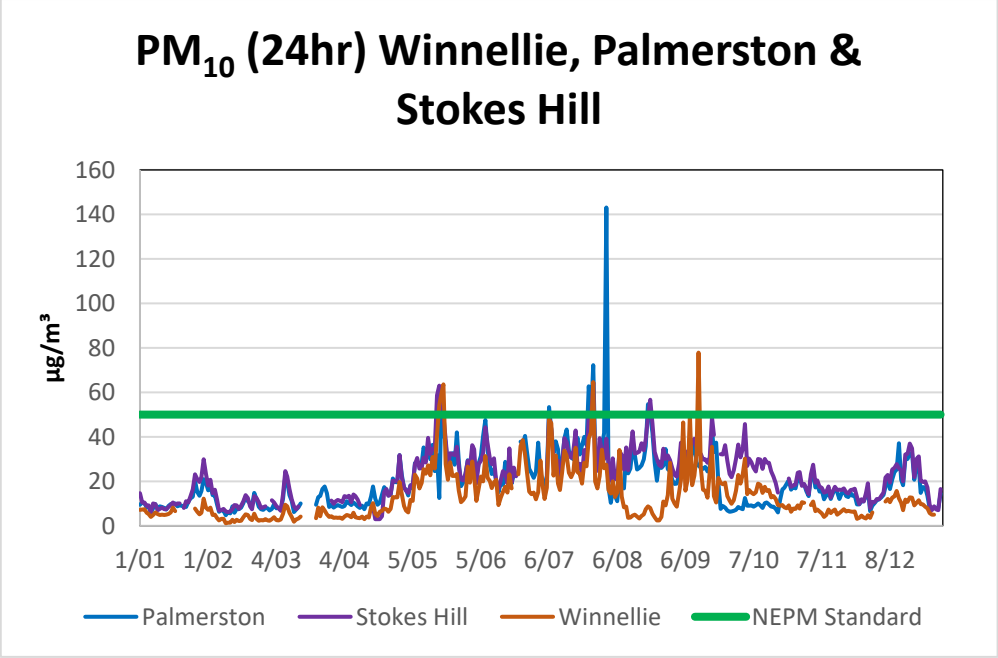

Figure 8: PM_{10} 1-day average

During 2018, exceedances of the PM_{10} 1-day standard were recorded. However, 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. Annual averages were below the standard. Compliance with the AAQ NEPM for PM_{10} was demonstrated at all sites.

4.6 Particulates $PM_{2.5}$

Table 10: 2018 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(% of Days)					Number of exceedances (days)	Annual average µg/m³	Performance against the standard and goal	
	Q1	Q2	Q3	Q4	Annual			24h	1y
Winnellie	84	97	100	89	92	19	9.1	Met	Not Met
Palmerston	93	97	98	100	97	15	8.7	Met	Not Met
Stokes Hill	81	85	93	95	89	13	8.3	Met	Not Met

During 2018, several exceedances of the $PM_{2.5}$ 1-day standard were recorded. However, these 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 above the AAQ standard at all the stations. Compliance with the AAQ NEPM standard for $PM_{2.5}$ was demonstrated at all sites for the 1-day average, but was not met for the annual average at any of the sites.

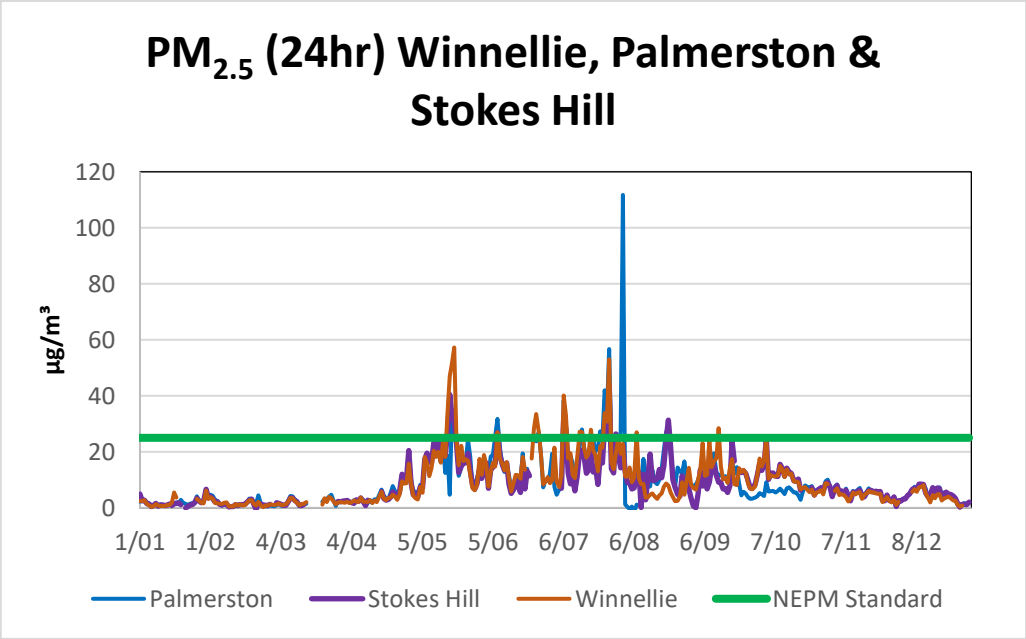

Figure 9: $PM_{2.5}$ 1-day average

5 Analysis of air quality data

Annual summary statistics are presented in this section. The AAQ NEPM states that short-term standards should not be exceeded on more than one day for carbon monoxide, nitrogen dioxide, ozone and sulfur dioxide 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 with the exception of a few events, levels of carbon monoxide, nitrogen dioxide and particularly sulfur dioxide, were significantly below the AAQ NEPM standards.

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.

Table 11: 2018 summary statistics for daily peak 8 hour CO in the Northern Territory

AAQ NEPM Standard

9.0 ppm (8-hour average)

Region/ Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date:hour)	2nd highest (ppm)	2nd Highest (date:hour)
Winnellie	336	15.0	08/11:23	1.44	19/05:05
Palmerston	335	5.40	02/08:06	4.45	01/08:08
Stokes Hill	340	0.82	21/06:24	0.74	24/06:12

Carbon monoxide (CO) levels at all the stations were substantially below the CO 8-hour rolling average standard for most days with the exception of three days when significant concentrations of CO were recorded. The highest event was recorded at Winnellie (15 ppm, 11pm on 8/11/2018) was ~170% of the AAQ standard. The plume peaked at 9pm on 8/11/2018, and back trajectory analysis of the plume showed that it had originated from the direction of Bladin Point, Wickham. This plume had high oxides of nitrogen (NOx) content, but no significant amount of particulates. The highest CO event at Palmerston (5.40 ppm CO, 6am on 2/08/2018) was greater than 50% of the standard; the plume for the event peaked at 4am and also originated from the direction of Bladin Point.

The other CO event at Palmerston (4.45 ppm CO, 8am on 1/08/2018) was caused by a plume that peaked at 6am and had originated from the direction of Kakadu National Park; this plume had high particulates and NO_x concentrations.

Table 12: 2018 summary statistics for daily peak 1 hour NO_2 in the Northern Territory

AAQ NEPM Standard

0.12 ppm (1-hour average)

Region/ Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date:hour)	2nd highest (ppm)	2nd Highest (date:hour)
Winnellie	316	0.026	19/05:23	0.024	18/05:24
Palmerston	354	0.057	01/08:04	0.014	07/04:23
Stokes Hill	338	0.022	18/05:20	0.019	02/05:20

Nitrogen dioxide (NO_2) levels were below the AAQ NEPM 1-hour nitrogen dioxide standard. The highest recorded reading was at Palmerston (0.057 ppm), which was twice the maximum values recorded at the other stations and about 50% of the AAQ standard, occurred at 4am on 1/08/2018. As pointed out in the previous section, this was the plume that originated from the direction of the Kakadu National Park and had high CO and particulates concentrations.

Table 13: 2018 summary statistics for daily peak 1 hour O_3 in the Northern Territory

AAQ NEPM Standard

0.10 ppm (1-hour average)

Region/ Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date:hour)	2nd highest (ppm)	2nd Highest (date:hour)
Winnellie	342	0.070	17/05:20	0.064	18/05:18
Palmerston	352	0.083	17/05:17	0.067	18/05:18
Stokes Hill	341	0.085	17/05:19	0.063	18/05:19

There were no exceedances of the 1-hour ozone standard at any of the monitoring sites; although there were exceedances of the 4-hour ozone standard at Palmerston and Stokes Hill on 17/05/2018, the AAQ NEPM allows for one exceedance day per year.

All the stations recorded their highest 1-hour peak ozone on the same day (17/05/2018): Palmerston ozone peaked first (5pm), followed by Stokes Hill (7pm), then Winnellie (8pm). The day was characterised with high temperatures (26 - 32 °C), low wind speeds (2 m/s, average)

and high solar radiation (800 W/m^2, maximum). The second highest 1-hour ozone peaks occurred on the same day (18/05/2018) and similar times at all the stations. The stations also recorded high particulate levels from bushfire smoke on both days. The highest 4-hour average ozone concentrations at Palmerston and Stokes Hill exceeded the AAQ Standard.

Table 14: 2018 summary statistics for daily peak 4 hour O_3 in the Northern Territory

AAQ NEPM Standard

0.08 ppm (4-hour average)

Region/ Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date:hour)	2nd highest (ppm)	2nd Highest (date:hour)
Winnellie	342	0.066	17/05:21	0.057	18/05:19
Palmerston	352	0.080	17/05:18	0.064	18/06:17
Stokes Hill	341	0.082	17/05:19	0.057	18/05:19

Table 15: 2018 summary statistics for daily peak 1 hour SO_2 in the Northern Territory

AAQ NEPM Standard

0.20 ppm (1-hour average)

Region/ Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date:hour)	2nd highest (ppm)	2nd Highest (date:hour)
Winnellie	344	0.0071	12/08:01	0.0050	19/07:04
Palmerston	350	0.0103	01/08:04	0.0062	29/11:19
Stokes Hill	340	0.0293	18/11:13	0.0132	08/09:12

Table 16: 2018 summary statistics for 24 hour SO_2 in the Northern Territory

AAQ NEPM Standard

0.08 ppm (1-day average)

Region/ Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date)	2nd highest (ppm)	2nd Highest (date)
Winnellie	344	0.00057	19/07	0.00042	23/06
Palmerston	350	0.00374	01/08	0.00118	17/05
Stokes Hill	340	0.00174	18/11	0.00128	05/03

Sulfur dioxide (SO_2) levels in the Darwin region were substantially below the AAQ NEPM 1-hour and 1-day sulfur dioxide standards. The highest recorded 1-hour reading was at Stokes Hill (0.0293 ppm). This value and the second highest recorded value (0.0132 ppm), also recorded at Stokes Hill, were much higher than values recorded at the other stations. The highest recorded 1-day average was at Palmerston (0.00374 ppm), on 01/08/2018.

The highest $PM_{2.5}$ and PM_{10} events occurred on the same date (01/08/2018) at Palmerston, and exceeded the AAQ NEPM standards. This large PM plume peaked at 4 am on 01/08/2018, with high NOx and CO content, and appeared have been caused by fires occurring in the direction of Kakadu National Park. 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 Air NEPM 1-day standards.

Table 17: 2018 summary statistics for 24 hour PM_{10} in the Northern Territory

AAQ NEPM Standard

50 μg/m³ (1-day average)

Region/ Performance monitoring station	Number of valid days	Highest (μg/m³)	Highest (date)	2nd highest (μg/m³)	2nd Highest (date)
Winnellie	339	77.9	12/09	64.6	26/07
Palmerston	356	143.1	01/08	72.2	26/07
Stokes Hill	325	64.4	26/07	63.0	17/05

Table 18: 2018 summary statistics for 24 hour $PM_{2.5}$ in the Northern Territory

AAQ NEPM Standard

25 μg/m³ (1-day average)

Region/ Performance monitoring station	Number of valid days	Highest (μg/m³)	Highest (date)	2nd highest (μg/m³)	2nd Highest (date)
Winnellie	339	57.3	19/05	53.1	26/07
Palmerston	356	111.7	01/08	56.7	26/07
Stokes Hill	325	48.7	21/08	43.6	26/07

6 Analysis of exceedances and progress in achieving Air NEPM goals

This section will analyse exceedance events that occurred during 2018 and were recorded at the three 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-November) and the Wet (December-April). In general, air quality was excellent during the Wet and poor during the Dry of 2018. Averaged daily levels of $PM_{2.5}$ across all stations over the six months of the Dry was 13.7 $\mu g/m^3$, well above the Air NEPM annual standard of 8 $\mu g/m^3$ and significantly higher than levels in several Australian cities. Averaged daily $PM_{2.5}$ levels during the Wet was 3.0 $\mu g/m^3$. The elevated $PM_{2.5}$ levels during the Dry are unavoidable and people with respiratory or cardiopulmonary issues may be impacted.

The 1-day standard for $PM_{2.5}$ had multiple exceedances in 2018 (Figure 9). There were 15 exceedances of the 1-day standard at Palmerston station, and the annual limit was exceeded. Stokes Hill station had 13 exceedances of the 1-day standard, and exceeded the annual limit. Winnellie recorded the highest number of exceedances of the 1-day standard (19) and likewise exceeded the annual limit.

The AAQ NEPM 1-day standard for PM_{10} was exceeded on 5 days at Palmerston; 5 days at Winnellie; and 6 days at Stokes Hill; however, 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: 2018 PM_{10} exceedances of AAQ NEPM reporting level at Palmerston

Date	PM_{10} ($\mu g/m^3$)	Inferred Cause
06/07	53.4	smoke
24/07	62.7	smoke
26/07	72.2	smoke
01/08	143.1	smoke
20/08	54.7	smoke

Table 20: 2018 PM_{10} exceedances of AAQ NEPM reporting level at Winnellie

Date	PM_{10} ($\mu g/m^3$)	Inferred Cause
17/05	54.0	smoke
18/05	58.9	smoke
19/05	63.7	smoke
26/07	64.6	smoke
12/09	77.9	smoke

Table 21: 2018 PM_{10} exceedances of AAQ NEPM reporting level at Stokes Hill

Date	PM_{10} ($\mu g/m^3$)	Inferred Cause
16/05	58.6	smoke
17/05	63.0	smoke
18/05	54.4	smoke
06/07	50.3	smoke
26/07	64.4	smoke
21/08	56.7	smoke

Table 22: 2018 $PM_{2.5}$ exceedances of AAQ NEPM reporting level at Palmerston

Date	$PM_{2.5}$ ($\mu g/m^3$)	Inferred Cause
18/05	35.0	smoke
19/05	28.4	smoke
06/06	25.5	smoke
07/06	31.7	smoke
25/06	27.0	smoke
06/07	38.3	smoke
07/07	30.2	smoke
14/07	28.0	smoke
22/07	27.3	smoke
24/07	42.0	smoke

25/07	33.7	smoke
26/07	56.7	smoke
31/07	27.3	smoke
01/08	111.7	smoke
20/08	27.1	smoke

Table 23: 2018 $PM_{2.5}$ exceedances of AAQ NEPM reporting level at Winnellie

Date	$PM_{2.5}$ ($\mu g/m^3$)	Inferred Cause
16/05	33.9	smoke
17/05	47.0	smoke
18/05	51.6	smoke
19/05	57.3	smoke
07/06	27.0	smoke
23/06	28.2	smoke
24/06	33.5	smoke
25/06	27.2	smoke
06/07	40.1	smoke
07/07	33.0	smoke
13/07	27.2	smoke
14/07	27.1	smoke
18/07	27.9	smoke
24/07	33.8	smoke
25/07	30.7	smoke
26/07	53.1	smoke
07/08	26.9	smoke
12/09	28.5	smoke
03/10	25.1	smoke

Table 24: 2018 $PM_{2.5}$ exceedances of AAQ NEPM reporting level at Stokes Hill

Date	$PM_{2.5}$ ($\mu g/m^3$)	Inferred Cause
12/05	25.2	smoke
16/05	26.6	smoke
17/05	40.4	smoke
18/05	32.8	smoke
19/05	30.5	smoke
07/06	26.8	smoke
06/07	32.5	smoke
07/07	27.8	smoke
24/07	30.2	smoke
25/07	26.8	smoke
26/07	43.6	smoke
29/07	26.4	smoke
21/08	31.4	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.

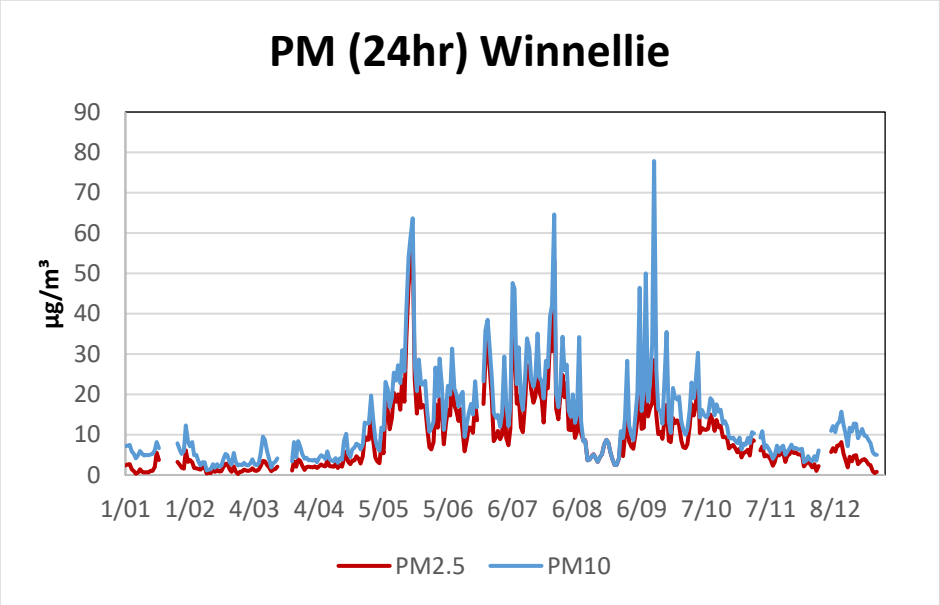

Figure 10: Particulates concentration at Winnellie AQMS

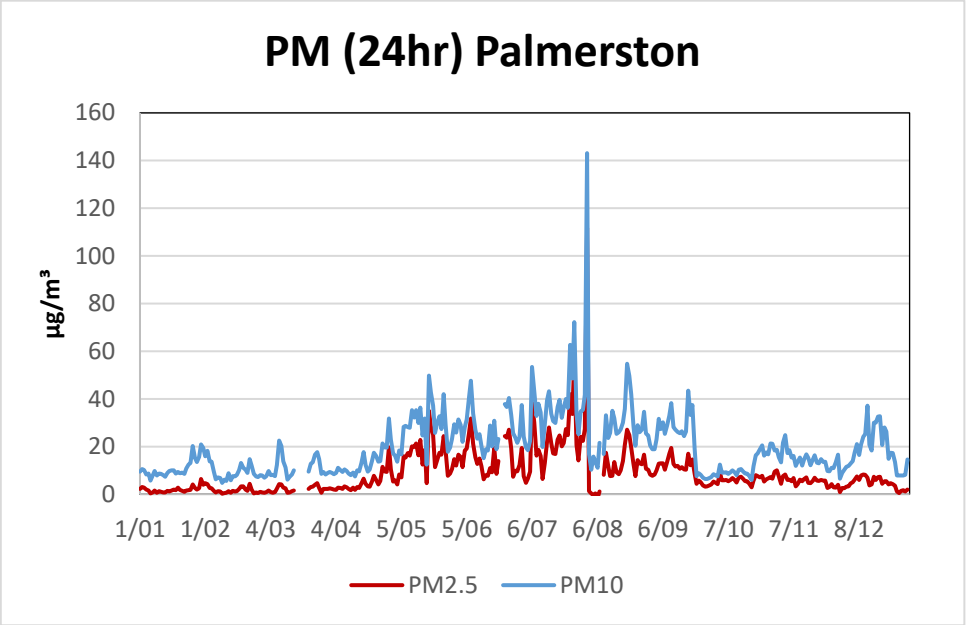

Figure 11: Particulates concentration at Palmerston AQMS

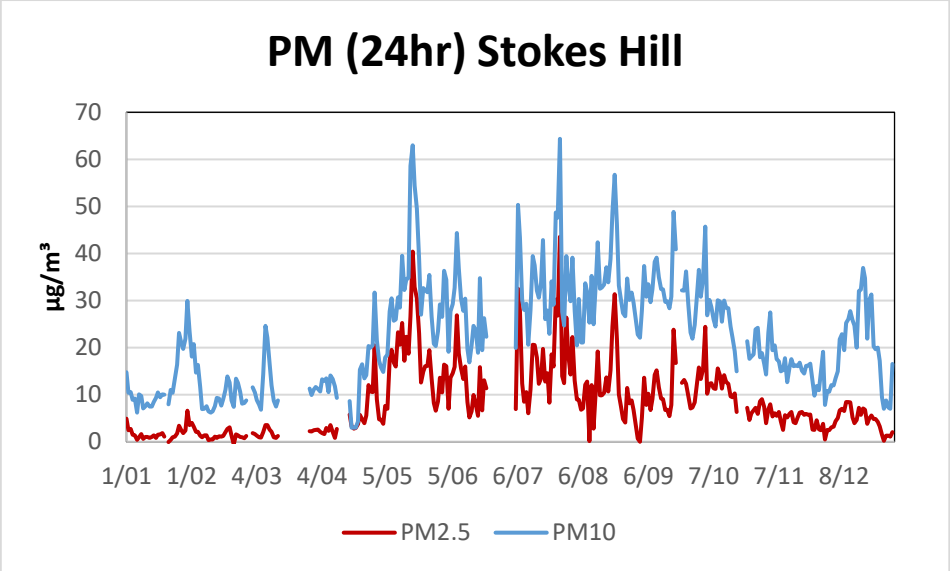

Figure 12: Particulates concentration at Stokes Hill AQMS

6.2 Ozone exceedances

Ozone is not expected to be a pollutant of concern in the Darwin region because of the relatively low emissions of ozone precursors (oxides of nitrogen and volatile organic compounds) into the airshed by motor vehicles as compared to other Australian cities. However, the 4-hour ozone standard was exceeded at Palmerston and Stokes Hill on 17/05/2018 (Table 25). The AAQ NEPM permits one exceedance day per year of this standard.

On the day of the exceedance (17/05/2018), elevated ozone levels as well as high particulate levels were recorded at all the stations. Particulates were ascribed to smoke from burning vegetation, an activity that has been linked to high ozone episodes.

Table 25: 2018 Ozone (4-hr average) exceedances of AAQ NEPM reporting level at Palmerston and Stokes Hill

Date	Ozone (ppm)	Inferred Cause
17/05/2018	0.0824 (Stokes Hill)	smoke
17/05/2018	0.0803 (Palmerston)	smoke

6.3 Carbon monoxide exceedance

Table 26: 2018 Carbon Monoxide (8-hr average) exceedance of AAQ NEPM reporting level at Winnellie

Date	Carbon Monoxide (ppm)	Inferred Cause
08/11/2018	15.0	industrial

As explained elsewhere (Chapter 5), the plume that caused this exceedance had high NOx, but low particulates content. It was attributed to a combustion source at an industrial facility. The AAQ NEPM permits one exceedance day per year of the CO standard.

7 Data analysis and trends

Tables 27 to 30 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 (TEOM and Partisol) and instruments have not been located consistently throughout the sampling period.

7.1 Trends in historical particulate data

Issues with historical data include:

- 2004 - data collection for this project did not commence until the second quarter.
- 2004 and 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.
- 2016 - data has not been analysed
- 2017 - Stokes Hill station started operating in May; TEOM data was only available from July.

Since the establishment of the Palmerston station in 2011 and then the Winnellie station in 2012 data quality has generally improved. 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 27: Trends - PM_{10} 2004-2018

Year	Casuarina			Palmerston			Winnellie			Stokes Hill		
	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)
2004	*69*	*1*	*54*									
2005	98	2	63									
2006	97	0	44									
2007	95	0	45									
2008	97	1	65									
2009	90	0	50									
2010	78	1	54									
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

Table 28: Averaged PM_{10} Key Metrics 2004-2018

Data Availability (%)	Number of Exceedances	Max Concentration (µg/m³)
83	3	66

Table 29: Trends $PM_{2.5}$, 2004-2018

Year	Casuarina			Palmerston			Winnellie			Stokes Hill		
	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)
2004	60	5	37									
2005	98	5	58									
2006	97	5	30									
2007	-	-	-									
2008	72	2	32									
2009	87	1	26									
2010	62	2	30									
2011				96	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

Table 30: Averaged $PM_{2.5}$ Key Metrics 2004-2018

Data Availability (%)	Number of Exceedances	Max Concentration (µg/m³)
81	6	45

Trend data for the 2004 to 2018 period is presented in Figures 13 to 18. This data shows that there is no clear trend in $PM_{2.5}$ or PM_{10} in the Darwin region over the period. Population of the greater Darwin region has increased from approximately 105,000 in 2004 to ~140,000 in 2018 showing a clear upward trend. 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.

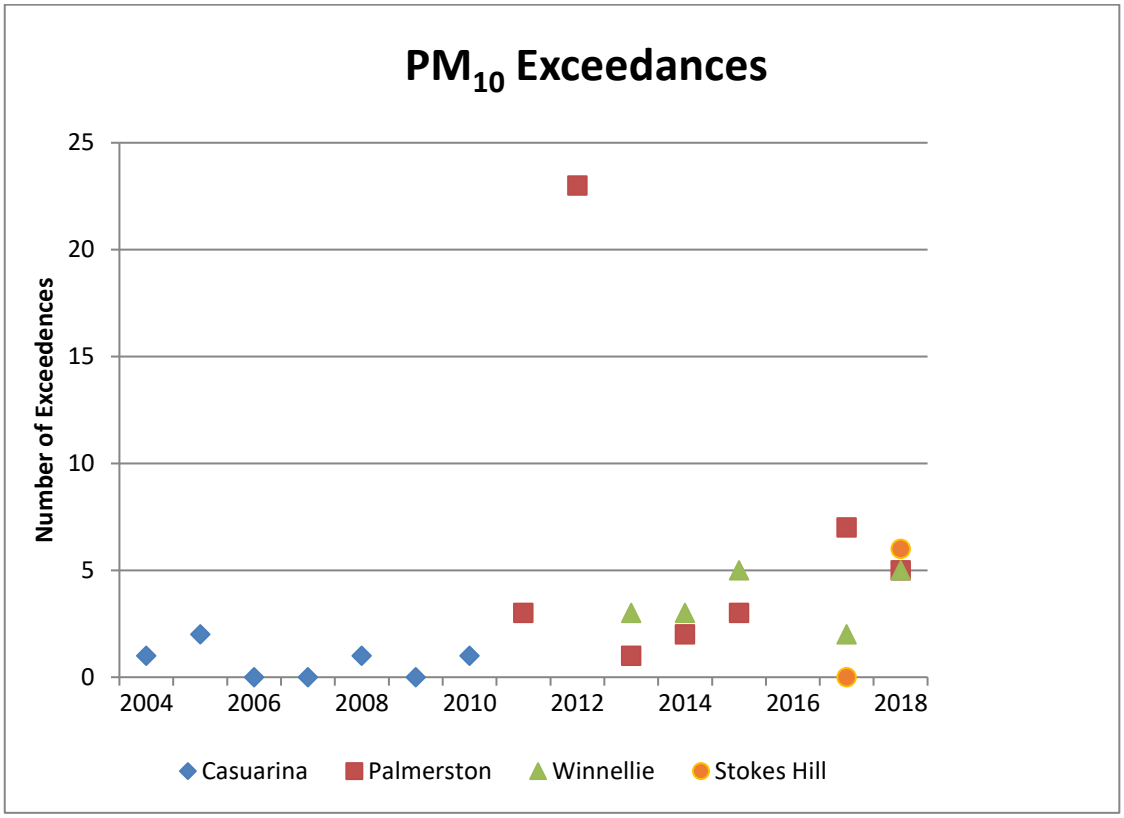

Figure 13: Historical PM10 exceedances

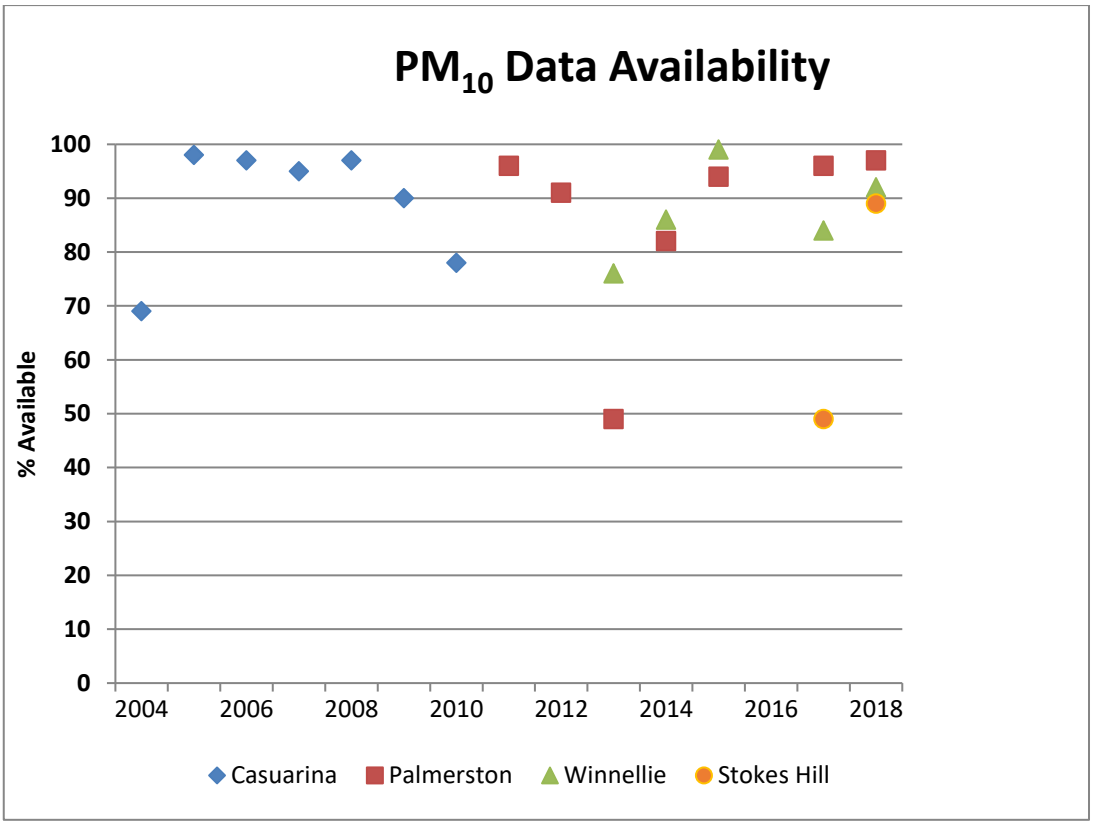

Figure 14: Historical PM10 data availability

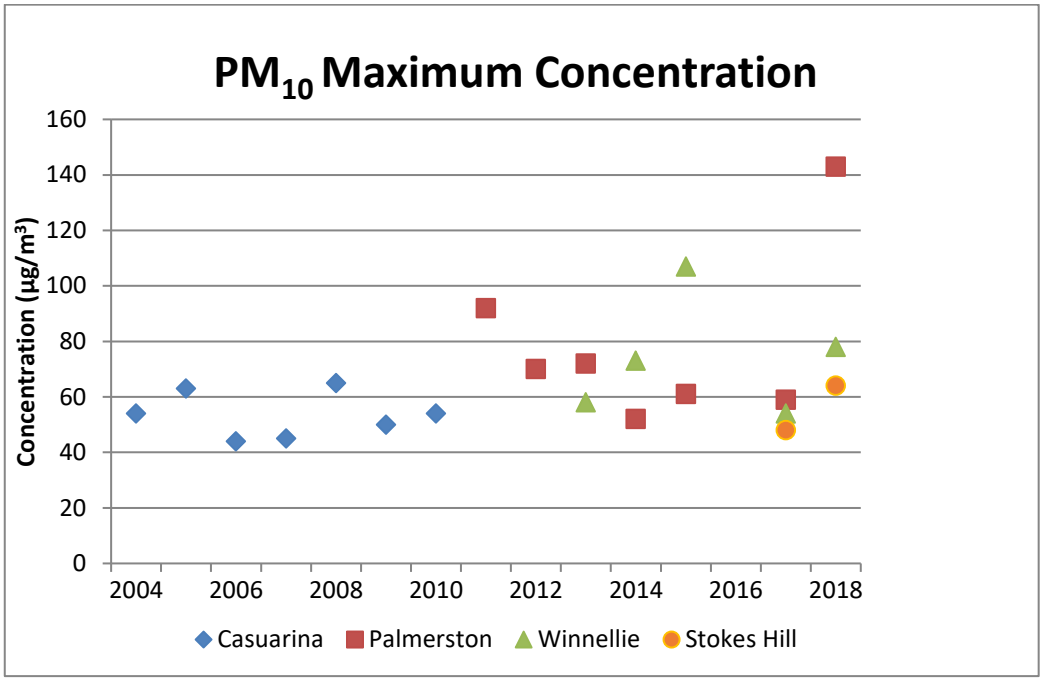

Figure 15: Historical maximum 24-hour PM10 concentrations

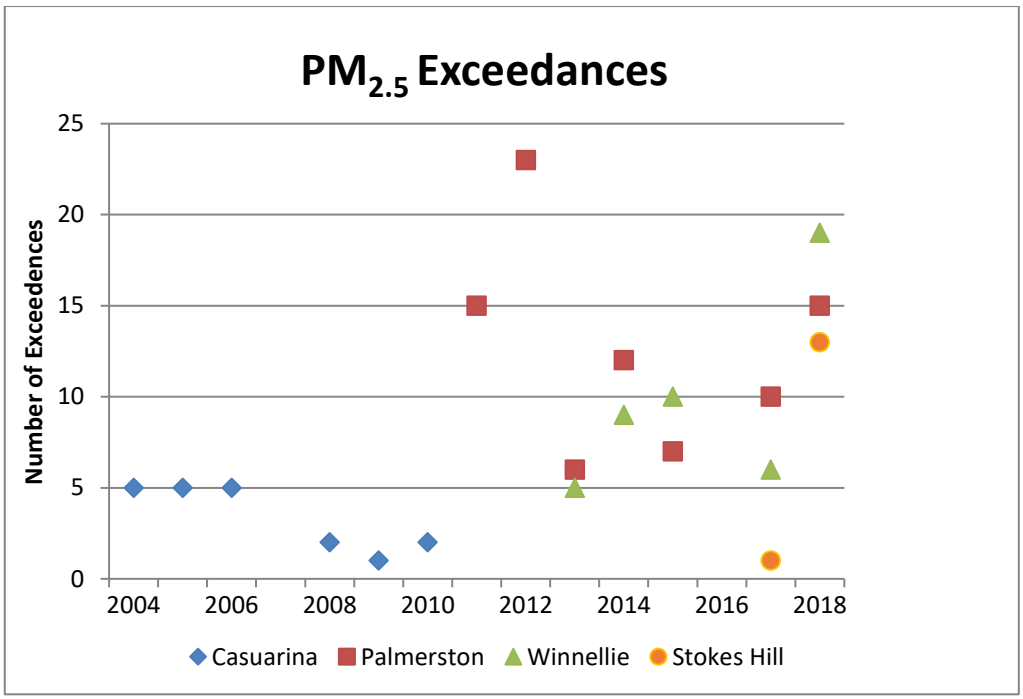

Figure 16: Historical PM2.5 exceedances

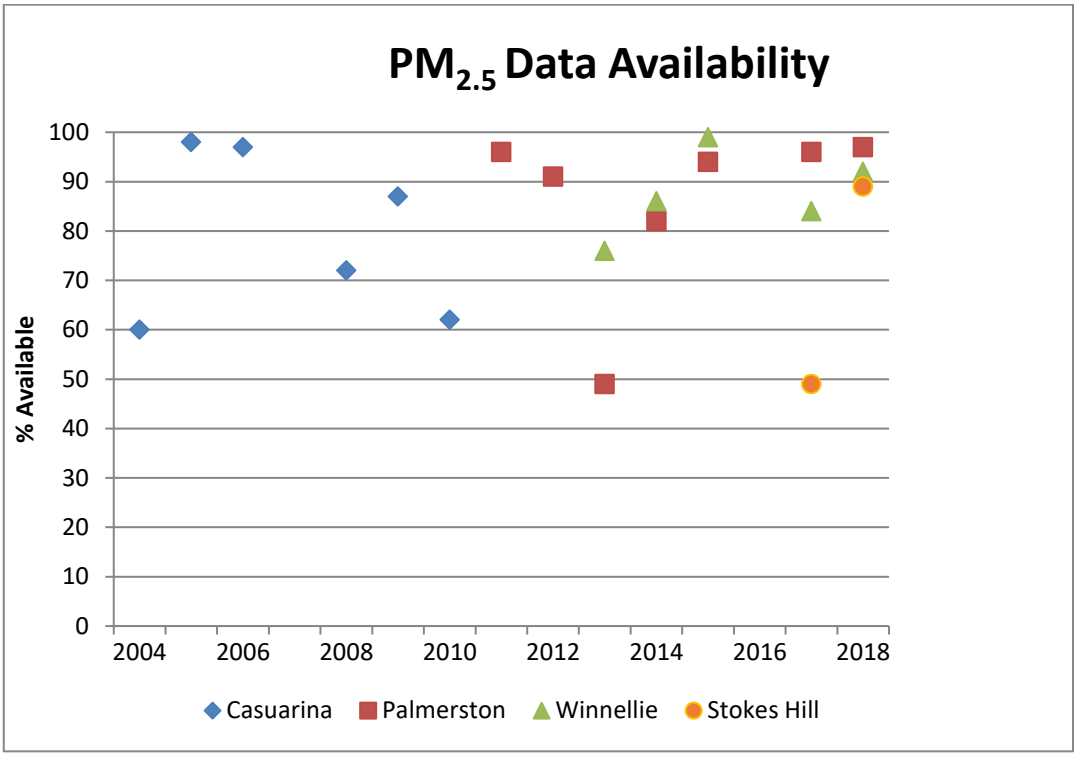

Figure 17: Historical PM2.5 data availability

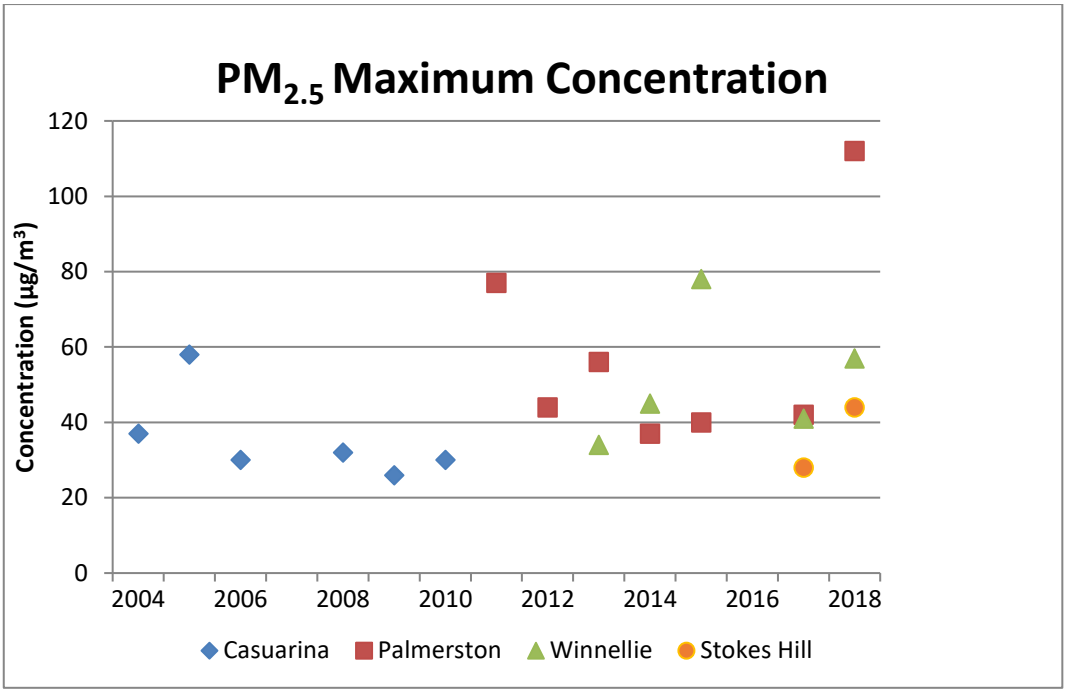

Figure 18: Historical PM2.5 24-hour maximum concentrations

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 2018) 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 37% of the area was burnt in 2018. A relationship was observed between the monthly area burnt and the monthly averaged $PM_{2.5}$ concentrations measured at the stations. Figure 19 shows that the monthly $PM_{2.5}$ concentrations increased sharply with area burnt in May. Although $PM_{2.5}$ levels peaked in July at all the stations (~20 μg/m^3), and the area burnt had peaked in May (14%), there was a general decline in both parameters after July.

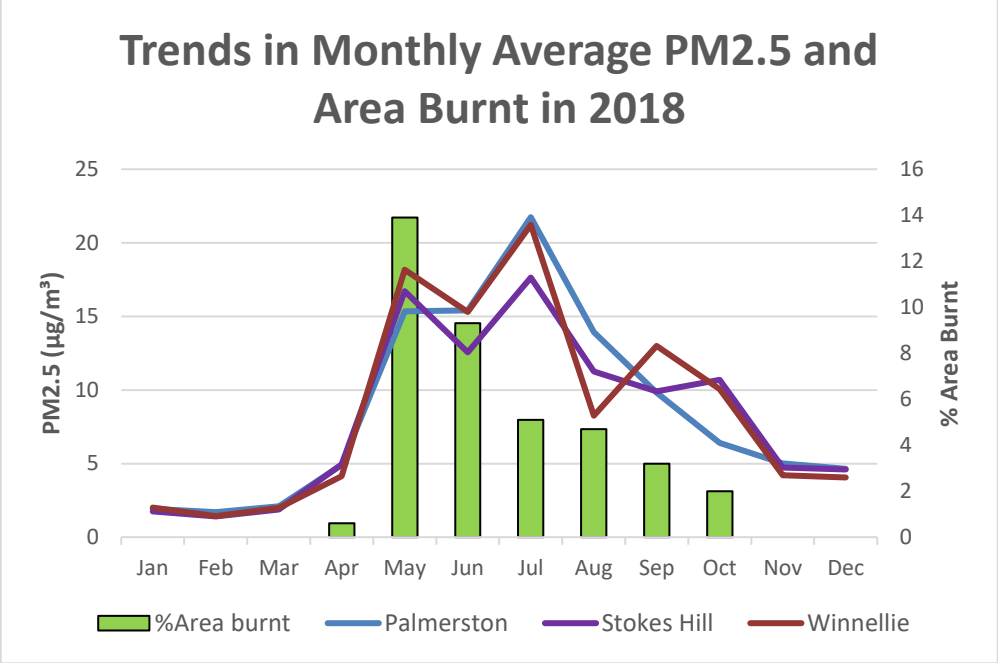

Figure 19: Comparison of $PM_{2.5}$ levels with Area Burnt (50 km radius)

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 are considered to 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 Air NEPM standards in the Darwin Region. However, the picture in Figure 20 shows that smoke from fires burning as far as 300km

southeast of Darwin on 18 May 2018, could have affected air quality in the Darwin region. On that day and the following day, all the stations recorded exceedances of the $PM_{2.5}$ AAQ NEPM standard (see the Appendix). Near ground level conditions such as wind-speed and temperature inversions are critical factors in determining the concentration of particulates from distant fires.

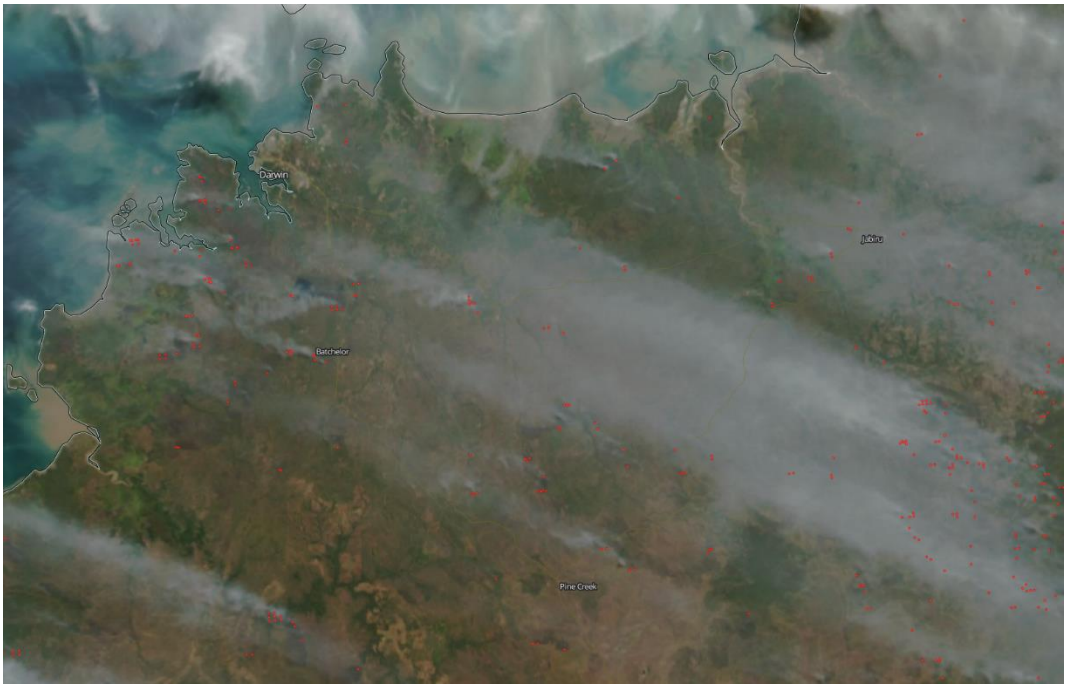

Figure 20: Large-scale fire event impacting Darwin on 18 May 2018 (Source: NASA Worldview)

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. Controlled burns present some opportunity for managing particulates. By timing the burn in consideration of wind direction and temperature inversion forecasts it may be possible to reduce population exposures to high particulate levels. There may also be scope for control of particulates from unintended fires (arson etc.) by pre-emptively burning areas identified for planned burning activity when conditions (wind direction and temperature inversion activity) were forecast to result in smoke being directed away from population centres.

8 References

National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM). www.nepc.gov.au/resource/national-environment-protection-ambient-air-quality-measure-annual-reporting

National Environment Protection (Ambient Air Quality) Measure Technical Paper No. 8: Annual Reports (NEPC Peer Review Committee 2010).

National Environment Protection (Ambient Air Quality) Measure Technical Paper No. 5: Data Collection and Handling (NEPC Peer Review Committee 2001).

NAFI (North Australian Fire Information) *Fire Reports, Fire History by Year - 2008-2018, Darwin region*. www.firenorth.org.au.

NASA Worldview application (https://worldview.earthdata.nasa.gov), part of the NASA Earth Observing System Data and Information System (EOSDIS).

9 Appendix: Particulates events for 2018

A particulates pollution event 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}.

	Daily average particulates concentration (µg/m³)					
	Palmerston		Stokes Hill		Winnellie	
Event Date	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}
12-May	21	35	**25**	40	20	27
16-May	19	32	**27**	**59**	**34**	41
17-May	5	12	**40**	**63**	**47**	**54**
18-May	**35**	50	**33**	**54**	**52**	**59**
19-May	**28**	43	**30**	50	**57**	**64**
6-Jun	**25**	40	16	33	15	20
7-Jun	**32**	48	**27**	44	**27**	31
23-Jun	24	38	n/a	n/a	**28**	36
24-Jun	24	37	n/a	n/a	**33**	39
25-Jun	**27**	40	n/a	n/a	**27**	32
6-Jul	**38**	**53**	**33**	**50**	**40**	48
7-Jul	**30**	43	**28**	43	**33**	46
13-Jul	22	39	21	39	**27**	34
14-Jul	**28**	43	21	37	**27**	31
18-Jul	23	37	20	43	**28**	35
22-Jul	**27**	40	19	34	22	28
24-Jul	**42**	**63**	**30**	49	**34**	39
25-Jul	**34**	49	**27**	48	**31**	42
26-Jul	**57**	**72**	**44**	**64**	**53**	**65**
29-Jul	24	35	**26**	39	20	22
31-Jul	**27**	42	14	30	19	26
1-Aug	**112**	**143**	22	39	23	27
7-Aug	1	22	12	34	**27**	34
20-Aug	**27**	**55**	24	49	9	9
21-Aug	25	50	**31**	**57**	8	8
12-Sep	12	27	9	32	**28**	**78**
3-Oct	9	12	24	46	**25**	30
Exceedances	**15**	**5**	**13**	**6**	**19**	**5**

Red – $PM_{2.5}$ exceedances; **Blue** – PM_{10} exceedances

(n/a – data not available for that day)