Air quality in the Upper Hunter: 2021 overview

Air quality in the Upper Hunter and throughout NSW continued to improve in 2021 compared to recent years. This was primarily due to the region experiencing cooler and wetter than average conditions. Particle levels at Muswellbrook and Singleton were within national benchmarks on 100% and 99.7% of days during 2021, respectively.

- Nitrogen dioxide (NO_2) levels were good, remaining within the benchmarks. Daily SO_2 levels remained within the benchmark. Hourly sulfur dioxide (SO_2) levels exceeded the new benchmark[1] for 1 hour in February 2021 at Muswellbrook.
- Daily average levels PM2.5[2] remained within the benchmark of 25 micrograms per cubic metre ($\mu g/m^3$) in 2021 (Table 1). The regional maximum daily PM2.5 level in 2021 was 19.7 $\mu g/m^3$.
- Daily average levels of PM10[2] were above the benchmark of 50 $\mu g/m^3$ on 6 days in 2021 (Table 2). Regional maximum daily PM10 levels on these days ranged from 53.3 to 82.0 $\mu g/m^3$.
  - PM10 levels were within the daily benchmark across half the network – Aberdeen, Bulga, Jerrys Plains, Merriwa, Muswellbrook, Muswellbrook NW and Wybong. At the remaining stations, there was from 1 day at Maison Dieu, Singleton and Singleton NW to 5 days at Mt Thorley (Table 1).
  - There was 1 day when a larger population station had levels over the PM10 benchmark. This occurred on 29 October at Singleton, as well as Camberwell, Maison Dieu, Mt Thorley, Singleton NW, Singleton South and Warkworth. This was an exceptional event due to widespread dust.
- Annual particle levels continued to decrease compared to earlier years. PM10 and PM2.5 remained within the 25 $\mu g/m^3$ and 8 $\mu g/m^3$ annual benchmarks, respectively, at all stations (Figure 1).
- Rainfall was very much above average in 2021, with highest on record rainfall totals in November.

The Upper Hunter seasonal newsletters and the NSW annual air quality statement 2021 provide more detail on the region's air quality in 2021.

Annual particle levels 2011 to 2021

Figure 1 shows the annual average PM10 and PM2.5 particle levels from 2011 to 2021.

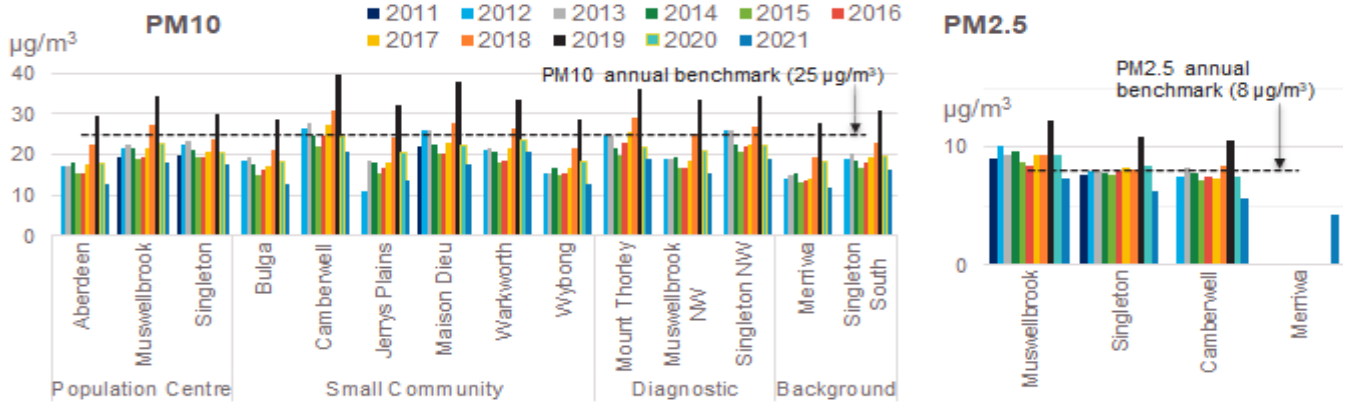

Figure 1 PM10 and PM2.5 annual averages: 2011 to 2021

Note: The Merriwa background air quality monitoring station was upgraded in July 2020 to also monitor PM2.5.

[1] The hourly SO2 benchmark was updated in May 2021 from 20 pphm to 10 pphm. The hourly Muswellbrook SO2 level of 12.3 pphm occurred on 4 February, meeting the benchmark at the time but exceeding the more stringent May 2021 benchmark.

[2] PM2.5 and PM10 refer to airborne particles, less than or equal to 2.5 and 10 micrometres in diameter, respectively.

- Annual average PM10 and PM2.5 particle levels decreased significantly throughout the region in 2021 compared to earlier years (especially compared to 2019). Air quality improved significantly due to continuing high rainfall totals (Figure 16) and cooler than average maximum temperatures (Figure 17). At the end of 2021, only 7% of the state was drought affected (Figure 2), compared to 3% at the end of 2020[3] and 100% at the end of 2019[4].
- Annual average PM10 levels were within the benchmark at all stations in 2021, ranging from 11.7 µg/m^3 at Merriwa to 20.8 µg/m^3 at Warkworth.

  From 2011 to 2020, maximum annual PM10 levels ranged from 22.0 µg/m^3 in 2015 to 39.9 µg/m^3 in 2019. Annual PM10 levels were over the benchmark in 2012, 2013, 2017, 2018 and 2019. In 2012 and 2013, this occurred at the Camberwell and Maison Dieu smaller community stations and Singleton Northwest (NW) diagnostic station. In 2017, this occurred at the Camberwell smaller community station and Mount Thorley diagnostic station. In 2018, this occurred at Muswellbrook large population centre, Camberwell, Maison Dieu and Warkworth smaller community stations and Mount Thorley and Singleton NW diagnostic stations. In 2019, this occurred at all 14 stations, during extreme drought and bushfire conditions.
- Annual average PM2.5 levels were within the benchmark at all stations in 2021, ranging from 4.2 µg/m^3 at Merriwa to 7.3 µg/m^3 at Muswellbrook. This is the first year, since monitoring began, that Muswellbrook recorded annual average PM2.5 levels within the benchmark.

  From 2011 to 2020, maximum annual PM2.5 levels ranged from 8.4 µg/m^3 in 2016 to 12.2 µg/m^3 in 2019. Annual PM2.5 levels were over the benchmark each year at Muswellbrook, and for 3 years at Camberwell in 2013, 2018 and 2019 and 4 years at Singleton in 2017, 2018, 2019 and 2020. Smoke from domestic wood heaters contributes significantly to particle levels at larger population centres[5].

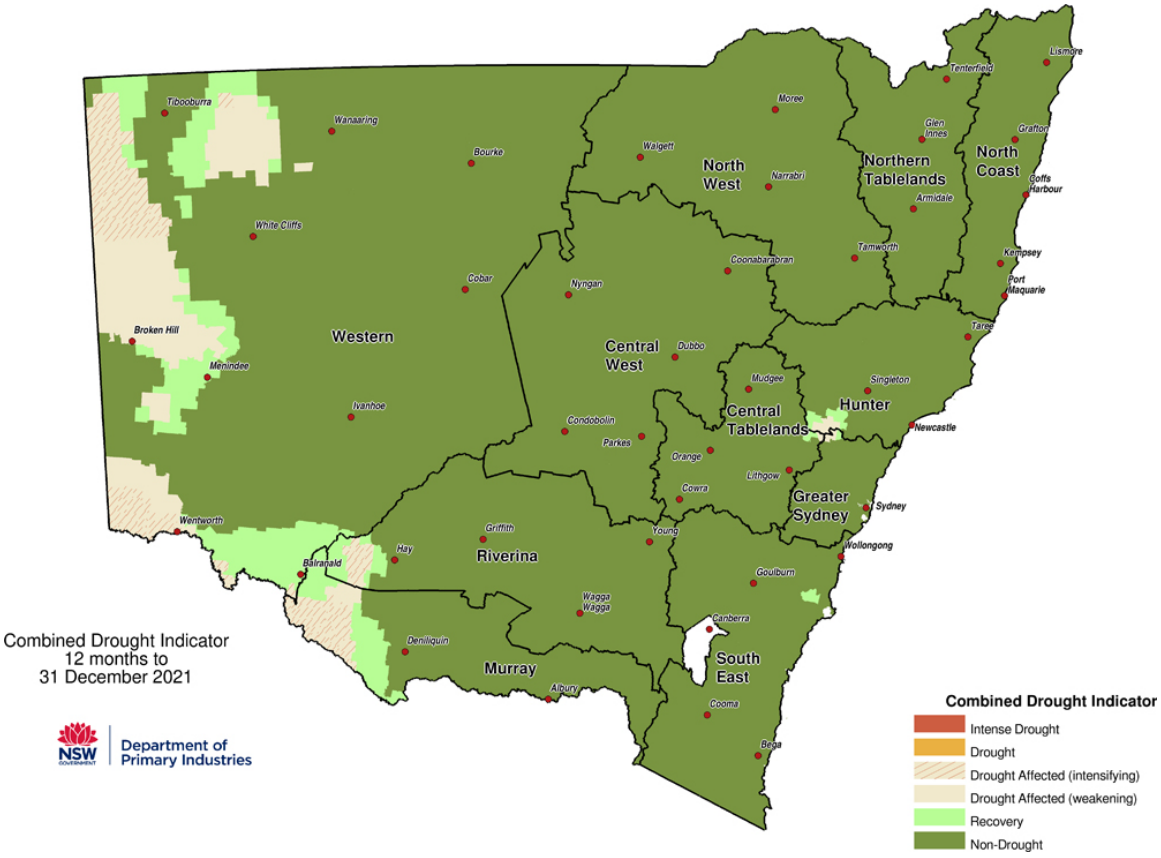

Figure 2 Department of Primary Industries NSW Combined Drought Indicator to 31 December 2021[6]

[3] Sourced from Department of Primary Industries NSW State seasonal update – December 2020 (accessed January 2023)

[4] Sourced from Department of Primary Industries NSW State seasonal update – December 2019 (accessed January 2023)

[5] The Upper Hunter Fine Particle Characterisation Study found smoke from domestic wood heaters contributed significantly to PM2.5 levels in Muswellbrook and Singleton.

[6] Sourced from the Department of Primary Industries NSW State seasonal update – December 2021 (accessed January 2023).

Days above benchmark concentrations

There were 6 days over the daily PM10 particle benchmark during 2021 across multiple locations and no days over the PM2.5 benchmark (Table 1 and Table 2). Particle levels were within national benchmarks between 98.6% of days at Mt Thorley and 100% of days at Aberdeen, Bulga, Jerrys Plains, Merriwa, Muswellbrook, Muswellbrook NW and Wybong during 2021 (Figure 3).

For PM10, 5 days (83% of PM10 event days) occurred in September and October. Wind speeds were at their highest during spring (Figure 19) and this was prior to record rainfall levels in November.

Gases are measured at Merriwa, Muswellbrook and Singleton in the Upper Hunter.

- All days were within the NO_2 8 pphm hourly benchmark at all stations. The maximum hourly NO_2 level in the region was 3.2 pphm, recorded at Merriwa on 27 April 2021, Muswellbrook on 8 September 2021 and Singleton on 11 September 2021.
- All stations recorded annual NO_2 levels within the 1.5 pphm annual benchmark at all stations. The maximum annual NO_2 level in the region was 0.8 pphm, measured at Muswellbrook.
- All days were within the SO_2 2 pphm daily benchmark at all stations. The maximum daily SO_2 level in the region was 1.6 pphm, measured at Muswellbrook on 29 January 2021.
- All days were within SO_2 10 pphm hourly benchmark at Merriwa and Singleton. Muswellbrook recorded an hourly SO_2 level of 12.3 pphm on 4 February 2021, exceeding the new benchmark.

Table 1 Number of days above the relevant national benchmarks 2021

Station type*	Station	PM10 daily (50 µg/m³ benchmark)	PM2.5 daily (25 µg/m³ benchmark)	SO_2 hourly (10 pphm benchmark)	SO_2 daily (2 pphm benchmark)	NO_2 hourly (8 pphm benchmark)
Population centre	**Aberdeen**	0	-	-	-	-
Population centre	**Muswellbrook**	0	0	1#	0	0
Population centre	**Singleton**	1	0	0	0	0
Smaller community	**Bulga**	0	-	-	-	-
Smaller community	**Camberwell**	4	0	-	-	-
Smaller community	**Jerrys Plains**	0	-	-	-	-
Smaller community	**Maison Dieu**	1	-	-	-	-
Smaller community	**Warkworth**	4	-	-	-	-
Smaller community	**Wybong**	0	-	-	-	-
Diagnostic	**Mount Thorley**	5	-	-	-	-
Diagnostic	**Muswellbrook NW**	0	-	-	-	-
Diagnostic	**Singleton NW**	1	-	-	-	-
Background	**Merriwa**	0	0	0	0	0
Background	**Singleton South**	2	-	-	-	-

µg/m³ = micrograms per cubic metre.
pphm = parts per hundred million by volume (i.e. parts of pollutant per hundred million parts of air)
- = not monitored.

= The hourly Muswellbrook SO_2 level of 12.3 pphm occurred on 4 February, meeting the benchmark at the time of 20 pphm but exceeding the more stringent May 2021 benchmark of 10 pphm.

* For explanation, refer to the end of the report Definitions: Upper Hunter monitoring station types.

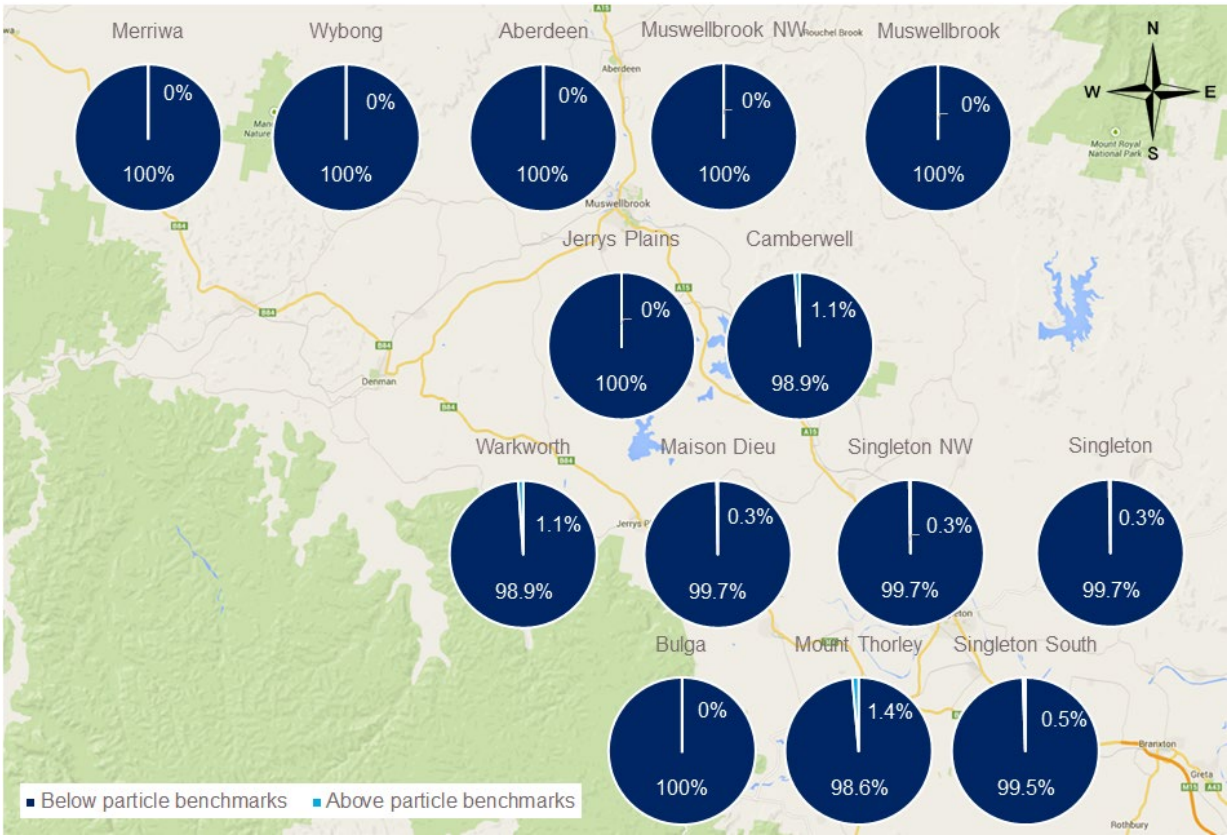

Figure 3 **Percentage of days above and below particle benchmarks across the Upper Hunter – 2021**

PM10 particle events

The number of days over the daily PM10 benchmark (PM10 particle events) at individual stations ranged from no days across half the network stations to 5 days at Mount Thorley diagnostic station (Table 1).

The most widespread event occurred on 29 October, with 7 stations recording PM10 levels over the daily benchmark (Table 2). These stations were in the south-east of the region, around Singleton. Elevated levels were observed under moderate to fresh north westerly winds. This was an exceptional event due to long-range dust transport from South Australia, combining with local dust sources.

Table 2 **Days and stations above the PM10 daily benchmark - 2021**

Date	Maximum daily PM10 (µg/m³)	Stations over benchmark	Station and daily PM10 (µg/m³) for each station type			
			Larger population	Smaller community	Diagnostic	Background
15/04/21	53.7	1	-	-	-	Singleton South (53.7)
12/09/21	65.6	3	-	Camberwell (64.3), Warkworth (64.1)	Mount Thorley (65.6)	-
24/09/21	53.3	1	-	-	Mount Thorley (53.3)	-
07/10/21	63.6	3	-	Camberwell (60.6), Warkworth (63.6)	Mount Thorley (58.6)	-
10/10/21	55.8	3	-	Camberwell (50.7), Warkworth (55.8)	Mount Thorley (55.3)	-
29/10/21	82.0	7	Singleton (58.2)	Camberwell (75.5), Maison Dieu (61.7), Warkworth (82.0)	Mount Thorley (70.5), Singleton NW (57.6)	Singleton South (58.2)

PM2.5 particle events

There were no days over the PM2.5 daily benchmark throughout the region (Table 1). The regional maximum daily PM2.5 level in 2021 was 19.7 µg/m³, measured at Muswellbrook on 8 July 2021.

Pollution roses

The PM10 and PM2.5 pollution rose maps[7] show hourly PM10 and PM2.5 concentrations, under dominant north-west and south-east prevailing winds in the Upper Hunter (Figure 4 and Figure 5). The pollution roses show that hourly PM10 and PM2.5 levels[8] were predominantly low during 2021.

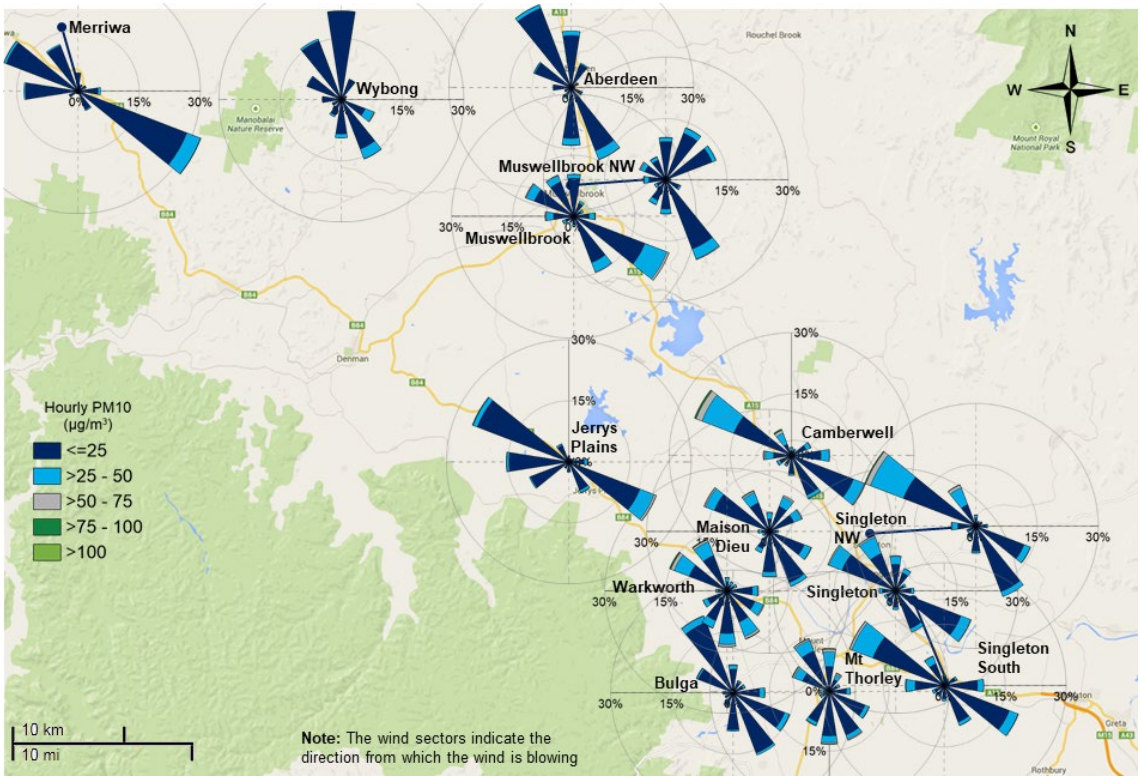

Figure 4 Hourly PM10 pollution rose map for the Upper Hunter region – 2021

Figure 5 Hourly PM2.5 pollution rose map for the Upper Hunter region – 2021

[7] Pollution roses show the wind direction and particle levels at a location. The length of each bar shows the percentage of time the wind blows from that compass direction. The colours along the bars indicate the particle levels, as presented in the key.

[8] There are no standards for hourly PM10 or PM2.5 in the National Environment Protection (Ambient Air Quality) Measure.

Daily time series plots

Figure 6 to Figure 13 show daily average time series plots for PM10, PM2.5 and SO_2 and daily one-hour maximum plots for NO_2 and SO_2. The shaded areas in the figures indicate the seasons. Elevated PM10 levels were mainly observed during spring, when higher wind speeds occurred.

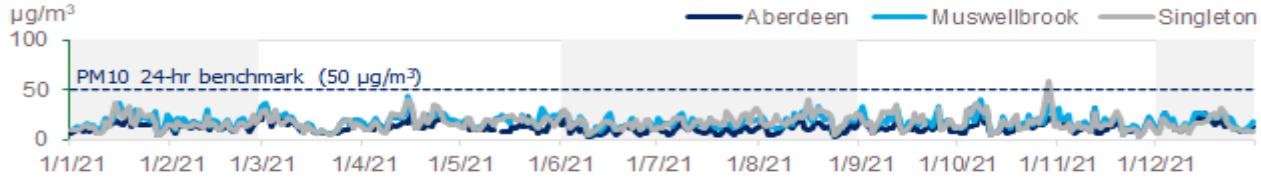

Figure 6 **Population centre stations: daily average PM10 – 2021**

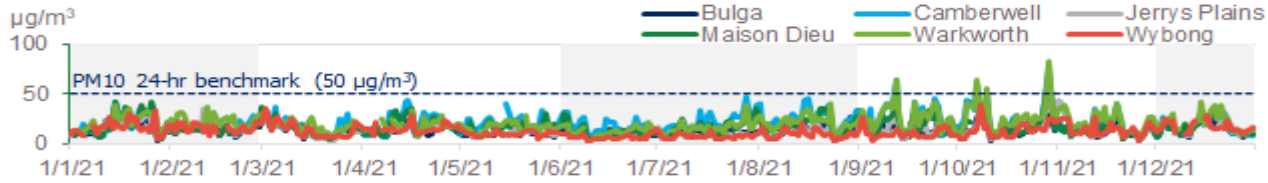

Figure 7 **Smaller community stations: daily average PM10 – 2021**

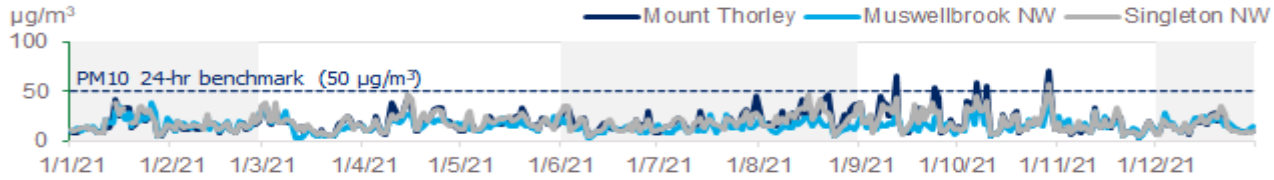

Figure 8 **Diagnostic stations: daily average PM10 – 2021**

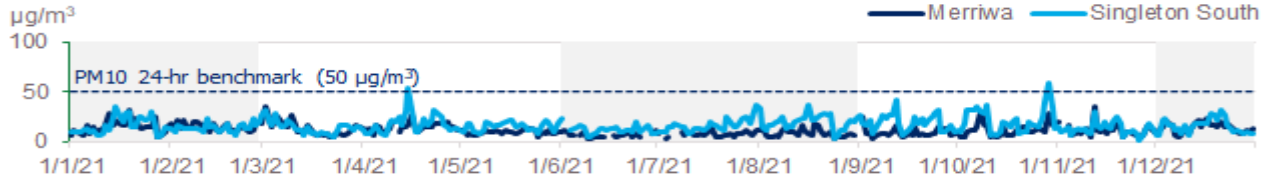

Figure 9 **Background stations: daily average PM10 – 2021**

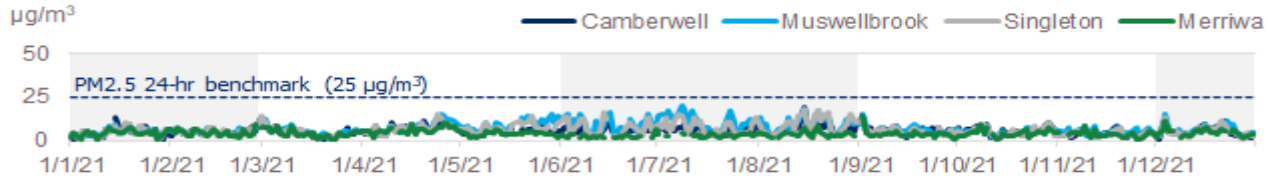

Figure 10 **Daily average PM2.5 – 2021**

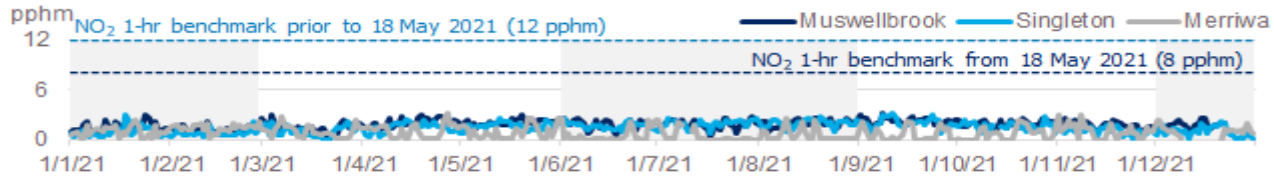

Figure 11 **Daily 1-hr maximum NO_2 – 2021**

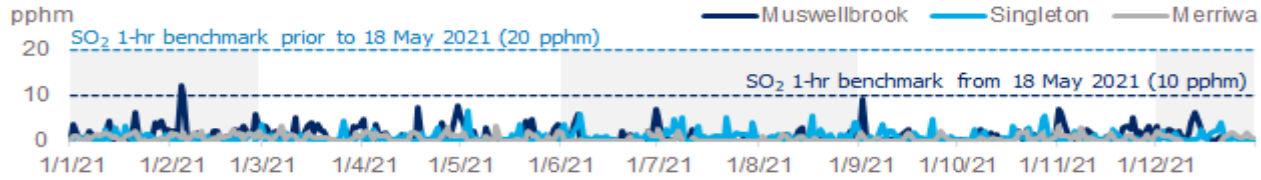

Figure 12 **Daily 1-hr maximum SO_2 – 2021**

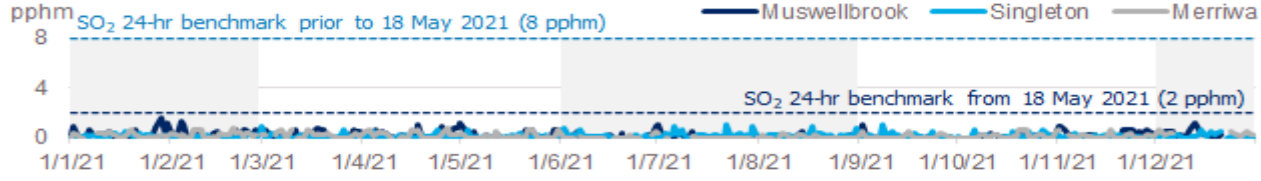

Figure 13 **Daily average SO_2 – 2021**

Annual comparisons 2012 to 2021

Hourly and annual NO_2 levels were within the new benchmarks in 2021. This is the same as all previous years.

Hourly SO_2 levels remained within the new more stringent 10 pphm benchmark[9] at Merriwa and Singleton in 2021. At Muswellbrook, there was 1 hour over the new benchmark on 4 February 2021, reaching 12.3 pphm. Previously, Muswellbrook alone would have exceeded the new hourly SO_2 benchmark from 1 day (2012 and 2015) to 6 days (2016) (Figure 14).

Daily SO_2 levels remained within the new SO_2 daily benchmark of 2 pphm in 2021. Previously, the new daily benchmark would have been exceeded at Muswellbrook up to 2 days (2013) (Figure 14).

In 2021, the region recorded 6 days over the PM10 benchmark. This was fewer than 2020, when there were 35 days over the benchmark. The number of days over the PM10 benchmark in earlier years ranged from 14 days in 2016 to 120 days in 2019, due to prolonged intense drought, extreme bushfires and dust storms (Figure 15).

At the larger population centres in 2021, Aberdeen and Muswellbrook remained within the PM10 benchmark while there was 1 day recorded over the benchmark at Singleton, during a widespread dust storm event. Previously, 2019 had recorded the most days at these stations with 40 days at Singleton, 51 days at Aberdeen and 58 days at Muswellbrook.

For PM2.5, there were no days over the benchmark in 2021, compared to 10 days in 2020. From 2012 to 2019, there was up to 32 days over the benchmark in 2019 (Figure 15). Generally, Muswellbrook recorded the most days prior to 2019, due to domestic woodsmoke[10].

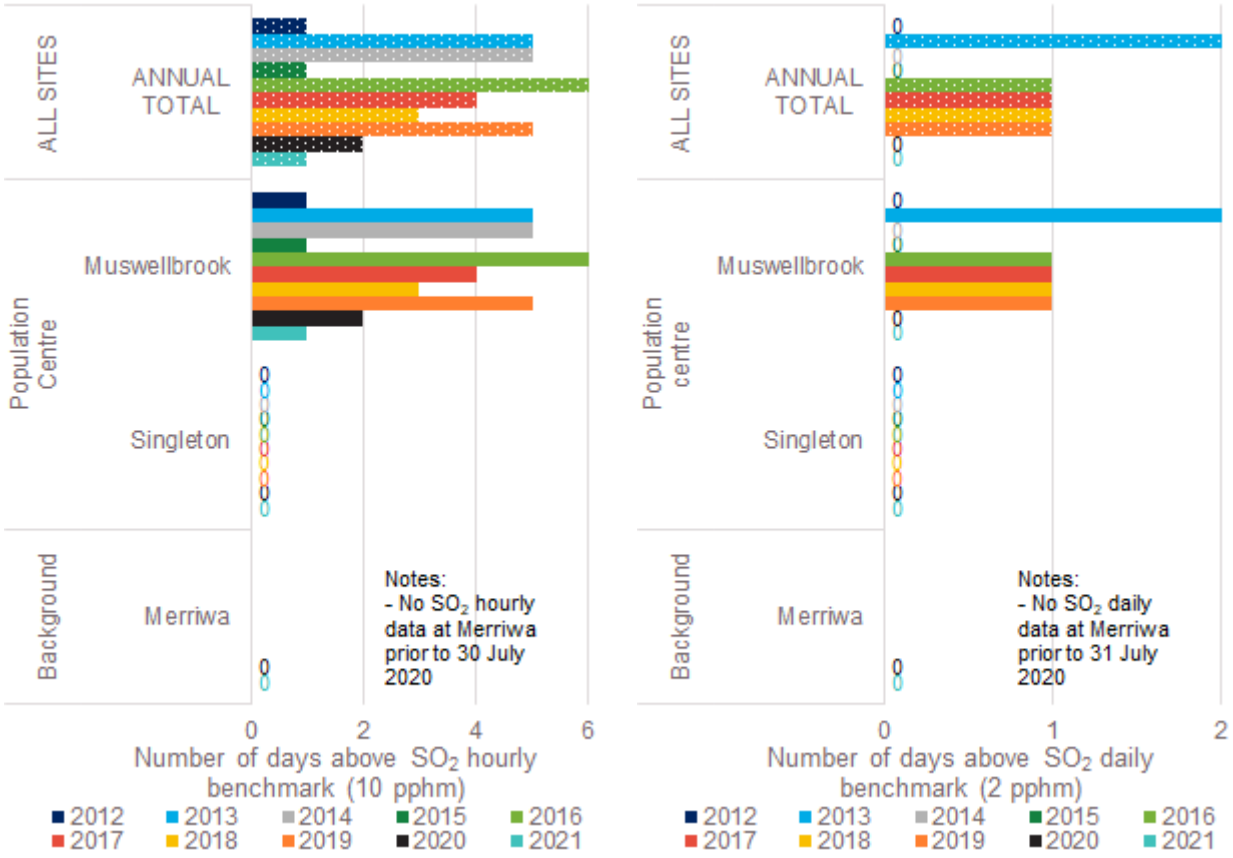

Figure 14 **Number of days above the hourly SO_2 (left) and daily SO_2 (right) benchmarks from 2012 to 2021[9]**

[9] New NO_2 and SO_2 benchmarks came into effect in May 2021 – National Environment Protection (Ambient Air Quality) Measure.

[10] The Upper Hunter Fine Particle Characterisation Study found smoke from domestic wood heaters contributes significantly to PM2.5 levels in Muswellbrook and Singleton during the cooler months.

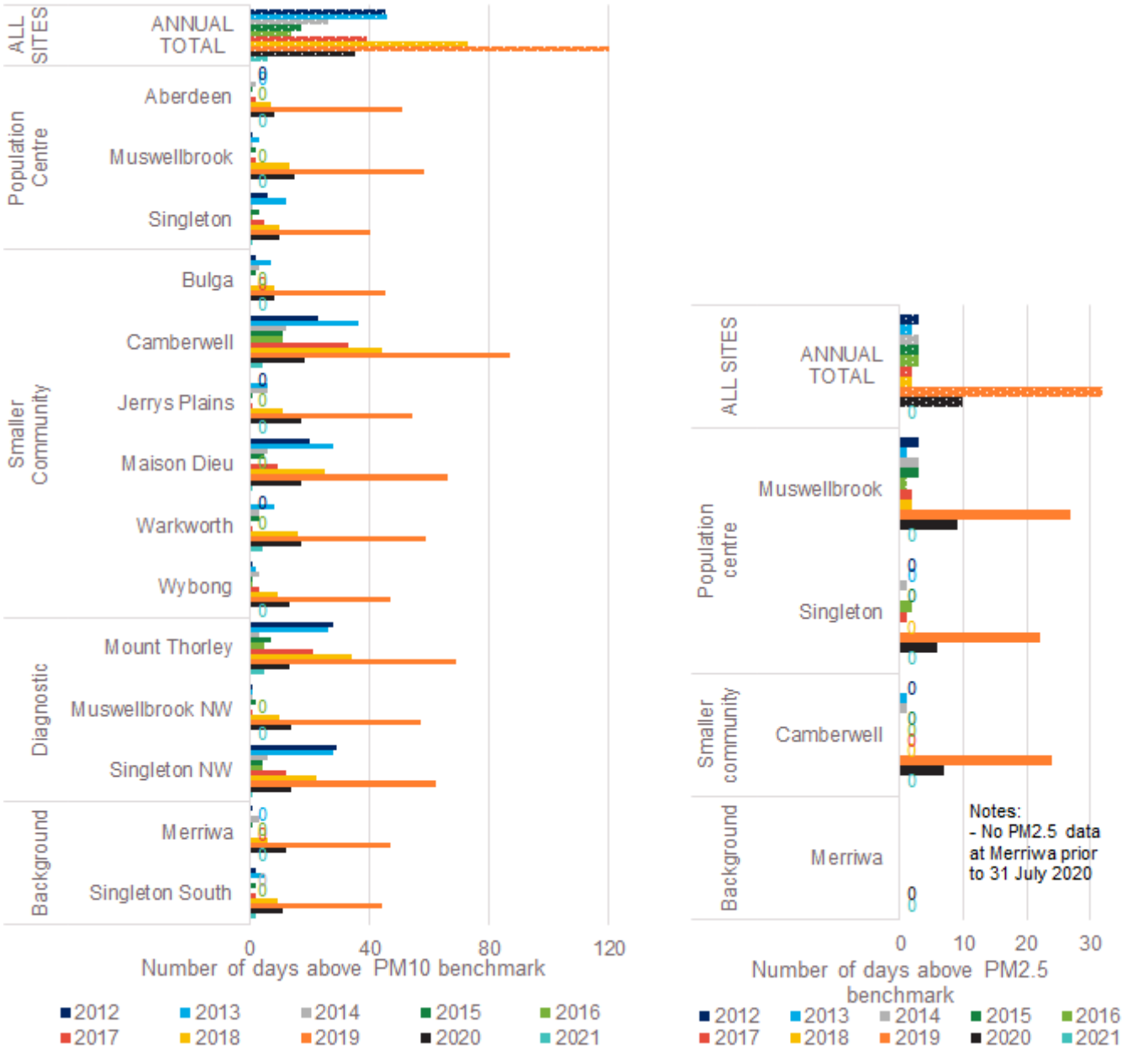

Figure 15 **Number of days above the daily PM10 (left) and PM2.5 (right) benchmarks from 2012 to 2021**

Meteorological summary

Rainfall and temperature[11]

Rainfall across the Upper Hunter was very much above average in 2021 (Figure 16). Some Bureau of Meteorology rainfall gauges recorded their highest annual total rainfall on record[12]. The region had similar rainfall levels to 2020, while it recorded rainfall totals 400 to 800 millimetres higher than 2018 and 2019. Most months in 2021 recorded average or above average rainfall (Figure 18). Rainfall levels were very much above average during March and highest on record in November.

Maximum temperatures were below average (Figure 17) and minimum temperatures were average.

[11] Rainfall and temperature information are from the Bureau of Meteorology New South Wales 2021 annual climate summary and climate maps (accessed October 2022).
[12] Bulga (South Wambo), Bulga (Down Town), Muswellbrook (Spring Creek (Castle Vale)) and Scone Airport AWS

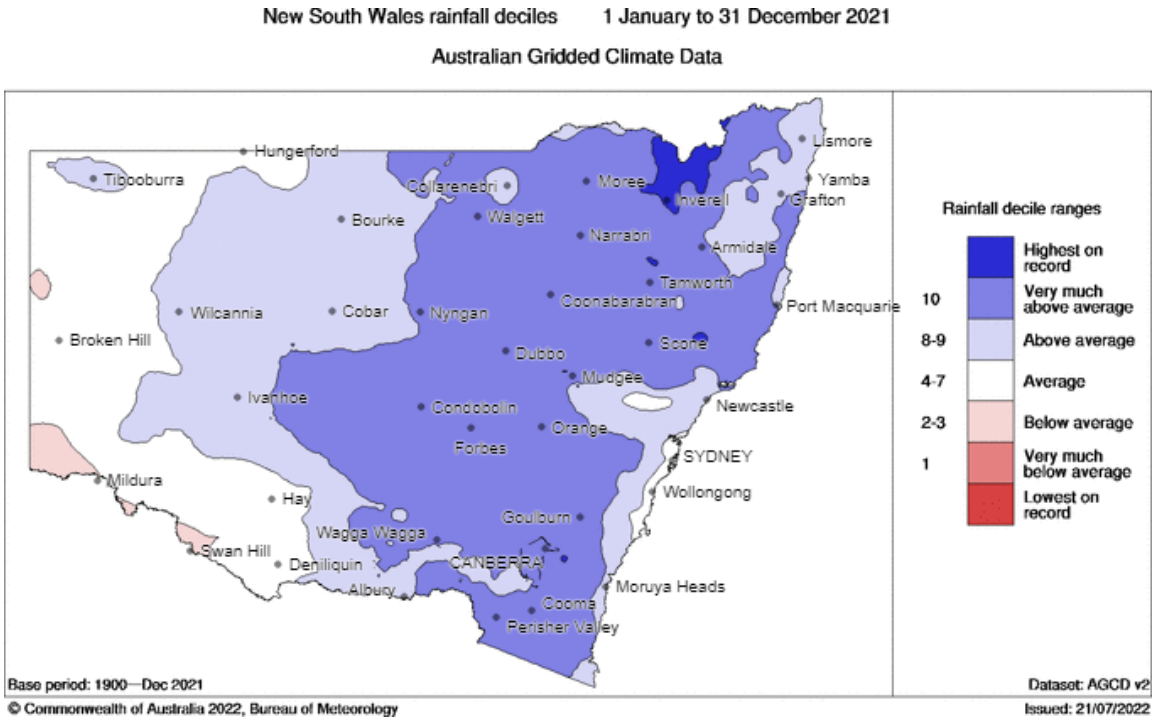

Figure 16 NSW rainfall deciles – 2021

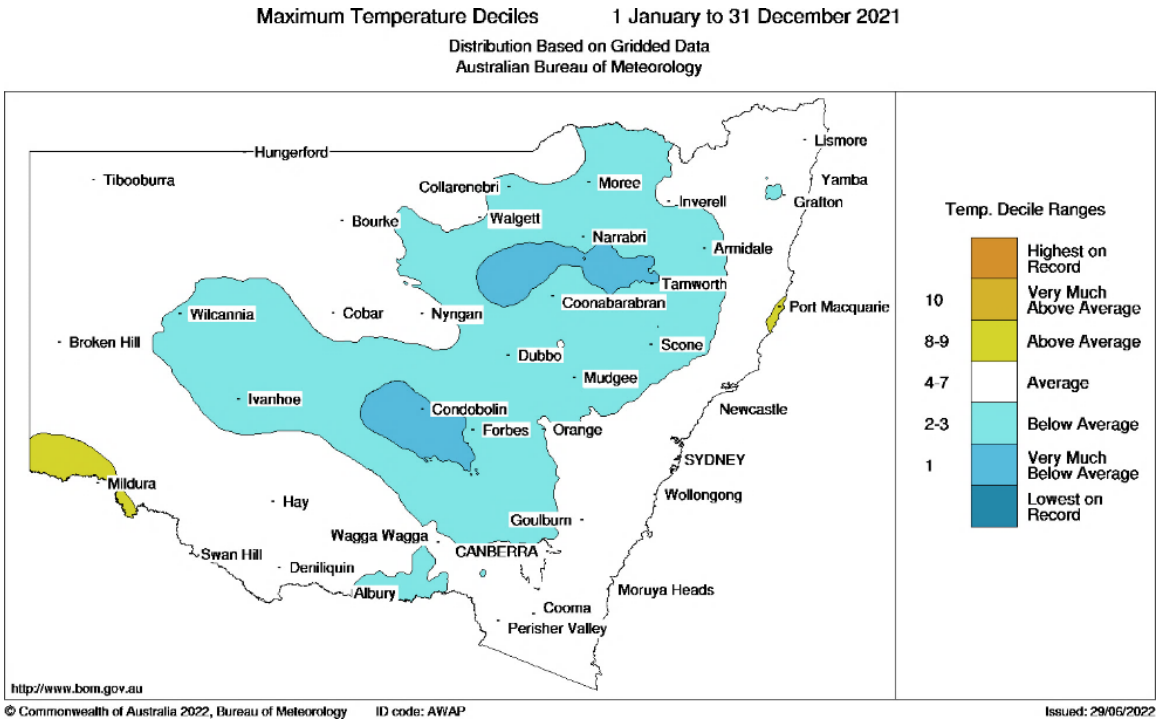

Figure 17 NSW maximum temperature deciles – 2021

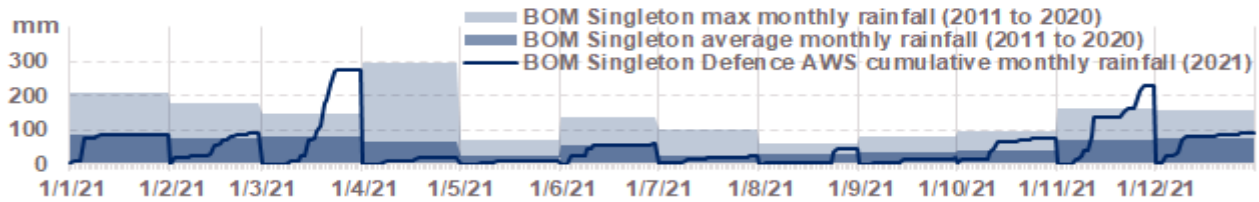

Figure 18 Bureau of Meteorology Singleton Defence AWS[13] cumulative monthly rainfall in 2021 plotted against maximum and average monthly rainfall from 2011 to 2020

[13] Sourced from the BOM Climate Data Online website (accessed October 2022). The BOM STP station was decommissioned in January 2019. Therefore, statistics have been calculated from a combination of the Singleton STP monthly rainfall data (accessed March 2020) from January 2011 to March 2017 and Singleton Defence AWS monthly rainfall data from April 2017.

Winds

Upper Hunter winds were predominantly from the south-east in summer and north-west in winter in 2021 (Figure 19). During autumn and spring, winds were variable as they turned from south-easterly to north-westerly in autumn and north-westerly to south-easterly in spring. The strongest winds were observed from the north-west in spring, followed by winter. Seasonal wind patterns observed in 2021 were typical for the region.

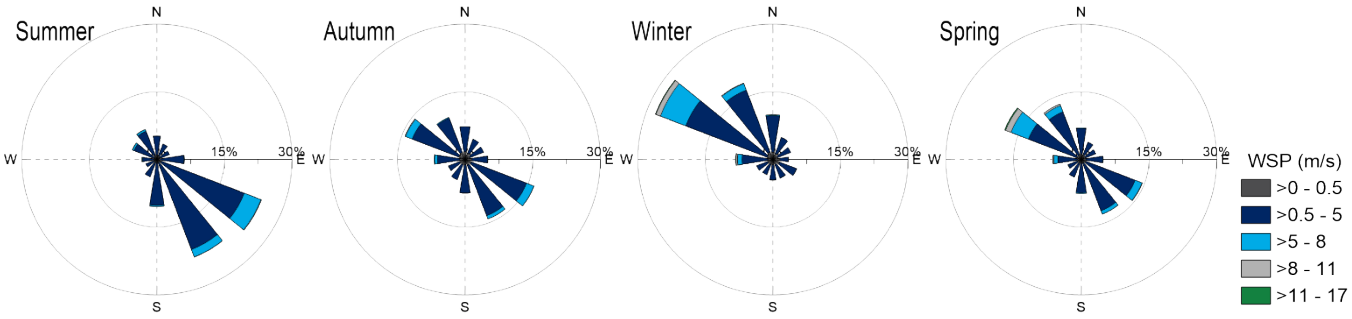

Figure 19 Seasonal wind roses using pooled wind data from all the Upper Hunter stations – 2021

Network performance

The target network performance is at least 95% available data for all parameters. The maximum online time that can be attained for NO_2 and SO_2 is 96%, due to daily calibrations.

In 2021, particle and meteorological parameters at most stations met this target (Table 3).

Table 3 Online performance (%) during 2021

Station	Particles PM10 daily	Particles PM2.5 daily	Gases SO_2 hourly	Gases NO_2 hourly	Meteorology Wind hourly
Aberdeen	99	-	-	-	100
Bulga	99	-	-	-	99
Camberwell	99	97	-	-	100
Jerrys Plains	98	-	-	-	99
Maison Dieu	97	-	-	-	98
Merriwa	96	94	89	89	96
Mount Thorley	99	-	-	-	100
Muswellbrook	99	99	92	92	100
Muswellbrook NW	99	-	-	-	99
Singleton	99	97	95	91	98
Singleton NW	99	-	-	-	99
Singleton South	99	-	-	-	98
Warkworth	95	-	-	-	98
Wybong	98	-	-	-	99

- = not monitored.

Refer to the 2021 Upper Hunter seasonal newsletters for more detail on the reduced operational times at Merriwa.

Definitions: Upper Hunter monitoring station types

The 14 monitoring stations in the Upper Hunter (Figure 20) serve different purposes.

Larger population: stations in the larger population centres monitor the air quality in these centres.

Smaller communities: stations in smaller communities monitor the air quality at those locations.

Diagnostic: stations provide data to help diagnose the likely sources and movement of particles across the region. Diagnostic stations do not provide information about air quality in population centres.

Background: the stations at Merriwa and Singleton South measure air quality at the north-west and south-east extents of the region. They provide background data by measuring the quality of air entering and leaving the Upper Hunter Valley under predominant winds (south-easterlies and north-westerlies).

The Upper Hunter Air Quality Monitoring Network is operated by the NSW Government and funded by Upper Hunter coal and power industries, in accordance with the Protection of the Environment Operations (General) Regulation 2021.

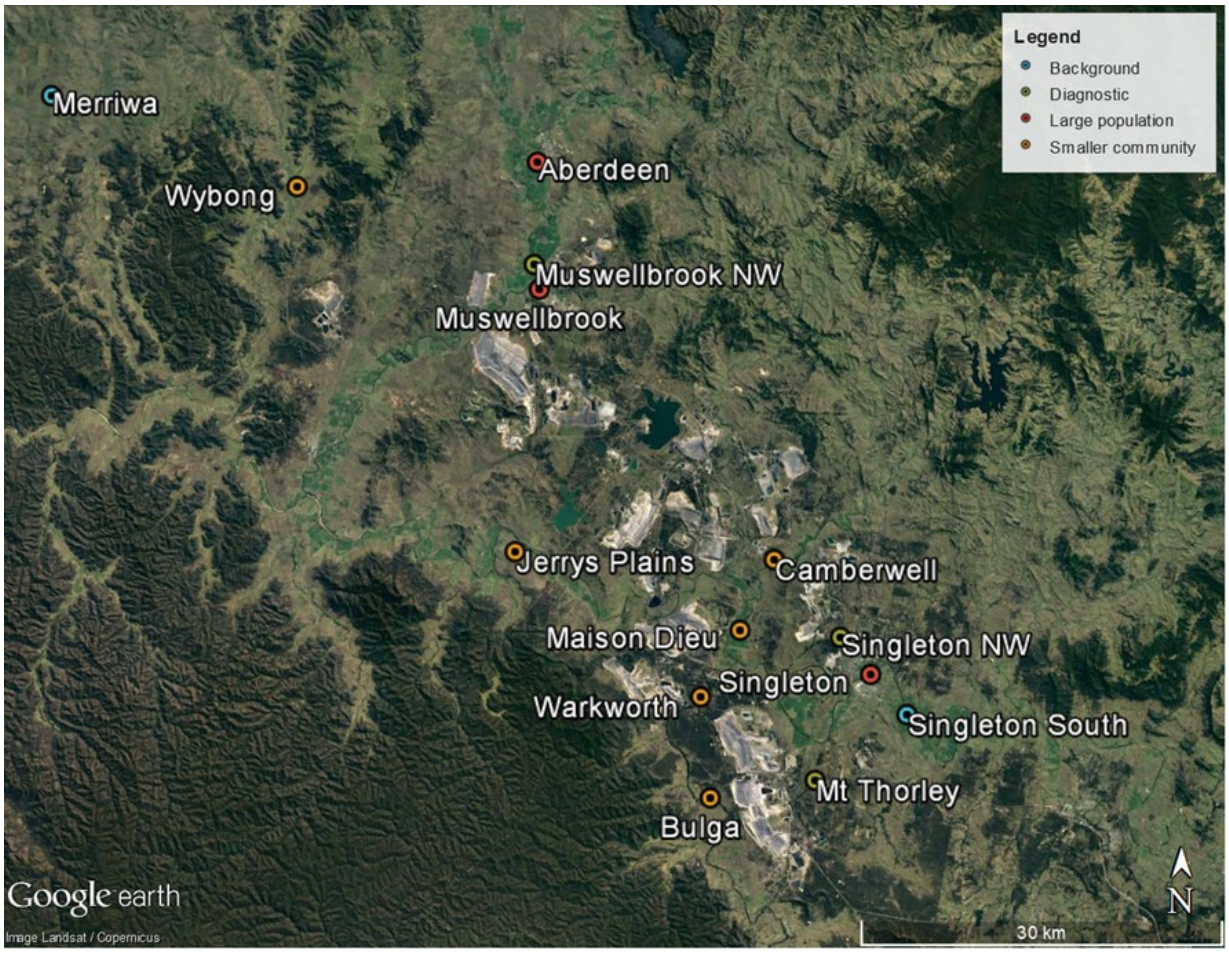

Figure 20 Upper Hunter air quality monitoring stations

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