Peace Airshed Zone Association
Box 21135 Grande Prairie, AB, T8V 6W7
P: 780-833-4343
www.paza.ca

VILLAGE OF RYCROFT

AIR QUALITY SUMMARY REPORT

MARCH 2016 TO OCTOBER 2018

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Prepared by Sirius Consulting Inc.
#100 – 111 5th Ave SW, Suite 390, Calgary, Alberta T2P 3Y6
p.403.208.6626 c.403.612.7894 f.1.866.591.5624
kas@siriusconsulting.ca www.siriusconsulting.ca

Executive Summary

The Village of Rycroft, Alberta is located about 60 km north of Grande Prairie in a rural region of mainly agriculture activity. The Peace Airshed Zone Association (PAZA) conducted an air quality survey near Rycroft from March 2016 to October 2018. The air quality survey was undertaken as a response to emergent local concerns around air quality stemming from new industrial activity in the area and the location was also identified as an area of interest in PAZA's 2013 Network Assessment. A new waste disposal facility was opened less than 1 km east of the monitoring location.

The PAZA roving monitoring station was used to continuously measure the following data during that period:

- Total reduced sulphur compounds (TRS);
- Sulphur dioxide (SO_2):
- Oxides of nitrogen (NO, NO_2, and NO_x);
- Ozone (O_3);
- Fine particulate matter ($PM_{2.5}$);
- Hydrocarbons (Total hydrocarbons (THC), Methane (CH_4) and Non-methane Hydrocarbons (NMHC); and
- Meteorology (Wind speed and Direction, and Temperature)

There were no exceedances of Alberta Ambient Air Quality Objectives (AAAQO) for TRS components, SO_2, NO_2, or O_3 measured at the monitoring station. Of the oxides of nitrogen, only NO_2 has an AAAQO. The $PM_{2.5}$ measurements show that the Alberta Ambient Air Quality Guideline (AAAQG) and AAAQO were exceeded infrequently during the monitoring period likely due to forest fires. The results are summarized as follows:

- The overall TRS measurements may be infrequently influenced by local agriculture or industry but in general measurements are indicative of low background levels.
- The data indicates that SO_2 levels in the area are generally low inferring that there are no significant sources of SO_2 in the area. The bias of higher average concentrations toward certain wind directions may be a sign of influence from long range transport from other industrial sources to the south.
- The ambient NO_2 data measured in Rycroft appears to suggest that local industry or rail traffic could be the main contributor to the measurements which is not unexpected given the location of the monitor. However, measurements are considered to be reflective of a typical rural setting.
- O_3 measurements are comparable with other areas in province. A typical diurnal profile is present in the O_3 measurements and relates with the diurnal patterns of NO and NO_2. This pattern shows slight photo-chemical formation and destruction of O_3 through complex

reactions with NO_x and volatile organic compounds (VOCs). The Rycroft monitor operated for 32 months and any measurements that were influenced by exceptional events have not been removed, and therefore, the results cannot be explicitly related to the Canadian Ambient Air Quality Standards (CAAQS) for O_3.

- Exceedances of the 1-hour $PM_{2.5}$ AAAQG were measured which in turn, led to calculated exceedances of the 24-hour AAAQO. It is likely that the elevated measurements were due to forest fires and do not indicate on-going air quality problems in the region; however, this was not investigated. The Rycroft monitor operated for only 32 months and any measurements that were influenced by exceptional events have not been removed, and therefore, the results cannot be explicitly related to the CAAQS. In general, $PM_{2.5}$ measurements were slightly lower than other areas in the province.
- Ambient measurements of THC in the area indicate the levels are slightly lower than other monitors in the province for the same time period. Very infrequent elevated concentrations of NMHC were measured; however the majority of NMHC measurements were zero suggesting the elevated measurements are not indicative of any air quality issues. Concentrations of specific hydrocarbons cannot be inferred from the data collected. For the most part, the THC and CH_4 measurements were essentially equal, and hence, the analysis focused on the THC measurements.
- Meteorology measurements indicate that the most frequent winds were from the southwest sector. As well, the highest wind speeds most frequently occur from the westerly directions.

The summary of the air quality survey in Rycroft is limited to the parameters measured in this study. Air quality surrounding the monitor may be affected by other compounds that PAZA was not equipped to measure such as speciated hydrocarbons, VOCs or ammonia.

The volume of data collected indicates that the air quality in this area is relatively good and is comparable to other rural areas in Alberta. A waste disposal facility and rail traffic close to the monitor appear to have influenced the TRS, NO_2 and THC measurements but not adversely.

Concentrations in excess of the AAAQO and AAAQG are likely due to exceptional events (forest fires) and do not necessarily indicate poor air quality in the area but do suggest that there are events and emissions sources that can influence the quality of the local air from time to time. It is recommended that PAZA consider looking into the possible contributors to the elevated $PM_{2.5}$ measurements to definitely determine if exceptional events were the cause.

Although the very infrequent elevated NMHC measurements are not necessarily a cause for concern, canister sampling for specific hydrocarbons or VOCs such as benzene, may provide further helpful information.

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1. INTRODUCTION

The Peace Airshed Zone Association (PAZA) is a nonprofit, multi-stakeholder organization that conducts ambient air quality monitoring in northwestern Alberta. PAZA is an unbiased, open and transparent organization, and our members collaborate to provide local solutions to local air quality concerns.

PAZA was formed in March 1999 in response to air quality concerns in the Peace region. As an independent third-party, PAZA has invested ten years into building trust among members of the public, industry, non-governmental organizations, Alberta Environment and Parks (AEP), Alberta Energy Regulator (AER), and Alberta Health Services.

The air quality monitoring program is a resource for the public to become informed about local air quality. Members work collaboratively to produce scientifically defensible data that can be used by stakeholders to ensure continuous improvement of regional air quality, protect environmental health, and influence public policy.

In 2003, PAZA became the fifth airshed zone in Alberta recognized by the Clean Air Strategic Alliance (CASA).

PAZA operates under the guidelines developed in the *CASA Airshed Zone Guidelines*. These guidelines include management by consensus, representation from affected stakeholders and public accessibility to data and information from monitoring activities.

Consensus is reached when there is unanimous agreement among our stakeholders, ensuring each one can live with the outcome of the decision. Stakeholders may not achieve all their goals, but the objective is to find the optimal solution that includes something for everyone. Decisions made through consensus processes are likely to be more innovative and longer lasting than those reached through traditional negotiation or top-down hierarchy.

Airshed zones are a key component in Alberta's strategy for the management of air quality within Alberta.

PAZA is funded by compulsory and voluntary membership through a funding mechanism which is based on calculated relative impacts to air quality within the PAZA boundaries. For more information about PAZA and regional air quality, please visit PAZA's web site[1].

PAZA currently operates a network of seven continuous monitoring stations and 32 passive monitoring stations that collectively monitor air quality across the airshed. One of these continuous stations is a portable or roving continuous monitoring station that is used to respond to various concerns. This roving station was setup from March 2016 to October 2018 near the Village of Rycroft (Rycroft) as a response to local landowners concerns over a nearby industrial facility and also because it was identified as an area of interest in PAZA's 2013 Network Assessment.

[1] http://www.paza.ca/

2. SITE SETTING

The air quality monitoring station was proposed to be located near Rycroft and the final site location was based on the following considerations while accounting for AEP's siting criteria. The siting criteria can be obtained from PAZA.

- Considerations
  - Current and future landowner(s)
  - Potential future land use change (avoid roads and right-of-ways)
  - All weather access
  - Power availability
  - Maximum security
- AEP Air Monitoring Directive (AMD) Siting Criteria
  - Away from nearby emission sources such as roads, oil and gas wells/batteries, gas processing plants, maintenance/fueling areas, etc.
  - Avoid low-lying areas and high areas to prevent local air flow biases
  - An open area away from buildings and tree canopies to ensure representative flows are recorded and to ensure passive samplers are appropriately exposed
  - Stations cannot be located in pastures because of potential damage

Accounting for the above criteria and considerations, the monitor that was used for the air quality survey was placed on private land just west of Range Road 45 and about 1 km south of Highway 49 on LSD 8-7-78-4 W6M. The geographic and projected coordinates of the site are:

- 55° 44' 31.4" N, 118° 35' 51.8" W (NAD 83)
- 55.742056° N, 118.597722° W (NAD 83)
- 399,696 m E, 6,178,528 m N (UTM Zone 11 – NAD 83)

The Rycroft monitor is about 6 km east-southeast of Rycroft and 60 km north-northeast of Grande Prairie A regional area map is shown in Figure 2.1. The PAZA monitoring network is shown in Figure 2.2. Figure 2.3 shows the local setting around the monitoring station. Photos of the monitoring station and views from it are shown in Figure 2.4.

The closest major industry to the monitor is a Secure Energy Waste Disposal Facility (Full Service Rail) which is located about 800 m to the west. Agriculture is the major activity in the local area. There is limited oil and gas activity in the area. The closest major road is Highway 49 which runs east/west about 1 km north of the monitor. According to Alberta Transportation, the Average Annual Daily Traffic Volume on that section of Highway 49 in 2016 to 2018[2] ranged from 1,140 to 1,240 vehicles/day. As well, a Canadian National railway east/west spur is located 100 m south of the monitor. The railway appears to service local interests and is not a major thoroughfare in the rail network. The amount of the rail traffic is not readily available.

[2] https://open.alberta.ca/opendata/traffic-volumes-at-points-on-the-highway

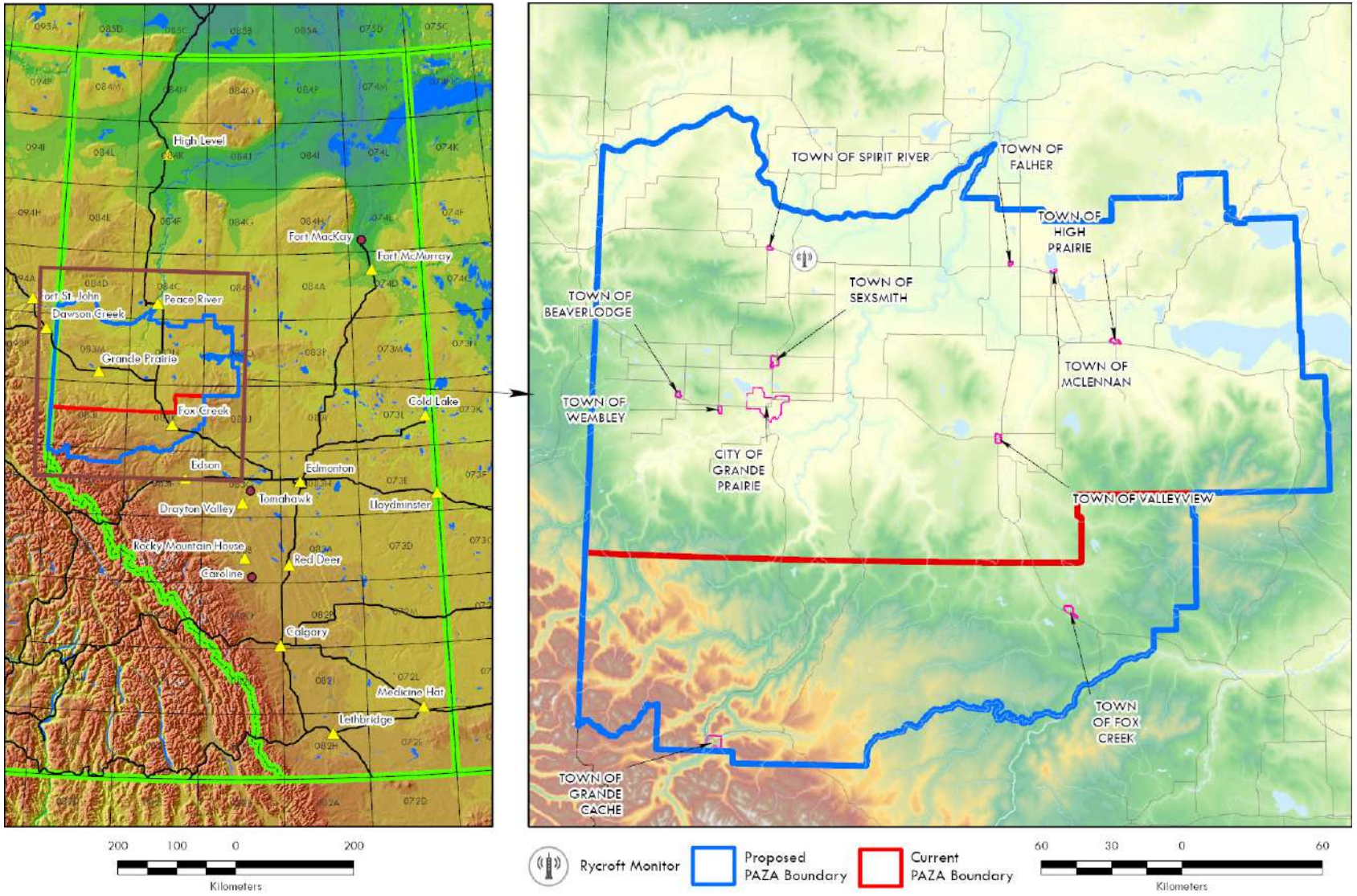

Figure 2.1 Regional Area Map showing location Rycroft and PAZA

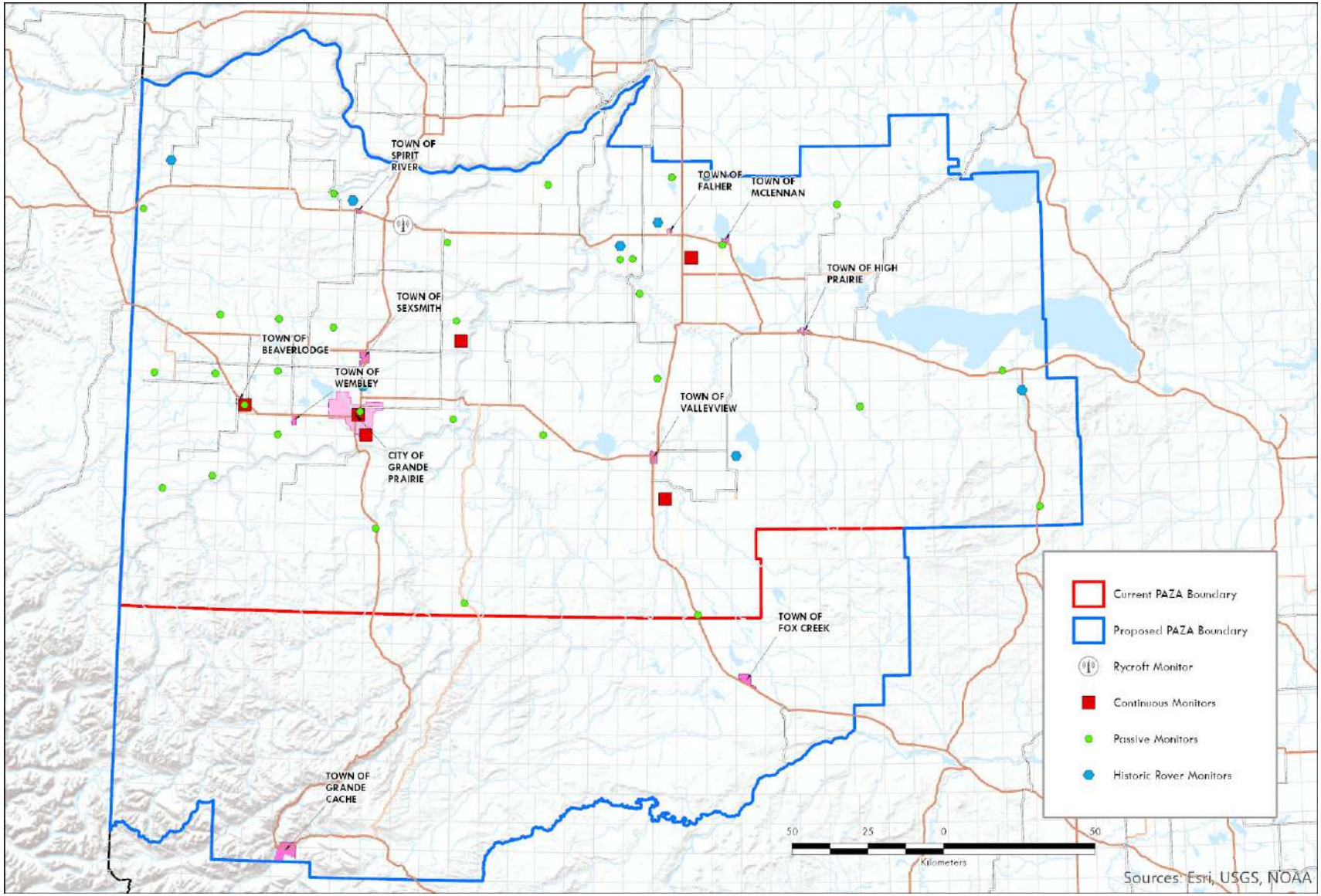

Figure 2.2 PAZA Monitoring Locations

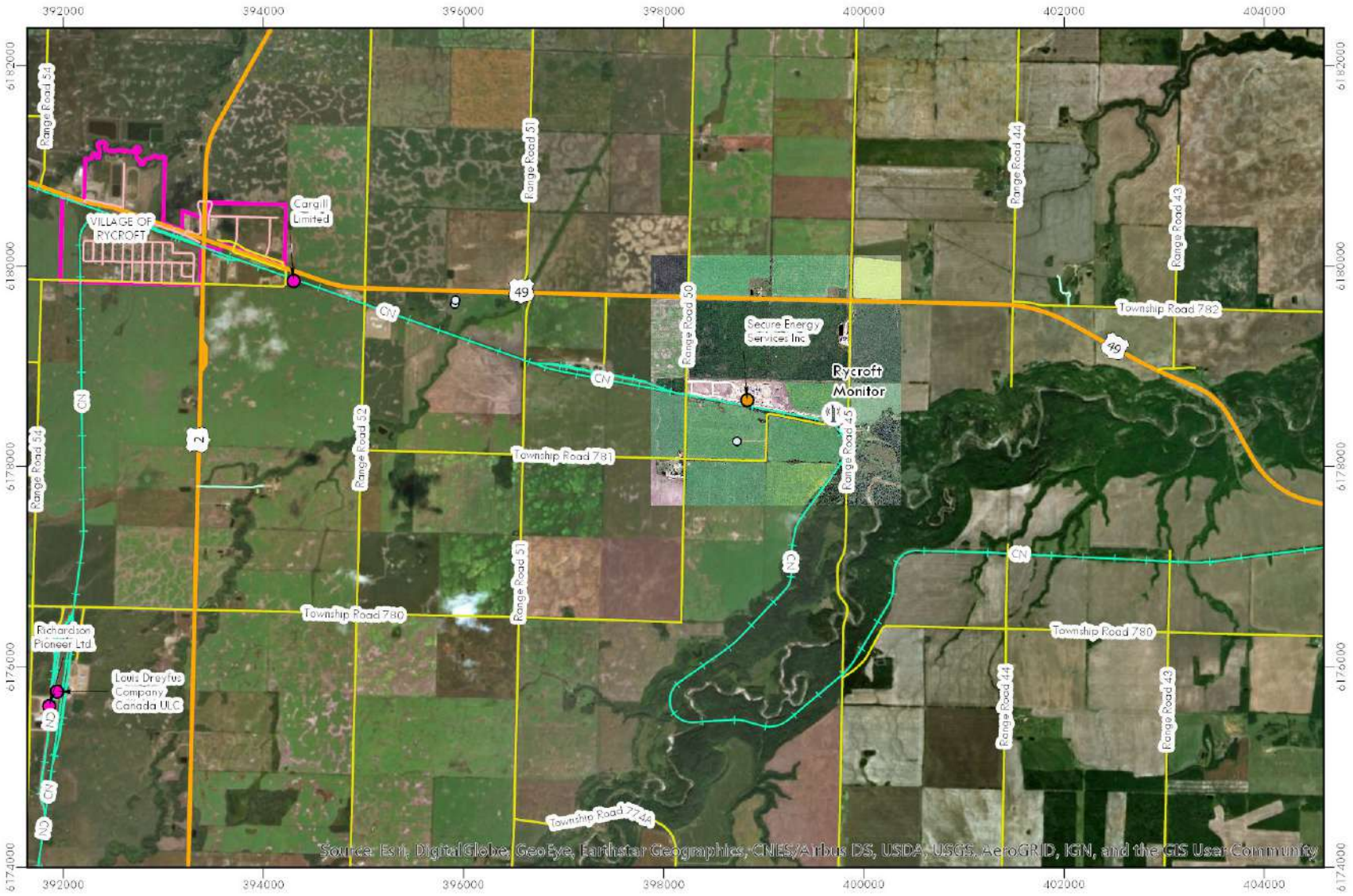

Figure 2.3 Local setting around Rycroft Monitor


Looking North


Looking South


Looking East


Looking West


Monitoring Trailer


Monitoring Trailer (on right)

Figure 2.4 Views from and of Rycroft Monitoring Station

3. AIR MONITORING (PARAMETERS, EQUIPMENT, ETC)

The monitoring station equipment is described in Table 3.1. The continuous monitoring station sampled for Total Reduced Sulphur (TRS), sulphur dioxide (SO_2), total oxides of nitrogen (NO_x), nitric oxide (NO), nitrogen dioxide (NO_2), ozone (O_3), fine particulate matter ($PM_{2.5}$), total hydrocarbons (THC), methane (CH_4), non-methane hydrocarbons (NMHC) and meteorology (wind speed, wind direction, and ambient temperature). Sampling occurred every second and 1-hour averages were calculated from the 1 second samples. The data acquisition system used was the CR3000. The monitoring station operated from March 1, 2016 13:00 to October 27, 2018 07:00 (23,275 hours). The continuous monitoring equipment was operated according to the AEP Air Monitoring Directive[3] (AMD) including daily instruments checks, monthly multipoint calibrations, and annual audits conducted by AEP. The monitoring station was audited by AEP while located in Rycroft in 2017 and 2018.

The Contractor's Standard Operating Procedures (SOPs) contain information on completeness, lower detection limits, ranges, accuracy, detection and calibration methods, and zero and span deviations.. SOPs for each of the parameters measured are listed in Table 3.1. For more information on SOPs please contact PAZA.

Continuous monitoring equipment uptime and downtime during the Rycroft air quality monitoring survey is presented in Table 3.2.

[3] https://www.alberta.ca/air-monitoring-directive.aspx

Table 3.1 Monitoring Station Equipment Description

Parameter	Instrument Make and Model	Units of Measure	Sampling Height (m)	Standard Operating Procedures Document
TRS	TEI/43-I with converter	Parts per billion (ppb)	4	WAQP-1.002
SO_2	TECO/43i	ppb	4	WAQP-1.001
Oxides of Nitrogen (NO, NO_2, NO_x)	TECO/42i	ppb	4	WAQP-1.003
O_3	TECO/49i	ppb	4	WAQP-1.004
$PM_{2.5}$	TEOM, Thermo/ 1400AB; Sensor Unit	$\mu g/m^3$	4	WAQP-1.011
Hydrocarbons (THC, CH_4, NMHC)	TECO/55i	Parts per million (ppm)	4	WAQP-1.006
Wind Speed	Met One 50.5H Sonic	km/hr	10	WAQP-2.002
Wind Direction	Met One 50.5H Sonic	Degrees direction from	10	WAQP-2.002
Temperature	Met One 064-2	°C	4	WAQP-2.006

Table 3.2 Monitoring Equipment Measurement Category Occurrences

Measurement	TRS	SO_2	NO_x	$PM_{2.5}$	O_3	THC	CH_4	NMHC	Temperature	Wind Speed and Direction
Valid Reading	94.43%	94.56%	94.36%	98.92%	94.48%	92.68%	71.46%	71.52%	93.09%	99.20%
Not in Service	0.21%	0.09%	0.09%	0.01%	0.11%	0.82%	1.30%	1.30%	6.70%	0.01%
Daily Automated Zero/Span Sequence	4.26%	4.30%	4.28%	0.00%	4.27%	4.21%	3.24%	3.24%	0.00%	0.00%
Calibration	0.58%	0.55%	0.76%	0.16%	0.56%	0.65%	0.52%	0.52%	0.00%	0.00%
Not Valid[a]	0.06%	0.06%	0.06%	0.33%	0.13%	1.26%	1.17%	1.11%	0.00%	0.57%
Maintenance	0.24%	0.21%	0.23%	0.33%	0.22%	0.13%	0.13%	0.13%	0.09%	0.08%
Span (Used for Manual Span)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	22.01%	22.01%	0.00%	0.00%
Temperature Limit Exceeded	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.00%	0.00%
Power Failure	0.09%	0.09%	0.09%	0.08%	0.09%	0.09%	0.06%	0.06%	0.05%	0.08%
Data Acquisition Failure	0.03%	0.03%	0.03%	0.07%	0.03%	0.07%	0.01%	0.01%	0.06%	0.06%

a) Not Valid is defined as data collected when the instrument is operating outside normal conditions

4. AMBIENT AIR QUALITY OBJECTIVES

4.1 Alberta

The Alberta Ambient Air Quality Objectives (AAAQOs) and Guidelines (AAAQGs) for the pollutants that were measured are shown in Table 4.1[4]. Objectives are used to determine adequacy of facility design, to establish required stack heights and other release conditions and to assess compliance and evaluate facility performance. Guidelines may be used for airshed planning and management, as a general performance indicator, and to assess local concerns.

There are currently no AAAQOs for TRS. However, hydrogen sulphide (H_2S) and carbon disulphide (CS_2) are classified as reduced sulphur compounds and have AAAQOs. Of the oxides of nitrogen compounds measured, only NO_2 has AAAQOs.

There are no AAAQOs for CH_4, THC (or some of its other main constituents such as ethane or propane) nor NMHC. AAAQOs do exist for specific NMHCs such as benzene. However, concentrations of specific hydrocarbon concentrations cannot be inferred from the data collected.

Except for O_3, the AAAQO are directly comparable to measured or modelled concentrations.

4.2 Canada

The Canadian Ambient Air Quality Standards (CAAQS) are shown in Figure 4.1. The CAAQS are a key component of the Air Quality Management System to drive improvement of air quality across Canada. CAAQS currently exist for $PM_{2.5}$ and O_3. There are CAAQS proposed for SO_2 and NO_2 that will take effect in 2020.

The CAAQS are compared to specific statistics of measured data that has removed the contribution of exceptional events such as forest fires. Except for annual NO_2 and SO_2, all the CAAQS involve a statistic over 3 years of monitored data. Since the Rycroft monitoring station only operated for about 32 months, direct comparison to the CAAQS cannot be made. Additionally, the contribution of exceptional events have not been removed from the Rycroft data.

[4] https://open.alberta.ca/publications/9781460134856

Table 4.1 Alberta Ambient Air Quality Objectives (AAAQO)and Guidelines (AAAQG).

Pollutant	Averaging Period				
	1-hr (ppb)	8-hr (ppb)	24-hr (ppb)	30 day (ppb)	Annual (ppb)
TRS	10 (H_2S) 10 (CS_2)	-	3 (H_2S)		
SO_2	172	-	48	11	8
NO_2	159	-	-	-	24
O_3	76[1]		-	-	-
$PM_{2.5}$ ($\mu g/m^3$)	80 (AAAQG)	-	29	-	

Note
1. The 1-hour daily maximum.

Pollutant	Averaging Time	Numerical Value			Statistical Form
		2015	2020	2025	
Fine Particulate Matter ($PM_{2.5}$)	24-hour	28 $\mu g/m^3$	27 $\mu g/m^3$		The 3-year average of the annual 98th percentile of the daily 24-hour average concentrations
	Annual	10.0 $\mu g/m^3$	8.8 $\mu g/m^3$		The 3-year average of the annual average of all 1-hour concentrations
Ozone (O_3)	8-hour	63 ppb	62 ppb	60 ppb	The 3-year average of the annual 4th highest of the daily maximum 8-hour average ozone concentrations
Sulphur Dioxide (SO_2)	1-hour	-	70 ppb	65 ppb	The 3-year average of the annual 99th percentile of the SO_2 daily maximum 1-hour average concentrations
	Annual	-	5.0 ppb	4.0 ppb	The average over a single calendar year of all 1-hour average SO_2 concentrations
Nitrogen Dioxide (NO_2)	1-hour	-	60 ppb	42 ppb	The 3-year average of the annual 98th percentile of the daily maximum 1-hour average concentrations
	Annual	-	17.0 ppb	12.0 ppb	The average over a single calendar year of all 1-hour average concentrations

Figure 4.1 Canadian Ambient Air Quality Standards (CAAQS).[5]

[5] http://airquality-qualitedelair.ccme.ca/en/

5. MONITORING RESULTS

This report provides an overall summary of the monitoring data; the detailed one-hour monitoring data results are available on the PAZA website, monthly and annual reports and at the AEP Air Data Warehouse[6].

In the sections that follow, several summary statistics are used in the discussion of monitoring results including the average, maximum, minimum, and percentile concentrations. An n^{th} percentile concentration indicates that n percent of data are less than that concentration, and (100 – n) percent of data are greater than that concentration. For example, a dataset with a 90^{th} percentile concentration of 50 ppb indicates that 90 % of the data will be less than 50 ppb and 10 % percent of the data will be greater than 50 ppb.

Frequency distributions and data distributions by wind direction known as wind, pollution or data roses depending on the data being analyzed are presented to help identify potential sources of pollutants.

Comparison with other areas of the province was undertaken using ambient measurements from the following locations for the same time period as the Rycroft monitoring. The locations of these stations are shown in Figure 2.1 and Figure 2.2.

- Beaverlodge (PAZA)
  - Small urban
- Evergreen Park – Grande Prairie (PAZA)
  - Small urban
- Henry Pirker – Grande Prairie (PAZA)
  - Small urban
- Caroline
  - Rural
- Calgary SE
  - Urban
- Cold Lake South
  - Small urban
- Fort McKay
  - Rural – near oil sands
- Tomahawk
  - Rural

Also included is a comparison of monthly averages from the closest PAZA passive monitoring station for SO_2 and NO_2. The closest passive stations to the Rycroft monitoring location are Wanham which is 16 km to the east-southeast, and Spirit River which is 25 km to the west-northwest.

[6] http://airdata.alberta.ca/

5.1 Meteorology

The following figures illustrate the meteorological conditions recorded at the Rycroft monitoring station during the period March 1, 2016 13:00 to October 27, 2018 07:00. Figure 5.1 shows that the most frequent winds were from the southwest sector. Figure 5.2 shows the monthly temperature and wind speed distributions. Overall, the data is considered to provide a good representation of the meteorology for that area of the province.

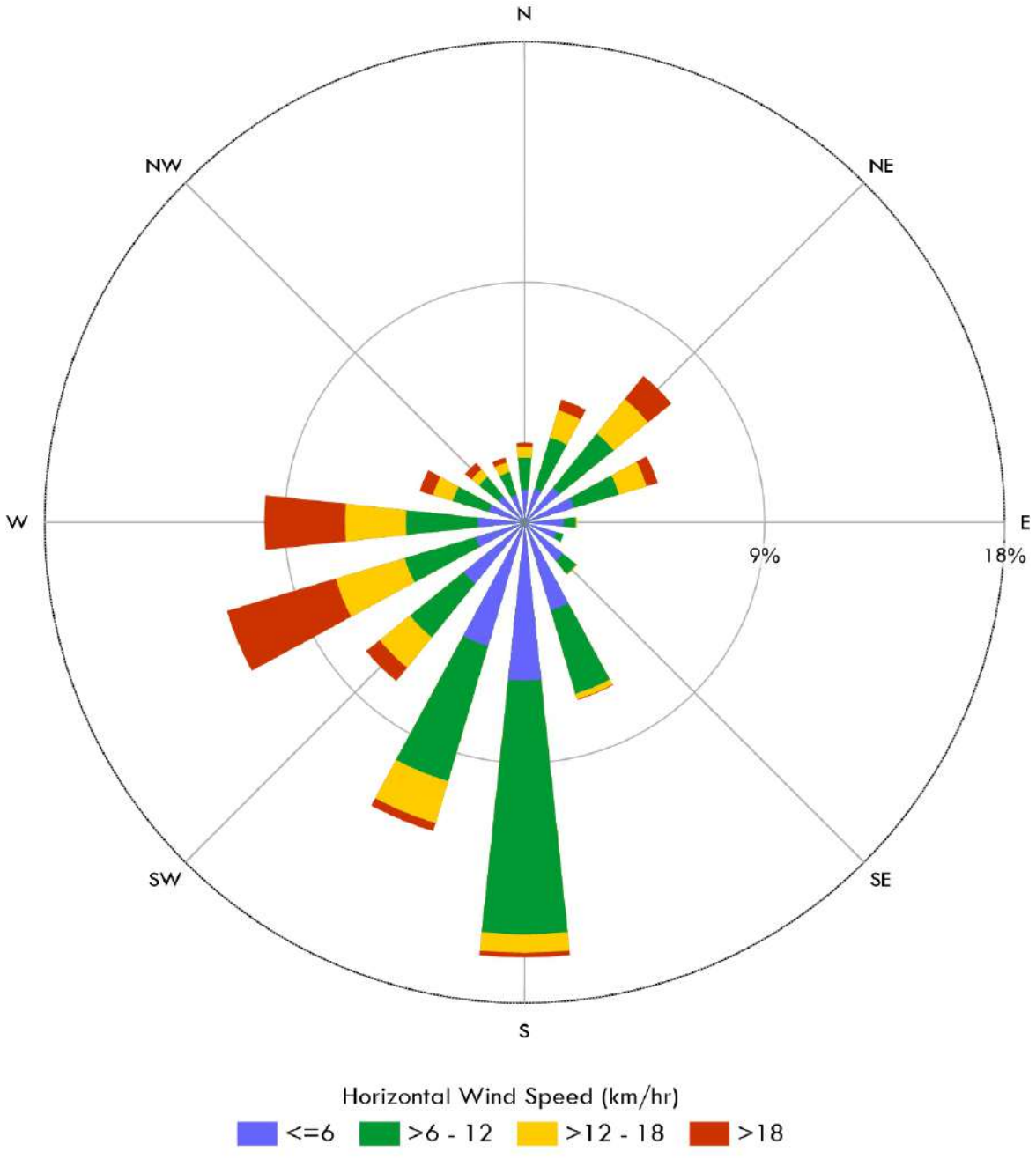

Figure 5.1 Wind Frequency Distribution at Rycroft Monitoring Station

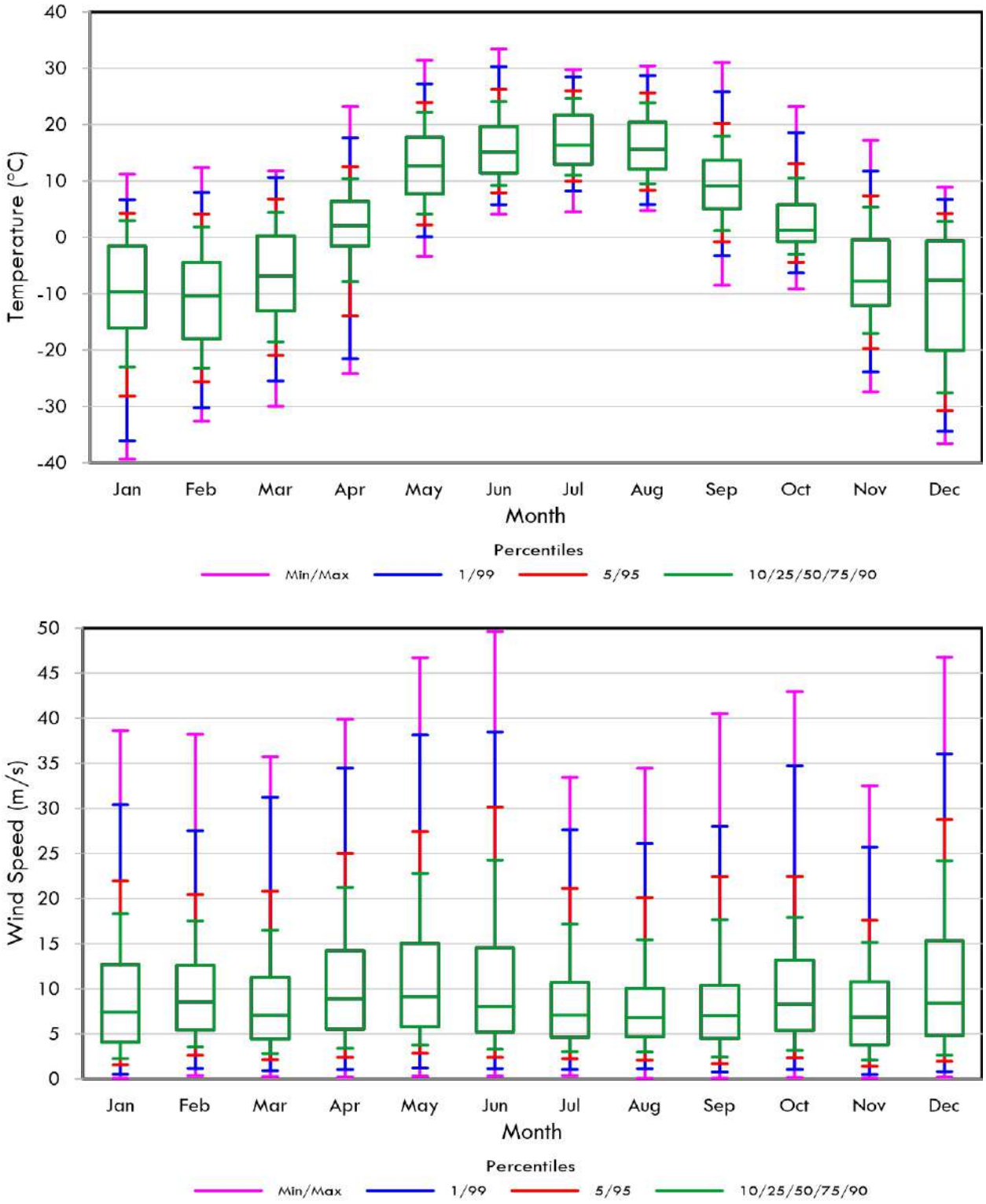

Figure 5.2 Monthly Temperature and Wind Speed Distribution Measured at Rycroft Monitoring Station

5.2 Total Reduced Sulphur Compounds

Reduced sulphur compounds are a complex family of substances. They are defined by the presence of sulphur in a reduced state and are generally characterized by strong odours at relatively low concentrations. Total reduced sulphur compounds (TRS) includes hydrogen sulphide (H_2S), carbon disulphide (CS_2), mercaptans, dimethyl sulphide, dimethyl disulphide and other sulphur compounds. Sulphur dioxide (SO_2) is not a reduced sulphur compound.

As noted earlier in Table 4.1, currently there are no AAAQO for TRS. However, there are AAAQOs for H_2S and CS_2 which are based on odour thresholds. H_2S is known to have highly toxic properties, and can cause negative health effects at even low concentrations.

Natural sources of reduced sulphur compounds in air include volcanoes and sulphur springs, oceans and estuaries, and exposed faces of sulphur-containing oil and coal deposits. The primary anthropogenic sources include sour oil and gas processing facilities, kraft pulp mills, chemical manufacturing plants, and livestock operations. TRS can be produced when manure undergoes anaerobic (absence of oxygen) fermentation.

In the area around the monitor, the main sources of TRS emissions would likely be the Secure Energy Facility and agricultural practices. Municipal sources such as landfills and sewage lagoons can also emit TRS; however, the existence of such sources near the monitor was not investigated. As well, swamps and sloughs can be natural sources of TRS. It is noted that there is limited oil and gas oil activity in the area.

A summary of TRS measurements are shown in Table 5.1 and the time series of measurements are shown in Figure 5.3. The measurements show that the AAAQO (H_2S and CS_2) were not exceeded during the monitoring period. Only nine occurrences in excess of 2 ppb were measured.

Figure 5.4 and Figure 5.5 shows the statistical concentrations as a function of wind direction. The highest measurements occurred for winds from the southwest to northwest sector, and from the southeast sector. This may indicate that the Secure Energy facility may have impacted the TRS measurements; however, this was not investigated further. For the average and lower percentile TRS concentrations, the highest values tend to occur for southeast winds.

Figure 5.6 presents the TRS measurements as a function of hour of day. In general, TRS measurements tended to be higher in the night and lower during the day. Figure 5.7 presents the TRS measurements by month. No discernible or significant trend is noted.

Figure 5.8 provides a comparison of TRS measurements from other monitoring stations in the province for the same time period. TRS is not a commonly measured suite of pollutants and would usually be measured in areas where TRS compounds are present and considered important from an air quality perspective. The figure shows that the measurements at Rycroft are low relative to other areas where TRS are measured. The ambient TRS data measured at Rycroft appears to adequately reflect the general rural setting with perhaps a minor influence from nearby industry.

Table 5.1 Summary of TRS Measurements (ppb) at Rycroft Monitoring Station

1-hour AAAQO	10 (H_2S and CS_2)
Maximum 1-hour Measurement	4.94
99.9th Percentile Measurement	1.24
99th Percentile Measurement	0.62
90th Percentile Measurement	0.39
Median (50th Percentile) Measurement	0.19
Average Measurement	0.21
24-hour AAAQO	3 (H_2S)
Maximum 24-hour Average Measurement	0.72

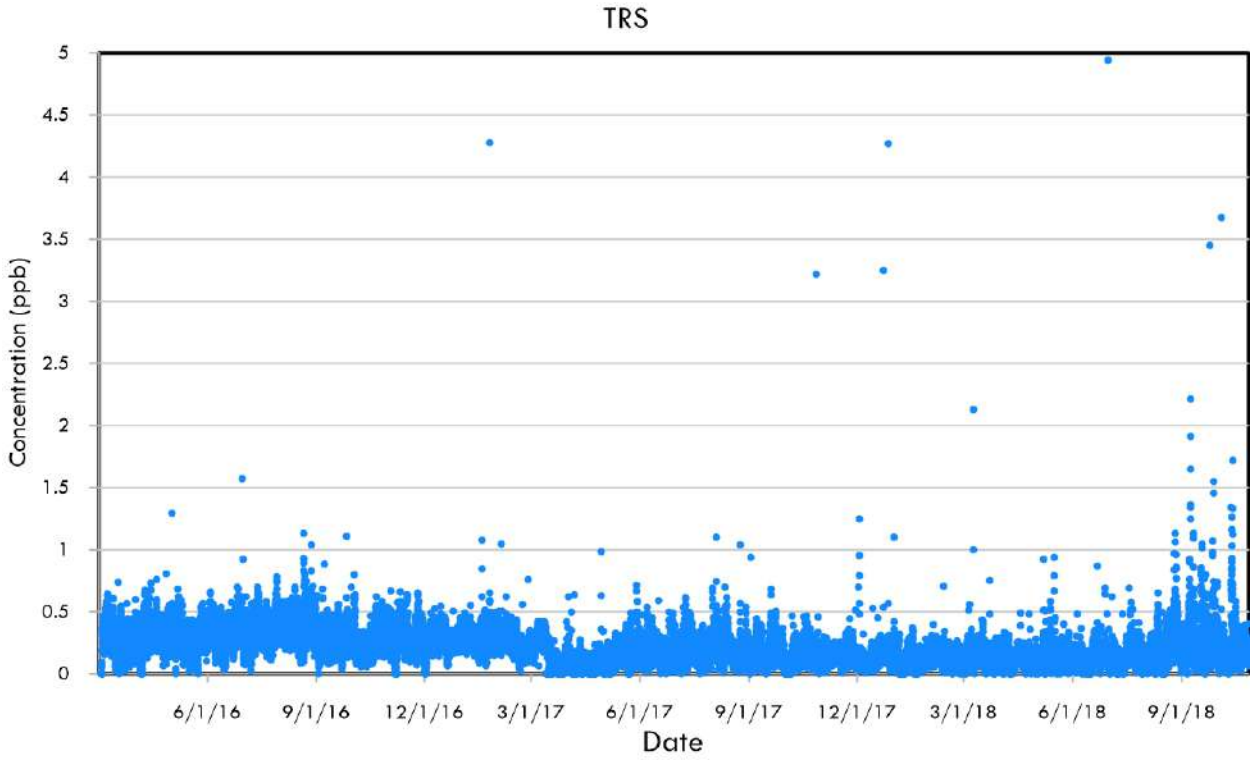

Figure 5.3 Time Series of the Hourly TRS Measurements

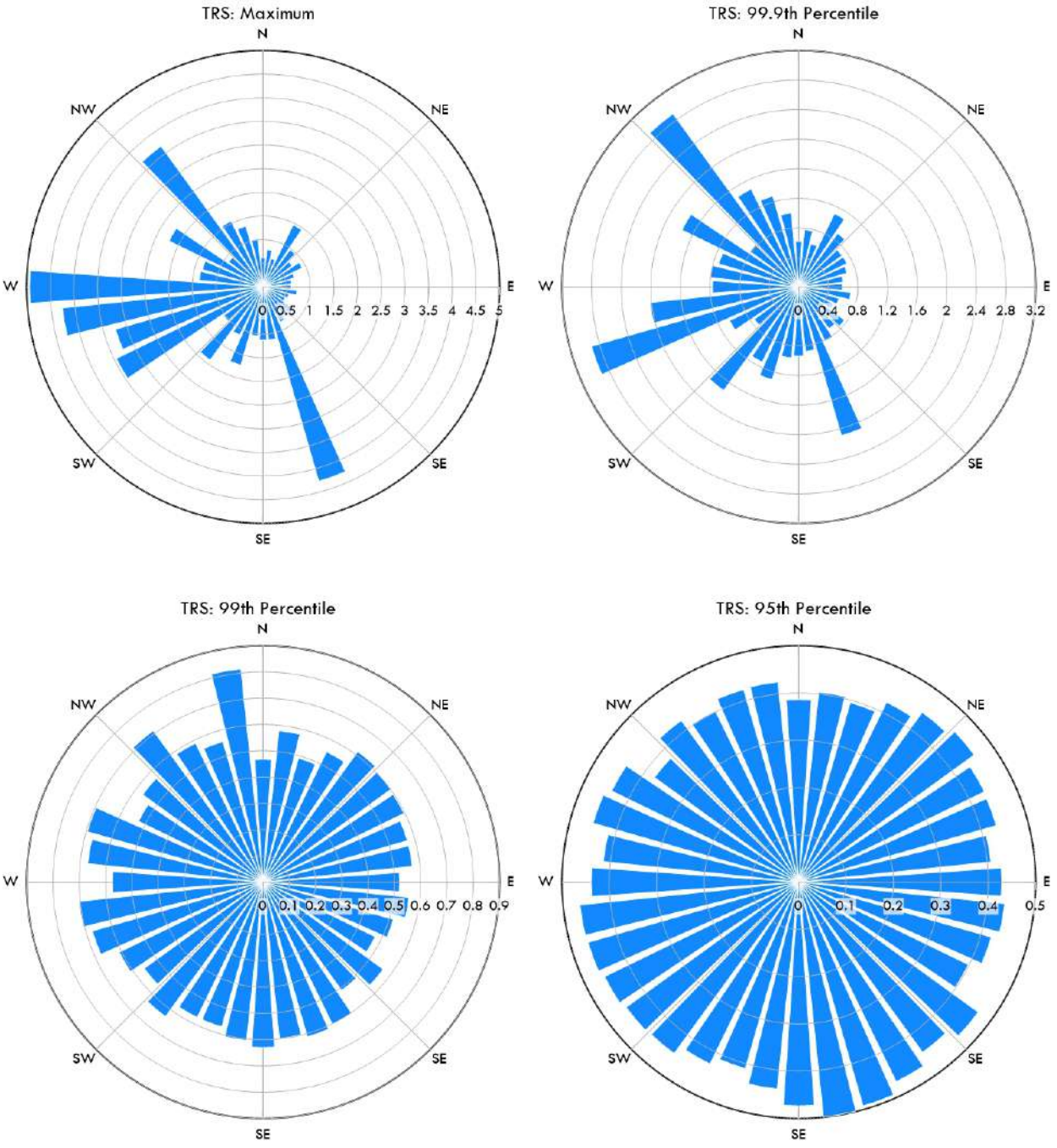

Figure 5.4 TRS Measurements by Wind Direction

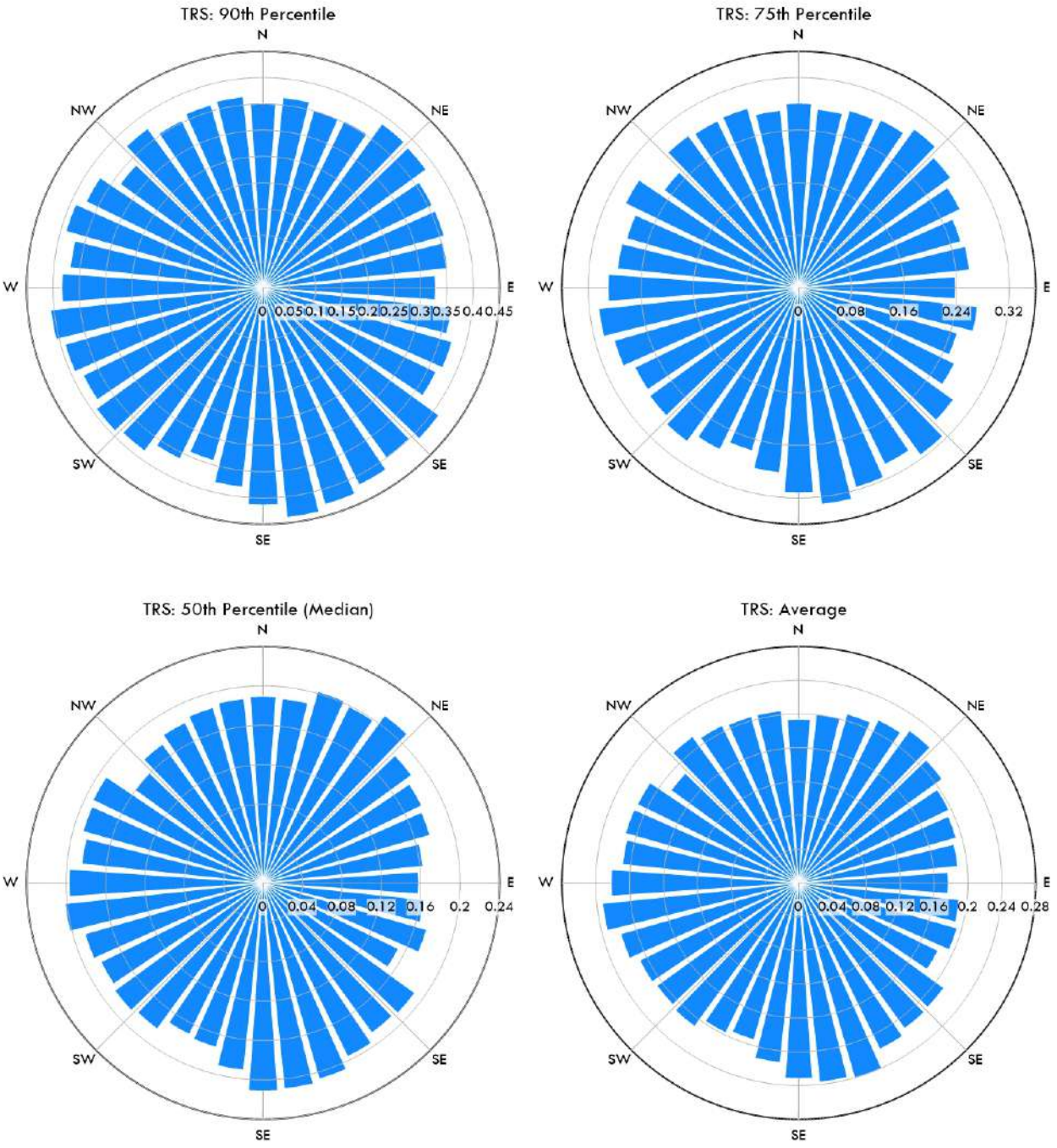

Figure 5.5 TRS Measurements by Wind Direction

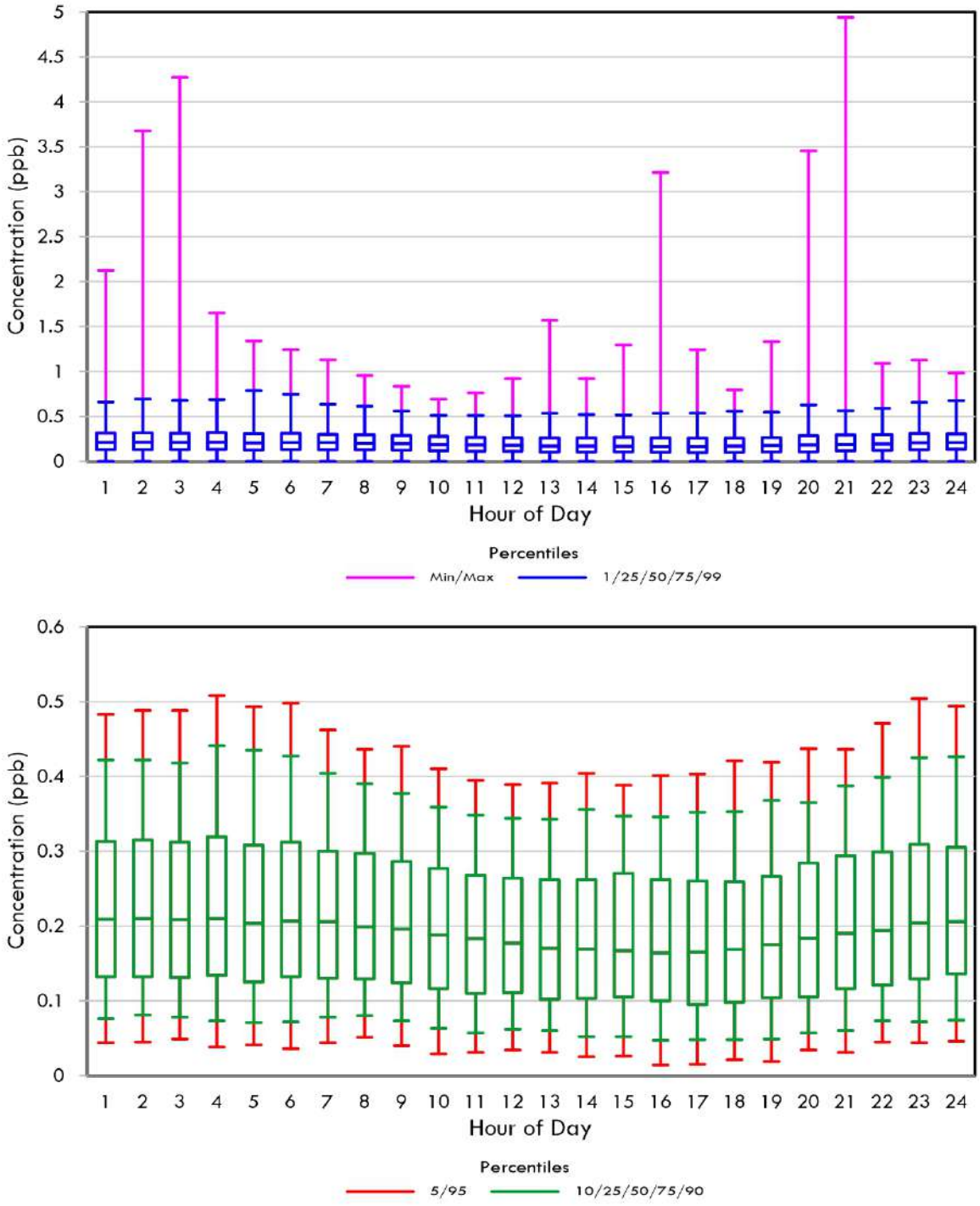

Figure 5.6 TRS Measurements by Hour of Day

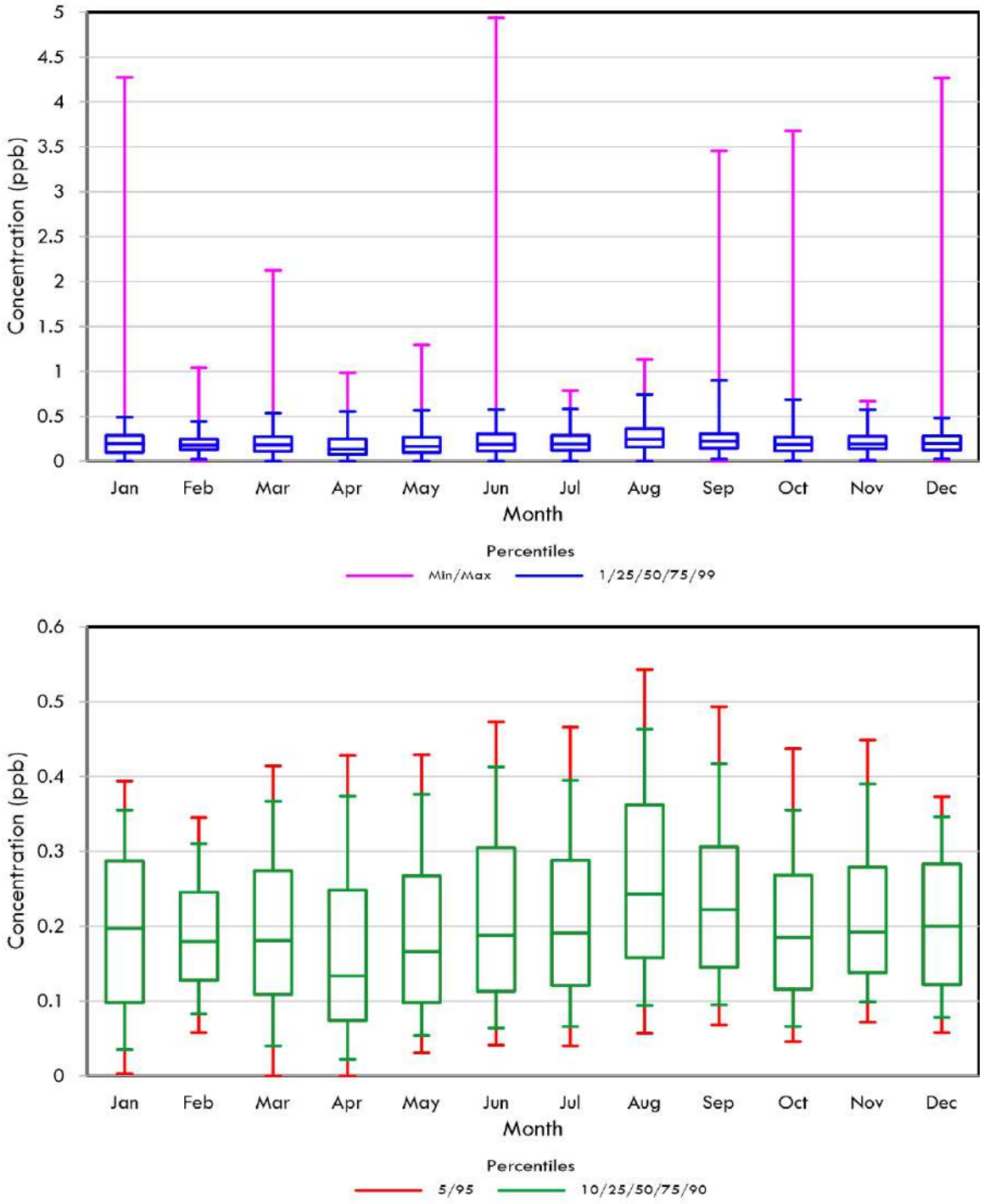

Figure 5.7 TRS Measurements by Month

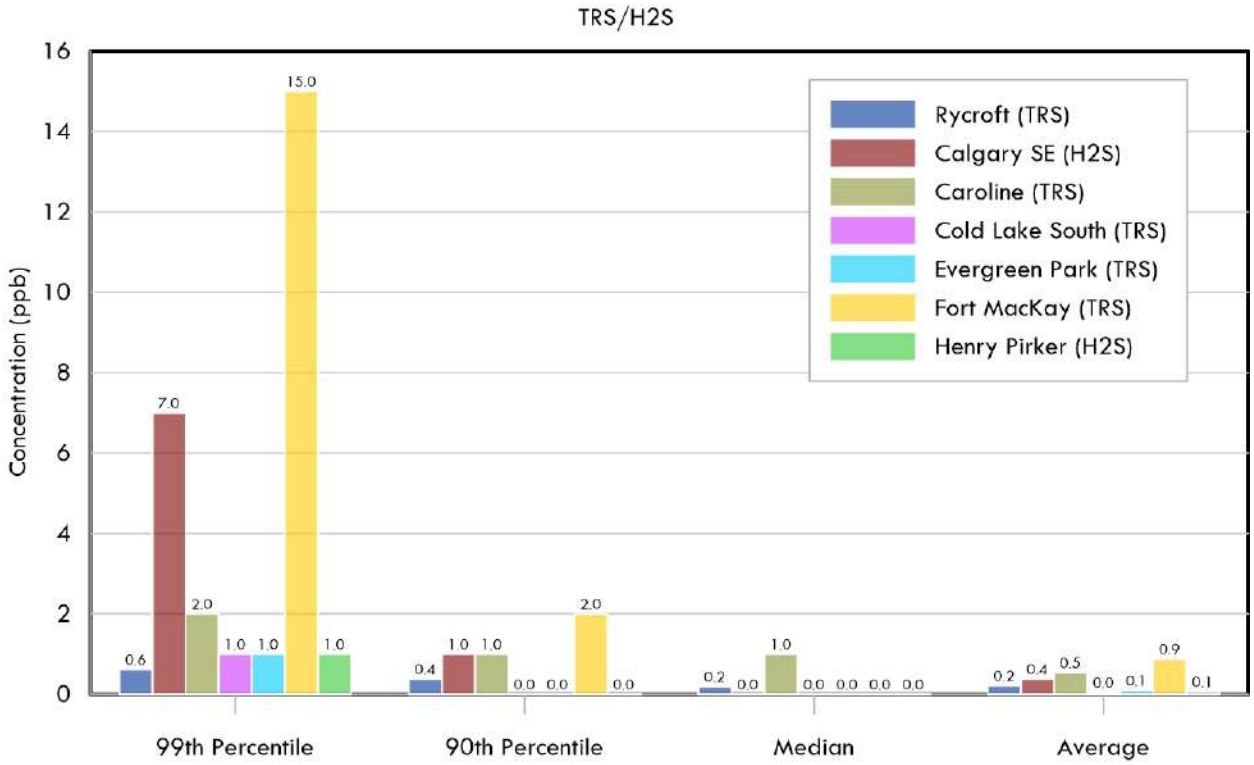

Figure 5.8 Comparison of TRS/H_2S Measurements from other Continuous Monitoring Stations

5.3 Sulphur Dioxide

Sulphur dioxide is a colourless, non-flammable gas with a sharp, pungent odour. Natural sources include volcanoes, decaying organic matter and solar action on seawater. The most significant anthropogenic emission sources of sulphur dioxide are from combustion of sulphur-containing fossil fuels, smelting sulphide ores, and petroleum refining. Other less significant sources include chemical and allied products manufacturing, metal processing, other industrial processes, and vehicle emissions.

Once sulphur dioxide is released into the atmosphere, it may be converted to other compounds and/or removed from the atmosphere by various mechanisms. Processes such as oxidation, wet deposition, dry deposition, absorption by vegetation and by soil, dissolution into water and other processes contribute to the removal of sulphur dioxide from the atmosphere. Exposure to high enough concentrations of SO_2 can affect human and environmental health.[7]

[7] https://open.alberta.ca/publications/ambient-air-quality-objectives-sulphur-dioxide

A summary of SO_2 measurements are shown in Table 5.2 and the time series of measurements are shown in Figure 5.9. The measurements were well below the SO_2 AAAQO and CAAQS in all instances.

Figure 5.10 and Figure 5.11 shows the statistical concentrations as a function of wind direction There is a slight trend for the highest SO_2 concentrations to occur from the southern sector.

Figure 5.12 presents the SO_2 measurements as a function of hour of day. In general, SO_2 measurements tended to be higher in the day and lower during the night. Figure 5.13 presents the SO_2 measurements by month. Higher measurements tended to occur in the winter months.

Figure 5.14 shows the average monthly SO_2 concentrations with the closest passive stations (Wanham and Spirit River). The figure shows that for the most part the average monthly concentrations are consistent with the measurements from the closest passive monitor. This likely indicates that there are no major sources of SO_2 in the area.

Figure 5.15 provides a comparison of SO_2 measurements from other monitoring stations in the province for the same time period. The figure shows that the measurements at Rycroft were comparable to other areas where SO_2 is measured.

The data indicates that SO_2 levels around Rycroft are generally low inferring that there are no significant sources of SO_2 in the area. The slight bias of higher concentrations toward certain wind directions may be a sign of influence from long range transport from other industrial sources located to the south.

Table 5.2 Summary of SO_2 Measurements (ppb) at Rycroft Monitoring Station

1-hour AAAQO	172
30-day AAAQO	11
Annual AAAQO	8
1-hour CAAQS (Effective 2020)[a]	70
Annual CAAQS (Effective 2020)	5
Maximum 1-hour Measurement	6.81
99.9th Percentile Measurement	3.59
99th Percentile Measurement	1.71
90th Percentile Measurement	0.65
Median (50th Percentile) Measurement	0.15
Average Measurement	0.27
Maximum Month Average	0.45
24-hour AAAQO	48
Maximum 24-hour Average Measurement	1.77

a) Based on 3-year average of the annual 99th percentile of daily maximum 1-hour average concentrations

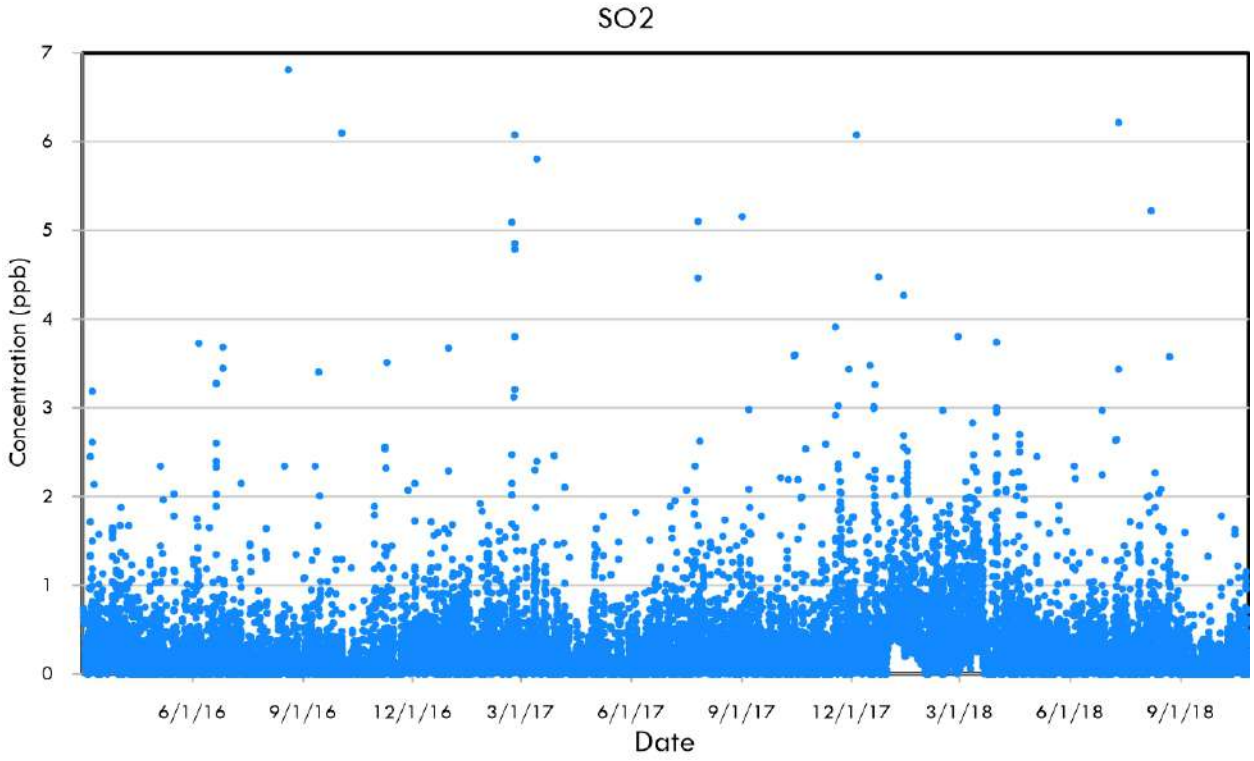

Figure 5.9 Time Series of the Hourly SO_2 Measurements

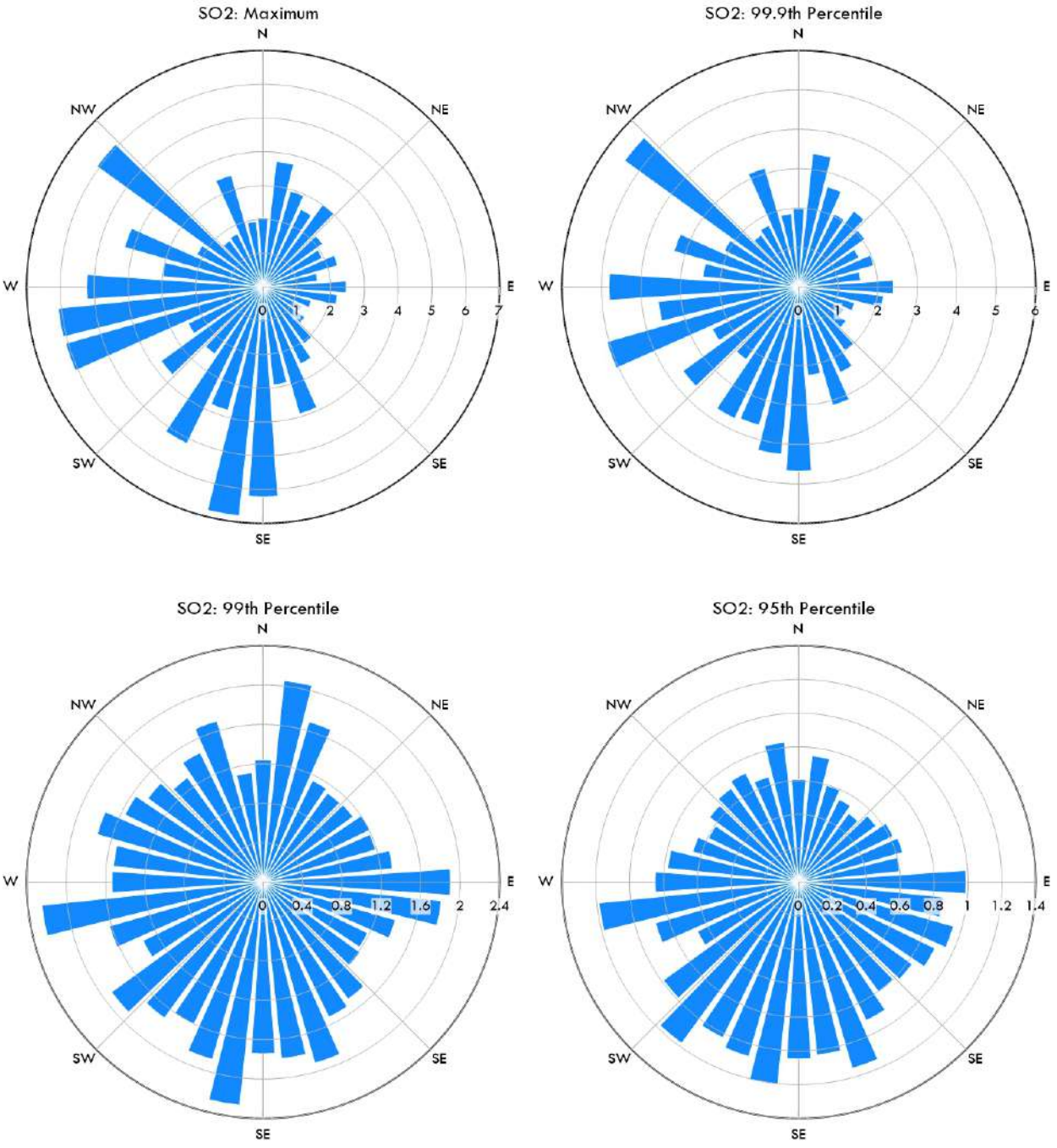

Figure 5.10 SO_2 Measurements by Wind Direction

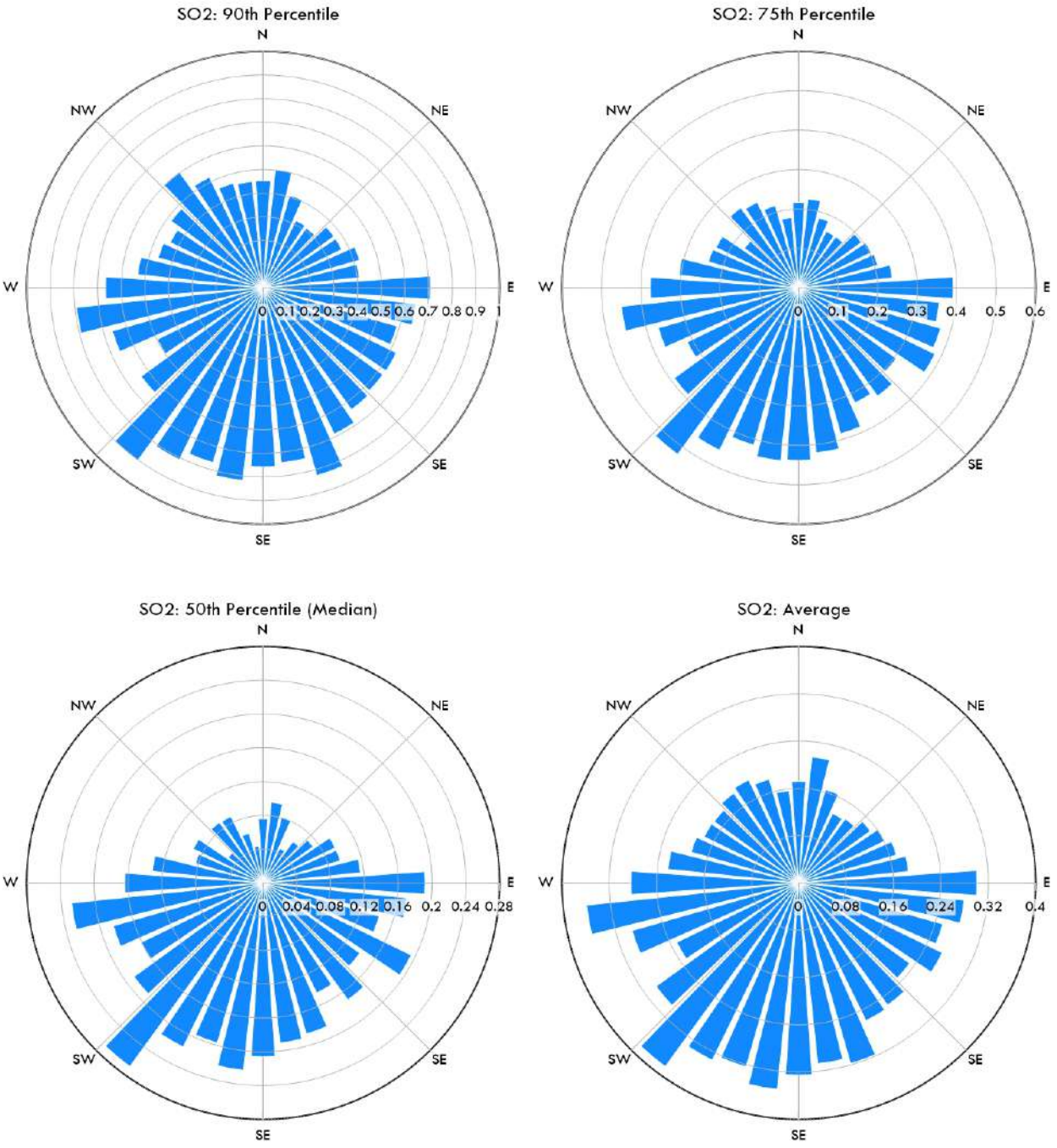

Figure 5.11 SO_2 Measurements by Wind Direction

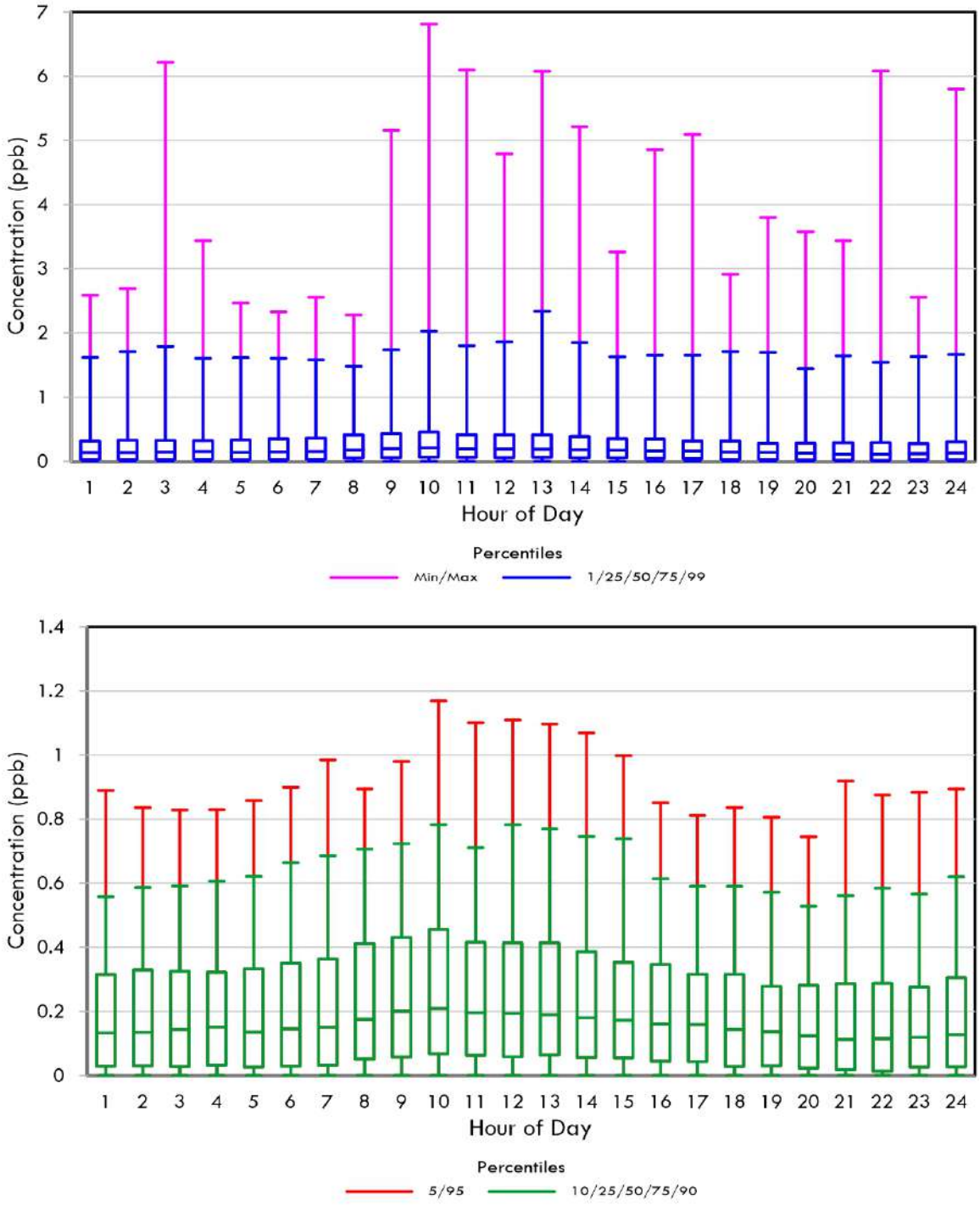

Figure 5.12 SO_2 Measurements by Hour of Day

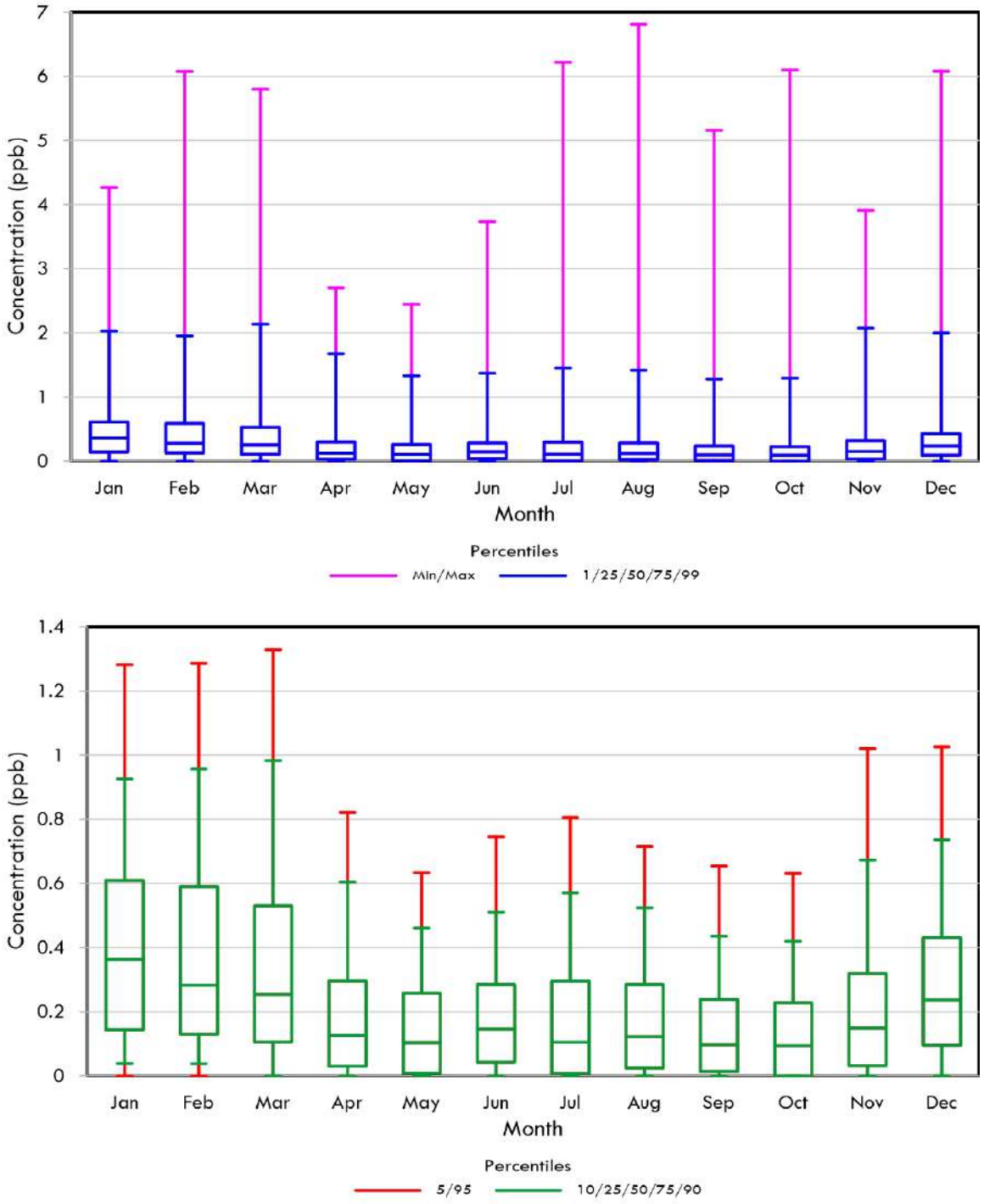

Figure 5.13 SO_2 Measurements by Month

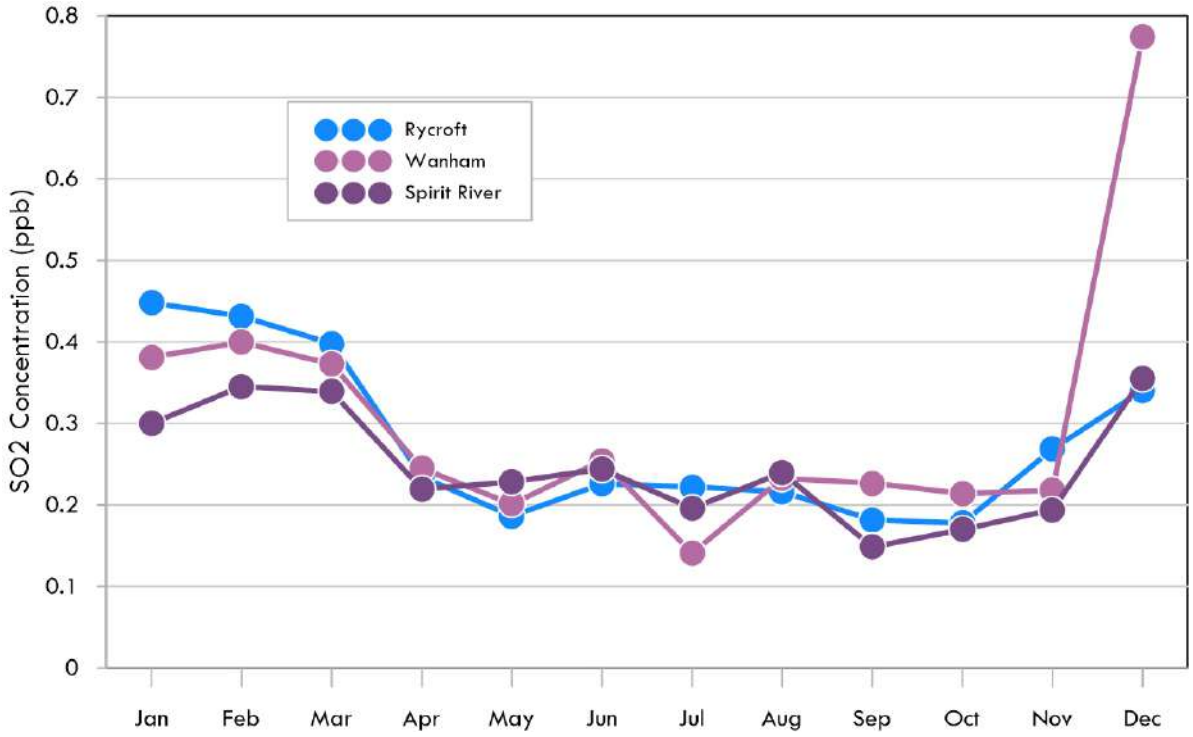

Figure 5.14 Average Monthly SO_2 Concentrations compared to closest Passive monitors

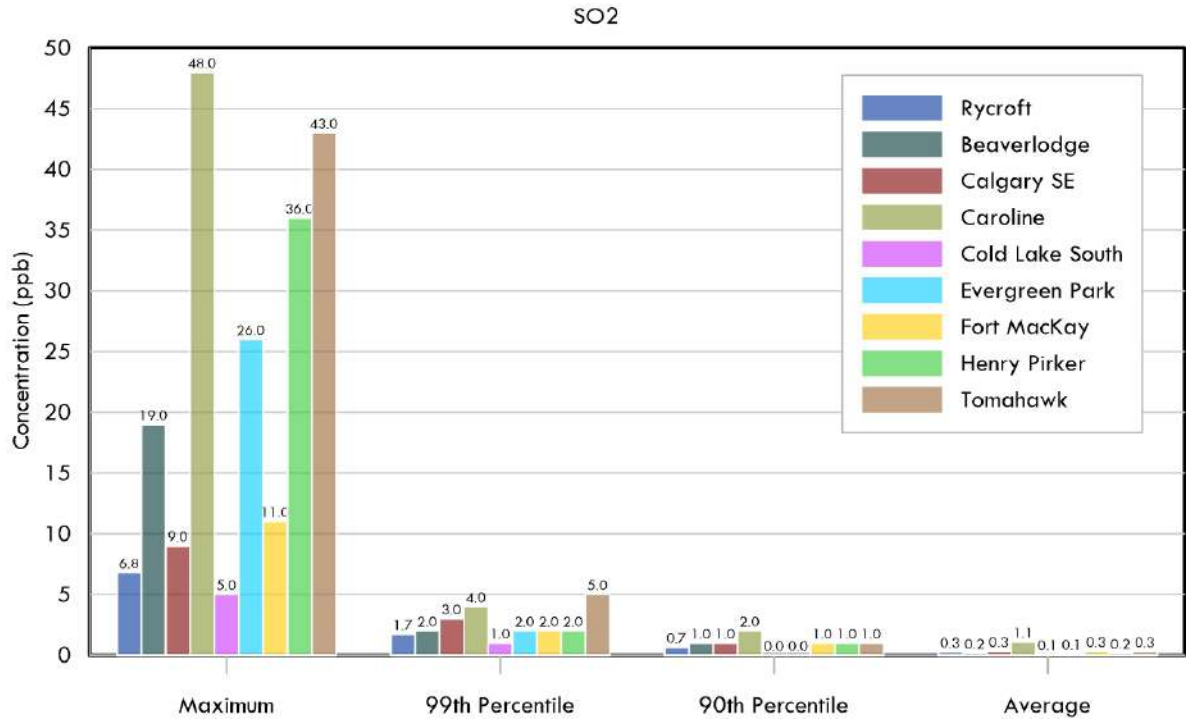

Figure 5.15 Comparison of SO_2 Measurements from other Continuous Monitoring Stations

5.4 Nitrogen Oxides

Nitrogen dioxide (NO_2) and nitric oxide (NO) are known collectively as oxides of nitrogen (NO_x). NO_x occurs naturally in the environment as a result of forest fires, atmospheric lightning discharges and biogenic oxidation of nitrogen containing compounds present in soil. Anthropogenic NO_x emissions are mainly the result of combustion processes, such as the combustion of fuel for vehicles or the combustion of coal, oil and natural gas for industrial processes. Emissions of NO_x from combustion processes are initially about 90 to 95% NO and about 5 to 10% NO_2. NO is oxidized to NO_2 in the atmosphere, and through further complex atmospheric chemical reactions can lead to the formation of ozone (see next section), nitric acid and nitrate-containing particles.

Of the NO_x species, an AAAQO exists for NO_2 only. Therefore, a summary of the NO_x measurements is restricted to NO_2. NO_2 is a reddish-orange-brown gas with an irritating, acrid, characteristic pungent odour. It is corrosive, highly oxidizing and non-combustible. At high enough concentrations, NO_2 can have respiratory effects on humans on which the 1-hour AAAQO is based. On a long term basis, NO_2 can have detrimental effects on vegetation which is reflected in the annual AAAQO.[8]

A summary of NO_2 measurements are shown in Table 5.3 and the time series of measurements are shown in Figure 5.16. The measurements were below the NO_2 AAAQO and CAAQS in all instances. It is noted in Figure 5.16 that there is an increase in the NO_2 data starting at about September 1, 2017. The average NO_2 concentration before this date is 2.1 ppb. The average NO_2 concentration after this date is 2.9 ppb. The reason for this was not investigated.

Figure 5.17 and Figure 5.18 show the statistical concentrations as a function of wind direction There is a slight trend for higher NO_2 concentrations to occur during winds from the western sector.

Figure 5.19 presents the statistics of the NO_2 measurements as a function of hour of day. In general, NO_2 measurements tended to be higher in the night and lower during the day. This diurnal pattern suggests that complex atmospheric processes (discussed in the ozone section) may be occurring. Figure 5.20 presents the statistics of the NO_2 measurements by month. Higher measurements tended to occur in the winter months.

Figure 5.21 shows the average monthly NO_2 concentrations with the closest passive stations (Wanham and Spirit River). The figure shows that the pattern between the 3 datasets is consistent but the concentrations at Rycroft were higher than the passive data for all months. This may suggest that there are local emissions impacting the data but this was not thoroughly investigated.

[8] https://open.alberta.ca/publications/ambient-air-quality-objectives-nitrogen-dioxide

Figure 5.22 provides a comparison of NO_2 measurements from other monitoring stations in the province for the same time period. The figure shows that NO_2 levels at Rycroft were lower relative to other areas in the province.

The ambient NO_2 data measured in Rycroft appears to suggest that the Secure Energy Services facility and locomotives could be the main contributor to the measurements which is not unexpected given the location of the monitor.

Table 5.3 Summary of NO_2 Measurements (ppb) at Rycroft Monitoring Station

1-hour AAAQO	159
Annual AAAQO	24
1-hour CAAQS (Effective 2020)[a]	60
Annual CAAQS (Effective 2020)	17
Maximum 1-hour Measurement	35.06
99.9th Percentile Measurement	22.52
99th Percentile Measurement	14.23
90th Percentile Measurement	5.24
Median (50th Percentile) Measurement	1.59
Average Measurement	2.46

a) Based on 3-year average of the annual 98th percentile of daily maximum 1-hour average concentrations

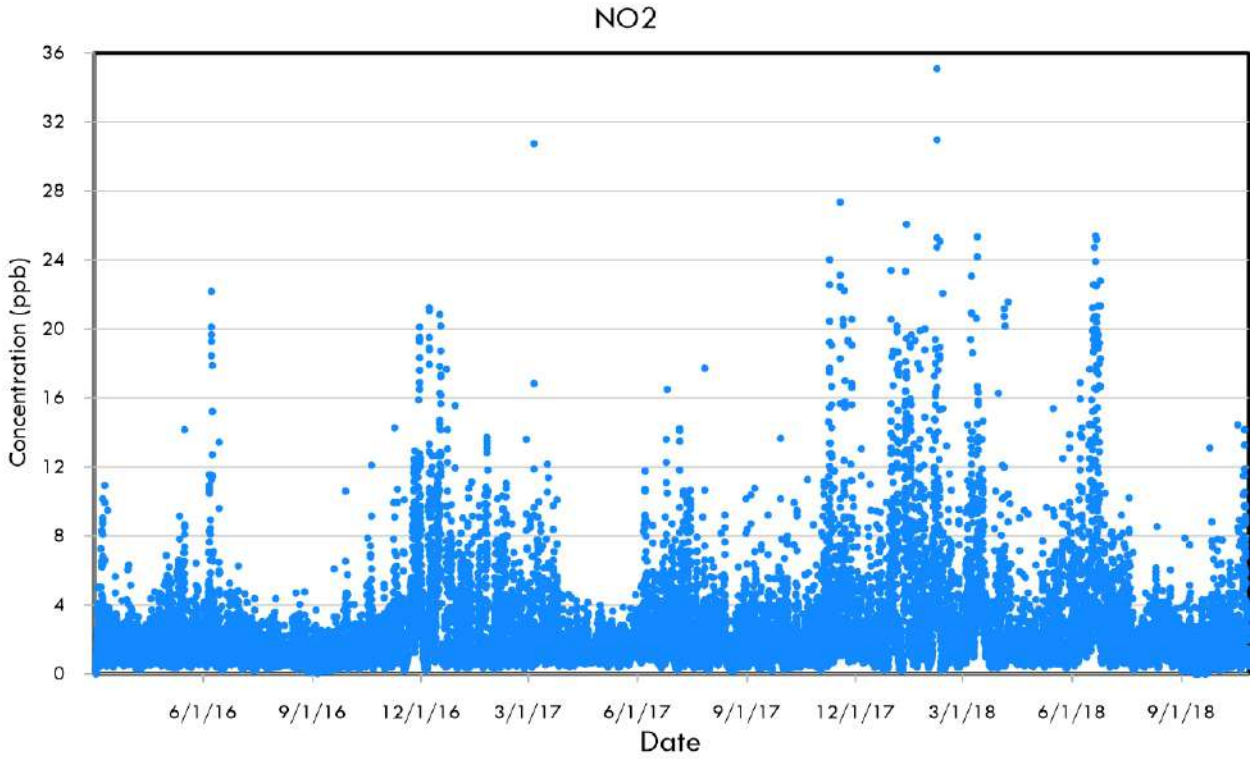

Figure 5.16 Time Series of the Hourly NO_2 Measurements

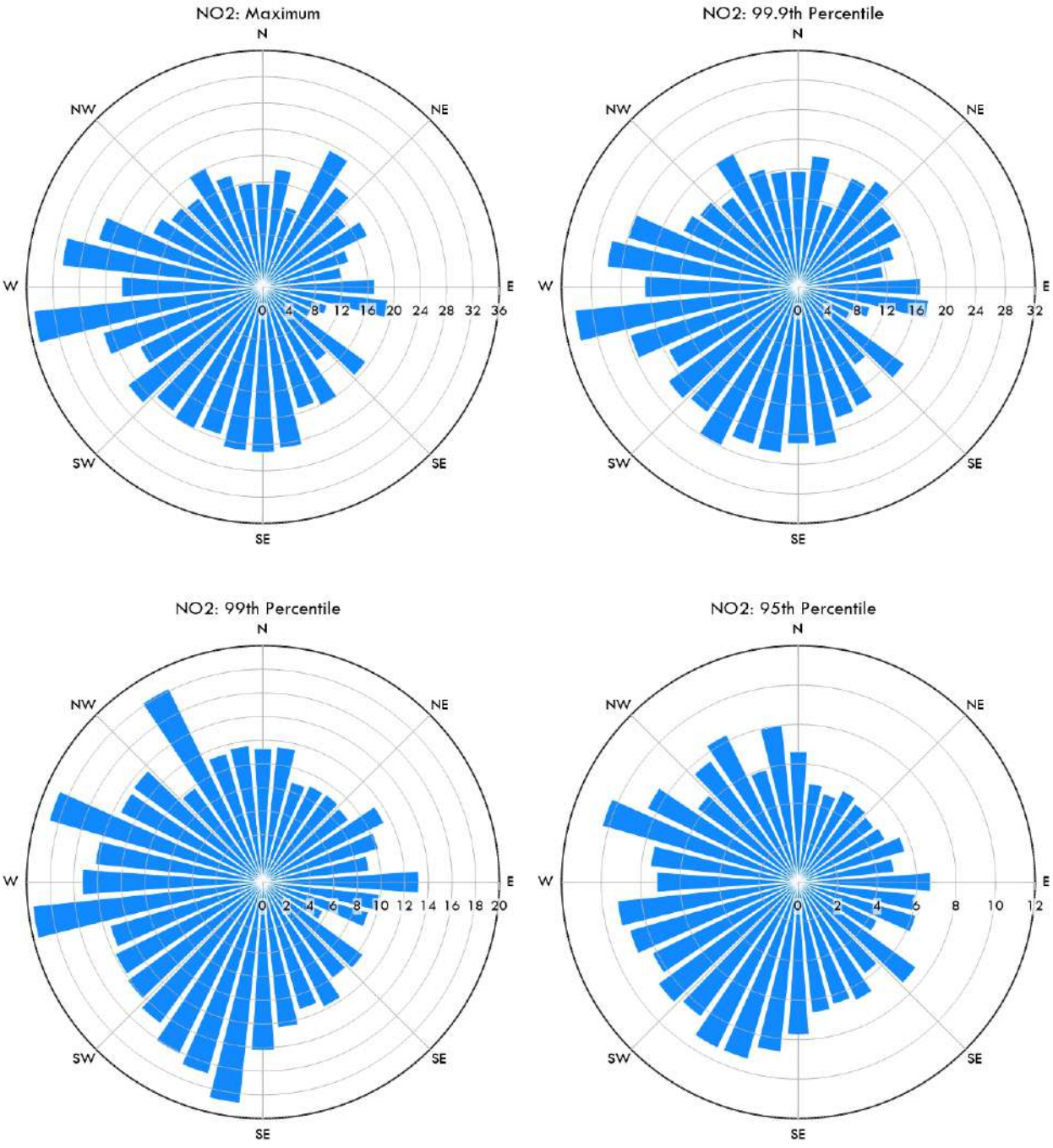

Figure 5.17 NO_2 Measurements by Wind Direction

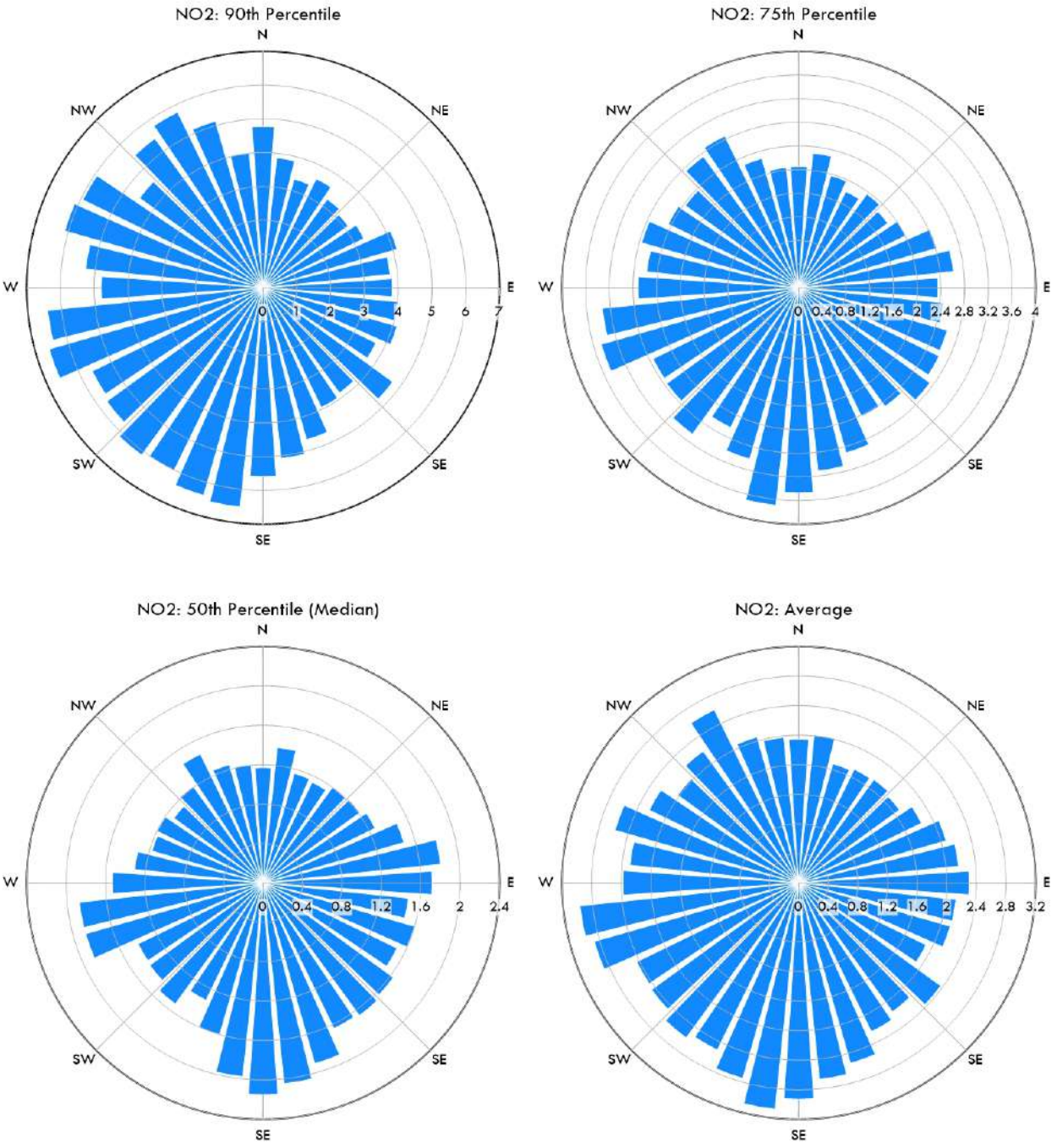

Figure 5.18 NO_2 Measurements by Wind Direction

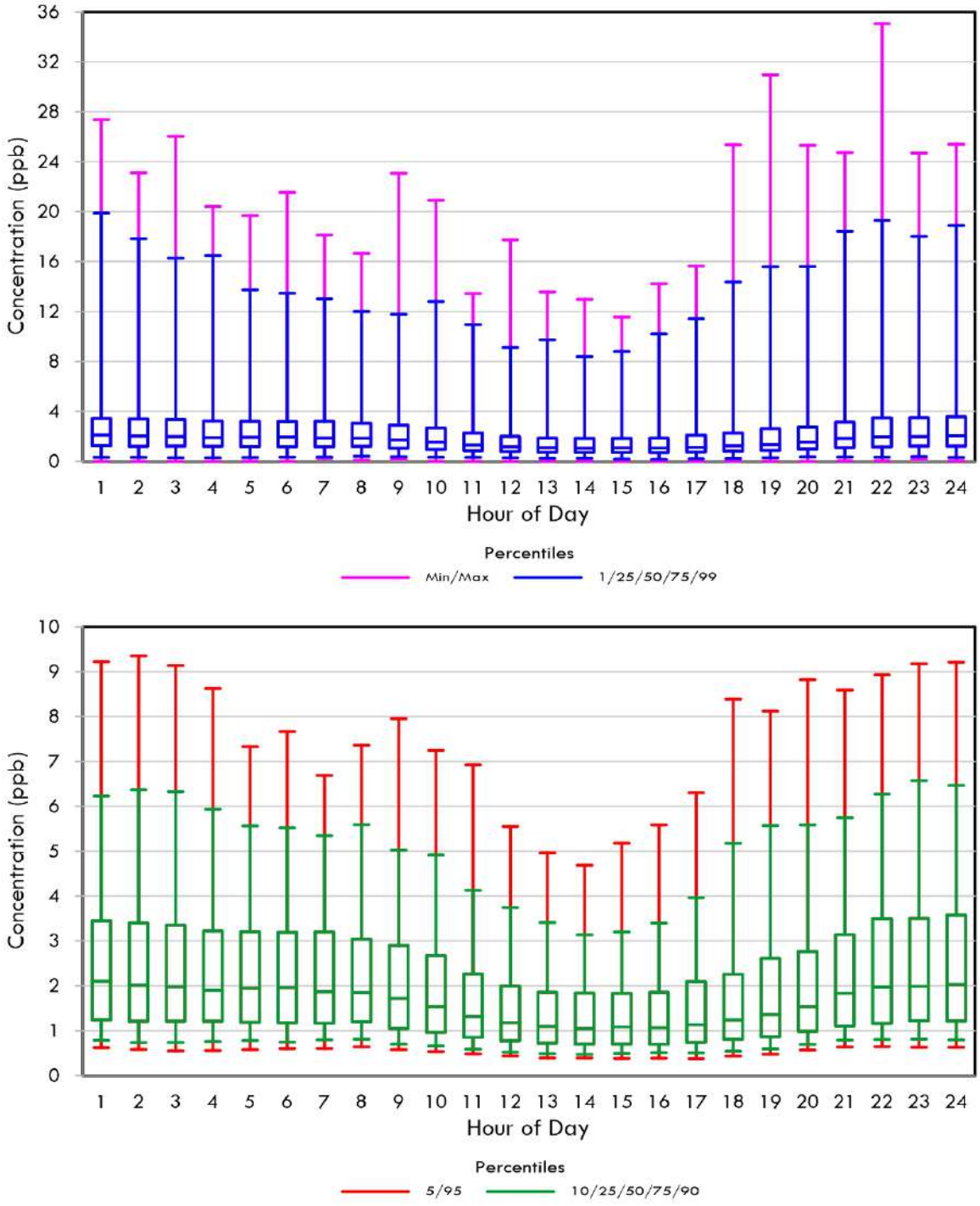

Figure 5.19 NO_2 Measurements by Hour of Day

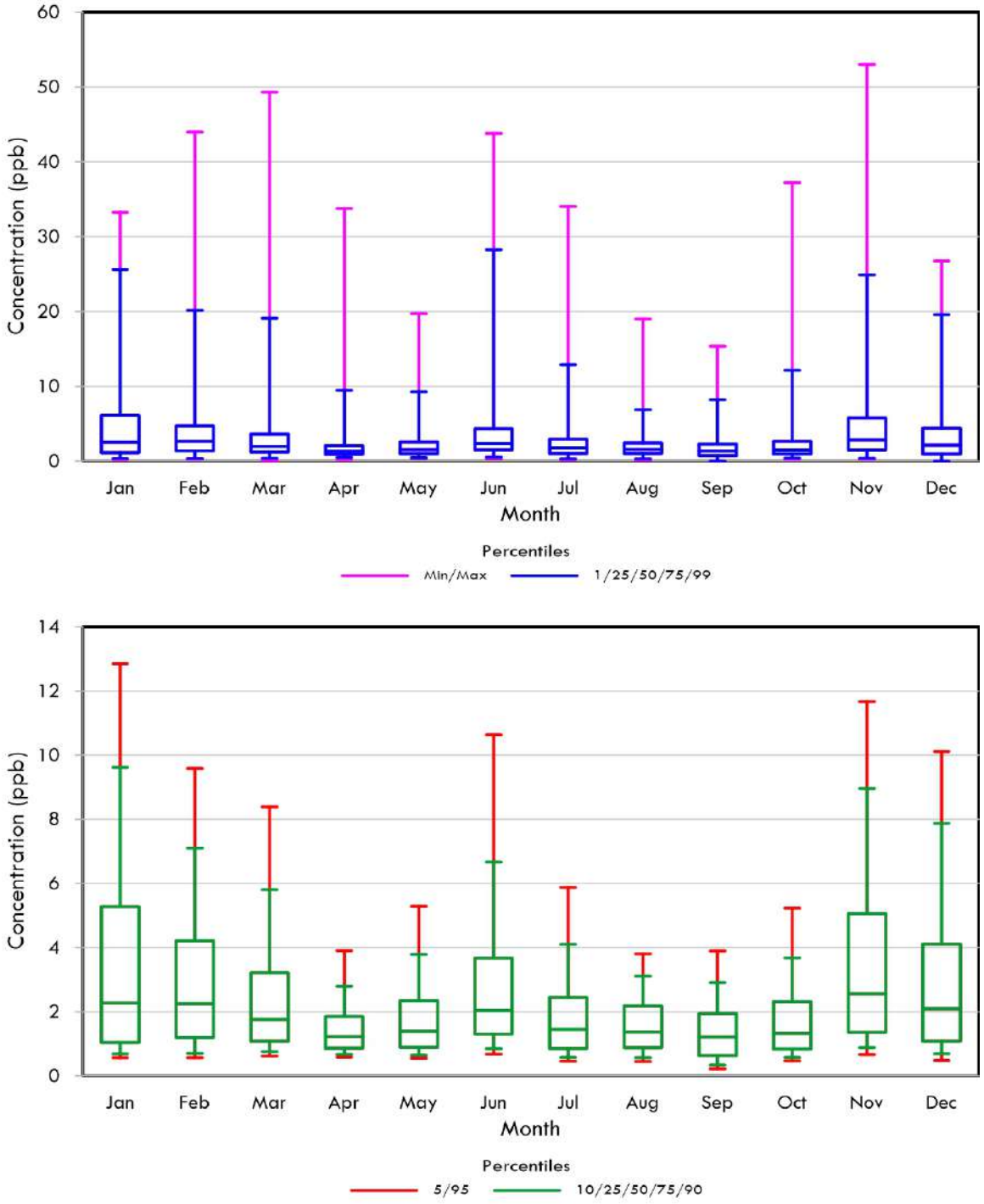

Figure 5.20 NO_2 Measurements by Month

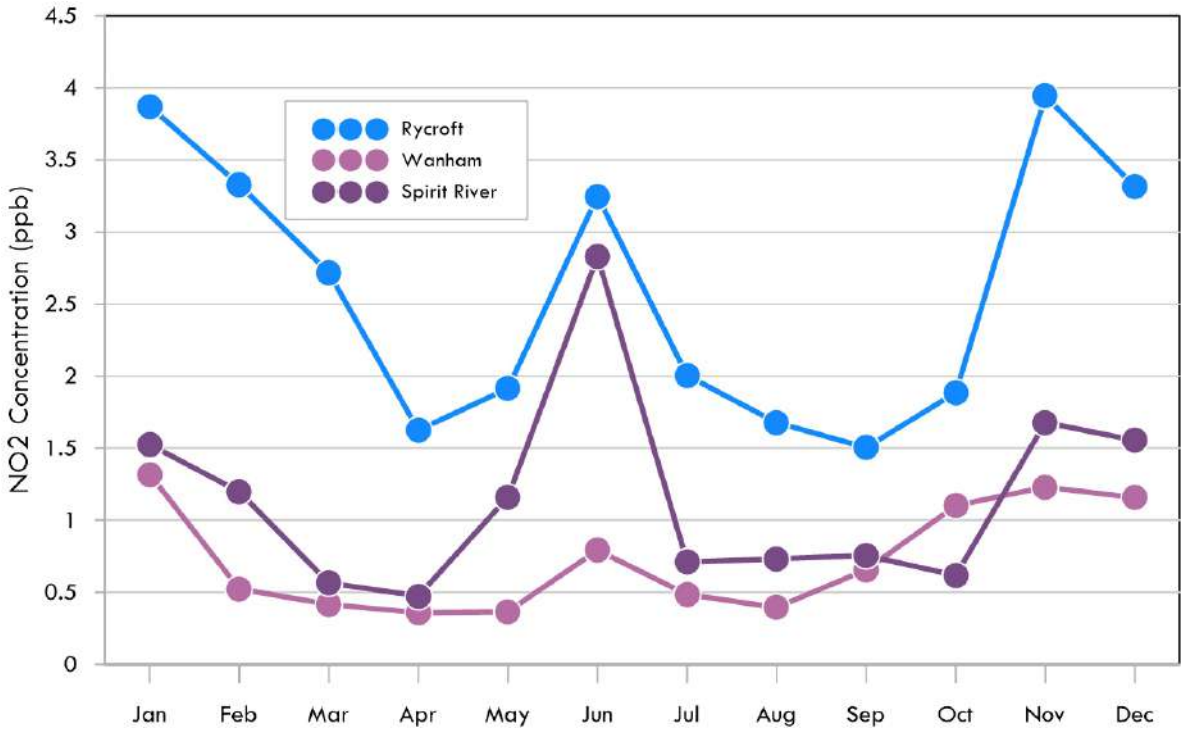

Figure 5.21 Average Monthly NO_2 Concentrations compared to the closest Passive monitors

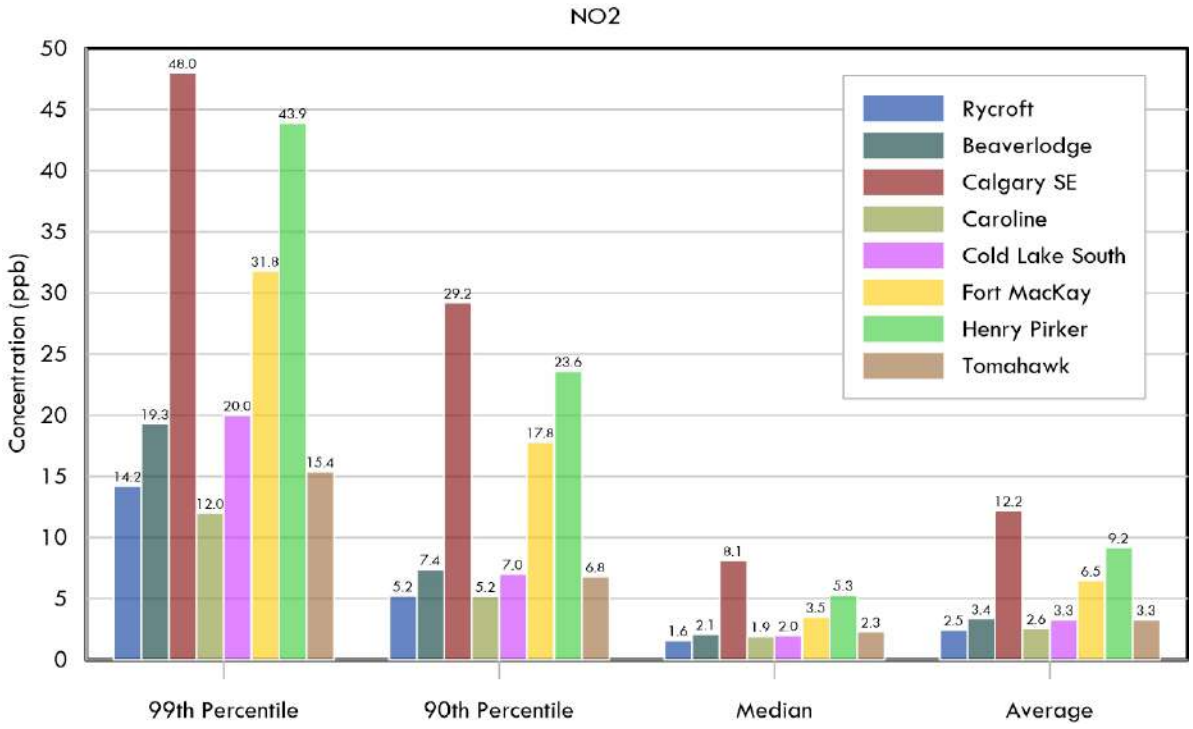

Figure 5.22 Comparison of NO_2 Measurements from other Continuous Monitoring Stations

5.5 Ozone

Ozone is a chemical whose effect on the environment is either beneficial or detrimental depending on where it occurs. Stratospheric ozone protects us from the sun's ultraviolet light, but can be toxic in the troposphere (atmospheric layer encompassing ground level). Ozone is a highly reactive, colourless gas. It has a sharp, clean odour that can often be detected around running electric motors, after lightning storms, and around new mown hay.

Ozone is not emitted by anthropogenic or natural processes. It is normally present in the troposphere as a result of naturally occurring photochemical and meteorological processes. Ground level ozone is formed through complex chemical reactions between precursor emissions of volatile organic compounds (VOCs) and NO_x in the presence of heat and sunlight. Combustion exhausts emit both VOCs and NO_x and in rural areas, trees and other vegetation naturally emit VOCs that can contribute to ozone formation. Changing weather patterns contribute to yearly differences in ozone concentrations from city to city. Ozone and the precursor substances that cause ozone also can be transported into an area from pollution sources hundreds of miles upwind.

Extensive scientific studies indicate that there can be significant health and environmental effects associated with ozone. Potential short-term effects include pulmonary function reductions, increased airway sensitivities, and airway inflammation on which the 1-hour AAAQO for ozone is based. [9]

A summary of O_3 measurements are shown in Table 5.4 and the time series of measurements are shown in Figure 5.23. The measurements were below the 1-hour AAAQO in all instances. The 4th highest 8-hr daily average over the monitoring period is greater than the CAAQS of 63 ppb. The CAAQS criteria is based on 3 year averages and removes all elevated measurements due to exceptional events such as forest fires. The Rycroft monitor operated for only 32 months and any measurements that were influenced by exceptional events have not been removed, and therefore, the results cannot be explicitly related to the CAAQS.

Figure 5.24 and Figure 5.25 show statistics of the O_3 measurements as a function of wind direction. There appears to be a bias of higher values occurring for winds from the northeast to southeast sector. This may be indicative of NO_x emissions from the west contributing to an O_3 sink for a few hours of the day but this was not investigated thoroughly.

Figure 5.26 present statistics of the measured O_3 concentrations as a function of month and hour of day. The highest measurements are occurring during the spring and early summer. Also seen, is a typical diurnal pattern of O_3 where O_3 is decomposed to O_2 through a reaction with NO in the early morning and then created during the day in complex reactions with VOCs and NO_2 in the presence of sunlight.

[9] https://open.alberta.ca/publications/9781460142769

Figure 5.27 provides a comparison of O_3 measurements from other monitoring stations in the province for the same time period. The figure shows that other O_3 levels at Rycroft were comparable to other areas in the province.

Figure 5.28 presents the diurnal relationships between NO, NO_2, and O_3 at the Rycroft monitoring station for the entire period, and for the months of December, April and August. The figures show the complex relationship between these pollutants that lead to O_3 formation.

The ambient O_3 data measured in Rycroft appears to adequately reflect the general rural setting; however, the ozone measurements may be affected by local NO_x emissions as the data is showing ozone formation and decomposition due to complex relationship with atmospheric NO_x and VOCs. Regardless, the O_3 measurements are below the AAAQO.

Table 5.4 Summary of O_3 Measurements (ppb) at Rycroft Monitoring Station

1-hour AAAQO	76
Maximum 1-hour Measurement	75.95
99.9th Percentile Measurement	65.79
99th Percentile Measurement	55.58
90th Percentile Measurement	42.93
Median (50th Percentile) Measurement	28.71
Average Measurement	28.56
8-hour CAAQS	63
4th Highest Daily 8-hour Measurement[a]	65.0

a. This value was calculated for presentation purposes only and cannot be directly compared to the CAAQS

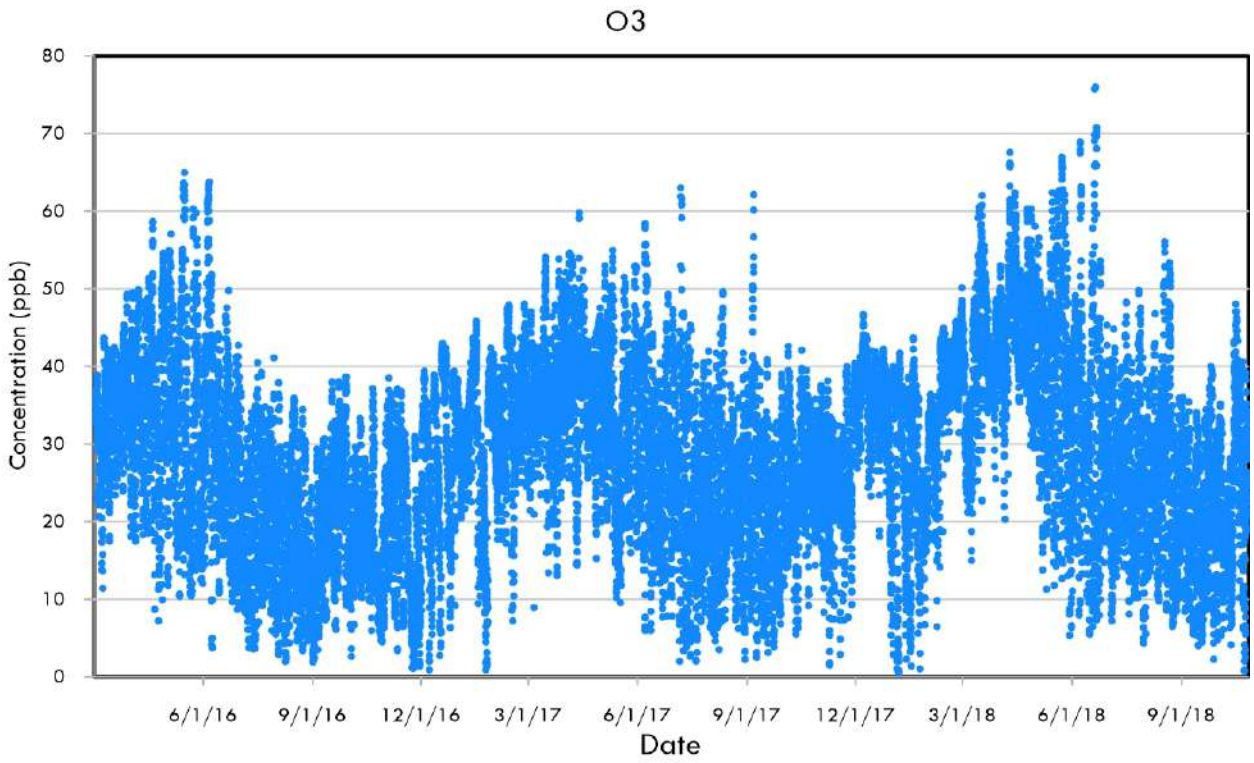

Figure 5.23 Time Series of the Hourly O_3 Measurements

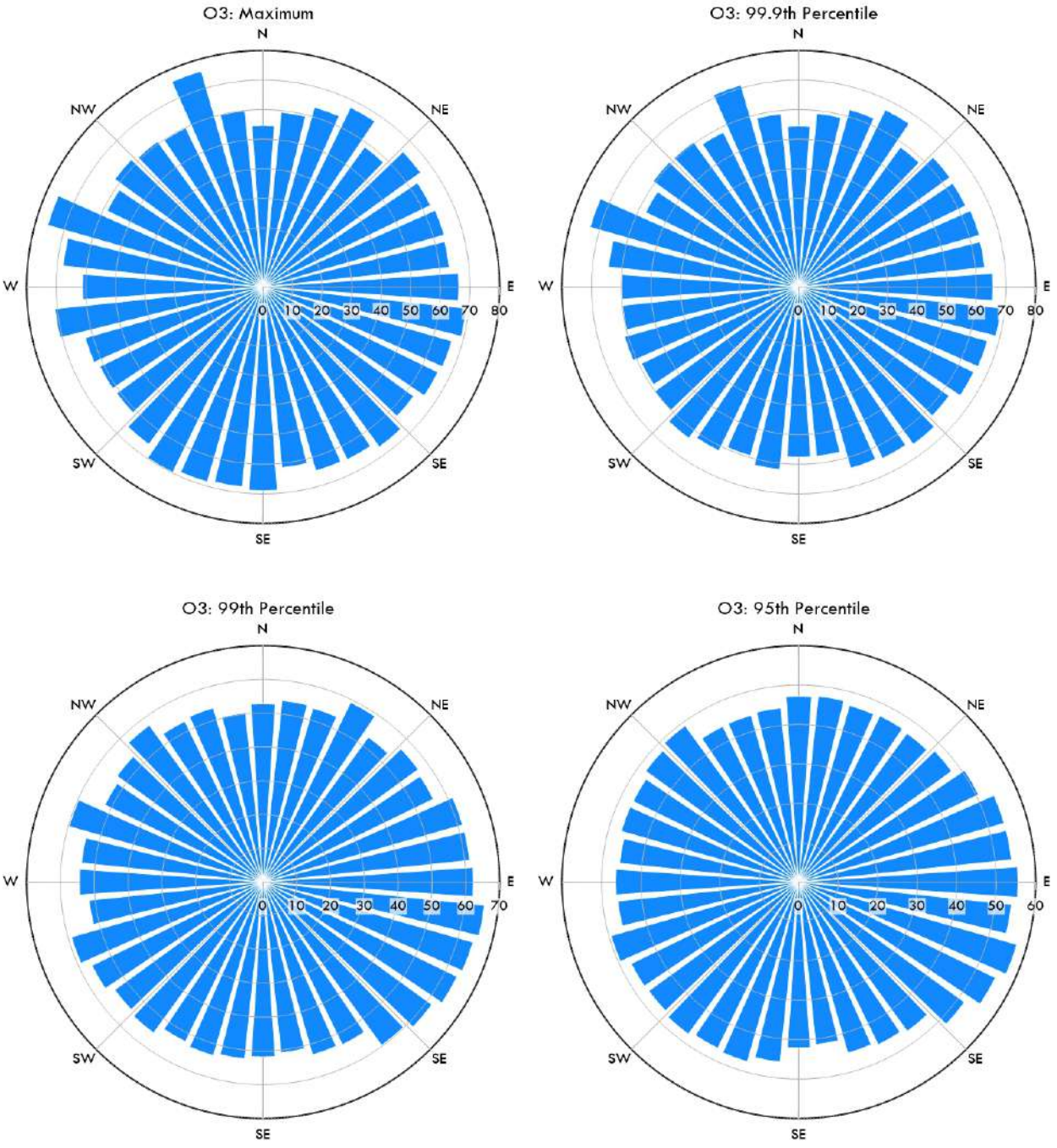

Figure 5.24 NO_2 Measurements by Wind Direction

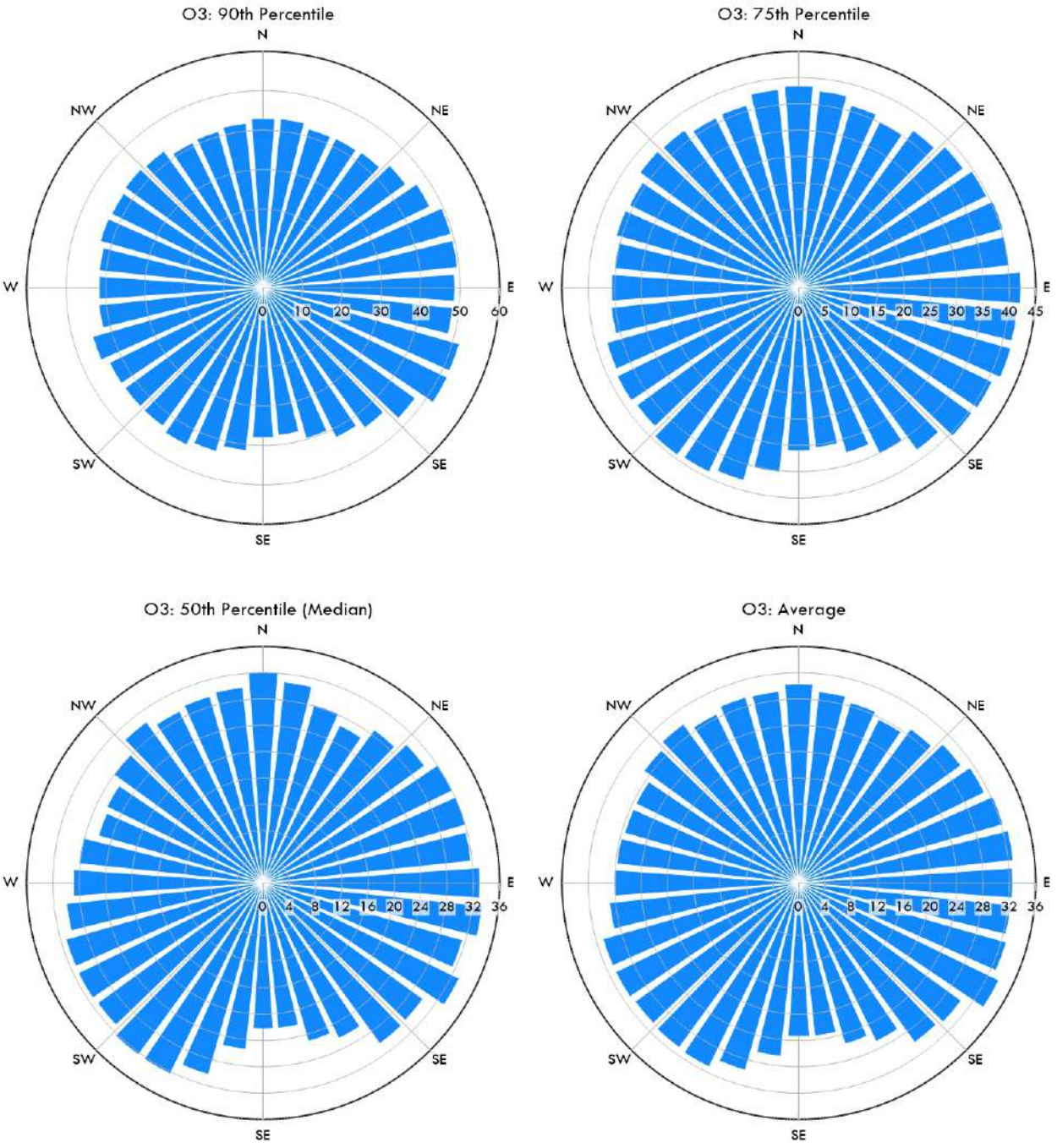

Figure 5.25 NO_2 Measurements by Wind Direction

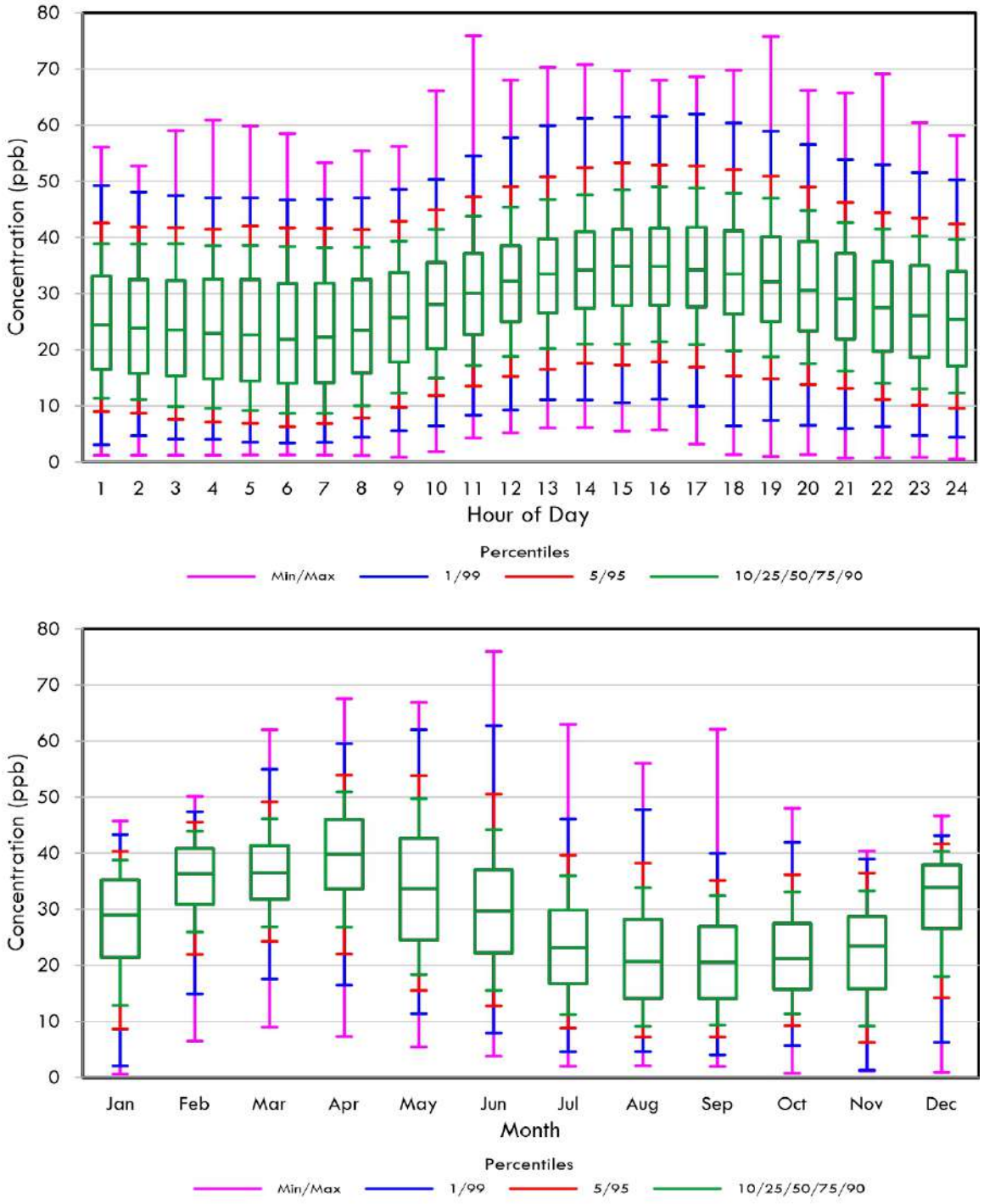

Figure 5.26 O_3 Measurements by Hour of Day and Month

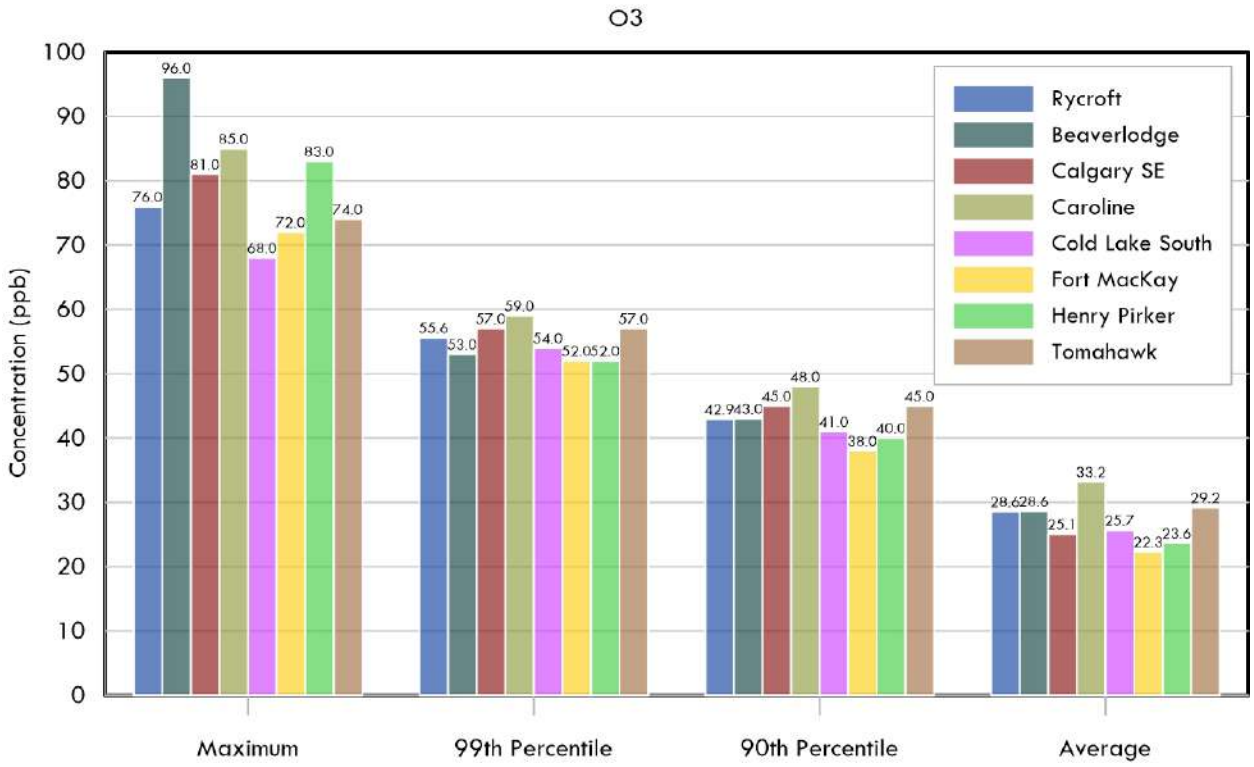

Figure 5.27 Comparison of O_3 Measurements from other Continuous Monitoring Stations

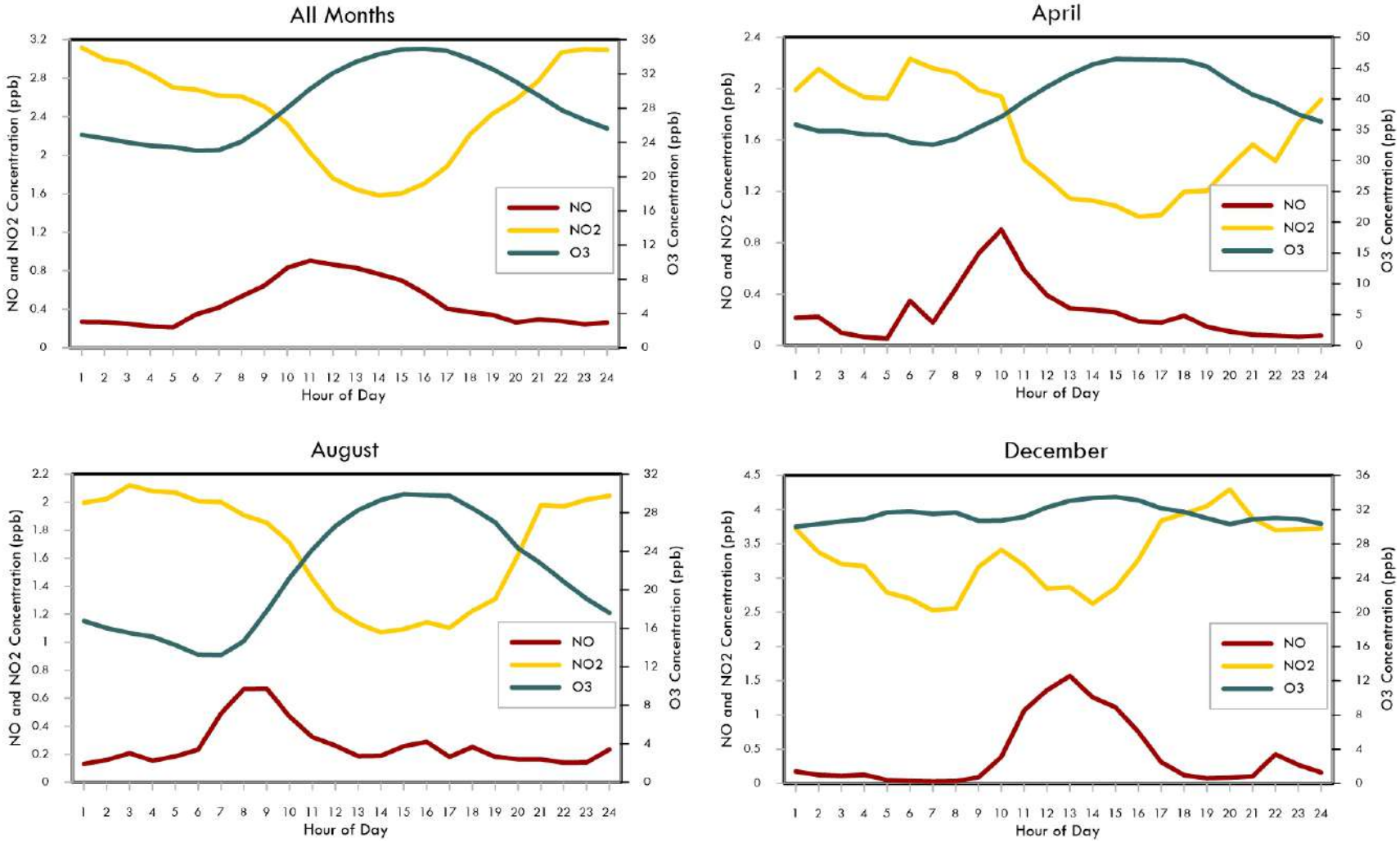

Figure 5.28 Diurnal Relationship between Average Measured O3, NO, and NO2 concentrations for entire period and selected months.

5.6 Fine Particulate Matter ($PM_{2.5}$)

Fine particulate matter ($PM_{2.5}$) refers to airborne solid or liquid particles that are 2.5×10^{-6}m (microns) or less in diameter. It is either emitted directly (primary PM) or formed in the atmosphere from precursor emissions (secondary PM). Important precursors of secondary PM are nitrogen oxides, sulphur dioxide, ammonia, and volatile organic compounds. The chemical composition of particles can vary widely and depends on location, time of year, and weather. Primary $PM_{2.5}$ is formed by combustion processes including: forest fires or residential wood fires; burning of fossil fuels in motor vehicles, furnaces, boilers, and heaters; and certain industrial processes. Secondary fine particles are created when chemicals react in the atmosphere and grow through particle-particle or gas-particle interactions.[10]

A summary of $PM_{2.5}$ measurements are shown in Table 5.5 and the time series of measurements are shown in Figure 5.29. The maximum and 99.9th percentile measurements exceeded the 1-hr AAAQG. The maximum 24-hr measurement exceeded the 24-hr AAAQO. These exceedances are likely due to forest fires .

The 98th percentile 24-hour average over the monitoring period is below the CAAQS of 28 µg/m^3. The average $PM_{2.5}$ measurement is below is the annual CAAQS of 10 µg/m^3. The CAAQS criteria is based on 3 year averages and removes all elevated measurements due to exceptional events such as forest fires. The Rycroft monitor operated for only 32 months and any measurements that were influenced by exceptional or natural events have not been removed, and therefore, the results cannot be explicitly related to the CAAQS.

Figure 5.30 and Figure 5.31 show statistics of the $PM_{2.5}$ measurements as a function of wind direction. The highest measurements occur for winds from the southwest sector. For lower percentile statistics, the measurements show higher measurements for easterly winds. .

Figure 5.32 and Figure 5.33 show the statistics of the measured $PM_{2.5}$ concentrations as a function of hour of day and month, respectively. No trend is observed in the monthly data as the data are skewed by the extremely high measurements likely associated with forest fires. The highest median measurements tend to occur in mid-morning and in early evening.

Figure 5.34 provides a comparison of $PM_{2.5}$ measurements from other monitoring stations in the province for the same time period. The figure shows $PM_{2.5}$ levels at Rycroft were slightly lower when compared to other areas in the province. The ambient $PM_{2.5}$ data measured in Rycroft appears to adequately reflect the general rural setting that is influenced by exceptional events (forest fires) infrequently in the warmer months.

[10] https://open.alberta.ca/publications/aaqo-fine-particulate-matter

Table 5.5 Summary of $PM_{2.5}$ Measurements ($\mu g/m^3$) at Rycroft Monitoring Station

1-hour AAAQG	80
24-hour AAAQO	29
24-hour CAAQS	28
Annual CAAQS	10
Maximum 1-hour Measurement	310.86
99.9th Percentile Measurement	146.56
99th Percentile Measurement	40.65
90th Percentile Measurement	7.23
Median (50th Percentile) Measurement	1.58
Average Measurement	3.64
Maximum 24-hour Average Measurement	121.93
98th Percentile 24-hour Average Measurement[a]	21.21

a. This value was calculated for presentation purposes only and cannot be directly compared to the CAAQS

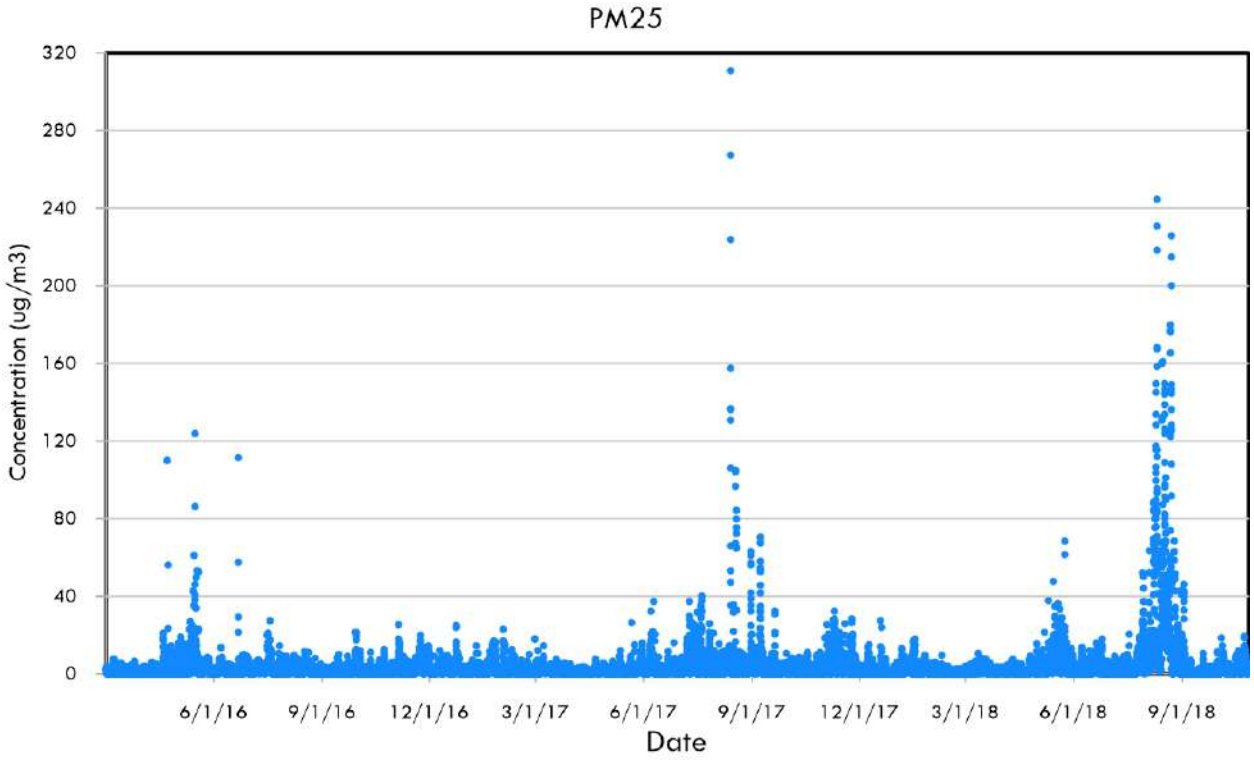

Figure 5.29 Time Series of the Hourly $PM_{2.5}$ Measurements

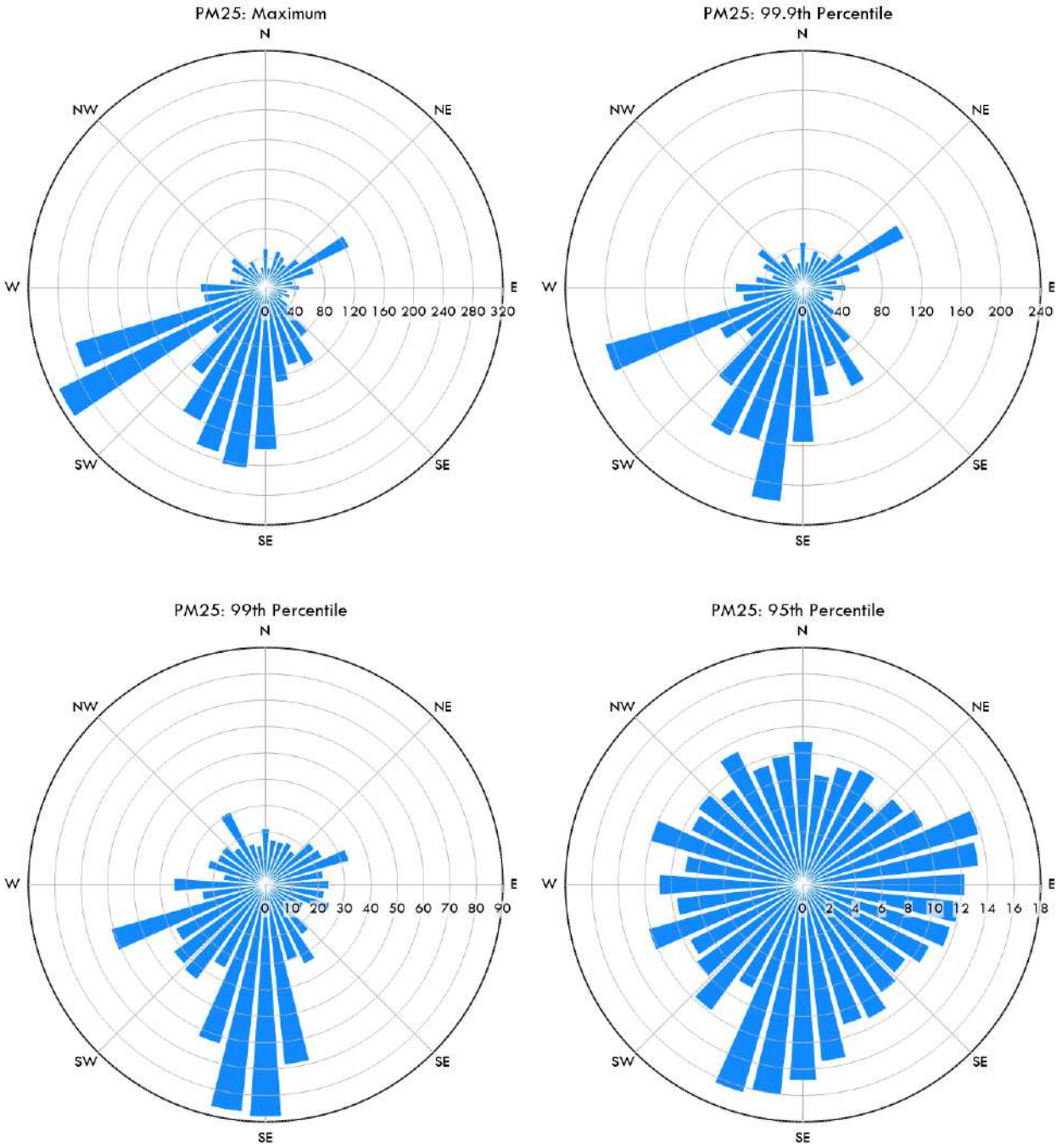

Figure 5.30 $PM_{2.5}$ Measurements by Wind Direction

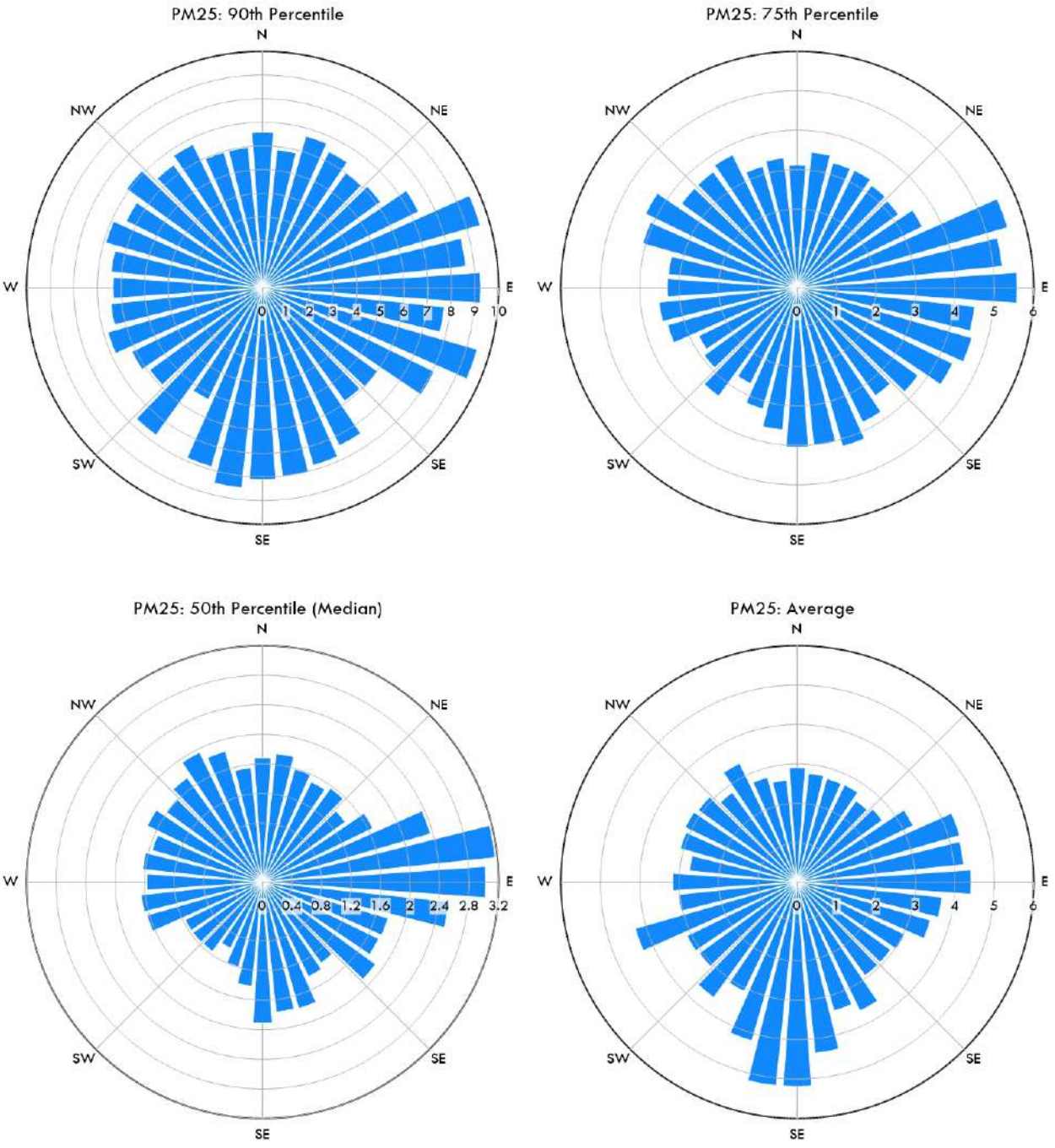

Figure 5.31 $PM_{2.5}$ Measurements by Wind Direction

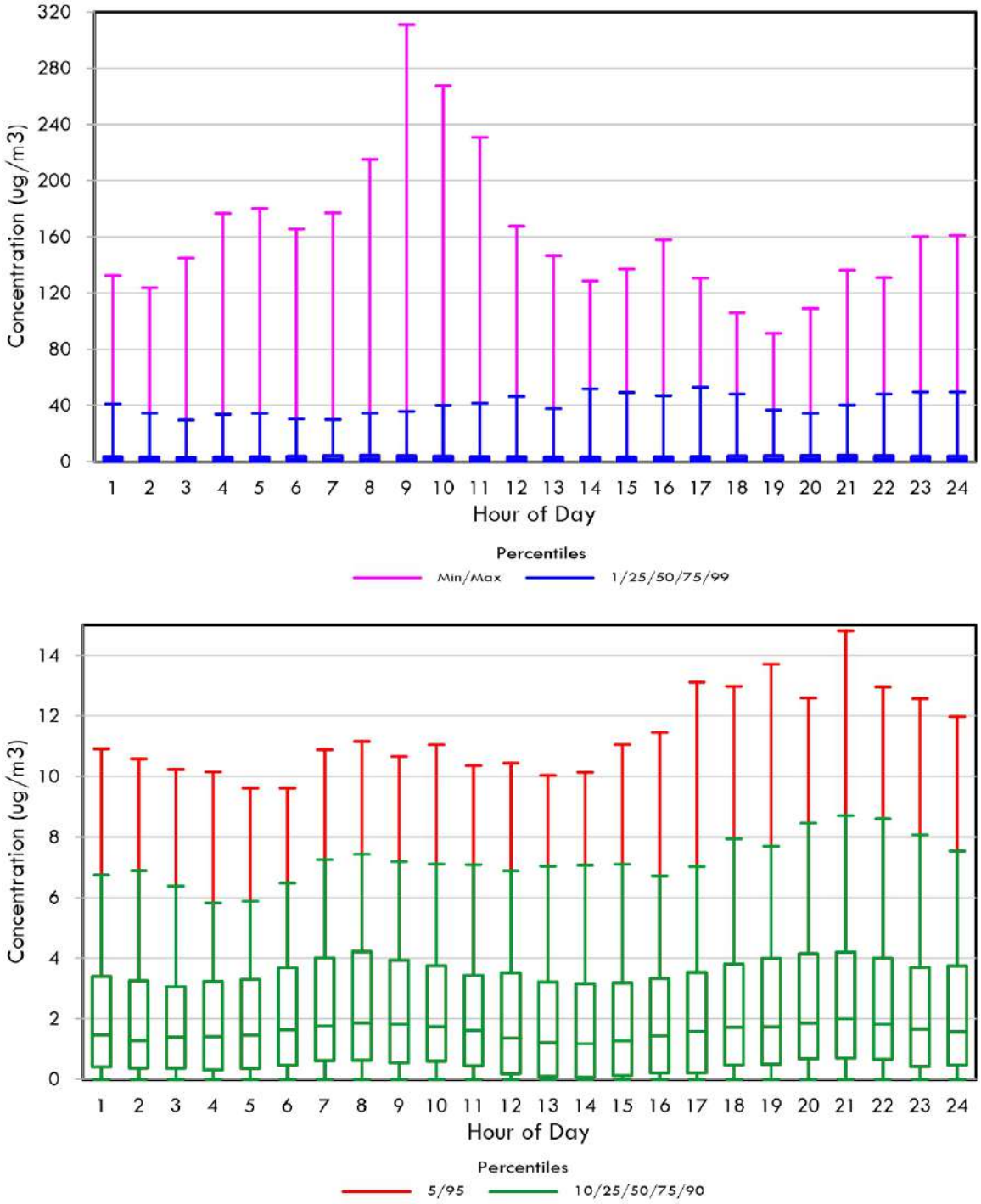

Figure 5.32 $PM_{2.5}$ Measurements by Hour of Day

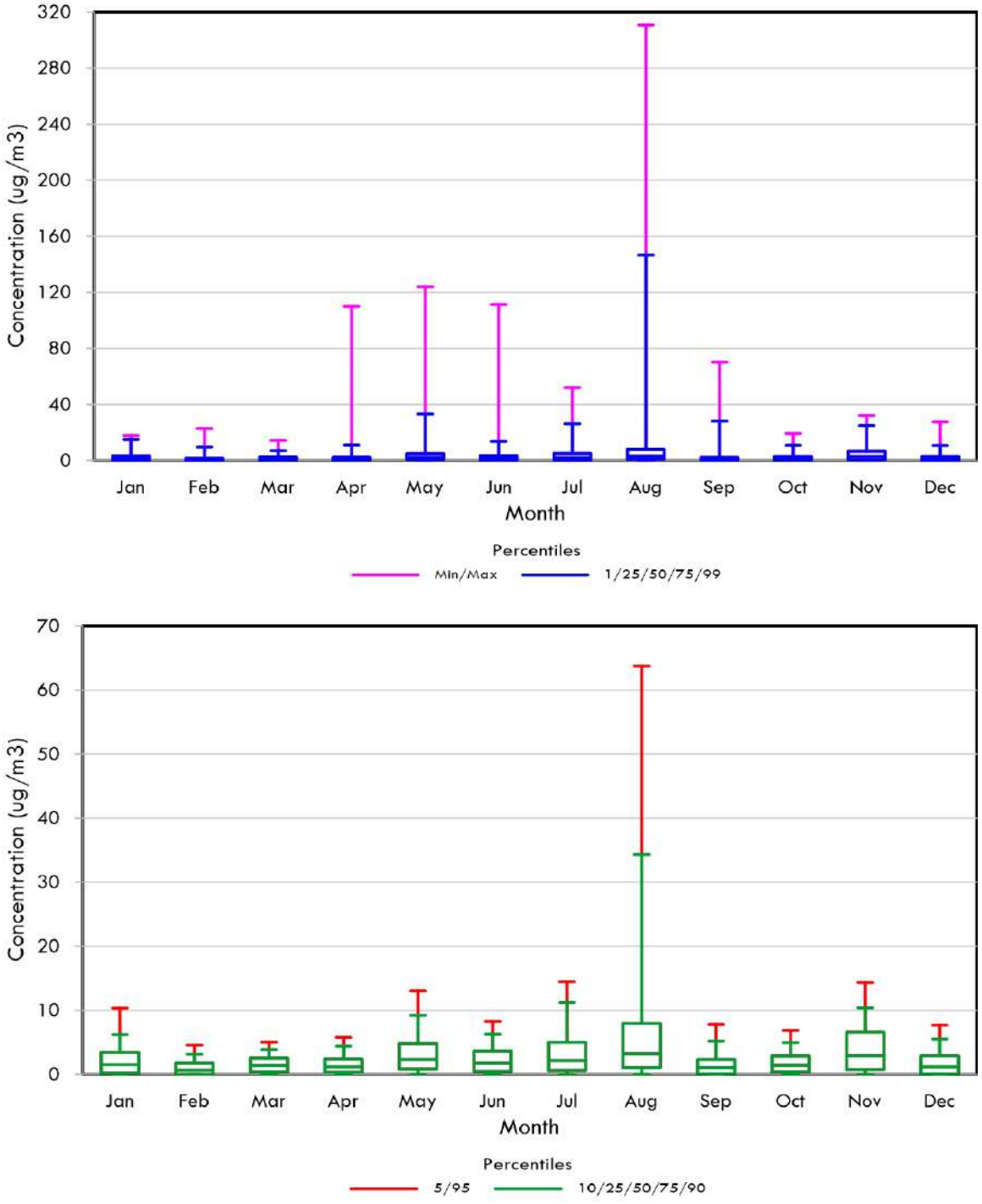

Figure 5.33 $PM_{2.5}$ Measurements by Month

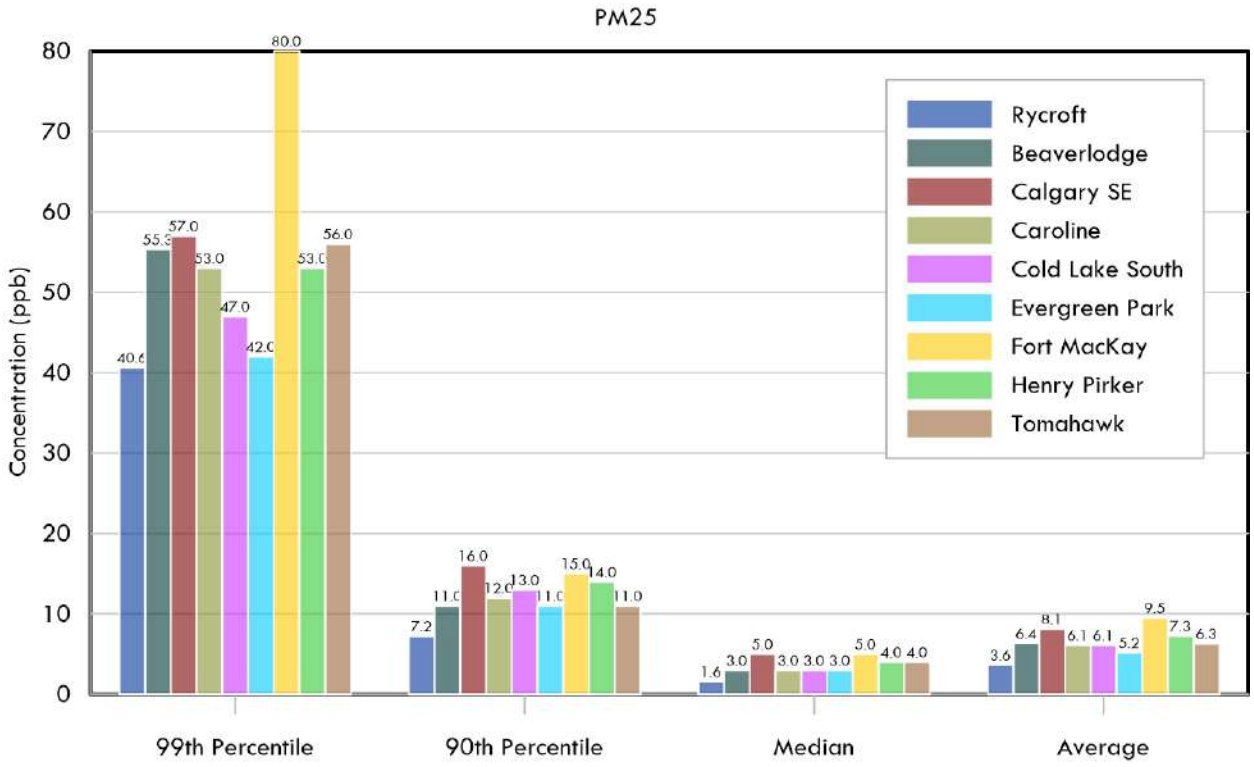

Figure 5.34 Comparison of $PM_{2.5}$ Measurements from other Continuous Monitoring Stations

5.7 Hydrocarbons

THC is a broad term used to describe compounds which contain hydrogen and carbon atoms. Anthropogenic sources of hydrocarbons include vehicle emissions, oil and gas facilities (combustion and fugitive sources), chemical industries, dry cleaning, and natural gas combustion. Natural sources of hydrocarbons include decomposition of organic material, and livestock.

Hydrocarbons are divided into two broad categories, "non-reactive" and "reactive" hydrocarbons. The major non-reactive hydrocarbon is the atmosphere is methane, which is a naturally occurring colourless, odourless gas recognized as a major contributor to the greenhouse effect. The reactive hydrocarbons consist of many VOCs, some of which react with oxides of nitrogen in the atmosphere to form ozone. They generally occur at much lower concentrations than methane. THC include both reactive and non-reactive hydrocarbons.

There are no AAAQOs for methane, THC (or the major constituents of THC) nor NMHC. However, AAAQOs do exist for specific NMHC such as benzene. However, concentrations of specific hydrocarbons cannot be inferred from the data collected. Background THC are primarily composed of methane (1.5 – 2.0 ppm in rural Alberta) and a small contribution from NMHC.

A summary of THC, methane, and NMHC measurements are shown in Table 5.6 and the time series of measurements are shown in Figure 5.35. As can be seen, most of the NMHC measurements were zero. Only 127 non-zero NMHC concentrations and 23 NMHC concentrations above 1 ppb were measured during the monitoring period. As a result, most of the THC and methane measurements were essentially identical. Hence, further analysis focussed on the THC measurements only.

It is noted in Figure 5.35 that there is a slight step increase in the THC and CH_4 data starting at about September 1, 2017. The average THC concentration before this date is 1.875 ppm. The average THC concentration after this date is 1.941 ppm. The reasons for this were not investigated.

Figure 5.36 and Figure 5.37 present statistics of the THC measurements as a function of wind direction. As THC is ubiquitous in the air, the radius scales have been exaggerated to highlight even small changes in the calculated statistics. The data appears to show a slightly higher contribution from the westerly, easterly and southerly directions but the contributions are not considered significant..

Figure 5.38 presents the maximum and average measured THC concentrations as a function of month and hour of day. Diurnal profiles indicate that THC measurements tend to peak in mid-morning and gradually decline to the late afternoon before gradually increasing to mid-morning. This may indicate some of the THCs are involved in the formation of ground level ozone; however, further investigation into that possibility is beyond the scope of this report. Monthly data indicate that the lowest measurements are occurring the summer months.

Figure 5.39 provides a comparison of THC measurements from other monitoring stations in the province for the same time period. The figure shows that THC levels at Rycroft were slightly lower than other areas in the province.

The hydrocarbon data measured appears to be consistent with the rural setting of the monitor. Two high measurements of NMHC were measured and would be cause for concern if they were more frequent; however, the majority of the NMHC readings were zero suggesting that the high readings could be anomalies assuming the equipment were working properly.

It is noted that the average THC measurement is slightly lower than the average CH_4 measurement. The reason for this anomaly is that for many of lower measurements of THC, a corresponding CH_4 was not measured due to a manual span occurring. Table 3.2 that shows there are about 20% more valid THC measurements than CH_4 measurements.

Table 5.6 Summary of Hydrocarbon Measurements (ppm) at Rycroft Monitoring Station

	THC	CH_4	NMHC
Maximum 1-hour Measurement[a]	2.43	2.38	0.43
99.9th Percentile Measurement	2.18	2.17	0.01
99th Percentile Measurement	2.10	2.10	0.00
90th Percentile Measurement	2.00	2.00	0.00
Median (50th Percentile) Measurement	1.91	1.91	0.00
Average Measurement	1.90	1.91	0.00

a. There are no AAAQOs for THC are its main constituent (Methane)

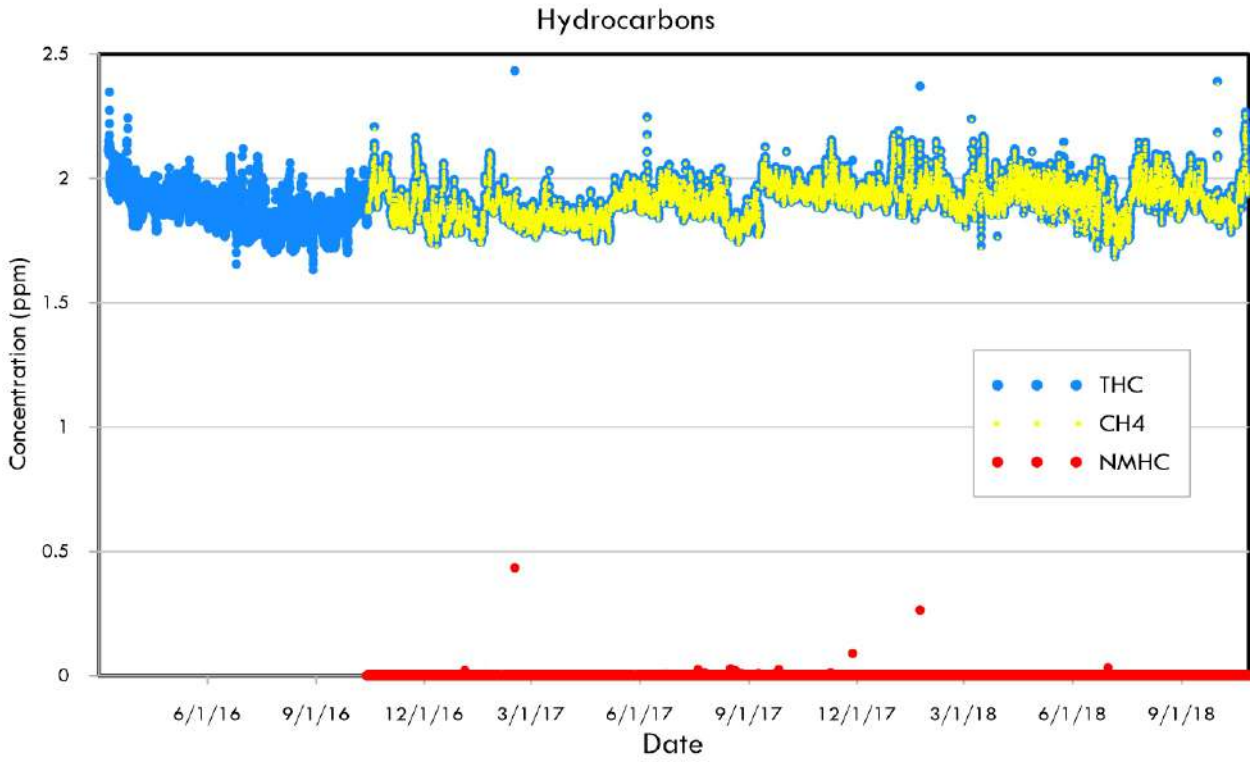

Figure 5.35 Time Series of the Hourly Hydrocarbon Measurements

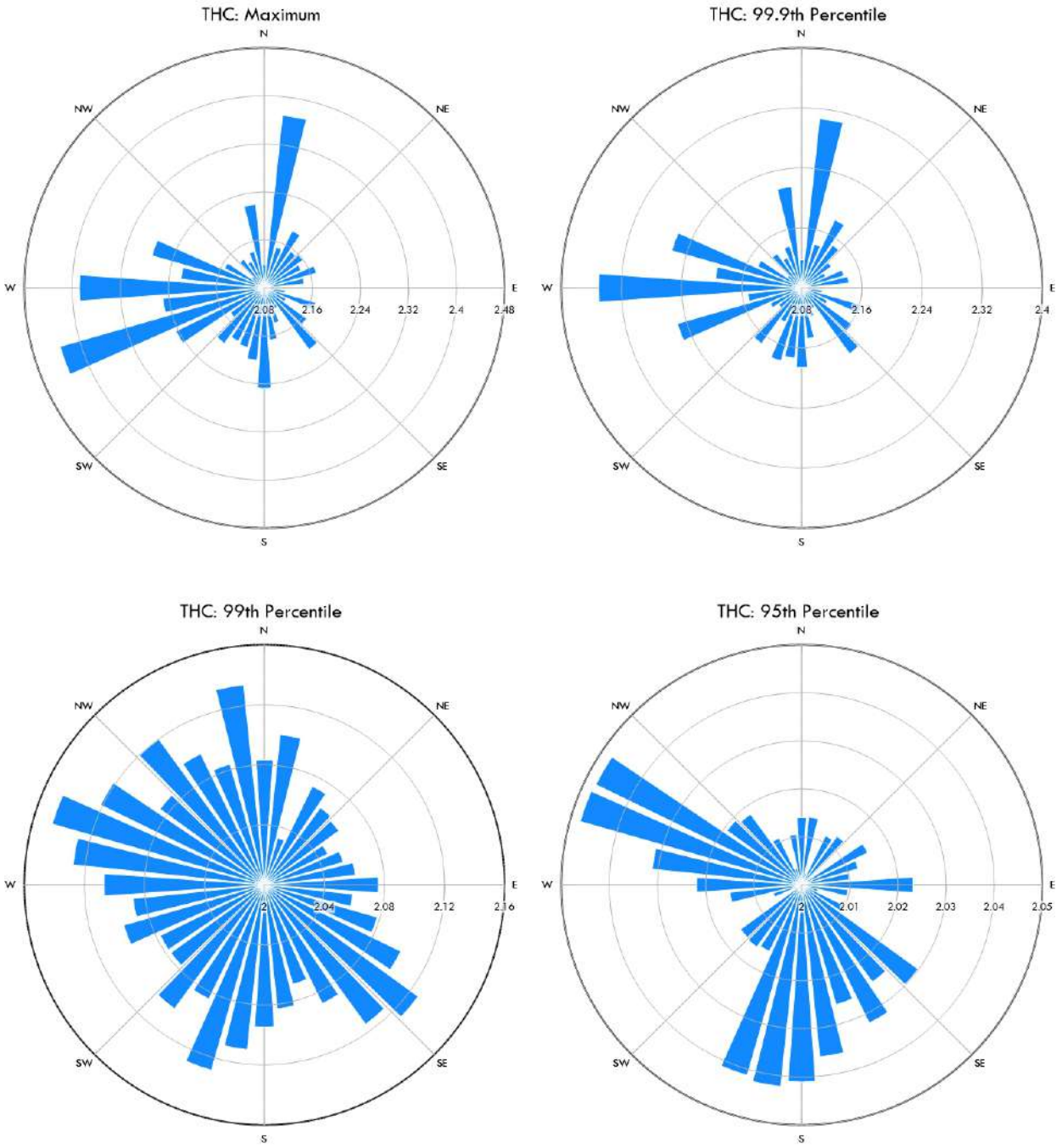

Figure 5.36 THC Measurements by Wind Direction

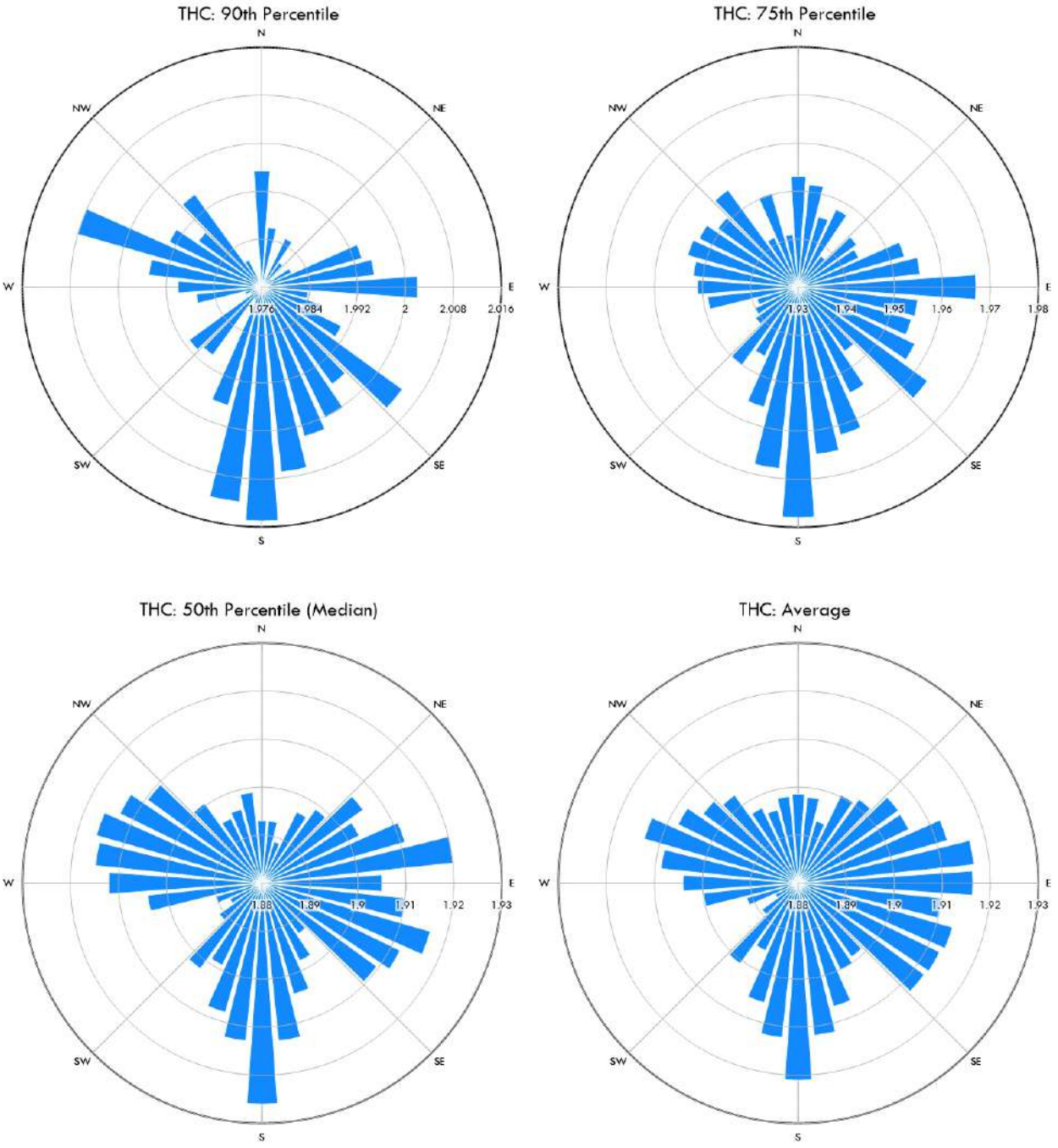

Figure 5.37 THC Measurements by Wind Direction

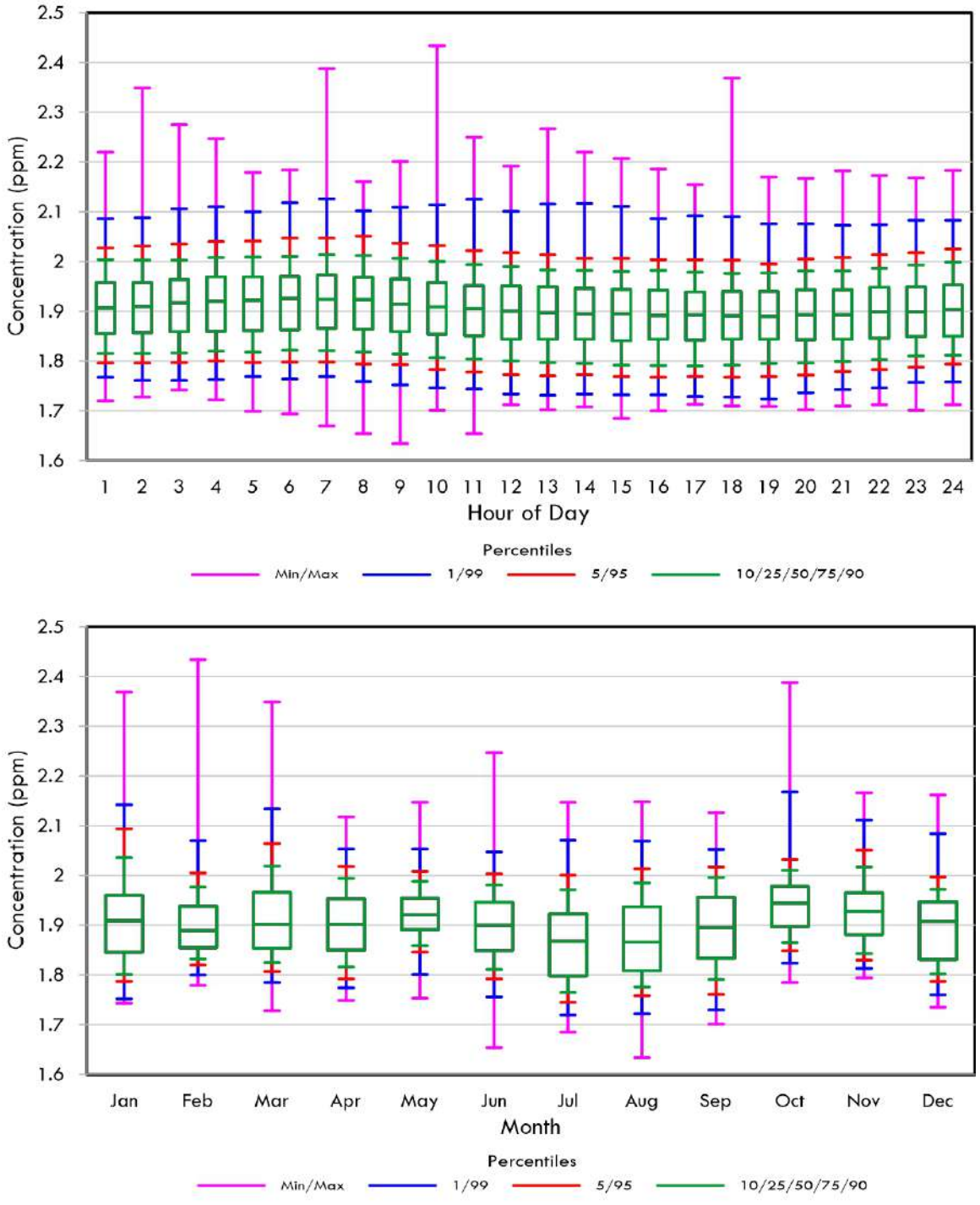

Figure 5.38 THC Measurements by Hour of Day and Month

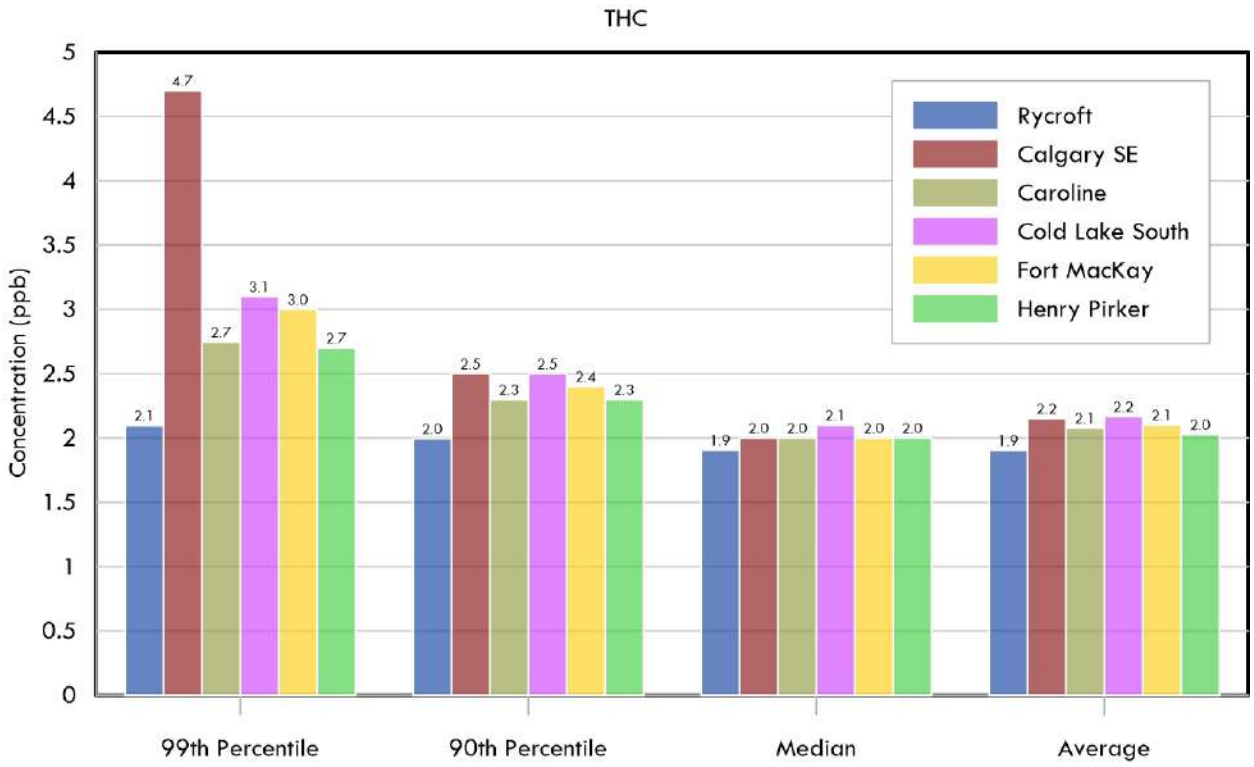

Figure 5.39 Comparison of THC Measurements from other Continuous Monitoring Stations

6. SUMMARY AND RECOMMENDATIONS

The monitoring data that PAZA collected through the Rycroft monitoring project suggests that the air quality in the area is relatively good. Measured concentrations of TRS, SO_2, NO_2, and O_3 were below the applicable or other representative AAAQOs. Diurnal profiles of O_3 and NO_2 measurements appear to show slight photo-chemical O_3 formation and decomposition. A waste disposal facility and rail traffic close to the monitor appear to have influenced the TRS, NO_2 and THC measurements but not adversely

Measurements of $PM_{2.5}$ indicated that the AAAQG and AAAQO were exceeded infrequently during the monitoring period which were likely due to forest fires and did not appear to be reminiscent of general poor air quality. It is recommended that PAZA consider looking into the possible contributors to the elevated $PM_{2.5}$ measurements to definitely determine if exceptional events were the cause.

Concentrations of THCs measured in the area were slightly lower than other areas in province for the same monitoring period. Very infrequent elevated concentrations of NMHC were measured but are not necessarily a cause for concern as the majority of NMHC measurements were zero. However, canister sampling for specific hydrocarbons or VOCs such as benzene would provide further helpful information as concentrations of specific hydrocarbons or VOCs cannot be inferred from the data collected.

The summary of the Rycroft air quality survey is limited to the parameters measured in this study. Air quality in the area may be affected by other compounds some of which PAZA was not equipped to measure such as speciated hydrocarbons, volatile organic compounds (VOCs) or ammonia.