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### 1.0 INTRODUCTION

The area referred to as "Alberta's Industrial Heartland" is located in western Canada near the city of Fort Saskatchewan. This region is a unique area since it is home to a highly concentrated industrial zone with more than 30 major industrial facilities. Several of the industries in the area are categorized as downstream oil and gas or petrochemical production. In addition, there exists industrial activity in the region that does not occur elsewhere in Canada. The region is located between a major urban center and a national park. The blend of industrial, rural and urban sources affecting the region provides a unique setting for monitoring and studying air quality issues.

There is further interest in the region's air quality given that several new industrial facilities have been proposed for Alberta's Industrial Heartland. The new facilities are oil sands upgraders designed to convert crude bitumen into a useable feed for refineries. Air quality data collected prior to the construction of these new facilities is important baseline information for this region.

Environment Canada and the Fort Air Partnership (FAP) worked in collaboration on a 19 month project to monitor the ambient volatile organic compound (VOC) concentrations in the Fort Saskatchewan area. The Fort Air Partnership is a voluntary partnership formed in 1997 that brings together government, industry and the public into a community-driven organization, which manages the local airshed monitoring network. The purpose of this VOC study is to characterize the ambient VOC concentrations in the Fort Saskatchewan region. A number of analysis methods are used to achieve this objective. These methods include simple statistics, comparison to other Canadian cities, principal component analysis and lagrangian stochastic modelling.

The analysis methods make use of the fact that at the time of the monitoring the only facility manufacturing 1,2-dichloroethane in Canada was located in the heart of the industrial zone. Given the long atmospheric lifetime of 1,2-dichloroethane (estimated range of 43 to 111 days, Government of Canada, 1994), the measured concentrations of 1,2-dichloroethane serve as an atmospheric chemical tracer.

Other specific VOCs emitted in the region that aid in characterizing industry related emissions include vinyl chloride, styrene and HCFC-22.

### 2.0 MONITORING PROGRAM

The Fort Saskatchewan VOC monitoring program started on September 12, 2004 and concluded on March 31, 2006. Twenty-four hour air samples were taken every six days in accordance with the National Air Pollution Surveillance (NAPS) Network protocol. Once a sample was collected, the canister was sent to Environment Canada's Environmental Technology Centre (ETC) in Ottawa for gas chromatography and mass spectrometry analysis. The Fort Saskatchewan VOC monitoring study measured 150 compounds, ranging from C<sub>3</sub>–C<sub>12</sub>. This is a common suite of VOCs that have been identified as ground-level ozone precursors, toxic chlorinated hydrocarbons and compounds found on the *Canadian Environmental Protection Act's* Priority Substance List (CEPA, 1999).

For this monitoring study, sampling occurred at six sites around the Fort Saskatchewan area. A map of the area with the sites marked is shown in Figure 1. Two of the sites were set up at residences: Sites A and C, while Site E was located in an undeveloped area near residences. Sites B, D and F were located at existing air monitoring stations, with Site F located in Elk Island National Park. Major anthropogenic point source emissions are reasonably well known due to requirements for industry to report emissions to the Government of Canada's National Pollutant Release Inventory (NPRI, 2005). Figure 1 also shows the NPRI reporting industries in the Fort Saskatchewan area. It should be noted that the city of Edmonton, population of approximately 1 million, is located southwest of the city of Fort Saskatchewan. Figure 2 shows the wind rose for the monitoring period. The dominant wind direction is from the southwest; however, it is not uncommon for the area to receive strong winds from the northwest.

### 3.0 DISCUSSION OF THE RESULTS

#### 3.1 Monthly Averages

The average total measured VOC concentrations throughout the study are shown in Figure 3. The total measured VOC concentrations were determined by taking the sum of all VOCs measured in each sample and then averaging the sums over each month of monitoring. Figure 3 shows the warmer spring and summer months (May – September) have lower total measured VOC concentrations as compared to the

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colder winter months. This observed seasonality in measured VOC concentrations can be explained by the increased dispersion during the warmer months (average daily maximum temperature is between 16 to 22 degrees C), compared to winter (average daily maximum temperature is between 10 to -10 degrees C) when there is reduced dispersion and increased frequency of daytime temperature inversions. Another reason for seasonality is that warmer temperatures and increased solar radiation affect the speed at which emitted VOCs react and degrade in the atmosphere. The peak in total measured VOCs shown in Figure 3 was a result of a sample taken on April 10, 2005 in which a routine turn-around and planned flaring event occurred at a natural gas liquids fractionation facility.

Biogenic emissions are an important source of VOCs and northern Alberta is predominantly boreal forest. The boreal forest is one of the largest vegetation zones in the world and it is characterized by large VOC

emissions with strong seasonal variations (Hakola et al., 2003). Several researches have noted that the biogenic VOC emissions are most abundant in the growing season. It is also generally assumed that the intensity of biogenic emissions is a function of temperature (Laurila et al., 1999). Isoprene is the dominant VOC emitted by forest species. As well, there is a considerable contribution of monoterpenes emitted by vegetation. Monoterpenes measured in this VOC study include  $\alpha$ -pinene,  $\beta$ -pinene, camphene, p-cymene and limonene. Figure 4 displays the total measured monoterpenes and isoprene concentrations in the Fort Saskatchewan area. As expected, Figure 4 shows the average total concentrations of biogenic substances are highest during May to September. The peak in biogenic substances at Site C was a result of a sample taken on October 31, 2005. A source was never identified, but it was suspected that events on the holiday of Halloween could have contributed to the higher biogenic substances measured in this sample.

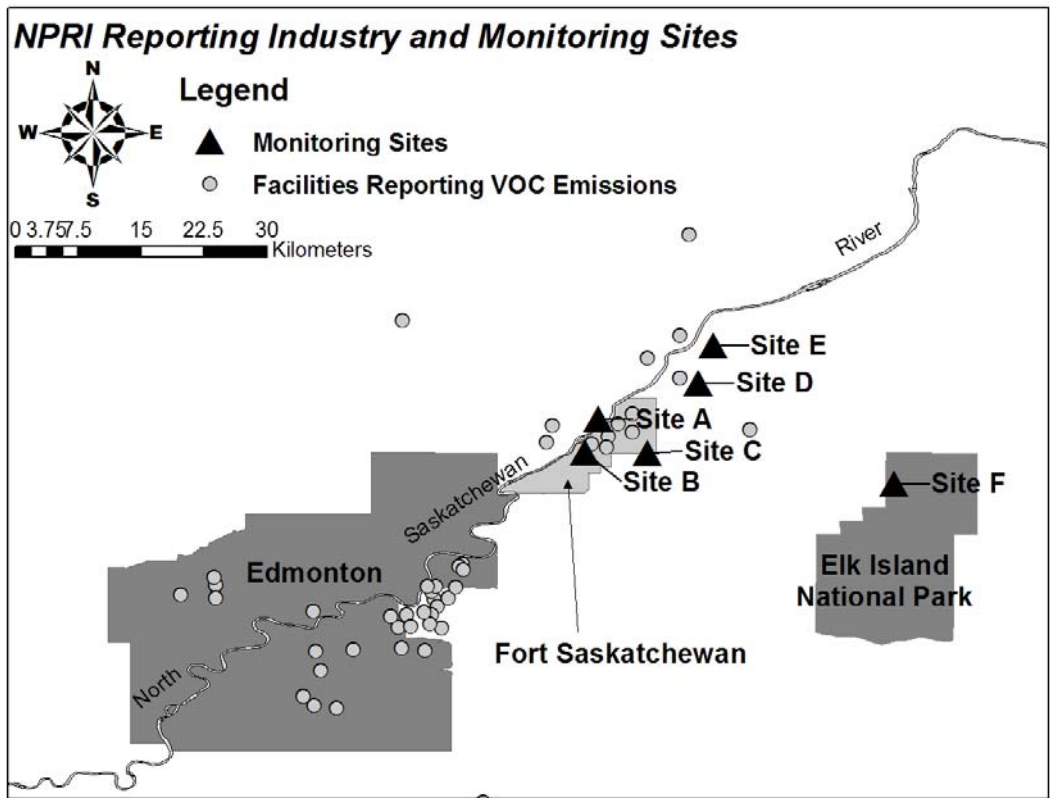


Figure 1. Map of study region and NPRI reporting industries

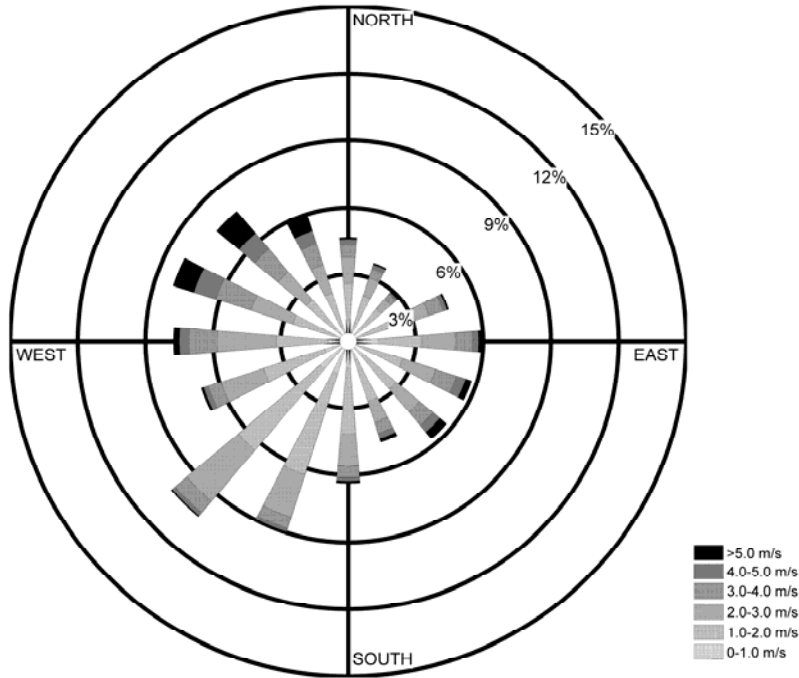


Figure 2. Fort Saskatchewan wind rose. Hourly wind direction data were taken from the Fort Saskatchewan station from January 1990 through December 2006 (Clean Air Strategic Alliance, 2007).

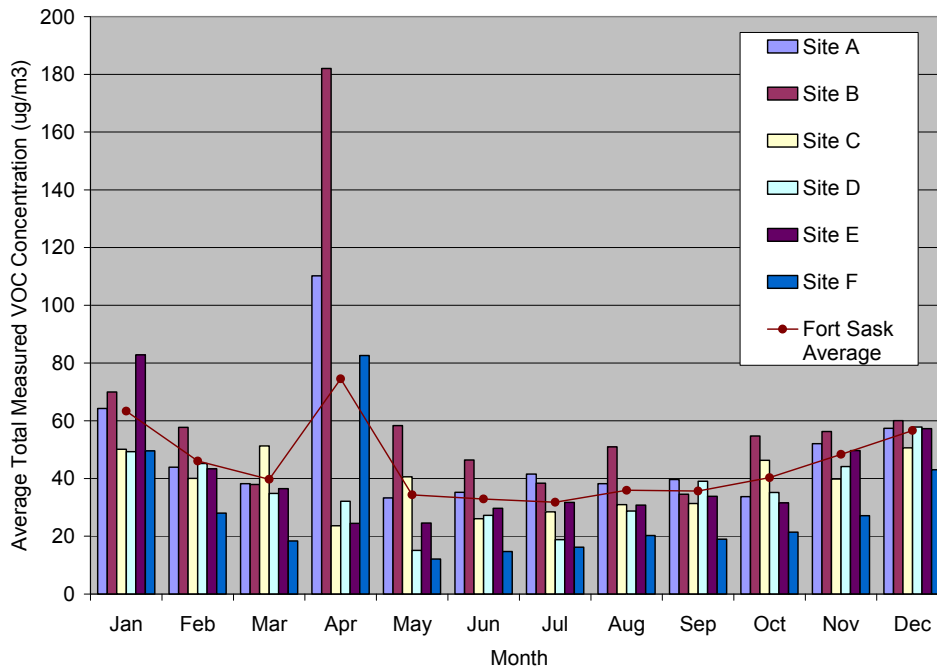


Figure 3. Average total measured VOC concentrations

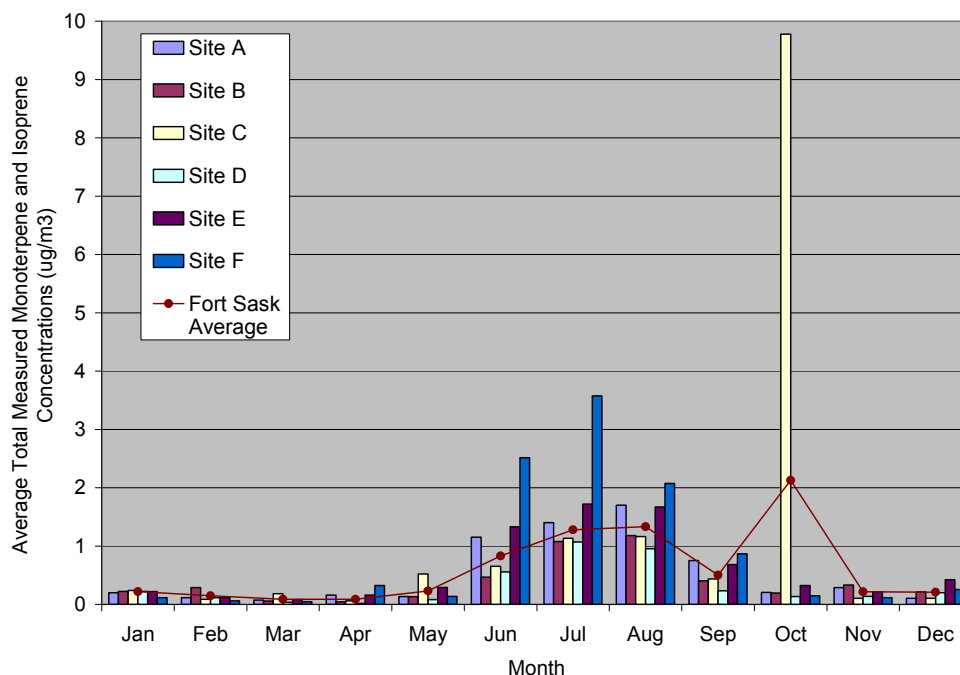


Figure 4. Average total measured monoterpene and isoprene concentrations

### 3.2 Statistics and Comparison to other Canadian Sites

Simple statistics, lower detection limits and the comparison to the average 2001 to 2003 values from selected NAPS monitoring sites in other Canadian cities are shown for Sites B and D in Tables 1 and 2. Only 30 VOCs are shown and the following criteria were used to select this sub-set of compounds:

1. Compounds with more than 50% of samples registering below method detection limits were excluded from analysis. This criterion eliminated 46 substances. Substances eliminated included chlorinated alkanes (C<sub>2</sub>+), chlorinated benzenes, butylbenzenes, and unsaturated straight-chained and branched C<sub>6</sub> and C<sub>7</sub>.
2. Compounds reported to the 2004 reporting year of the National Pollutant Release Inventory (NPRI) in amounts greater than 2 tonnes per year were included in analysis.
3. The predominantly biogenic compounds isoprene and  $\alpha$ -pinene were included for analysis.
4. The remaining compounds were selected based on decreasing average ambient concentrations at each site.

Table 1 shows that the average concentrations of 1,2-dichloroethane, 3-methylhexane, n-heptane, HCFC-22 and vinyl chloride are higher at Site B than compared to the "Group Average". Table 2 shows that the average concentrations of 1,2-dichloroethane, vinyl chloride and styrene are higher at Site D than compared to the "Group Average". Although the total comparison with all 150 VOCs is not shown here, the results can be found at:

[http://www.fortair.org/file/VOC%20Final%20Report\\_finalR%20-%20Fort%20Sask-Sept%202006.pdf](http://www.fortair.org/file/VOC%20Final%20Report_finalR%20-%20Fort%20Sask-Sept%202006.pdf). For the total set of data and across all six sites, 142 of the 150 VOCs sampled were below the "Group Average".

### 3.3 Principal Component Analysis

Principal component analysis (PCA) with varimax rotation was performed on the 30 VOCs shown in Tables 1 and 2 for Sites B and D. Further details on the PCA method for this data set can be found at Mintz and McWhinney (2008). Challenges existed in interpreting the PCA results from 24-hour integrated samples in such a highly industrialized region; however use of 1,2-dichloroethane, vinyl chloride, styrene and HCFC-22 allowed for easy identification of an industrial contribution. For factors that were not easily distinguishable, three corroborating tests were devised to help distinguish contributing sources. These additional PCA tests were conducted using carbon monoxide concentrations, wind direction data and seasonal splitting of the samples. To test if a specific industrial source with known emissions was a source, appropriate wind direction was included in the PCA and the factor re-analyzed. The wind data were expressed as the fraction of the twenty-four hour period the hourly wind direction was either north, northeast, east, southeast, south, southwest, west, and northwest. To test if VOCs varied with emissions from two nearby urban sites (Edmonton Central and Fort Saskatchewan), carbon monoxide concentrations, averaged over 24 hours, were included in the PCA, and the factor was re-analyzed. Carbon monoxide (CO) was chosen for the corroborating test since it is

known to be emitted from incomplete combustion of fossil fuels in urban areas (Guo et al., 2007). The downtown of Edmonton is strongly influenced by vehicle emissions (Cheng et al., 1997) and the monitoring site in Fort Saskatchewan is expected to have the same influence given its proximity to traffic sources. A third test to rule out the possibility that a factor was representative of a seasonal effect was to split the VOC samples into cold (November – April) and warm season (May-October) sub-sets based on when the sample was taken.

Table 3 presents the summary for Site B's PCA results. Factor 1 accounted for 43% of the variance in the data, and the five factors together accounted for a total of 82% of the variance. The VOCs loading on each factor for Site B are shown in Table 4. Factor 1 was the most difficult to interpret given the number of compounds loading on this one factor. No single wind direction loaded strongly on Factor 1. Without any particular wind direction narrowed down, no one industry could be considered the contributing source. The corroborating test with CO, however, showed loadings of 0.522 and 0.475 for Fort Saskatchewan and Edmonton. The corroborating test with a seasonal split showed some differences to 1,2,4-trimethylbenzene, toluene and *m*-,*p*-, and *o*-xylenes. The seasonal test provided inconclusive results since 1,2,4-trimethylbenzene, toluene and xylenes are all emitted by industry in the region (NPRI, 2005), as well as by vehicles (Rogak, 1998). Factor 1 is then attributed to a combination of industry and vehicle related emissions.

Factor 2 at Site B accounted for 17% of the variance. With the exception of isoprene, Factor 2 shows VOCs emitted by industry in the region. The PCA test with a seasonal split removes isoprene from this factor in the warm season and the cold season PCA test causes Factor 2 to change entirely. Therefore, Factor 2 shows a mixture of industry and seasonal related variance.

Interpretation of the other three factors was more straightforward. Factor 3 at Site B shows loadings from VOCs that are subjected to long range transport and accounts for 12% of the variance. Factor 4 at Site B accounts for 5% of the variance and has clear loadings from 1,2-dichloroethane and vinyl chloride, both industry related VOCs. Factor 5 at Site B shows loadings of  $\alpha$ -pinene, a biogenic, and HCFC-22, an industrial refrigerant. The corroborating test for seasonality indicated Factor 5 is influenced by seasons and can therefore be attributed to seasonal effects.

The PCA results for Site D are similar to Site B and are not shown here, but can be found in Mintz and McWhinney, 2008.

### 3.4 Lagrangian-Stochastic Modeling

Given the interest in 1,2-dichloroethane in this study, lagrangian stochastic modeling was used to further understand the relationship between its emissions and the ambient measurements. The short-range, first order lagrangian stochastic model used (MLCD) was appropriate for this scenario since there was only one source and 1,2-dichloroethane has a relatively long atmospheric lifetime. Two sampling dates with relatively high measured ambient 1,2-dichloroethane concentrations were selected to be modeled (Table 5). The lagrangian stochastic model was operated in a forward dispersion mode in which one unit of 1,2-dichloroethane was released as a fugitive emission at a constant rate from the industrial facility. Wind profiles were extracted from the 3-D regional GEM meteorological model at 5 levels: 10m, 40m, 120m, 215m and 325m. One simulation was conducted using wind profiles directly taken from the GEM regional analyses, and a second simulation was conducted with the same profiles but where the 10m GEM winds were adjusted for better consistency with the observed 10m winds. An example of the resulting modeled plume is shown in Figure 5. The model inferred 50-100 kg/hr of 1,2-dichloroethane was emitted for the 24-hour sampling dates listed in Table 5. This modeled release rate is higher than the reported NPRI annual emissions for the facility. The facility reported a total of 4 tonnes (approximately 10 kg/hr) of 1,2-dichloroethane for 2005 (NPRI, 2005). There are a number of potential reasons for the discrepancy in the modeled values and the reported release values. Two important reasons for the discrepancy are either (or both) 1) that the model results in an over-predicted release rate and/or 2) that the facility emissions have been under-reported. These two issues are described below.

1. The surface (10m) winds were compared with hourly observations from nearby meteorological stations (Oliver and Elk Island). In general, winds were relatively light during the sampling period, and as such, there were differences in wind direction between the stations, making it difficult to accurately model the wind profiles. An important limitation to the model is that if the modeled winds are not in line with the monitor, and the real winds are, then the model may require a higher modeled release rate in order to achieve the same actual measured concentration. The result is that the model may over-predict the release rate. For the May 22 modeling run, the actual winds directed from the 1,2-dichloroethane facility affect the monitor at Site B for longer than the modeled GEM winds. With the May 22 modeling run, a release rate of 100 kg/h is predicted. For the November 24 modeling run, the GEM winds compare well with the actual winds at both Sites D and E. The release rate is estimated by the model to be 100 kg/h in order to model the measured concentration at Site D, and a release rate of 50 kg/h is estimated by the model in order to obtain the measured Site E concentration.

2. Fugitive emissions can be either an area source or an equipment leak. Equipment leaks are unintentional

emissions that are not released through a stack, duct or other confined enclosure and are not treated or controlled by specific equipment. Such equipment leakage is defined as the uncontrolled and unintentional loss of process fluid. There are challenges in quantifying fugitive emissions partly due to: i) the available monitoring technologies, ii) the number of inaccessible components in any given facility, and iii) the calculations used to quantify emissions are based on empirical factors and assumptions which may not be in line with actual conditions. Current methods for quantifying fugitive emissions in Canada (CCME, 1993) are based on the US EPA Method 21 (U.S. EPA). This method is internationally recognized and the challenges in quantifying emissions are a widespread phenomenon. Regulators are working in a number of jurisdictions to update and refine leak detection and quantification techniques. The discrepancy between the model release rate and the reported NPRI value for the 1,2-dichloroethane emitting facility could be a result of the challenges with quantification of emissions. More investigation is needed in order to understand the limitations and to improve accuracy of fugitive emissions measuring methods in the quantification of emissions.

#### 4.0 CONCLUSIONS

The VOC data from the Fort Saskatchewan study was analyzed using a number of methods. The comparison of the VOCs to selected Canadian cities showed that despite the number of industrial facilities in Alberta's Industrial Heartland most compounds were below the "Group Average". The analysis with principal component analysis indicates that the majority of the variance can be described by a combination of industry and vehicle related VOC emissions. The lagrangian stochastic modeling of 1,2-dichloroethane found that the reported emissions for the particular facility did not agree with the modeled emissions rate. This discrepancy may be attributed to either the limitations in the model due to differences in wind profiles and/or to the limitations in quantifying fugitive emissions.

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Table 1. Site B statistics and comparison to other Canadian sites, all units  $\mu\text{g}/\text{m}^3$

Compound	Mean	Standard Deviation	Max	LDL	# of Samples <LDL	CGY*	EDM-D*	EDM-I*	MTL*	SAR*	VAN*	WPG*	Group Avg
1,2,4-Trimethylbenzene	0.46	0.78	4.91	0.006	4	0.96	0.94	0.60	0.78	0.46	0.92	0.65	0.76
1,2-Dichloroethane	0.70	3.05	21.51	0.005	0	0.06	0.08	0.10	0.06	0.06	0.09	0.06	0.07
2-Methylbutane	3.15	3.86	20.49	0.009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylpentane	0.82	0.94	4.39	0.011	0	1.55	1.94	5.72	1.79	1.88	2.09	1.15	2.30
3-Methylhexane	3.13	25.68	245.32	0.005	2	0.55	0.76	1.13	0.66	0.53	0.80	0.50	0.70
3-Methylpentane	0.59	0.64	2.93	0.011	0	0.88	1.30	3.27	1.19	1.52	1.39	0.75	1.47
Benzene	0.73	0.74	4.12	0.008	0	1.29	1.56	1.79	1.69	1.39	1.48	1.03	1.46
<i>n</i> -Butane	6.71	9.49	67.34	0.06	0	7.80	8.88	34.8	5.10	5.80	13.4	3.94	11.4
Carbon Tetrachloride	0.56	0.06	0.69	0.007	0	0.72	0.63	0.62	0.65	0.64	0.65	0.64	0.65
CFC-11	1.56	0.14	1.94	0.005	0	1.94	1.84	1.80	1.84	1.81	1.79	1.82	1.83
CFC-113	0.59	0.07	0.75	0.009	0	0.70	0.78	0.96	0.95	1.29	0.69	0.69	0.86
CFC-12	2.61	0.26	3.16	0.007	0	2.96	3.11	2.74	3.17	3.30	2.79	2.85	2.99
Chloromethane	1.06	0.14	1.39	0.006	0	1.21	1.19	1.16	1.19	2.84	1.16	1.18	1.42
Cyclohexane	0.19	0.21	1.18	0.007	1	0.27	0.32	1.50	0.29	1.03	0.40	0.16	0.57
Ethylbenzene	0.33	0.42	2.13	0.004	0	0.73	0.95	0.70	1.03	0.58	1.45	0.60	0.86
HCFC-22	3.00	3.41	17.46	0.008	0	2.96	3.11	2.74	3.17	3.30	2.79	2.85	2.99
<i>n</i> -Heptane	2.79	22.68	216.63	0.026	0	0.47	0.69	1.64	0.50	0.50	0.73	0.41	0.71
<i>n</i> -Hexane	0.94	1.46	12.35	0.019	0	0.95	1.53	5.38	1.09	2.13	1.30	0.88	1.89
Isobutane	3.14	4.08	24.24	0.005	0	2.44	3.18	13.6	4.22	2.95	4.67	1.86	4.70
Isoprene	0.17	0.30	1.41	0.01	10	0.35	0.48	0.61	0.28	0.22	0.23	0.38	0.36
<i>m,p</i> -Xylene	1.40	1.83	7.86	0.008	0	2.65	3.39	2.38	3.27	1.33	4.95	2.06	2.86
Methylcyclopentane	0.44	0.50	2.75	0.004	0	0.58	0.88	2.40	0.72	0.75	0.88	0.52	0.96
<i>o</i> -Xylene	0.50	0.68	3.30	0.003	0	0.88	1.12	0.80	1.00	0.46	1.64	0.66	0.94
<i>n</i> -Pentane	1.69	1.75	7.91	0.012	1	1.86	2.72	22.2	2.17	2.76	2.85	1.32	5.12
Propane	8.04	10.47	74.68	0.009	0	6.24	9.15	24.6	3.09	6.41	5.53	3.05	8.30
Propene	0.59	0.74	4.03	0.011	0	1.48	1.58	0.95	1.26	1.80	1.35	0.90	1.33
Styrene	0.08	0.14	0.91	0.001	2	0.13	0.18	0.50	0.16	0.13	1.30	0.23	0.37
Toluene	3.55	5.00	26.90	0.007	0	3.97	4.15	3.33	6.07	3.90	7.23	4.70	4.77
Vinyl Chloride	0.09	0.32	2.14	0.004	4	0.02	0.03	0.03	0.02	0.05	0.02	0.02	0.03
$\alpha$ -Pinene	0.06	0.11	0.69	0.005	30	N/A	0.23	N/A	N/A	N/A	N/A	0.21	N/A

\*Site acronyms: CGY = Calgary, EDM-D = Edmonton Downtown, EDM-I = Edmonton Industrial, MTL = Montreal, SAR = Sarnia, VAN = Vancouver, WPG = Winnipeg

Table 2. Site D statistics and comparison to other Canadian sites, all units in µg/m<sup>3</sup>

Compound	Mean	Standard Deviation	Max	LDL	# of Samples <LDL	CGY*	EDM-D*	EDM-I*	MTL*	SAR*	VAN*	WPG*	Group Avg
1,2,4-Trimethylbenzene	0.09	0.14	1.03	0.006	1	0.96	0.94	0.60	0.78	0.46	0.92	0.65	0.76
1,2-Dichloroethane	0.44	1.22	10.19	0.005	0	0.06	0.08	0.10	0.06	0.06	0.09	0.06	0.07
2-Methylbutane	2.68	2.75	13.51	0.009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylpentane	0.70	0.72	3.97	0.011	0	1.55	1.94	5.72	1.79	1.88	2.09	1.15	2.30
3-Methylpentane	0.48	0.49	2.43	0.011	0	0.88	1.30	3.27	1.19	1.52	1.39	0.75	1.47
Benzene	1.03	1.89	16.41	0.008	0	1.29	1.56	1.79	1.69	1.39	1.48	1.03	1.46
<i>n</i> -Butane	4.74	5.09	28.13	0.06	0	7.80	8.88	34.8	5.10	5.80	13.4	3.94	11.4
Carbon Tetrachloride	0.58	0.06	0.71	0.007	0	0.72	0.63	0.62	0.65	0.64	0.65	0.64	0.65
CFC-11	1.56	0.14	1.96	0.005	0	1.94	1.84	1.80	1.84	1.81	1.79	1.82	1.83
CFC-113	0.60	0.08	0.83	0.009	0	0.70	0.78	0.96	0.95	1.29	0.69	0.69	0.86
CFC-12	2.60	0.26	3.27	0.007	0	2.96	3.11	2.74	3.17	3.30	2.79	2.85	2.99
Chloromethane	1.09	0.13	1.46	0.006	0	1.21	1.19	1.16	1.19	2.84	1.16	1.18	1.42
Cyclohexane	0.17	0.18	0.85	0.007	0	0.27	0.32	1.50	0.29	1.03	0.40	0.16	0.57
Ethylbenzene	0.36	0.79	6.49	0.004	0	0.73	0.95	0.70	1.03	0.58	1.45	0.60	0.86
HCFC-22	0.55	0.06	0.74	0.008	0	2.96	3.11	2.74	3.17	3.30	2.79	2.85	2.99
<i>n</i> -Heptane	0.47	1.82	16.48	0.026	5	0.47	0.69	1.64	0.50	0.50	0.73	0.41	0.71
<i>n</i> -Hexane	0.73	0.77	3.96	0.019	1	0.95	1.53	5.38	1.09	2.13	1.30	0.88	1.89
Isobutane	2.66	2.74	13.92	0.005	0	2.44	3.18	13.6	4.22	2.95	4.67	1.86	4.70
Isoprene	0.15	0.39	2.79	0.01	34	0.35	0.48	0.61	0.28	0.22	0.23	0.38	0.36
<i>m,p</i> -Xylene	0.47	0.76	5.46	0.008	0	2.65	3.39	2.38	3.27	1.33	4.95	2.06	2.86
Methylcyclohexane	0.25	0.34	2.81	0.003	0	0.26	0.44	1.61	0.34	0.31	0.60	0.25	0.55
Methylcyclopentane	0.35	0.38	2.83	0.004	0	0.58	0.88	2.40	0.72	0.75	0.88	0.52	0.96
<i>o</i> -Xylene	0.16	0.25	1.80	0.003	0	0.88	1.12	0.80	1.00	0.46	1.64	0.66	0.94
<i>n</i> -Pentane	1.66	1.51	7.88	0.012	0	1.86	2.72	22.2	2.17	2.76	2.85	1.32	5.12
Propane	7.61	7.27	34.96	0.009	0	6.24	9.15	24.6	3.09	6.41	5.53	3.05	8.30
Propene	0.39	0.40	2.28	0.011	0	1.48	1.58	0.95	1.26	1.80	1.35	0.90	1.33
Styrene	0.37	1.51	14.06	0.001	0	0.13	0.18	0.50	0.16	0.13	1.30	0.23	0.37
Toluene	1.11	2.71	24.75	0.007	0	3.97	4.15	3.33	6.07	3.90	7.23	4.70	4.77
Vinyl Chloride	0.27	0.53	2.61	0.004	2	0.02	0.03	0.03	0.02	<b>0.05</b>	0.02	0.02	0.03
$\alpha$ -Pinene	0.04	0.06	0.32	0.005	40	N/A	0.23	N/A	N/A	N/A	N/A	0.21	N/A

\*Site acronyms: CGY = Calgary, EDM-D = Edmonton Downtown, EDM-I = Edmonton Industrial, MTL = Montreal, SAR = Sarnia, VAN = Vancouver, WPG = Winnipeg



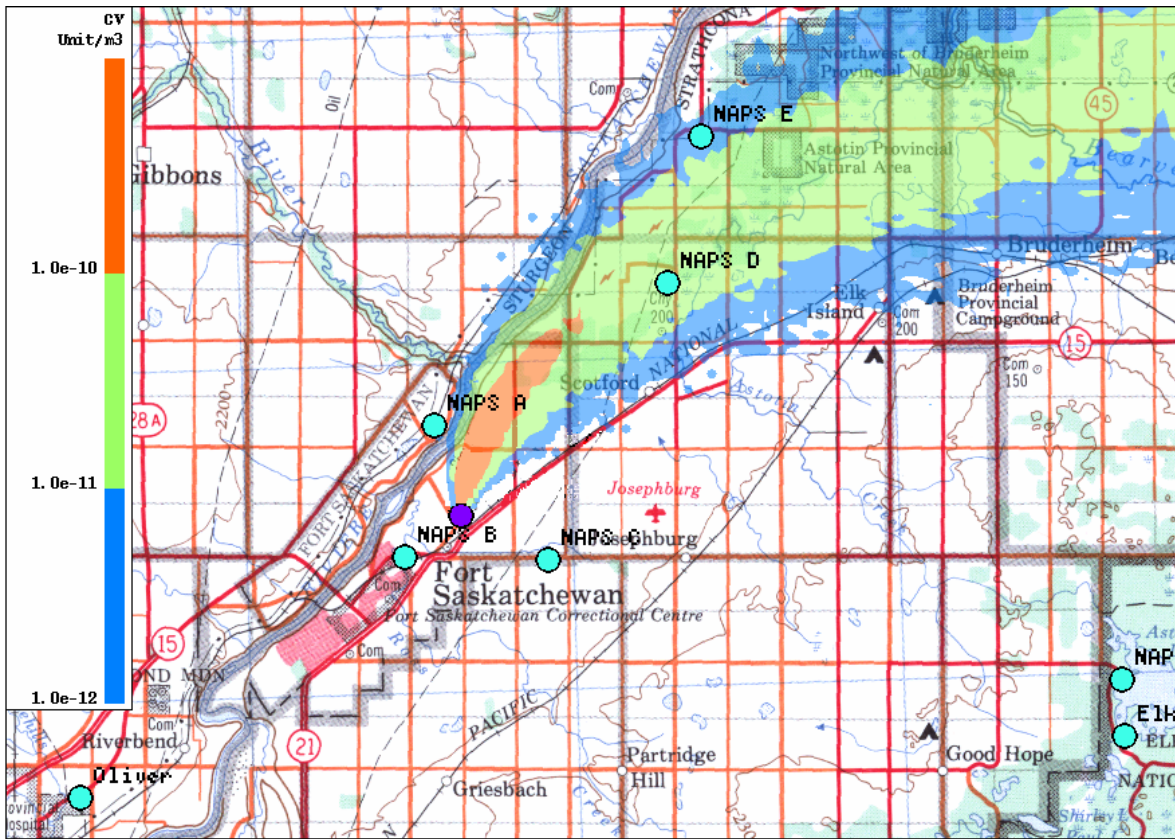
Table 3. Results summary for Site B PCA with varimax rotation

	F1	F2	F3	F4	F5
<b>Initial Eigenvalue</b>	14	4	3	2	1
<b>% of Variance</b>	43	17	12	5	4
<b>Cumulative %</b>	43	60	72	77	82

Table 4. Site B factor loadings from PCA with varimax rotation

Compound	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1,2,4-Trimethylbenzene	0.209	<b>0.906</b>	-0.009	0.051	-0.078
1,2-Dichloroethane	0.146	0.022	0.020	<b>0.856</b>	-0.111
2-Methylbutane	<b>0.889</b>	0.251	-0.016	-0.048	-0.162
2-Methylpentane	<b>0.959</b>	0.220	-0.026	0.029	-0.005
3-Methylhexane	<b>0.853</b>	0.052	-0.111	0.059	0.134
3-Methylpentane	<b>0.936</b>	0.201	0.066	0.061	0.042
Benzene	<b>0.931</b>	0.145	0.031	-0.087	-0.111
<i>n</i> -Butane	<b>0.915</b>	0.186	0.065	-0.028	-0.220
Carbon Tetrachloride	-0.017	0.154	<b>0.757</b>	0.343	-0.152
CFC-11	0.024	0.137	<b>0.912</b>	-0.015	-0.071
CFC-113	0.095	-0.164	<b>0.865</b>	-0.059	-0.019
CFC-12	-0.013	0.001	<b>0.932</b>	0.036	0.152
Chloromethane	-0.211	-0.011	<b>0.595</b>	-0.155	0.104
Cyclohexane	<b>0.797</b>	-0.136	-0.187	0.027	0.400
Ethylbenzene	<b>0.758</b>	<b>0.619</b>	-0.020	-0.019	-0.114
HCFC-22	-0.245	<b>0.655</b>	0.221	0.008	<b>0.516</b>
<i>n</i> -Heptane	<b>0.825</b>	-0.036	-0.112	-0.058	0.339
<i>n</i> -Hexane	<b>0.807</b>	-0.009	0.120	0.176	0.237
Isobutane	<b>0.891</b>	0.138	-0.020	-0.010	-0.226
Isoprene	-0.021	<b>0.648</b>	0.007	0.028	<b>0.538</b>
<i>m,p</i> -Xylene	<b>0.555</b>	<b>0.802</b>	0.028	-0.013	-0.118
Methylcyclopentane	<b>0.912</b>	0.136	-0.067	0.092	0.277
<i>o</i> -Xylene	<b>0.544</b>	<b>0.813</b>	0.014	0.009	-0.097
<i>n</i> -Pentane	<b>0.925</b>	0.154	0.019	0.138	-0.051
Propane	<b>0.861</b>	-0.101	0.052	0.165	-0.071
Propene	<b>0.872</b>	0.242	0.073	0.039	-0.178
Styrene	<b>0.611</b>	0.467	-0.067	-0.108	-0.018
Toluene	-0.001	<b>0.903</b>	0.029	0.076	0.182
Vinyl Chloride	0.061	0.087	0.081	<b>0.765</b>	0.203
$\alpha$ -Pinene	0.452	0.440	-0.095	-0.203	0.079

*Values greater than 0.5 are bolded*



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Figure 5. Example plume from lagrangian stochastic modeling. 1,2-Dichloroethane emitting facility is indicated by the purple circle.

Table 5. Sampling dates and measured 1,2-dichloroethane concentrations used in the lagrangian stochastic modeling

Sampling Date	Site	1,2-Dichloroethane Concentration ( $\mu\text{g}/\text{m}^3$ )
May 22, 2005	A	0.14
	B	21.51
	C	0.13
	D	0.04
	E	0.05
	F	0.14
November 24, 2005	A	6.45
	B	N/A
	C	0.43
	D	10.19
	E	3.29
	F	0.07