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One-Year Air Data Technical Review for the Screwdriver Creek Valley Continuous Air Monitoring Station

Screwdriver Creek Valley, AB

Final Report

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SUBMITTED TO

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TABLE OF CONTENTS

Tables

Figures

1. BACKGROUND

On December 5, 2012, RWDI Air Inc. (RWDI) submitted to Shell Canada Limited (Shell) the final report titled “Ambient Air Monitoring Program Design”. This was a technical review of the existing and historical ambient air quality and meteorological monitoring in the Waterton Screwdriver Creek Valley (SCV) including recommendations for improvement and/or modifications of the air monitoring design at the time of the review (RWDI 2012).

Furthermore, RWDI performed an ambient air monitoring siting study to develop site recommendations to monitor for ambient levels of SO_2 and H_2S associated with flaring activities in the SCV (RWDI 2013). Subsequently, Shell changed the Waterton air monitoring design based on the recommendations and established a new one-year pilot continuous air quality monitoring station within the SCV, along with additional temporary mobile and stationary monitors.

This present report provides a technical review of the ambient measurements collected over the study year in conjunction with information provided by Shell on flaring activities in the SCV area. A satellite image of the SCV area including the locations of the flares of interest and monitoring stations discussed in this report is shown in Figure 1.

Figure 1: Satellite Image of the SCV Area Showing the Locations of the Flares, the SCV Continuous Ambient Monitoring Station, the Temporary Continuous Ambient Monitoring Station, the Passive Air Monitors and the Locations of the Mobile Air Quality Units Used During Two of the Flaring Events.

2. DATA AND METHODS

This section describes the ambient measurements and additional information that were available for the study year and the methods that were applied to analyze these measurements.

2.1 Monitoring Data

The following data over the study year from April 2014 through March 2015 was available for the analysis:

1. Hourly measurements from the SCV continuous monitoring station. Based on the recommendations in the siting study (RWDI 2013), the initial air monitoring report (RWDI 2012), and collaboration with the Waterton Air Group (WAG) committee, this trailer was installed at 49.462254° N and 114.242638° W, which is close to one of the residences within the SCV. The measurements at this station are performed every one-minute. The raw data goes through a QA/QC procedure to eliminate non-valid readings (e.g. calibrations, zero spanning). RWDI also received the non-QA'd raw data for periods of interest.

2. Data from a mobile unit located downwind during flaring activities at Waterton 68 in August and October 2014.

3. Passive monitoring results from three stations within the Waterton 68/SCV area for the study year.

4. Monitoring data at the temporary continuous monitoring station close to one of the residences within the SCV from August 16, 2014 to October 27, 2014.

These data sets are summarized in Table 1 and described in further detail in the following subsections. The locations of the monitors are shown in Figure 1.

Table 1: Monitoring Results Available for Analysis

	Continuous at Location 1	Temporary Mobile 1	Temporary Mobile 2	Passive	Temporary Continuous at Location 2
Operator	AGAT Laboratories	Dexter Oilfield Inc.	Dexter Oilfield Inc.	AGAT Laboratories	Independent Energy Solutions Corp.
Location	East of one of the residences (49.4622°N, 114.2426°W)	Varies (downwind of flaring)	Varies (downwind of flaring)	At three locations: (49.4661°N, 114.236°W); (49.4509°N, 114.248°W); (49.4807°N, 114.217°W)	At one of the residences (49.4499°N, 114.2480°W)
Data Period	Apr. 2014 to Mar. 2015	Aug. 14, 2014 to Aug. 24, 2014	Oct. 7, 2014 to Oct. 18, 2014	Apr. 2014 to Mar. 2015	Aug. 16, 2014 to Oct. 27, 2014
Frequency of Measurements	Hourly	Continuous and Intermittent	Continuous and Intermittent	Monthly	Continuous and Intermittent
Measured Quantities	SO_2, H_2S, Temperature, Wind Speed, Wind Direction	SO_2, H_2S, Temperature, Wind Speed, Wind Direction	SO_2, H_2S, Temperature, Wind Speed, Wind Direction	SO_2, H_2S	SO_2, H_2S, Wind Speed, Wind Direction

2.2 Flaring within the SCV

In order to put the monitoring data into perspective, emissions and other information regarding flaring activities at the SCV were provided by Shell. This data is summarized in the following subsections.

2.2.1 Flaring of Vent/Vapor Tank Gas at Waterton 68

A detailed report for enrichment venting at Waterton 68 was provided by Grant Production Testing Services Ltd. This report included the date and time, temperature, pressure, and volume of vented methane enrichment gas and raw gas for the period of August 17, 2014 to October 17, 2014; the flare was continuously lit during this period. Based on the information that was provided to RWDI, below are the times/date periods that flaring occurred within the SCV:

- August 20th started: 07:30 and ended: 08:15;
- August 23rd started: 18:30 and ended: 20:35;
- September 11th started: 17:45 and ended: 18:30;
- October 10th started: 23:30 and ended: October 11th at 01:30;
- October 11th started: 02:30 and ended: 04:30;

- October 17th started: 8:30 and ended: 10:01; and,
- October 17th started: 15:45 and ended: 18:10.

The total volumes of vented raw and methane gas were also provided for each period. The location of the Waterton 68 well is shown in Figure 1.

2.2.2 Bi-Weekly Pigging at Waterton Junction and Junction 6-12

In addition to the non-routine flaring at Waterton 68, routine pigging and flaring occurred at Waterton Junction (WAT-JCT) and Junction 6-12 (JCT 6-12). These events typically lasted less than 45 minutes each. Each event is made up of three short releases of raw and diluted gas. The schedule for these flaring events is shown in Table 2. The locations of these two flares are shown in Figure 1.

Table 2: Routine Maintenance Flaring within the SCV

Location	Schedule
WAT-JCT	Approximately 13:30 on Tuesdays and Thursdays
JCT 6-12	Approximately 09:00 on Wednesdays

2.3 Reported Events with Potential for Exceedances of Ambient SO_2 and H_2S Concentrations

To determine if a correlation can be made between operations at the Waterton Complex and measured concentrations in the SCV area, the 2014 Annual Air Monitoring Report for the Waterton Complex was reviewed. There were a number of short-term upset events in 2014. The Waterton Complex is located approximately 25 km southeast of the SCV. The monitoring results collected during these events were analyzed to check the potential effect on air quality readings in the SCV. A summary of the dates and times of these events (during the study year) is presented in Table 3.

Table 3: Short-Term Upset Events at Shell Waterton Complex in 2014 [1]

Date	Location	Event	Hour Ending	Reading	Wind Direction at SCV (in degrees from true North)
Jun. 26, 2014	Shell Waterton Complex	Hourly SO_2 emissions above 2.2 tonnes/hour	17:00	2.45 tonnes/hour	314
		In-stack concentration of SO_2 above 3,900 ppm	16:00	8, 097 ppm	353
			17:00	10,868 ppm	314
			18:00	4,518 ppm	94
Oct. 5, 2014	Shell Waterton Complex	Hourly start-up SO_2 emission above 2.61 tonnes/hour	13:00	3.03 tonnes/hour	202
Nov. 2, 2014	Shell Waterton Complex	Hourly SO_2 emissions above 2.2 tonnes/hour	04:00	2.95 tonnes/hour	37
			05:00	2.50 tonnes/hour	354
		In-stack concentration of SO_2 above 3,900 ppm	03:00	4,326 ppm	34
			04:00	7,411 ppm	37
			05:00	5,293 ppm	354
Nov. 9, 2014	Shell Waterton Complex	Hourly stack-top temperature below 400° C	17:00	376° C	43

Note: [1] This table presents the events that occurred during the study year (Shell 2015).

Table 4 also shows the wind direction measured at the SCV continuous monitoring station. During these events, none of the measured winds in the SCV were blowing from the Shell Waterton Complex from the southeast (135° ± 11.25°) which would indicate plume transport of SO_2 towards the SCV; therefore, no further analysis was conducted to detect any potential connection between these events and readings of SO_2 and H_2S concentrations within the SCV.

2.4 Historical Annual Emissions

Shell provided RWDI with their historical annual SO_2 and H_2S emission totals for the years of 2000 to 2014 at the Waterton Complex (see Table 4). This information is used to provide a historical context and indicate the representativeness of the study year relative to historical operating levels.

Table 4: Historical Emissions of SO_2 and H_2S at the Waterton Complex (tonnes/year)

Year	Annual SO_2 Emissions	Annual H_2S Emissions
2000	12,500	127
2001	10,000	110
2002	11,000	156
2003	12,400	52.4
2004	10,200	113
2005	11,600	N/A
2006	10,500	31.1
2007	6,290	33.9
2008	2,300	5.8
2009	4,500	0.0
2010	8,370	7.4
2011	10,200	8.0
2012	5,630	5.6
2013	8,880	N/A
2014	6,970	N/A

Note: 'N/A' indicates not available

2.5 Data Reduction Methods

Statistical analysis of the monitoring results was performed to obtain maximum, average, 90th, and 50th percentile levels for the observations. Observed concentrations of SO_2 and H_2S were compared with the Alberta Ambient Air Quality Objectives (AAAQO) set by Alberta Environment and Parks (AEP 2013a) as well as odour detection thresholds provided by the American Industrial Hygiene Association (AIHA 2013) shown in Table 5 and Table 6, respectively.

Table 5: Alberta Ambient Air Quality Objectives for SO_2 and H_2S

Contaminant	1-Hour (ppb)	1-Hour ($\mu g/m^3$)	24-Hour (ppb)	24-Hour ($\mu g/m^3$)	30-Day (ppb)	30-Day ($\mu g/m^3$)
SO_2	172	450	48	125	11	30
H_2S	10	14	3	4	-	-

Notes: '-' indicates no value specified

Source: AEP 2013a.

Table 6: Selected Odour Detection Thresholds for SO_2 and H_2S, Based on 3-minute Averaging

Contaminant	Selected Odour Detection Threshold (ppb)	Selected Odour Detection Threshold ($\mu g/m^3$)
SO_2 [1]	330	870
H_2S [2]	10	14

Notes: [1] Based on the minimum threshold reported in AIHA 2013.

[2] Based on the 1-hour AAAQO for H_2S which is on the basis of odour perception

Observed values were also compared with representative background concentration of SO_2 and H_2S. Ambient background concentrations of 0.2 ppb for SO_2 and 0.4 ppb for H_2S were provided in the air monitoring study (RWDI 2012) and are shown in Table 8.

Table 7: Representative Ambient Background Levels of SO_2 and H_2S

Contaminant	Measured Annual Average Ambient Background Concentration (in ppb)
SO_2	0.2 [1]
H_2S	<0.4 [2]

Notes: [1] Taken from WCAS High Tower Station (2009)

[2] Taken from PAMZ Red Deer – Riverside Station (2011)

3. RESULTS

3.1 Comparison of Year 2014 Emissions with Historical Emissions

To provide a historical context and indicate if the study year is representative of Shell operations in the SCV area in terms of SO_2 and H_2S emissions, historical emissions were compared with 2014 emissions.

Emissions of SO_2 from the Waterton Complex in 2014 were compared with previous annual emissions. As shown in Figure 2, 6,970 tonnes of SO_2 was released in the year of 2014. From year 2000 to 2006, the annual SO_2 emissions were fairly consistent ranging from 10,000 to 12,500 tonnes/year, all of which were greater than the SO_2 emissions that occurred in 2014. From years 2007 to 2013, SO_2 emissions from the Waterton complex were quite variable ranging from 2,200 to 10,500 tonnes/year. Relative to the study year of 2014, SO_2 emissions were 4,800 tonnes greater than the 2008 emissions and were 3,200 tonnes less than the 2011 emissions.

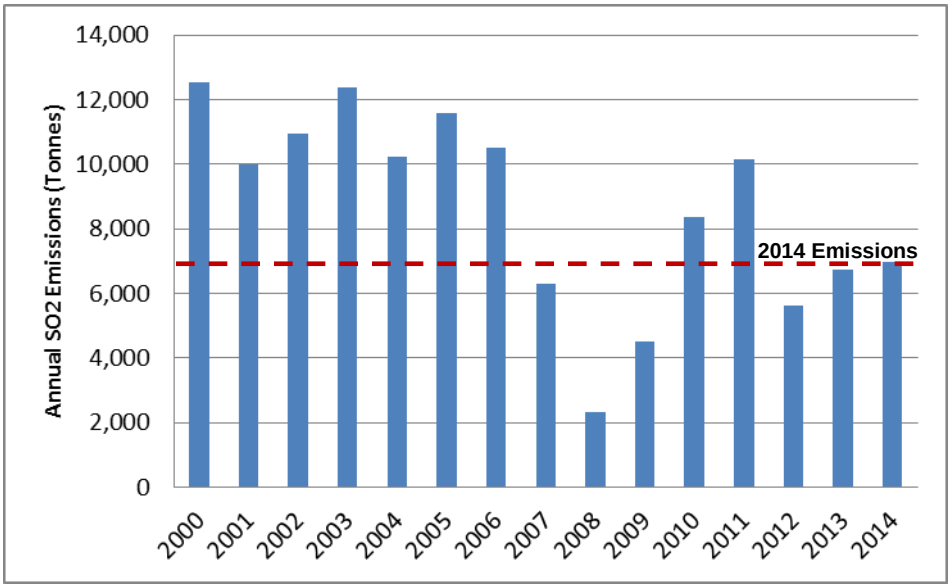

Figure 2: Historical and Year 2014 SO_2 Emissions from the Shell Waterton Complex (tonnes/year)

Overall, the 2014 SO_2 emissions from the Waterton Complex were substantially lower than pre-2007 emissions but very close to the previous 5-year average, indicating that the study year appears to be representative of a typical recent operation year. Emissions of H_2S showed a similar trend to that of SO_2.

3.2 Analysis of Continuous Hourly Data at SCV Continuous Air Monitoring Station

The location of this station was selected based on detailed air dispersion modelling and other technical parameters listed in the Ambient Air Monitoring Siting Study (RWDI, 2013). The survey location was intended to capture any measureable concentrations of SO_2 and H_2S near residents which could be correlated to odour issues in the SCV due to flaring activities (see Figure 1). One year of hourly concentrations of SO_2 and H_2S were collected and provided the basis for analysis in this report. Wind speed and wind direction were also measured at this station. Most of the winds at this station were uniform in direction and follow the topography of the valley, blowing predominantly from the southwest (30%) and south-southwest (38%). Figure 3 shows the wind rose which graphically represents the percentage of time that the wind originated form the given direction and by wind speed.

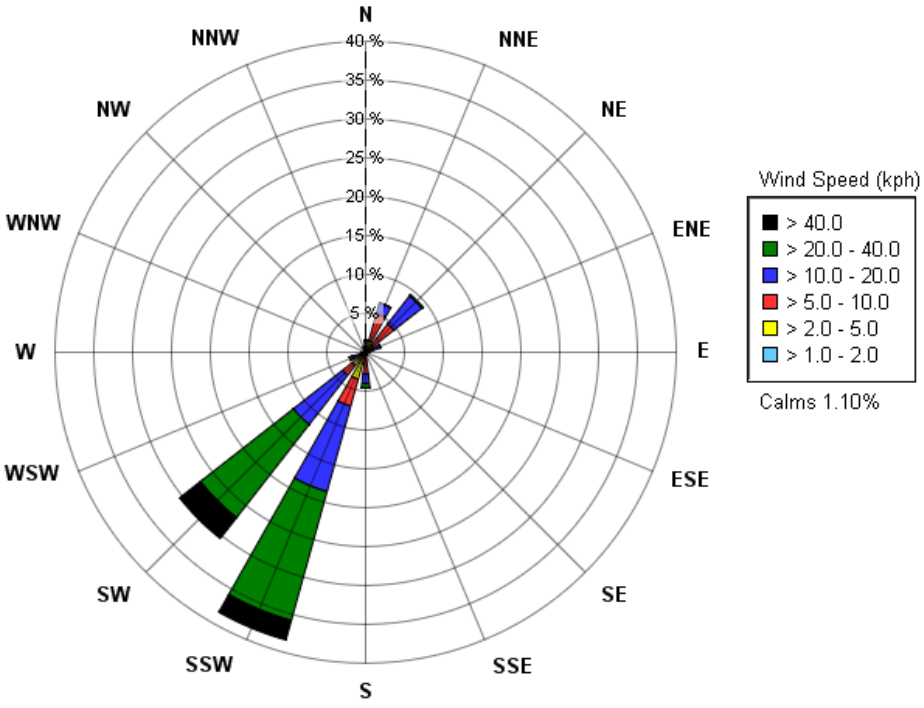

Figure 3: Wind Rose for the SCV Continuous Monitoring Station for the Period April 1, 2014 to March 31, 2015.

Statistical analysis of ambient SO_2 and H_2S measurements at the SCV continuous monitoring station, showed no exceedances of their applicable AAAQO. Table 9 summarizes the primary analysis for this dataset.

Table 8: Statistical Summary of the SO_2 and H_2S Measurements from SCV Continuous Monitoring Station for the Period, April 1, 2014 to March 31 2015 (in ppb)

Pollutant	Maximum	Average	90th Percentile	50th Percentile	Data Completeness[1]
SO_2	5.3	0.14	0.30	0.10	95%
H_2S	0.5	0.03	0.10	0.00	95%

Note: [1] Data Completeness is calculated based on the number of hours with valid readings and the total number of hours in the study year (8760) as per Alberta Air Quality Model Guideline (AEP 2013b).

The maximum observed concentration of SO_2 occurred during the flaring at Waterton 68 (October 17, hour 9:00), which will be discussed in further detail in this section. The maximum observed H_2S occurred on three different occasions (April 8, hours 18:00 and 19:00, and October 23, hour 20:00) in the absence of flaring activity.

Odour detection thresholds shown in Table 6 are based on a 3-minute averaging period. To further investigate the potential for odour detection, this study looked into the non-QA'd 1-minute average measurements during the hours with the highest hourly SO_2 or H_2S concentrations mentioned above. Based on these readings, during the October 17 event, the maximum 3-minute SO_2 concentration was 15.8 ppb which is well below the odour detection threshold of 330 ppb. During the April 8 event, the maximum 3-minute H_2S concentration was 0.68 ppb. During the October 23 event, 1-minute averages were only available during the first 18 minutes of the hour 20:00; the full data set of the 1-min data was affected due to a short-term power outage in the field and a problem with the backup data logger. In this period, the maximum 3-minute H_2S concentration was 0.53 ppb. Based on the available measurements and relative to the odour detection threshold of 10 ppb for H_2S, no potential for odour in the SCV is expected.

Figure 4 shows the time series of hourly SO_2 and H_2S concentrations at this station for the study year.

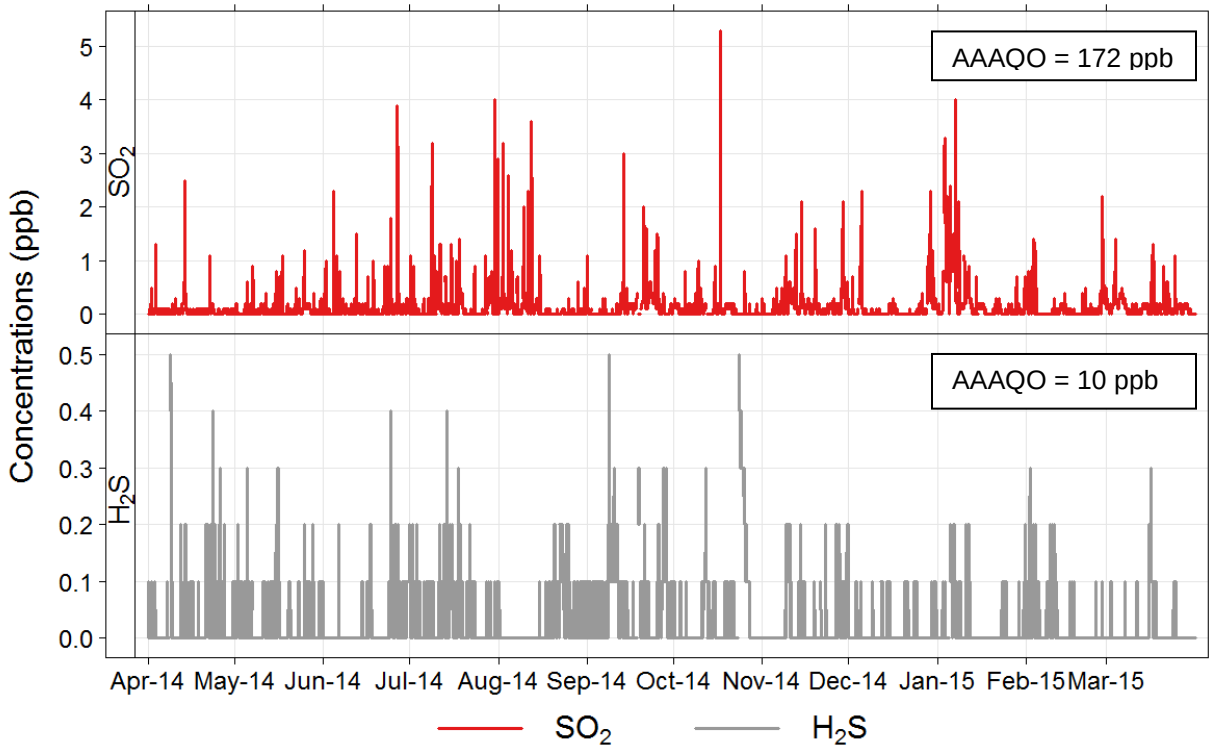

Figure 4: Time Series of SO_2 and H_2S Concentrations at the SCV Continuous Monitoring Station for the Period April 1, 2014 to March 31, 2015.

All hourly readings of SO_2 and H_2S were below their respective AAAQO and odour detection limits. To put the measured concentrations of SO_2 and H_2S into context, average concentrations in Table 8 can be compared with representative background concentrations of SO_2 and H_2S shown in Table 7.

To further analyze the monitoring data from the SCV continuous monitoring station, potential connections between flaring events and higher readings of SO_2 and H_2S were examined. Table 9 shows the date and time of flaring events at Waterton 68, as well as SO_2 and H_2S concentrations and wind direction at the SCV continuous monitoring station. Waterton 68 is located west-southwest of the station; therefore, for wind directions of 247.5 ± 11.25 degrees there is a potential for emissions to lead to measurable ambient concentrations at the monitoring station if they are above the reporting level.

Table 9: Comparison of the Waterton 68 Flaring Events and the Ambient Measurements from the SCV Continuous Monitoring Station

Flaring Date	Time	SO_2 Concentration (ppb)	H_2S Concentration (ppb)	Wind Speed (km/hr)	Wind Direction (in degrees from True North)
Aug. 20	07:00	N/A	N/A	6.0	3
	08:00	0	0.2	3.1	48
	09:00	0	0.1	2.2	31
Aug. 23	18:00	0	0.1	2.4	166
	19:00	0	0.1	1.6	106
	20:00	0	0	0.8	206
	21:00	0	0.1	2.5	197
Sept. 11	17:00	0.1	0.1	14.9	203
	18:00	0	0.1	11.3	205
	19:00	0.1	0.1	14.2	205
Oct. 10	23:00	0.1	0.1	14.9	211
Oct. 11	00:00	0.2	0	13.2	210
	01:00	0.1	0	17.4	212
	02:00	0.1	0	19.8	218
	03:00	0.1	0.1	18.8	217
	04:00	0	0.1	21.4	217
	05:00	0	0.1	21.9	215
Oct. 17	08:00	1.0	0	17.0	221
	09:00	5.3	0	20.2	220
	10:00	0.6	0	17.9	221
	11:00	0.1	0	23.2	216
	15:00	0.1	0	26.0	222
	16:00	0.1	0	23.8	222
	17:00	0.1	0	23.8	221
	18:00	0	0	23.7	217
	19:00	0.1	0	28.9	209

Note: 'N/A' indicates not available. Zero/span checks for the monitoring station were in progress.

Large-scale westerly winds are quite common in the Waterton area. These winds are frequently channeled and redirected through the SCV from a southwesterly direction. Therefore, under westerly winds, emissions at Waterton 68 can be transported to the monitoring station. This might explain the SO_2 concentrations observed on October 17 at 09:00 and on October 11 at 0:00, when the wind direction at the SCV indicated channeling through the valley. The Environment Canada data at Pincher Creek in the open Prairies to the west of the study area, suggested larger-scale westerly winds. This explains why

higher concentrations were measured at the SCV continuous monitoring station during these meteorological conditions.

3.3 Analysis of Continuous Measurements at the Temporary Continuous Monitoring Station

Hourly concentrations of SO_2 and H_2S as well as wind speed and direction from the temporary continuous station were available for the period of August 16, 2014 to October 27, 2014. During this period, the winds at this station were predominantly blowing from the southwest (37%) and south-southwest (23%). Figure 5 shows a wind rose based on these readings. The location of this station is shown in Figure 1.

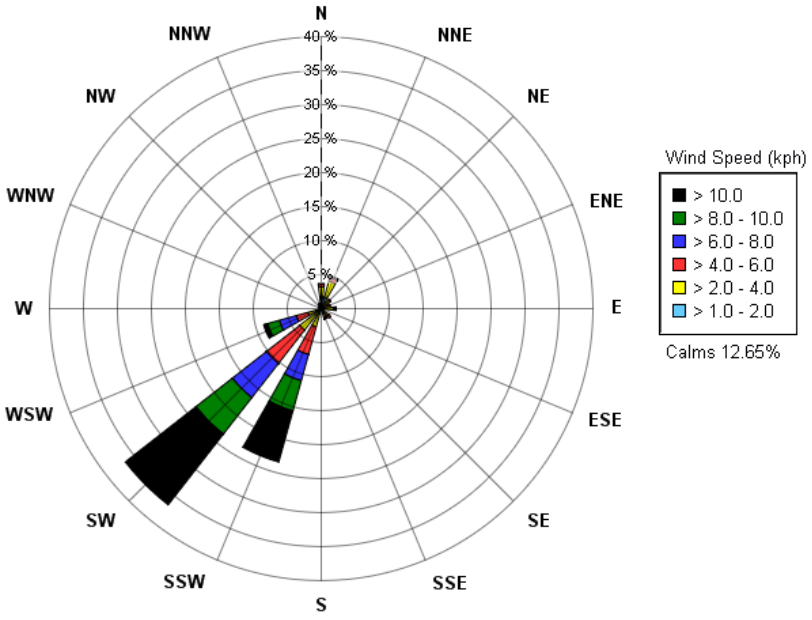

Figure 5: Wind Rose for the Temporary Continuous Monitoring Station for the Period August 16, 2014 to October 27, 2014

Table 10 summarizes the concentrations observed at this station. No detectable readings of SO_2 and H_2S occurred during the monitoring period for this station.

Table 10: Maximum and Average SO_2 and H_2S Concentrations for the Temporary Continuous Monitoring Station for the Period of August 16, 2014 to October 27, 2014

Pollutant	Maximum (ppb)	Average (ppb)	Maximum ($\mu g/m^3$)	Average ($\mu g/m^3$)
SO_2	0.0	0.0	0.0	0.0
H_2S	0.0	0.0	0.0	0.0

3.4 Analysis of Hourly Mobile Monitoring Readings

Downwind air monitoring was performed using a mobile air quality monitoring van during the Waterton 68 flaring events. The monitoring van changed its location in an attempt to stay downwind from the Waterton 68 well pad; however, this was constrained by the use of existing public roads. Locations at which the monitoring van made measurements during the two flaring periods are shown in Figure 1 as 'M'.

Table 12 summarizes the observations from the mobile van. The majority of the readings of SO_2 and H_2S were 0 ppb. All concentrations were below their respective AAAQO and odour detection thresholds. The maximum reading of 7.0 ppb for SO_2 occurred on October 17th at 09:30. At the time of this reading, the monitoring van was located on Road 61, about 1.2 km downwind from the Waterton 68 well site. The maximum H_2S reading of 5.0 ppb occurred on August 23rd at 01:00 when the monitoring van was located at the Waterton 68 well pad. There were several other measurements where the van was downwind of the flare but no significant readings of SO_2 and H_2S occurred. These results indicate that ambient concentrations of SO_2 and H_2S in the SCV were mainly not affected by the Waterton 68 flaring activities.

Table 11: Maximum and Average SO_2 and H_2S Concentrations Measured by the Mobile Air Monitoring Unit (in ppb)

Pollutant	Mobile 1 (Aug 14-24, 2014)		Mobile 2 (Oct 7-18, 2014)		AAAQO	Odour Detection Threshold
	Maximum	Average	Maximum	Average	1-Hour	3-Minute Average
SO_2	0.0	0.0	7.0	0.11	172	330
H_2S	5.0	0.06	0.0	0.0	10	10

3.5 Passive Monitoring Results

Passive monitoring samples were collected on a monthly basis. Results from the three passive stations in the Waterton 68/SCV area were available for the study year, April 2014 to March 2015. The locations of these monitors are shown in Figure 1. The summary of the laboratory analysis from the passive samples is provided in Table 12 and indicates that the SO_2 concentrations were below the 30-day average AAAQO of 11 ppb. There is no 30-day AAAQO for H_2S.

Table 12: Maximum and Average for the Passive SO_2 and H_2S Monitoring Results for the Period April 2014 to March 2015

Station	Maximum (ppb)	Average (ppb)	Maximum ($\mu g/m^3$)	Average ($\mu g/m^3$)	AAAQO 30-Day (ppb)
SO_2	0.60	0.08	1.57	0.22	11
H_2S	0.08	0.03	0.11	0.04	-

Note: '-' indicates no value specified

4. RECOMMENDATIONS AND CONCLUSIONS

One year (study year, April 2014 to March 2015) of ambient air monitoring data in the SCV was considered in this assessment. Considering the historical emissions of SO_2 and H_2S from the Shell Waterton Complex, the study year appears to be a suitable representation of Shell Waterton activities involving sulphur emissions in the SCV area.

The monitored ambient SO_2 and H_2S concentrations in the SCV presented in this report show no exceedances of their respective AAAQO or odour detection thresholds. The maximum readings at the SCV continuous monitoring station were 5.3 ppb for SO_2 and 0.5 ppb for H_2S. Observations suggest that the measured ambient concentrations in the SCV area are typical of background values measured at other Alberta stations. No non-zero SO_2 or H_2S readings were made by the temporary continuous monitoring station. Readings at the mobile monitoring station were small and also showed no exceedances of the AAAQO or odour detection thresholds during the study year. Monthly passive monitoring data were also less than the 30-day AAAQO for SO_2 during the study year.

When compared to flaring activities in the SCV, slightly higher than background SO_2 concentrations were recorded; however, these concentrations occurred only over 2 or 3 hours of the annual record of ambient measurements. Readings of H_2S could not be correlated to any flaring activities. During Shell Waterton Complex short-term upset events, there were no correlated or elevated readings observed in the SCV. Similarly, no elevated readings of SO_2 and H_2S occurred during the weekly pigging at WAT-JCT and JCT 6-12.

The location of the SCV station is such that it is capable of picking up potentially elevated concentrations due to flaring activities in the SCV. Furthermore, emissions over the study year were representative of recent emissions, and the full year of data provided a broad spectrum of meteorological conditions. During the study year, observed concentrations were well below their respective AAAQO and odour detection thresholds. Based on this evidence, it is not anticipated that the SCV continuous monitoring station will measure any exceedances of the AAAQO or the odour detection thresholds due to future flaring activities in the SCV. This suggests that continuation of the SCV continuous station is unnecessary and this station can be removed from operation.

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