Three Creeks Area Ambient Air Quality Monitoring Data Review

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May 2014

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Abbreviations

AAAQO	Alberta Ambient Air Quality Objective (specified by ESRD)
AAQC	Ambient Air Quality Criteria
AER	Alberta Energy Regulator (formerly the ERCB)
AITF	Alberta Innovates – Technology Futures (formerly the Alberta Research Council)
AM	Average Measured
AMD	Air Monitoring Directive (issued by ESRD)
C1C4	Hydrocarbon compounds with 1 to 4 carbon atoms
CPF	Central Plant Facility
E	East (direction wind is blowing from)
ESL	Effects Screening Level
ERCB	Energy Resources Conservation Board
ESRD	Environment and Sustainable Resources Development
GC-MS-FID	Gas Chromatograph-Mass Spectrometer-Flame Ionization Detector
LTB	Long Term Benchmark
MAML	Mobile Air Monitoring Laboratory
MDL	Minimum Detection Limit
MM	Maximum Measured
MOE	Ontario Ministry of the Environment
N	North (direction wind is blowing from)
NAD 83	North American Datum of 1983
NAPS	National Air Pollution Surveillance
NMHC	Non-methane hydrocarbons.
ME	Ontario Ministry of the Environment
OT	Odour Threshold
PAH	Polycyclic Aromatic Hydrocarbon
PAMS	Photochemical Assessment Monitoring Station
ppb	Parts Per Billion (by volume)
ppm	Parts Per Million (by volume)
PRC	The Peace River Complex ambient monitoring station. For this report, the heavy oil extraction and processing facility is written out in full; PRC only refers to the associated monitoring station.

P/M	Peak concentration to mean concentration ratio. The peak concentration (P) typically references a short term averaging period ranging from 5 seconds to 3 minutes. The mean concentration (M) typically refers to a 60-minute average.
QA	Quality Assurance refers to the development of operating practices to control factors affecting data quality. (e.g., calibration and chain of custody procedures).
QC	Quality Control activities verify that the data meet the overall monitoring program objectives (e.g., are complete and are correct).
RSC	Reduced Sulphur Compound
S	South (direction wind is blowing from)
STB	Short Term Benchmark
TCEQ	Texas Commission on Environmental Quality
THC	Total Hydrocarbons (THC includes methane and NMHC)
TRS	Total Reduced Sulphur
UTM	Universal Transverse Mercator, a two dimensional global coordinate system
VOC	Volatile Organic Compounds. VOCs are organic compounds that have boiling points roughly in the range of 50 to 250 °C. VOCs exclude methane, ethane, halogenated hydrocarbons (organic compounds containing chlorine and fluorine), acetone and methyl acetate. VOCs, as defined, are organic compounds that participate in atmospheric photochemical reactions. VOCs are a subset of NMHC.
W	West (direction wind is blowing from)
WHO	World Health Organization
WISSA	Western Interprovincial Scientific Studies Association

Acknowledgements

This assessment and report was prepared for the Three Creeks Industry Air Quality Working Group by Stantec Consultants Ltd., located in Calgary, Alberta. The principal investigator for the assessment was Mervyn Davies who was assisted by Nasrin Mostafavipak and Swandoyo Hartono. Reid Person acted as a senior reviewer.

Sanjay Prasad of Aurora Atmospherics Inc. assisted in the review of the ambient monitoring program and Yori Jamin of Clearstone Engineering Ltd. provided the industry location information.

Summary

S1 BACKGROUND

The Three Creeks area is approximately 50 km northeast of the town of Peace River and has an east-west extent of about five ranges (30 miles or 50 km) and a north-south extent of about two townships (12 miles or 20 km). Over the last several years, there have been numerous complaints with respect to odours and health concerns that are potentially associated with industry emissions in the area.

A multi-stakeholder group, the Three Creeks Working Group, consisting of residents, industry, Northern Sunrise County, and the provincial government was formed in November 2011. The objectives of an existing, associated Air Monitoring Subcommittee are to gain a better understanding of local meteorology, air emissions, and air quality, as well as to gather data that will strengthen future decision making to manage these emissions. To execute scientific air studies in the Three Creeks area, a Three Creeks Industry Air Quality Working Group was formed from the Air Monitoring Subcommittee. The following ambient air quality monitoring activities have been undertaken by industry and the Air Monitoring Subcommittee:

- **Meteorology** parameters are measured at three continuous ambient air quality monitoring stations in the region. One is an industry station that has been in operation for more than 7 years and the other two are operated by the Air Monitoring Subcommittee.

- Community **odour complaints** are reported to the AER. The AER provided an odour complaint log that spanned the period Feb 11, 2010 to Sep 30, 2013. During this period, 847 odour complaints were documented.

- **Passive monitoring** data are collected by industry. The passive samplers measure 30 day average SO_2, H_2S and NO_2 concentrations.

- Ambient SO_2, TRS, H_2S, THC, methane and NMHC concentrations are measured at three **continuous ambient air quality monitoring** stations in the region. These are the stations that measure meteorology parameters.

- Evacuated stainless steel **canisters** are used to collect ambient air samples that can be analyzed for several hundred hydrocarbon and reduced sulphur compounds. Four types of canister sampling programs were undertaken:

  – Grab Sample collection by residents and ESRD. These are instantaneous samples that were collected during odour complaints.

- Integrated Sample collection by ESRD. These are time averaged samples (i.e., 1-h averages) that are collected during the same period as the grab samples.
- Campaign Sample collection during an intensive ESRD mobile monitoring program.
- Station Triggered Sample collection at the continuous monitoring stations when the NMHC concentration reached a threshold level.

- ESRD coordinated the canister sample collection and conducted a mobile air monitoring campaign; the results are described in two **ESRD reports**. ESRD also collected **PAH samples** in the region.

Stantec Consulting, in conjunction with Aurora Atmospherics and Clearstone Engineering, were engaged by the Air Monitoring Subcommittee to perform a comprehensive review of these data. The objective of the review is to recommend potential areas for improvement and/or modification to the current air monitoring approach. The review of air monitoring data focuses on two components, namely an examination of:

- Ambient concentration data in context of relevant ambient benchmarks (i.e., air quality objectives, criteria, standards and guidelines), and
- Ambient air quality data in the context of odours.

The review does not focus on identifying or quantifying potential emission source – ambient air quality relationships. However, some understanding of the emission sources is required to recommend areas for improvements and/or modification of the current monitoring approach. In a companion Air Monitoring Subcommittee study, hydrocarbon emission sources are being identified and associated hydrocarbon emission rates are being estimated (Clearstone 2014).

S2 FINDINGS

S2.1 Emissions

There are estimated to be about 600 industrial hydrocarbon emission sources in the region. Typical hydrocarbon emissions result from fugitive and combustion sources that tend to occur on a continuous basis while hydrocarbon emissions resulting from truck filling operations tend to occur on an episodic basis. The heavy oil extraction facilities are generally located to the east of the residential areas.

S2.2 Meteorology

The two Air Monitoring Subcommittee stations were each located at two sites for the period examined. The original locations were changed during the measurement period to improve the exposure of the wind sensors. The measurements at the monitoring sites confirm that temporal

and spatial meteorological variations occur. From a temporal perspective, the following are noted:

- The wind directions have a systematic diurnal trend with west-southwesterly (WSW) and southwesterly (SW) winds occurring during the day. During the night, more southerly (S) and easterly (E) winds occur.

- The wind speeds have a systematic trend with lower winds occurring during the night and increasing wind speeds during the day.

From a spatial perspective the following are noted:

- The Highway 986a and 842a sites were deemed to be influenced by local obstructions, which is one of the reasons that lead to the monitoring stations being relocated to the Highway 986b and 842b sites.

- The wind data from the Highway 986a and 842a sites may not always be representative of regional winds. The associated wind directions will have more uncertainties when correlating high concentration measurements to upwind emission source regions.

- While certain spatial trends can be identified, there is a variability (i.e., a randomness) associated with winds.

- Under high wind speed conditions, the winds tend to be more uniform over the region.

For near surface emission sources (e.g., tank vents, short stacks), the highest downwind ambient concentrations typically occur under low wind-speed, stable atmospheric conditions (i.e., these conditions are associated with small plume spreads and low mixing heights). Under these conditions, the air flow can also become disorganized and have a large meandering component. In these cases, high concentration events will be influenced by the winds several hours proceeding the measurement period and not just the single hour associated with the concentration event.

S2.3 Odour complaints

An examination of the odour complaint data indicated the following:

- The odour complaints occurred most frequently during the night and early morning period. This is consistent with poor dispersion during the associated stable atmospheric conditions.

- The odour complaints occurred most frequently with low wind speed conditions (i.e. with wind speeds less than 5 km/h). High concentrations due to low-level fugitive emission sources are typically associated with stable low wind speed conditions.

- The most frequent odour complaints tend to be associated with upwind sources located to the east of the residential areas. A trajectory analysis considers multiple hours before the odour complaint and can be used to refine the determination of the upwind source directions.

S2.4 Passive Monitoring

Passive monitors have been deployed in the region to primarily measure ambient SO_2 and H_2S concentrations on a monthly average basis. As a consequence, passive monitoring is limited in its ability to provide indicators of shorter-term (i.e., ~ 1-hour to 1-day) exposures. The passive monitors, however, are relatively easy to deploy since they do not require electrical power or substantive real estate to establish a monitoring network.

The passive data collected in the region demonstrates the ability of the passive monitors to identify temporal trends (e.g., the long term PRC monitoring show decreased SO_2 and H_2S concentrations when low sulphur fuel gas was adopted) and spatial trends (e.g., the PRC stations show decreased concentrations with increasing distance from an emission source). Comparison of the longer term PRC monitors with the more recent shorter term monitors indicate that the concentrations associated with the more recent monitors are low. That is, the monthly average SO_2 and H_2S concentrations are typically about 0.3 and 0.15 ppb, respectively.

S2.5 Continuous Monitoring

Continuous air quality stations are typically used to collect ambient concentration on an hourly average basis. An examination of the continuous ambient air quality data collected at three locations indicates the following:

SO_2, H_2S and TRS Concentrations

- The PRC continuous station showed high ambient SO_2 and H_2S concentrations in 2008 and 2009, the period corresponding to the use of sour fuel gas at the Peace River Complex. Since 2009, ambient concentrations show a downward trend corresponding to the implementation of various emission mitigation measures and, sparing the occasional peaks associated with short-term temporary upset conditions, have been much lower in the 2011 to 2013 period.

- The ambient SO_2 concentrations at the Highway 986 (a and b) and the Highway 842 (a and b) sites are very low.

- The ambient TRS concentrations at the Highway 986 (a and b) and the Highway 842b sites are very low. In May and June 2012, relatively high TRS concentrations occurred at the Highway 842b site; these were associated with easterly and southwesterly to westerly source wind directions.

THC, Methane and NMHC Concentrations

- There were challenges with the THC, methane and NMHC analyzer operability that reduced the amount of valid data. The NMHC concentrations are of most interest with respect to the regional air quality issues.
- THC 1-hour peaks are in the 4 to 10 ppm range, and tend to be intermittent. These peaks tend to be primarily composed of methane.
- The minimum ambient methane concentration is typically about 1.8 to 2 ppm; this corresponds to the current global background concentration.
- There are periodic NMHC 1-hour peaks that are in the 0.5 to 1.5 ppm (500 to 1500 ppb) range.
- The Highway 986a NMHC data indicate an ENE upwind source direction, and Highway 842a NMHC data indicate an ENE upwind source direction.
- The Highway 986b data indicate an E upwind source direction, and the Highway 842b data indicate an ESE upwind source direction.
- As indicated in the review of the meteorological data, a higher confidence level is placed with the Highway 986b and 842b wind direction data.
- Single point high NMHC concentrations at both sites are associated with winds from the W for the Highway 986b site and from the WNW for Highway 842a site.
- All high NMHC concentrations tend to be associated with low wind speeds (i.e., less than 5 km/h).
- High NMHC concentrations do not appear to be correlated to either SO_2 or H_2S/TRS concentrations.
- Under low wind speed conditions, the associated plume meander may result in wind directions that have greater variability, making it more difficult to correlate high concentrations to an upwind source.

S2.6 Canister Monitoring

The canister sampling approach is effectively the only way to determine a more complete speciation of hydrocarbons and reduced sulphur compounds in the atmosphere. This sampling greatly enhances the information base and complements other sampling. An examination of the canister ambient air quality data collected indicates the following:

- The highest Grab Samples indicated that the top contributors were butane, pentane and hexane related compounds. A casual review of the source sample analysis provided in ESRD (2010) indicates that these compounds are present and there appears to be a correlation between the grab sample and the emission source profiles associated with the heavy oil extraction operations.

- It is surprising that ambient concentrations were not greater than the odour thresholds more frequently or for more compounds since the grab sample collection was biased to occur when odour complaints occurred. Minimum detection limit, sample and analytical limitations, exposure to multiple odourants, and individual sensitivity considerations could account for this apparent contradiction.

- The findings associated with the Integrated Samples are similar to those associated with the Grab Samples.

- The Campaign Samples were collected at random, and generally were associated with lower concentrations than those associated with the Grab Samples or the Integrated Samples.

- The Triggered Sample collection was the most comprehensive in terms of number of samples, and the length of record. Similar to the Grab sample collection, it would be biased to high concentration events. The Triggered Sample collection indicted 21 compounds within a factor of three of the odour threshold, 16 compounds that were greater than short-term benchmarks and 26 compounds that were greater than long-term benchmarks.

- For all sample collection types, there were compounds that showed up frequently, while for other compounds, they only showed up a few times (e.g., methanol, vinyl acetate, and acetone). High concentrations associated with an infrequently occurring compound may provide a “signature” indicator that could help identify the emission source.

The canister analysis can be further examined to identify time series profiles for selected compounds and to more formally relate the maximum concentrations of all samples to wind directions to determine upwind source directions. As with the odour complaint assessment and the high continuous measurements, back trajectory analysis can also be used to help identify upwind source directions associated with the canisters.

S2.7 ESRD Reports and PAH Sampling

The ESRD findings are based on a subset of the data analyzed in this report. Both the ESRD reports and this report flagged the maximum hexanal and nonanal concentrations as being greater than the Nagata odour thresholds. This report found other compounds that were greater than the respective odour thresholds as this report considers a larger database than the ESRD reports.

The examination of the PAH concentration measurements for three days indicated very low values relative to the associated ambient benchmarks.

S2.8 Integration

The analysis and the previous sections focus on presenting the results for each type of monitoring activity. The main interest of the Three Creeks Air Monitoring Subcommittee is to determine if there is a convergence of evidence that identifies an upwind emission source region that is the potential cause of odour and/or health concerns reported by residents. To help address this, pollution roses showing odour complaints and measured concentrations are plotted and superimposed over the area of interest. The plots also show the identified hydrocarbon emission sources.

Odour complaints

Figure S-1 shows the wind direction distribution of odour complaints reported at three sites. The three selected sites are the locations where most of the odour complaints were recorded (i.e., ~200 events per site). The most frequent wind directions identify a potential source region in Township 84 Range 18W5.

SO_2 Concentrations

Figure S-2 shows the pollution roses associated with SO_2 concentrations greater than 5 ppb. The purple bars represent concentration between 5 and 10 ppb. The ranges for the other colour bars are 10 to 30 ppb (blue), 30 to 50 ppb (green), 50 to 100 ppb (orange) and greater than 100 ppb (red).

The PRC station is the only site with concentrations greater than 30 ppb, and the data point to the Peace River Complex as the potential SO_2 emission source. The PRC data includes the period when the Peace River Complex SO_2 emissions were greater than they are now. The concentrations associated with the Highway 986a, 986b and 842b stations are much lower and hence there is a lower level of confidence with the associated plots.

TRS Concentrations

Figure S-3 shows the pollution roses associated with TRS concentrations greater than 2 ppb. The purple bars represent concentrations between 2 and 4 ppb. The ranges for the other colour bars are 4 to 6 ppb (blue), 6 to 8 ppb (green), 8 to 10 ppb (orange) and greater than 10 ppb (red).

The highest TRS values at the PRC station are associated with southerly winds, which is quite different from the direction associated with high SO_2 concentrations. This indicates that the Peace River Complex is not the likely source of the greater TRS concentrations.

While there is a lower level of confidence associated with the Highway 986a winds due to nearby obstruction, the 4 to 6 ppb concentrations associated with WNW winds indicate the pulp

mill as a potential source for these values. The Highway 986b and Highway 842b frequent occurrences tend to point to a similar region as indicated by the odour complaint occurrences (Township 84 Range 18W5 area).

THC Concentrations

Figure S-4 shows the pollution roses associated with THC concentrations greater than 3 ppm. The purple bars represent concentrations between 3 and 4 ppm. The ranges for the other colour bars are 4 to 5 ppm (blue), 5 to 6 ppm (green), 6 to 7 ppm (orange) and greater than 7 ppm (red).

The PRC station THC data are similar to the associated TRS data that indicate a source region to the south. Higher concentrations tend to be monitored at the Highway 986a, 986b and 842b stations, and they tend to point to a similar region as indicated by the odour complaint occurrences (Township 84 Range 18W5 area).

NMHC Concentrations

Figure S-4 shows the pollution roses associated with NMHC concentrations greater than 0.2 ppm. The purple bars represent concentrations between 0.2 and 0.4 ppm. The ranges for the other colour bars are 0.4 to 0.6 ppm (blue), 0.6 to 0.8 ppm (green), 0.8 to 1.0 ppm (orange) and greater than 1.0 ppm (red).

The highest NMHC at the PRC station tend to point to the Peace River Complex as a contributor, likely due to its very close proximity. This is different from the THC data at this station that pointed to potential sources located to the south. The Highway 986b and Highway 842b frequent occurrences tend to point to a similar potential source region indicated by the odour complaint occurrences (e.g., the Township 84 Range 18W5 area). Hence the Peace River Complex is not a key contributor to NMHC at the community monitoring stations.

Comment

When comparing the Highway 986a and 986b sites, it is noted that the higher level of confidence is placed with the 986b wind directions due to siting limitations associated with the 986a site. The Highway 842a data have not been presented as: all SO_2 data were reported as zero; and the high TRS, THC and NMHC were associated with the first few months of operation and appear to be anomalous with respect to the rest of the data.

The Highway 986a and 986b sites not only represent two locations separated by about four kilometres, they also represent two different temporal periods. Similarly, the Highway 842a and 842b sites also represent two temporal periods. Any differences between the respective site pairs therefore may be due to temporal rather than spatial considerations.

There is some convergence to suggest that facilities located in Township 84 Range18W5 and Township 85 Range 18W5 are potential sources of high measured concentrations and odour complaints.

S3 GAPS/RECOMMENDATIONS

Gaps and associated recommendations are provided in Table S-1 to S-7. These gaps and recommendations are in the context that the odour and associated health concerns reported by residents are continuing at similar levels of intensity as for the period examined in this review.

Definition of Objectives

The air quality monitoring activities being undertaken by the Three Creeks Air Monitoring Subcommittee are being conducted in response to residential odour and health issue complaints. This is a relatively broad monitoring objective and more detailed articulation may be required by the Air Monitoring Subcommittee to more precisely define the objective of the monitoring activities, the measureable goals, and the benchmarks to define the appropriate level of these activities. Ambient monitoring activities and objectives need to be linked to other related activities such as the emissions inventory preparation and emission modification programs.

Improvements for Existing Activities

A common thread is the implementation of improvements to the current monitoring activities. These include:

- Calibration of all wind direction and wind speed sensors.
- More detailed odour complaint documentation to help better link the complaints to the upwind source regions and activities.
- Industry to track activities that could potentially result in emissions that could result in odours and/or increased concentration values. The focus here would be the documentation of intermittent activities. Industry not only includes the heavy oil operation, but also other potential emission sources (e.g., the landfill and Kraft pulp mill).
- The continuous monitoring focuses on SO_2, TRS and THC/methane/NMHC monitoring. The SO_2 and TRS measurements are linked to compliance requirements. While trace analyzers are available to obtain improved precision at the lower concentration levels (e.g., down to 0.2 ppb), it is not clear that this will be a benefit for this study where the concerns appear to be related to hydrocarbon emissions.
- The operability of the THC/methane/NMHC monitoring system requires improvement. At this stage it is not clear if the problems relate to the instrumentation technology or to the data

processing. In the event that operability problems cannot be resolved, readily available backup analyzers for deployment should be considered to reduce data gaps.

- Heat treated stainless steel sample lines are recommended for the collection of triggered canister samples.

- The analytical methods used to determine the sulphur compound concentrations in the canisters needs to be reviewed to determine if lower detection limit alternatives are available. Alternate sampling approaches using cryogenic trapping or carbon filter packs/columns have been developed (e.g., Khan et al 2012). These approaches, however, may be oriented more to research applications and may have limitations for routine monitoring programs. The Wood Buffalo Environmental Association (WBEA) is currently examining the use of filter packs for this purpose but so far this monitoring has not been integrated into the routine monitoring activities.

Additional Monitoring

Another common thread is the installation of a fourth continuous ambient air quality monitoring station in the identified potential source region. This installation would:

- Provide an indicator of the concentration magnitude closer to the identified source region. Greater concentrations would potentially result in more compounds being detected above the minimum detection limit.

- Allow better wind direction discrimination since emission sources would be located in all upwind directions, not just one general upwind direction.

- Allow for improved trajectory calculations via wind direction measurements in the potential source region.

- Provide additional passive monitoring relative to the installation of passive VOC samplers. The number of sampling sites and locations can be better defined when the source and emission inventory is completed.

Data Format and Metadata

“Data” refers to the actual air quality sample measurement and is typically expressed as a concentration in units of “ppb” or “ppm”. “Metadata” refers to information relating to the concentration and includes: sample collection time, sample collection location, method of collection, minimum detection limits, calibration, proof of chain of custody procedures, etc. “Raw data” refers to the actual measurement before being corrected for baseline and calibration drifts associated with the instrumentation. The appropriately corrected data is then referred to as quality controlled data. In conducting this study, ambient air quality data that had undergone the quality review process and metadata were requested. There are areas for

improvements with respect to both the data and the metadata. For the **data**, improvements can be related to the following items:

- For the continuous data, it is recommended that a single file for each monitoring site with one record representing one period be adopted. This would reduce the need for manipulation to organize the data, reduce the potential for adding errors, and make it easier for independent third parties to review the data.

- The continuous data should not contain erroneous information such as daily calibration data or suspect data associated with the hydrocarbon monitoring where there are inconsistent methane concentrations.

- The canister data should be integrated into a common database to allow the ongoing review of the data as it is collected instead of having to integrate several years of data at once.

The above recommendations are consistent with the continuous air quality data that are submitted to the CASA Alberta Ambient Air Data Management System (AAADMS) where there is a strict air quality review process, and all the data are publically accessible (see http://www.casadata.org/).

For an end user of ambient air quality data, the **metadata** is as important as the data itself. Improvements associated with the metadata include:

- A more rigorous and open chain-of-custody documentation is required for all samples collected in the field. It is important that an ambient air quality measurement unambiguously be related to the sample collection site expressed in UTM or latitude/longitude coordinates (not just a coloured dot on a map that can be “500 m” in diameter) and sample identification (ID) that documents the time and date of the sample.

- Another common thread is to provide more direct measurement and reporting of the minimum detection levels, and the uncertainty associated with each measurement. Duplicates and travel blanks can assist with this.

- Reporting of the measurements and an analysis on a regular basis is recommended. Specifically, one winter report for the six month period October to March, and one summer report for the six month period April to September are recommended. More frequent reporting has the risk of insufficient data to draw conclusions, and less frequent reporting give the impression of no activity.

Responsibilities

This assessment focuses on identifying gaps and associated recommendations to bridge the gaps. The recommendations are presented on the assumption that the Three Creeks Air Monitoring Subcommittee will review them, prioritize them, and assign associated responsibilities.

For the most part, we suspect the responsibilities will continue as is. Specifically the parties and associated responsibilities include:

- The AER will continue to be associated with the collection, examination, and distribution of odour complaint information.
- The individual industrial operators will continue to conduct passive monitoring. The role to collect additional passive VOC data could be assigned to the respective operators or be the direct responsibility of the Three Creeks Air Quality Monitoring Subcommittee.
- The Three Creeks Air Quality Monitoring Subcommittee will continue to assume responsibility for the two existing community continuous monitoring stations (i.e., Highway 986b and Highway 842b) and any new monitoring undertaken as a result of this review. Maxxam is the current operator of the existing stations.
- The deployment of the triggered VOC sample collection is currently administered by the Three Creeks Air Quality Monitoring Subcommittee with Maxxam being responsible for the sample collection and Alberta Innovates – Technology Futures (AITF) being responsible for the laboratory analysis.

Closing

The odour and human health complaints have been associated with ambient air quality in the region. There have been several initiatives to explore this association that include: the ambient air quality monitoring activities that are the subject of this report, a systematic identification and quantification of VOC emissions from the heavy oil operations in the area (e.g., the ongoing Clearstone study), and the AER Public Proceeding #1769924 (Odours and Emissions from Heavy Oil Operations in the Peace River Area) held in January 2014.

This report indicates that increased concentrations are primarily associated with upwind heavy oil operations. Additional monitoring and air assessments can be undertaken to refine potential sources on an individual facility basis. These additional activities, however, may not be required if there are actions that are being undertaken in the region to reduce the emissions that are potentially related to the complaints, and it can also be demonstrated with the existing monitoring activities that the actions have reduced ambient concentrations and associated odour complaints.

Table S-1 Meteorological Monitoring Gaps and Recommendations

Meteorological Monitoring Gaps and Recommendations	
Gap Recommendation M1:	The ESRD AMD siting requirements at the original Highway 986a and 842a locations did not appear to be met as this is one of the reasons for moving the monitoring stations. While this has been corrected, it is still cited as a gap to reinforce the need for appropriate site selection with respect to nearby tree canopies and other obstructions. If there are challenges to finding a site, taller towers may be used to compensate for nearby obstructions.
Gap Recommendation M2:	Odour complaints and high concentrations tend to occur under low wind speed conditions. Under these conditions, the air flow can be disorganized making it difficult to determine upwind source directions. Wind speeds measured at the Highway 986a and Highway 986b sites tend to be less than those measured at the other sites. The calibration of the 986 station wind sensor and/or the data logger programming needs to be confirmed. The performance of all three instruments needs to be confirmed and documented via a calibration check.
Gap Recommendation M3:	Wind monitoring conducted at the Highway 986 and Highway 842 sites are near residence areas. There is no wind monitoring in the main source area to the south of the PRC site. An additional wind monitoring site in this region would help relate source and receptor regions. The ESRD AMD siting requirements need to be met for any new monitoring site (see Gap/Recommendation M1)

Table S-2 Odour Complaint Gaps and Recommendations

Odour Complaint Gaps and Recommendations	
Gap **Recommendation O1:**	Privacy issues could have limited the external review of odour complaint information. This would have been unfortunate since the occurrence of an odour complaint is a key piece of information that needs to be examined in more detail. It is often the only end-point documentation related to an air quality event. In the end, odour information was forwarded to the study team for this assessment. It is recommended that additional information be collected by AER including: • The time of the odour complaint: The assessment was based on the assumption of standard time. At the end of our assessment, the AER confirmed that times were a combination of standard time and daylight savings time. An explicit indication of the time basis is desirable. • The intensity of the odour complaint: This would facilitate any correlation between odour complaints and simultaneous ambient air sampling. An intensity scale based on a 1 to 5 ranking could be used. • The duration of the odour complaint: A long duration would provide an indication of steady winds, providing more confidence in identifying upwind source directions. • An improved description of the odour type: The four types are somewhat limited. There are more descriptive terms that can be used that may help better identify the offending compounds. A list of these descriptors should be provided to residents. While the odour examination focused on determining trends based on the most frequent occurrences, one should not discount the odours occurring with less frequent conditions.
Gap **Recommendation O2:**	The analysis of each odour complaint by AER likely focuses on examining the wind direction associated with the hour when the event occurred and not on the calculation of multiple-hour back trajectories. While the determination of more rigorous and complete back-trajectories was out of scope for this assessment, this task is a possibility if there is a need to better delineate upwind source regions in future. Confirmation of the existing wind sensor performance and an additional meteorological monitoring station can improve the confidence of using winds to determine odour and potential source relationships.
Gap **Recommendation O3:**	We are not clear with respect to the feedback local residents or industry receives following the submission of a complaint to AER. Further investigation may be warranted to ensure adequate feedback is provided to relevant parties after a complaint has been investigated by AER.

Table S-3 Passive Sampling Gaps and Recommendations

Passive Sampling Gaps and Recommendations	
Gap Recommendation P1:	The primary passive monitoring focuses on SO_2 and H_2S to meet EPEA approval requirements. The associated concentrations were examined and were found to be very low. The main stakeholder issue in the region is associated with hydrocarbon emissions. For this reason, a passive monitoring program associated with VOC samples is recommended. Passive VOC sampling was conducted for the WISSA cattle health study (Davies et al 2006). The VOC samplers were deployed for nominal 30 day exposure periods, and the samples were analyzed for a suite of 26 compounds. The same laboratory that analyzed the WISSA passive VOC samplers (AirZone One) has since extended the list to 46 compounds (see Table 6-6). The VOC sampling sites would not be identical to the existing passive monitoring sites. The deployment of passive VOC samplers should be in the region where potential emission sources are located and in the region where the residents are located. Representative background site(s) distant from any nearby sources is recommended. The source region locations can be better selected when the Clearstone (2014) inventory has been completed.
Gap Recommendation P2:	Duplicate and field blank samples for the VOC samplers need to be taken to provide a measure of the detection limits and the uncertainty of the sample measurement. Typically, 10% of the samples would fall into this category.

Table S-4 Continuous Monitoring Gaps and Recommendations

Continuous Monitoring Gaps and Recommendations	
Gap Recommendation C1:	The continuous monitoring focuses on SO_2, TRS, and THC/methane/NMHC. As indicated in the passive monitoring section, the main stakeholder issue in the region is associated with hydrocarbon emissions. For this reason, future continuous monitoring needs to emphasize THC/methane/NMHC measurements.
Gap Recommendation C2:	There have been difficulties operating the continuous THC/methane/NMHC analyzers. This problem needs to be resolved to increase the level of stakeholder confidence with the associated data. An independent auditor, the contractor, and a Three Creeks Air Monitoring Committee representative meeting at the site would help resolve the issue.
Gap Recommendation C3:	The two Three Creeks Air Monitoring Subcommittee continuous air quality monitoring stations are located near the residential areas. An additional monitoring station located in the middle of the potential source region would help determine the contribution of these sources. The ambient air quality monitoring station in this region would provide an indication of air quality in the source region on a continuous basis.
Gap Recommendation C4:	Although the ambient temperature is of secondary importance, the results that were reported at the Highway 842a station show that incorrect information can get into the database. A sequential time series of meteorological measurements should be included in the monthly reports from the monitoring station contractor to catch these types of occurrences.
Gap Recommendation C5:	The documentation and reporting associated with the Highway 986 and Highway 842 stations has been confusing. The name of the stations tended to change with different information sources. For example the two Highway 986 sites have varyingly been referenced as the Langer station, Site A, Site 1, Highway 986 and the Penn West station. An effort needs to be made by all involved parties to adopt a consistent naming convention.
Gap Recommendation C6:	There was an indication that some of the data were reported to the nearest 10 ppb. While this may be viewed as being sufficient for compliance monitoring, it provides limitations when examining the data for other purposes. The instruments should be able to collect ambient measurements to the nearest 1 ppb. An independent auditor, the contractor, and a Three Creeks Air Monitoring Committee representative meeting at the site would help resolve the issue.

Table S-5 Canister Monitoring Gaps and Recommendations

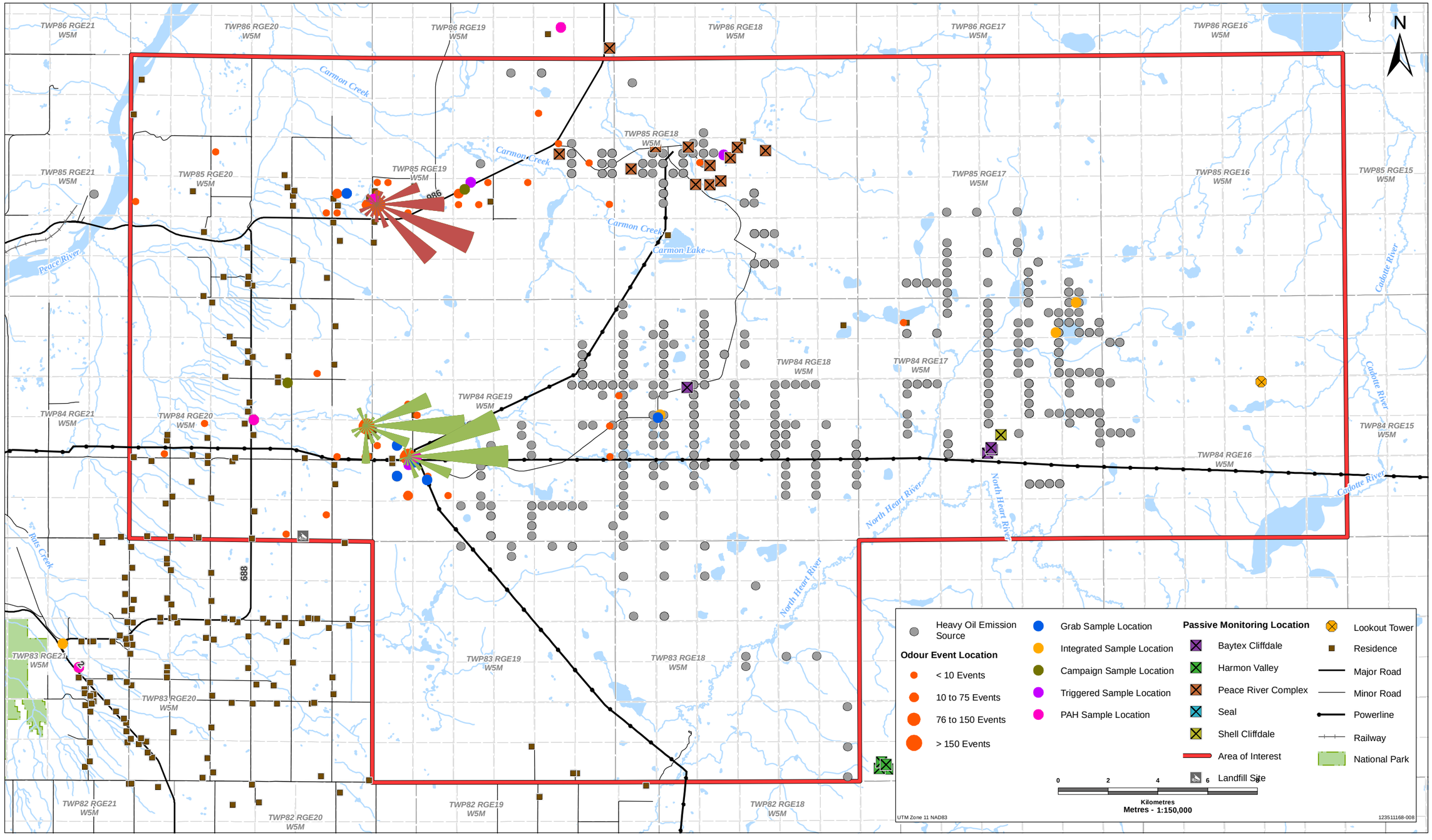
Canister Monitoring Gaps and Recommendations	
Gap Recommendation V1:	A key component with any field sample collection program is the establishing and maintaining a robust chain of custody system. The chain of custody system unambiguously defines the time and location associated with each measured value from the sample collection to the reporting of the measurement in the final report. The samples that were collected and analyzed did not appear to have followed any chain of custody approach. Examples are provided in the main text. Attempts were made to resolve the ambiguity, but some samples were not included in this review, and some of the samples may have been miss-categorized. A review of this assessment by field staff is required to confirm that the samples are appropriately included and categorized (i.e., can the chain of custody be re-created?).
Gap Recommendation V2:	As indicated in Section 3.0, the provided minimum detection limits were greater than the odour threshold for several compounds; mostly for the aldehydes, the phenols, and the reduced sulphur compounds. Alternate analytical methods need to be examined to reduce the detection limits. This should be discussed with AITF, the laboratory contractor.
Gap Recommendation V3:	The AIFT provided minimum detection limits (MDLs) of 50 ppb for the C1C4 scan, 1 ppb for the RSC scan, 0.5 ppb for the PAMS scan, and 0.5 ppb for most compounds associated with the VOC-PT scan. It was not stated if these MDLs are associated with analytical limitations or with the whole sampling approach. The analysis of several duplicate and blank samples would provide an indicator of the uncertainty that could be associated with each measurement, and the analysis of several field blanks would help confirm the MDLs.
Gap Recommendation V4:	Coupled with the meteorology Gap/Recommendation M3 to install another wind instrument in the emission source area, and with the continuous monitoring Gap/Recommendation C3 to locate another monitoring station in the emission source area, the collection of triggered samples in the source region would help define potential emission sources.
Gap Recommendation V5:	Different NMHC trigger levels were adopted for the Triggered Sample collection. In many cases the sum of hydrocarbon and reduced sulphur compounds were much less than the trigger threshold. Therefore it is difficult to recommend a specific threshold level. The three most frequently occurring odour complaint sites identified an average of 54 events per year for each site. The numbers of triggered samples collected were 33 in 2011 and 52 in 2012. To determine trends and relationships associated with high concentration events, at least 50 to 60 samples per year are desirable.
Gap Recommendation V6:	There is a considerable amount of information associated with the analysis of the canisters. This report and the associated ESRD reports do not make full use of this data. Further analysis of the data is recommended in the future after additional quality control and recommendations outlined herein have been undertaken.

Table S-6 ESRD Reporting Gaps and Recommendations

Mobile Monitoring Reporting Gaps and Recommendations	
Gap Recommendation E1:	The canister Gap/Recommendation V1 identified a chain of custody challenge. This challenge extends to the reports. We view it as desirable for the report analysis to have the link back to the Sample ID. This will allow reviewers to confirm the findings. In addition, all sampling locations should be geo-referenced to UTM coordinates or to latitude/longitude coordinates and not be shown as a "dot on a map".
Gap Recommendation E2:	We recognize that comparing ambient concentrations to odour thresholds helps place the ambient air quality measurements in perspective. Industry, regulator, and community stakeholders, however, need to be aware that there are uncertainties with respect to correlating measurements to odours.

Table S-7 PAH Sampling Gaps and Recommendations

PAH Sampling Gaps and Recommendations	
Gap Recommendation H1:	The ESRD PAH monitoring only focused on three days. While the values are low relative to the ambient air quality benchmarks, they may not necessarily be representative of the highest values that could occur in the area. The NAPS schedule of sampling every sixth day produces about 60 to 61 samples per year. Having 60 samples per year provides a better indicator of conditions than three samples. Like the campaign sampling, the air quality that is measured is random and the limited samples collected are unlikely to have occurred on days characterized by poor air quality.
Gap Recommendation H2:	Information about the PAH data in terms of minimum detection levels or uncertainty were not provided by ESRD. Field blanks and duplicate data samples in future studies by ESRD would provide an indicator of measurement quality.



THREE CREEKS MONITORING

Odour Wind Directions Associated With Three Locations

Acknowledgements: Original Drawing By Stantec, Basedata: Altalis, Canvec, National Road Network

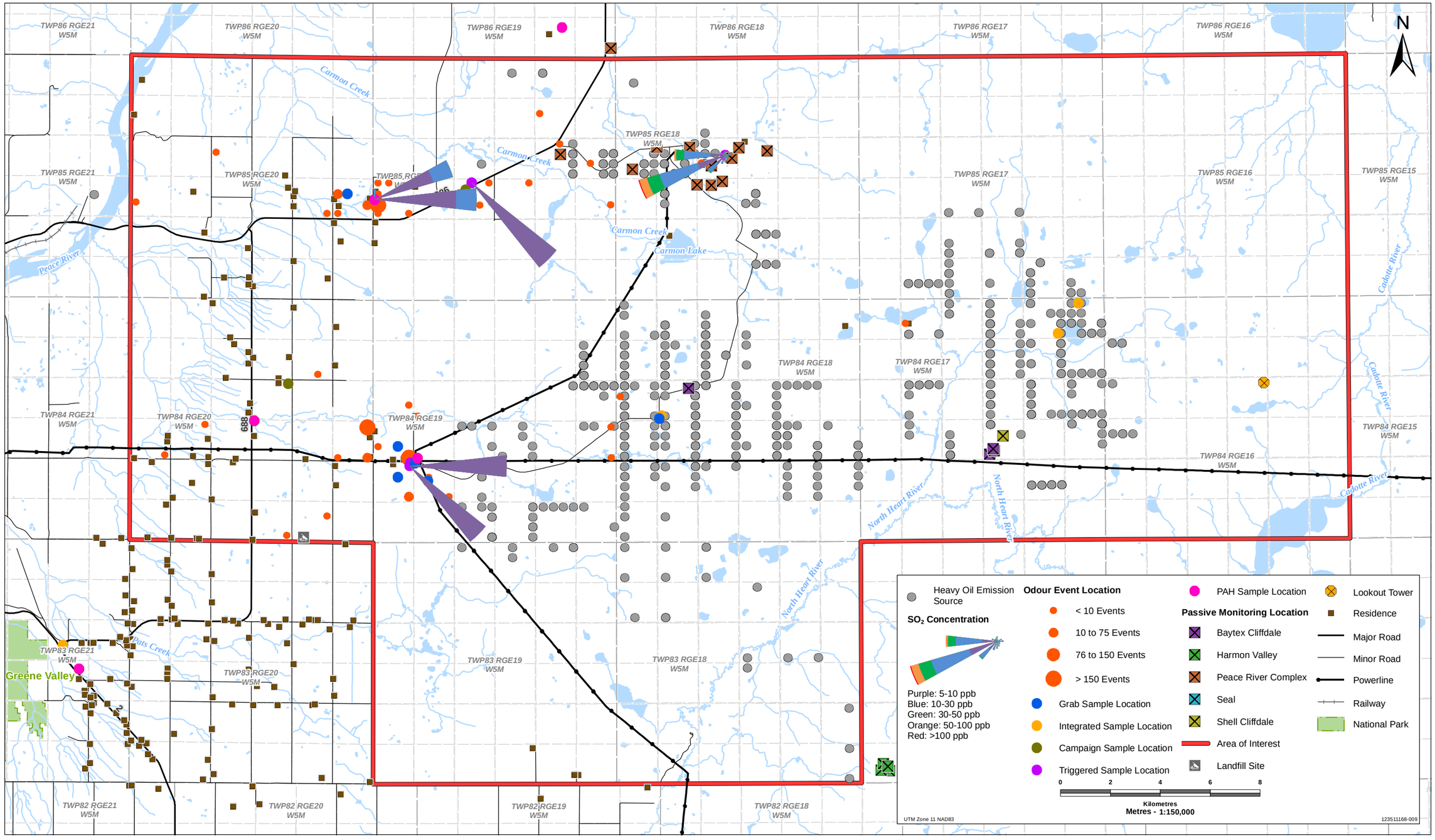
PREPARED BY

Stantec

FIGURE NO.

S-1

Last Modified: 4/2/2014 By: csteiner



THREE CREEKS MONITORING

Directional Distribution of SO_2 Concentrations Greater Than 5 ppb

Acknowledgements: Original Drawing By Stantec, Basedata: Altalis, Canvec, National Road Network

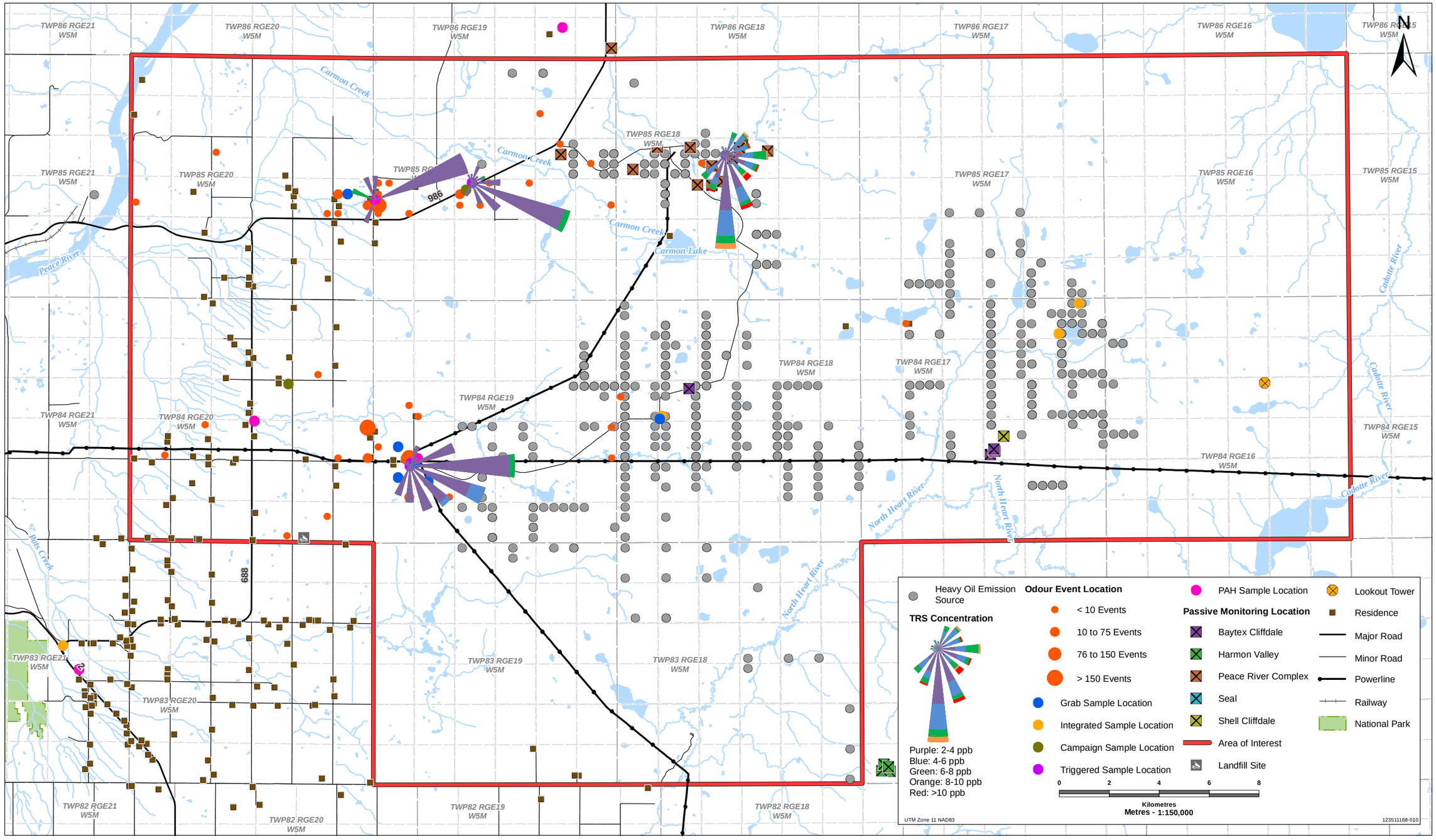
PREPARED BY

Stantec

FIGURE NO.

S-2

Last Modified: 4/2/2014 By: csteiner



THREE CREEKS MONITORING

Directional Distribution of TRS Concentrations Greater Than 2 ppb

Acknowledgements: Original Drawing By Stantec, Basedata: Altalis, Canvec, National Road Network

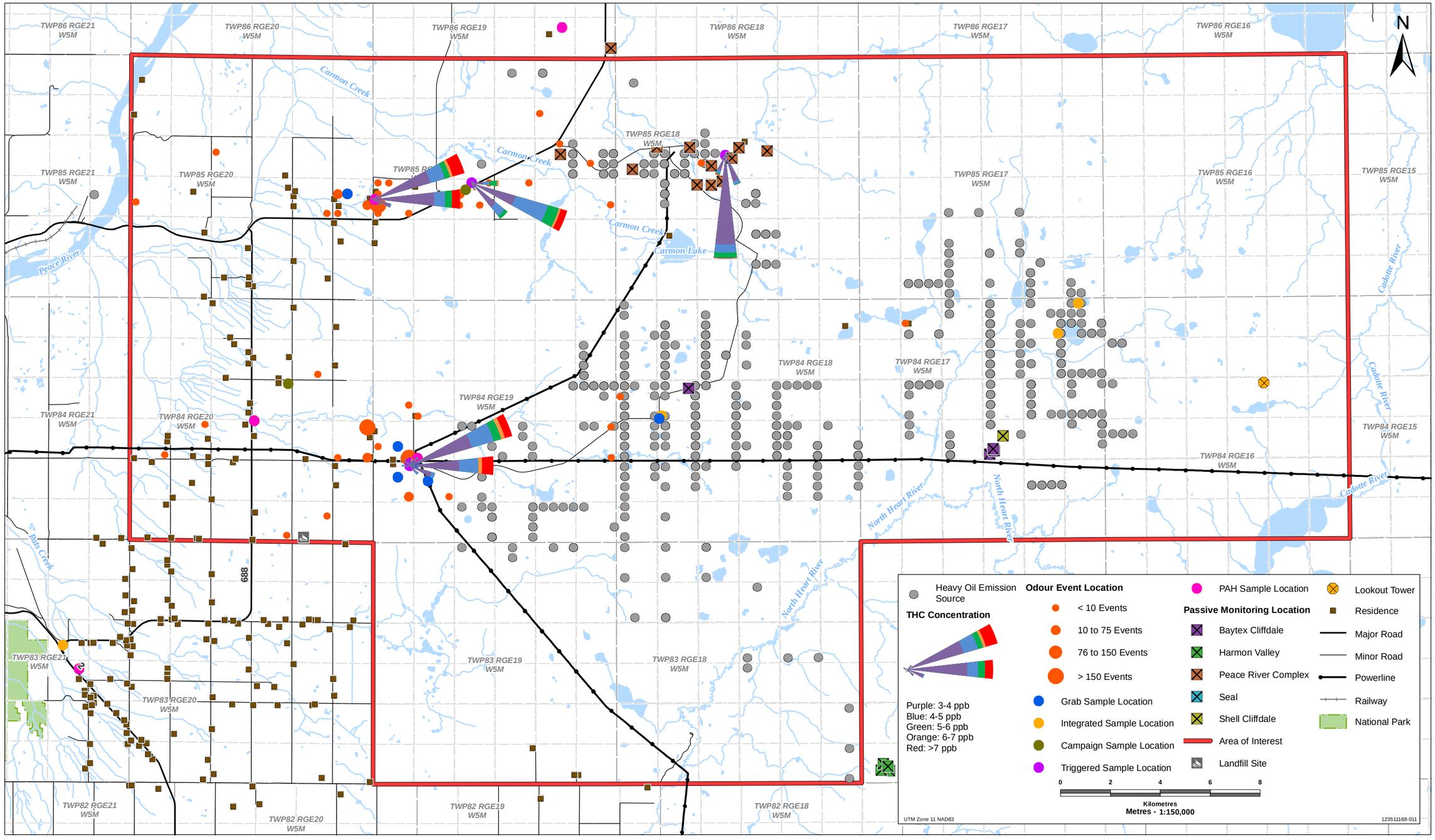
PREPARED BY

Stantec

FIGURE NO.

S-3

Last Modified: 4/2/2014 By: cstainer



THREE CREEKS MONITORING

Directional Distribution of THC Concentrations Greater Than 3 ppm

Acknowledgements: Original Drawing By Stantec, Basedata: Altalis, Canvec, National Road Network

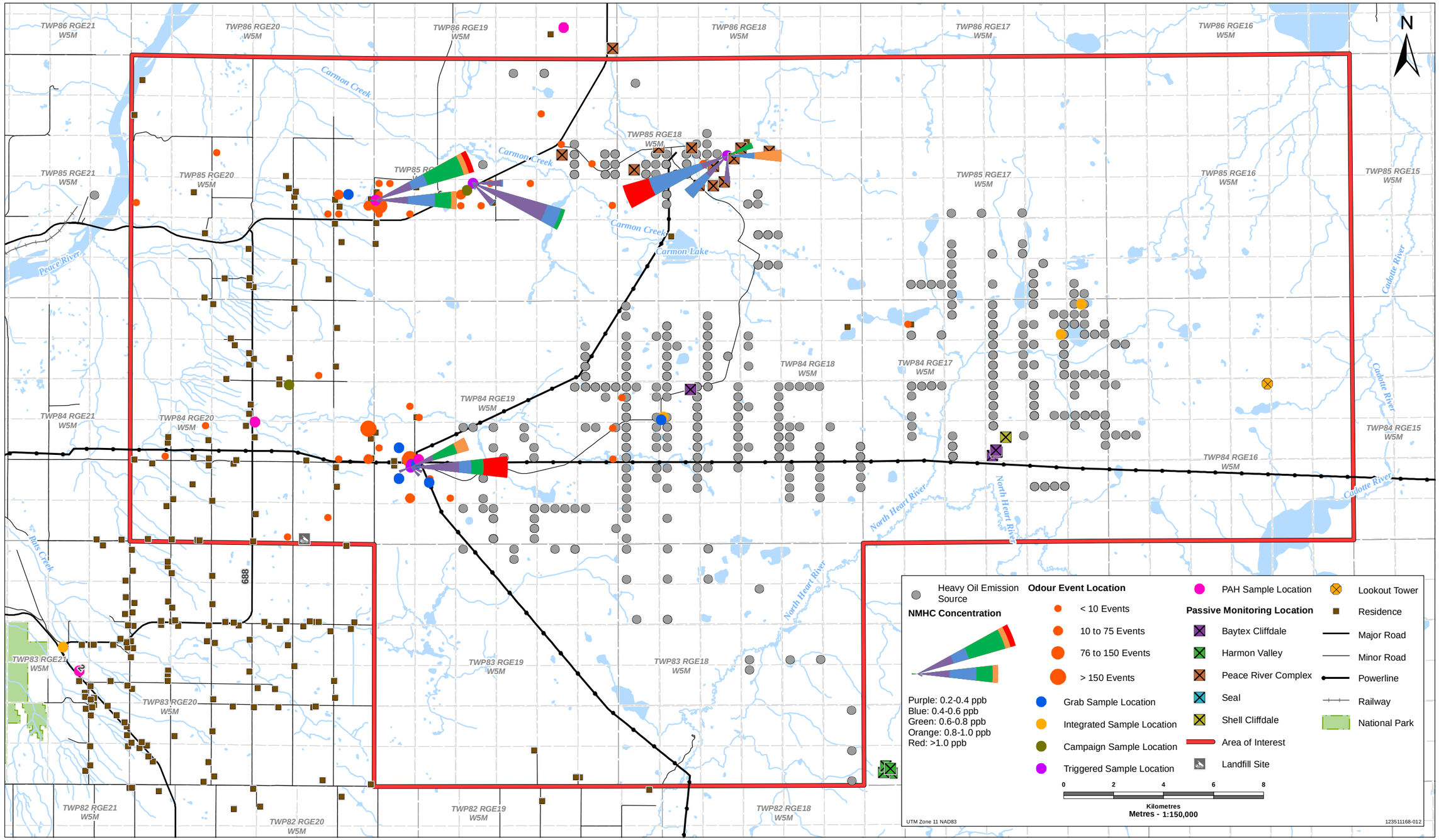
PREPARED BY

Stantec

FIGURE NO:

S-4

Last Modified: 4/2/2014 By: cstelmer



THREE CREEKS MONITORING

Directional Distribution of NMHC Concentrations Greater Than 0.2 ppb

Acknowledgements: Original Drawing By Stantec, Basedata: Altalis, Canvec, National Road Network

PREPARED BY

Stantec

FIGURE NO:

S-5

Last Modified: 4/2/2014 By: csteiner

1.0 Introduction

1.1 BACKGROUND

The Three Creeks area is approximately 50 km northeast of the town of Peace River and has an east-west extent of about five ranges (30 miles or 50 km) and a north-south extent of about two townships (12 miles or 20 km). Over the last several years, there have been numerous complaints about odours and health concerns associated with industry hydrocarbon and reduced sulphur emissions in the area.

An Air Monitoring Subcommittee was formed in November 2011 to support the Three Creeks Working Group, a multi-stakeholder group consisting of residents, industry, Northern Sunrise County, and the provincial government. The objectives of the Air Monitoring Subcommittee are to gain a better understanding of local meteorology, air emissions, and air quality, as well as to gather data that will strengthen future decision making with regards to air quality management in the Three Creeks area.

To execute scientific air studies in the Three Creeks area, a Three Creeks Industry Air Quality Working Group was formed from the Air Monitoring Subcommittee. The Three Creeks Industry Air Quality Working Group consists of representatives from Baytex Energy Ltd., Husky Energy, Murphy Oil Company Ltd., Penn West Exploration, and Shell Canada Ltd.

The oil and gas industry in the Three Creeks area has been conducting air quality monitoring in the area for several years. There are presently three industry-operated, continuous air monitoring stations in the area that sample for sulphur dioxide (SO_2), total reduced sulphur (TRS), total hydrocarbons (THC), and meteorology (primarily wind speed and wind direction). In addition, two of these stations are outfitted to collect canister samples for volatile organic compounds (VOC). There are also 24 passive air monitoring stations throughout the area, and measurements collected by the ESRD Mobile Air Monitoring Laboratory (MAML).

1.2 STUDY OBJECTIVES

The objective of the study is to conduct a scientific review of air monitoring data in the Three Creeks area, and to recommend potential areas for improvement and/or modification to the current air monitoring approach. The review of air monitoring data focuses on two components, namely an examination of:

- Ambient concentration data in context of relevant ambient air quality benchmarks (i.e., objectives, standards and guidelines), and
- Ambient air quality data in the context of odours.

The air quality measurement characterization does not focus on identifying potential emission source – ambient air quality relationships. However, some understanding of the emission sources is required to recommend areas for improvements and/or modification of the current monitoring approach.

1.3 STUDY AREA

Figures 1-1 and 1-2 show the Three Creeks study area of interest. Figure 1-1 includes background imagery that depicts the land use that delineates agricultural areas to the west and forested areas to the east. Figure 1-2 is a simpler outline without the background imagery; this figure shows residence locations and is used in this report as a base map to depict the locations of emission sources and ambient monitoring activities.

The area of interest for this study consists of 12 Townships associated with the extraction of heavy oil by *in situ* methods. There are several operators in the region that include: Baytex Energy (Baytex), Husky Energy (Husky), Murphy Oil Company (Murphy), Penn West Exploration (Penn West), and Shell Canada (Shell). These extraction operations include central processing plants (CPFs) that typically include combustion equipment, and supporting well pads. The CPFs and the well pads may include fugitive emission sources (e.g., hydrocarbon tank vents).

1.4 REPORT ORGANIZATION

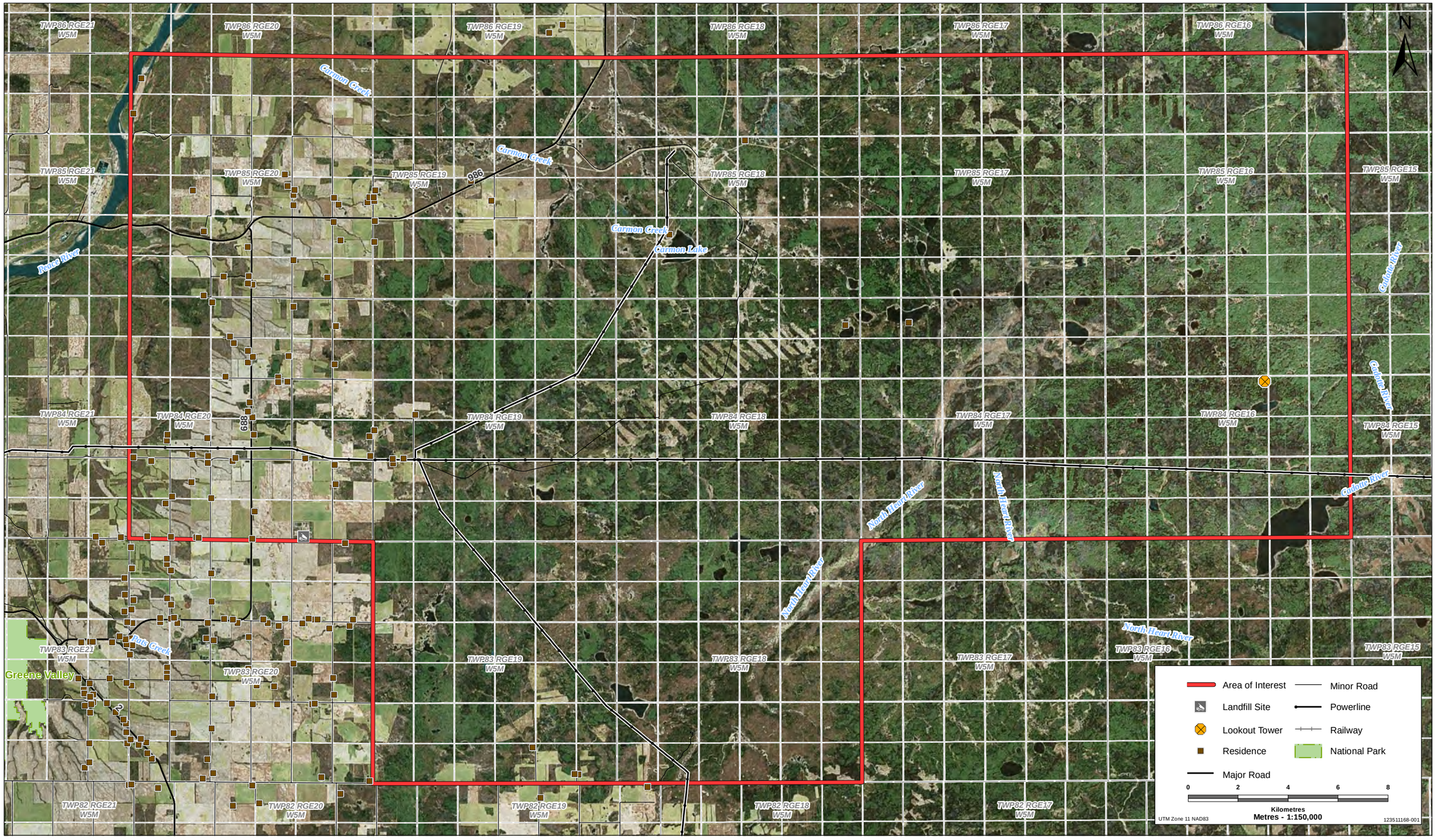
This report is organized as follows:

- Section 2 provides an overview of ambient air monitoring in the Three Creeks area with respect to locations of emission sources, types of ambient monitoring, temporal periods associated with the monitoring, and locations of the monitoring activities.
- Section 3 provides an overview of the ambient air quality benchmarks that are compared to the ambient measurements. The benchmarks address various end-point effects, including human health and odours.
- Section 4 provides a summary of the meteorological measurements in the region.
- Section 5 provides the details associated with the odour complaint log provided by the AER.
- Section 6 reviews the passive monitoring data collected by the Air Quality Subcommittee and industry.
- Section 7 reviews the continuous ambient quality station monitoring data collected by industry.

- Section 8 reviews the canister data coordinated by ESRD and the Air Quality Subcommittee.

- Section 9 provides a summary of the mobile air monitoring campaign measurements conducted by ESRD.

The study findings and conclusions are provided in an executive summary section that precedes the introduction section. The targeted report audience includes members of the public, industry and regulators. For this reason, detailed tables and figures are provided to ensure that the content is sufficiently complete to meet various audience needs. The tables and figures are provided in the relevant sections rather than in an appendix to avoid fragmenting the presentation.



THREE CREEKS MONITORING

Three Creeks Ambient Air Quality Monitoring Review Area of Interest (with Imagery)

Acknowledgements: Original Drawing By Stantec, Basedata: Altalis, Canvec, National Road Network

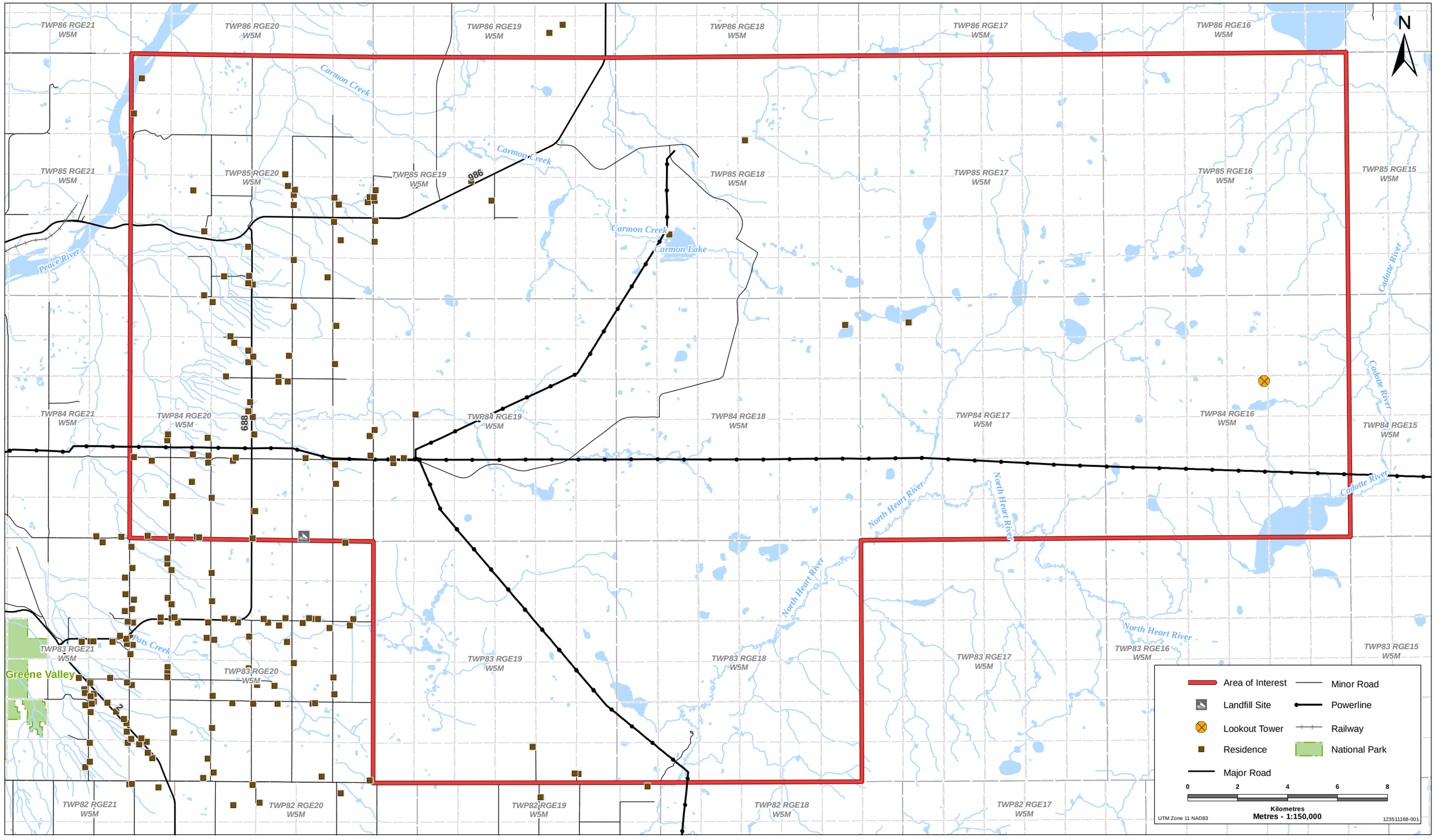
PREPARED BY

Stantec

FIGURE NO.

1-1

Last Modified: 4/2/2014 By: cstelner



THREE CREEKS MONITORING

Three Creeks Ambient Air Quality Monitoring Review Area of Interest

Acknowledgements: Original Drawing By Stantec, Basedata: Altalis, Canvec, National Road Network

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FIGURE NO.

1-2

Last Modified: 4/2/2014 By: cstelner

2.0 Ambient Monitoring Overview

This section provides an overview of emission source locations and ambient air quality related monitoring activities that were undertaken in the Three Creeks air quality review area.

2.1 EMISSION SOURCES

A companion Three Creeks Industry Air Quality Working Group study is underway and this study will identify and quantify VOC emissions from heavy oil production and residential sources (Clearstone 2014). Figure 2-1 shows the locations of the estimated 600 industry sources located in the area of interest. For the most part, the industry VOC emission sources are located southeast (SE), east (E), or northeast (NE) of the residence areas.

The Clearstone (2014) source and emission inventory includes the following heavy oil production differing source types:

- Fugitive losses result from equipment components that leak as a result of wear, poor design or improper installation. The primary emission sources include but are not limited to: threaded and flanged connections, valve stem packing leaks, leakage past valve seats to the atmosphere, pump seals, pressure regulator vents, sampling ports and compressor seal vents.

- Truck filling emissions occur when loading oil from production tanks into trucks, and hence are episodic.

- Industrial combustion emissions result primarily from the combustion of natural gas, with minor contributions from diesel, gasoline and propane fuel. This source type includes residential combustion sources.

Figure 2-1 also shows the locations of two industrial emission sources that are not associated with the production of heavy oil: a Kraft pulp mill that is located just outside the area of interest to the northwest; and an industrial landfill site (SW ¼ 2-84-20W5M) that is located southwest of the Highway 842 monitoring site.

2.2 AMBIENT MONITORING

Figure 2-1 also shows the locations of ambient monitoring activities. The following are noted:

- Odour complaint locations tend to be clustered around the residences that are the closest to the emission sources, and also include locations where residences have not been identified.

- The passive sites tend to be clustered around respective heavy oil extraction facilities due to regulatory requirements.

- The location of the Highway 986 continuous station changed in July 2011. The two locations are referred to as Highway 986a (previous) and Highway 986b (current).
- The location of the Highway 842 continuous station changed in November 2012. The two locations are referred to as Highway 842a (previous) and Highway 842b (current).
- Canister monitoring tends to be focused in locations where most of the odour complaints occurred, that is, near the residences located closest to the emission sources.

More details with respect to the monitoring activities are provided in the respective sections of this report.

2.2.1 Meteorology

Continuous ambient air quality monitoring stations are typically equipped with a 10 m mast and instrumentation to measure wind speed and wind direction. In some cases, ambient temperatures are also measured.

In the Three Creeks area, there are three continuous ambient air quality monitoring stations. Meteorological data were obtained from the respective operators of these stations. Figure 2-2 is a photograph of one of the stations in the region showing the attached tower. Further details and a review of the meteorological data are provided in Section 4.0.

2.2.2 Odour Complaints

The AER has an odour response protocol where community members can report odours, and the AER follows up to determine potential sources of the odour and determine the nature of mitigation actions.

The AER (Candace McDonald, personal communication 2013) provided an odour complaint log that spanned the period Feb 11, 2010 to Sep 30, 2013. During this period, 847 events were documented. Each event is composed of: the incident number, the location (Section, Township, and Range), the incident date and time, and the type of odour. Further details and a review of the odour complaint log data are presented in Section 5.0.

2.2.3 Passive Monitoring

This monitoring technology is referred to as “passive” since it does not require a pump to draw an ambient air sample through an adsorptive medium or past an instrument detector. A passive sampler relies on the movement of air past an adsorptive surface and has traditionally been used to measure ambient exposures in occupational settings. In an environmental monitoring setting, they are typically used to obtain monthly average ambient air concentrations. Passive environmental samplers have been developed for SO_2, H_2S, NO_2, NO_X, NH_3, HNO_3, O_3 and certain VOCs.

In the Three Creeks area, passive samplers primarily focus on SO_2 and H_2S, with one operator additionally measuring NO_2. A photograph of a passive sampling site and the passive sampler are shown in Figure 2-3. The passive sampling data are identified in Table 2-1. Further details and a review of the passive ambient air quality data are presented in Section 6.0.

2.2.4 Continuous Monitoring

Continuous monitoring relies on pumps that draw an ambient air sample past a fast response detector to provide continuous ambient air quality measurements. Each substance being measured requires monitoring technology specific to that substance. Continuous instruments have been developed for SO_2, H_2S, TRS, NO, NO_X, NO_2, HNO_3, THC, NMHC, methane, CO, O_3, and PM. Ambient measurements are typically recorded as one-hour (1-h) averages. Continuous ambient monitoring stations also typically measure and record meteorological parameters such as wind speed and wind direction.

In the Three Creeks area, continuous monitoring focuses on SO_2, TRS, THC, NMHC, and methane monitoring. Figure 2-4 is a photograph showing the SO_2 and H_2S analyzers in one of the stations. Continuous monitoring data are identified in Table 2-2. Further details and a review of the ambient air quality continuous data are presented in Section 7.0.

2.2.5 Canister Monitoring

Evacuated stainless steel canisters are used to collect ambient air samples that can be analyzed for several hundred compounds. The sample collection duration is controlled be the canister filling rate, and these durations can range from near instantaneous to one hour. The filling of the canister can be undertaken manually or automated. For the latter, the filling can be at a prescribed time or triggered by an event.

In the Three Creeks area, 6 litre (6 L) canisters were used to collect samples at several locations. Four types of canister sampling programs were undertaken:

- Grab Sample collection by residents and ESRD staff. These are instantaneous samples that were collected during odour complaints.

- Integrated Sample collection by ESRD staff. These are time averaged samples (i.e., 1-h averages) that are collected during the same period as the grab samples.

- Campaign Sample collection during an intensive ESRD mobile monitoring program (which is described in Section 2.2.6).

- Station Triggered Sample collection at the continuous monitoring stations when the NMHC concentration reached a threshold level. Figure 2-5 shows a canister inside one of the stations that collected these samples.

The canisters were documented and shipped to a chemical laboratory where they were analyzed for VOC and RSC compounds. The canister data obtained from ESRD are summarized in Table 2-3.

Some of the canister monitoring results are provided in two ESRD reports: ESRD (2010) examines the period February to May 2010, and ESRD (2011) examines the period April to December 2010. The ESRD reports provide analysis and preliminary interpretation of the results collected for the respective periods. The canister data collected in the 2011 to 2013 period have not been summarized in a formal report to date; however, they are evaluated herein. Further details and a review of the canister ambient air quality data are presented in Section 8.0.

2.2.6 Mobile Monitoring

ESRD deployed their Mobile Air Monitoring Laboratory (MAML) to collect ambient air quality measurements in the Three Creeks area for the period October 24 to 28, 2010. Activities associated with this period included:

- Deployment of the MAML at six locations for four evenings.
- Supplemental canister collection at these six locations (identified as the campaign samples in Section 2.2.5).
- Ambient PAH samples collected on the National Air Pollution Survey (NAPS) six day cycle. Samples were collected six sites for the 24-hour period November 10, November 16 and November 22 (all in 2010).

The data obtained from ESRD are summarized in Table 2-4. Further details and a review of the mobile and PAH ambient air quality data are presented in Section 9.0.

2.3 TEMPORAL PERIOD

Figure 2-6 provides a chart indicating the respective periods represented by the different types of monitoring. The ending period for most of the data are July, August or September, 2013; the date being dependent when the data were supplied to the study team. The longest period of record is associated with the Shell Peace River Complex, which is one of the older operations in the region. Monitoring effort was increased in 2010 in response to local resident concerns.

Table 2-1 Passive Monitoring in the Three Creeks Area

Operator	Facility	Substances	Number of Passive Sites	Period Examined (months)
Shell	Peace River Complex	SO_2, H_2S	12	Oct 2005 to Jul 2013 (94 months)
Shell	Cliffdale	SO_2, H_2S	1	May 2012 to Aug 2013 (17 months)
Baytex	Cliffdale	SO_2, H_2S	4	Apr 2012 to July 2013 (16 months)
Penn West	Harmon Valley	SO_2, H_2S, NO_2	4	May 2013 to Aug 2013 (4 months)
Penn West	Seal	SO_2, H_2S, NO_2	3	May 2013 to Aug 2013 (4 months)

Table 2-2 Continuous Monitoring in the Three Creeks Area

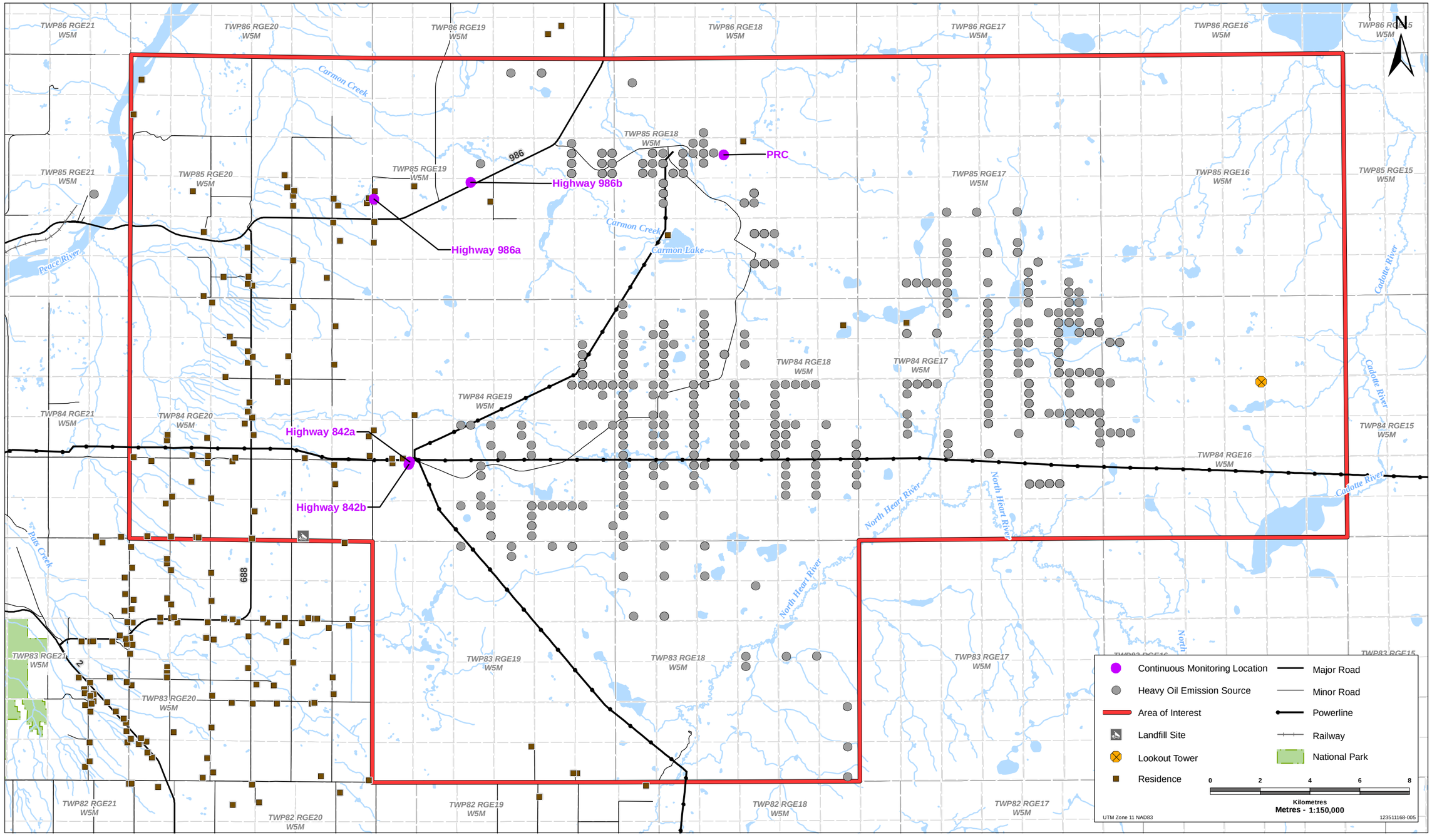
Operator	Location	Substances	Period Examined
Shell	Peace River Complex (PRC)	SO_2, H_2S, TRS, THC, methane, NMHC, wind, and Temperature	• Jan 1 2008 to Apr 30 2013 (AGAT) • May 1 2013 to Aug 31 2013 (MAXXAM)
Three Creeks Air Monitoring Subcommittee	Highway 986a	SO_2, H_2S, THC, methane, NMHC and wind	• Mar 18 2010 to Jul 6 2011 (MAXXAM)
Three Creeks Air Monitoring Subcommittee	Highway 986b	SO_2, H_2S, THC, methane, NMHC and wind	• Jul 6 2011 to Aug 31 2013 (MAXXAM)
Three Creeks Air Monitoring Subcommittee	Highway 842a	SO_2, H_2S, THC, methane, NMHC and wind	• Apr 1 2012 to Oct 31, 2012 (AGAT)
Three Creeks Air Monitoring Subcommittee	Highway 842b	SO_2, H_2S, THC, methane, NMHC and wind	• Nov 8 2012 to Aug 31 2013 (MAXXAM)
NOTE: The contractor associated with the monitoring is identified (AGAT or MAXXAM)			

Table 2-3 Canister Sample collection in the Three Creeks Area

Type	Number of Samples	Number of Locations	Period Examined
Grab Sampling (Resident)	21	5	Jul 7 2010 to Dec 18 2010
Grab Sampling (ESRD)	5	3	Apr 11 2010 to Aug 30 2010
Integrated Sampling	12	7	Mar 7 2010 to Dec 18 2010
Campaign (ESRD)	24	6	Oct 24 2010 to Oct 28 2010
Station Triggered	116	Highway 986a Highway 986b	Jul 14 2010 to Dec 6 2010
Station Triggered	2	Highway 842b	Feb 14 2011 to July 21 2013
Total	**180**		
NOTE: Samples were varyingly analyzed for different VOC and TRS substances.			

Table 2-4 ESRD Monitoring in the Three Creeks Area

Type	Number of Samples	Number of Locations	Period Examined
MAML Continuous (1-h averages)	CO, NO_X, SO_2 and THC	6	Oct 24 2010 to Oct 28 2010
Canister (also identified in Table 2-3)	24	6	Oct 24 2010 to Oct 28 2010
PAH (24-h)	6	6	Nov 10 2010
	6	6	Nov 16 2010
	6	6	Nov 22 2010



THREE CREEKS MONITORING

Location of Industry Sources

Acknowledgements: Original Drawing By Stantec, Basedata: Altalis, Canvec, National Road Network

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Stantec

FIGURE NO.

2-1

Last Modified: 4/2/2014 By: cstelner

Figure 2-2 Photograph of the Highway 986b continuous air quality monitoring station (courtesy of Maxxam)

Figure 2-3 Photograph example of a passive monitoring site (courtesy of Shell) and passive sampler (courtesy of Maxxam)

Figure 2-4 Photograph showing the SO_2 and TRS analyzers located in one of the continuous ambient monitoring stations (courtesy of Maxxam)

Figure 2-5 Photograph of a 6-L sampling canister located in one of the continuous ambient monitoring stations (courtesy of Maxxam)

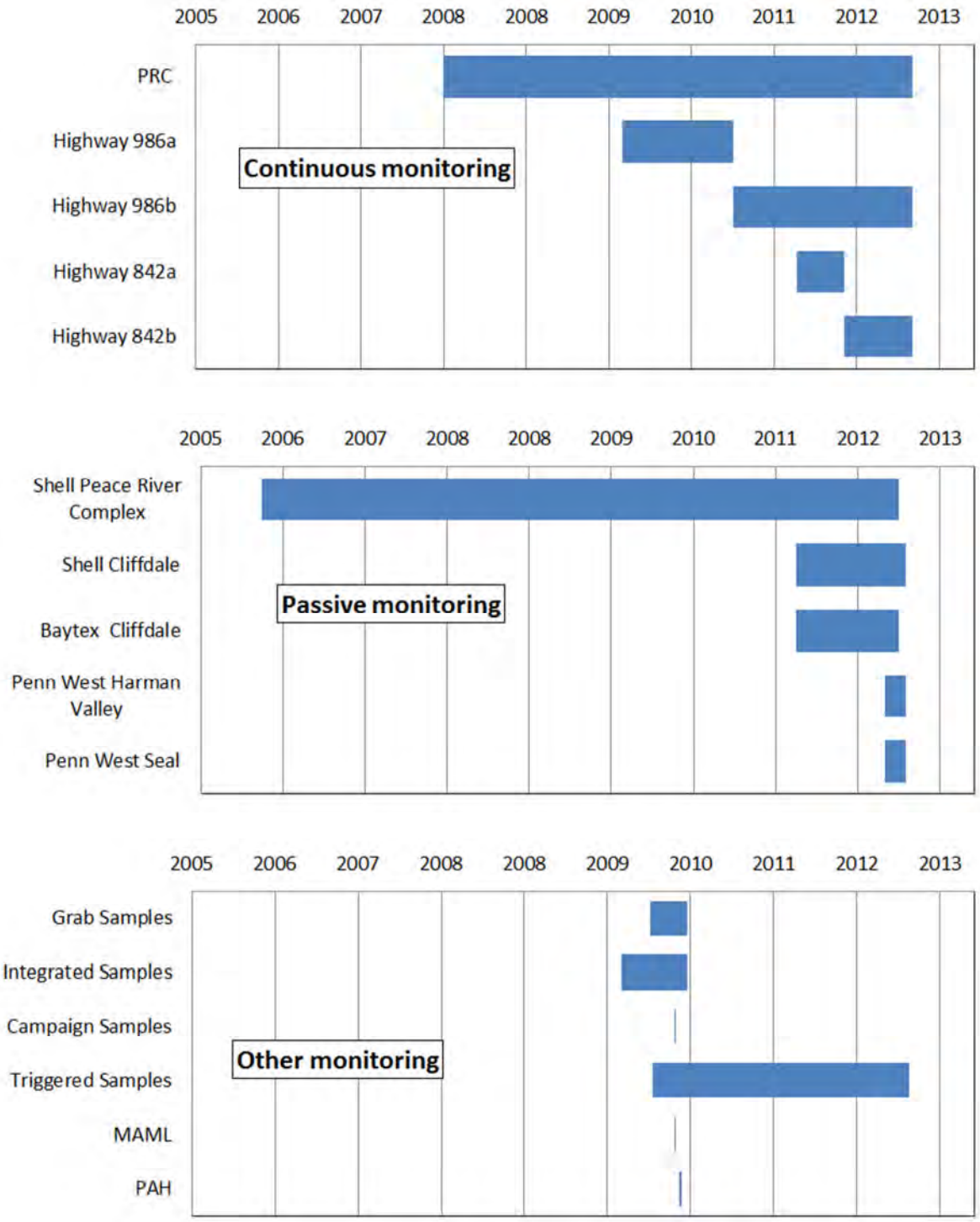


Figure 2-6 Ambient monitoring time periods

3.0 Ambient Air Quality Benchmarks

3.1 REGULATORY BENCHMARKS

To help place ambient air quality measurements into context with respect to human health and environmental concerns, they are compared to ambient air quality benchmarks. Ambient benchmarks have been established by regulatory agencies and other organizations, and are referred to as objectives, guidelines, standards, criteria, or screening levels depending on the regulatory agency or organization. For this assessment the following benchmarks are referenced:

- The Alberta Ambient Air Quality Objectives (AAAQOs) developed by ESRD (ESRD 2013). The AAAQO identify objectives for 48 substances. The AAAQO address multiple averaging periods ranging from 1-h to one year, depending on the substance. The list given in Table 3-1 is a subset of 32 substances that are relevant to what was measured in the Three Creeks area. The AAAQO are provided in units of µg/m^3 and ppb. The ppb values are shown in Table 3-1.

- The Ambient Air Quality Criteria (AAQC) developed by the Ontario Ministry of the Environment (MOE) (MOE 2012). The MOE has AAQC for 334 substances. The AAQC address multiple averaging periods ranging from 10 minutes to one year, depending on the substance. The list given in Table 3-2 is a subset of 73 substances that are relevant to what was measured in the Three Creeks area.

- The Effects Screening Levels (ESLs) developed by the Texas Commission on Environmental Quality (TCEQ 2013). The TECQ defines ESL for 5424 substances for short-term and long-term, depending on substance. The status for the ESLs are as follows:

  - Interim (5125)
  - Under Review (152)
  - Final (136)
  - Criteria Pollutant (8)
  - Undefined (2)
  - TCEQ Reg Standard (1)

  The ESLs include 101 VOCs, 16 PAHs, 18 carbonyls and 28 RSCs. Short-term generally indicates a 1-hour averaging period, and long-term refers to an annual period. ESLs are not ambient air standards, and exceeding an ESL does not necessarily indicate a problem. The list given in Table 3-3 is a subset of 252 substances that are relevant to what was measured in the Three Creeks area.

- The World Health Organization (WHO) developed air quality standards for 16 organic pollutants, 12 inorganic pollutants, and four classical pollutants (WHO 2000).The standards

address multiple averaging periods ranging from 10 minutes to one year, depending on the substance. The list given in Table 3-4 is a subset of 11 substances that are relevant to what was measured in the Three Creeks area.

- The previous tables focus on VOC and RSC compounds. Table 3-5 provides ambient benchmarks for PAHs compounds. These benchmarks are primarily based on the TECQ short-term and long-term ESLs. The exception being the annual AAAQO for benzo(a)pryene.

Ambient concentrations in the region are measured in units of ppb for all compounds other than PAHs; PAHs being measured in units of ng/m^3. The ambient benchmarks are varying given in units of ppm, ppb, or µg/m^3. All benchmarks in the tables have been converted into the units that correspond to the respective measurements.

For each chemical compound identified in the tables, a Chemical Abstracts Service Registry Number (CAS #) is provided. The CAS # is a unique numerical identifier assigned to every chemical compound described in the scientific literature. Historically, an individual chemical compound can be identified by multiple synonyms that can lead to confusion. For example, the aldehyde $CH_3(CH_2)_4(CHO)$ (also referred to as $C_6H_{12}O$) is varyingly referred to as hexanal, hexaldehyde, hexylaldehyde, caproaldehyde, and caproic aldehyde (CAS # 66-25-1). In one of the ESRD Three Creek reports (ESRD 2010), this compound is referred to as both “hexanal” and “hexanol”. The latter, hexanol, is a different compound, being an alcohol with a CAS # 111-27-3. The use of “hexanol” in ESRD (2010) is a typographic error. The CAS # was therefore used to compare the compounds that were measured in the Three Creeks area to the respective ambient air benchmarks to reduce the potential for incorrect comparisons.

This assessment compares ambient concentration measurements to the above regulatory benchmarks. The assessment does not determine the inferences of exceeding any of the benchmarks. That is, this assessment should not be construed as being a health risk assessment.

3.2 ODOUR THRESHOLDS

3.2.1 Threshold Values

The selection of regulatory benchmarks considers various adverse endpoints, one of which is the potential for odours. As odours are one of the issues in the Three Creeks area, a more detailed accounting of odours is examined. Specifically, the ambient concentrations are compared to odour thresholds. Odour thresholds reported in the scientific literature span a wide range of concentrations that can depend on the approach used to define and determine them. Odour thresholds have varyingly been reported as “minimum perceptible”, “detection” and “recognition”. Odour panels are often used to determine these thresholds, and the thresholds can be based on 50% or 100% of the panel responses. Odour threshold determination has been conducted in clean indoor environments and in the outside environment.

For consistency with the ESRD (2010) report that reviews the Three Creeks ambient air quality measurements, the odour thresholds reported by Nagata (2003) are adopted herein. Nagata

(2003) provides odour thresholds for 223 compounds that were determined over the period 1976 to 1988. Recent studies indicate that the Nagata values are still representative (e.g., TCEQ 2013). Table 3-6 provides the odour thresholds associated with all 223 compounds. While not all compounds are relevant to the Three Creeks area measurements, odour thresholds for all compounds are provided for completeness. The Nagata odour thresholds are given in units of ppm and have been converted to ppb in Table 3-6.

There is a wide range of odour thresholds that have been reported in the scientific literature. Table 3-7 compares odour thresholds from differing information sources for three aldehydes and three sulphur compounds. Cometto-Muniz and Abraham (2010) provide the odour detection limits based on the most sensitive subject, the least sensitive subject and the median panel. The median values are consistent with the Nagata values. The range from the least to most sensitive subjects for hexanal is a factor of 53 and 15 for nonanal.

The character of the odour can change with the concentration. For example, low H_2S concentrations are associated with a “freshly boiled egg” or a “Limburger cheese” odour. At higher concentrations, the associated odour is described as a “rotten egg” odour (Amoore 1985). This variability with respect to odour thresholds needs to be considered.

3.2.2 Peak to Mean Concentration Ratio

Prior to comparing an ambient concentration to an odour threshold, it is important to adjust the time average measurement (i.e., the mean or M) to a short-term exposure that can be associated with odour (i.e., the peak or P). Numerous approaches have been developed to account for the P/M ratio, which depends on factors such as the emission source type (e.g., a tall stack or a ground based release), the meteorological conditions (e.g., atmospheric stability), and the downwind distance from the emission source (i.e., travel time).

The application of a commonly used power law relationship with an exponent of 0.2 indicates a P/M value of 1.8 for 3-minutes and 3.2 for 10-seconds when based on a 60-minute reference period. Field measurements conducted under stable atmospheric conditions for ground based emission sources near Calgary indicate an exponent of 0.3 can be used to relate a 3-minute average to a 60-minute reference period (ERCB1990); for this case, the P/M ratio is 2.4. In Germany, a P/M value of 4.0 is used to calculate peak concentrations from 1-hour average model predictions for all atmospheric conditions; this assumption has been challenged in that a P/M value of 2.0 is recommended for stable atmospheric conditions (Piringer et al 2012). In Queensland, Australia, a P/M value of 10 is recommended for wake-free stacks and a value of 2.0 is recommended for wake-affected stacks and ground level sources (Department of Environment and Heritage Production 2013). Based on theoretical atmospheric considerations, Zelt (2013) shows a downwind decrease in the 3-minute to 60-minute P/M value from 4.5 at 1 m from the emission source to 2.5 at 300 m from the emission source.

For this assessment, a value of 3.0 as recommended by Ruijten et al (2009) was adopted to account for this peak to mean (P/M) relationship. This factor is viewed as being representative

for relating time averaged concentrations to shorter term peak values that are associated with the perception of odour.

3.3 APPLICATION OF BENCHMARKS

As indicated in the previous sections, there are numerous ambient air quality benchmarks for several thousand chemical compounds and for several averaging periods. The canister sampling deals with the largest number of compounds and this sampling examines over 500 reduced sulphur and hydrocarbon compounds. To facilitate comparison of these measurements to the ambient benchmarks, the following is undertaken:

- A short-term benchmark (STB) is defined as the most stringent (i.e., the lowest) regulatory benchmarks based on the 10 minute, one-half hour and 1-hour exposure periods. The STB is compared to the maximum measured (MM) by calculating the ratio MM/STB. Values of MM/STB greater than unity indicate that the maximum measured value is greater than the most stringent benchmark.

- A long-term benchmark (LTB) is defined from the most stringent (i.e., the lowest) regulatory benchmarks based on 24-h, 1-week, 1-month and annual exposure periods. The LTB is compared to the average measured (AM) by calculating the ratio AM/LTB. Values of AM/LTB greater than unity indicate that the maximum measured value is greater than the most stringent benchmark.

- The maximum measured (MM) is compared to the odour thresholds (OT) by calculating the ratio MM/OTC. Values of MM/OT greater than 0.33 are identified.

This approach is viewed as being conservative and of value in identifying potential ambient air quality issues that would warrant further examination.

Table 3-1 Alberta Ambient Air Quality Objectives (AAAQO) (ppb)

Substance	CAS #	1-h	8-h	24-h	3-d	30-d	Annual
Acetaldehyde	75-07-0	50	-	-	-	-	-
Acetic_acid	67-19-7	102	-	-	-	-	-
Acetone	67-64-1	2,400	-	-	-	-	-
Acrolein	107-02-8	1.9	-	0.17	-	-	-
Acrylic_acid	79-10-7	20	-	-	-	-	0.34
Acrylonitrile	107-13-1	19	-	-	-	-	0.9
Ammonia	7664-41-7	2000	-	-	-	-	-
Benzene	71-43-2	9	-	-	-	-	0.9
Benzo[a]pyrene	50-32-8	-	-	-	-	-	0.000029
Carbon_disulphide	75-15-0	10	-	-	-	-	-
Carbon_monoxide	630-08-0	13,000	5,000	-	-	-	-

Table 3-1 Alberta Ambient Air Quality Objectives (AAAQO) (ppb)

Substance	CAS #	1-h	8-h	24-h	3-d	30-d	Annual
Cumene	98-82-8	100	-	-	-	-	-
Dimethyl-ether	115-10-6	10,100	-	-	-	-	-
2-Ethylhexanol	104-76-7	110	-	-	-	-	-
Ethylbenzene	100-41-4	460	-	-	-	-	-
Ethyl_chloroformate	541-41-3	0.13	-	-	-	-	-
Ethylene	74-85-1	1,050	-	-	40	-	26
Ethylene_oxide	75-21-8	8	-	-	-	-	-
Formaldehyde	50-00-0	53	-	-	-	-	-
n-Hexane	110-54-3	5,960	-	1,990	-	-	-
Hydrogen_sulphide	7783-06-4	10	-	3	-	-	-
Isopropanol	67-63-0	3,190	-	-	-	-	-
Methanol	67-56-1	2,000	-	-	-	-	-
Methylene_bisphenyl_diisocyanate	101-68-8	0.05	-	-	-	-	-
Monoethylamine	75-04-7	0.645	-	-	-	-	-
Nitrogen_dioxide	10102-44-0	159	-	-	-	-	24
Propylene_oxide	75-56-9	200	-	-	-	-	13
Styrene	100-42-5	52	-	-	-	-	-
Sulphur_dioxide	7446-09-5	172	-	48	-	11	8
Sulphuric Acid	7664-93-9	2.5	-	-	-	-	-
Toluene	108-88-3	499	-	106	-	-	-
Vinyl_Chloride	75-01-4	51	-	-	-	-	-
Xylenes	1330-20-7	530	-	161	-	-	-

NOTES:

There are AAAQO for 48 chemical compounds. The table shows a subset of 32 compounds. The compounds that are not shown in the table include two chlorine compounds (Cl and ClO_2), ozone (O_3) and particles (e.g., TSP, $PM_{2.5}$, and metals). For gases, ESRD provides AAAQO in units of both µg/m^3 and ppb.

For this study, the MDL for VOCs is 0.5 ppb and the MDL for RSCs is 1 ppb. Odour thresholds less than the MDLs are shaded.

Table 3-2 Ontario OME Ambient Air Quality Criteria (AAQC) (ppb)

Compound	CAS #	10 min	1 hour	24 hour	Annual
.alpha.-Methylstyrene	98-83-9	-	4973	-	-
1,1,1-Trichloroethane	71-55-6	-	-	21301	-
1,1-Dichloroethane	75-34-3	-	-	41	-
1,1-Dichloroethylene	75-35-4	-	-	3	-
1,2,3-Trimethylbenzene	526-73-8	-	-	45	-
1,2,4-Trichlorobenzene	120-82-1	-	-	54	-
1,2,4-Trimethylbenzene	95-63-6	-	-	45	-
1,2-Dibromoethane	106-93-4	-	-	0.4	-
1,2-Dichlorobenzene	95-50-1	-	5108	-	-
1,2-Dichloroethane	107-06-2	-	-	-	0.1
1,2-Dichloropropane	78-87-5	-	-	519	-
1,3,5-Trimethylbenzene	108-67-8	-	-	45	-
1,3-Butadiene	106-99-0	-	-	-	0.9
1,4-Dichlorobenzene	106-46-7	-	-	16	-
1,4-Dioxane	123-91-1	-	-	972	-
1-Butanol	71-36-3	-	-	304	-
1-Decene	872-05-9	-	-	10479	-
1-Hexanol, 2-ethyl-	104-76-7	-	113	-	-
1-Octene	111-66-0	-	-	10915	-
2-Butanone	78-93-3	-	-	340	-
2-Heptanone	110-43-0	-	-	987	-
2-Hexanone, 5-methyl-	110-12-3	135	-	-	-
2-Pentanone, 4-methyl-	108-10-1	-	-	293	-
2-Propanol, 2-methyl-	75-65-0	-	-	10011	-
Acetaldehyde	75-07-0	-	-	278	-
Acetic Acid	64-19-7	-	-	1019	-
Acetone	67-64-1	-	-	5008	-
Acetophenone	98-86-2	-	238	-	-
Acetylene	74-86-2	-	-	52662	-
Acrolein	107-02-8	-	-	0.2	-
Benzene	71-43-2	-	-	-	0.14
Benzene, (1-methylethyl)-	98-82-8	-	-	82	-
Bromomethane	74-83-9	-	-	347	-
Carbon disulphide	75-15-0	-	-	106	-

Table 3-2 Ontario OME Ambient Air Quality Criteria (AAQC) (ppb)

Compound	CAS #	10 min	1 hour	24 hour	Annual
Carbon tetrachloride	56-23-5	-	-	0.4	-
Chlorobenzene	108-90-7	-	757	-	-
Chloroethane	75-00-3	-	-	2106	-
Chloroform	67-66-3	-	-	-	0.04
Chloromethane	74-87-3	-	-	156	-
Cyclohexane	110-82-7	-	-	1776	-
Decane	124-18-5	-	10331	-	-
Dimethyl disulphide	624-92-0	15	-	-	-
Dimethyl sulphide	75-18-3	12	-	-	-
Dimethylether	115-10-6	-	-	1114	-
Ethanol	64-17-5	-	10099	-	-
Ethyl Acetate	141-78-6	-	5279	-	-
Ethyl benzene	100-41-4	-	-	231	-
Ethylene	74-85-1	-	-	35	-
Formaldehyde	50-00-0	-	-	53	-
Freon-11	75-69-4	-	-	1071	-
Freon-113	76-13-1	-	-	104599	-
Freon-114	76-14-2	-	-	100088	-
Freon-12	75-71-8	-	-	101033	-
Heptane	142-82-5	-	-	2690	-
Hexane	110-54-3	-	-	711	-
Isopropyl Alcohol	67-63-0	-	-	2975	-
Methane, chlorodifluoro-	75-45-6	-	-	99506	-
Methanol	67-56-1	-	-	3056	-
Methyl Methacrylate	80-62-6	-	-	210	-
Methyl Tert Butyl Ether	1634-04-4	-	-	1945	-
Methylene chloride	75-09-2	-	-	-	13
Naphthalene	91-20-3	-	-	4	-
Octane	111-65-9	13254	-	-	-
Phenol	108-95-2	-	-	8	-
Propene	115-07-1	-	-	2329	-
Styrene	100-42-5	-	-	94	-
Tetrachloroethylene	127-18-4	-	-	53	-
Tetrahydrofuran	109-99-9	-	-	31581	-

Table 3-2 Ontario OME Ambient Air Quality Criteria (AAQC) (ppb)

Compound	CAS #	10 min	1 hour	24 hour	Annual
Toluene	108-88-3	-	-	532	-
trans-1,2-Dichloroethylene	156-60-5	-	-	26	-
Tribromomethane	75-25-2	-	-	5	-
Trichloroethylene	79-01-6	-	-	-	0.43
Vinyl chloride	75-01-4	-	-	-	0.08
NOTE: The values in the table are converted to ppb from the µg/m^3 AAQC values.					

Table 3-3 Texas TCEQ Effects Screening Levels (ESL) (ppb)

Compound	CAS #	Short Term	Long Term
.alpha.-Methylstyrene	98-83-9	52	10
.DELTA. 3 CARENE	13466-78-9	201	20
1,1,1-Trichloroethane	71-55-6	519	278
1,1,2,2-Tetrachloroethane	79-34-5	10	1
1,1,2-Trichloroethane	79-00-5	102	10
1,1-Dichloroethane	75-34-3	998	100
1,1-Dichloroethylene	75-35-4	53	25
1,2,3-Trimethylbenzene	526-73-8	255	25
1,2,4-Trichlorobenzene	120-82-1	54	5
1,2,4-Trimethylbenzene	95-63-6	143	25
1,2-Cyclohexanediol	931-17-9	53	5
1,2-Dibromoethane	106-93-4	1	0.05
1,2-Dichlorobenzene	95-50-1	100	10
1,2-Dichloroethane	107-06-2	40	1
1,2-Dichloropropane	78-87-5	100	10
1,3,5,7-Tetraazatricyclo[3.3.1.1(3,7)]de	100-97-0	30	3
1,3,5-Trimethylbenzene	108-67-8	255	25
1,3-Butadiene	106-99-0	231	4
1,3-Cyclopentadiene	542-92-7	741	74
1,3-Dichlorobenzene	541-73-1	100	10
1,3-Pentadiene, (Z)-	1574-41-0	647	65
1,4-Dichlorobenzene	106-46-7	120	5
1,4-Dioxane	123-91-1	250	25
1-Butanol	71-36-3	25	20
1-Butene	106-98-9	358	-
1-Butene, 3-methyl-	563-45-1	251	779
1-Decanol	112-30-1	6	42
1-Decanol, 2-hexyl-	2425-77-6	10	1
1-Decanol, 2-methyl-	18675-24-6	14	1
1-Decene	872-05-9	20	17
1-Heptanol	111-70-6	400	57
1-Hexanol, 2-ethyl-	104-76-7	75	30
1-Hexene	592-41-6	140	49
1-Nonanol	143-08-8	17	46

Table 3-3 Texas TCEQ Effects Screening Levels (ESL) (ppb)

Compound	CAS #	Short Term	Long Term
1-Octadecanol	112-92-5	9	18
1-Octene	111-66-0	4	74
1-Pentanol, 2-methyl-	105-30-6	5	0.48
1-Pentene	109-67-1	101	-
1-Pentene, 2,4,4-trimethyl-	107-39-1	393	39
1-Propanol, 2,2-dimethyl-	75-84-3	422	42
1-Propene, 2-methyl-, trimer	7756-94-7	262	26
1-Tridecanol	112-70-9	6	1
2,2,4-Trimethylpentane	540-84-1	671	75
2,2-Dimethylbutane	75-83-2	995	100
2,3,4-Trimethylpentane	565-75-3	751	75
2,3-Dimethylbutane	79-29-8	421	100
2,3-Dimethylpentane	565-59-3	856	86
2,4-Dimethylpentane	108-08-7	856	86
2,5-dimethyl Thiophene	638-02-8	22	2
2-.BETA.-PINENE	127-91-3	32	63
2-Butanol, 2-methyl-	75-85-4	89	56
2-Butanone	78-93-3	441	883
2-Butanone, 3-methyl-	563-80-4	500	200
2-Butenal	4170-30-3	3	0.31
2-Butene, 2-methyl-	513-35-9	2620	-
2-ethyl butanol	97-95-0	70	72
2-ethyl Thiophene	872-55-9	22	2
2-Heptanone	110-43-0	7	180
2-Hexanone, 5-methyl-	110-12-3	12	10
2-Hexene	592-43-8	140	49
2-Hexene, (Z)-	7688-21-3	140	49
2-HEXENE, 5,5-DIMETHYL-	39761-61-0	218	22
2-methyl Thiophene	554-14-3	25	2
2-Methyl-1-pentene	763-29-1	140	49
2-Methylheptane	592-27-8	109	75
2-Methylhexane	591-76-4	421	75
2-Methylpentane	107-83-5	995	100
2-Pentanone	107-87-9	28	151

Table 3-3 Texas TCEQ Effects Screening Levels (ESL) (ppb)

Compound	CAS #	Short Term	Long Term
2-Pentanone, 4-methyl-	108-10-1	171	20
2-Pentenal, 2-methyl-	623-36-9	92	9
2-Pentene, 2,4,4-trimethyl-	107-40-4	393	39
2-Propanol, 2-methyl-	75-65-0	205	20
2-Propenoic acid, 2-ethylhexyl ester (CA	103-11-7	47	5
3-Buten-2-one	78-94-4	2	0.21
3-Heptanone	106-35-4	101	10
3-methyl Thiophene	616-44-4	25	2
3-Methylheptane	589-81-1	751	75
3-Methylhexane	589-34-4	751	75
3-Methylpentane	96-14-0	995	100
3-Pentanol	584-02-1	289	56
4,7-Methano-1H-indene, 3a,4,7,7a-tetrahy	77-73-6	11	5
4-Cyanocyclohexene	100-45-8	13	1
4-Methyl-1-pentene	691-37-2	291	29
Acetaldehyde	75-07-0	8	25
Acetaldehyde, chloro-	107-20-0	9	1
Acetic Acid	64-19-7	6	10
Acetone	67-64-1	2487	249
Acetophenone	98-86-2	100	10
Acetylene	74-86-2	25014	2501
Acrolein	107-02-8	1	0.07
Allyl sulphide	592-88-1	0.21	3
alpha Pinene	80-56-8	18	63
Benzaldehyde	100-52-7	21	2
Benzene	71-43-2	53	1
Benzene, (1-methylethyl)-	98-82-8	47	51
Benzene, 1,2,3,5-tetramethyl-	527-53-7	228	23
Benzene, 1,2,4,5-tetramethyl-	95-93-2	228	23
Benzene, 1-chloro-4-(trifluoromethyl)-	98-56-6	249	25
Benzene, 1-ethyl-2,3-dimethyl-	933-98-2	467	28
Benzene, 1-methyl-4-(1-methylethyl)- (CA	99-87-6	502	50
Benzene, 2-ethyl-1,3-dimethyl-	2870-04-4	467	47
Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	467	47

Table 3-3 Texas TCEQ Effects Screening Levels (ESL) (ppb)

Compound	CAS #	Short Term	Long Term
Benzenemethanol, .alpha.,.alpha.-dimethy	617-94-7	108	11
Benzyl Chloride	100-44-7	10	1
Bicyclo[2.2.1]hept-2-ene, 5-ethenyl-	3048-64-4	88	9
Bromodichloromethane	75-27-4	106	11
Bromomethane	74-83-9	31	3
Butanal	123-72-8	5	25
Butanal, 3-methyl-	590-86-3	28	51
Butane	106-97-8	27822	3035
Butane, 1-ethoxy-	628-81-9	561	56
Butane, 2,2,3-trimethyl-	464-06-2	856	86
Butyl mercaptan	109-79-5	0.002	0.45
Camphene	79-92-5	9	1
Camphor	76-22-2	3	0.32
Carbon disulphide	75-15-0	10	1
Carbon tetrachloride	56-23-5	21	2
Carbonyl sulfide	463-58-1	55	1
Chlorobenzene	108-90-7	100	10
Chloroethane	75-00-3	188	19
Chloroform	67-66-3	21	2
Chloromethane	74-87-3	504	50
cis-1,3-Dichloropropylene	542-75-6	10	1
cis-2-Butene	590-18-1	2096	-
cis-2-Pentene	627-20-3	2620	-
Cyclododecane	294-62-2	757	76
Cycloheptane	291-64-5	848	85
Cyclohexane	110-82-7	990	99
Cyclohexane, 1-methyl-2-propyl-	4291-79-6	611	61
Cyclohexane, ethyl-	1678-91-7	4082	408
Cyclohexane, isocyanato-	3173-53-3	0.14	0.02
Cyclohexane, propyl-	1678-92-8	679	68
Cyclohexanone	108-94-1	120	20
Cyclohexanone, 3,3,5-trimethyl-	873-94-9	175	17
Cyclohexene	110-83-8	179	298
Cyclooctane	292-64-8	764	76

Table 3-3 Texas TCEQ Effects Screening Levels (ESL) (ppb)

Compound	CAS #	Short Term	Long Term
Cyclopentane	287-92-3	1188	119
Cyclopentane, 1,1,2-trimethyl-	4259-00-1	764	76
Cyclopentane, 1,1,3-trimethyl-	4516-69-2	764	76
Cyclopentane, 1,2-dimethyl-, trans-	822-50-4	873	87
Cyclopentane, 1,3-dimethyl-, cis-	2532-58-3	873	87
Cyclopentane, 1,3-dimethyl-, trans-	1759-58-6	873	87
Cyclopentane, butyl-	2040-95-1	679	68
Cyclopentane, ethyl-	1640-89-7	4067	407
Cyclopentane, propyl-	2040-96-2	764	76
Cyclopentene	142-29-0	2912	291
Cyclopentene, 4-methyl-	1759-81-5	2415	242
Decane	124-18-5	622	172
Dibromochloromethane	124-48-1	83	8
Diethyl disulfide	110-81-6	2	3
Dimethyl disulphide	624-92-0	5	4
Dimethyl sulphide	75-18-3	3	10
Dimethylether	115-10-6	10084	1008
Disulfide, dipropyl	629-19-6	15	2
dl-Limonene	138-86-3	38	20
Dodecane	112-40-3	111	50
Dodecane, 2,6,10-trimethyl-	3891-98-3	404	40
Ethanamine, N-ethyl-N-nitroso-	55-18-5	0.24	0.02
Ethanol	64-17-5	1015	999
Ethene, 1,1-difluoro-	75-38-7	10	1
Ethyl Acetate	141-78-6	389	400
Ethyl benzene	100-41-4	171	131
Ethyl mercaptan	75-08-1	0.32	1
Ethyl methyl sulphide	624-89-5	5	5
Ethyl sulphide	352-93-2	6	4
Ethylacetylene	107-00-6	7426	743
Ethylene	74-85-1	1223	30
Formaldehyde	50-00-0	12	3
Freon-11	75-69-4	4997	500
Freon-113	76-13-1	4968	497

Table 3-3 Texas TCEQ Effects Screening Levels (ESL) (ppb)

Compound	CAS #	Short Term	Long Term
Freon-114	76-14-2	10009	1001
Freon-12	75-71-8	10103	1010
Furan	110-00-9	101	10
Furan, 2,3-dihydro-	1191-99-7	349	35
Heptanal	111-71-7	51	9
Heptane	142-82-5	672	86
Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	503	50
Heptane, 3-methylene-	1632-16-2	218	22
Heptane, 4-methyl-	589-53-7	751	75
Heptyl mercaptan	1639-09-4	0.19	1
Hexachlorobutadiene	87-68-3	0.19	0.02
Hexadecane	544-76-3	379	38
Hexanal	66-25-1	20	200
Hexane	110-54-3	1507	57
Hexane, 3-ethyl-	619-99-8	751	75
Hexyl mercaptan	111-31-9	6	1
Indene	95-13-6	15	5
ISOAMYLALCOHOL	123-51-3	42	20
Isobutane	75-28-5	9696	3035
Isobutyl mercaptan	513-44-0	1	0.38
Isobutylene	115-11-7	1310	13971
Isopentane	78-78-4	1290	2411
Isoprene	78-79-5	22	2
Isopropyl Alcohol	67-63-0	2005	200
Isopropyl mercaptan	75-33-2	0.26	0.03
m,p-Xylene	108-38-3	79	42
m-Diethylbenzene	141-93-5	69	46
Methane, chlorodifluoro-	75-45-6	5117	512
Methane, nitro-	75-52-5	200	20
Methane, trifluoro-	75-46-7	4995	499
Methanol	67-56-1	2002	200
Methyl Butyl Ketone	591-78-6	10	1
Methyl ethyl disulphide	20333-39-5	14	3
Methyl mercaptan	74-93-1	1	1

Table 3-3 Texas TCEQ Effects Screening Levels (ESL) (ppb)

Compound	CAS #	Short Term	Long Term
Methyl Methacrylate	80-62-6	210	51
Methyl Tert Butyl Ether	1634-04-4	125	50
Methylcyclohexane	108-87-2	150	402
Methylcyclopentane	96-37-7	757	76
Methylene chloride	75-09-2	1048	102
m-Ethyltoluene	620-14-4	18	25
Naphthalene	91-20-3	38	10
Naphthalene, 1-methyl-	90-12-0	5	1
Naphthalene, 2-methyl-	91-57-6	5	1
Nonanal	124-19-6	258	26
Nonane	111-84-2	2006	201
n-Propylbenzene	103-65-1	47	51
Octane	111-65-9	751	75
Octane, 4-methyl-	2216-34-4	669	67
Octyl mercaptan	111-88-6	5	1
o-Ethyltoluene	611-14-3	73	25
o-Xylene	95-47-6	381	42
p-Diethylbenzene	105-05-5	69	46
Pentane	109-66-0	1392	2411
Pentane, 2,2-dimethyl-	590-35-2	856	86
Pentane, 3-ethyl-2-methyl-	609-26-7	751	75
Pentyl mercaptan	110-66-7	0.02	0.47
p-Ethyltoluene	622-96-8	8	25
Phenol	108-95-2	11	5
Propane, 1-chloro-	540-54-5	9404	940
Propanenitrile, 2-methyl-	78-82-0	78	8
Propyl mercaptan	107-03-9	1	1
Propyne	74-99-7	10025	1002
sec-Butyl mercaptan	513-53-1	0.03	0.49
Styrene	100-42-5	26	33
tert-Butyl mercaptan	75-66-1	0.03	0.49
Tetrachloroethylene	127-18-4	295	4
Tetradecane	629-59-4	432	43
Tetrafluoroethane	811-97-2	9993	999

Table 3-3 Texas TCEQ Effects Screening Levels (ESL) (ppb)

Compound	CAS #	Short Term	Long Term
Tetrahydro thiophene	110-01-0	1	3
Tetrahydrofuran	109-99-9	71	51
Thiophene	110-02-1	1	3
Toluene	108-88-3	922	319
trans-1,2-Dichloroethylene	156-60-5	1999	200
trans-2-Butene	624-64-6	2096	-
trans-2-Hexene	4050-45-7	140	49
trans-2-Pentene	646-04-8	2620	-
Tribromomethane	75-25-2	5	0.49
Trichloroethylene	79-01-6	101	10
Tridecane	629-50-5	465	47
Undecane	1120-21-4	549	55
Vinyl Acetate	108-05-4	43	4
Vinyl chloride	75-01-4	7762	0.47

Note:
The values in the table are converted to ppb from the µg/m^3 ESL values.
For this study, the MDL for VOCs is 0.5 ppb and the MDL for RSCs is 1 ppb. Odour thresholds less than the MDLs are shaded.

Table 3-4 WHO Standards (ppb)

	CAS #	10 min	30 min	1 h	8 h	24 h	1 week	Annual
Carbon disulphide	75-15-0	-	-	-	-	32	-	-
Carbon Monoxide	630-08-0	90,000	50,000	25,000	10,000	-	-	-
1,2-Dichloroethane	107-06-2	-	-	-	-	177	-	-
Dichloroethane	1300-21-6	-	-	-	-	741	111	-
Formaldehyde	50-00-0	-	81	-	-	-	-	-
Styrene	100-42-5	-	16	-	-	-	-	-
Tetrachloroethylene	127-18-4	-	-	-	-	-	-	100
Toluene	108-88-3	-	265	-	-	-	69	-
Hydrogen sulphide	7783-06-4	-	5	-	-	108	-	-
Nitrogen dioxide	10102-44-0	-	-	106	-	-	-	21
Sulphur dioxide	7446-09-5	191	-	-	-	8	-	-

NOTE:
The values in the table are converted to ppb from the µg/m^3 WHO values.

Table 3-5 Target PAH compounds and associated benchmarks (ng/m³)

PAH Compound	CAS #	Short-term	Long-term
napthalene	91-20-3	200000	50000
acenaphthylene	208-96-8	1000	100
acenaphthene	83-32-9	1000	100
fluorene	86-73-7	10000	1000
2-me-fluorene	1430-97-3	-	-
phehanthrene	85-01-8	500	50
anthracene	120-12-7	500	50
fluoranthene	206-44-0	500	50
pyrene	129-00-0	500	50
retene	483-65-8	-	-
benzo[a]fluorene	238-84-6	-	-
benzo[b]fluorene	243-17-4	500	50
1-me-pyrene	-	-	-
benzo[g,h,i]fluoranthene	203-12-3	-	-
benz[a]anthracene	56-55-3	500	50
triphenylene	217-59-4	-	-
chrysene	218-01-9	500	50
7-me-benz[a]anthracene	-	-	-
benzo[b]fluoranthene	205-99-2	500	50
benzo[k]fluoranthene	207-08-9	500	50
benzo[e]pyrene	192-97-2	500	50
benzo[a]pyrene	50-32-8	30	0.1
perylene	198-55-0	500	50
3-me-cholanthrene	56-49-5	20	2
indeno[1,2,3-cd]fluoranthene	193-43-1	-	-
indeno[1,2,3-cd]pyrene	193-39-5	500	50
dibenz[a,h]anthracene	53-70-3	500	50
benzo[b]chrysene	214-17-5	-	-
benzo[g,h,i]perylene	191-24-2	500	50
anthanthrene	191-26-4	-	-

NOTE:
The values for the short-term and long-term benchmarks are from TECQ, except the long term criteria for benzo[a]pyrene that is from OME.

Table 3-6 Odour Thresholds (From Nagata 2003)

Group	Substance	CAS #	Odour Threshold	
			(ppm)	(ppb)
Aldehydes	Formaldehyde	50-00-0	0.5	500
	Acetaldehyde	75-07-0	0.0015	1.5
	Propionaldehyde	123-38-6	0.001	1
	n-Butylaldehyde	123-72-8	0.00067	0.67
	Isobutylaldehyde	78-84-2	0.00035	0.35
	n-Valeraldehyde	110-62-3	0.00041	0.41
	Isovaleraldehyde	590-86-3	0.0001	0.1
	n-Hexylaldehyde	66-25-1	0.00028	0.28
	n-Heptylaldehyde	111-71-7	0.00018	0.18
	n-Octylaldehyde	124-13-0	0.00001	0.01
	n-Nonylaldehyde	124-19-6	0.00034	0.34
	n-Decylaldehyde	112-54-9	0.0004	0.4
	Acrolein	107-02-8	0.0036	3.6
	Methacrolein	78-85-3	0.0085	8.5
	Crotonaldehyde	123-73-9	0.023	23
Alcohols	Methanol	67-56-1	33	33000
	Ethanol	64-17-5	0.52	520
	n-Propanol	71-23-8	0.094	94
	Isopropanol	67-63-0	26	26000
	n-Butanol	71-36-3	0.038	38
	Isobutanol	78-83-1	0.011	11
	sec.Butanol	78-92-2	0.22	220
	tert.Butanol	75-65-0	4.5	4500
	n-Pentanol	71-41-0	0.1	100
	Isopentanol	123-51-3	0.0017	1.7
	sec.Pentanol	6032-29-7	0.29	290
	tert.Pentanol	75-85-4	0.088	88
	n-Hexanol	111-27-3	0.006	6
	n-Heptanol	111-70-6	0.0048	4.8
	n-Octanol	111-87-5	0.0027	2.7
	Isooctanol	70955-04-3	0.0093	9.3
	n-Nonanol	28473-21-4	0.0009	0.9
	n-Decanol	112-30-1	0.00077	0.77

Table 3-6 Odour Thresholds (From Nagata 2003)

Group	Substance	CAS #	Odour Threshold	
			(ppm)	(ppb)
Alcohols (cont'd)	2-Ethoxyethanol	110-80-5	0.58	580
	2-n-Buthoxyethanol	111-76-2	0.043	43
	1-Butoxy-2-propanol	5131-66-8	0.16	160
Phenols	Phenol	108-95-2	0.0056	5.6
	o-Cresol	95-48-7	0.00028	0.28
	m-Cresol	108-39-4	0.0001	0.1
	p-Cresol	106-44-5	0.000054	0.054
	Geosmin	16423-19-1	0.0000065	0.0065
Organic acids	Acetic acid	64-19-7	0.006	6
	Propionic acid	79-09-4	0.0057	5.7
	n-Butyric acid	107-92-6	0.00019	0.19
	Isobutyric acid	79-31-2	0.0015	1.5
	n-Valeric acid	109-52-4	0.000037	0.037
	Isovaleric acid	503-74-2	0.000078	0.078
	n-Hexanoic acid	142-62-1	0.0006	0.6
	Isohexanoic acid	646-07-1	0.0004	0.4
Sulphur Compounds	Sulfur dioxide	7446-09-5	0.87	870
	Carbonyl sulfide	463-58-1	0.055	55
	Hydrogen sulfide	7783-06-4	0.00041	0.41
	Dimethyl sulfide	75-18-3	0.003	3
	Methyl allyl sulfide	10152-76-8	0.00014	0.14
	Diethyl sulfide	352-93-2	0.000033	0.033
	Allyl sulfide	592-88-1	0.00022	0.22
	Carbon disulfide	75-15-0	0.21	210
	Dimethyl disulfide	624-92-0	0.0022	2.2
	Diethyl disulfide	110-81-6	0.002	2
	Diallyl disulfide	2179-57-9	0.00022	0.22
	Methyl mercaptan	74-93-1	0.00007	0.07
	Ethyl mercaptan	75-08-1	0.0000087	0.0087
	n-Propyl mercaptan	107-03-9	0.000013	0.013
	Isopropyl mercaptan	75-33-2	0.000006	0.006
	n-Butyl mercaptan	109-79-5	0.0000028	0.0028
	Crotonaldehyde	123-73-9	0.023	23

Table 3-6 Odour Thresholds (From Nagata 2003)

Group	Substance	CAS #	Odour Threshold	
			(ppm)	(ppb)
Sulphur Compounds (cont'd)	sec. Butyl mercaptan	513-53-1	0.00003	0.03
	tert. Butyl mercaptan	75-66-1	0.000029	0.029
	n-Amyl mercaptan	110-66-7	0.00000078	0.00078
	Isoamyl mercaptan	541-31-1	0.00000077	0.00077
	n-Hexyl mercaptan	111-31-9	0.000015	0.015
	Thiophene	110-02-1	0.00056	0.56
	Tetrahydrothiophene	110-01-0	0.00062	0.62
Inorganics	Nitrogen dioxide	10102-44-0	0.12	120
	Ammonia	7664-41-7	1.5	1500
Amines	Methylamine	74-89-5	0.035	35
	Ethylamine	75-04-7	0.046	46
	n-Propylamine	107-10-8	0.061	61
	Isopropylamine	75-31-0	0.025	25
	n-Butylamine	109-73-9	0.17	170
	Isobutylamine	78-81-9	0.0015	1.5
	sec.Butylamine	13952-84-6	0.17	170
	tert.Butylamine	75-64-9	0.17	170
	Dimethylamine	124-40-3	0.033	33
	Diethylamine	109-89-7	0.048	48
	Trimethylamine	75-50-3	0.000032	0.032
	Triethylamine	121-44-8	0.0054	5.4
Nitriles	Acetonitrile	75-05-8	13	13000
	Acrylonitrile	107-13-1	8.8	8800
	Methacrylonitrile	126-98-7	3	3000
	Pyridine	110-86-1	0.063	63
	Indole	120-72-9	0.0003	0.3
	Skatole	83-34-1	0.0000056	0.0056
	Ethyl-o-toluidine	94-68-8	0.026	26

Table 3-6 Odour Thresholds (From Nagata 2003)

Group	Substance	CAS #	Odour Threshold	
			(ppm)	(ppb)
Aliphatics	Propane	74-98-6	1500	1500000
	n-Butane	106-97-8	1200	1200000
	n-Pentane	109-66-0	1.4	1400
	Isopentane	78-78-4	1.3	1300
	n-hexane	110-54-3	1.5	1500
	2-Methylpentane	107-83-5	7	7000
	3-Methylpentane	96-14-0	8.9	8900
	2,2-Dimethylbutane	75-83-2	20	20000
	2,3-Dimethylbutane	79-29-8	0.42	420
	n-Heptane	142-82-5	0.67	670
	2-Methylhexane	591-76-4	0.42	420
	3-Methylhexane	589-34-4	0.84	840
	3-Ethylpentane	617-78-7	0.37	370
	2,2-Dimethylpentane	75-83-2	38	38000
	2,3-Dimethylpentane	565-59-3	4.5	4500
	2,4-Dimethylpentane	108-08-7	0.94	940
	n-Octane	111-65-9	1.7	1700
	2-Methylheptane	592-27-8	0.11	110
	3-Methylheptane	589-81-1	1.5	1500
	4-Methylheptane	589-53-7	1.7	1700
	2,2,4-Trimethylpentane	540-84-1	0.67	670
	n-Nonane	111-84-2	2.2	2200
	2,2,5-Trimethylhexane	3522-94-9	0.9	900
	n-Undecane	1120-21-4	0.87	870
	n-Decane	124-18-5	0.62	620
	n-Dodecane	112-40-3	0.11	110
	Propylene	115-07-1	13	13000
	1-Butene	106-98-9	0.36	360
	Isobutene	115-11-7	10	10000
	1-Pentene	109-67-1	0.1	100
	1-Hexene	592-41-6	0.14	140
	1-Heptene	592-76-7	0.37	370
	1-Octene	111-66-0	0.001	1

Table 3-6 Odour Thresholds (From Nagata 2003)

Group	Substance	CAS #	Odour Threshold	
			(ppm)	(ppb)
Aliphatics (cont'd)	1-Nonene	124-11-8	0.00054	0.54
	1,3-Butadiene	106-99-0	0.23	230
	Isoprene	78-79-5	0.048	48
Aromatics	Benzene	71-43-2	2.7	2700
	Toluene	108-88-3	0.33	330
	Styrene	100-42-5	0.035	35
	Ethylbenzene	100-41-4	0.17	170
	o-Xylene	95-47-6	0.38	380
	m-Xylene	108-38-3	0.041	41
	p-Xylene	106-42-3	0.058	58
	n-Propylbenzene	103-65-1	0.0038	3.8
	Isopropylbenzene	98-82-8	0.0084	8.4
	1,2,4-Trimethylbenzene	95-63-6	0.12	120
	1,3,5-Trimethylbenzene	108-67-8	0.17	170
	o-Ethyltoluene	611-14-3	0.074	74
	m-Ethyltoluene	620-14-4	0.018	18
	p-Ethyltoluene	622-96-8	0.0083	8.3
	o-Diethylbenzene	68608-82-2	0.0094	9.4
	m-Diethylbenzene	141-93-5	0.07	70
	p-Diethylbenzene	105-05-5	0.00039	0.39
	n-Butylbenzene	104-51-8	0.0085	8.5
Aromatics	1,2,3,4-Tetramethylbenzene	488-23-3	0.011	11
	1,2,3,4-Tetrahydronaphthalene	119-64-2	0.0093	9.3
PAC	α-Pinene	80-56-8	0.018	18
	β-Pinene	127-91-3	0.033	33
	Limonene	138-86-3	0.038	38
	Methylcyclopentane	96-37-7	1.7	1700
	Cyclohexane	110-82-7	2.5	2500
	Methylcyclohexane	108-87-2	0.15	150

Table 3-6 Odour Thresholds (From Nagata 2003)

Group	Substance	CAS #	Odour Threshold	
			(ppm)	(ppb)
Formates	Methyl formate	107-31-3	130	130000
	Ethyl formate	109-94-4	2.7	2700
	n-Propyl formate	110-74-7	0.96	960
	Isopropyl formate	625-55-8	0.29	290
	n-Butyl formate	592-84-7	0.087	87
	Isobutyl formate	542-55-2	0.49	490
Acetates	Methyl acetate	79-20-9	1.7	1700
	Ethyl acetate	141-78-6	0.87	870
	n-Propyl acetate	109-60-4	0.24	240
	Isopropyl acetate	108-21-4	0.16	160
	n-Butyl acetate	123-86-4	0.016	16
	Isobutyl acetate	110-19-0	0.008	8
	sec.Butyl acetate	105-46-4	0.0024	2.4
	tert.Butyl acetate	540-88-5	0.071	71
	n-Hexyl acetate	142-92-7	0.0018	1.8
Propionates	Methyl propionate	554-12-1	0.098	98
	Ethyl propionate	105-37-3	0.007	7
	n-Propyl propionate	106-36-5	0.058	58
	Isopropyl propionate	637-78-5	0.0041	4.1
	n-Butyl propionate	590-01-2	0.036	36
	Isobutyl propionate	105-37-3	0.02	20
Butyrates	Methyl n-butyrate	623-42-7	0.0071	7.1
	Methyl isobutyrate	547-63-7	0.0019	1.9
	Ethyl n-butyrate	105-54-4	0.00004	0.04
	Ethyl isobutyrate	97-62-1	0.000022	0.022
	n-Propyl n-butyrate	105-66-8	0.011	11
	Isopropyl n-butyrate	638-11-9	0.0062	6.2
	n-propyl isobutyrate	644-49-5	0.002	2
	Isopropyl isobutyrate	617-50-5	0.035	35
	n-Butyl n-butyrate	109-21-7	0.0048	4.8
	Isobutyl n-butyrate	539-90-2	0.0016	1.6
	n-Butyl isobutyrate	97-87-0	0.022	22
	Isobutyl isobutyrate	97-85-8	0.075	75

Table 3-6 Odour Thresholds (From Nagata 2003)

Group	Substance	CAS #	Odour Threshold	
			(ppm)	(ppb)
Valerates	Methyl n-valerate	624-24-8	0.0022	2.2
	Methyl isovalerate	556-24-1	0.0022	2.2
	Ethyl n-valerate	539-82-2	0.00011	0.11
	Ethyl isovalerate	141-78-6	0.000013	0.013
	n-Propyl n-valerate	141-06-0	0.0033	3.3
	n-Propyl isovalerate	557-00-6	0.000056	0.056
	n-Butyl isovalerate	109-19-3	0.012	12
	Isobutyl isovalerate	589-59-3	0.0052	5.2
Acrylates	Methyl acrylate	96-33-3	0.0035	3.5
	Ethyl acrylate	140-88-5	0.00026	0.26
	n-Butyl acrylate	141-32-2	0.00055	0.55
	Isobutyl acrylate	106-63-8	0.0009	0.9
	Methyl methacrylate	80-62-6	0.21	210
	2-Ethoxyethyl acetate	111-15-9	0.049	49
Ketones	Acetone	67-64-1	42	42000
	Methyl ethyl ketone	78-93-3	0.44	440
	Methyl n-propyl ketone	107-87-9	0.028	28
	Methyl isopropyl ketone	563-80-4	0.5	500
	Methyl n-butyl ketone	591-78-6	0.024	24
	Methyl isobutyl ketone	108-10-1	0.17	170
	Methyl sec.butyl ketone	565-61-7	0.024	24
	Methyl tert.butyl ketone	75-97-8	0.043	43
	Methyl n-amyl ketone	110-43-0	0.0068	6.8
	β-Methyl isoamyl ketone	NA	0.0021	2.1
	Diacetyl	431-03-8	0.00005	0.05
Other	Ozone	10028-15-6	0.0032	3.2
	Furan	110-00-9	9.9	9900
	2,5-Dihydrofuran	1708-29-8	0.093	93

Table 3-6 Odour Thresholds (From Nagata 2003)

Group	Substance	CAS #	Odour Threshold	
			(ppm)	(ppb)
Halogenated	Chlorine	7782-50-5	0.049	49
	Dichloromethane	75-09-2	160	160000
	Chloroform	67-66-3	3.8	3800
	Trichloroethylene	79-01-6	3.9	3900
	Carbon tetrachloride	56-23-5	4.6	4600
	Tetrachloroethylene	127-18-4	0.77	770

NOTES:
Nagata identified odour thresholds for 223 substances.
Not all are applicable to the Three Creeks review but are included for completeness.
For this study, the MDL for VOCs is 0.5 ppb and the MDL for RSCs is 1 ppb. Odour thresholds less than the MDLs are shaded.

Table 3-7 Comparison of Odour Thresholds for selected compounds

Substance	CAS #	Information Source	Odour Threshold (ppb)
Acetaldehyde	75-07-0	**Nagata (2003)**	**1.5**
		Schiffman (2001)	186
		AIHA (1989,1997 reprint)	2.8
Hexanal	66-25-1	**Nagata (2003)**	**0.28**
		Schiffman (2001)	13.8
		Cometto-Muniz and Abraham(2010) 50% of panel	0.33
		Cometto-Muniz and Abraham(2010) most sensitive subject	0.060
		Cometto-Muniz and Abraham(2010) least sensitive subject	3.2
Nonanal	124-19-6	**Nagata (2003)**	**0.34**
		Schiffman (2001)	2.24
		Cometto-Muniz and Abraham(2010) 50% of panel	0.53
		Cometto-Muniz and Abraham(2010) most sensitive subject	0.17
		Cometto-Muniz and Abraham(2010) least sensitive subject	2.6
Hydrogen sulphide	7783-06-4	**Nagata (2003)**	**0.41**
		Schiffman (2001)	17.8
		AIHA (1989,1997 reprint)	1.0
		Wilby (1969)	4.1
Methyl mercaptan	74-93-1	**Nagata (2003)**	**0.07**
		Schiffman (2001)	1.05
		AIHA (1989,1997 reprint)	0.002
		Wilby (1969)	0.8
Ethyl mercaptan	75-08-1	**Nagata (2003)**	**0.0087**
		Schiffman (2001)	1.06
		AIHA (1989,1997 reprint)	0.098
		Wilby (1969)	0.32

4.0 Meteorological Monitoring

Meteorology strongly influences the transport and dispersion of emissions from an emission source (e.g., a stack or a vent) to the receptor (e.g., a nearby residence). The main meteorological parameters of importance are wind direction that determines the transport direction; and wind speed and atmospheric turbulence that determine the dispersion. Atmospheric turbulence is determined by vertical temperature gradients and by surface roughness. Wind and turbulence levels vary temporally and spatially. Temporal trends are associated with a wide range of time scales ranging that include hourly (e.g., associated with diurnal solar heating and cooling trends), several-day (e.g., the passage of larger scale weather systems over the region), seasonal (e.g., associated with seasonal solar heating and cooling trends) and year-to-year trends. Spatial variations are associated with the surface cover influences on air flow (e.g., tree canopies, buildings, and terrain features).

While detailed turbulence information is required by air quality simulation models, the examination of wind speed and wind direction is sufficient to examine relationships between emission sources and ambient concentration measurements. There are three continuous ambient air quality monitoring stations operating in the Three Creeks area that measure wind and temperature. Given the importance of meteorology, the data from the three stations are examined to determine spatial and temporal trends.

Figure 4-1 shows the locations of these stations, and they are as follows:

- The **Peace River Complex** monitoring station is operated by Shell as part of the associated Environmental Protection and Enhancement Act (EPEA) approval. The station is located about 0.9 km eastnortheast (ENE) of the PRC central plant facility. The station coordinates are 56° 23′ 9″ N and 116° 46′ 35″ W (513802 UTM mE and 6249039 UTM mN)(identified as **PRC** on the figure).

  Hourly data were provided by Shell for the period January 1 2008 to August 31 2013. AGAT was the contractor for the period January 1 2008 to April 30 2013, and MAXXAM was the contractor for the period May 1 2013 to August 31 2013.

- The **Highway 986** monitoring station is managed by the Three Creeks Air Monitoring Subcommittee and was installed in response to community concerns about air emissions. The station was installed on Mar 18 2010 at 56° 22′ 11.78″ N and 117° 00′ 13.97″ W (499764 UTM mE and 6247262 UTM mN) (identified as **986a** on the figure). On July 6 2011, the station was moved to 56° 22′ 33.7″ N and 116° 56′ 26.2″ W (503680 UTM mE and 6247933 UTM mN) (identified as **986b** on the figure). The new location is approximately 4.55 km to the eastnortheast (ENE) of the old location.

  Hourly data were provided for the period March 18 2010 to August 31 2013. MAXXAM was the contractor for this period.

- The **Highway 842** monitoring station is also managed by the Three Creeks Air Monitoring Subcommittee and was also installed in response to community concerns about air emissions. The station was installed on April 1 2012 at 56° 16′ 30.4″ N and 116° 58′ 51.0″ W (501190 UTM mE and 6236700 UTM mN) (identified as **842a** on the figure). On November 7, 2012, the station was moved to 56° 16′ 26.7″ N and 116° 58′ 53.3″ W (501148 UTM mE and 6236596 UTM mN) (identified as **842b** on the figure). The new location is approximately 112 m to the south (S) of the old location.

  Hourly data were provided for the period April 1 2012 to August 31 2013. AGAT was the operator for the period April 1 2012 to October 31, 2012, and MAXXAM was the operator for the period November 8 2012 to August 31 2013.

All the above UTM coordinates provided are referenced to Zone 11 (NAD 83). The wind speed and wind direction sensors (i.e., anemometer and vane) are typically mounted on a minimum 10 m mast to reduce interference from nearby obstructions. The Alberta Air Monitoring Directive (AMD) provides additional siting criteria to reduce interferences from nearby obstructions (e.g., minimum distances to nearby tree canopies and buildings). The presence of nearby obstructions was one of the reasons that the Highway 986 and 842 stations were moved from their respective original locations.

All three stations measure wind speed, wind direction, and ambient temperature on a continuous basis as hourly averages. The continuous data were provided in multiple files that were organized into a consistent format with one record for each hour.

4.1 WIND ROSES

Wind direction and wind speed are often summarized in the form of a wind rose, which is a stacked bar chart in a polar format. The direction of the bar indicates the direction the wind is blowing from based on a 16 point compass (N, NNE, NE, ENE, E, etc.). The length of the bar indicates the frequency (%) the wind is blowing from the associated direction. Stacked bars represent different wind speed classes. For this assessment, wind speed classes in 5 km/h increments are selected. A wind rose is therefore a joint frequency distribution plot of wind speed and wind direction.

4.1.1 Time of Day Trends

Wind roses are provided for all hours of the day, and for day and night periods. The day period focuses on the period from noon to 6 PM (12 to 18), which is associated with increased turbulence due to solar heating. The night period focuses on the period from midnight to 8 AM (0 to 8), which is associated with suppressed turbulence due to radiative cooling.

4.1.1.1 PRC Site

Figure 4-2 shows the wind roses for the PRC site. Based on **day** hours, the most frequent winds are from the WSW and SW sector. Based on **night** hours, the most frequent winds are from the S and

SSW sector, with frequent winds also occurring from the E sector. The wind rose based on all hours is a composite of the day and night trends. Winds at the PRC site therefore have differing time of day trends.

4.1.1.2 Highway 986 Sites

Wind roses are provided separately for the 986a and 986b sites. These two sites are separated by approximately 4.55 km. The 986a site was closer to nearby trees and buildings that could influence its ability to represent regional air flow.

Figure 4-3 shows the wind roses for the 986a site. Based on **day** hours, the most frequent winds are from the WSW sector. Based on **night** hours, the most frequent winds are from the ENE to E sector. The wind rose based on all hours is a composite of the day and night trends. Winds at the 986a site therefore have differing time of day trends.

Figure 4-4 shows the wind roses for the 986b site. Based on **day** hours, the most frequent winds are from all westerly sectors. Based on **night** hours, the most frequent winds are from the ESE to SE sector. Winds at the 986b site therefore have differing time of day trends.

The wind direction frequencies at the 986b site are more uniformly distributed than those at the 986a site. This is likely due to the 986b site being located in a more open area.

4.1.1.3 Highway 842 Sites

Wind roses are provided separately for the 842a and 842b sites. These two sites are separated by approximately 110 m. The 842a site is closer to a nearby tree canopy that could influence its ability to represent regional air flow.

Figure 4-5 shows the wind roses for the 842a site. Based on **day** hours, the most frequent winds are from the WSW sector. Based on **night** hours, the most frequent winds are from the ENE and WSW sectors. The wind rose for all hours is a composite of the day and night trends. Winds at the 842a site therefore have differing time of day trends.

Figure 4-6 shows the wind roses for the 842b site. Based on the **day** hours, the most frequent winds are from the WSW sector. Based on the **night** hours, the most frequent winds are from the E sector. Winds at the 842b site therefore have differing time of day trends.

The day time winds at the 842a and 842b sites are similar. Although the night wind trends are also similar, the most frequent wind sectors tend to differ by one compass point.

4.1.2 Seasonal Trends

Wind roses are provided on a seasonal basis: spring being March, April, and May; summer being June, July, and August; fall being September, October, and November; and winter being

December, January, and February. The provided wind roses are presented for all hours of the day.

4.1.2.1 PRC Site

Figure 4-7 shows the wind roses for the PRC site. Spring, summer and fall show similar trends. During the winter, there are more frequent winds from the SSW sector.

4.1.2.2 Highway 986 Sites

Figures 4-8 and 4-9 show the wind roses for the 986a and 986b sites. The frequent ENE and E sectors at the 986a site are consistently shifted to the ESE and SE sectors at the 986b site for all seasons. There are much less frequent NW sector winds at site 986a that at site 986b during the fall. Similarly, SE winds at the 986a site are much less frequent than at the 986b site during the winter.

4.1.2.3 Highway 842 Sites

Figures 4-10 and 4-11 show the wind roses for the 842a and 842b sites. There are no data for the winter period at the 842a site as the site was decommissioned in November. There were more frequent ENE winds at the 842a site than at the 842b site. The fall winds at the 842b site are only based on one month of data (November 2012), therefore, the statistics represented in the associated wind rose may not be as representative as the other data.

4.1.3 Comments

The wind rose plots provided in Figures 4-2 to 4-11 represent differing locations and periods of record. The plots indicate that wind trends vary with location, and some of this variation is likely attributable to site specific geographical characteristics or the presence of nearby tree canopies and buildings. In some cases (i.e., for the 986a and 842a sites), this can mean that the measured winds are not necessarily representative of regional airflow. The plots also indicate that winds vary systematically with time-of-day and with season. The time-of-day variation is important as air quality is strongly linked to the diurnal heating and cooling processes in the atmosphere.

4.2 WIND SPEED

Table 4-1 provides wind speed statistics for each monitoring site. The average wind speeds range from 5.6 to 8.3 km/h, with the lower values occurring at the Highway 986a and 986b sites. The maximum wind speeds are in the 32.0 to 49.8 km/h range.

Table 4-2 shows the year-to-year variation of the wind speed statistics measured at the PRC station; the station with the longest monitoring period. The information in the table indicates that 2009 was the windiest year. The information indicates that there are temporal as well as spatial wind speed variations.

Figure 4-12 provides time series plots of the measured wind speeds at the respective monitoring sites. While there is a consistent vertical scale (i.e., the wind speed scale) to facilitate comparison, the horizontal scales (i.e., date and time) are specific for each monitoring station. The wind speeds measured at the PRC station in 2009 are greater than those measured for other years and at the other sites. The quality of some of the PRC wind data during 2009, however, is suspect as persistent high winds occurred for extended periods of time (e.g., the period August to October 2009 is noted as one of these periods).

Figure 4-13 shows the wind speed frequency distributions at the various sites. The most frequent winds are in either the 0 to 5 km/h range or the 5 to 10 km/h range, depending on the site. Low winds are the most frequent at the 986a and 986b sites.

Figure 4-14 provides the wind speed variation with time of day at the various sites. Lower wind speeds tend to occur during the night and higher wind speeds during the afternoon. This trend is the same for all monitoring sites. The figure, again, shows that lower wind speeds were measured at the 986a and 986b sites than at the other three sites. It is not clear if these lower wind speeds are attributable to site specific characteristics or a result of an instrumentation problem.

4.3 TEMPERATURE

While ambient temperature plays a lesser role in the transport and dispersion of emissions, the temperatures measured at the monitoring sites are examined for completeness. Table 4-3 provides temperature statistics for the monitoring sites. The largest variations from site-to-site are related to the maxima and minima. The larger temperature values at site 842a are due to anomalous temperatures being recorded for the period prior to November 2012.

Table 4-4 shows the year-to-year variation of the temperature statistics measured to the PRC station; the station with the longest monitoring period. The information indicates that there are temporal as well as spatial ambient temperature variations.

Figure 4-15 shows a time series of hourly temperatures measured at each station. While there is a consistent vertical scale (i.e., temperature scale) to facilitate comparison, the horizontal scales (i.e., date and time) are specific for each monitoring station. The ambient temperatures at the Highway 842a site are anomalous and are likely the result of a failed temperature sensor or a data logger programming error.

4.4 FINDINGS

The two Air Monitoring Subcommittee stations were each located at two sites for the period examined. The original locations were changed during the measurement period to improve the exposure of the wind sensors. The measurements at the monitoring sites confirm that temporal and spatial meteorological variations occur. From a temporal perspective, the following are noted:

- The wind directions have a systematic diurnal trend with west-southwesterly (WSW) and southwesterly (SW) winds occurring during the day. During the night, more southerly (S) and easterly (E) winds occur.

- The wind speeds have a systematic trend with lower winds occurring during the night and increasing wind speeds during the day.

From a spatial perspective the following are noted:

- The Highway 986a and 842a sites were deemed to be influenced by local obstructions, which is one of the reasons that lead to the monitoring stations being relocated to the Highway 986b and 842b sites.

- The wind data from the Highway 986a and 842a sites may not always be representative of regional winds. The associated wind directions will have more uncertainties when correlating high concentration measurements to upwind emission source regions.

- While certain spatial trends can be identified, there is a variability (i.e., a randomness) associated with winds.

- Under high wind speed conditions, the winds tend to be more uniform over the region.

For near surface emission sources (e.g., tank vents, short stacks), the highest downwind ambient concentrations typically occur under low wind-speed, stable atmospheric conditions (i.e., these conditions are associated small plume spreads and low mixing heights). Under these conditions, the air flow can also become disorganized and have a large meandering component. In these cases, high concentration events will be influenced by the winds several hours proceeding the measurement period and not just the single hour associated with the concentration event.

4.5 GAPS AND RECOMMENDATIONS

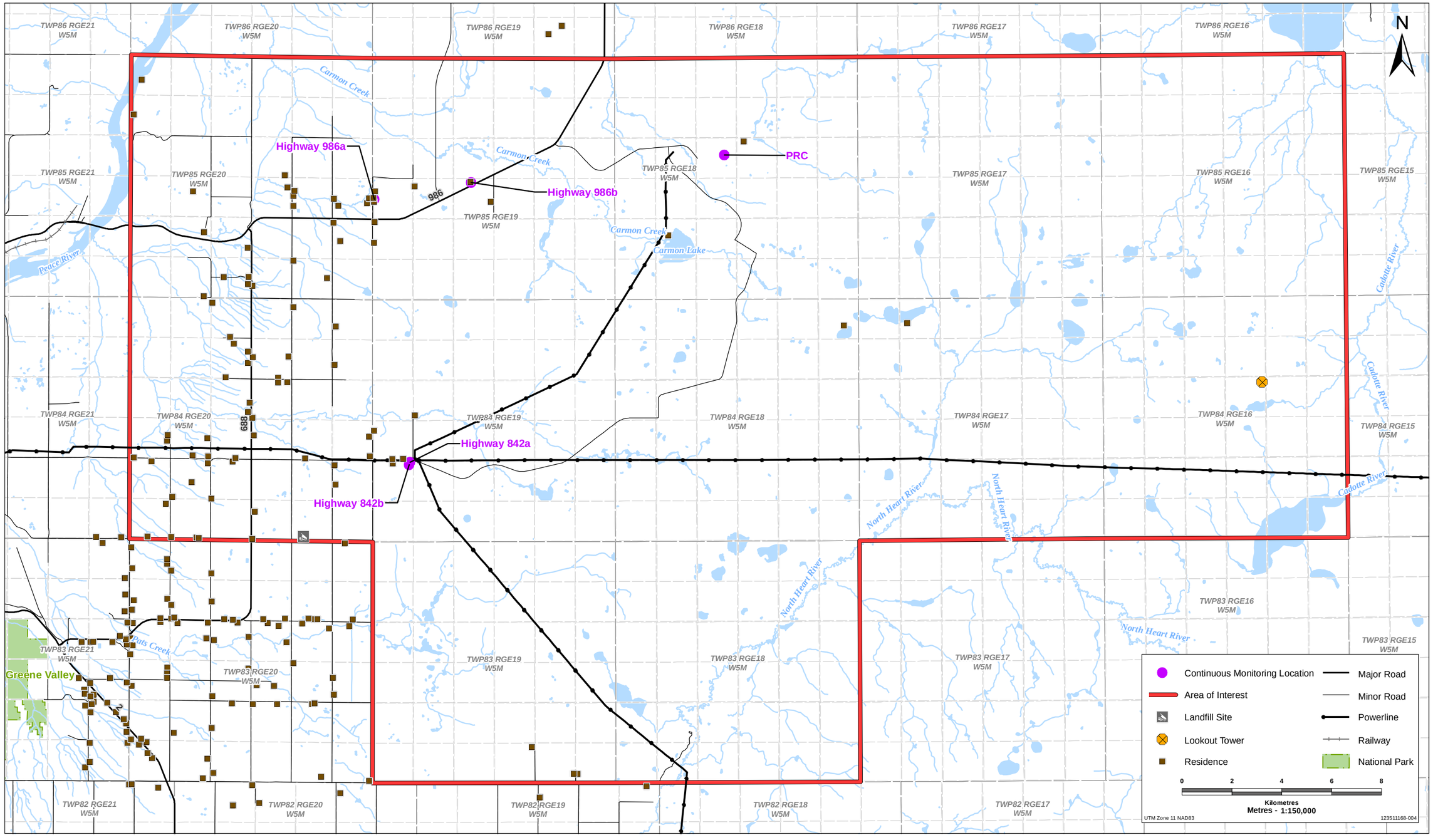
The Alberta Air Monitoring Directive (AMD) specifies siting criteria, equipment specifications, operating procedures and reporting requirements. ESRD periodically audits air quality monitoring stations to determine compliance to the AMD. Audit reports and monthly air quality monitoring reports were provided for examination. A review of the voluntary ESRD station audits for the Highway 986 and 842 residential area monitoring stations relative to the meteorological

monitoring is provided in Table 4-5. Based on the audits and the examination of the data, the following information gaps and recommendations are made:

- **Gap/Recommendation M1:** The ESRD AMD siting requirements at the original Highway 986a and 842a locations did not appear to be met as this is one of the reasons for moving the monitoring stations. While this has been corrected, it is still cited as a gap to reinforce the need for appropriate site selection with respect to nearby tree canopies and other obstructions. If there are challenges to finding a site, taller towers may be used to compensate for nearby obstructions.

- **Gap/Recommendation M2:** Odour complaints and high concentrations tend to occur under low wind speed conditions. Under these conditions, the air flow can be disorganized making it difficult to determine upwind source directions. Wind speeds measured at the Highway 986a and Highway 986b sites tends to be less than those at other sites. The calibration of this wind sensor and/or the data logger programming needs to be confirmed. The performance of all three instruments needs to be confirmed and documented via a calibration check.

- **Gap/Recommendation M3:** Wind monitoring conducted at the Highway 986 and Highway 842 sites are near residence areas. There is no wind monitoring in the main source area to the south of the PRC site. An additional wind monitoring site in this region would help relate source and receptor regions. The ESRD AMD siting requirements need to be met for any new monitoring site (see Gap/Recommendation M1).



THREE CREEKS MONITORING

Location of Continuous Air Quality Monitoring Stations

Acknowledgements: Original Drawing By Stantec, Basedata: Altalis, Canvec, National Road Network

PREPARED BY

Stantec

FIGURE NO.

4-1

Last Modified: 4/2/2014 By: cstefner

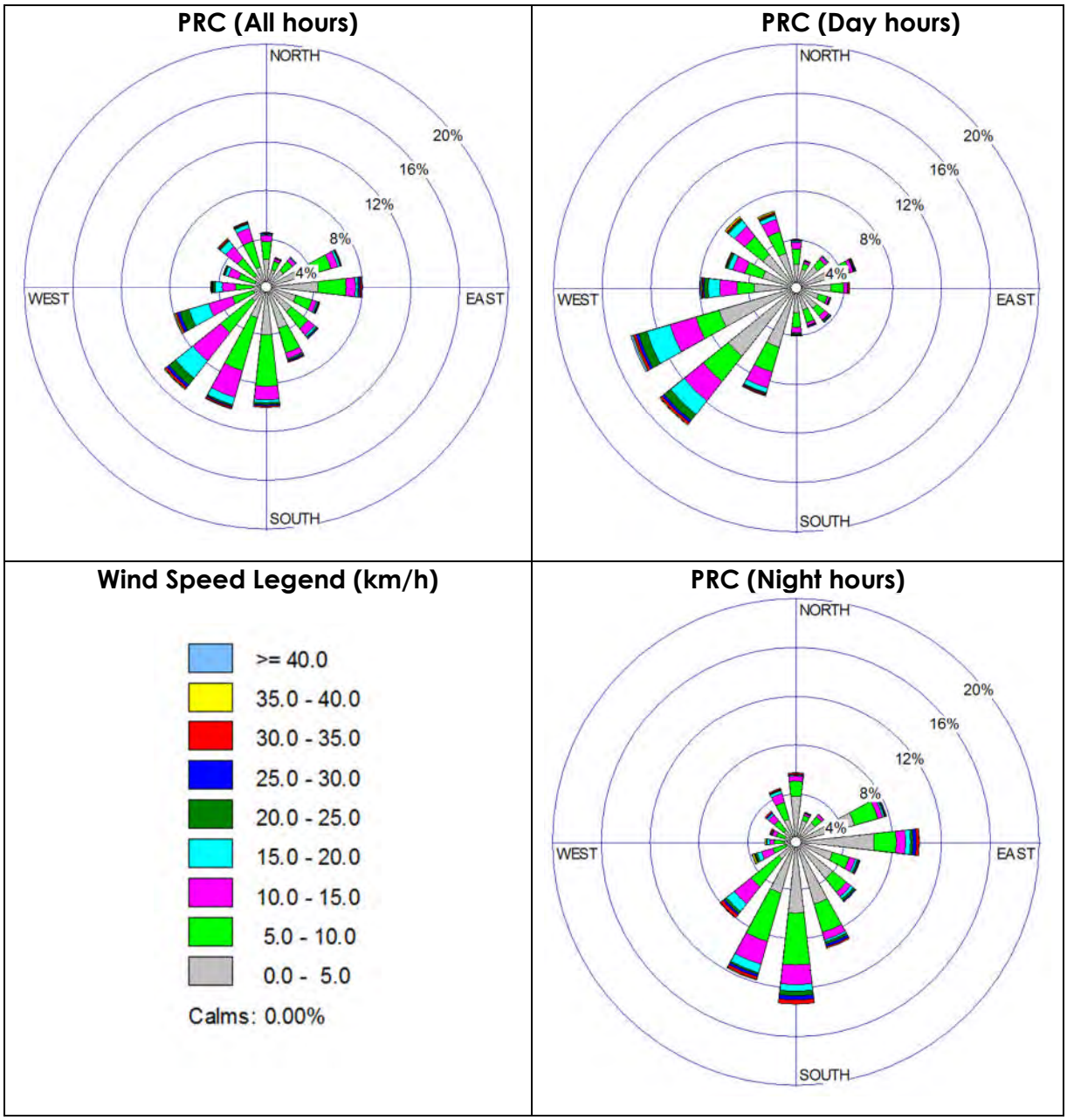


Figure 4-2 Wind roses at the PRC continuous air quality monitoring site (All, Day and Night hours)

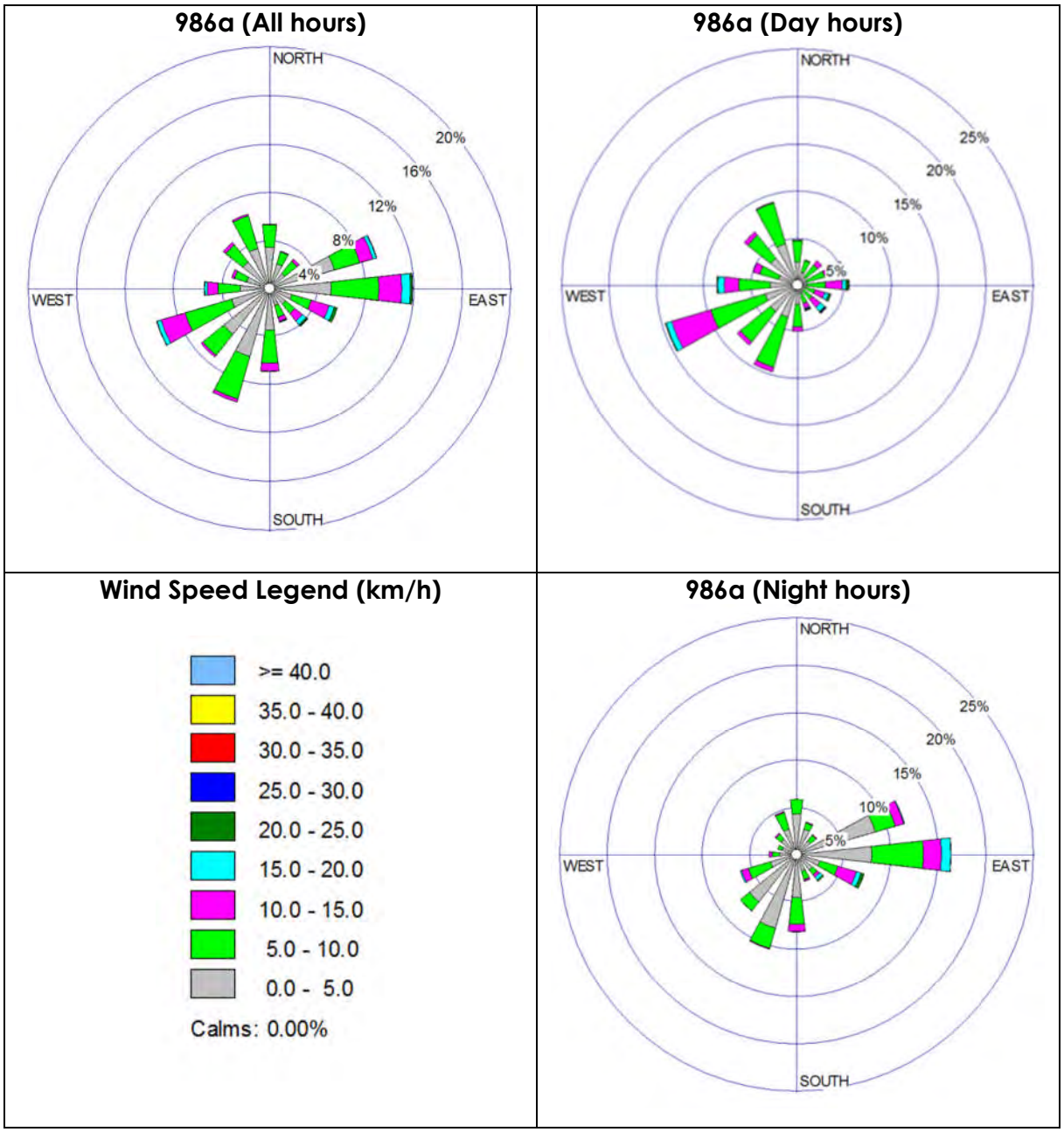


Figure 4-3 Wind roses at the Highway 986a continuous air quality monitoring site (All, Day and Night hours)

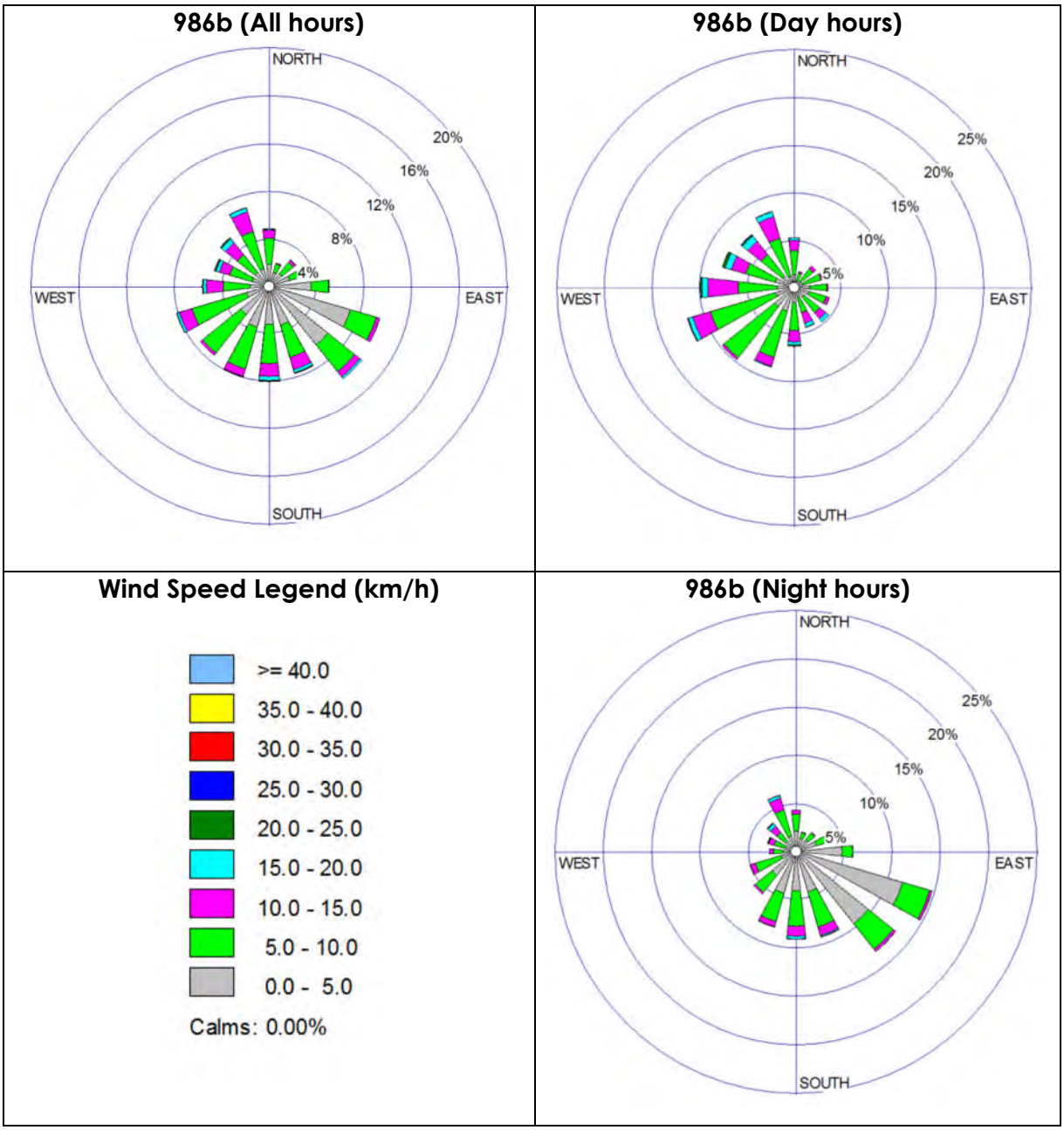


Figure 4-4 Wind roses at the Highway 986b continuous air quality monitoring site (All, Day and Night hours)

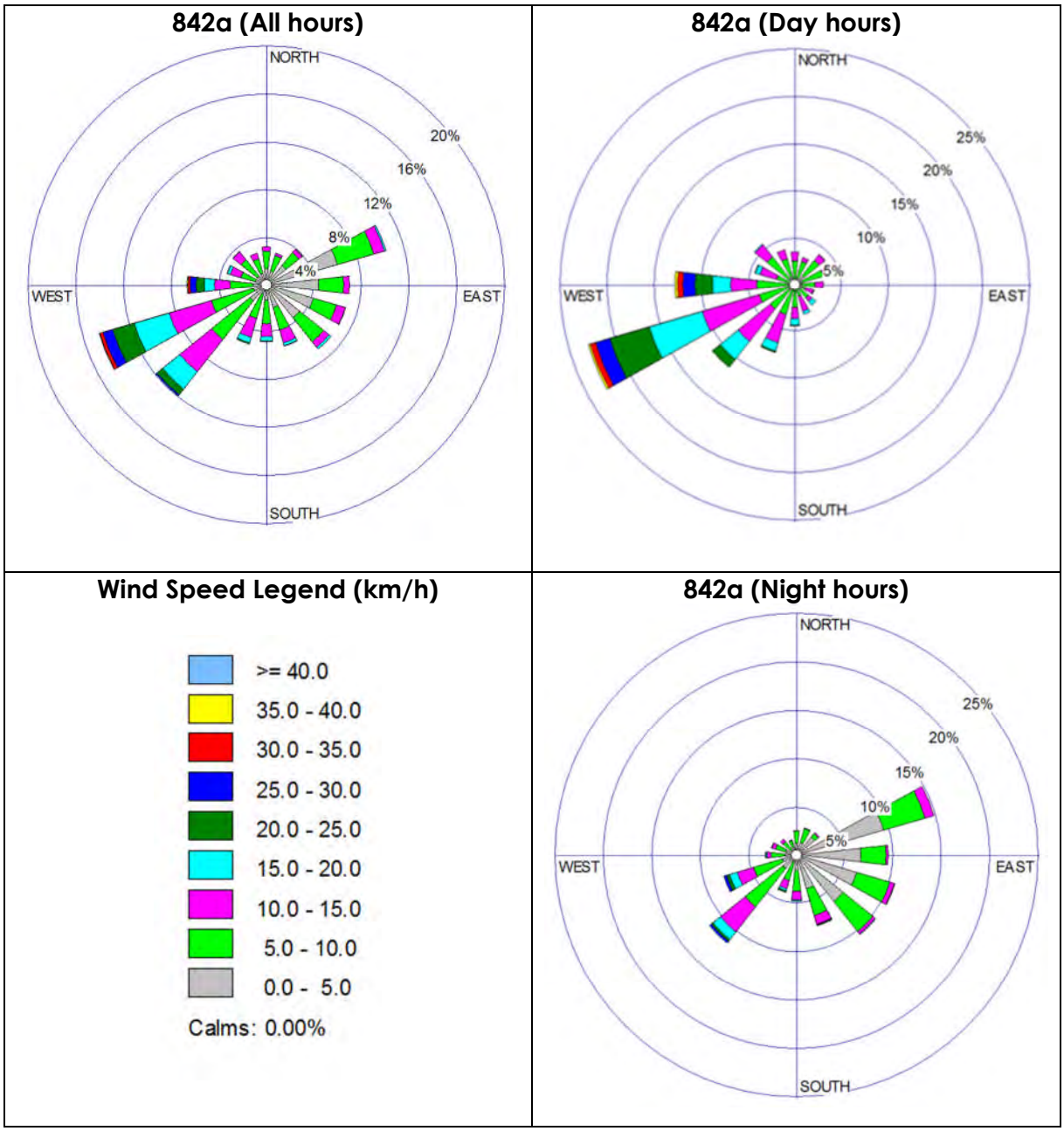


Figure 4-5 Wind roses at the Highway 842a continuous air quality monitoring site (All, Day and Night hours)

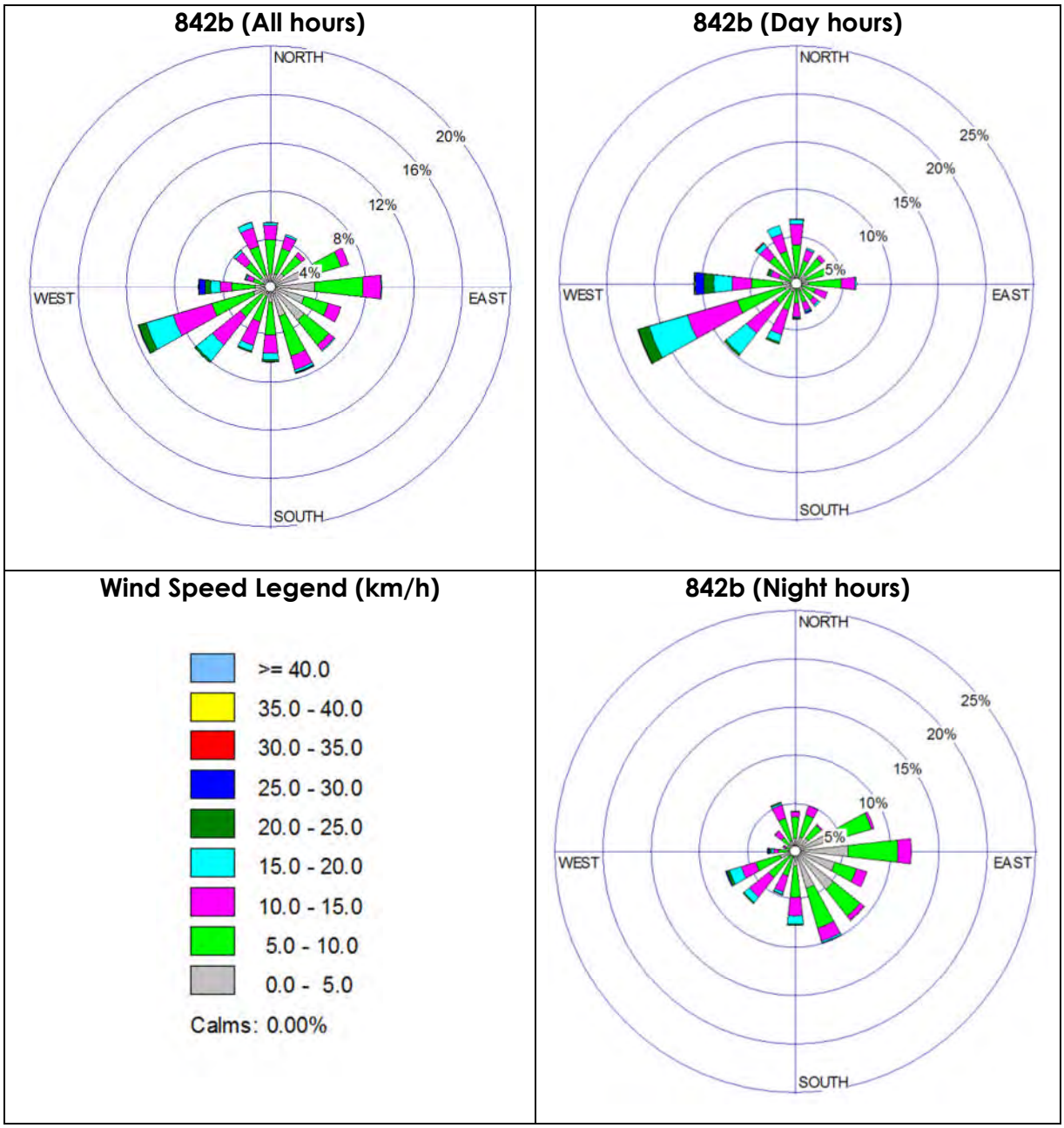


Figure 4-6 Wind roses at the Highway 842b continuous air quality monitoring site (All, Day and Night hours)

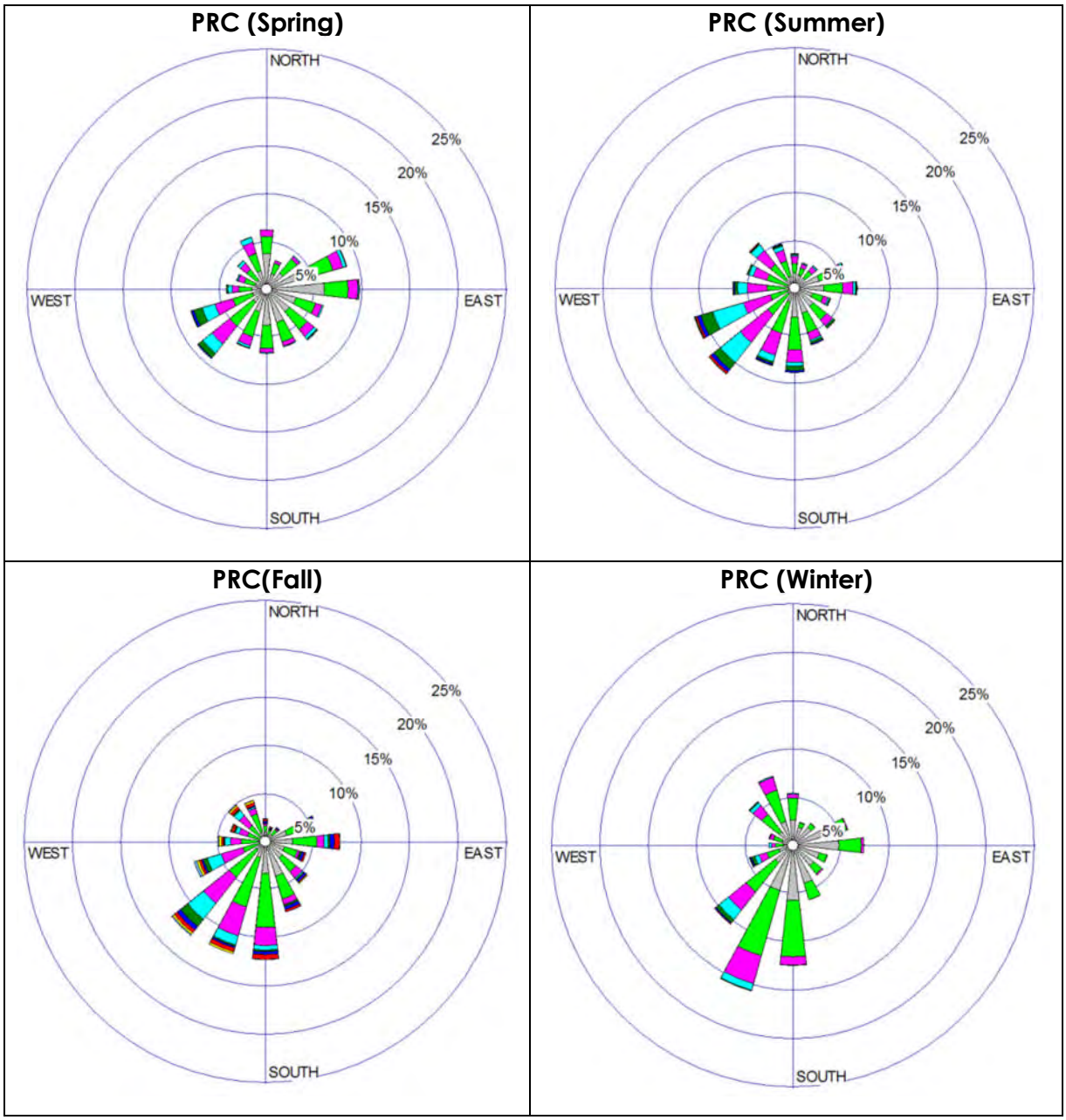


Figure 4-7 Seasonal wind roses at the PRC continuous air quality monitoring site

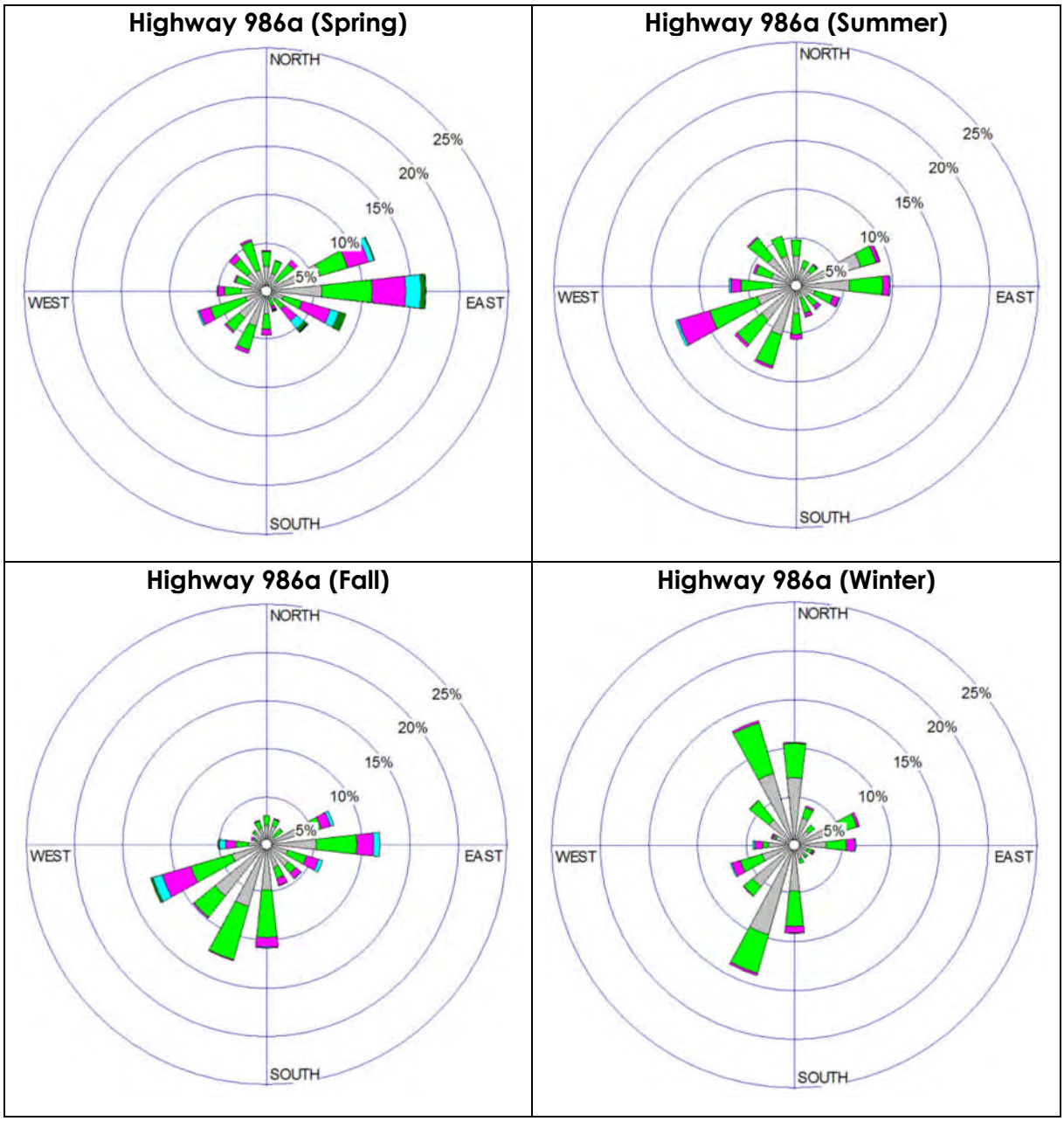


Figure 4-8 Seasonal wind roses at the Highway 986a continuous air quality monitoring site

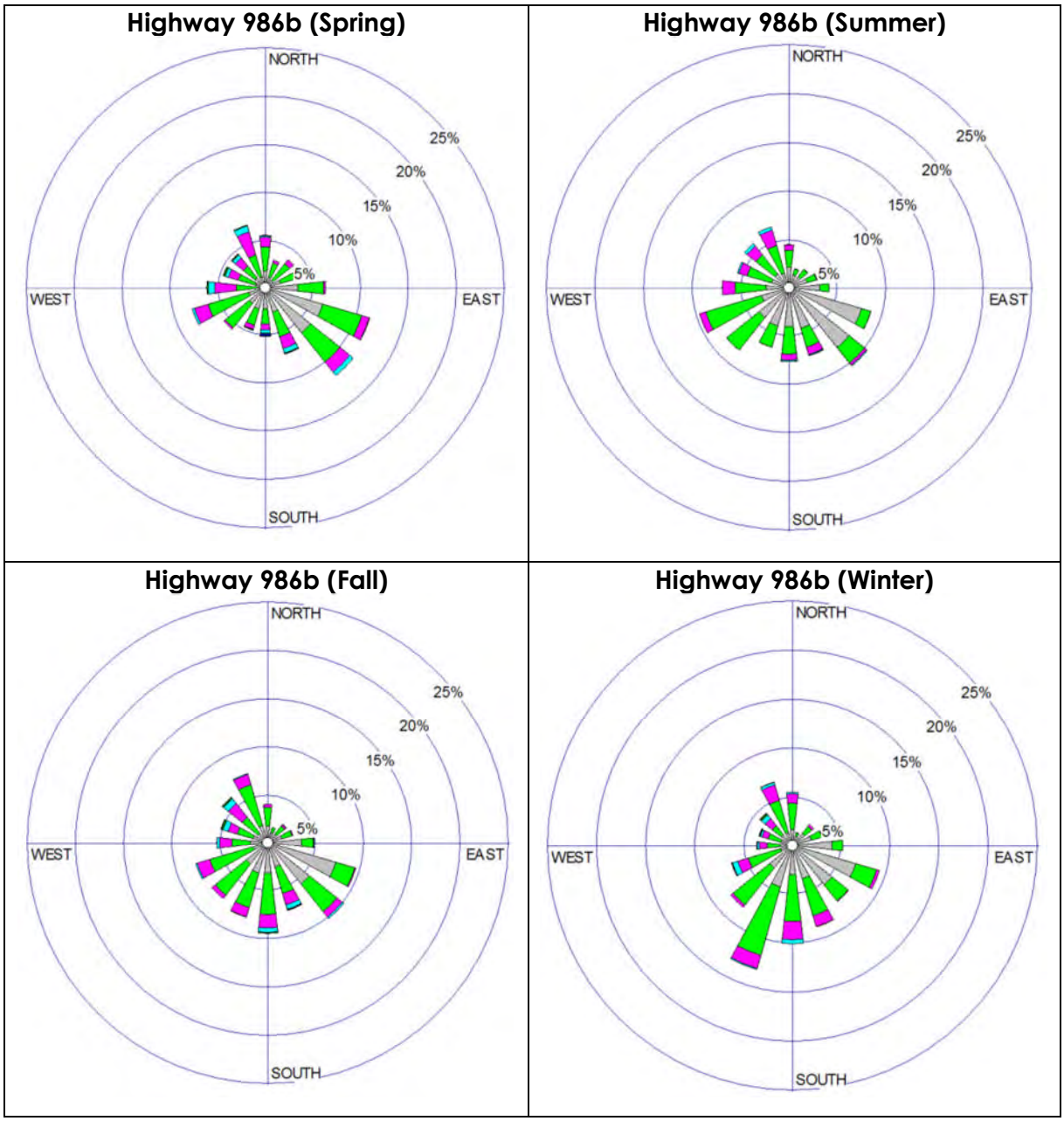


Figure 4-9 Seasonal wind roses at the Highway 986b continuous air quality monitoring site

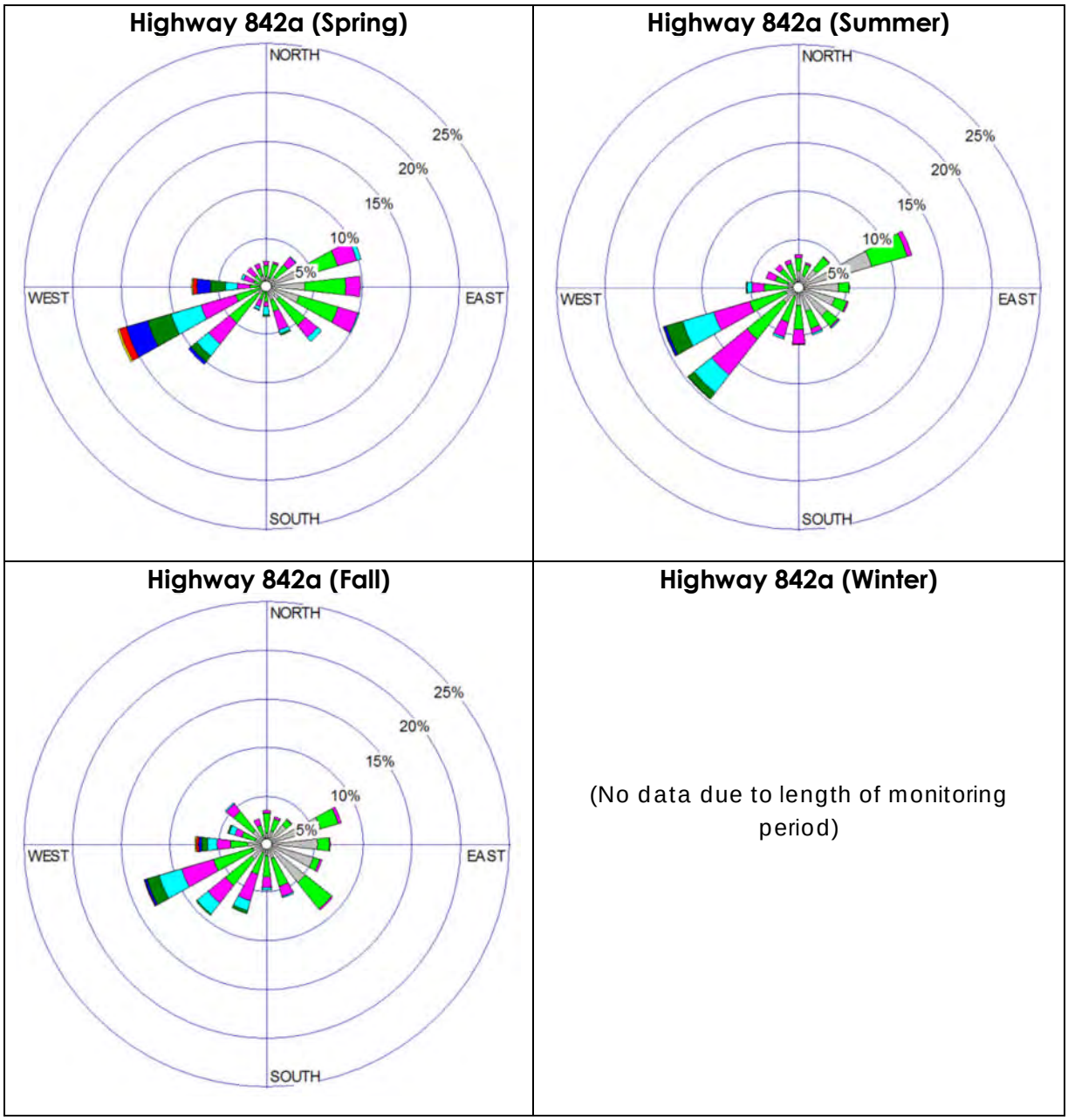


Figure 4-10 Seasonal wind roses at the Highway 842a continuous air quality monitoring site

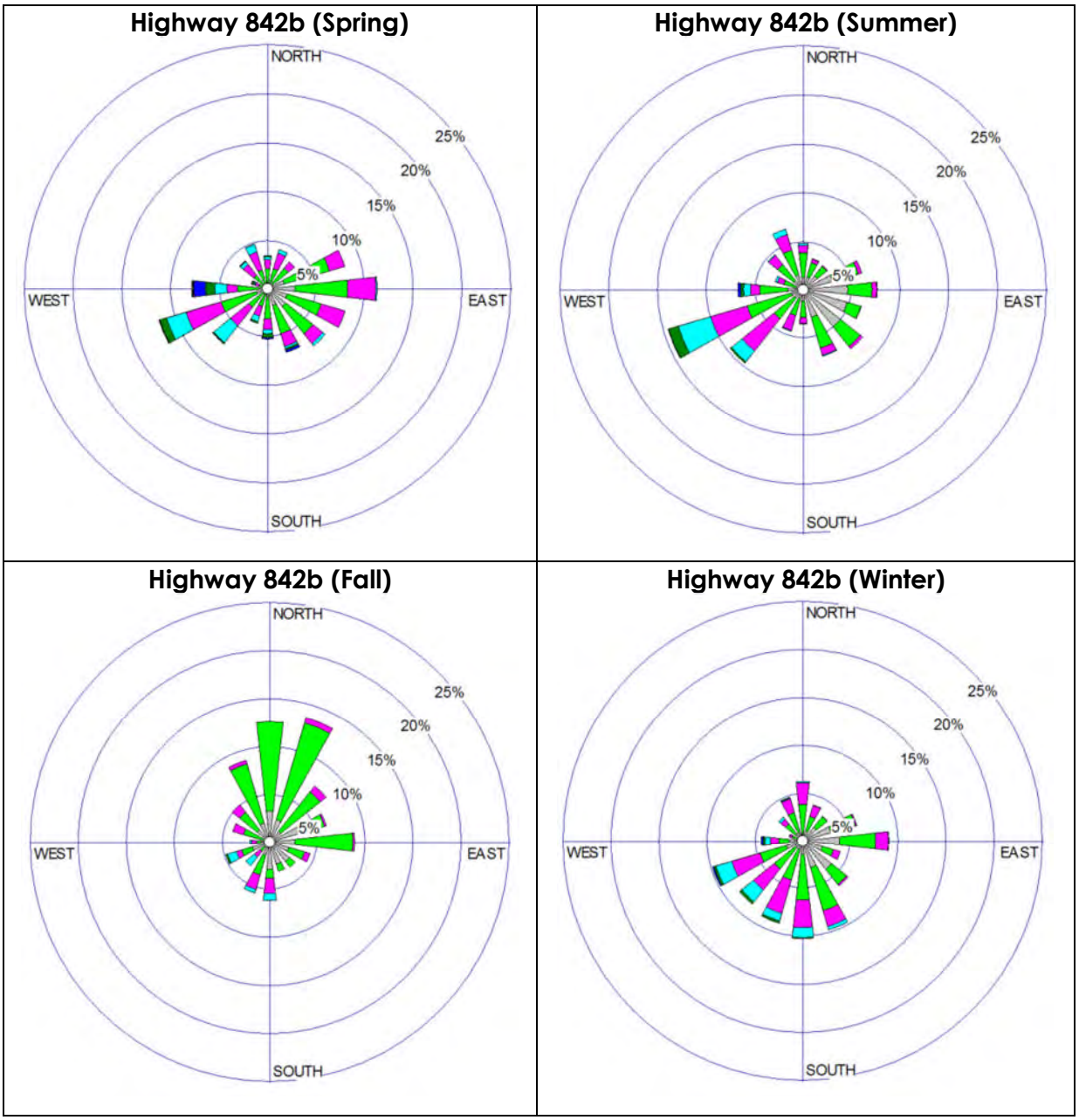


Figure 4-11 Seasonal wind roses at the Highway 842b continuous air quality monitoring site (Highway 842b fall wind rose only based on one month of data)

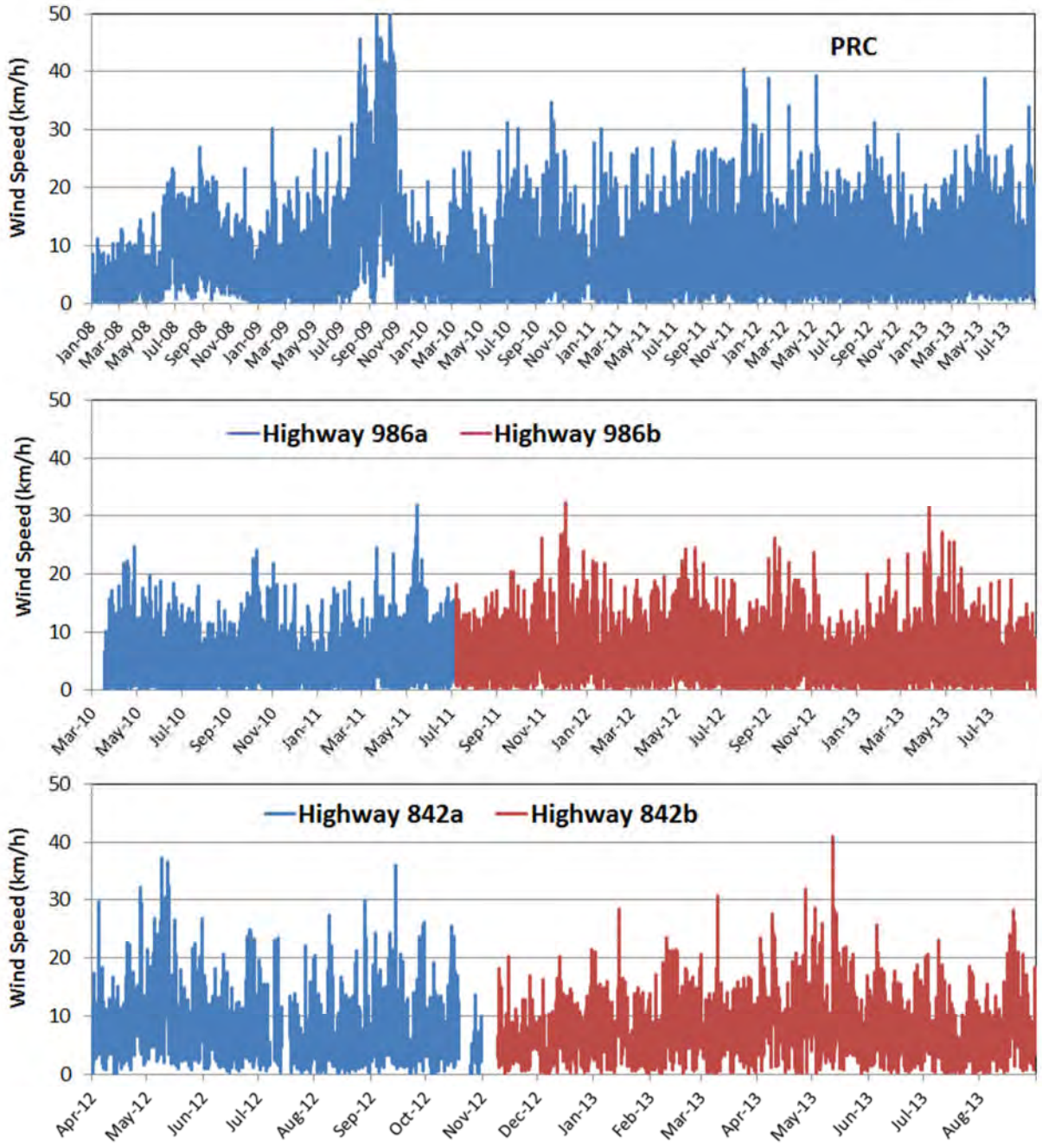


Figure 4-12 Wind speeds measured at the continuous air quality monitoring sites

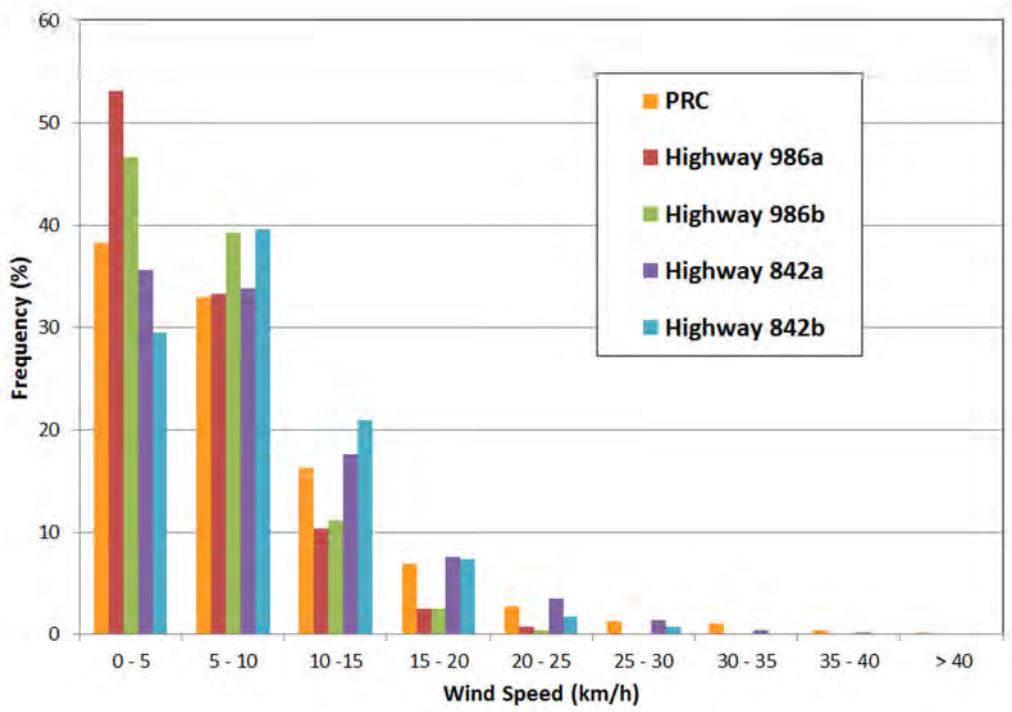


Figure 4-13 Wind speed frequency distributions at the continuous air monitoring sites

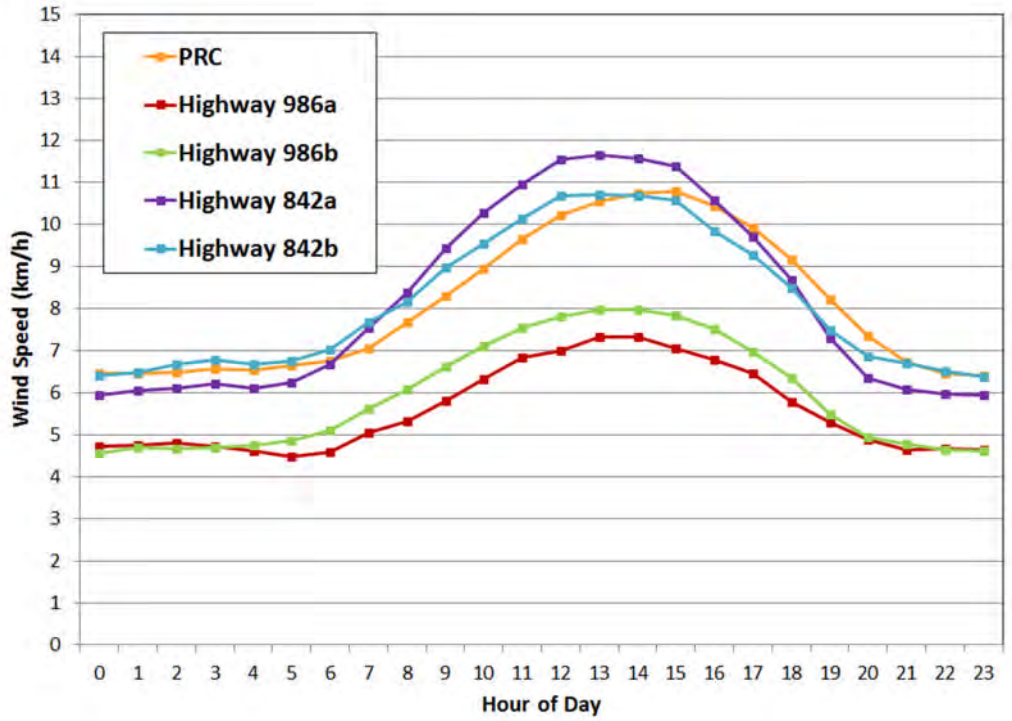


Figure 4-14 Average wind speed variation with time of day at the continuous air monitoring sites

Table 4-1 Wind speed (km/h) statistics for the continuous ambient air quality monitoring sites

Statistic	Location				
	PRC	Highway 986a	Highway 986b	Highway 842a	Highway 842b
Number of Months	69	16	26	10	17
Maximum	49.8	32.0	32.4	37.3	41.0
90th Percentile	16.4	11.2	11.2	16.6	14.9
75th percentile	10.9	7.7	7.9	11.1	10.9
Average	**8.1**	**5.6**	**6.0**	**8.3**	**8.1**
Median	6.5	4.7	5.2	6.8	7.3
25th Percentile	3.5	2.6	3.1	3.8	4.5
10th Percentile	1.6	1.2	1.7	2.2	2.5
Minimum	0.0	0.0	0.0	-0.1	0.1

Table 4-2 Annual wind speed (km/h) statistics for the PRC continuous ambient air quality monitoring site

Statistic	Year					
	2008	2009	2010	2011	2012	2013
Number of Months	12	12	12	12	12	8
Maximum	27.1	49.8	34.7	40.5	39.2	38.9
90th Percentile	14.7	28.9	13.0	15.7	14.4	16.2
75th percentile	10.8	16.1	8.5	10.9	10.1	11.7
Average	**7.4**	**11.0**	**6.0**	**8.0**	**7.6**	**8.7**
Median	6.4	7.0	4.8	6.9	6.6	7.6
25th Percentile	3.3	3.4	2.1	4.0	3.9	4.6
10th Percentile	1.8	1.3	0.5	2.1	1.9	2.6
Minimum	0.0	0.0	0.0	0.0	0.0	0.0

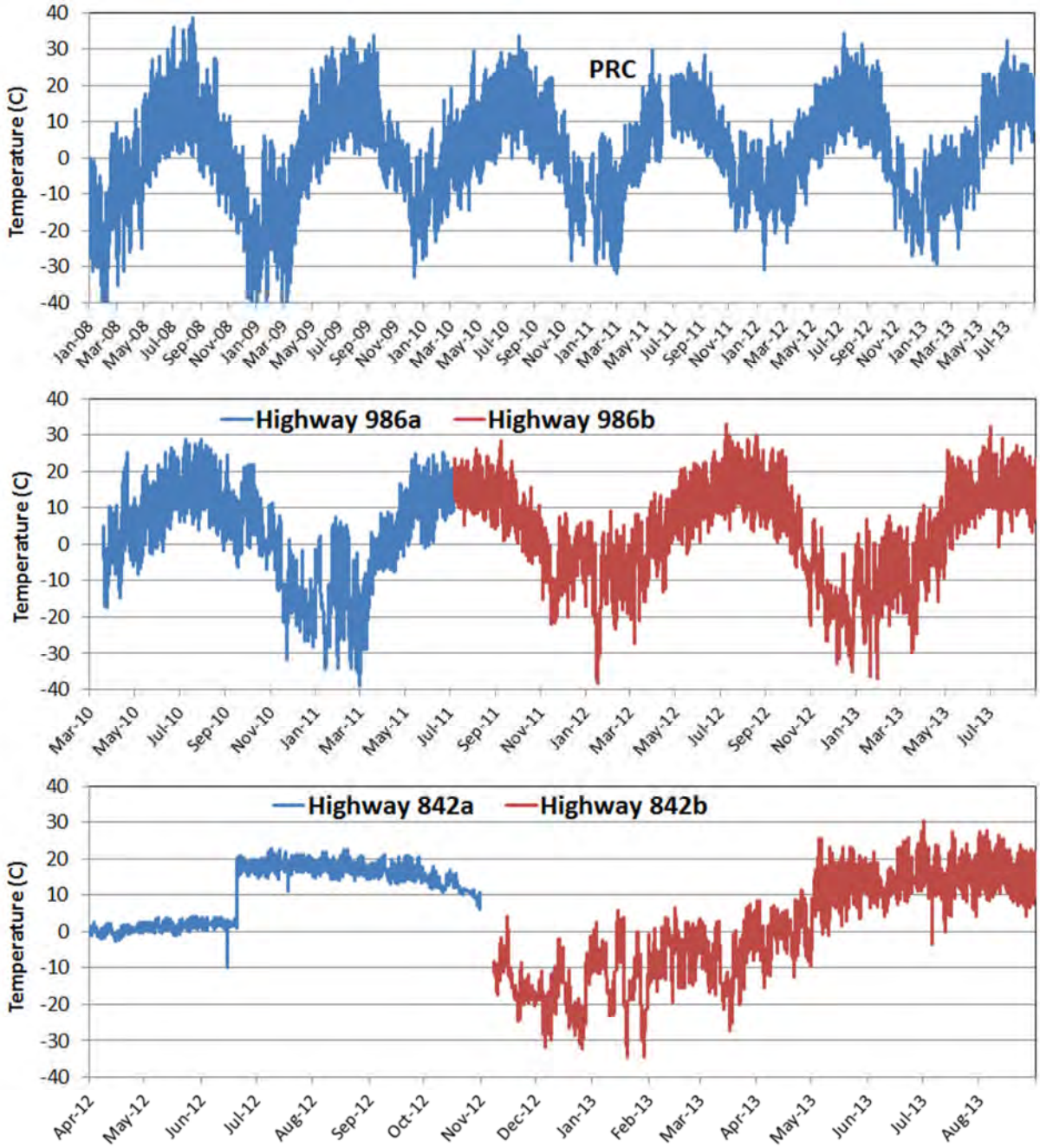


Figure 4-15 Ambient temperatures measured at the continuous air quality monitoring sites

Table 4-3 Ambient temperature (°C) statistics for the continuous ambient air quality monitoring sites

Statistic	Location				
	PRC	Highway 986a	Highway 986b	Highway 842a	Highway 842b
Number of Months	69	16	26	10	17
Maximum	38.7	28.9	33.0	23.0	30.5
90th Percentile	18.1	18.0	19.3	19.5	18.9
75th percentile	11.7	12.8	13.7	17.5	13.1
Average	**1.6**	**2.8**	**3.7**	**10.8**	**0.8**
Median	2.3	5.0	5.3	14.2	0.5
25th Percentile	-7.3	-4.7	-5.5	2.0	-11.0
10th Percentile	-16.2	-17.8	-14.8	0.4	-18.1
Minimum	-45.0	-38.9	-38.5	-10.0	-34.6

Table 4-4 Ambient temperature (°C) statistics for the PRC continuous ambient air quality monitoring site

Statistic	Year					
	2008	2009	2010	2011	2012	2013
Number of Months	12	12	12	12	12	8
Maximum	38.7	33.5	33.7	29.8	34.3	32.2
90th Percentile	17.0	18.6	18.7	16.3	18.5	19.6
75th percentile	9.1	11.1	12.2	10.8	12.0	14.4
Average	**-1.9**	**0.3**	**3.6**	**1.8**	**2.2**	**4.4**
Median	-0.7	1.0	4.3	2.6	2.5	5.4
25th Percentile	-11.6	-8.6	-4.7	-5.7	-7.2	-5.2
10th Percentile	-23.5	-20.6	-12.5	-15.0	-15.2	-12.5
Minimum	-45.0	-44.8	-28.2	-31.9	-30.8	-29.2

Table 4-5 Monitoring station meteorology audit findings for the Highway 986 and 842 monitoring stations

Station and Audit Date	Parameter	Audit Comment
Highway 986		
May 14, 2010	Wind head properly oriented	Yes
	Wind head functioning properly	Yes
November 9, 2010	Wind speed/direction	Wind was audited in last audit
August 22, 2012	Wind speed/direction	Passed Wind calibration and servicing due
	Wind head orientation	Passed
	Ambient Temperature	OK
June 11, 2013	Wind speed/direction	Passed
	Wind head orientation	Passed
	Ambient Temperature	OK
Highway 842		
August 23, 2012	Wind speed/direction	Passed Summary report did not indicate if wind equipment was operating properly Wind tower was not at minimum 10 m height Sixty foot trees noted 25 m away
	Wind head orientation	Passed
	Ambient Temperature	Not monitored
June 11, 2013	Wind speed/direction	Passed
	Wind head orientation	Passed
	Ambient Temperature	Opportunity for improvement

5.0 Odour complaints

The AER provided an odour complaint log for the Three Creeks study area that spanned the period February 11, 2010 to September 30, 2013; this represents a 3.64 year period (Candace McDonald, personal communication 2013). During this period, 847 events were documented; this represents an average of 233 events per year. Each event is composed of: an incident number, the location of the incident (e.g., Legal, Subdivision, Section, Township, and Range), the incident date and time, and the type of odour.

5.1 TRENDS

The frequency analysis of the odour complaint data indicates:

- **Year (Figure 5-1):** Out of the 847 events, the year with the lowest frequency is 2010 (18.8% of the events); and the year with the highest frequency is 2012 (36.2% of the events). While this variation is essentially a factor of two, it is not clear that 2012 should be regarded as being "twice as bad" as 2010 with respect to odorous emissions and concentrations. Confounding factors include resident participation associated with recognition that a reporting process was available and/or reporting fatigue.

- **Month (Figure 5-2):** Out of the 847 events, the month with the lowest frequency is November (5.0% of the events); and the month with the highest frequency is September (11.0% of the events). This, again, represents a factor of two variation from the minimum to the maximum values. Note that there is one less "October", "November", and "December" in 2013 due to the data period ending in September.

- **Time of Day (Figure 5-3):** There is a very clear diurnal variation associated with the odour complaint data. The trends indicate:

  - Most of the events occur in the morning period 5 AM to 9AM (5 to 9 on the figure).
  - There is a minor secondary peak in the evening around 10 PM (22 on the figure).
  - The lowest frequencies occur in the afternoon period 12 PM to 6 PM (12 to 18 on the figure).

  These variations are likely due to both meteorology and resident behavior. During the day, atmospheric dispersion is enhanced by solar heating diluting the emissions from industry sources (i.e., good dispersion conditions). During the night, atmospheric dispersion is reduced due to nocturnal cooling and lower wind speeds; therefore emissions from industry sources are not as diluted, producing plumes with higher concentrations (i.e., poor dispersion conditions).

  The times that are associated with the odour complaints likely represent a mixture of standard time (October to March) and daylight savings time (April to September). The odour

data presented in Figure 5-3 were not adjusted for the time basis. In contrast, all ambient monitoring is conducted using standard time.

Residents, typically sleeping during the 11 PM to 6 AM period, may be less likely to respond to an odour than when they are awake. This likely results in lower incidences during the night time period. The early morning period, when residents are waking up and poor dispersion conditions occur are likely the reason that peak odour complaints occur at this time.

- **Location (Figure 5-4):** The 847 events were associated with 44 locations. Figure 5-6 provides a plot showing the locations of the reported odour complaints. Most of the events were associated with three locations (69.4%). Site 8 (1-18-84-19W5) recorded 170 events, Site 19 (5-18-85-19W5) recorded 207 events, and Site 39 (16-13-84-20W5) recorded 211 events. Eight locations account for 91.6% of the odour complaints.

  For the top three event locations, there was an average of 54 events per year at each location. Twenty-nine (29) locations reported 1 or 2 events for the whole period. The presence of a relatively large number of events at a few locations likely reflects a specific source – residence proximity, and/or persistence of the affected resident.

- **Odour Type (Figure 5-5):** The AER data logged odour type in the following categories: Drilling Waste, H_2S, SO_2, THC, and Other. Clearly, most of the odours (i.e., 90.9%) were categorized as being a "hydrocarbon" type odour (i.e., THC). An Alberta Health Services (2011) survey for the area indicates: 91% of the odours were industrial and the remaining 9% were agricultural; 48% of the odours are very noticeable or offensive; and the industry odours were reported as "tar-like or asphalt", "natural gas", chemical or "rotten eggs or sulphur".

The findings associated with the review of the odour complaint data indicates that odours tended to occur during the night and early morning when dispersion conditions are reduced, and that most of the events tend to occur at a few locations. The latter may be associated with specific residence – emission source proximity.

5.2 METEOROLOGY

5.2.1 Winds

Wind direction and wind speed from the three continuous monitoring sites associated with the time of each odour complaint were matched for the three locations where the number of odour complaints were the highest:

- For Site 8 (Figure 5-6), the closest wind data are from the Highway 842a and 842b sites (which are essentially co-located with Site 8).

- For Site 19, the closest wind data are from the Highway 986a (which is essentially co-located with Site 19) and the Highway 986b site (which is about 4 km west of Site 19).

- For Site 39, the closest wind data are from the Highway 842a and 842b sites (which are about 2 km northeast (NE) of Site 39).

Figure 5-7 shows the concurrent wind direction and wind speed frequency distributions associated with odour complaints at Site 8. Based on the Highway 842 wind data, the odour complaints are primarily associated with ENE and E winds. Based on PRC and Highway 986 wind data, the odour complaints are primarily associated with ENE, E, and ESE winds. Most of the odour complaints are associated with wind speeds less than 5 km/h.

Figure 5-8 shows the concurrent wind direction and wind speed frequency distributions associated with odour complaints at Site 19. Based on the Highway 986 wind data, the odour complaints are primarily associated with ESE and SE winds. Based on PRC and Highway 842 wind data, the odour complaints are primarily associated ENE, E, ESE and SE winds. There is a secondary peak associated with Highway 842 SW winds, indicating a potential upwind source to the southwest of Site 19. Most of the odour complaints are associated with wind speeds less than 5 km/h.

Figure 5-9 shows the concurrent wind direction and wind speed frequency distributions associated with odour complaints at Site 39. Based on the Highway 842 wind data, the odour complaints are primarily associated with ENE and E winds. Based on PRC and Highway 986 wind data, the odour complaints are primarily associated ENE, E, ESE and SE winds. Most of the odour complaints are associated with wind speeds less than 5 km/h.

5.2.2 Back Trajectory Analysis

Wind data are often used to help determine the source of an odour or a high concentration event. Typically, winds concurrent with the event are used. As indicated, most of the odour complaints are associated with low wind speeds and during night time periods (referred to as low wind speed, stable atmospheric conditions). Under these conditions, the winds can vary substantively from hour to hour. An hourly average wind speed of 2.5 km/h corresponds to a travel distance of 2.5 km. If the potential emission source is 10 km upwind of an odour complaint location, then the associated travel time is at least 4 hours. Therefore, 4 to 5 hours of wind data prior to the odour complaint need to be examined to determine a source – odour complaint correlation. For distances greater than 10 km, a longer time period may be required (unless the wind speeds are high).

Sample back-trajectories are calculated for several events at each of the three high frequency locations (Sites 8, 19 and 39) in Figures 5-10 to 5-13. Although wind data from all the stations are used, the wind data from the nearest meteorological station is identified. Back trajectories are based on the winds associated with the event and for the four hours preceding the event (for a total of five hours).

The wind data are referenced to standard time and reflect a one-hour period prior to the indicated time. For example, winds at 0800 are the average from 7:00AM to 7:59AM. If an odour complaint was reported at 8:10 AM (or at 8:50AM), the first wind data to be used were the

preceding hour winds (i.e., the 7:00 to 7:59 AM winds). The odours are assumed to be reported in both standard time (e.g., during the winter) and daylight savings time (e.g., during the summer). No adjustments for daylight savings times were made for these initial comparisons.

5.2.2.1 Site 8 Back Trajectories

Figure 5-10 shows three sample back trajectories for Site 8 (1-18-84-19W5):

- The left-hand trajectories are under high wind speed conditions. For the first two hours preceding the event, the Highway 986 and Highway 842 winds point to ESE sources.
- The center trajectories are under moderate wind speeds. For the first few hours preceding the event, the Highway 986 and Highway 842 winds point to SSE sources.
- The right-hand trajectories are under low wind speeds. For the first few hours preceding the event, the PRC and Highway 842 winds point to SSE sources.

For the first two examples, the trajectories based on the PRC winds deviated from the other trajectories. For the third example, the trajectories based on the Highway 986 winds deviate from the other two trajectories.

5.2.2.2 Site 19 Back Trajectories

Figure 5-11 shows three sample back trajectories for Site 19 (5-18-85-19W5):

- For the left-hand trajectories, the Highway 842 winds show a strong directional change between the first and second hour. After the first hours, the Highway 986 and Highway 842 winds point to ESE sources.
- For the center trajectories, all three trajectories diverge from one another. The closest Highway 986 winds point to SE/ESE sources. If the first hour for Highway 842 is ignored, then the Highway 986 and Highway 842 trajectories would converge to indicate ESE sources.
- For the right-hand trajectories, the Highway 986 winds show a strong directional change between the first and second hour. Ignoring the first hour, the Highway 986 winds point to sources to the ESE and SE hours. In contrast, the Highway 842 and PRC winds consistently point to SW sources.

These examples are from April when daylight savings times are in effect. During periods of varying winds, the start time to calculate the back trajectories becomes important.

Figure 5-12 shows three additional sample back trajectories for Site 19 (5-18-85-19W5):

- For the left-hand trajectories, all winds generally indicate easterly sources. The Highway 986 and Highway 842 winds for the first hour point to ESE sources.

- For the center trajectories, the closest Highway 986 winds are disorganized due to the variability associated with low wind speeds. There is no clear indication of an upwind source region.

- For the right-hand trajectories, the Highway 842 winds are very different from those at the other two locations. The Highway 986 and PRC winds point to ESE/SE sources.

5.2.2.3 Site 39 Back Trajectories

Figure 5-13 shows three sample back trajectories for Site 39 (5-18-85-19W5):

- The left-hand trajectories are virtually identical to the left-hand trajectories for an odour complaint at Site 19 (Figure 5-11). Both events occur on the same day, at essentially the same time (7:10 and 7:55).

- For the center trajectories, the closest Highway 842 winds point to NE sources. If the first hour for Highway 842 is ignored, then the Highway 842 winds point to E sources.

- For the right-hand trajectories, the first few hours of the Highway 986 and Highway 842 winds indicate ESE sources.

The trajectories based on PRC winds often differ from those based on the other station winds.

5.2.3 Comments

The initial application of back trajectory wind analysis indicates that the winds can be used to link odour complaints to upwind source regions. While the winds are subject to spatial variability, a more rigorous accounting for the start time or the use of winds for sub-hourly period could improve on the upwind source region identification. While there may be challenges for an individual back trajectory calculation, the use of numerous analyses would allow more definitive trends to be established.

5.3 FINDINGS

An examination of the odour complaint data indicated the following:

- The odour complaints occurred most frequently during the night and early morning period. This is consistent with poor dispersion during the associated stable atmospheric conditions.

- The odour complaints occurred most frequently with low wind speed condition (i.e. with wind speeds less than 5 km/h). High concentrations due to low-level fugitive emission sources are typically associated with stable low wind speed conditions.

- The most frequent odour complaints tend to be associated with upwind source located to the east of the residential areas. A trajectory analysis considers multiple hours before the odour complaint can be used to refine the determination of the upwind source directions.

5.4 GAPS AND RECOMMENDATIONS

The raw odour data could not be provided by the AER due to privacy issues, therefore, only the processed data that was described were provided.

Gap/Recommendation O1: Privacy issues could have limited the external review of odour complaint information. This would have been unfortunate since the occurrence of an odour complaint is a key piece of information that needs to be examined in more detail. It is often the only end-point documentation related to an air quality event. In the end, odour information was forwarded to the study team for this assessment. It is recommended that additional information be collected by AER including:

- The time of the odour complaint: The assessment was based on the assumption of standard time. At the end of our assessment, the AER confirmed that the times provided were a combination of standard time and daylight savings time. An explicit indication of the time basis is desirable.

- The intensity of the odour complaint: This would facilitate any correlation between odour complaints and simultaneous ambient air sampling. An intensity scale based on a 1 to 5 ranking could be used.

- The duration of the odour complaint: A long duration would provide an indication of steady winds, providing more confidence in identifying upwind source directions.

- An improved description of the odour type: The four types are somewhat limited. There are more descriptive terms that can be used that may help better identify the offending compounds. A list of these descriptors should be provided to residents.

While the odour examination focused on determining trends based on the most frequent occurrences, one should not discount the odours occurring with less frequent conditions.

Gap/Recommendation O2: The analysis of each odour complaint by AER likely focuses on examining the wind direction associated with the hour when the event occurred and not on the calculation of multiple-hour back trajectories. While the determination of more rigorous and complete back-trajectories was out of scope for this assessment, this task is a possibility if there is a need to better delineate upwind source regions in future. Confirmation of the existing wind sensor performance and an additional meteorological monitoring station can improve the confidence of using winds to determine odour and potential source relationships.

Gap/Recommendation O3: We are not clear with respect to the feedback local residents or industry receives following the submission of a complaint to AER. Further investigation may be warranted to ensure adequate feedback is provided to relevant parties after a complaint has been investigated by AER.

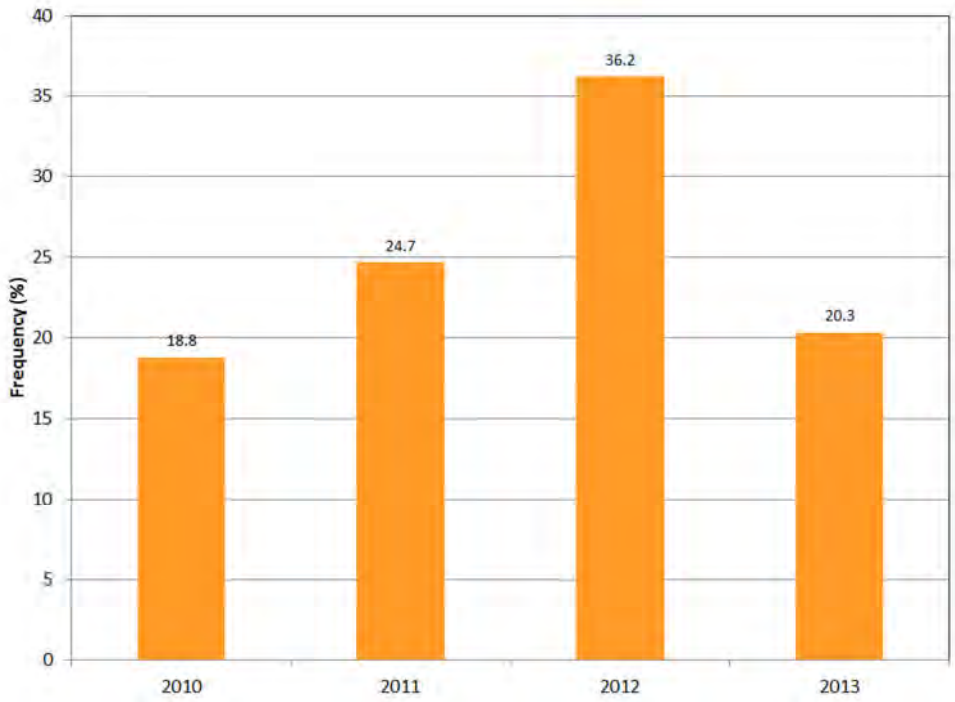


Figure 5-1 Odour complaint variation with year (Feb 11 2010 to Sep 30 2013)

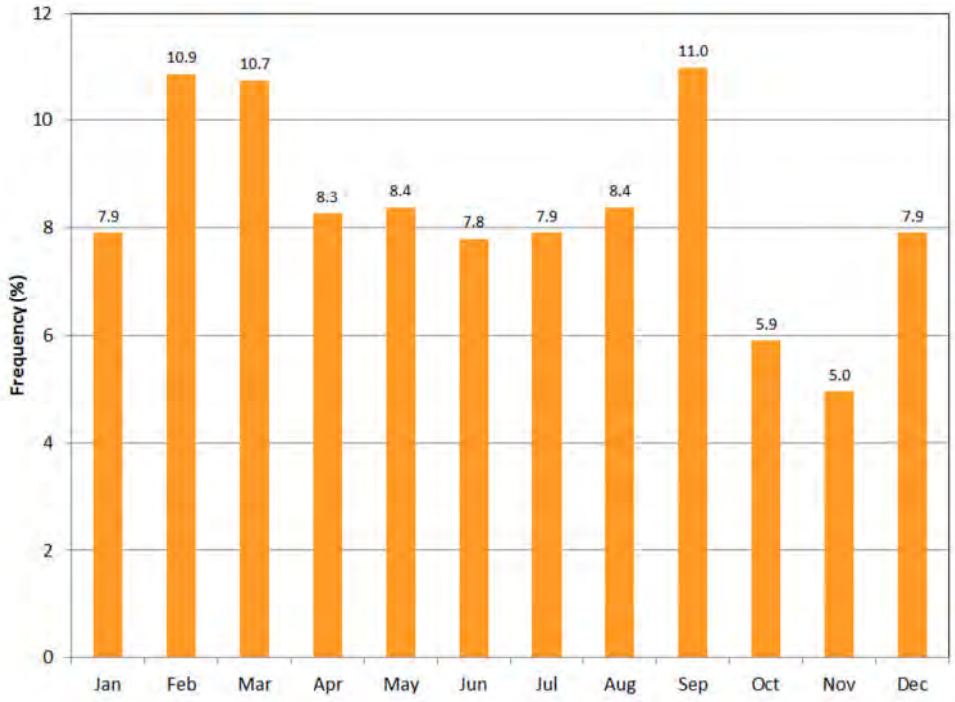


Figure 5-2 Odour complaint variation with month (Feb 11 2010 to Sep 30 2013)

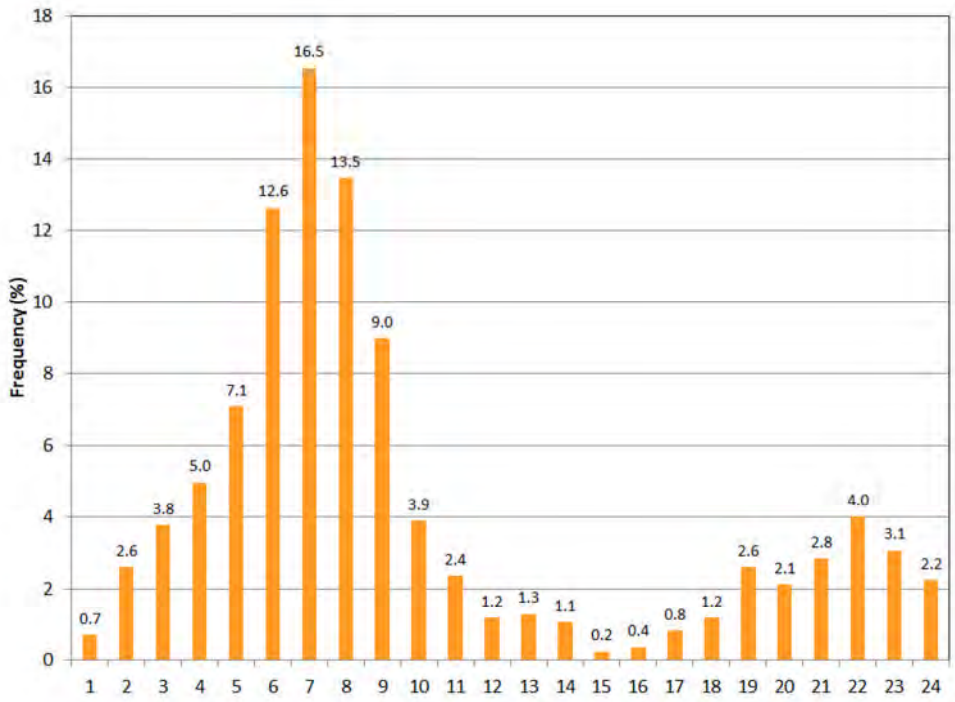


Figure 5-3 Odour complaint variation with time of day (Feb 11 2010 to Sep 30 2013)

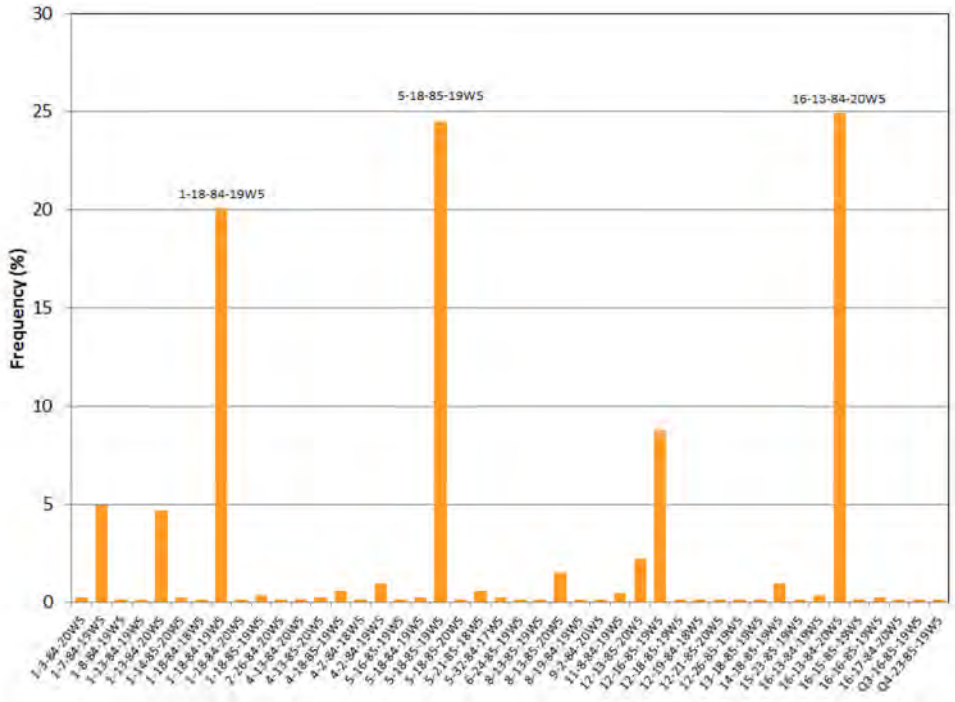


Figure 5-4 Odour complaint variation with location (Feb 11 2010 to Sep 30 2013)

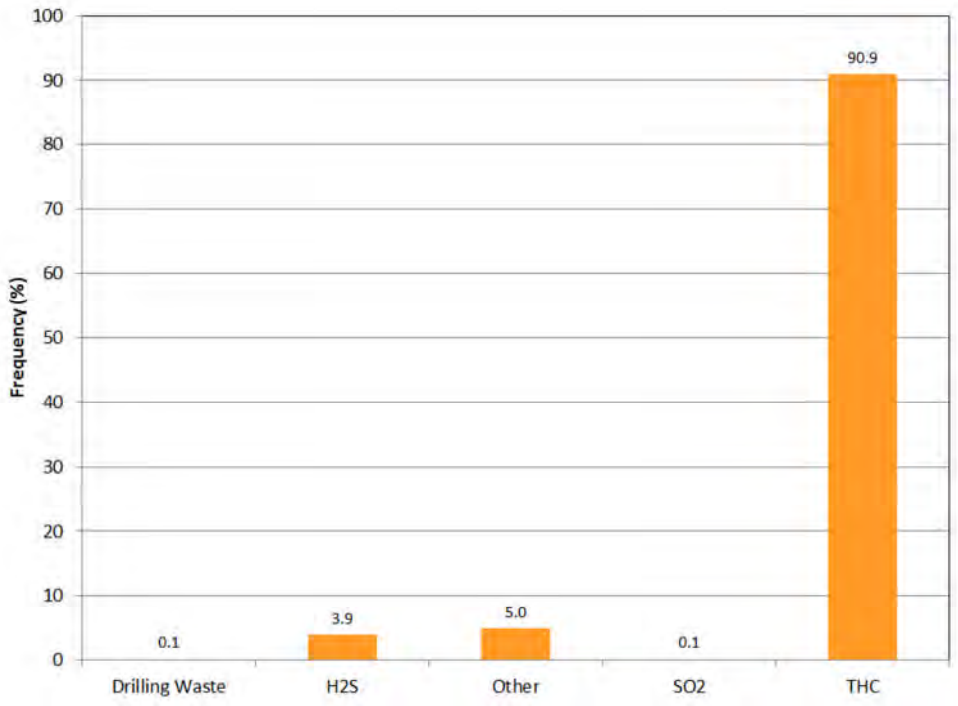
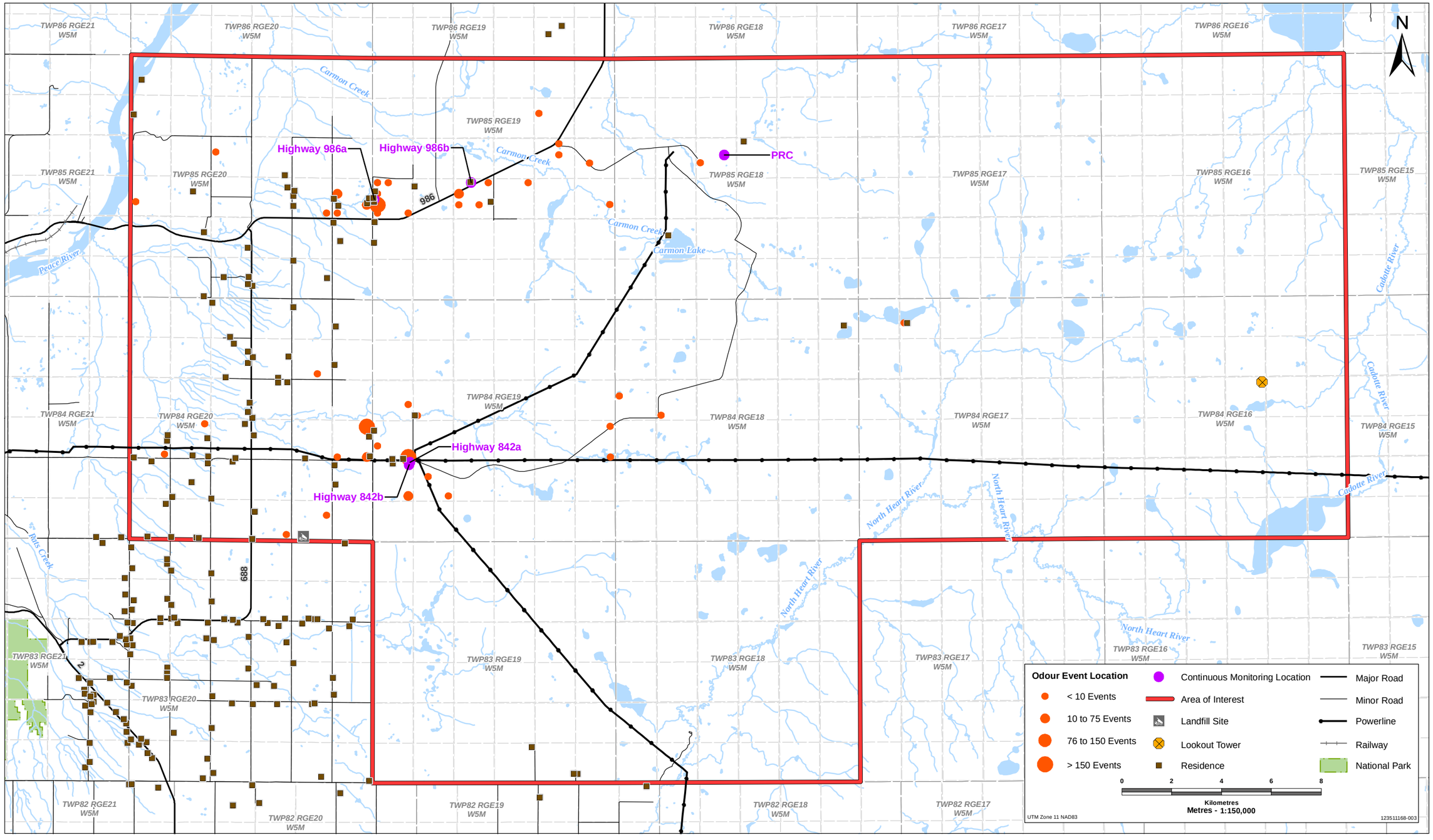


Figure 5-5 Odour complaint variation with odour type (Feb 11 2010 to Sep 30 2013)



THREE CREEKS MONITORING

Location of Odour Events

Acknowledgements: Original Drawing By Stantec, Basedata: Altalis, Canvec, National Road Network

PREPARED BY

Stantec

FIGURE NO

5-6

Last Modified: 4/2/2014 By: cstefner

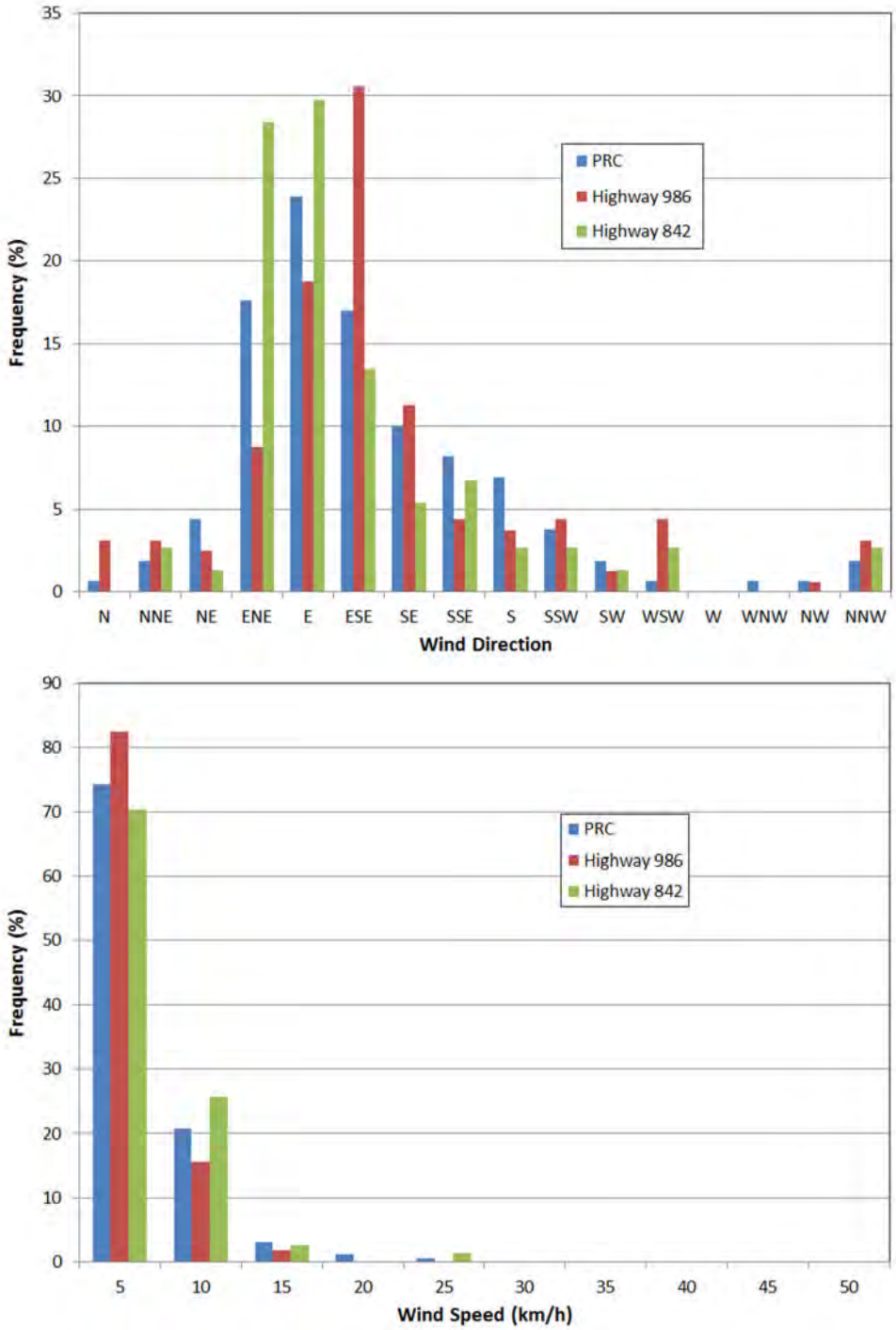


Figure 5-7 Site 8 (1-18-84-19W5) odour complaint trends with wind direction and wind speed (nearest station = Highway 842 (Green Bar))

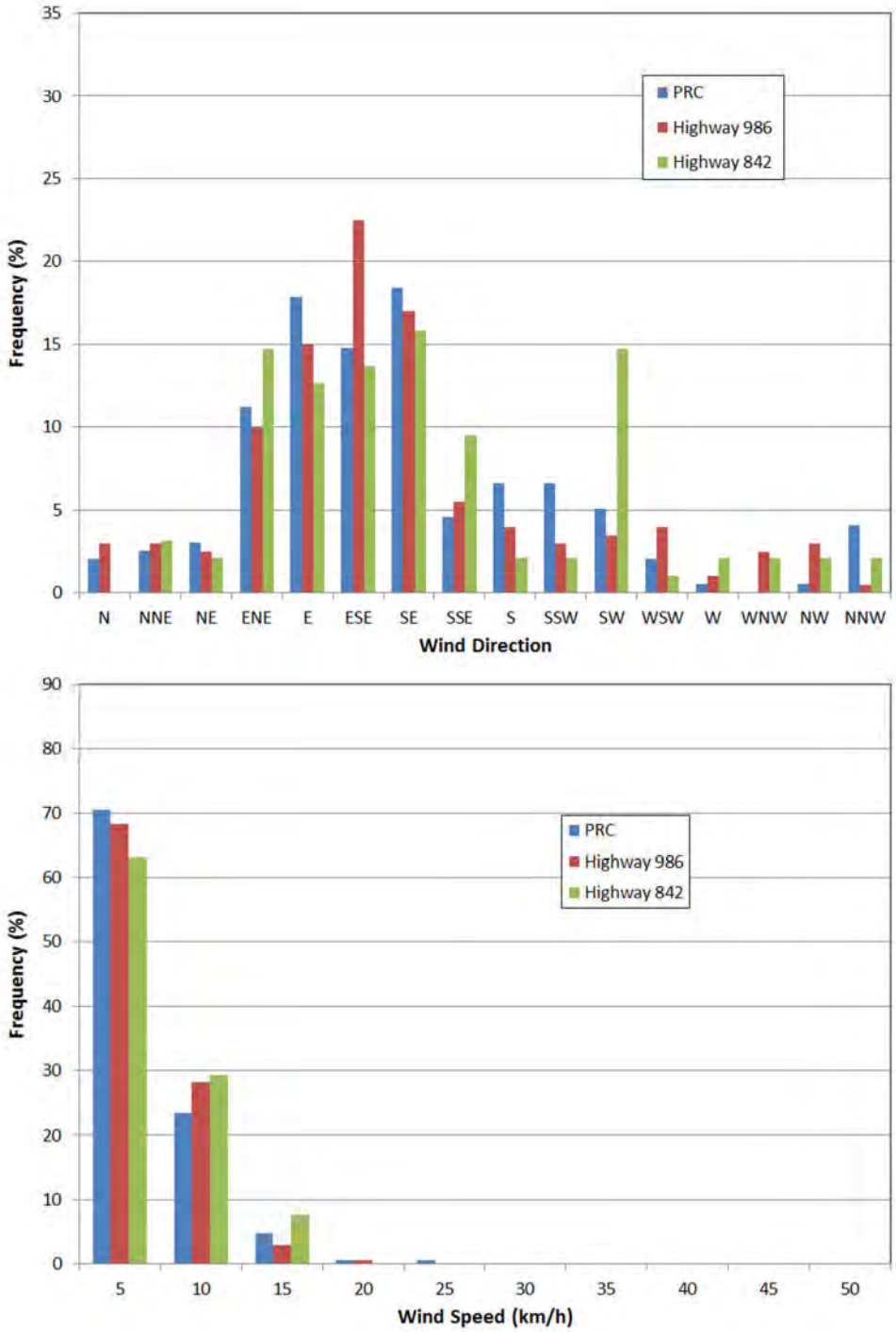


Figure 5-8 Site 19 (5-18-85-19W5) odour complaint trends with wind direction and wind speed (nearest station = Highway 986 (Red Bar))

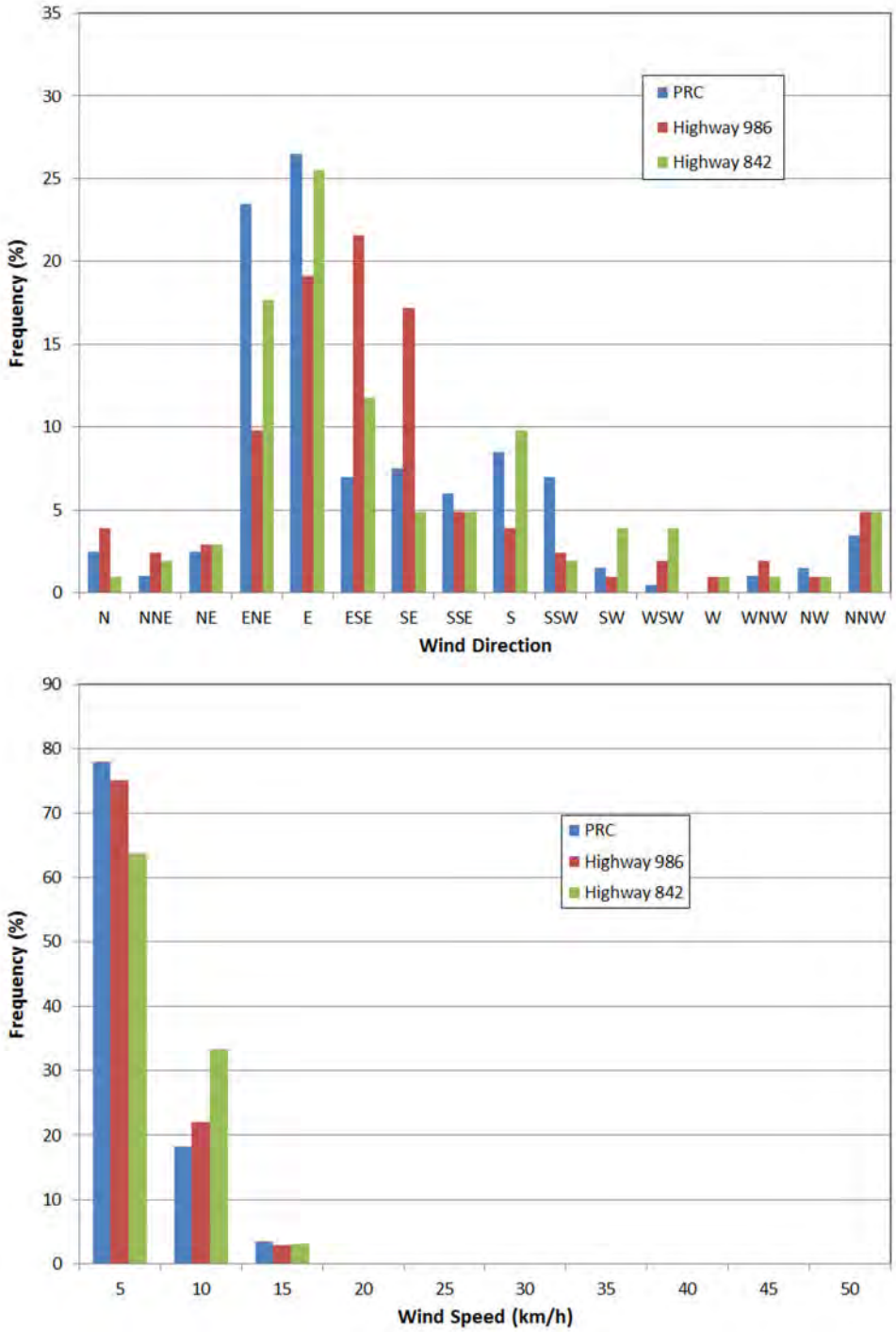
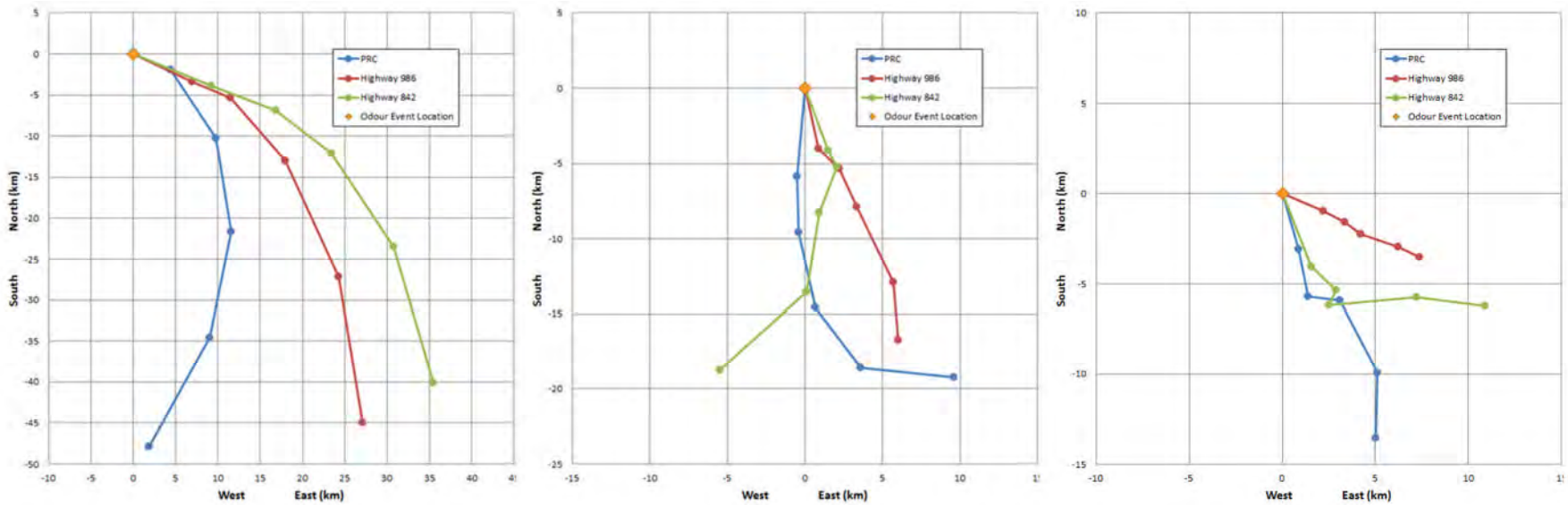


Figure 5-9 Site 39 (16-13-84-20W5) odour complaint trends with wind direction and wind speed (nearest station = Highway 842 (Green bar))

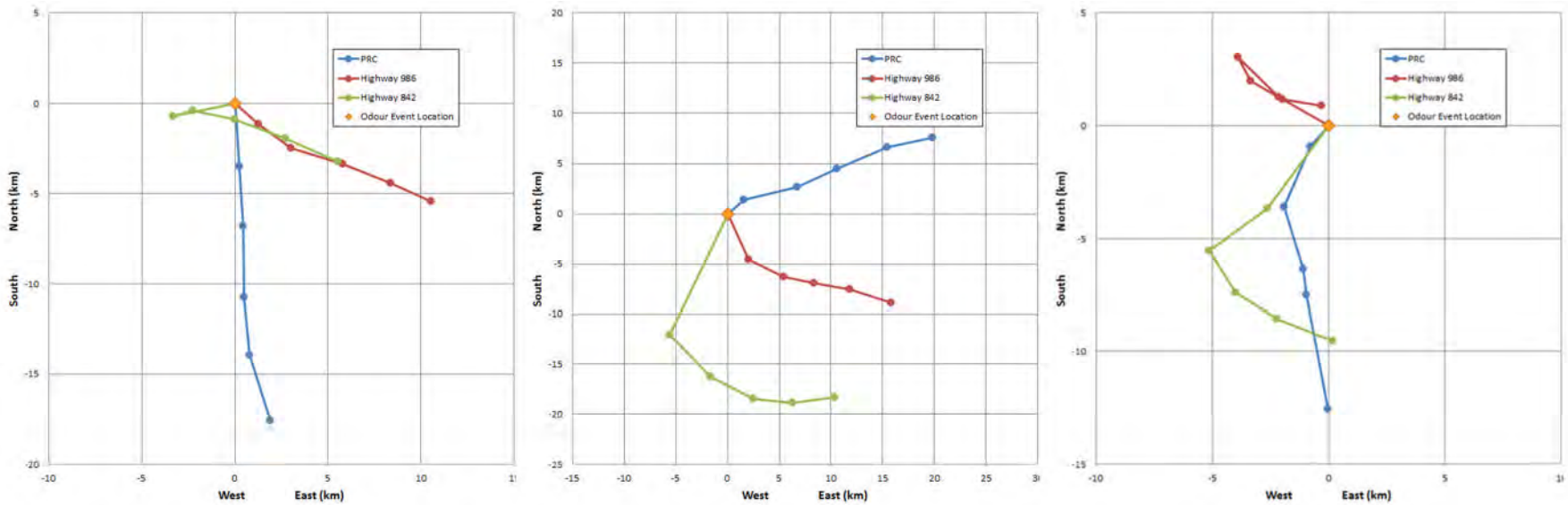


Odour complaint: (Site 8) 1-18-84-19W5
Period: 4/2/12 20:21

Odour complaint: (Site 8) 1-18-84-19W5
Period: 5/31/13 22:00

Odour complaint: (Site 8) 1-18-84-19W5
Period: 6/22/13 6:30

Figure 5-10 Back trajectories for three odour complaints at Site 8 (nearest station = Highway 842 (Green Trajectory)). The coordinates of the odour complaint location is (0,0).

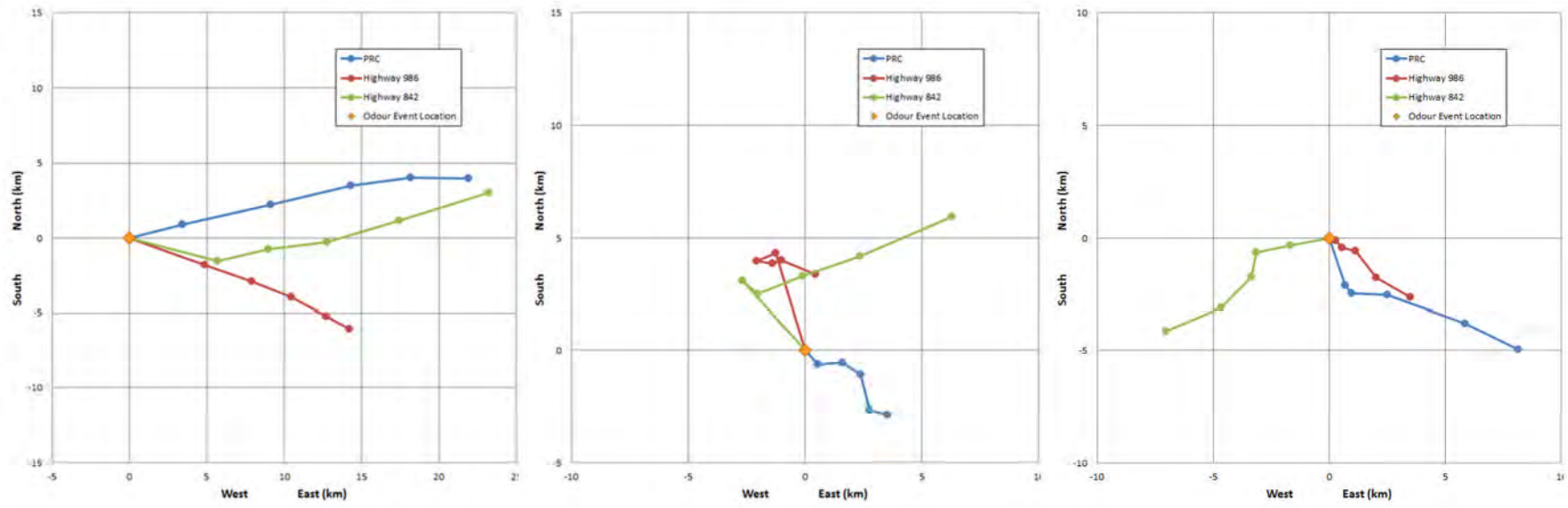


Odour complaint: (Site 19) 5-18-85-19W5
Period: 4/7/12 7:55

Odour complaint: (Site 19) 5-18-85-19W5
Period: 4/20/12 8:00

Odour complaint: (Site 19) 5-18-85-19W5
Period: 4/22/12 9:10

Figure 5-11 Back trajectories for three odour complaints at Site 19 (nearest station = Highway 986 (Red Trajectory)). The coordinates of the odour complaint location is (0,0).



Odour complaint: (Site 19) 5-18-85-19W5

Period: 4/23/12 7:51

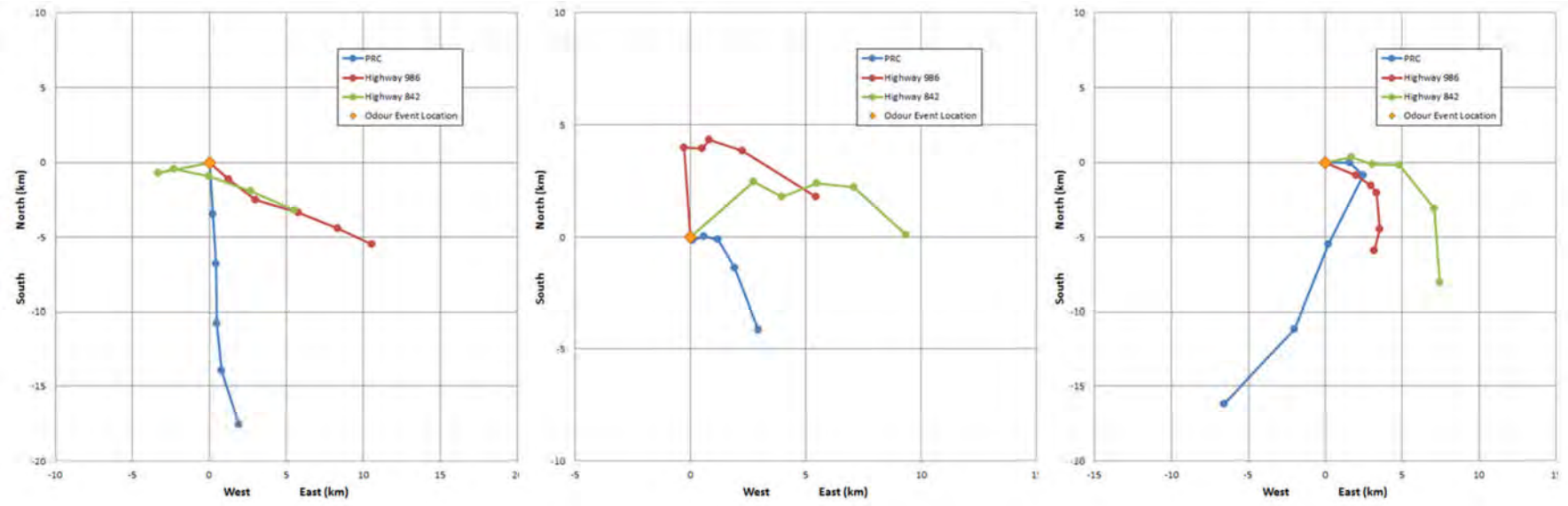
Odour complaint: (Site 19) 5-18-85-19W5

Period: 5/25/12 7:35

Odour complaint: (Site 19) 5-18-85-19W5

Period: 6/3/12 5:00

Figure 5-12 Back trajectories for three odour complaints at Site 19 (nearest station = Highway 986 (Red Trajectory)). The coordinates of the odour complaint location is (0,0).



Odour complaint: (Site 39) 16-13-84-20W5
Period: 4/7/12 7:10

Odour complaint: (Site 39) 16-13-84-20W5
Period: 5/24/12 7:11

Odour complaint: (Site 39) 16-13-84-20W5
Period: 8/31/12 21:20

Figure 5-13 Back trajectories for three odour complaints at Site 39 (nearest station = Highway 842 (Green Trajectory)). The coordinates of the odour complaint location is (0,0).

Odour complaints
May 2014

6.0 Passive Monitoring

Industry is typically required to deploy passive monitors as part of the respective EPEA approvals issued by ESRD. The approvals specify what is to be monitored and the number of required sampling sites. The passive samplers are deployed and collected on a calendar month basis, and therefore provide monthly average ambient concentration measurements. The samplers are shipped to a laboratory for analysis to determine the associated ambient concentrations. The values are reported in concentration units of parts per billion by volume (i.e., ppb) as follows:

- For SO_2 concentrations, the values are typically reported to the nearest 0.1 ppb and the associated reportable detection limit is 0.1 ppb.
- For H_2S concentrations, the values are typically reported to the nearest 0.01 ppb and the associated reportable detection limit is 0.02 ppb.
- For NO_2 concentrations, the values are typically reported to the nearest 0.1 ppb and the associated reportable detection limit is 0.1 ppb.

As passive samplers are relatively inexpensive, they are used to determine temporal and spatial trends. Since the measurements represent monthly averages, they do not directly convey any information with respect to higher peak concentrations that could occur for shorter time periods (e.g., peak 1-h or peak 24-h averages). Passive sampling data were obtained from industry and examined.

6.1 PASSIVE MONITORING SITES

6.1.1 PRC Sites

The longest period of record (i.e., 93 months or 7.75 years of data) is associated with the Shell Peace River Complex (PRC), which is one of the older operations in the region. Ambient SO_2 and H_2S concentrations are measured at 12 sites near the PRC:

- Sites 3 and 7 are the nearest to the PRC central plant facility (CPF).
- Sites 11, 12, and 14 are the furthest west and northwest of the PRC CPF.
- Site 9 is the furthest to the east of the PRC CPF.

Figure 6-1 shows the locations of these passive monitoring sites.

6.1.2 Other Sites

Passive ambient air quality data are also collected by other industry members as follows:

- Shell Cliffdale with 17 months of SO_2 and H_2S measurements at 1 site.
- Baytex Cliffdale with 16 months of SO_2 and H_2S measurements at 4 sites.
- Penn West Harmon Valley with 4 months of SO_2, H_2S and NO_2 measurements at 4 sites.
- Penn West Seal with 4 months of SO_2, H_2S and NO_2 measurements at 3 sites.

Figure 6-1 also shows the locations of these other passive monitoring sites. The West Seal sites are not located on the map; they are about 9 km from the southern map border as indicated.

6.2 SO_2 CONCENTRATIONS

6.2.1 PRC Sites

Figure 6-2 (upper plot) shows the monthly average SO_2 concentrations for all PRC passive monitoring sites for the full 93 month period October 2005 to July 2013. Figure 6-2 (lower plot) is a simplified version showing only the monthly maxima, averages, and minima for the same period. The following are noted:

- The highest concentrations are associated with the period prior to mid-2009 and the lowest concentrations with the period after mid-2010. The decrease is associated with emission reduction initiatives undertaken by Shell during the 2009-2010 period (including the addition of the Cliffdale Gas Gathering System, elimination of solution gas venting, and reduction of continuous flaring).
- The <u>highest</u> SO_2 concentrations were associated with <u>PRC Site 3</u> that is located nearest to the PRC CPF. SO_2 concentration statistics for this site are:
  - Maximum (Oct 2005 to Dec 2010) = 11.6 ppb
  - Average (Oct 2005 to Dec 2010) = 3.7 ppb
  - Maximum (Jan 2011 to Jul 2013) = 1.6 ppb
  - Average (Jan 2011 to Jul 2013) = 0.7 ppb.
- The <u>lowest</u> SO_2 concentrations are associated with <u>PRC Site 14</u> that is located about 5 km to the northwest of the PRC CPF. SO_2 concentration statistics for this site are:
  - Maximum (Oct 2005 to Dec 2010) = 0.9 ppb
  - Average (Oct 2005 to Dec 2010) = 0.4 ppb

- Maximum (Jan 2011 to Jul 2013) = 0.5 ppb
- Average (Jan 2011 to Jul 2013) = 0.3 ppb.

Relative to the PRC, Site 14 (the furthest north site) can be considered a background site.

Figure 6-3 (upper plot) shows the monthly average SO_2 concentrations for the 31 month period January 2011 to July 2013. Figure 6-3 (lower plot) is a corresponding simplified version showing only the monthly maxima, averages, and minima for the same period. The scale for these two figures has been changed from the previous two figures. Figure 6-3 reflects current conditions near the PRC sites.

Table 6-1 provides a summary of the maximum and annual SO_2 concentration at each PRC site for the period when the Peace River Complex was burning sour produced gas and for the period associated with the use of sweet gas. The 30-day AAAQO of 11 ppb was exceeded at one site (i.e., PRC 3) once in 2007. This is associated with the period prior to the elimination of solution gas venting by Shell. The site is located within the CPF fenceline, where AAAQO are not applied.

The corresponding values are plotted against downwind distance from the CPF in graphical format in Figure 6-4. The concentration decrease with increasing distance is substantive with background levels of about 0.3 ppb occurring at about five kilometers from the CPF.

6.2.2 Other Sites

Table 6-2 shows the maximum and average SO_2 concentrations measured at the other sites. Figure 6-5 shows the monthly average SO_2 concentrations for the Shell Cliffdale and the Baytex Cliffdale monitoring sites, and Figure 6-6 shows the monthly average SO_2 concentration plots for the Harmon Valley and Seal monitoring sites. The following are noted:

- The maximum SO_2 concentration statistics are similar to those associated with the PRC passive sites after the Peace River Complex switched to a sweet fuel gas.

- The average SO_2 concentrations are similar to the background value that was associated with the PRC sites (i.e., ~0.3 ppb).

On average, the ambient SO_2 concentrations at these locations are low relative to the 30-day AAAQO of 11 ppb for SO_2.

6.3 H_2S CONCENTRATIONS

6.3.1 PRC Sites

Figure 6-7 (upper plot) shows the monthly average H_2S concentrations for all PRC passive monitoring sites for the full 93 month period October 2005 to July 2013. Figure 6-7 (lower plot) is a

simplified version showing only the monthly maxima, averages, and minima for the same period. The following are noted:

- The highest concentrations are associated with the period prior to mid-2009 and the lowest concentrations with the period after mid-2010. The decrease is associated with the elimination of solution gas venting.

- The highest H_2S concentrations were associated with PRC Sites 3 and 4 that are located near the PRC CPF. H_2S concentration statistics for these sites are:

  - Maximum (Oct 2005 to Dec 2010) = 3.53 ppb (Site 3) and 3.88 ppb (Site 4)
  - Average (Oct 2005 to Dec 2010) = 1.12 ppb (Site 3) and 0.49ppb (Site 4)
  - Maximum (Jan 2011 to Jul 2013) = 0.64 ppb (Site 3) and 1.15 ppb (Site 4)
  - Average (Jan 2011 to Jul 2013) = 0.20 ppb(Site 3) and 0.30 ppb (Site 4)

- The lowest H_2S concentrations are associated with PRC Site 9 that is located about 5 km to the northeast of the PRC CPF. H_2S concentration statistics for this site are:

  - Maximum (Oct 2005 to Dec 2010) = 0.32 ppb
  - Average (Oct 2005 to Dec 2010) = 0.16 ppb (and 0.14 ppb at Site 14)
  - Maximum (Jan 2011 to Jul 2013) = 0.22 ppb
  - Average (Jan 2011 to Jul 2013) = 0.13 ppb

  Relative to the PRC, Site 9 (the furthest east site) can be considered a background site.

Figure 6-8 (upper plot) shows the monthly average H_2S concentrations for the 31 month period January 2011 to July 2013. Figure 6-8 (lower plot) is a corresponding simplified version showing only the monthly maxima, averages, and minima for the same period. The scale for these two figures has been changed from the previous two figures. Figure 6-8 reflects current conditions near the PRC.

Table 6-3 provides a summary of the maximum and annual H_2S concentration at each PRC site for the period when the Peace River Complex was burning sour produced gas and for the period associated with the use of sweet gas. The corresponding values are plotted against downwind distance from the CPF in graphical format in Figure 6-9. The higher values tend to occur near the CPF and decrease with increasing distance from the CPF. The concentration decrease with increasing distance is substantive with background levels of about 0.15 ppb occurring at about five kilometers from the CPF.

6.3.2 Other Sites

Table 6-4 shows the maximum and average H_2S concentrations measured at the other sites. Figure 6-10 shows the monthly average H_2S concentrations for the Shell Cliffdale and the Baytex Cliffdale monitoring sites, and Figure 6-11 shows the monthly average H_2S concentration plots for the Harmon Valley and Seal monitoring sites. The following are noted:

- The maximum H_2S concentration statistics are similar to those associated with the PRC passive sites after the Peace River Complex switched to a sweet fuel gas.

- The average H_2S concentrations are similar to the background value that was associated with the PRC sites (i.e., ~0.15 ppb).

There are no 30-day ambient benchmarks for H_2S.

6.4 NO_2 CONCENTRATIONS

Ambient NO_2 concentrations are only measured at the Baytex Cliffdale and the Harmon Valley monitoring Sites. The maximum and average values are provided in Figure 6-12 and Table 6-5. Depending on the site, the maximum NO_2 concentrations tend to be in the 0.9 to 5.3 ppb range with an overall average of 1.4 ppb. While there are no 30-day ambient benchmarks for NO_2, the annual AAAQO is 24 ppb. The measurements therefore indicate low NO_2 concentrations at these sites.

6.5 FINDINGS

Passive monitors have been deployed in the region to measure air quality on a monthly average basis. On this basis, passive monitoring is limited in providing indicators of shorter-term (i.e., ~ 1-hour to 1-day) exposures. The passive monitors are relatively easy to deploy since they do not require electrical power or substantive real estate to establish a monitoring network.

The passive data collected in the region demonstrates the ability of the passive monitors to identify temporal trends (e.g., the long term PRC monitoring show decreased concentrations when low sulphur fuel gas was adopted) and spatial trends (e.g., the PRC stations show decreased concentrations with increasing distance from an emission source). Comparison of the longer term PRC monitors with the more recent shorter term monitors indicate that the concentrations associated with the more recent monitors are low. That is, the monthly average SO_2 and H_2S concentrations are typically about 0.3 and 0.15 ppb, respectively.

6.6 GAPS AND RECOMMENDATIONS

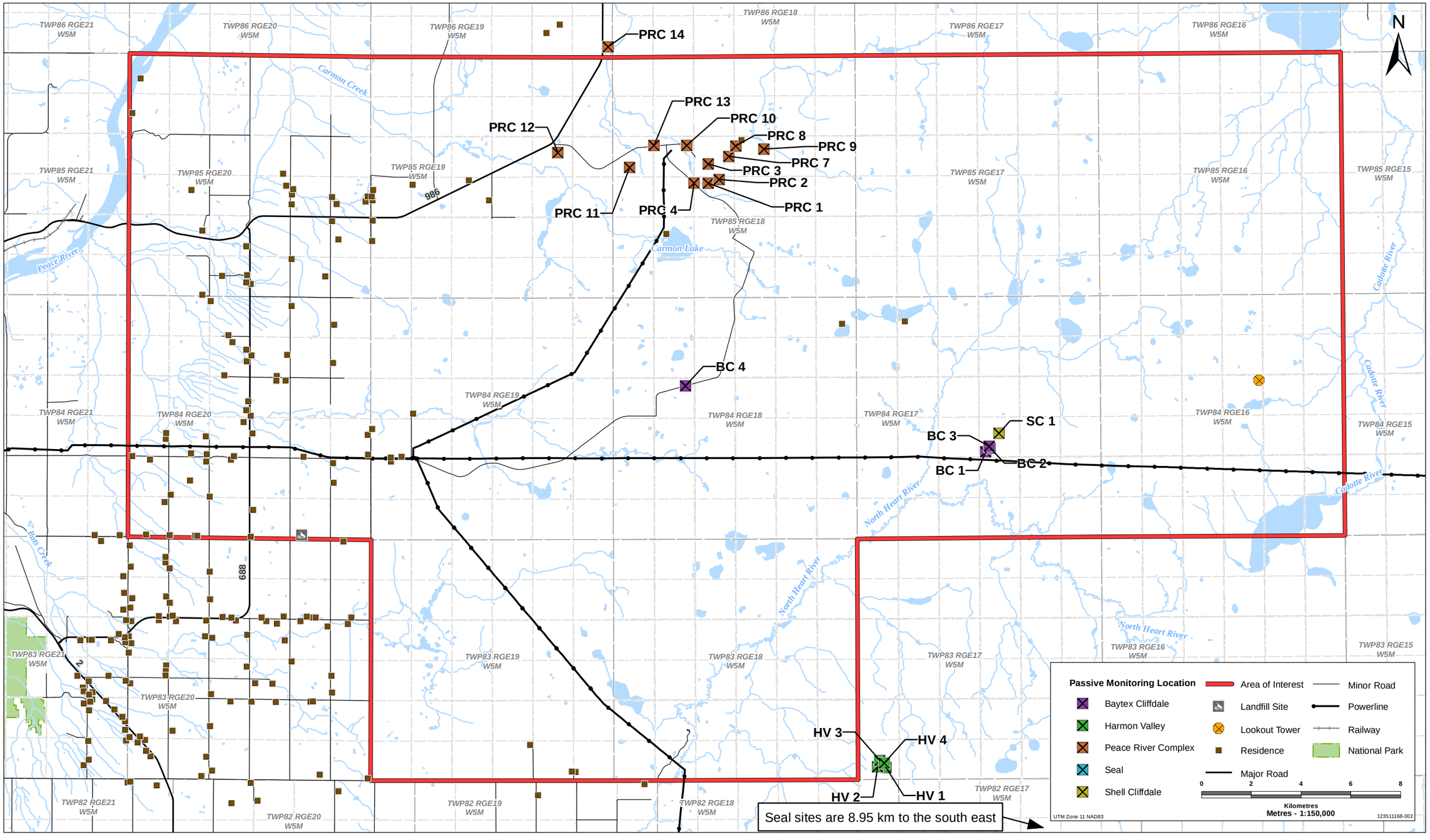
The following preliminary gaps and recommendations focusing on the passive monitoring are as follows:

- **Gap/Recommendation P1:** The primary passive monitoring focuses on SO_2 and H_2S to meet EPEA approval requirements. The associated concentrations were examined and were found to be very low. The main stakeholder issue in the region is associated with hydrocarbon emissions. For this reason, a passive monitoring program associated with VOC samples is recommended.

  Passive VOC sampling was conducted for the WISSA cattle health study (Davies et al 2006). The VOC samplers were deployed for nominal 30 day exposure periods, and the samples were analyzed for a suite of 26 compounds. The same laboratory that analyzed the WISSA passive VOC samplers (AirZone One) has since extended the list to 46 compounds (see Table 6-6).

  The VOC sampling sites would not be identical to the existing passive monitoring sites. The deployment of passive VOC samplers should be in the region where potential emission sources are located and in the region where the residents are located. Representative background site(s) distant from any nearby sources is recommended. The source region locations can be better selected when the Clearstone (2014) inventory has been completed.

- **Gap/Recommendation P2:** Duplicate and field blank samples for the VOC samplers need to be taken to provide a measure of the detection limits and the uncertainty of the sample measurement. Typically, 10% of the samples would fall into this category.



THREE CREEKS MONITORING

Location of Passive Monitoring Sites

Acknowledgements: Original Drawing By Stantec, Basedata: Altalis, Canvec, National Road Network

PREPARED BY

Stantec

FIGURE NO.

6-1

Last Modified: 4/2/2014 By: cstamer

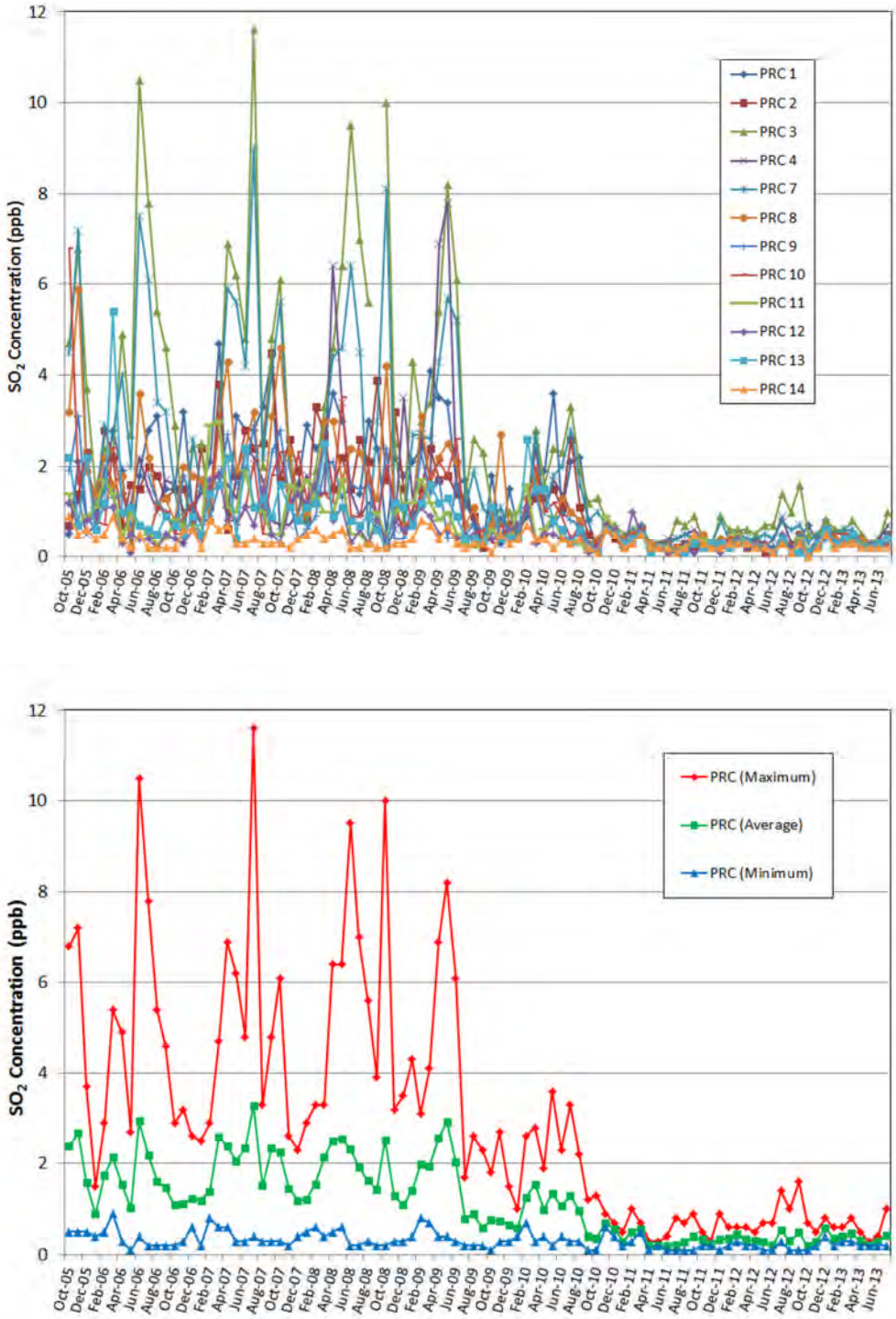


Figure 6-2 Monthly average SO_2 concentrations at the 12 Shell PRC passive monitoring sites (October 2005 to July 2013)

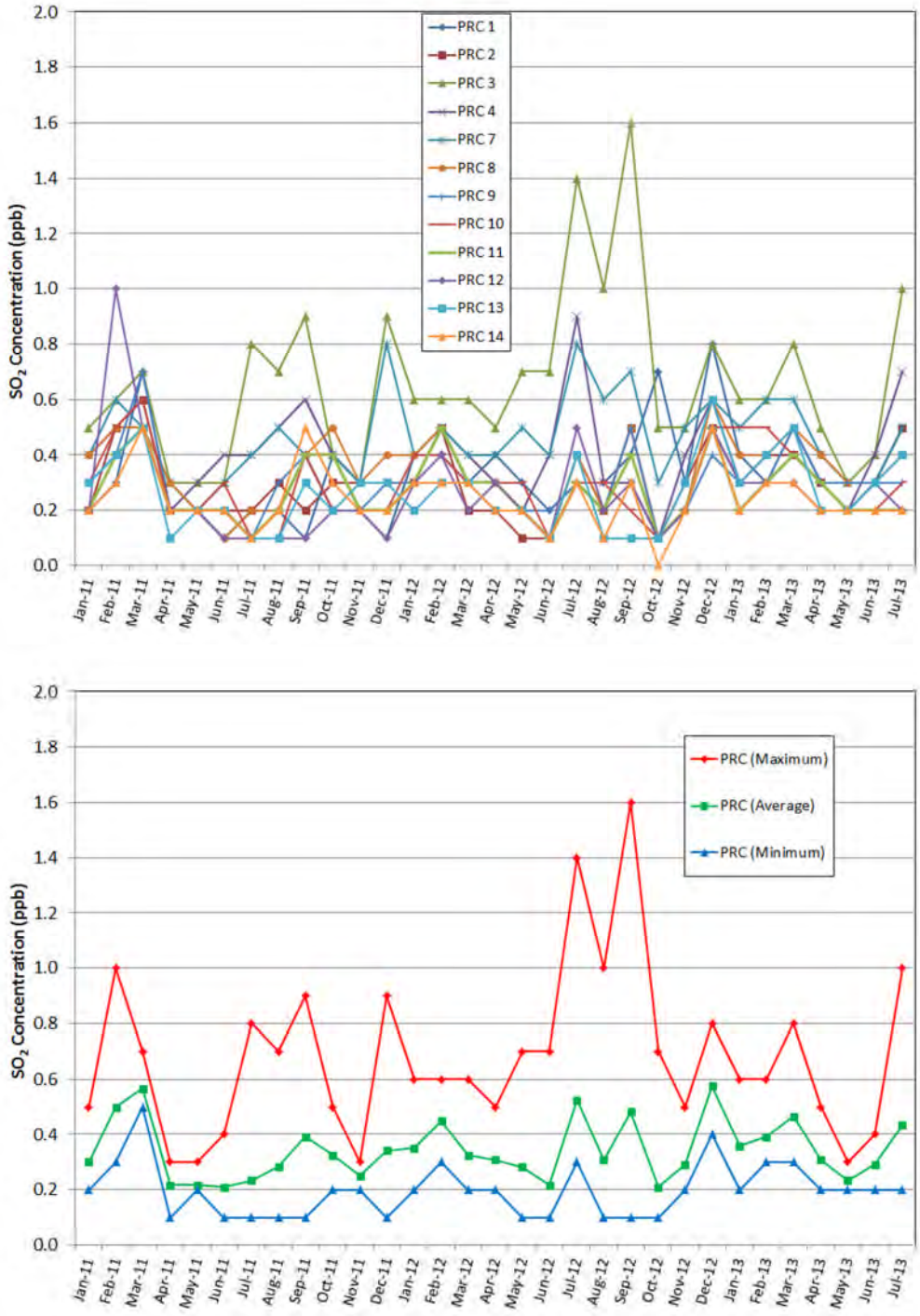


Figure 6-3 Monthly average SO_2 concentrations at the 12 Shell PRC passive monitoring sites (January 2011 to July 2013)

Table 6-1 Ambient SO_2 concentrations (ppb) measured at the PRC sites

Monitoring Site	October 2005 to Dec 2010		Jan 2011 to Jul 2103	
	Maximum	Average	Maximum	Average
PRC 1	4.7	1.9	0.8	0.3
PRC 2	4.5	1.6	0.6	0.3
PRC 3	11.6	3.7	1.6	0.7
PRC 4	7.8	1.5	0.9	0.4
PRC 7	9.0	2.9	0.8	0.5
PRC 8	5.9	1.8	0.6	0.3
PRC 9	3.1	1.2	0.7	0.3
PRC 10	6.8	1.3	0.6	0.3
PRC 11	3.0	0.9	0.5	0.3
PRC 12	2.5	0.7	1.0	0.3
PRC 13	5.4	1.1	0.6	0.3
PRC 14	0.9	0.4	0.5	0.3
All (max)	**11.6**	**3.7**	**1.6**	**0.7**
All (Mean)	**5.4**	**1.6**	**0.8**	**0.3**
NOTE: Detection limit = 0.1 ppb				

Table 6-2 Ambient SO_2 concentrations (ppb) measured at the other sites

Monitoring Site	Maximum	Average
Shell Cliffdale	0.5	0.2
Baytex BC 1	0.5	0.3
Baytex BC 2	0.5	0.3
Baytex BC 3	0.5	0.2
Baytex BC 4	0.9	0.4
Penn West HV 1	0.4	0.3
Penn West HV 2	0.3	0.3
Penn West HV 3	0.3	0.3
Penn West HV 4	0.4	0.3
Penn West S 1	0.5	0.4
Penn West S 2	0.5	0.5
Penn West S 3	0.4	0.4
Penn West S 4	0.3	0.3
All (max)	0.9	0.5
All (Mean)	**0.5**	**0.3**
NOTE: Detection limit = 0.1 ppb		

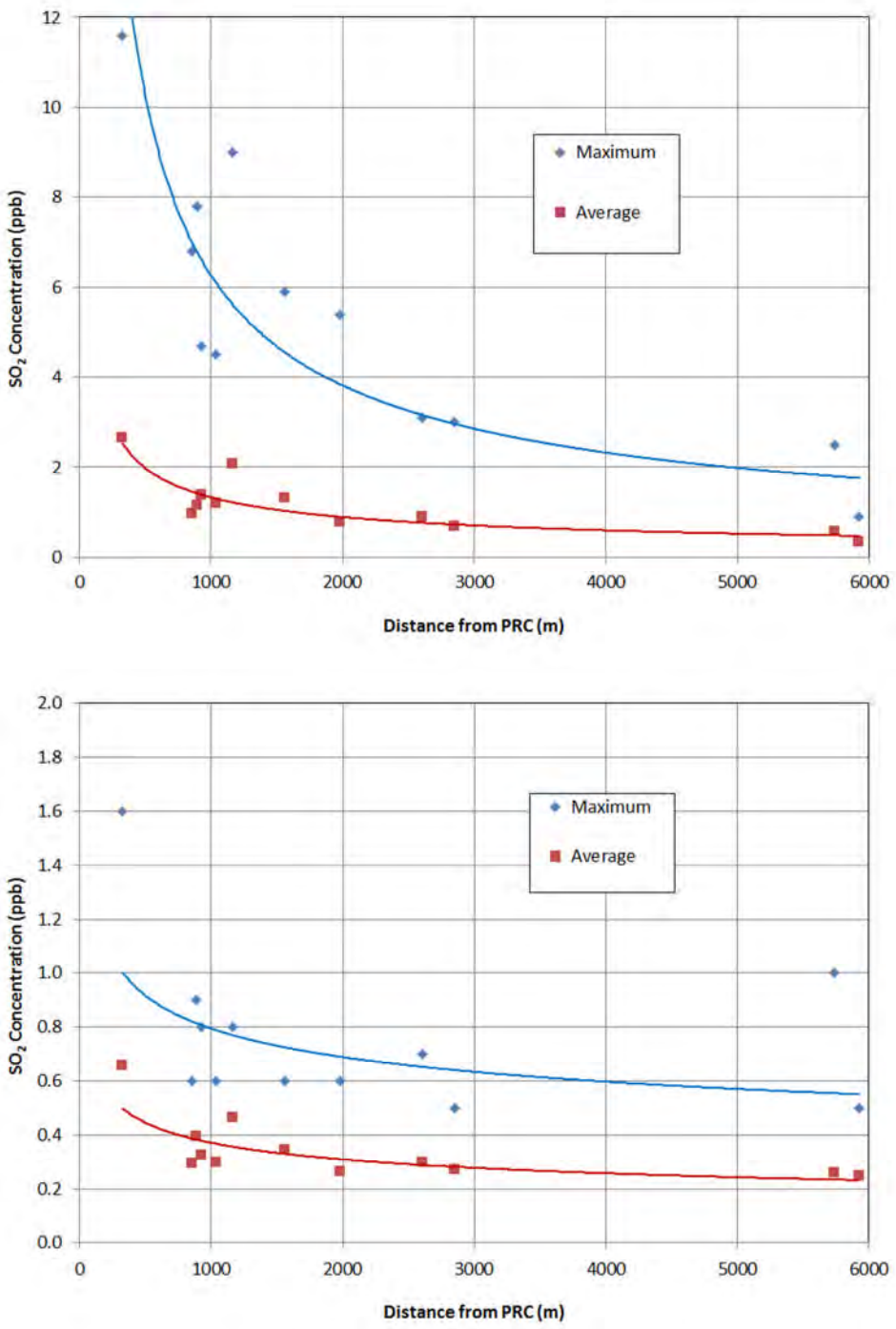


Figure 6-4 SO_2 concentration variation with distance from the PRC (Top: October 2005 to December 2010; Bottom: January 2011 to July 2013)

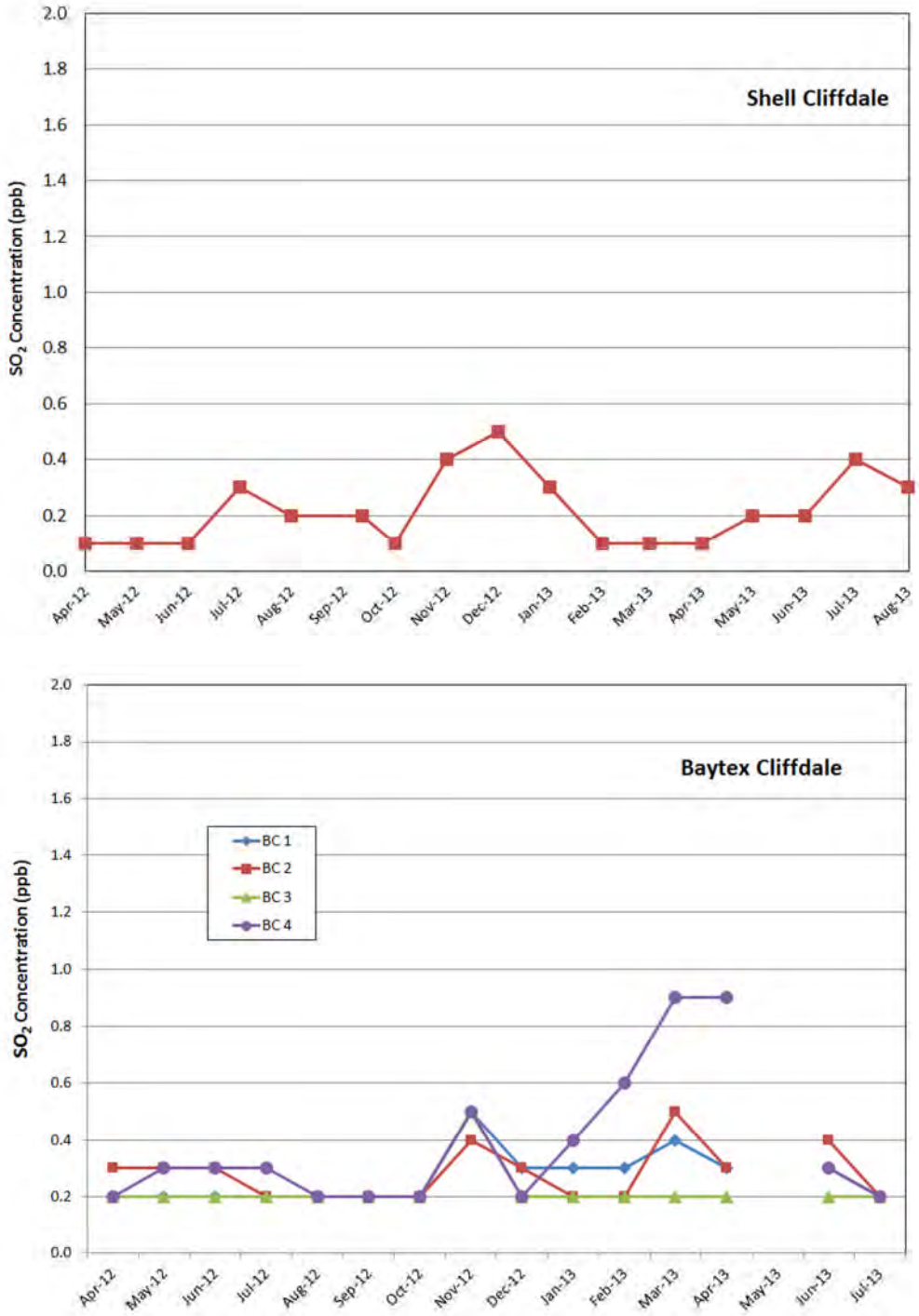
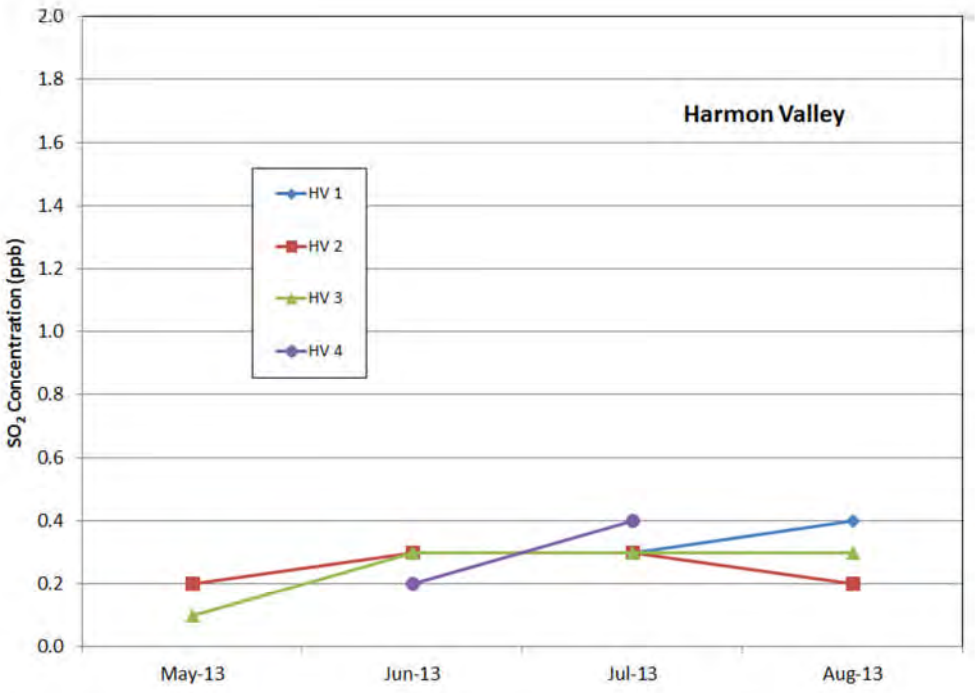


Figure 6-5 Monthly average SO_2 concentrations at the Shell Cliffdale and the Baytex Cliffdale passive monitoring sites (April 2012 to July 2013)



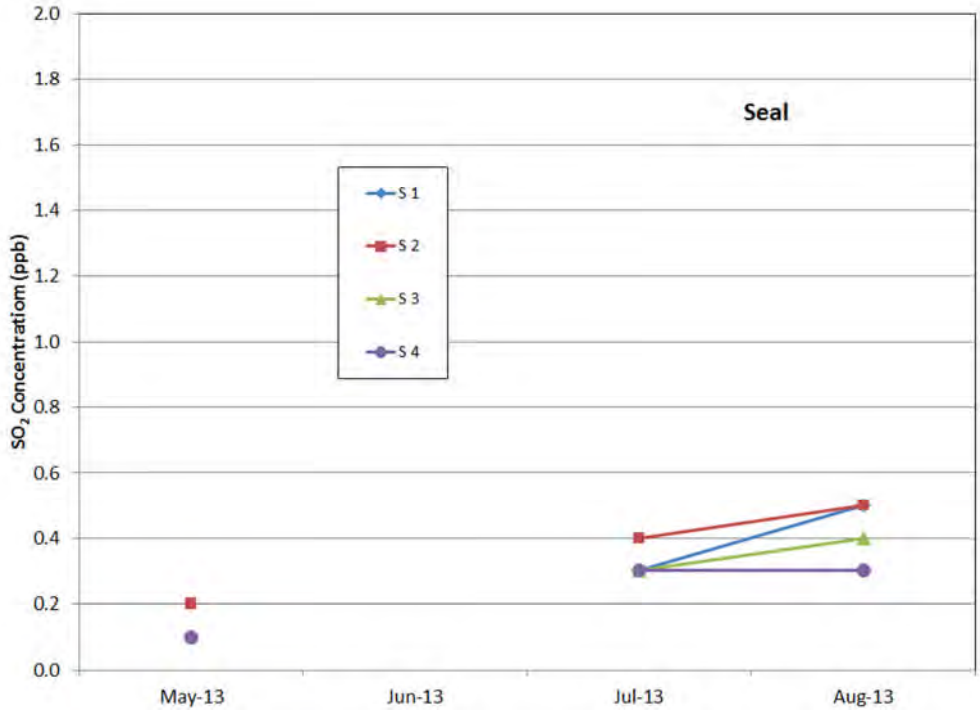
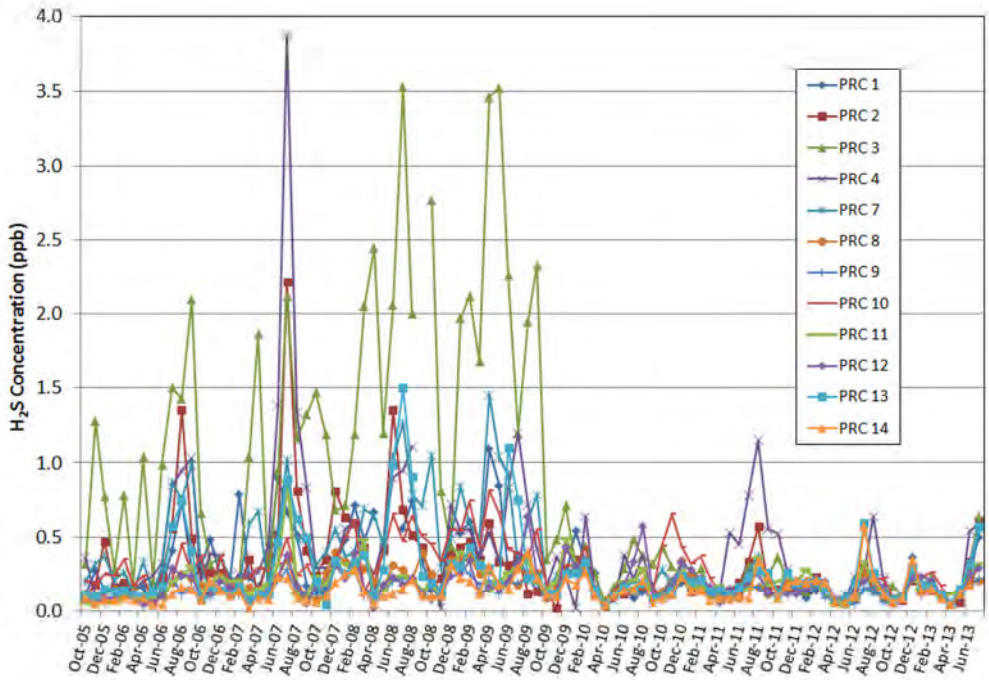


Figure 6-6 Monthly average SO_2 concentrations at the Penn West Harmon Valley and Seal passive monitoring sites (May 2013 to August 2013)



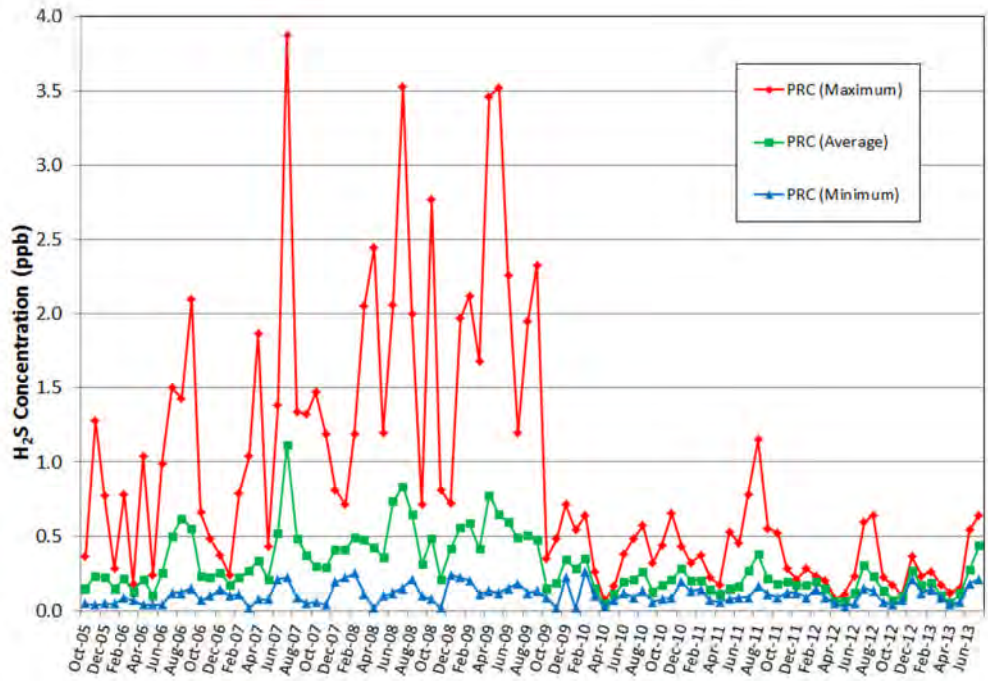


Figure 6-7 Monthly average H_2S concentrations at the 12 Shell PRC passive monitoring sites (October 2005 to July 2013)

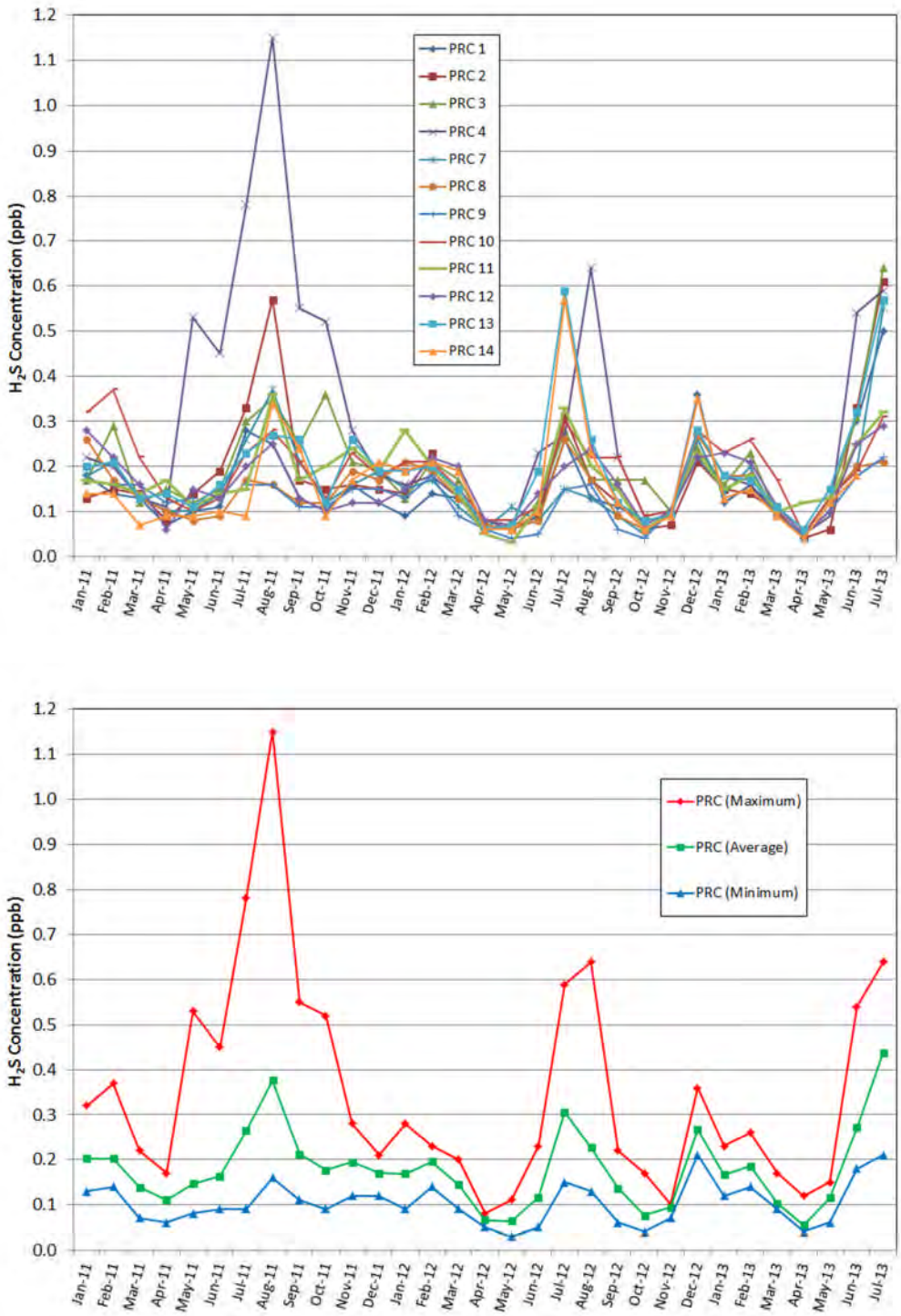


Figure 6-8 Monthly average H_2S concentrations at the 12 Shell PRC passive monitoring sites (January 2011 to July 2013)

Table 6-3 Ambient H_2S concentrations (ppb) measured to the PRC sites

Monitoring Site	October 2005 to Dec 2010		Jan 2011 to Jul 2103	
	Maximum	Average	Maximum	Average
PRC 1	1.09	0.33	0.50	0.15
PRC 2	2.22	0.37	0.61	0.18
PRC 3	3.53	1.12	0.64	0.20
PRC 4	3.88	0.49	1.15	0.30
PRC 7	1.45	0.47	0.55	0.16
PRC 8	0.40	0.20	0.27	0.14
PRC 9	0.32	0.16	0.22	0.13
PRC 10	0.81	0.34	0.37	0.19
PRC 11	0.88	0.21	0.36	0.17
PRC 12	0.64	0.19	0.29	0.16
PRC 13	1.50	0.30	0.59	0.20
PRC 14	0.39	0.14	0.57	0.16
All (max)	**3.88**	**1.12**	**1.15**	**0.30**
All (Mean)	**1.43**	**0.36**	**0.51**	**0.18**

NOTE:
Detection Limit = 0.02 ppb

Table 6-4 Ambient H_2S concentrations (ppb) measured at the other sites

Monitoring Site	Maximum	Average
Shell Cliffdale	0.31	0.13
Baytex BC 1	0.29	0.10
Baytex BC 2	0.88	0.19
Baytex BC 3	0.31	0.08
Baytex BC 4	0.52	0.22
Penn West HV 1	0.17	0.15
Penn West HV 2	0.13	0.13
Penn West HV 3	0.14	0.13
Penn West HV 4	0.18	0.18
Penn West S 1	0.17	0.14
Penn West S 2	0.19	0.15
Penn West S 3	0.25	0.21
Penn West S 4	0.15	0.13
All (max)	**0.88**	**0.22**
All (Mean)	**0.33**	**0.15**
NOTE: Detection Limit = 0.02 ppb		

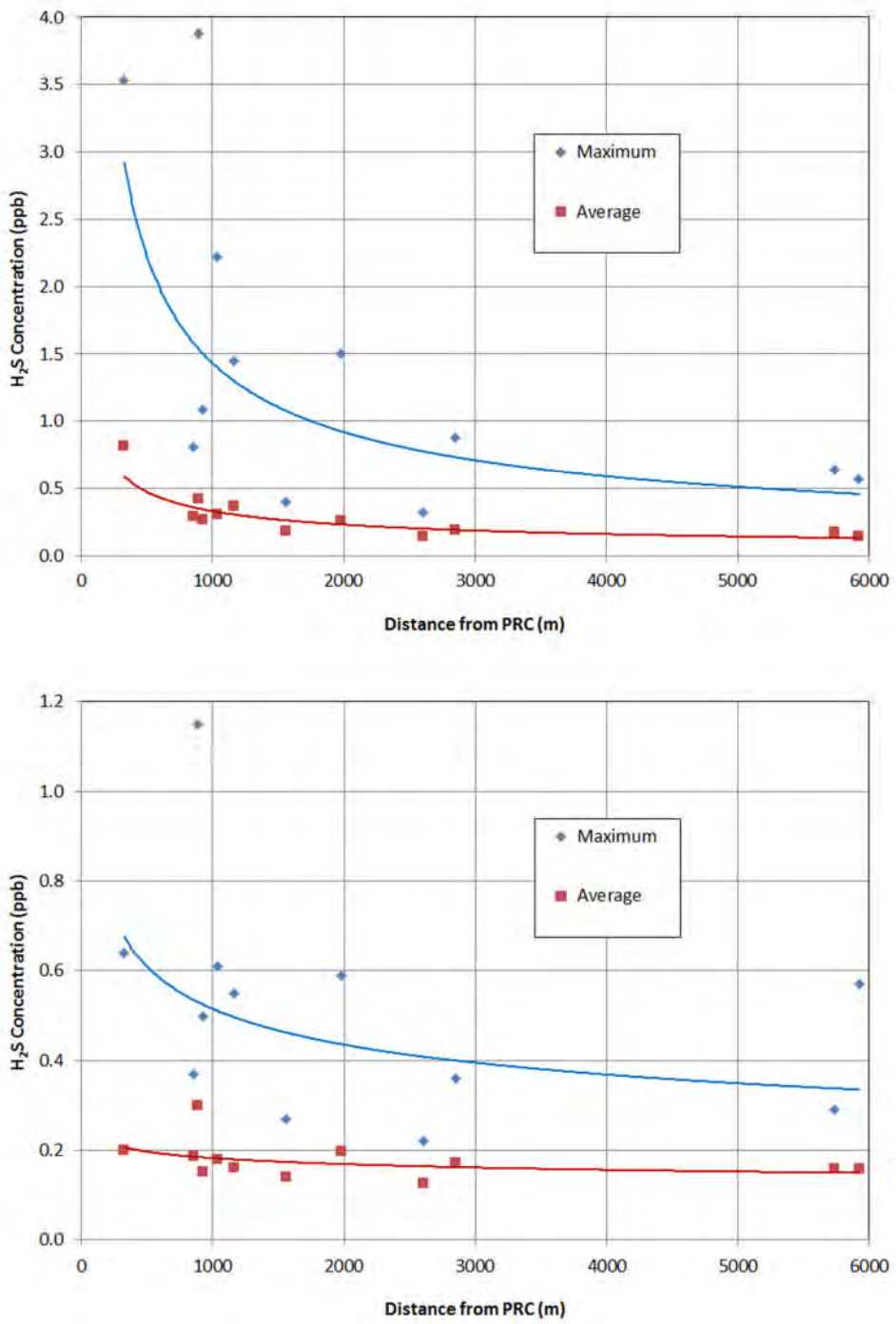
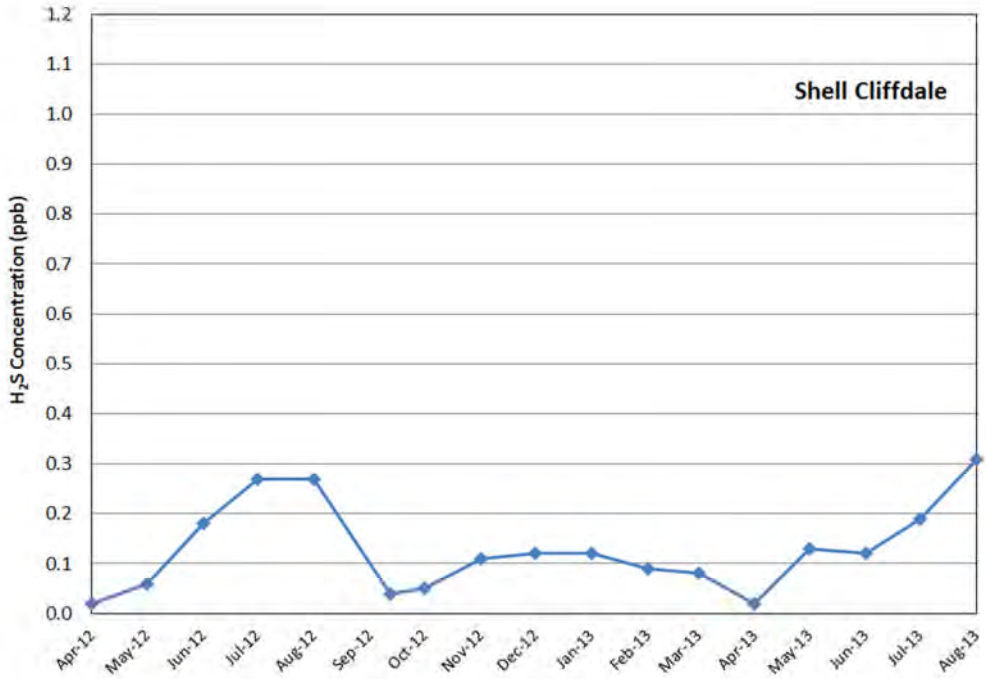


Figure 6-9 H_2S concentration variation with distance from the PRC (Top: October 2005 to December 2010; Bottom: January 2011 to July 2013)



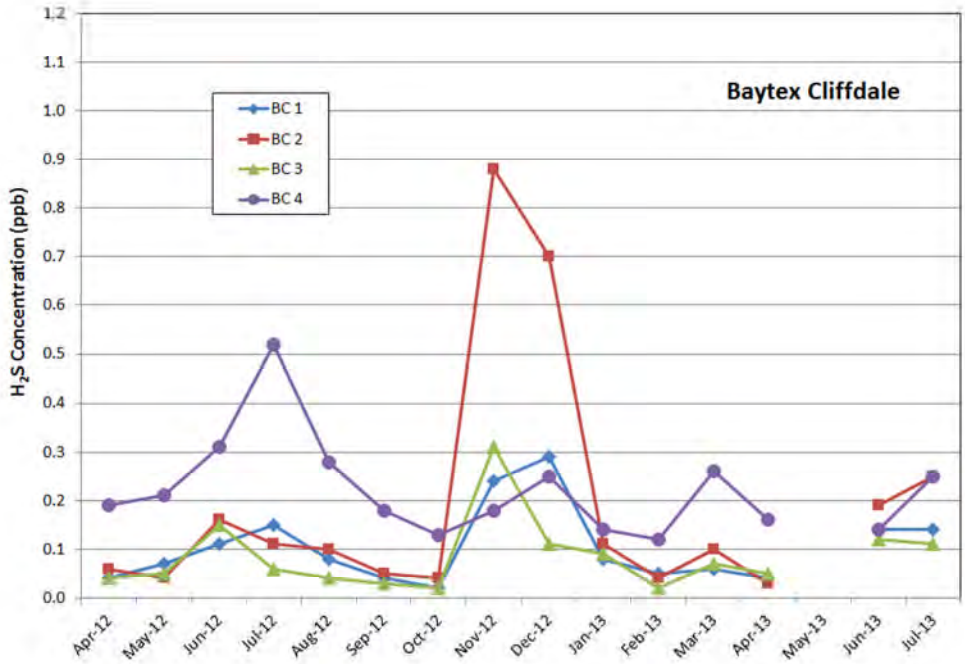


Figure 6-10 Monthly average H_2S concentrations at the Shell Cliffdale and Baytex Cliffdale passive monitoring sites (April 2012 to July 2103)

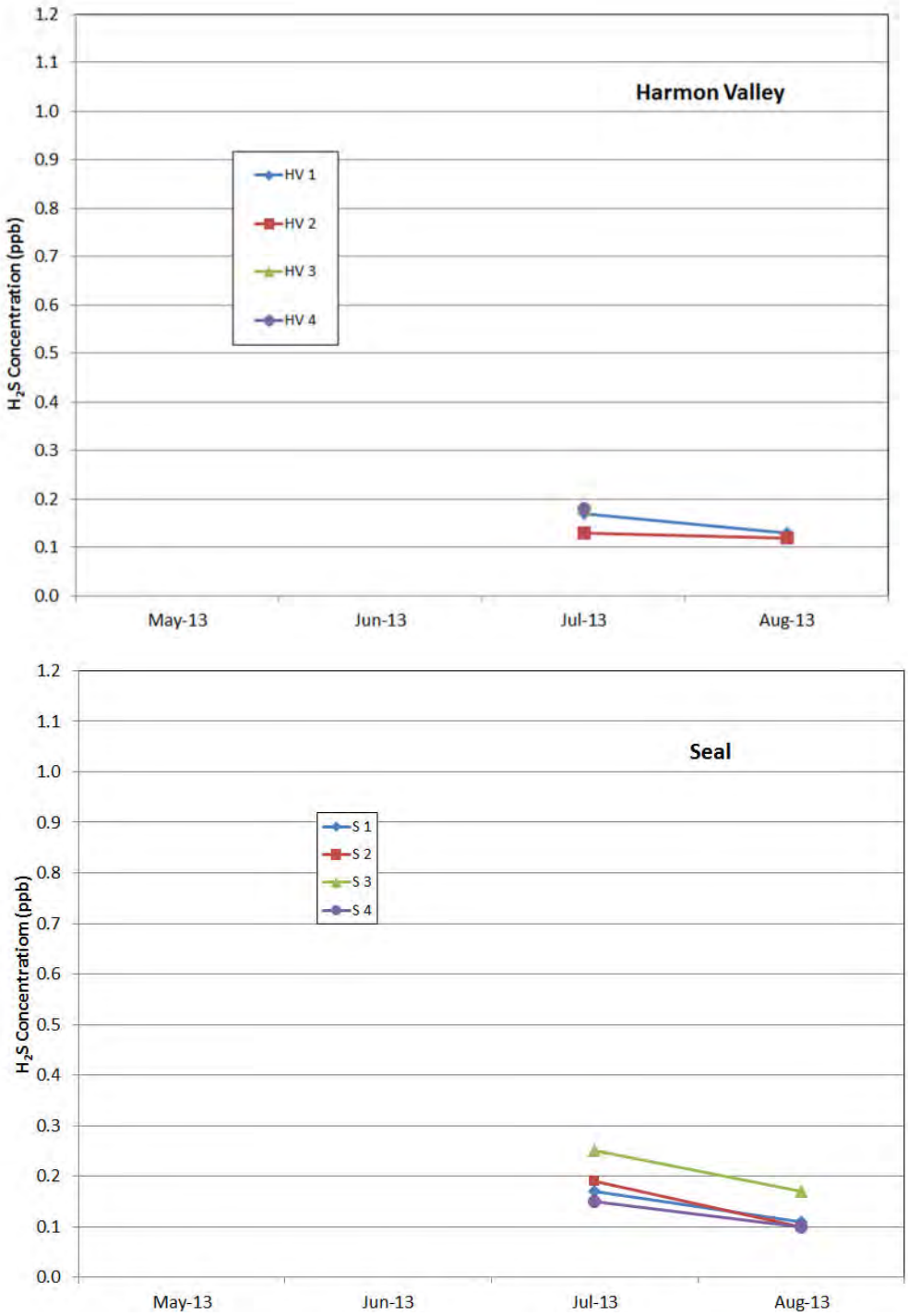
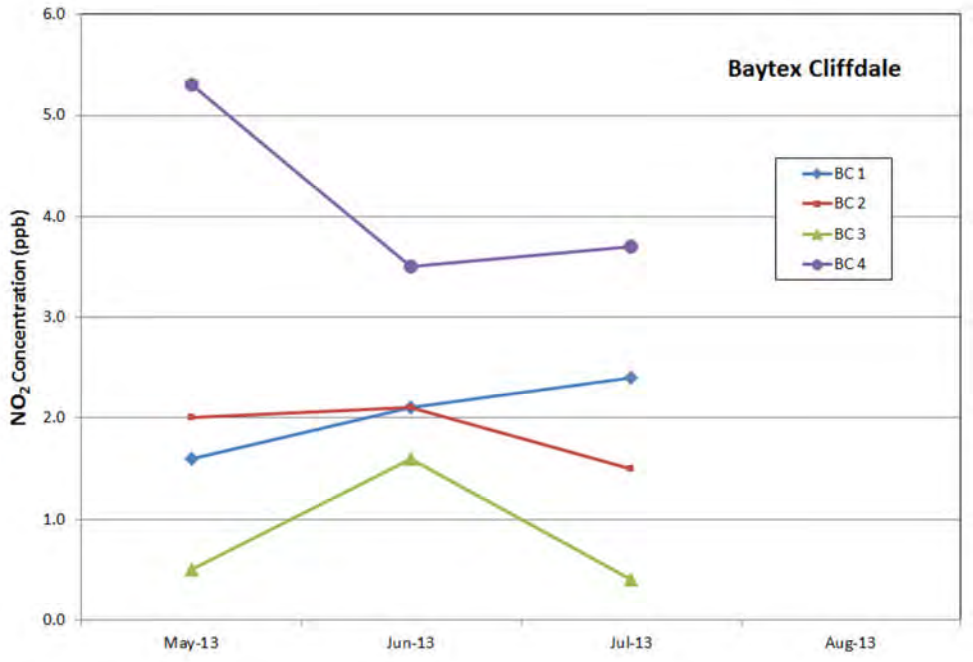


Figure 6-11 Monthly average H_2S concentrations at the Penn West Harmon Valley and Seal passive monitoring sites (May 3013 to August 3013)



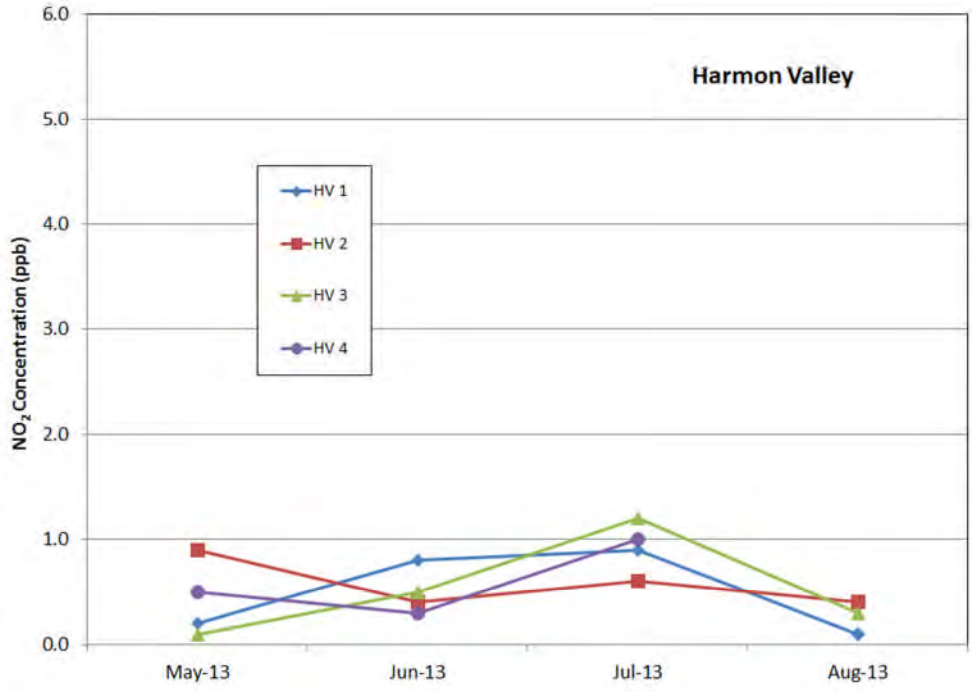


Figure 6-12 Monthly average NO_2 concentrations at the Baytex Cliffdale and the Penn West Harmon Valley passive monitoring sites (May 2013 to August 2013)

Table 6-5 Ambient NO_2 concentrations (ppb)

Monitoring Site	Maximum	Average
Baytex BC 1	2.4	2.0
Baytex BC 2	2.1	1.9
Baytex BC 3	1.6	0.8
Baytex BC 4	5.3	4.2
Penn West S 1	0.9	0.5
Penn West S 2	0.9	0.6
Penn West S 3	1.2	0.5
Penn West S 4	1.0	0.6
All (max)	**5.3**	**4.2**
All (Mean)	**1.9**	**1.4**
NOTE: Detection Limit = 0.1 ppb		

Table 6-6 List of VOCs that can be measured using passive samplers (source: AirZone One Ltd.)

Number	Volatile Organic Compounds	CAS #
1	Pentane (C5)	109-66-0
2	Ethanol	64-17-5
3	2,2-Dimethylbutane	75-83-2
4	iso-Propyl alcohol (IPA)	67-63-0
5	Dichloromethane	75-09-2
6	Methyl t-butyl ether (MTBE)	1634-04-4
7	Hexane (C6)	110-54-3
8	Methyl ethyl ketone (2-Butanone, MEK)	78-93-3
9	Ethyl acetate	141-78-6
10	Chloroform	67-66-3
11	2-Methylhexane	591-76-4
12	Carbon tetrachloride	56-23-5
13	1,2-Dichloroethane	107-06-2
14	Benzene	71-43-2
15	2,2,4-Trimethylpentane	540-84-1
16	Heptane	142-82-5
17	Trichloroethylene	79-01-6
18	2-Methylheptane	107-83-5
19	Methyl isobutyl ketone (MIBK)	108-10-1
20	Toluene	108-88-3
21	Octane (C8)	111-65-9
22	Tetrachloroethylene	127-18-4
23	n-Butyl acetate	123-86-4
24	Ethylbenzene	100-41-4
25	(m+p)-Xylene	108-38-3 / 106-42-3
26	o-Xylene	95-47-6
27	Styrene	100-42-5
28	Cumene	98-82-8
29	a-Pinene	80-56-8
30	1,1,2,2-Tetrachloroethane	79-34-5
31	Decane (C10)	124-18-5
32	1,3,5-Trimethylbenzene	108-67-8
33	1,2,4-Trimethylbenzene	95-63-6
34	Pentachloroethane	76-01-7

Table 6-6 List of VOCs that can be measured using passive samplers (source: AirZone One Ltd.)

Number	Volatile Organic Compounds	CAS #
35	d-Limonene	5989-27-5
36	p-Cymene	99-87-6
37	1,3-Dichlorobenzene	541-73-1
38	1,4-Dichlorobenzene	106-46-7
39	1,3-Diethylbenzene	141-93-5
40	Hexachloroethane	67-72-1
41	Dodecane (C12)	112-40-3
42	1,2,4-Trichlorobenzene	120-82-1
43	Naphthalene	91-20-3
44	1,2,3-Trichlorobenzene	87-61-6
45	Tetradecane (C14)	629-59-4
46	Hexadecane (C16)	544-76-3

7.0 Continuous Monitoring

There are three continuous ambient air quality monitoring station operating in the Three Creeks area. These stations are as follows:

- The **Peace River Complex (PRC)** monitoring station is operated by Shell as part of the associated EPEA approval. This station measures ambient concentrations of SO_2, H_2S, TRS, THC, methane and NMHC; and meteorological parameters (i.e., wind speed, wind direction and ambient temperature). These parameters are measured on a continuous basis as hourly averages.

  The station is located about 0.9 km eastnortheast of the PRC central plant facility. The station coordinates are 513802 UTM mE and 6249039 UTM mN (Zone 11, NAD83). The station location is identified as "PRC".

  Hourly data were provided by Shell for the period Jan 1 2008 to Aug 31 2013. AGAT was the contractor for the period Jan 1 2008 to Apr 30 2013, and MAXXAM was the contractor for the period May 1 2013 to Aug 31 2013.

- The **Highway 986** monitoring station is managed by the Three Creeks Air Monitoring Subcommittee and was installed in response to community concerns about air emissions. This station measures ambient concentrations of SO_2, H_2S, TRS, THC, methane and NMHC; and meteorological parameters (i.e., wind speed, wind direction and ambient temperature). These parameters are measured on a continuous basis as hourly averages.

  The station was installed on Mar 18 2010 at 499764 UTM mE and 6247262 UTM mN (Zone 11, NAD83). This station location is identified as "986a". On Jul 6 2011, the station was moved to 503680 UTM mE and 6247933 UTM mN (Zone 11, NAD83). The new station location is identified as "986b"and is 4.55 km to the east northeast of the old location.

  Hourly data were provided for the period Mar 18 2010 to Aug 31 2013. MAXXAM was the operator for this period.

- The **Highway 842** monitoring station is managed by the Three Creeks Air Monitoring Subcommittee and was also installed in response to community concerns about air emissions. This station measures ambient concentrations of SO_2, H_2S, TRS, THC, methane and NMHC; and meteorological parameters (i.e., wind speed, wind direction and ambient temperature). These parameters are measured on a continuous basis as hourly averages.

  The station was installed on Apr 1 2012 at 501190 UTM mE and 6236700 UTM mN (Zone 11, NAD83). This station location is identified as "842a". On Nov 7 2012, the station was moved to 501148 UTM mE and 6236596 UTM mN (Zone 11, NAD83). The new station location is identified as "842b" and is 112 m to the south of the old location.

Hourly data were provided for the period Apr 1 2012 to Aug 31 2013. AGAT was the operator for the period Apr 1 2012 to Oct 31, 2012, and MAXXAM was the operator for the period Nov 8 2012 to Aug 31 2013.

The continuous data were provided in multiple files that were organized into a consistent format with one record for each hour.

7.1 Continuous SO_2 Concentration

Table 7-1 provides a statistical summary of ambient SO_2 concentrations measured at the PRC continuous monitoring site on a year-by-year basis. The highest concentrations were measured in 2008 and 2009, the period associated with the combustion of produced sour gas. For the 2011 to 2013 period, the SO_2 concentrations were much less due to the use of sweet fuel gas. The ambient concentrations for the latter period are more representative of current conditions.

Table 7-2 provides a statistical summary of ambient SO_2 concentrations measured at the continuous monitoring sites. The Highway 842a values are all zero, presumably due to reporting SO_2 concentrations to the nearest 10 ppb. The measured values at the Highway 842a and Highway 986a, and Highway 986b sites are slightly less than the recently measured values (i.e., 2011 to 2013) at the PRC site.

7.1.1 Temporal Trends

Figure 7-1 shows the hourly time series of ambient SO_2 concentrations (ppb) measured the PRC, Highway 986 and Highway 842 stations. While a common vertical concentration scale is adopted to facilitate comparisons between stations, the horizontal time scales reflect the period associated with each monitoring station.

The higher SO_2 concentration peaks (i.e., those greater than 50 ppb) are most frequent at the longer period PRC station. Since Jan 2011, the peak concentrations at this site are much lower. This is consistent with the passive SO_2 concentration data collected near the PRC CPF, and reflects the emission reduction initiatives undertaken by Shell during the 2009-2010 period (including the addition of the Cliffdale Gas Gathering System, elimination of solution gas venting, and reduction of continuous flaring). The SO_2 data since Jan 2011 better represent current conditions near the PRC.

For the period January 2009 to December 2010, it appears that the low SO_2 concentrations at the PRC station are reported to the nearest 10 ppb. Prior to and after this period, the SO_2 concentrations appear to be reported to the nearest 1 ppb. Reporting to the nearest 10 ppb appears to be based on a legacy compliance monitoring approach where concentrations were typically reported to the nearest 0.01 ppm (i.e., 10 ppb). Prior to Nov 2012, all SO_2 concentrations at the Highway 842 station are reported as zero. Again, this could be an artifact of reporting to the nearest 10 ppb.

The SO_2 concentrations at both the Highway 986 and Highway 842 concentrations tend to be low. Similarly, the recent (since Jan 2011) SO_2 concentrations at the PRC are also low with occasional peak values in the 10 ppb range.

Figure 7-2 shows the ambient SO_2 concentration variation with time of day for the continuous stations. There does not appear to be a consistent diurnal trend.

7.1.2 Meteorological Trends

Figure 7-3 shows the ambient SO_2 concentration variation with wind direction for the continuous stations. The greater SO_2 concentrations measured at the PRC and Highway 986a sites are clearly correlated to preferred directions. The PRC directions (247° to 259°) point to the Peace River Complex. The Highway 986a wind directions (76° to 82°) also point to the Peace River Complex. The ambient concentrations associated with the Highway 986b, Highway 842a and Highway 842b sites are relatively low and there is insufficient information to reliably point to an upwind source.

Figure 7-4 shows the ambient SO_2 concentration variation with wind speed for the continuous stations. The greater SO_2 concentrations measured at the PRC site tend to occur with winds in the 7 to 22 km/h range. The greater SO_2 concentrations measured at the Highway 986a site tend to occur with winds in the 5 to 12 km/h range.

7.1.3 Comparison to Ambient Benchmarks

The 1-hour AAAQO for SO_2 is 172 ppb. The recent PRC, the Highway 842 (a and b), and the Highway 842 (a and b) maxima are all much less than this AAAQO. The odour threshold for SO_2 is 870 ppb; the ambient SO_2 concentrations are all less than the odour threshold.

Table 7-1 SO_2 concentration statistics (ppb) for the PRC continuous ambient air quality monitoring site

Statistic	Year					
	2008	2009	2010	2011	2012	2013
Number of Hours	8329	8695	8546	8660	8027	5629
Maximum	126.5	133.3	69.9	43.8	16.6	21.0
90th Percentile	4.0	7.5	2.5	0.7	1.1	1.0
75th percentile	1.4	1.0	0.4	0.3	0.4	0.2
Average	**3.0**	**2.6**	**1.5**	**0.3**	**0.4**	**0.3**
Median	1.0	0.3	0.1	0.2	0.1	0.0
25th Percentile	0.6	0.1	0.0	0.0	0.0	0.0
10th Percentile	0.4	-0.5	-0.2	-0.1	-0.1	0.0
Minimum	-1.0	-3.0	-0.9	-6.3	-1.0	0.0

Table 7-2 SO_2 concentration statistics (ppb) for the continuous ambient air quality monitoring sites

Statistic	Location				
	PRC	Highway 986a	Highway 986b	Highway 842a	Highway 842b
Number of Hours	47886	10801	17903	5131	6748
Maximum	133.3	13.0	5.0	0.0	6.0
90th Percentile	1.6	1.0	1.0	0.0	1.0
75th percentile	0.8	0.0	1.0	0.0	0.0
Average	**1.4**	**0.2**	**0.3**	**0.0**	**0.3**
Median	0.2	0.0	0.0	0.0	0.0
25th Percentile	0.0	0.0	0.0	0.0	0.0
10th Percentile	-0.1	0.0	0.0	0.0	0.0
Minimum	-6.3	0.0	0.0	0.0	0.0

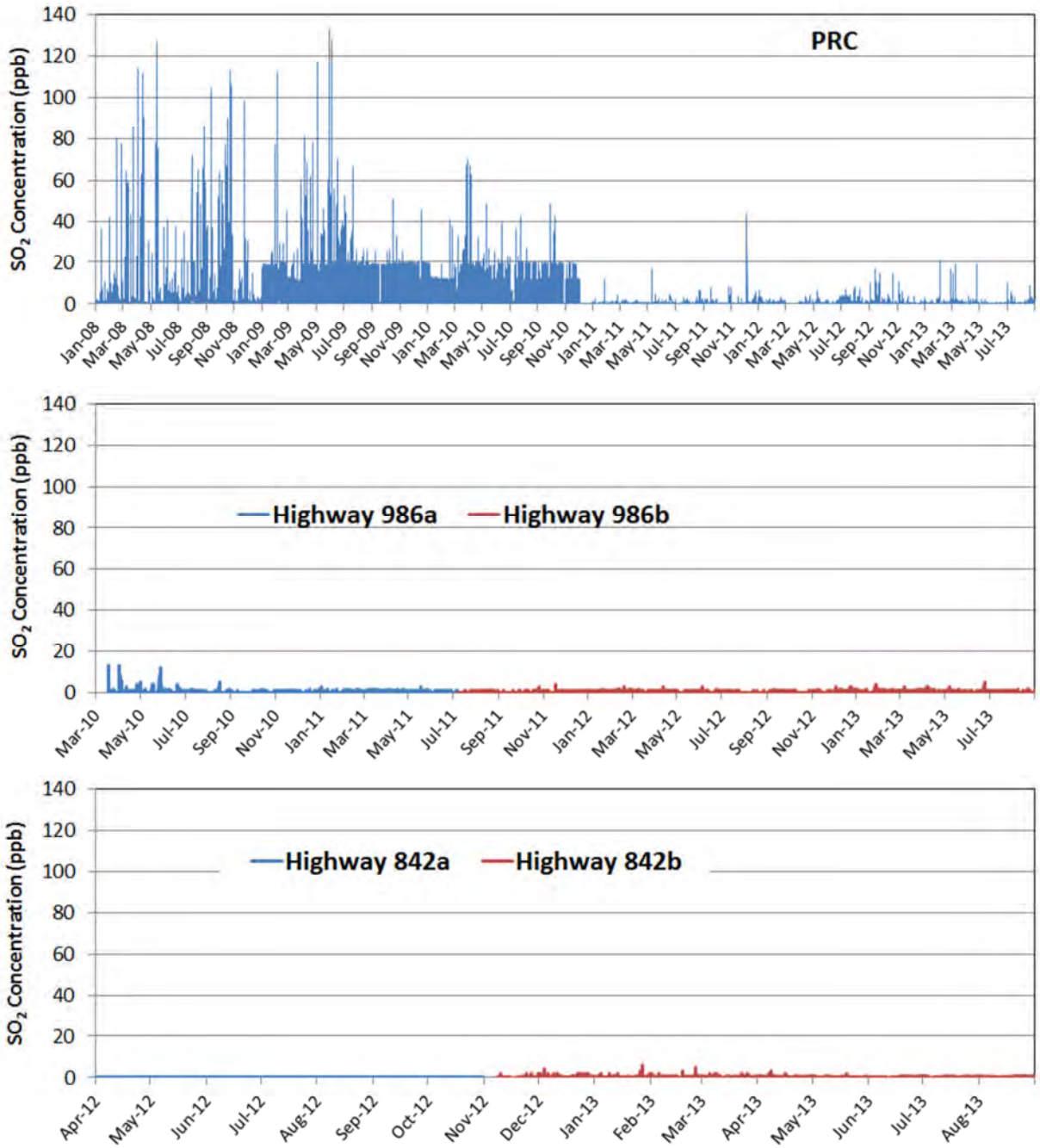


Figure 7-1 Ambient SO_2 concentration time series measured at the three continuous air quality monitoring stations (AAAQO = 172 ppb)

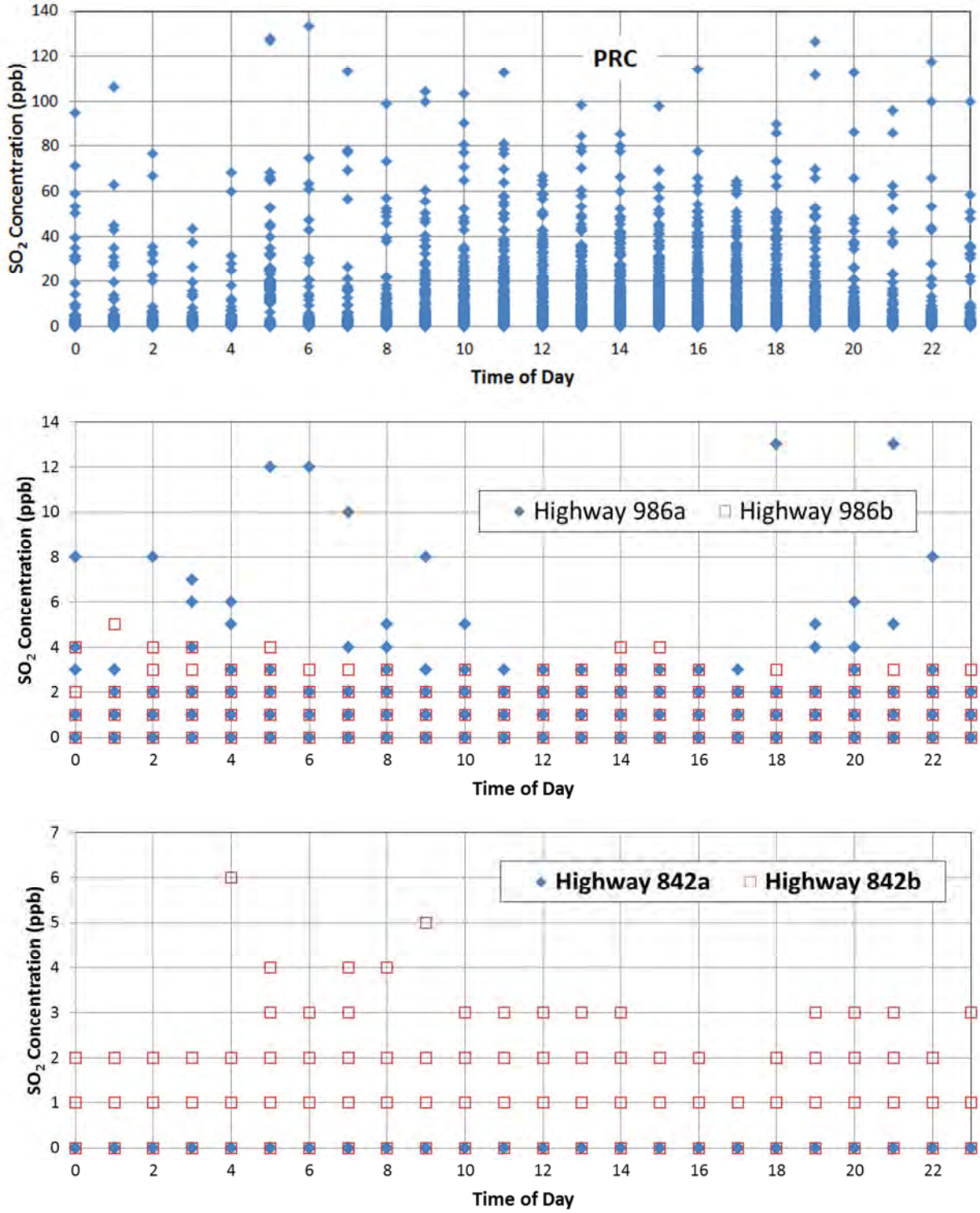


Figure 7-2 Ambient SO_2 concentration variation with time of day at the three continuous air quality monitoring stations. Associated periods are as indicated in Figure 7-1.

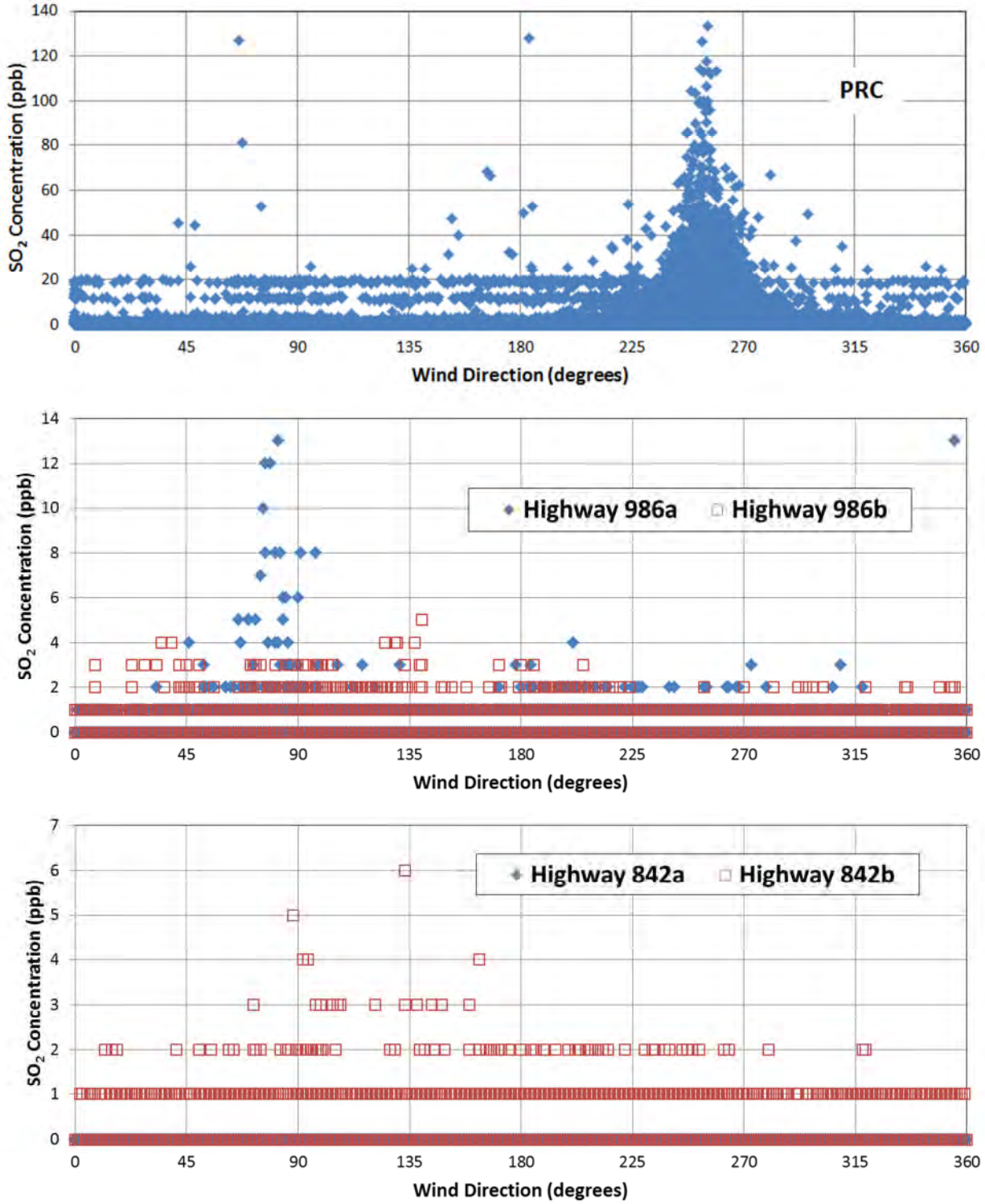


Figure 7-3 Ambient SO_2 concentration variation with wind direction at the three continuous air quality monitoring stations. Associated periods are as indicated in Figure 7-1.

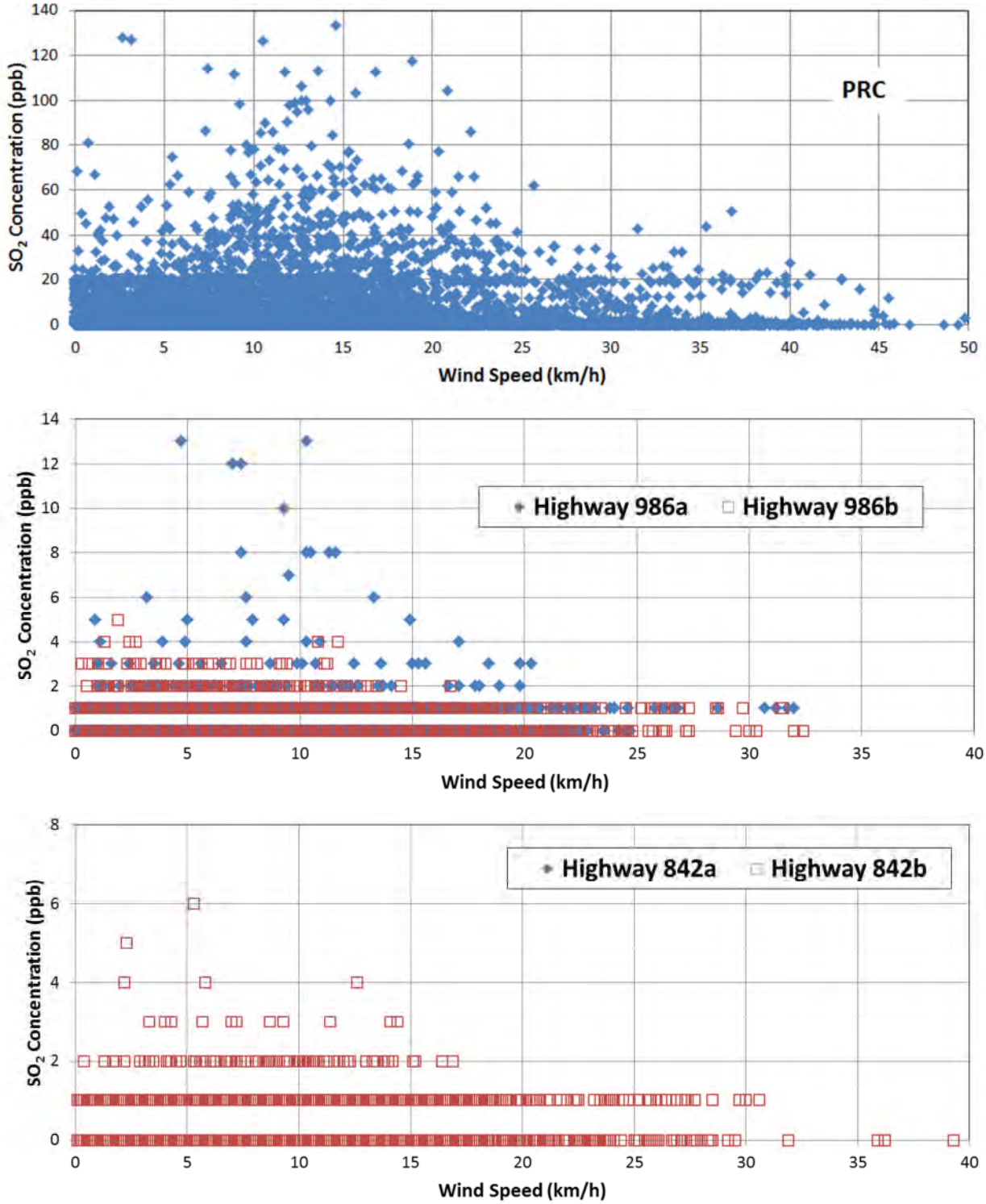


Figure 7-4 Ambient SO_2 concentration variation with wind speed at the three continuous air quality monitoring stations. Associated periods are as indicated in Figure 7-1.

7.2 CONTINUOUS TRS CONCENTRATIONS

Table 7-3 provides a statistical summary of ambient H_2S concentrations measured at the PRC continuous monitoring site on a year-by-year basis. The highest concentrations were measured in 2008 to 2010 period, the period associated with the use of produced sour gas. For the 2011 to 2012 period, the maximum H_2S concentrations were less due to the use of sweet fuel gas. Greater values occurred in 2013; the reason for these values is not clear. Negative concentration values indicate that instrument baseline drift adjustments are not accounted for in the supplied database. The ambient concentrations for the latter period are more representative of current conditions.

Table 7-4 provides a statistical summary of ambient H_2S/TRS concentrations measured at the continuous monitoring sites. The Highway 986a, Highway 986b and Highway 842b values are very low. Greater values occurred at the Highway 986b site.

7.2.1 Temporal Trends

Figure 7-5 shows the hourly time series of ambient H_2S and TRS concentrations (ppb) measured the PRC, Highway 986 and Highway 842 stations. While the vertical scales are similar, the horizontal time scales reflect the period associated with each monitoring station.

At the PRC station, H_2S concentrations are available from January 2008, and TRS monitoring started in Dec 2010. Greater H_2S concentrations at the PRC station coincide with greater SO_2 values at the same station. Recently (2013), greater H_2S and TRS concentrations have started to reoccur at this station. These events were potentially related to the presence of sulphur reducing bacteria in a large, nearby standing body of water. The TRS concentrations at the Highway 986 (a and b) station have remained consistent over the associated monitoring period. The TRS values at the Highway 842a station occurred in May and June 2012. Since then they have been relatively low at both the Highway 842a and Highway 842b sites.

Figure 7-6 shows the ambient H_2S/TRS concentration variations with time of day for the continuous stations. For the PRC site, greater concentrations tend to occur in the late morning or the late afternoon, evening period. Due to the low concentrations, there is no trend for the Highway 986 site. For the Highway 842b site, the greatest concentrations tend to occur during the early morning period. For the Highway 842a site, the greatest concentrations tend to occur late afternoon, early morning period.

7.2.2 Meteorological Trends

Figure 7-7 shows the ambient H_2S/TRS concentration variation with wind direction for the continuous stations. The greater H_2S concentrations measured at the PRC site are clearly correlated to preferred directions (243° to 255°) that point to the Peace River Complex. The ambient concentrations associated with the Highway 986 (a and b) sites are relatively low and there is insufficient information to reliably point to an upwind source direction. The greater Highway 842a concentrations tend to point to easterly upwind source directions and to

southwesterly upwind source directions. There is a slight bias for greater concentrations to be associated with easterly winds at the Highway 842b site.

Figure 7-8 shows the ambient H_2S and TRS concentration variation with wind speed for the continuous stations. The greater H_2S concentrations events at the PRC site seem to show the trends similar to the corresponding SO_2 values, with the exception of three high values being associated with high wind speeds (30 to 35 km/h). The greater TRS concentrations measured at the Highway 842a site tend to occur with winds less than 15 km/h. Even though the concentrations are low, the greater TRS values at the Highway 986 (a and b) and Highway 842b sites tend to be associated with wind speeds less than 5 km/h.

7.2.3 Comparison to Ambient Benchmarks

The 1-hour AAAQO for H_2S is 10 ppb. Historically, the AAAQO at the PRC station was exceeded a number of times during the period when the Peace River Complex was using sour fuel. There was only one recent event in 2013 where the AAAQO was exceeded; this event was potentially related to the presence of sulphur reducing bacteria in a large, nearby standing body of water. Assuming that one can conservatively apply the AAAQO for H_2S to TRS, the AAAQO was exceeded several times at the Highway 842a site. The maximum TRS concentrations measured at the Highway 986 (a and b) and the Highway 842b are all less than this AAAQO.

The odour threshold for H_2S is 0.41 ppb. Ambient TRS and H_2S measurements are typically reported to the nearest 1 ppb, suggesting an accuracy of 0.5 ppb. Manufacturers' specifications typically indicate a lower detection limit of 0.4 ppb. As indicated in Table 7-3, the 90th percentile H_2S readings at the PRC station are in the 0.37 to 1.00 ppb range, depending on year. This implies that the odour threshold could be exceeded at least 10% of the time (i.e., about 870 hours per year).

As indicated in Table 7-4, the 90th percentile TRS measurements at the Highway 986b and Highway 842 (a and b) sites are 1.0 ppb. Conservatively assuming an equivalency of H_2S and TRS, this would suggest H_2S related odours at these sites could be occurring more than 10% of the time. As previously stated, concentrations at the Highway 842 (a and b) sites tend to point to easterly and southwesterly upwind source directions. As indicated in Section 3.2, there is considerable variation with respect to the odour threshold for H_2S. The respective frequencies of exceeding a reported odour threshold is associated with a large uncertainty due to the reporting precision at low concentration (i.e., concentrations less than 1 ppb).

Table 7-3 H_2S concentration (ppb) statistics for the PRC continuous ambient air quality monitoring site

Statistic	Location					
	2008	2009	2010	2011	2012	2013
Number of Hours	8333	7951	8565	8648	8038	5666
Maximum	22.6	42.3	21.9	4.21	3.01	13.00
90th Percentile	0.44	0.63	0.38	0.44	0.37	1.00
75th percentile	0.09	0.28	0.25	0.27	0.23	0.28
Average	**0.07**	**0.28**	**0.19**	**0.21**	**0.18**	**0.37**
Median	-0.03	0.10	0.15	0.16	0.14	0.08
25th Percentile	-0.15	-0.02	0.07	0.08	0.07	0.00
10th Percentile	-0.41	-0.13	0.01	0.01	0.00	0.00
Minimum	-2.53	-2.09	-0.44	-5.01	-0.48	0.00

Table 7-4 TRS concentration (ppb) statistics for the continuous ambient air quality monitoring sites

Statistic	Location				
	PRC	Highway 986a	Highway 986b	Highway 842a	Highway 842b
Number of Hours	47201	10707	17907	4665	6734
Maximum	42.3	3.00	3.00	15.00	6.00
90th Percentile	0.47	0.00	1.00	1.00	1.00
75th percentile	0.24	0.00	0.00	0.00	1.00
Average	**0.21**	**0.01**	**0.12**	**0.32**	**0.56**
Median	0.12	0.00	0.00	0.00	1.00
25th Percentile	0.00	0.00	0.00	0.00	0.00
10th Percentile	-0.09	0.00	0.00	0.00	0.00
Minimum	-5.01	0.00	-1.00	0.00	0.00

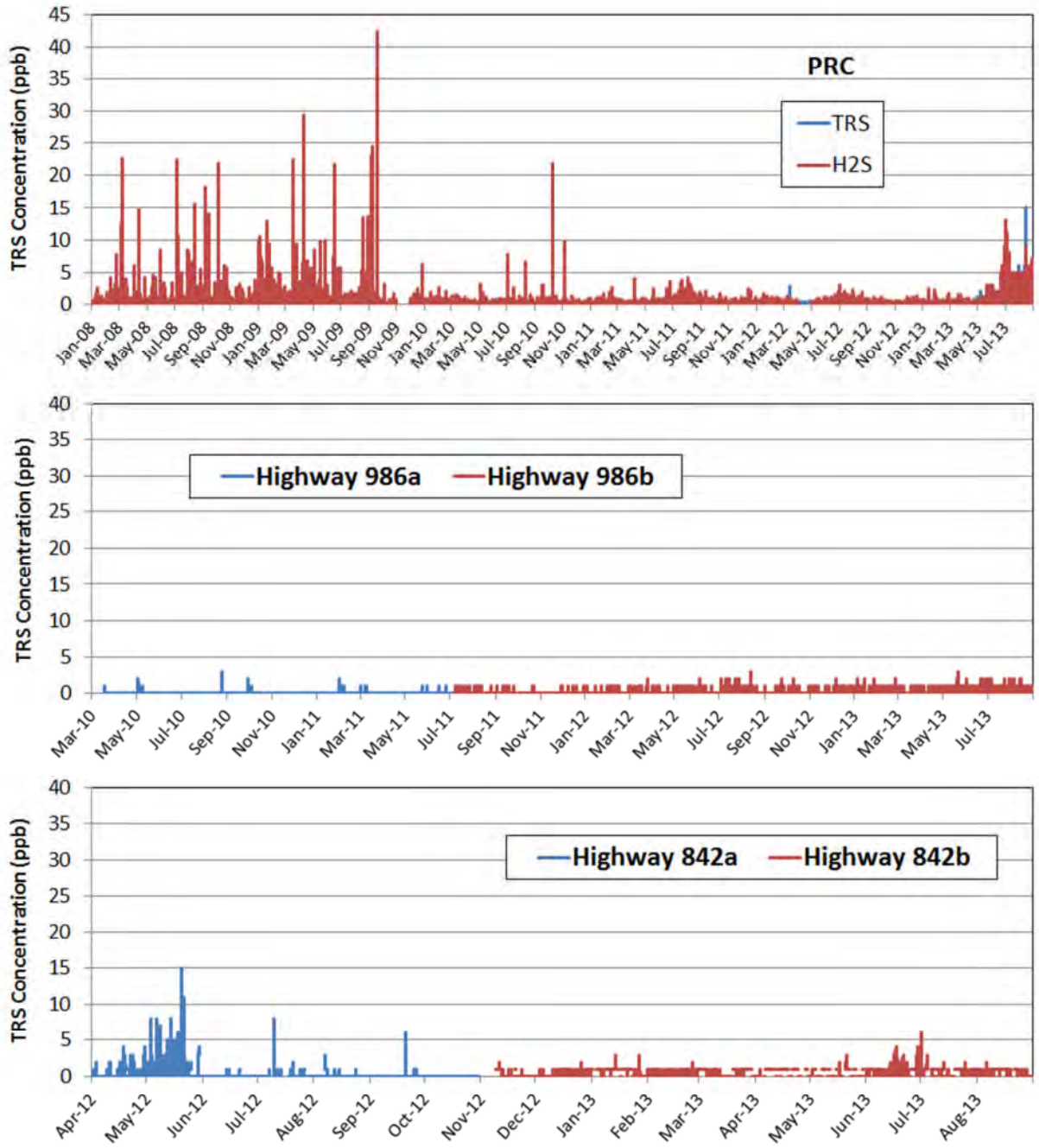


Figure 7-5 Ambient TRS concentration time series measured at the three continuous air quality monitoring stations

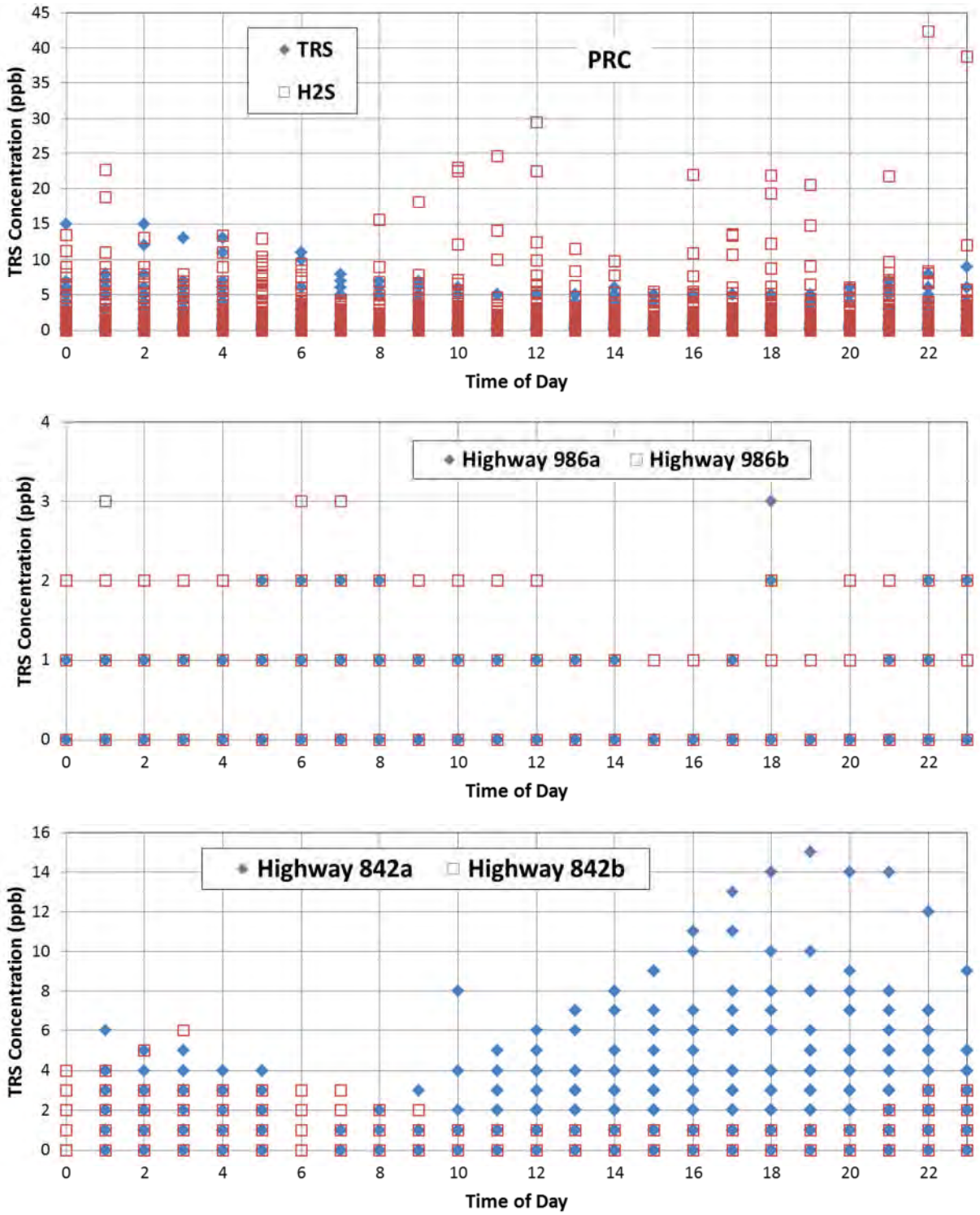


Figure 7-6 Ambient TRS concentration variation with time of day at the three continuous air quality monitoring stations (AAAQO for H_2S = 10 ppb). Associated periods are as indicated in Figure 7-5.

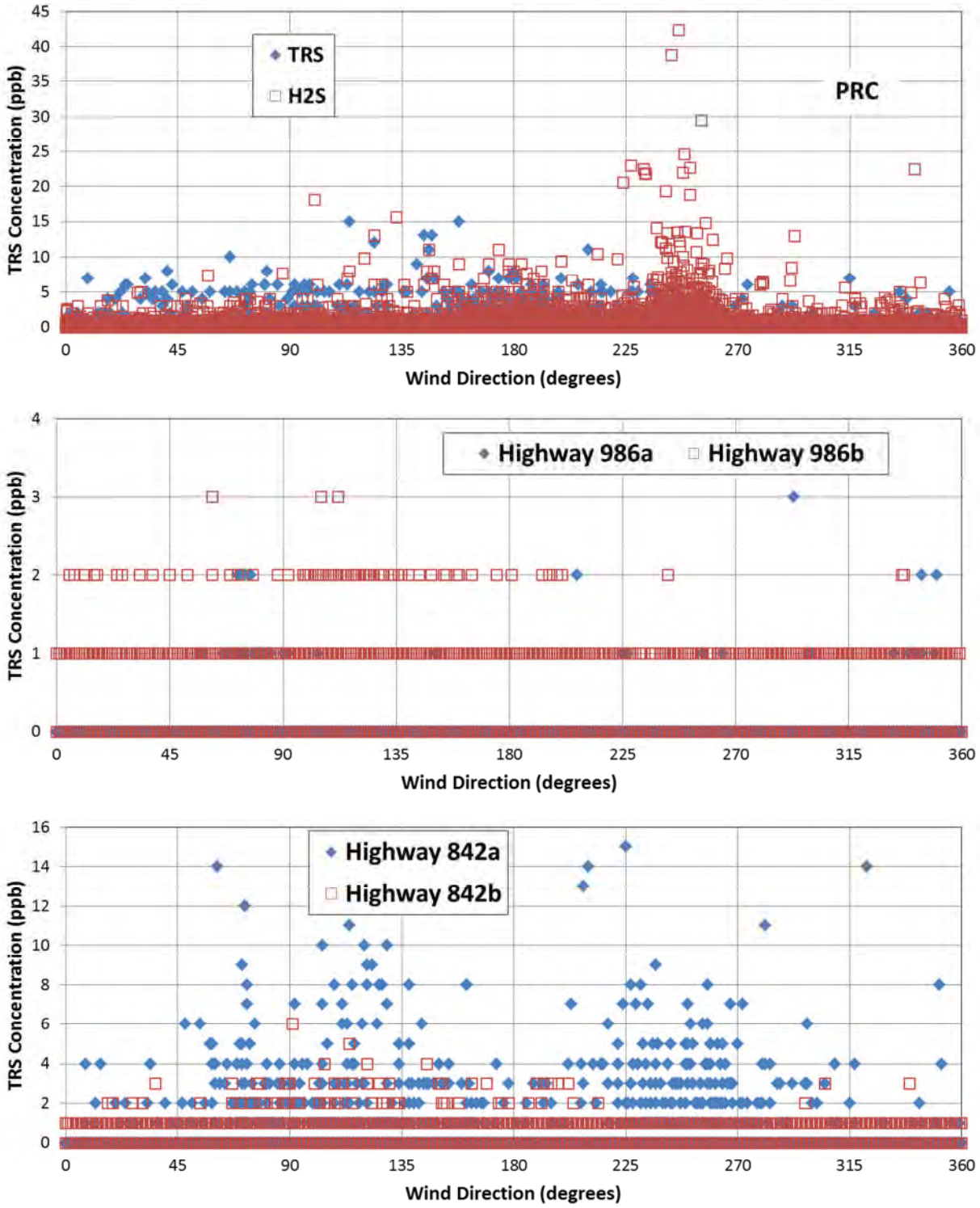


Figure 7-7 Ambient TRS concentration variation with wind direction at the three continuous air quality monitoring stations. Associated periods are as indicated in Figure 7-5.

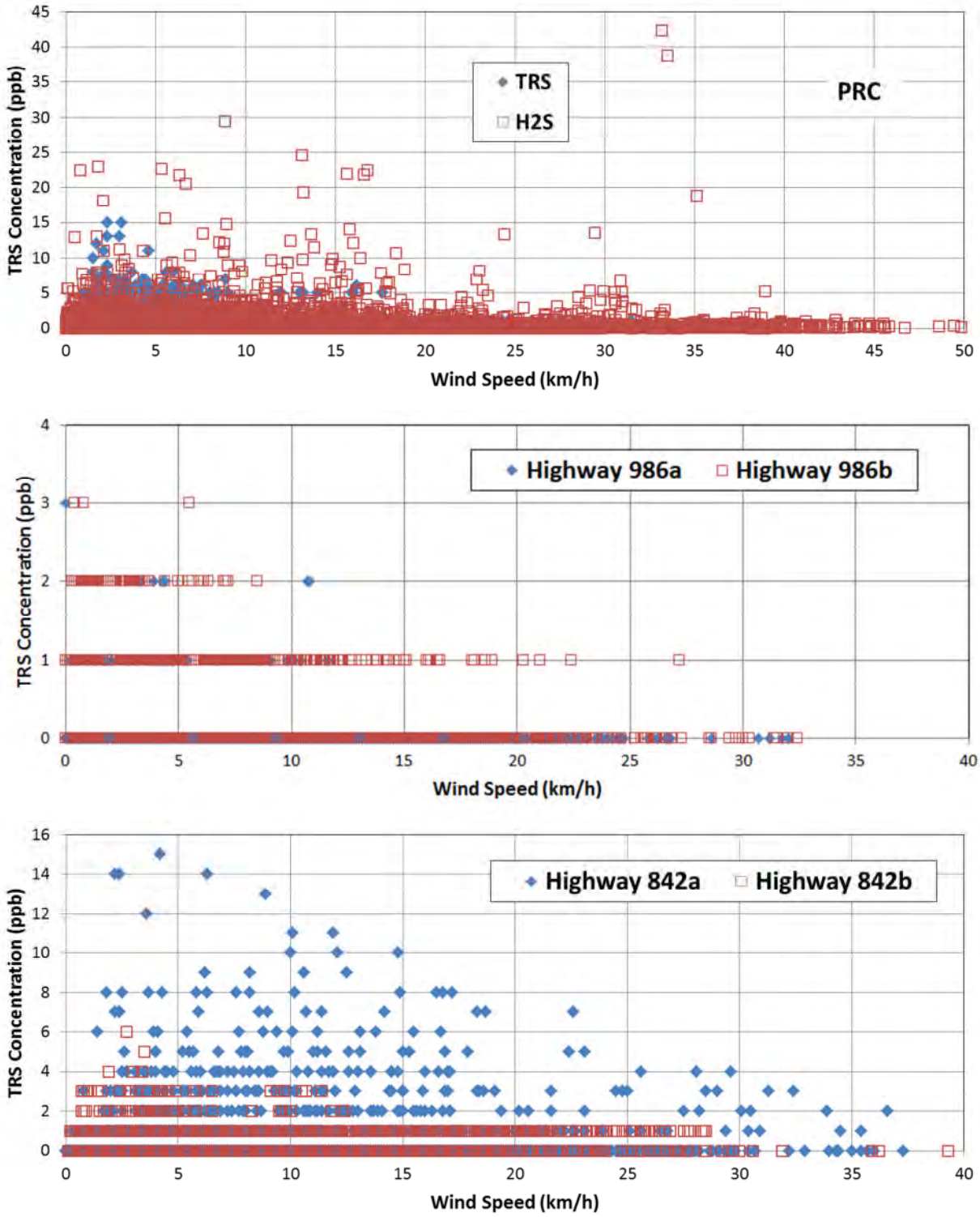


Figure 7-8 Ambient TRS concentration variation with wind speed at the three continuous air quality monitoring stations. Associated periods are as indicated in Figure 7-5.

7.3 CONTINUOUS HYDROCARBON CONCENTRATIONS

THC is the sum of methane and NMHC, and the current global background methane concentration is about 1.8 ppm (http://www.epa.gov/climatechange/images/indicator_downloads/ghg-concentrations-download2-2013.png). Therefore, the THC and methane values should nominally be equal or greater than 1.8 ppm, with the NMHC contribution due to oil and gas extraction operations.

Table 7-5 provides a statistical summary of ambient THC, methane, and NMHC concentrations measured at the continuous monitoring sites. Most of the measurements are consistent in that the average THC and methane concentrations tend to be ~ 2 ppm. This is consistent with ESRD (2011) that indicates that background THC concentration in Alberta tend to be 2 ppm or less. The PRC, the Highway 986b and Highway 842a values, however, indicate a problem with the instrument baseline as the minimum THC and minimum methane values are ~ 0 ppm.

7.3.1 THC Concentrations

7.3.1.1 Temporal Trends

Figure 7-9 shows the hourly time series of ambient THC concentrations (ppb) measured at the PRC, Highway 986 and Highway 842 stations. While the same vertical concentration scales are adopted to facilitate comparisons between stations, the horizontal time scales reflect the period associated with each monitoring station.

THC monitoring at the Highway 986 (a and b) station shows a consistent baseline concentration of about 2 ppm that corresponds to the global ambient methane concentration in the atmosphere. For the most part, the THC concentrations at Highway 842 (a and b) sites are also about 2 ppm. In contrast, the zero baseline at the PRC station for the Nov 2012 to May 2013 period was due to a datalogger programming discrepancy with the baseline correction. These data can potentially be adjusted by adding 1.8 to 2.0 ppm for the appropriate data period.

Figure 7-10 shows the ambient THC concentration variation with time of day for the three continuous stations. There is a trend for greater THC concentration to occur during the early morning hours (0500 to 1000) at all sites. This is somewhat of a different trend from the ambient SO_2 and TRS measurement trends, but is similar to the occurrence of odour complaints.

7.3.1.2 Meteorological Trends

Figure 7-11 shows the ambient THC concentration variation with wind direction for the continuous stations. The higher PRC station concentration events tend to point to the south (166° to 197°); this is in contrast to the higher SO_2 and TRS concentrations that were associated with SE winds. This suggests that the Peace River Complex is not the source of the higher THC concentration events.

The Highway 986a winds tend to point to THC sources located to the ENE, while the Highway 986b winds tend to point to sources to the ESE. As pointed out in Section 4.1.3, the winds at the Highway 986a site may not be representative of regional airflow due to nearby siting obstructions. On this basis, a higher level of confidence is placed on the Highway 986b trends. The higher concentration events at the Highway 842 (a and b) sites indicate sources located to the ENE and E.

Figure 7-12 shows the ambient THC concentration variation with wind speed for the continuous stations. The higher concentration events for the PRC, Highway 986 (a and b) and the Highway 842 (a and b) sites all occur with wind speeds that are typically less than 7 km/h. Most of the odour complaints are associated with wind speeds less than 5 km/h (Figure 5-8).

Table 7-5 Hydrocarbon concentration (ppm) statistics for the continuous ambient air quality monitoring sites

	Location				
	PRC	Highway 986a	Highway 986b	Highway 842a	Highway 842b
THC Statistics					
Number of Hours	17492	10586	17370	2718	6226
Maximum	8.17	10.25	10.75	9.00	13.81
90th Percentile	2.20	2.30	2.11	2.30	2.10
75th percentile	2.04	2.10	1.95	2.10	1.96
Average	1.55	2.05	1.97	2.10	1.95
Median	1.93	1.96	1.88	2.00	1.89
25th Percentile	1.46	1.89	1.84	1.90	1.84
10th Percentile	0.00	1.84	1.80	1.90	1.81
Minimum	0.00	1.14	0.00	0.30	1.64
Methane Statistics					
Number of Hours	17492	6073	17443	3023	6227
Maximum	4.55	9.47	10.05	7.70	12.57
90th Percentile	1.83	2.15	2.12	2.20	2.10
75th percentile	0.07	2.00	1.96	2.00	1.96
Average	0.32	1.99	1.98	1.88	1.95
Median	0.04	1.93	1.89	1.90	1.89
25th Percentile	0.00	1.88	1.85	1.90	1.85
10th Percentile	0.00	1.85	1.81	1.60	1.82
Minimum	0.00	1.14	0.00	0.00	1.64
NMHC Statistics					
Number of Hours	2730	6073	17341	2716	6227
Maximum	1.64	1.06	0.71	1.30	1.24
90th Percentile	0.00	0.00	0.00	0.20	0.01
75th percentile	0.00	0.00	0.00	0.10	0.00
Average	0.00	0.00	0.01	0.06	0.00
Median	0.00	0.00	0.00	0.00	0.00
25th Percentile	0.00	0.00	0.00	0.00	0.00
10th Percentile	0.00	0.00	0.00	0.00	0.00
Minimum	0.00	0.00	0.00	0.00	0.00

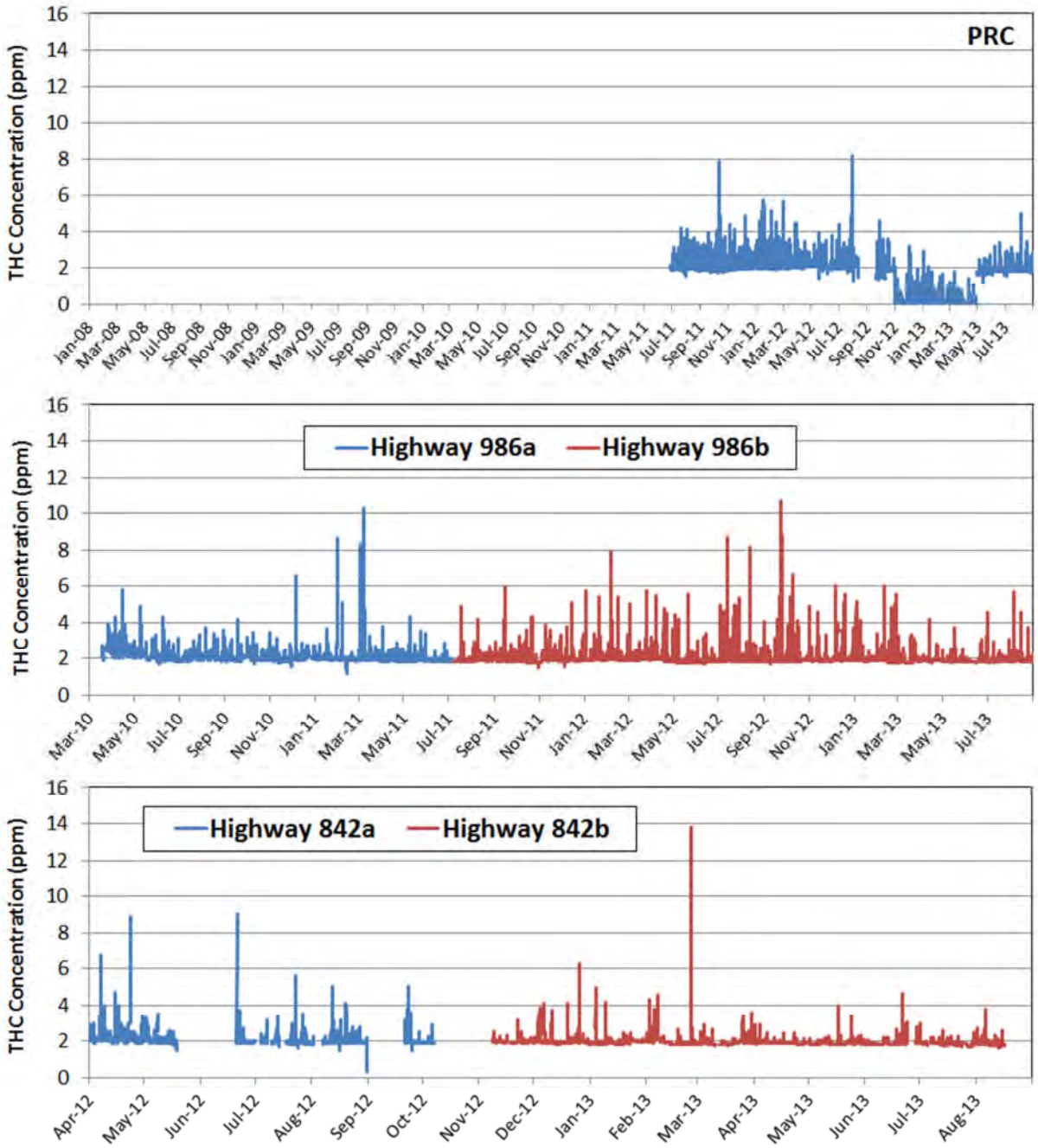


Figure 7-9 Ambient THC concentration time series measured at the three continuous air quality monitoring stations

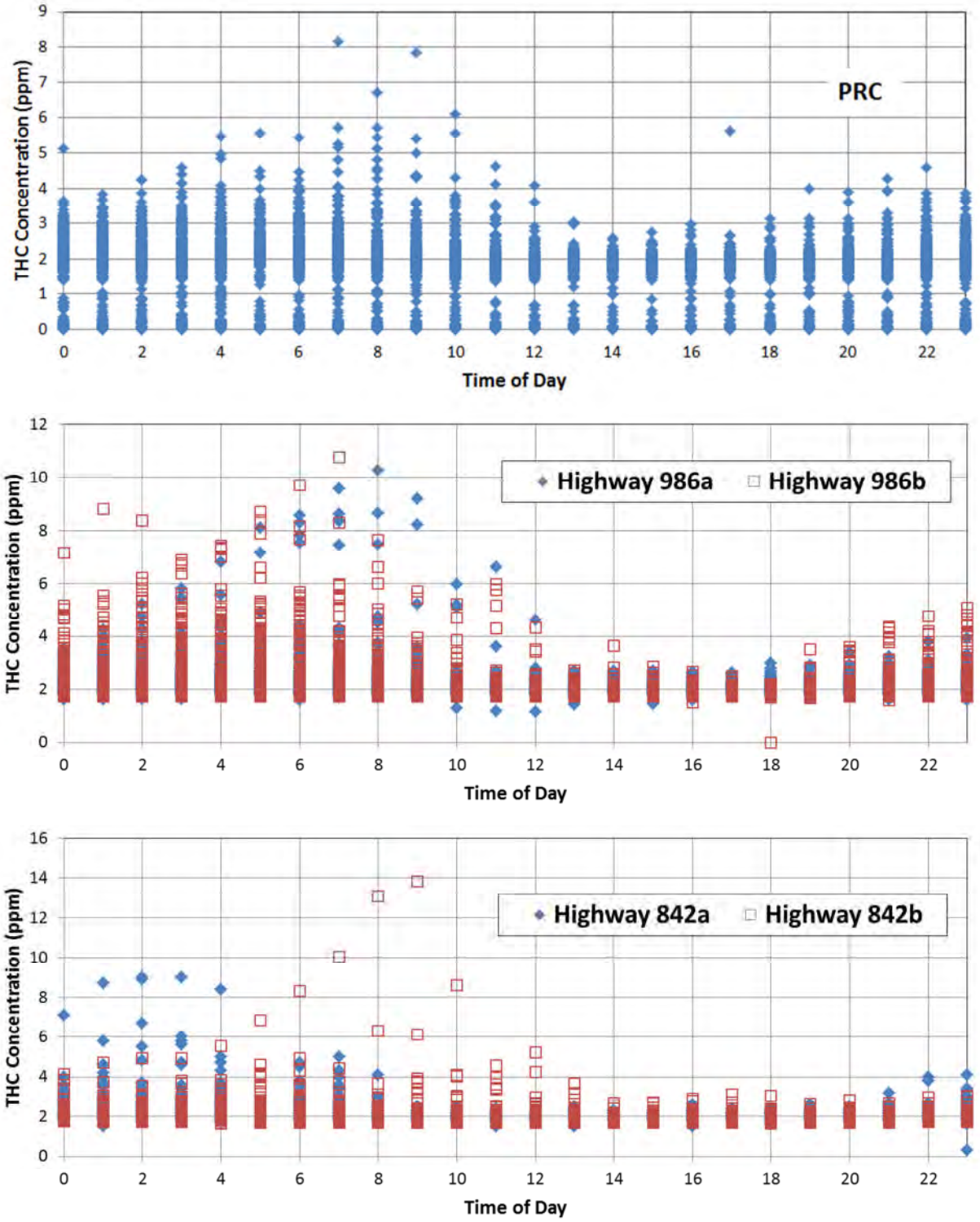


Figure 7-10 Ambient THC concentration variation with time of day at the three continuous air quality monitoring stations. Associated periods are as indicated in Figure 7-9.

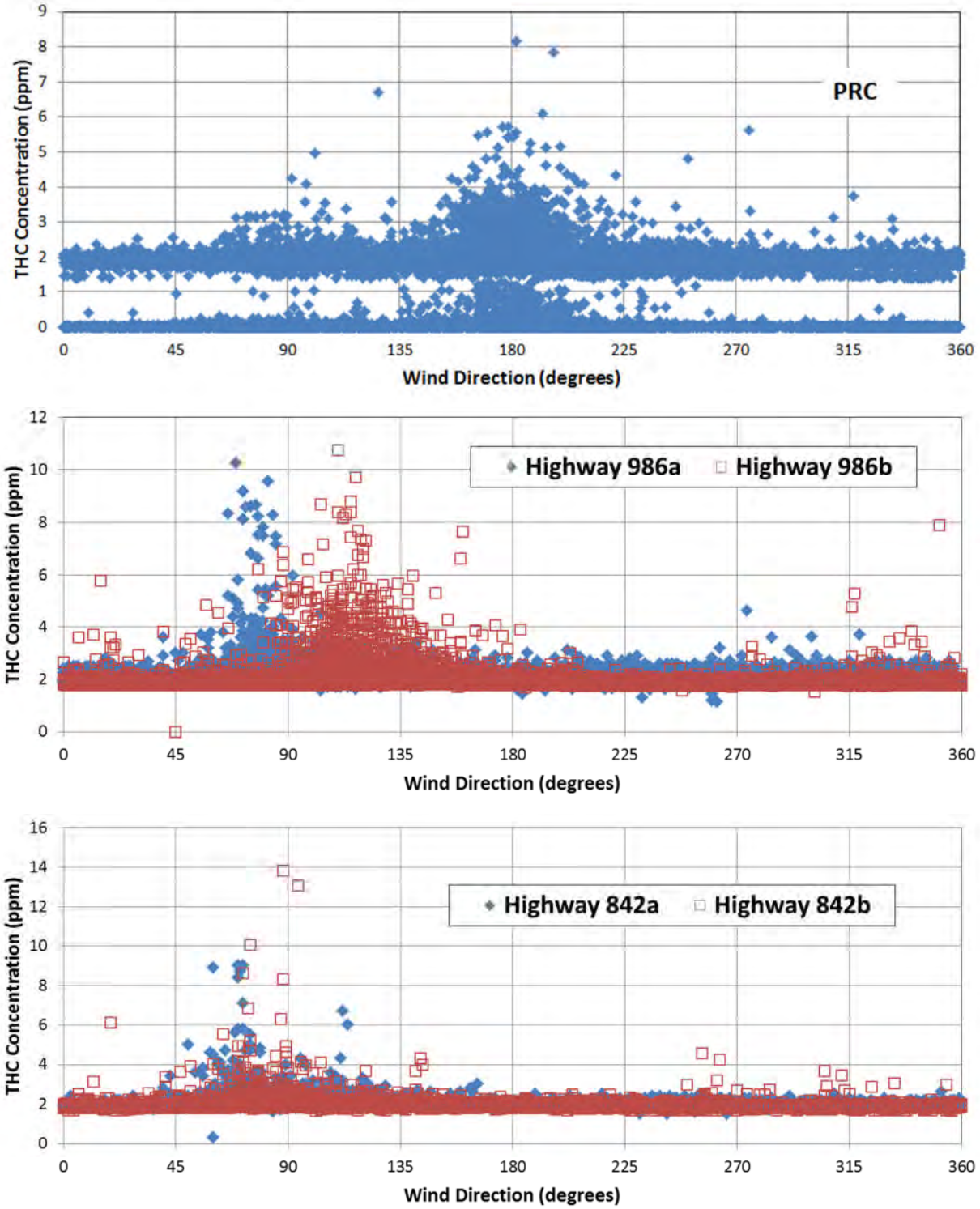


Figure 7-11 Ambient THC concentration variation with wind direction at the three continuous air quality monitoring stations. Associated periods are as indicated in Figure 7-9.

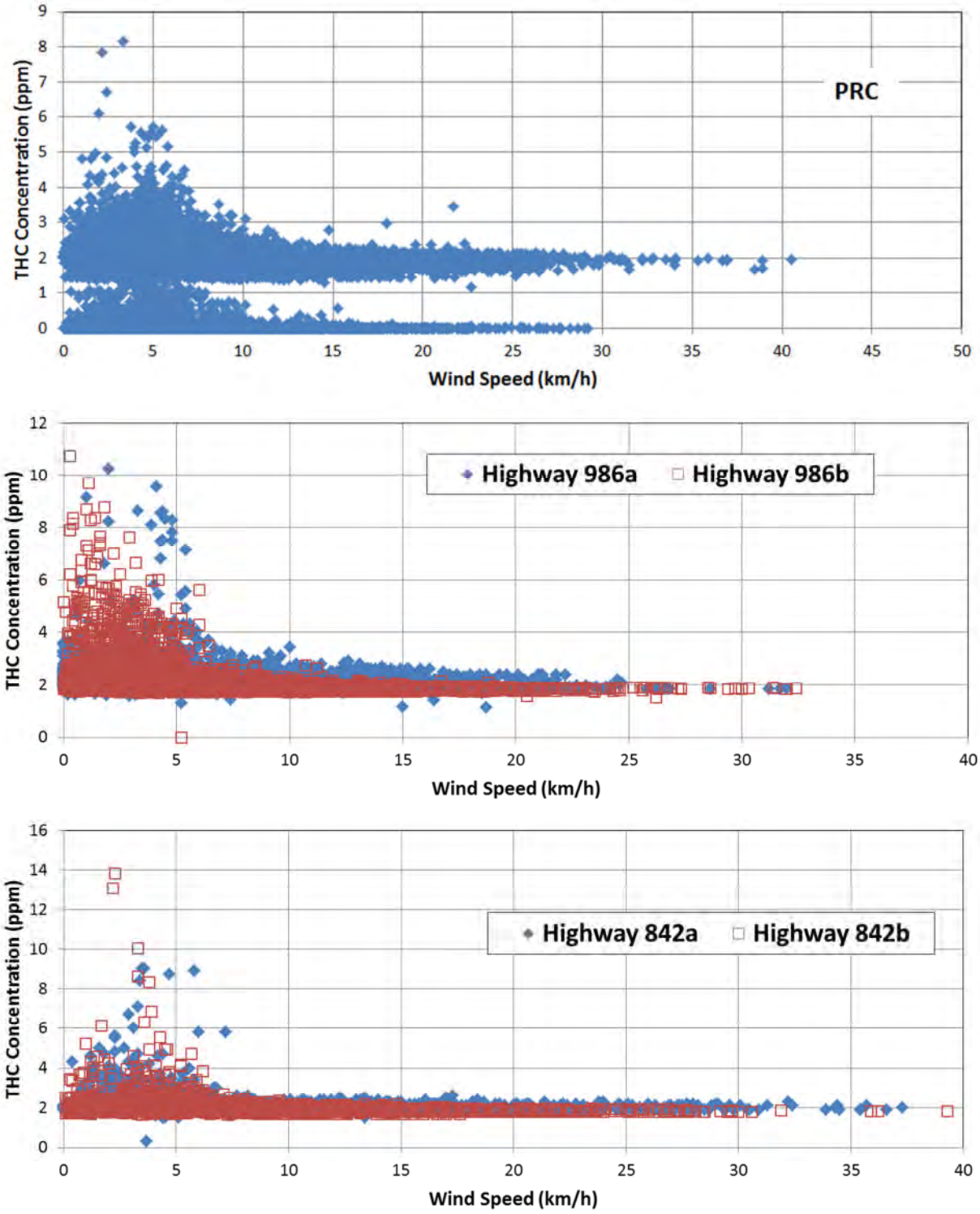


Figure 7-12 Ambient THC concentration variation with wind speed at the three continuous air quality monitoring stations. Associated periods are as indicated in Figure 7-9.

7.3.2 Methane Concentrations

7.3.2.1 Temporal Trends

Figure 7-13 shows the hourly time series of ambient methane concentrations (ppb) measured at the PRC, Highway 986 and Highway 842 sites. While a common vertical concentration scale is adopted to facilitate comparisons between stations, the horizontal time scales reflect the period associated with each monitoring station. The instrumentation problems associated with monitoring THC also affect the methane measurements. Periods with acceptable data appear to be: May 2013 to Aug 2013 for the PRC site; all for the Highway 986 (a and b) site; and all for the Highway 842b site. There are few short periods associated with the Highway 842a site that are likely affected by instrumentation operation.

Figure 7-14 shows the ambient methane concentration variation with time of day for the continuous stations. The time of day trends associated with the greater methane values are somewhat similar to those associated with the THC measurements.

7.3.2.2 Meteorological Trends

Figure 7-15 shows the ambient methane concentration variation with wind direction for the continuous stations. The wind direction trends associated with the greater methane values are somewhat similar to those associated with the THC measurements.

Figure 7-16 shows the ambient methane concentration variation with wind speed for the continuous stations. The wind speed trends associated with the greater methane values are somewhat similar to those associated with the THC measurements.

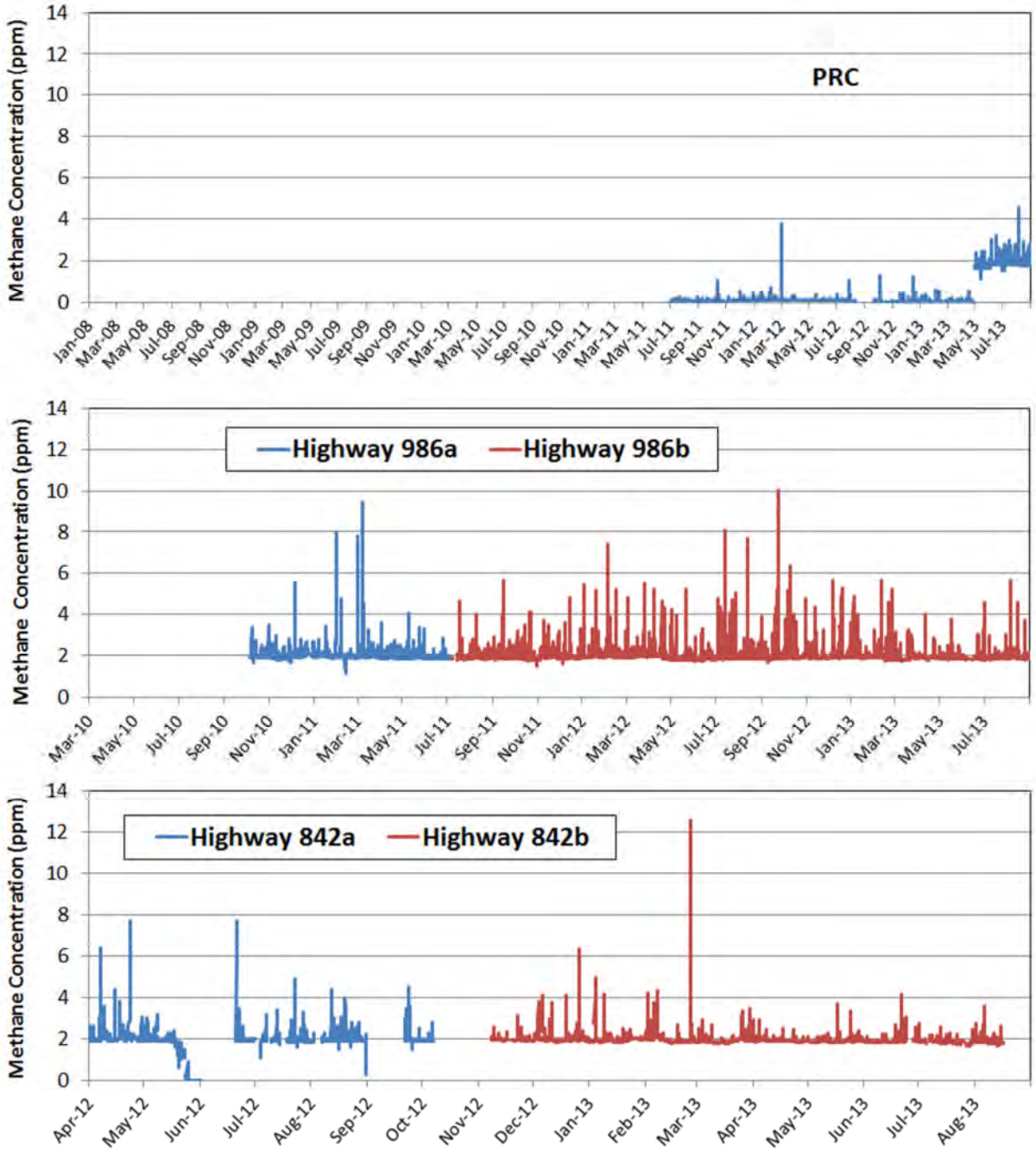


Figure 7-13 Ambient Methane concentration time series measured at the three continuous air quality monitoring stations

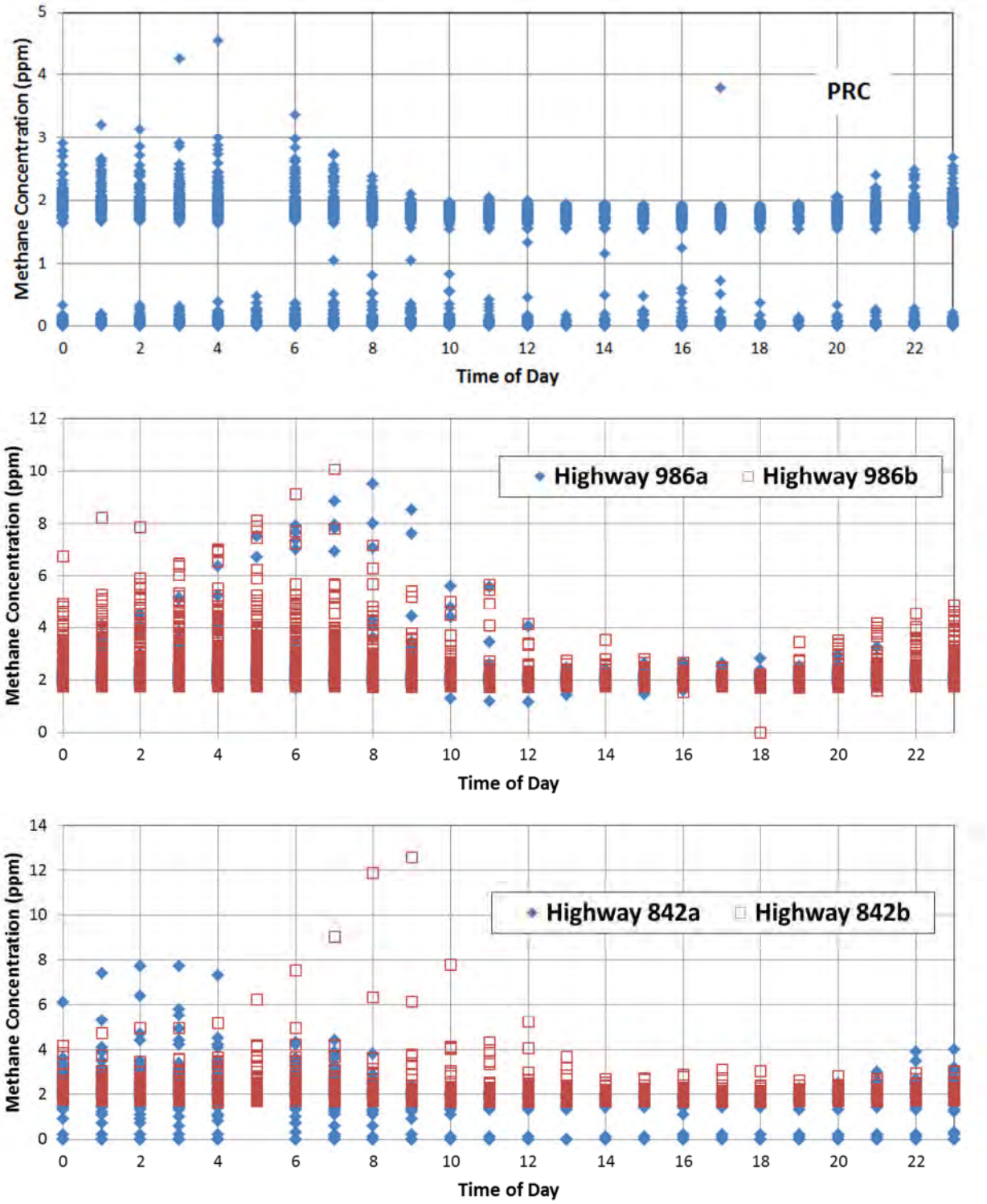


Figure 7-14 Ambient Methane concentration variation with time of day at the three continuous air quality monitoring stations. Associated periods are as indicated in Figure 7-13.

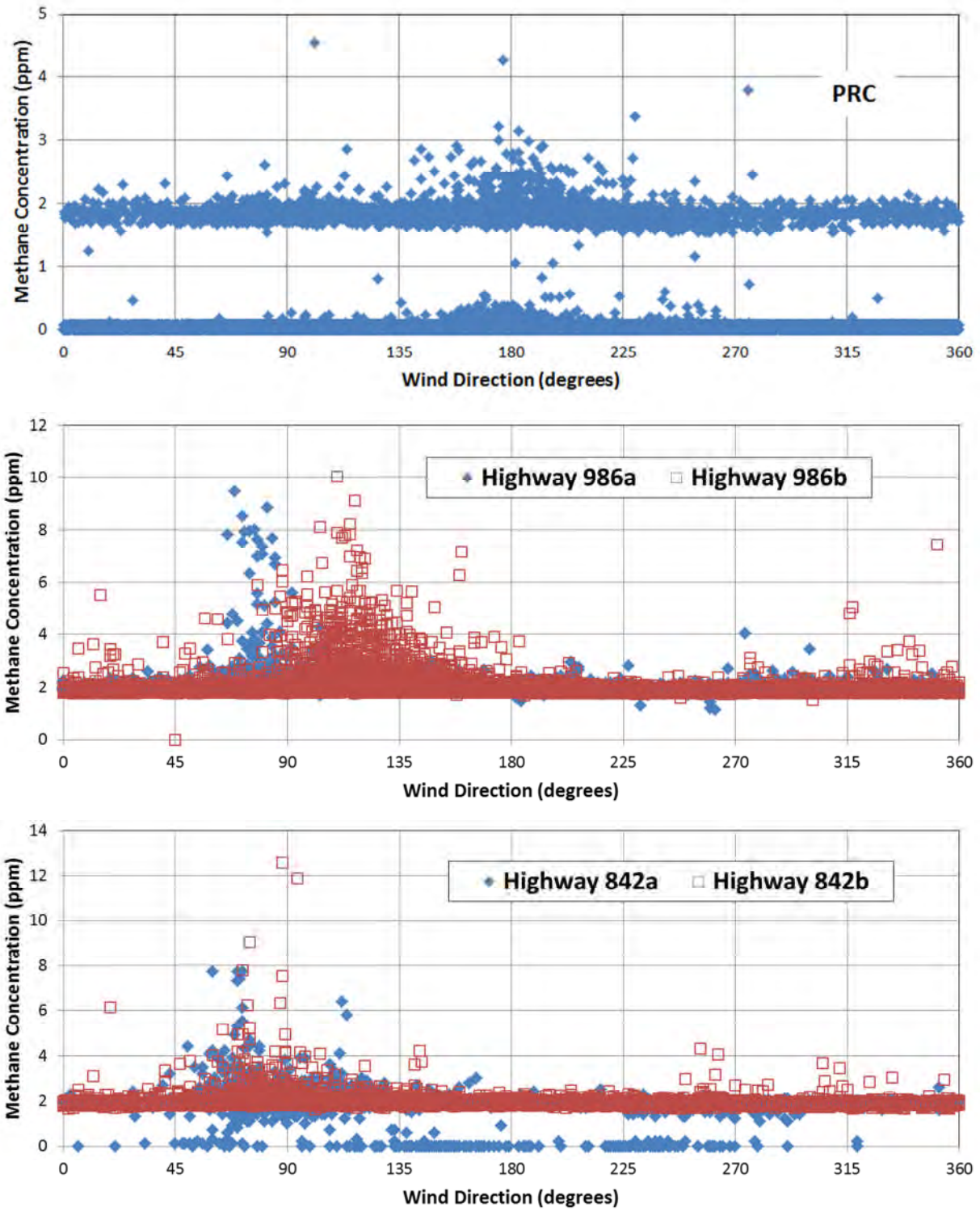


Figure 7-15 Ambient Methane concentration variation with wind direction at the three continuous air quality monitoring stations. Associated periods are as indicated in Figure 7-13.

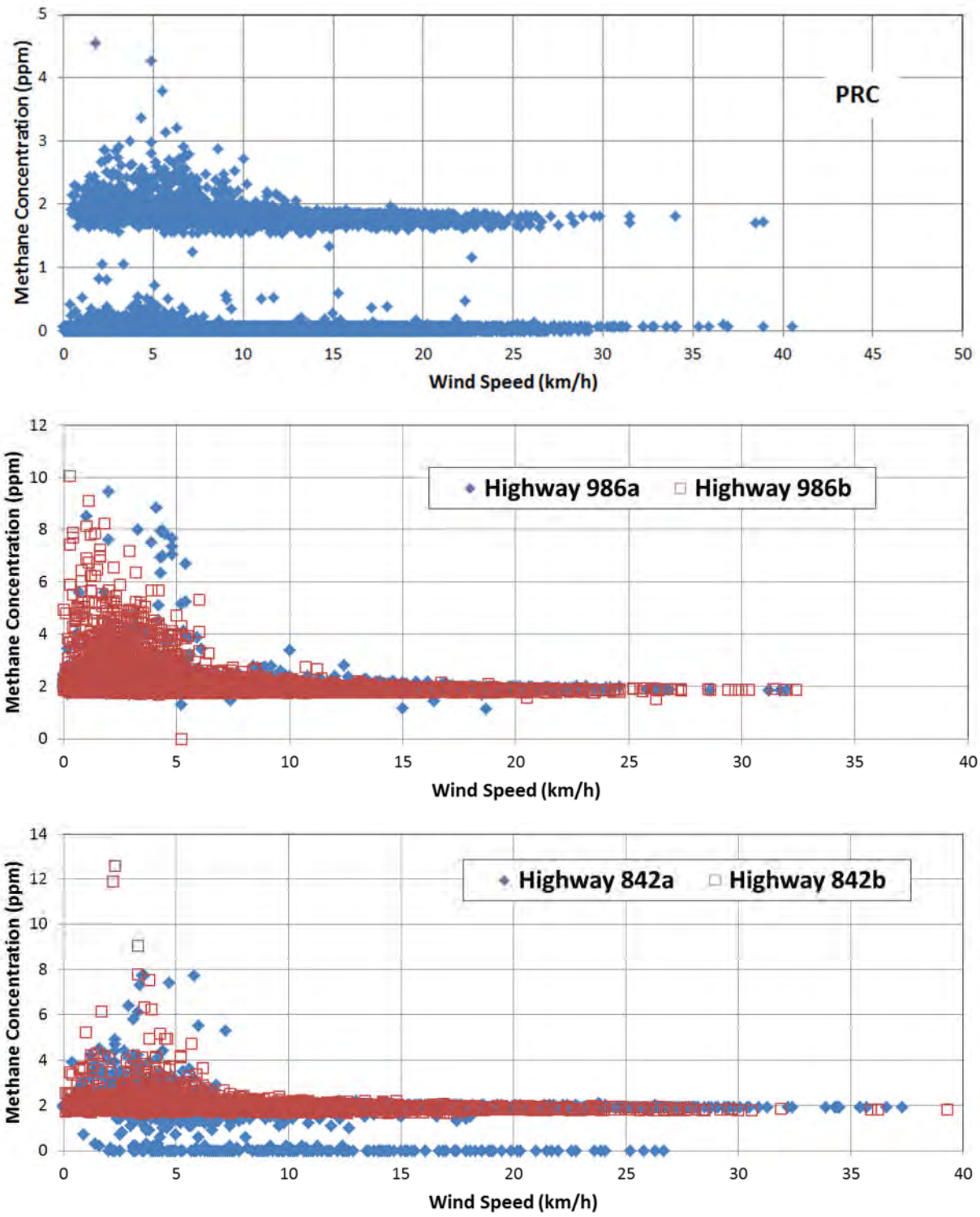


Figure 7-16 Ambient Methane concentration variation with wind speed at the three continuous air quality monitoring stations. Associated periods are as indicated in Figure 7-13.

7.3.3 NMHC Concentrations

From an odour and air quality effects perspective, NMHC are more significant than the THC that includes methane, and the methane component.

7.3.3.1 Temporal Trends

Figure 7-17 shows the hourly time series of ambient NMHC concentrations (ppb) measured at the PRC, Highway 986 and Highway 842 sites. While a common vertical concentration scale is adopted to facilitate comparisons between stations, the horizontal time scales reflect the period associated with each monitoring station. The NMHC concentration peaks at all stations generally tend to be in the 0.5 to 1.5 ppm (500 to 1000 ppb) range.

Figure 7-18 shows the ambient NMHC concentration variation with time of day for the continuous stations. With only 4 months of data at the PRC station, the determination of a trend is limited. The Highway 986 (and b) and the Highway 842 (a and b) trends are similar to respective THC trends.

7.3.3.2 Meteorological Trends

Figure 7-19 shows the ambient NMHC concentration variation with wind direction for the continuous stations. There are a few peak values (i.e., up to 1.5 ppm) at the PRC station that point to the Peace River Complex and may be associated with short-term temporary upset conditions; note the length of record for the PRC station is only four months. The wind direction trends associated with high NMHC values for the Highway 986 (a and b) and the Highway 842 (a and b) sites are somewhat similar to those associated with the THC measurements.

The Highway 986a winds tend to point to NMHC sources located to the ENE, while the Highway 986b winds tend to point to sources to the ESE. As pointed out in Section 4.1.3, the winds at the Highway 986a site may not be representative of regional airflow due to nearby siting obstructions. On this basis, a higher level of confidence is placed on the Highway 986b trends. The higher concentration events at the Highway 842 (a and b) sites indicate sources located to the ENE and E. There is one high NMHC concentration at the Highway 842a site associated with the WSW winds.

Figure 7-20 shows the ambient NMHC concentration variation with wind speed for the continuous stations. Some of the peak NMHC values at the PRC site are associated with wind speeds of about 20 km/h. Most of the other peak NMHC values tend to be associated with wind speeds less than 7 km/h.

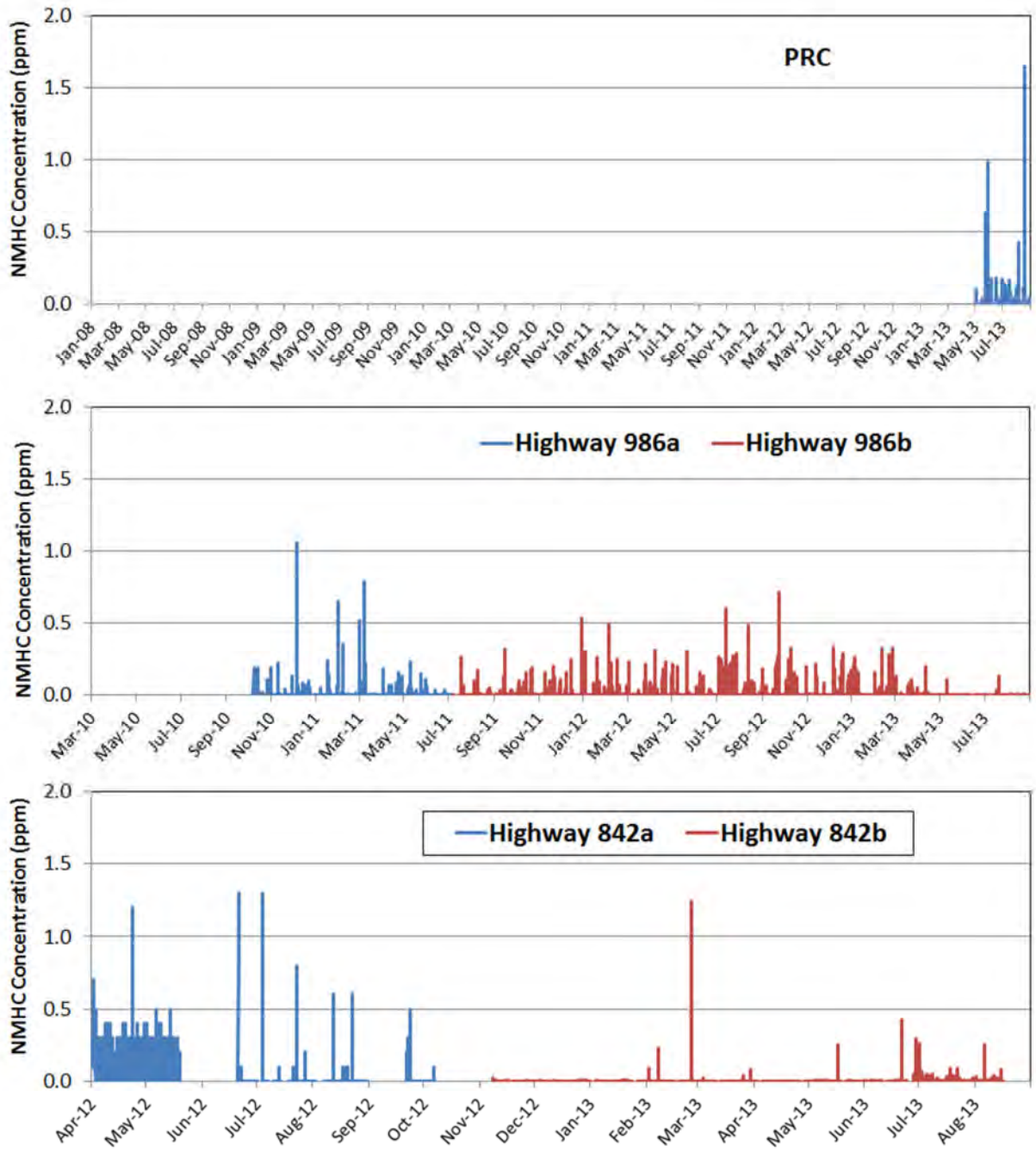


Figure 7-17 Ambient NMHC concentration time series measured at the three continuous air quality monitoring stations

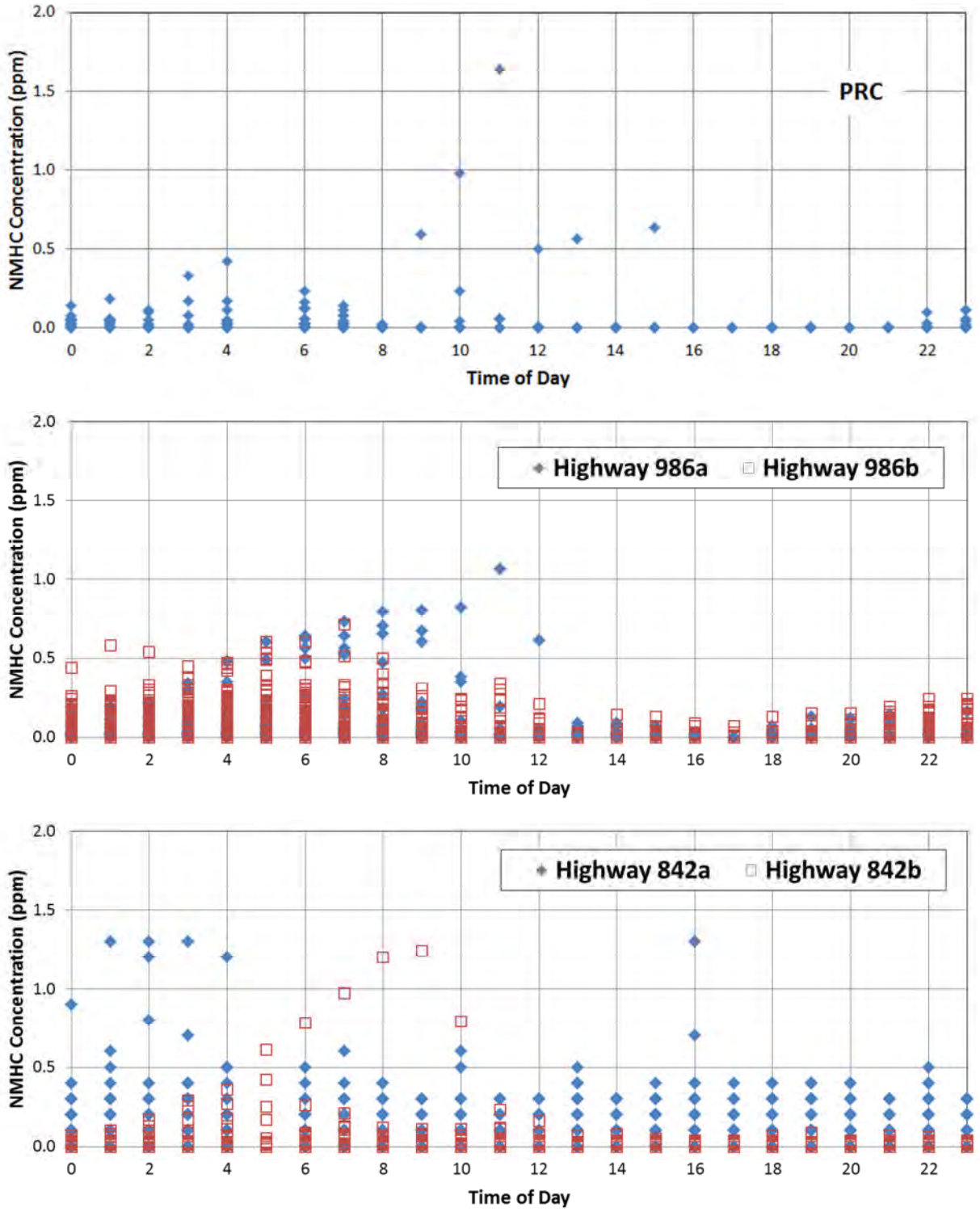


Figure 7-18 Ambient NMHC concentration variation with time of day at the three continuous air quality monitoring stations. Associated periods are as indicated in Figure 7-17.

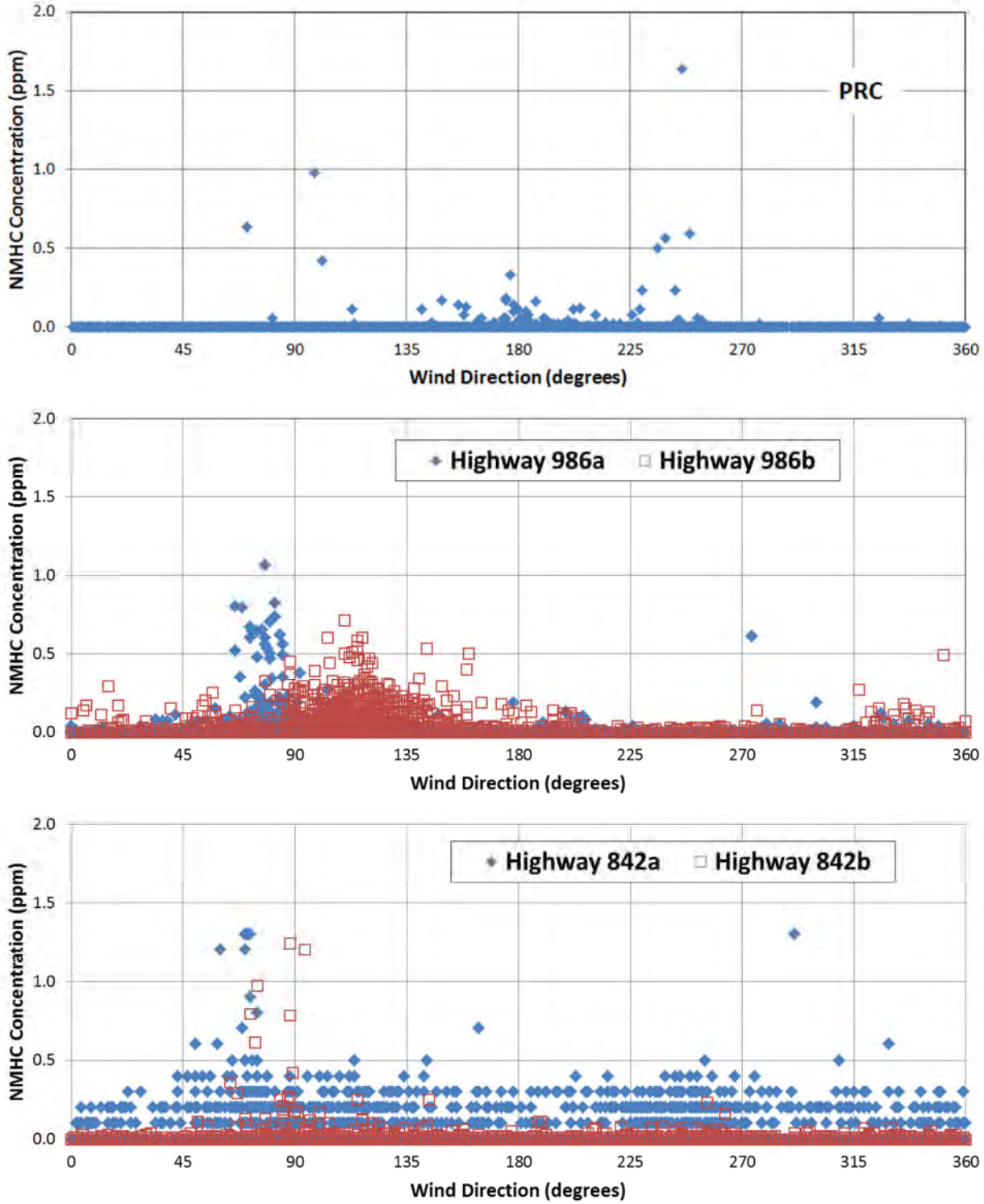


Figure 7-19 Ambient NMHC concentration variation with wind direction at the three continuous air quality monitoring stations. Associated periods are as indicated in Figure 7-17.

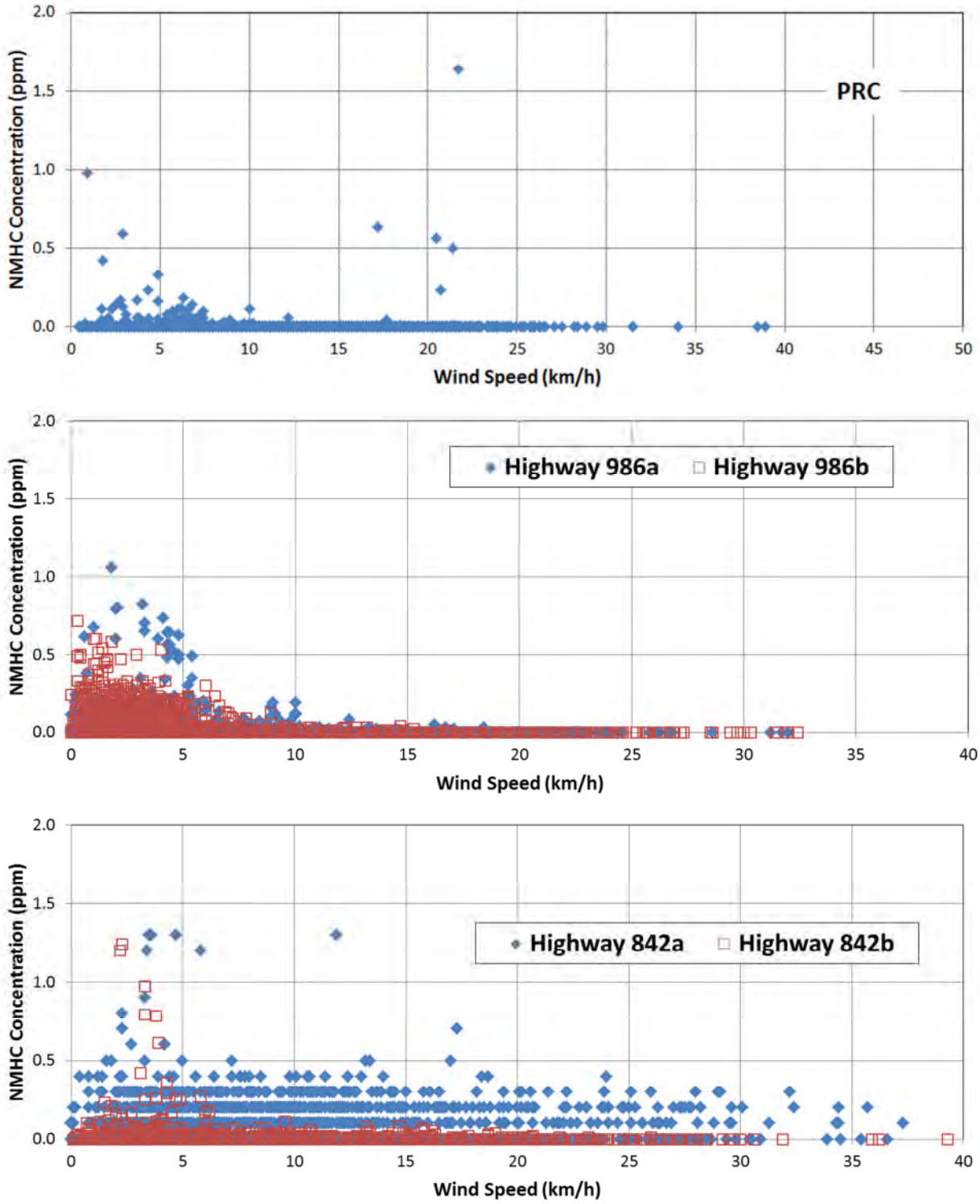


Figure 7-20 Ambient NMHC concentration variation with wind speed at the three continuous air quality monitoring stations. Associated periods are as indicated in Figure 7-17.

7.3.4 Sub-hourly NMHC Concentrations

While continuous ambient air quality monitoring typically focusses on 1-hour averaging periods, the dataloggers in the monitoring station are sometimes programed to collect and store concentration for averaging periods that are less than 1 hour (e.g., 1 minute or 5 minute averages). The 5-minute average NMHC concentrations from the Highway 986b and Highway 842b sites were examined and compared to the associated 1-hour average values.

At the Highway 986b site, 5-minute average NMHC values are only available since January 2012. Figure 7-21 shows the1-hour and 5-minute NMHC concentrations. The 1-hour and 5-minute plots are shown with the same vertical scale, and an additional 5-minute plot is also shown in a vertical scale that captures the peak event values. The following two "events" show up in the 5-minute data:

- The 5-minute NMHC values of about 7 ppm occur on Jan 21 2012 between 2:45 and 5:40. This event occurs after a daily calibration and the methane concentrations for the period before, during and following are 0 ppm. We do not see 1-hour NMHC concentration of about 7 ppm at this time. We view this event showing up on the 5-minute data as erroneous; it appears to have been removed from the 1-hour data during the routine data QA/QC process.

- The 5-minute data values for the period August 8 to 12, 2013 are in the 2 to 3 ppm range. The methane concentrations for the period before, during and following are 0 ppm. We do not see 1-hour NMHC concentrations between 2 and 3 ppm at this time. We view this event showing up on the 5-minute data as erroneous; it appears to have been removed from the 1-hour data during the routine data QA/QC process.

Discounting these two periods, the 5-minute and 1-hour data show the similar trends and the 5-minute data peaks do not appear to be extraordinarily greater than the 1-hour data. Detailed comparison statistics were not undertaken as this would require substantive quality control of the file.

At the Highway 842b site, 5-minute and 1-hour average NMHC values are available since November 2012. Figure 7-22 shows the1-hour and 5-minute NMHC concentrations. The 1-hour and 5-minute plots are shown with the same vertical scale, and an additional 5-minute plot is also shown in a vertical scale that captures the peak event values. The following two "events" show up in the 5-minute data:

- A single 5-minute NMHC value of about 25 ppm occurs on December 12 2012 at 17:20. For the preceding period, the methane concentrations are about 1.9 ppm, but the NMHC values are missing. The NMHC concentrations for the period following are 0 ppm. It is not clear if this single 5-minute event is erroneous or real.

- For the period June 1 to June 24, 2013, it appears that the daily NMHC 14 ppm calibration data has not been removed from the 5-minute data. This affects five 5-minute periods once per day.

Discounting these two periods, the 5-minute and 1-hour data show similar trends and the 5-minute data peaks do not appear to be extraordinarily greater than the 1-hour data. Detailed comparison statistics were not undertaken as this would require substantive quality control of the file.

7.3.5 Concentration Comparisons

7.3.5.1 NMHC and SO_2 and H_2S Trends

Figure 7-23 shows scatter plots of NMHC concentrations as a function of SO_2 and TRS/H_2S concentrations measured at the PRC site. High NMHC concentrations do not appear to be related to either high SO_2 or to TRS/H_2S concentrations.

Figure 7-24 shows scatter plots of NMHC concentrations as a function of SO_2 and TRS concentrations measured at the Highway 986 (a and b) sites. High NMHC concentrations do not appear to be related to high SO_2 concentrations. There may be a weak association between high NMHC and high TRS concentrations.

Figure 7-25 shows scatter plots of NMHC concentrations as a function of SO_2 and TRS/H_2S concentrations measured at the Highway 842 (a and b) sites. There may be a weak association between high NMHC and high TRS concentrations.

7.3.5.2 NMHC and Methane Trends

Figures 7-26 to 7-28 show scatter plots of NMHC concentrations as a function of methane concentrations for the PRC, Highway 986 and Highway 842 stations respectively. For high concentrations, there appears to be a liner relationship between NMHC and methane. If both NMHC and methane are emitted by the same source, then the slope of the linear relationship can be used to determine the fraction of NMHC relative to THC. The following are noted:

- The relationship for the PRC site implies that methane is 85% of the THC. While the vertical line implies that for some cases, the THC is all NMHC; this is an artefact of the reporting of 0 ppm methane. Figure 7-26.

- There are two linear relationships for the Highway 986 sites: the Highway 986a site implies that methane is 75% of the THC, and the Highway 986b site implies that methane is 90% of the THC. The horizontal line indicates that for some cases that THC is essentially 100% methane. Figure 7-27.

- There are also two linear relationships for the Highway 842 sites: the Highway 842a site implies that methane is 80% of the THC, and the Highway 842b site implies that methane is 88% of the THC. Figure 7-28.

This understanding may help identify THC emission sources that are the cause of high ambient concentrations. As an example, the PRC station is near the Shell Peace River Complex CPF and ESRD obtained and analyzed two gas samples from this facility, identified as "Plant Sample" and "Tank 1010 Inlet" (ESRD 2010). The NMHC contents of these two samples are 93% and 76% of THC, respectively. On the basis that these two samples equally represent fugitive emissions from the Peace River Complex CPF, then the average NMHC emission is 85% of THC; this is the same percentage as implied by the linear relationship shown in Figure 7-26.

7.3.6 Comparison to Ambient Benchmarks

There are no ambient air quality benchmarks for THC, methane or NMHC. While there are no regulatory agencies or organizations that currently have ambient benchmarks in place for total VOC, there are benchmarks for individual hydrocarbon compounds.

7.4 FINDINGS

Continuous air quality stations are typically used to collect ambient concentration on an hourly average basis. An examination of the continuous ambient air quality data collected at three locations indicates the following:

SO_2, H_2S and TRS Concentrations

- The PRC continuous station showed high ambient SO_2 and H_2S concentrations in 2008 and 2009, the period corresponding to the use of sour fuel gas at the Peace River Complex. Since 2009, ambient concentrations show a downward trend corresponding to the implementation of various emission mitigation measures and, sparing the occasional peaks associated with short-term temporary upset conditions, have been much lower in the 2011 to 2013 period.

- The ambient SO_2 concentrations at the Highway 986 (a and b) and the Highway 842 (a and b) sites are very low.

- The ambient TRS concentrations at the Highway 986 (a and b) and the Highway 842b sites are very low. In May and June 2012, relatively high TRS concentrations occurred at the Highway 842b site; these are associated with easterly and southwesterly to westerly source wind directions.

THC, Methane and NMHC Concentrations

- There were challenges with the THC, methane and NMHC analyzer operability that reduced the amount of valid data. The NMHC concentrations are of most interest with respect to the regional air quality issues.

- THC 1-hour peaks are in the 4 to 10 ppm range, and tend to be intermittent. These peaks tend to be primarily composed of methane.

- The minimum ambient methane concentration is typically about 1.8 to 2 ppm; this corresponds to the current global background concentration.

- There are periodic NMHC 1-hour peaks that are in the 0.5 to 1.5 ppm (500 to 1500 ppb) range.

- The Highway 986a NMHC data indicate an ENE upwind source direction, and Highway 842a NMHC data indicate an ENE upwind source direction.

- The Highway 986b data indicate an E upwind source direction, and the Highway 842b data indicate an ESE upwind source direction.

- As indicated in the review of the meteorological data, a higher confidence level is placed with the Highway 986b and 842b wind direction data.

- Single point high NMHC concentrations at both sites are associated with winds from the W for the Highway 986b site and from the WNW for Highway 842a site.

- All high NMHC concentrations tend to be associated with low wind speeds (i.e., less than 5 km/h).

- High NMHC concentrations do not appear to be correlated to either SO_2 or H_2S/TRS concentrations.

- Under low wind speed conditions, the associated plume meander may result in wind directions that have greater variability, making it more difficult to correlate high concentrations to an upwind source.

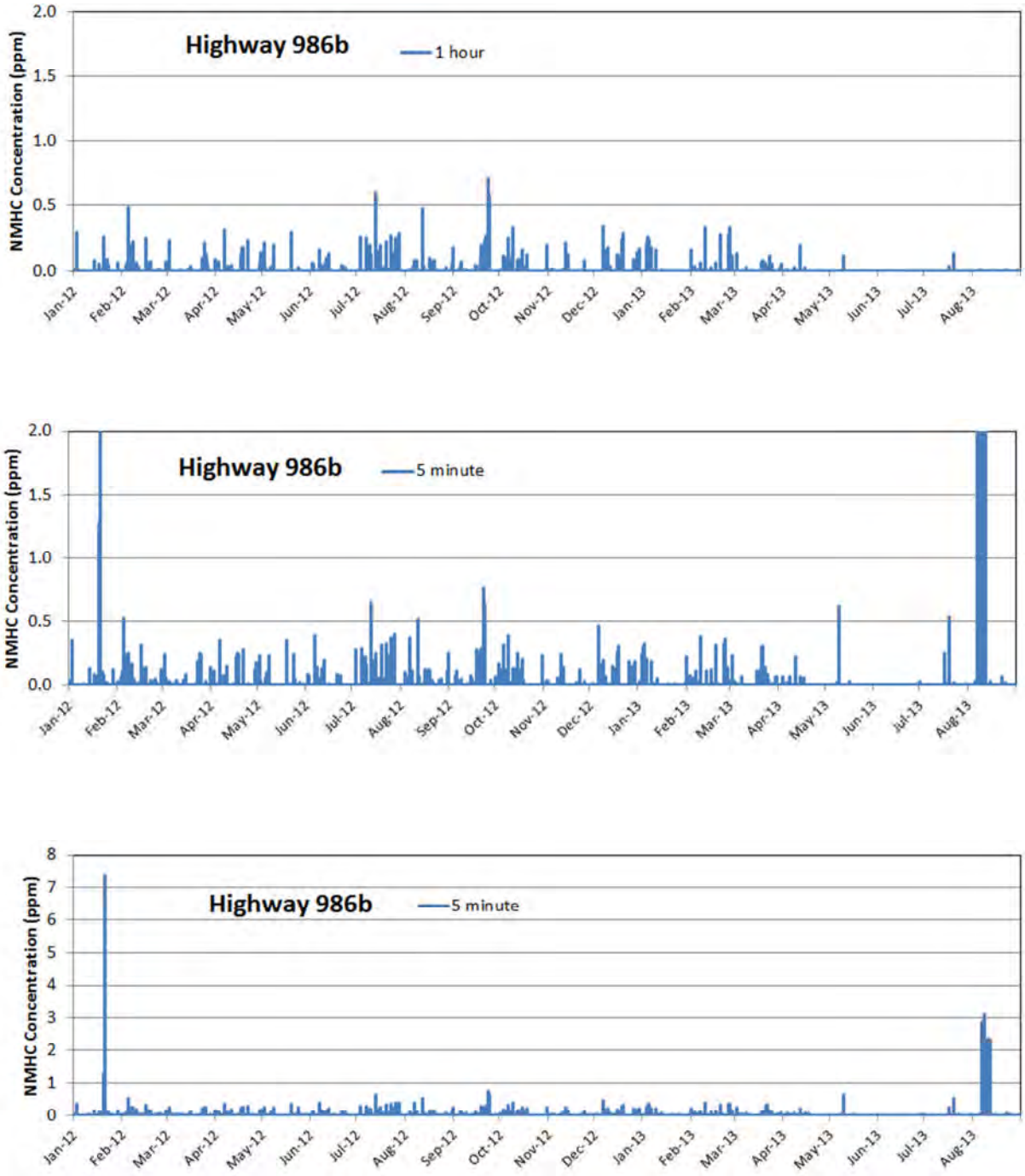


Figure 7-21 Comparison of 1-hour and 5-minute average ambient NMHC concentrations at the Highway 986b continuous air quality monitoring site (January 2012 to August 2013)

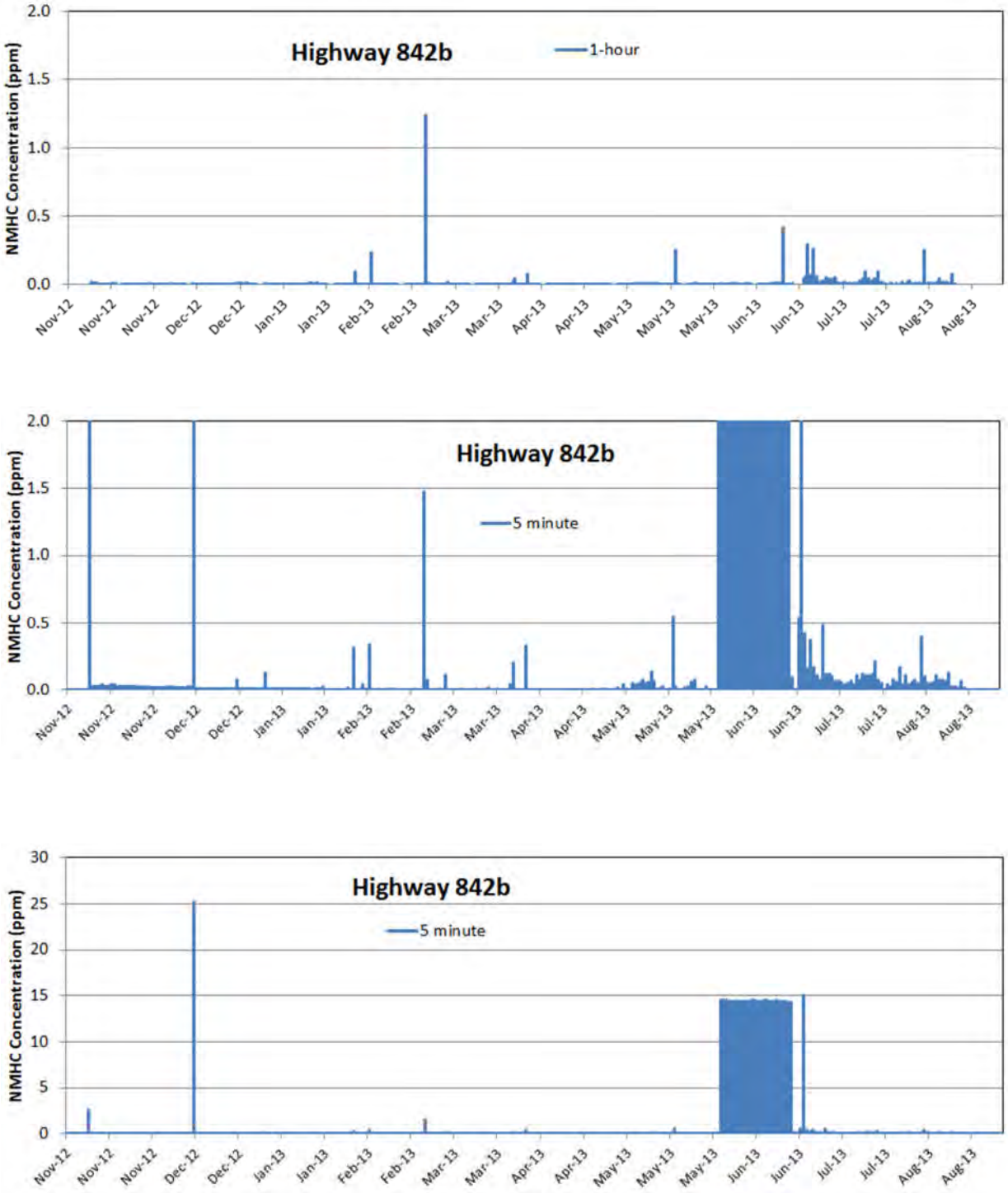


Figure 7-22 Comparison of 1-hour and 5-minute average ambient NMHC concentrations at the Highway 842b continuous air quality monitoring site (November 2012 to August 2013)

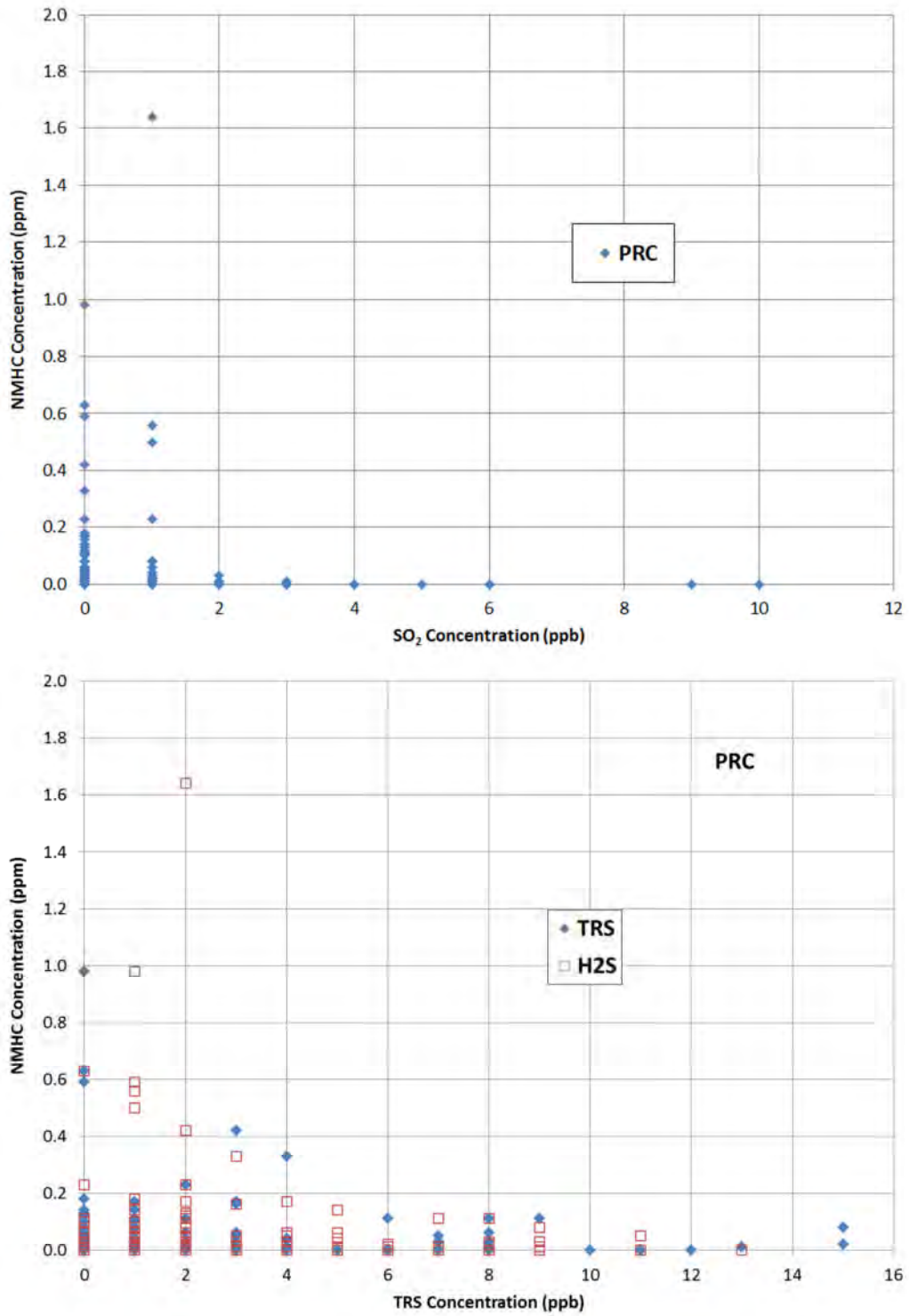


Figure 7-23 Ambient NMHC concentration variation with ambient SO_2 and TRS/H_2S concentration at the PRC continuous air quality monitoring site

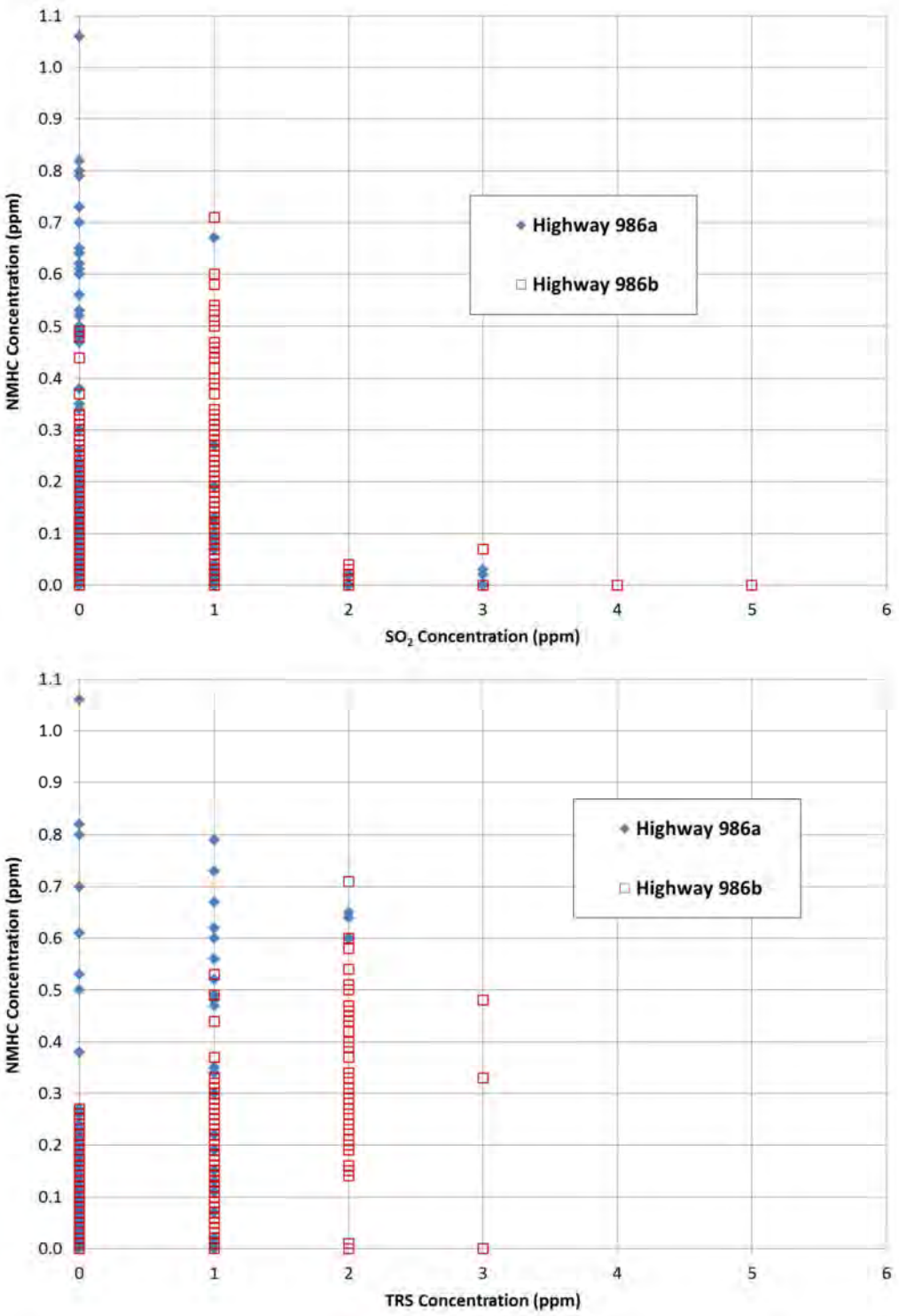


Figure 7-24 Ambient NMHC concentration variation with ambient SO_2 and TRS concentration at the Highway 986 continuous air quality monitoring site

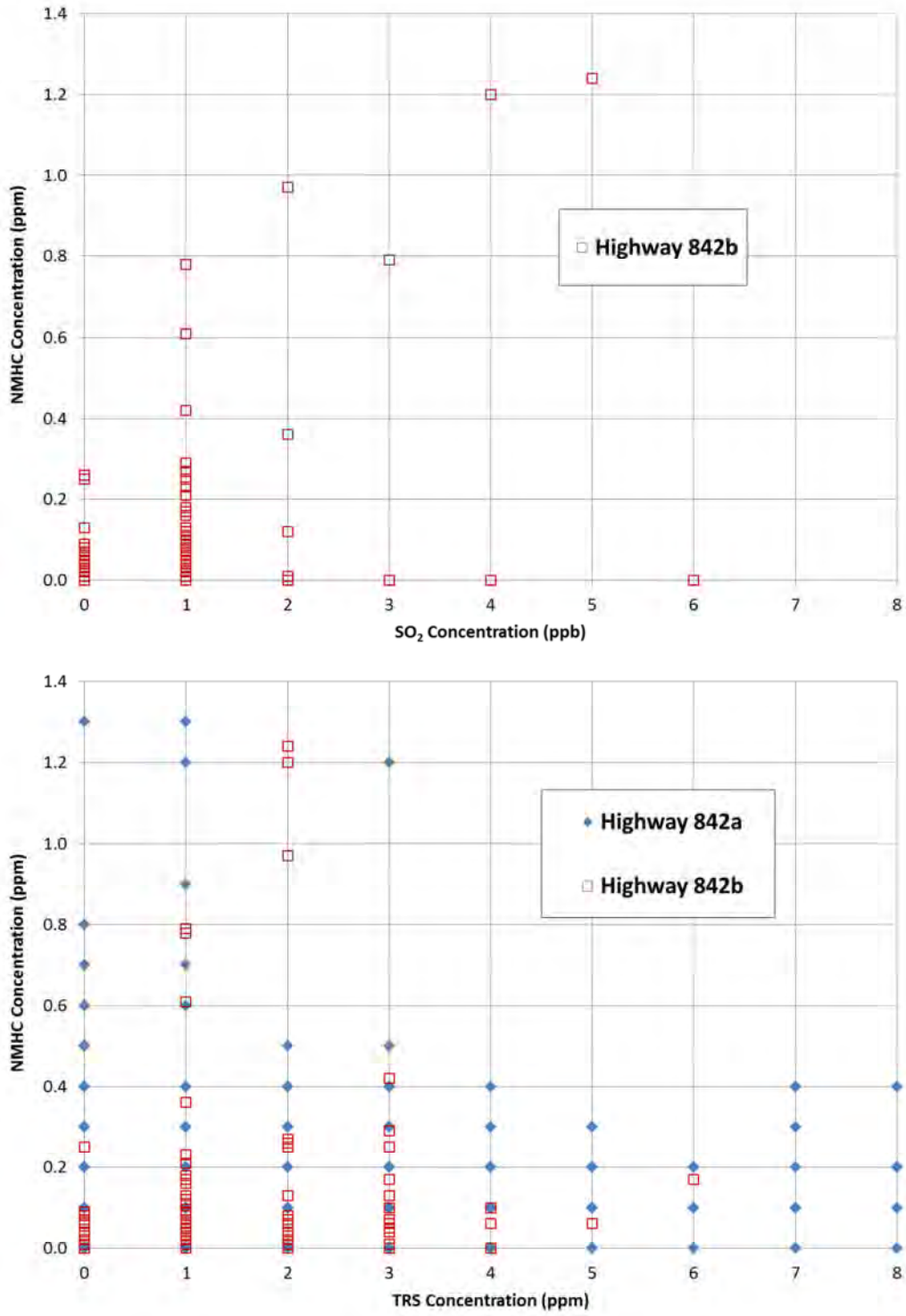


Figure 7-25 Ambient NMHC concentration variation with ambient SO_2 and TRS concentration at the Highway 842 continuous air quality monitoring site

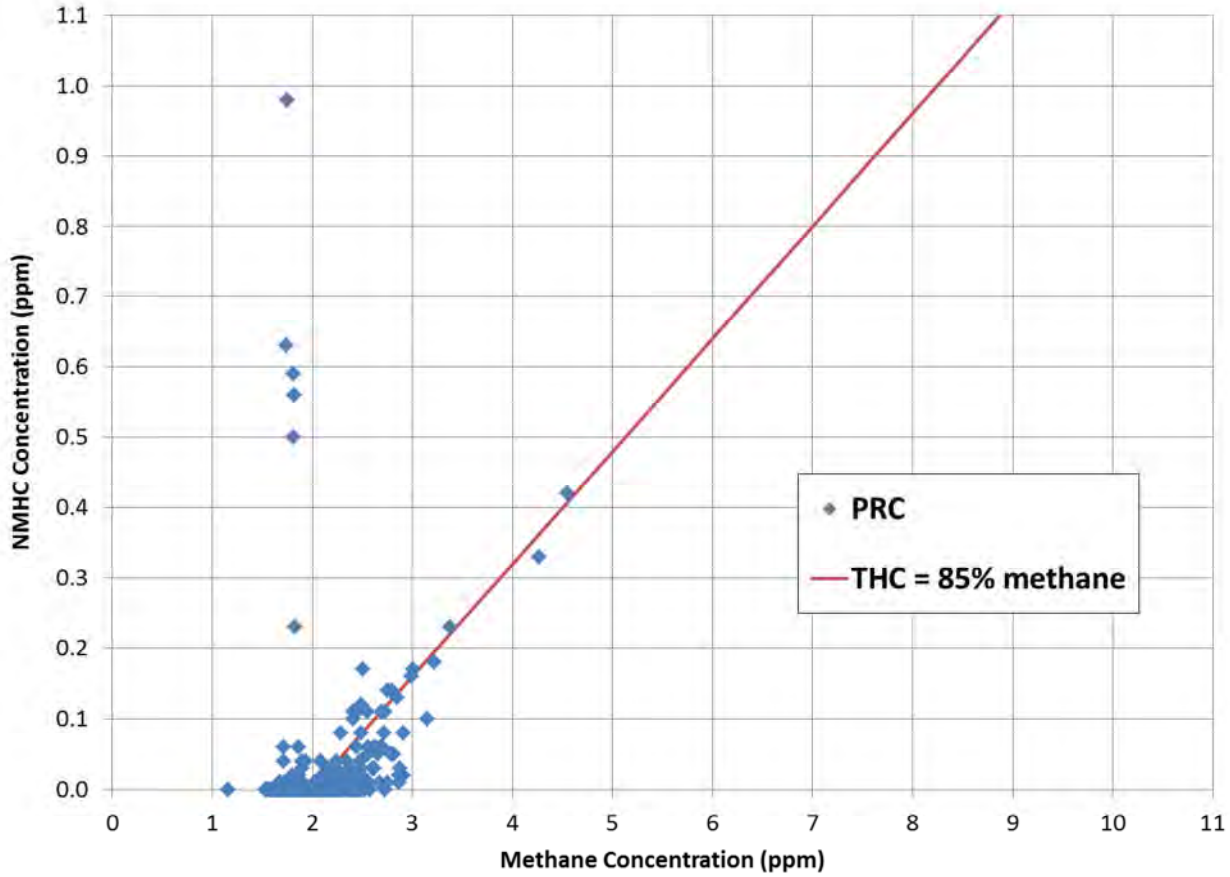


Figure 7-26 Ambient NMHC concentration variation with ambient Methane concentration at the PRC continuous air quality monitoring site

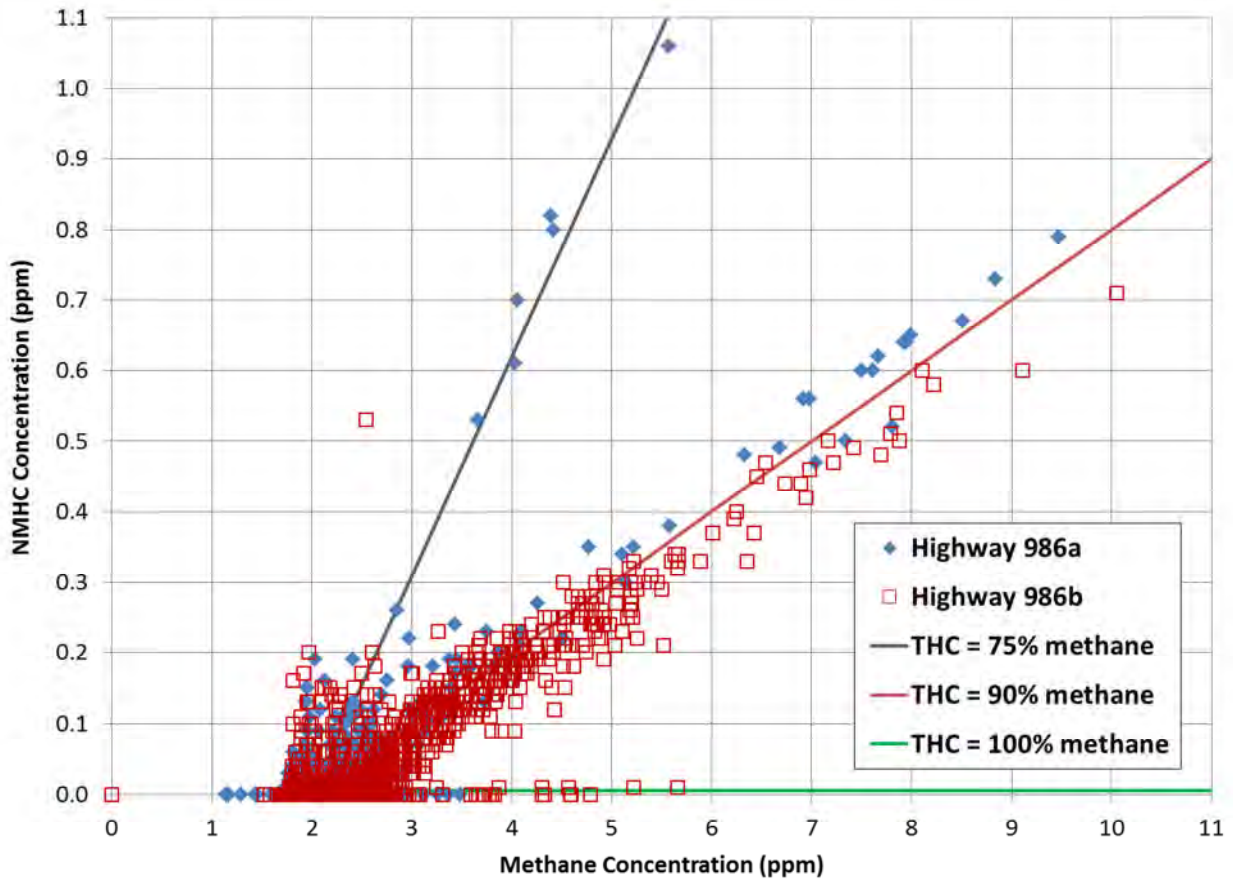


Figure 7-27 Ambient NMHC concentration variation with ambient Methane concentration at the Highway 986 continuous air quality monitoring sites

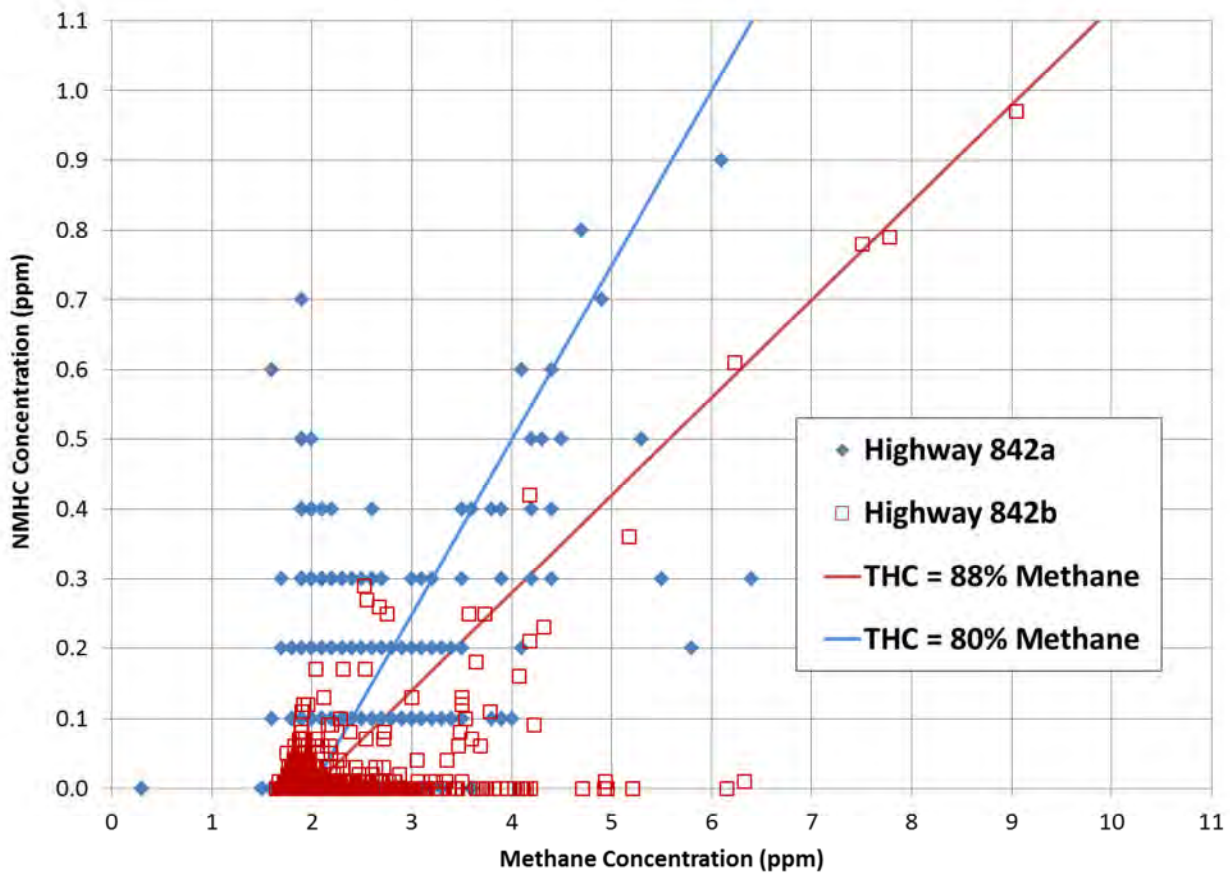


Figure 7-28 Ambient NMHC concentration variation with ambient Methane concentration at the Highway 842 continuous air quality monitoring sites

7.5 GAPS AND RECOMMENDATIONS

The Alberta Air Monitoring Directive (AMD) specifies siting criteria, equipment specifications, operating procedures and reporting requirements. ESRD periodically audits air quality monitoring stations to determine compliance to the AMD. Audit reports and monthly air quality monitoring reports were provided for examination. A review of the station audits relative to the air quality monitoring is provided in Table 7-6. Based on the audits and the examination of the data, the following information gaps and recommendations are made:

- **Gap/Recommendation C1:** The continuous monitoring focuses on SO2, TRS, and THC/methane/NMHC. As indicated in the passive monitoring section, the main stakeholder issue in the region is associated with hydrocarbon emissions. For this reason, future continuous monitoring needs to emphasize THC/methane/NMHC measurements.

- **Gap Recommendation C2:** There have been difficulties operating the continuous THC/methane/NMHC analyzers. This problem needs to be resolved to increase the level of stakeholder confidence with the associated data. An independent auditor, the contractor, and a Three Creeks Air Monitoring Committee representative meeting at the site would help resolve the issue.

- **Gap Recommendation C3:** The two Three Creeks Air Monitoring Subcommittee continuous air quality monitoring stations are located near the residential areas. An additional monitoring station located in the middle of the potential source region would help determine the contribution of these sources. The ambient air quality monitoring station in this region would provide an indication of air quality in the source region on a continuous basis.

- **Gap/Recommendation C4:** Although the ambient temperature is of secondary importance, the results that were reported at the Highway 842a station show that incorrect information can get into the database. A sequential time series of meteorological measurements should be included in the monthly reports from the monitoring station contractor to catch these types of occurrences.

- **Gap/Recommendation C5:** The documentation and reporting associated with the Highway 986 and Highway 842 stations has been confusing. The name of the stations tended to change with different information sources. For example the two Highway 986 sites have varyingly been referenced as the Langer station, Site A, Site 1, Highway 986 and the Penn West station. An effort needs to be made by all involved parties to adopt a consistent naming convention.

- **Gap/Recommendation C6:** here was an indication that some of the data were reported to the nearest 10 ppb. While this may be viewed as being sufficient for compliance monitoring, it provides limitations when examining the data for other purposes. The instruments should be able to collect ambient measurements to the nearest 1 ppb. An independent auditor, the

contractor, and a Three Creeks Air Monitoring Committee representative meeting at the site would help resolve the issue.

It should be noted that while valid air quality information can be extracted from data where there have been some audit deficiencies and compromises, public confidence is quickly eroded if there are deficiencies. For this reason, it is prudent to equip, operate and maintain and air quality station to the highest possible standards.

Table 7-6 Monitoring station air quality audit findings for the Highway 986 ad 842 monitoring stations

Station and Audit Date	Parameter	Audit Comment
Highway 986		
May 14, 2010	Calibration	Absolute difference = 1 to 9%
November 9, 2010	NMHC Calibration	Absolute difference = 1%
August 22, 2012	All items	All "Pass" or "OK"
	Calibration	Absolute difference = 1 to 5%
	Station documentation	Needs review or missing
June 11, 2013	All items	All "Pass" or "OK"
	Calibration	Percent difference = 2 to 4%
Highway 842		
August 23, 2012	Calibration	TRS greater than 15%. Others 3 to 5%
	Safety	Loose cylinders
	Housekeeping	Damaged door
June 11, 2013	Inlet manifold	Dusty (need for improvement)
	Calibration	Absolute difference = 3 to 5%

8.0 Canister Monitoring

Over the 2010 to 2013 period, evacuated canisters were deployed to collect air samples that were analyzed for various hydrocarbon and sulphur compounds. The canisters are equipped with a valve that determines the filling rate. The filling rates were varied from near instantaneous to specified intervals (e.g., 10 minutes, 15 minutes, 1 hour).

The collection of these canisters broadly falls into one of the following categories:

- **Grab Sample:** Over the period Apr to Dec 2010, grab samples were collected by local residents and ESRD staff. Typically, the samples were collected when an odour was perceived. A total of 22 samples were obtained; 21 collected by residents and 1 by ESRD. The grab samples typically represent instantaneous sample collection.

- **Integrated Sample:** Over the period when grab samples were collected (Apr to Dec 2010), time averaged samples were also collected by ESRD. A total of 12 samples were obtained. Typically, the samples represent sampling periods ranging from 10 minutes to 1-hour.

- **Campaign Sample:** Over the five-day period Oct 24 to 28 2010, ESRD collected samples at six locations in the region. A total of 24 samples were collected over a five-day period. Each sample represents a nominal 1-hour period, and all samples were collected during the night.

- **Triggered Sample:** Samples were collected automatically at the air quality monitoring stations when the ambient NMHC concentration reached a predetermined value. A total of 118 triggered samples were collected with 11 samples in 2010, 33 samples in 2011, 52 samples in 2012 and 22 samples in 2013. Virtually all the samples were collected at the Highway 986a and Highway 986b sites. Each sample represents a nominal 10 or 15 minute period.

Figure 8-1 shows the locations of the canister sampling collection sites. The letter designation based on the ESRD naming is adopted (i.e., sites M, O, N, P and Q for the Grab Samples; sites C, E, F, G, H and M for Integrated Samples; and sites A, B, H, J, K and L for the Campaign Samples).

The sampling results were provided by ESRD in a file format that in some cases represented one sample, and in other cases represented multiple samples. In some cases, the sample files did not indicate when the sample was collected. When the sampling date was missing, the received date was used.

Each analysis has a unique identification (ID) code. This report identifies the codes that provide a traceable record back to the original data. This will also allow for third party confirmation of the findings presented in this report.

8.1 TARGET COMPOUNDS

After the air samples are collected in the canisters by residents, ESRD or MAXXAM; the canisters are documented and shipped to the Alberta Innovates Technology Futures (AITF) laboratory in Vegreville, Alberta. Here the samples are analyzed to determine concentrations of individual chemical compounds. Specifically a gas chromatograph (GC) is used to separate the individual compounds due to differing retention times. A mass spectrometer is used to identify the peaks associated with each compound. A specific retention time and associated spectrum for an unknown compound are compared to the corresponding parameters for the pure compound on the same instrument.

The identified chemical compounds are classified as target compounds or non-target compounds. The highest level of confidence is placed with the target compounds that can be positively identified since the analytical methodology is calibrated for these compounds. Other compounds that are present (i.e., the non-target compounds) have a lower level of confidence. The confidence level for the non-targeted compounds can be judged by a match-quality parameter. The confidence level decreases when the match quality level is less than 70%. ESRD (2010) indicates that the match quality for many of the non-targeted compounds were greater than 80%. The ESRD (2010 and 2011) reports assessed the target and non-target compounds as separate groupings. This assessment groups them together for the purpose of identifying trends and comparing to the associated concentrations to the ambient air benchmarks.

Tables 8-1 to 8-4 identify the target compounds and the associated approach:

- Table 8-1 identifies hydrocarbon compounds with 1 to 4 carbons (**C1C4 scan**), and the scan is based on a flame ionization detector (FID). This scan focusses on 15 chemical compounds and the minimum detection level (MDL) for each compound is typically 50 ppb.

- Table 8-2 identifies reduced sulphur compounds (**RSC scan**), and the scan is based on a sulphur chemiluminescence detector (SCD). This scan focusses on 23 chemical compounds and the MDL for each compound is typically 1 ppb.

- Table 8-3 identifies volatile organic compounds (VOC) associated with the US EPA Photochemical Assessment Monitoring Station (**PAMS**) monitoring approach. These VOCs are precursors to ozone formation and are measured in this context; the US EPA approach focusses on 54 target hydrocarbon compounds. The scan is based on a gas chromatograph/mass spectrometer-flame ionization detector (GC/MS-FID). This scan focusses on 26 VOCs and the MDL for each VOC is typically 0.5 ppb.

- Table 8-4 identifies volatile organic compounds (VOC) based on toxic considerations. The compounds are based on the US EPA TO-15 and TO-17 methods. Although the US EPA does not have a specific target list, many laboratories focus on 60 to 75 target hydrocarbon compounds. The scan is based on a gas chromatograph/mass spectrometer-flame

ionization detector (GC/MS-FID). This scan focusses on 64 VOCs and the MDL for each VOC is typically 0.5 ppb.

For some compounds, the MDL is greater than the odour threshold indicated in Table 3.6. For example, the odour threshold for methyl mercaptan is 0.07 ppb, which is much less than the 1 ppb MDL. This means that the odours could have been occurring even though the measurements indicate a "non-detect" that implies a "zero" concentration.

Others have found it a challenge to relate odour complaints to ambient concentration measurements. The Wood Buffalo Environmental Monitoring Association (WBEA) has adopted more advanced monitoring technologies pursuing this endeavor. For example, O'Brien et al (2012) report on the use of gas chromatography to measure VOC and reduced sulphur compounds. They note a correlation between TRS measurements in Fort McKay and perceived odours, and the TRS concentrations associated with the odour complaints were less than 2 ppb. While H_2S may have been responsible for some of the odour complaints when high TRS concentrations were measured, it is not clear what other reduced sulphur compounds are responsible for odours when low TRS values are measured. O'Brien et al speculate that compounds such as methyl mercaptan, dimethyl-disulphide, diethyl-disulphide and methyl-ethyldisulphide are potential candidates as the associated odour thresholds are less than 1 ppb.

Table 8-1 Target compounds associated with the C1C4 analytical scan

Chemical compound	CAS #
1,3-Butadiene	106-99-0
1-Butene	106-98-9
Acetylene	74-86-2
Butane	106-97-8
Ethane	74-84-0
Ethylacetylene	107-00-6
Ethylene	74-85-1
Isobutane	75-28-5
Isobutylene	115-11-7
Methane	74-82-8
Propane	74-98-6
Propylene	115-07-1
Propyne	74-99-7
cis-2-Butene	590-18-1
trans-2-Butene	624-64-6
NOTES: 15 chemical compounds The MDL is 50 ppb for each compound	

Table 8-2 Target compounds associated with the RSC analytical scan

Chemical compound	CAS #
2,5-dimethyl Thiophene	638-02-8
2-ethyl Thiophene	872-55-9
2-methyl Thiophene	554-14-3
3-methyl Thiophene	616-44-4
Allyl sulphide	592-88-1
Butyl mercaptan	109-79-5
Butyl sulphide	544-40-1
Carbon disulphide	75-15-0
Carbonyl sulphide	463-58-1
Dimethyl disulphide	624-92-0
Dimethyl sulphide	75-18-3
Dimethyl trisulphide	3658-80-8
Ethyl mercaptan	75-08-1
Ethyl sulphide	352-93-2
Hexyl mercaptan	111-31-9
Hydrogen sulphide	7783-06-4
Isopropyl mercaptan	75-33-2
Methyl mercaptan	74-93-1
Propyl mercaptan	107-03-9
Thiophene/iso+sec butyl mercaptan	513-44-0
n-Amyl mercaptan	110-66-7
tert-Amyl mercaptan	1679-09-0
tert-Butyl mercaptan	75-66-1
NOTES: 23 chemical compounds The MDL is 1 ppb for each compound	

Table 8-3 Target compounds associated with the PAMS analytical scan

Chemical compound	CAS #
Isobutane	75-28-5
1-Butene	106-98-9
n-Butane	106-97-8
Trans-2-Butene	624-64-6
Cis-2-Butene	590-18-1
Isopentane	78-78-4
1-Pentene	109-67-1
n-Pentane	109-66-0
Isoprene	78-79-5
Trans-2-Pentene	646-04-8
Cis-2-Pentene	627-20-3
2,2-Dimethylbutane	75-83-2
Cyclopentane	287-92-3
2,3-Dimethylbutane	79-29-8
2-Methylpentane	107-83-5
3-Methylpentane	96-14-0
1-Hexene	592-41-6
n-Hexane	110-54-3
Methylcyclopentane	96-37-7
2,4-Dimethylpentane	108-08-7
Benzene	71-43-2
Cyclohexane	110-82-7
2-Methylhexane	591-76-4
2,3-Dimethylpentane	565-59-3
3-Methylhexane	589-34-4
2,2,4-Trimethylpentane	540-84-1
NOTES: 26 chemical compounds The MDL is 0.5 ppb for each compound	

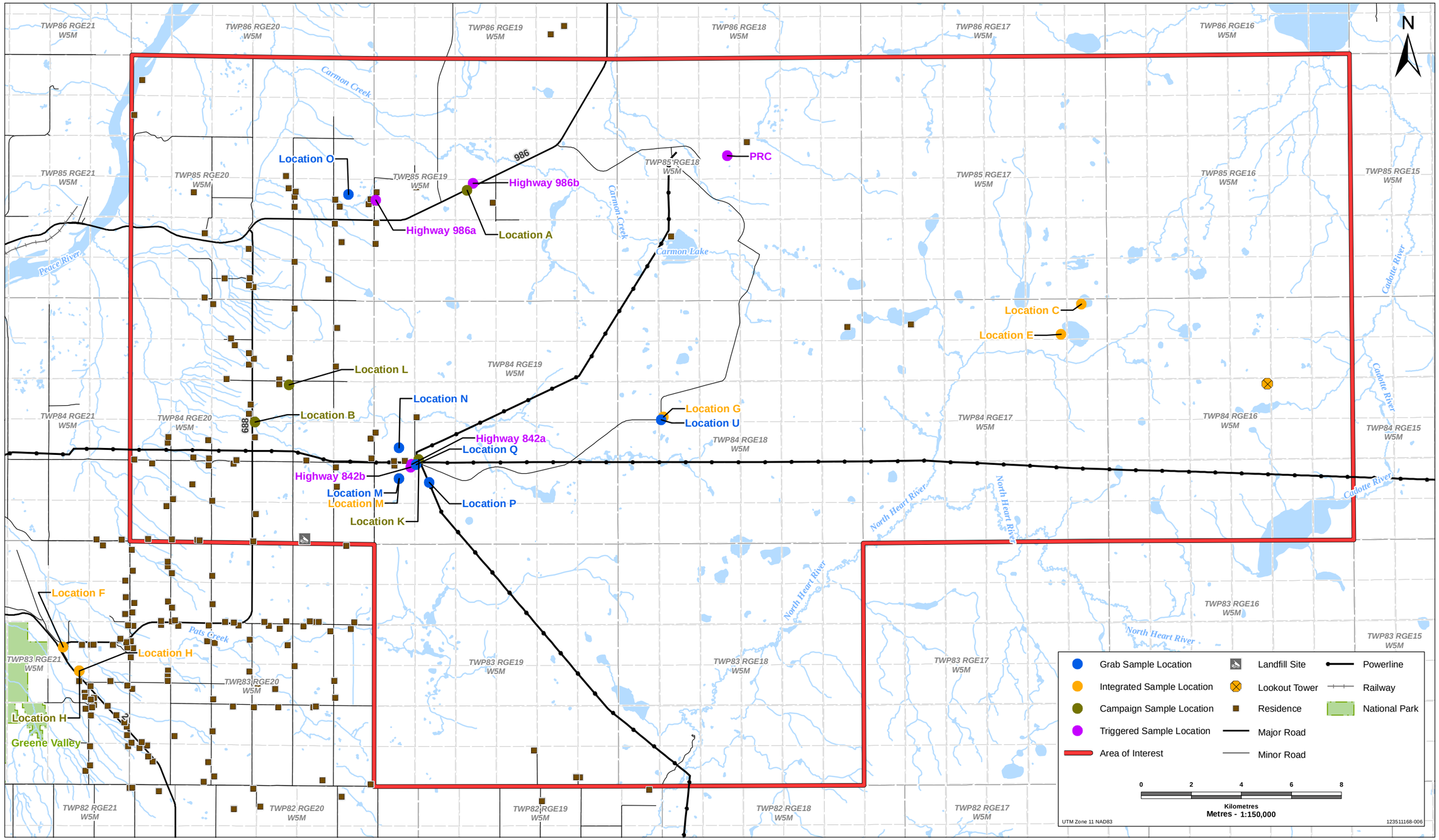
Table 8-4 Target compounds associated with the VOC-PT analytical scan

Chemical compound	CAS #	Chemical compound	CAS #
Propylene	115-07-1	1,2-Dichloropropane	78-87-5
Freon-12	75-71-8	Trichloroethylene	79-01-6
Chloromethane	74-87-3	Bromodichloromethane	75-27-4
Freon-114	76-14-2	1,4-Dioxane	123-91-1
Vinyl Chloride	75-01-4	Methyl Methacrylate	80-62-6
1,3-Butadiene	106-99-0	Heptane	142-82-5
Bromomethane	74-83-9	Cis-1,3-Dichloropropene	10061-01-5
Chloroethane	75-00-3	Methyl Isobutyl Ketone	108-10-1
Ethanol *	64-17-5	Trans-1,3-Dichloropropene	10061-02-6
Acrolein *	107-02-8	1,1,2-Trichloroethane	79-00-5
Acetone	67-64-1	Toluene	108-88-3
Freon-11	75-69-4	Methyl Butyl Ketone	591-78-6
Isopropyl Alcohol	67-63-0	Dibromochloromethane	124-48-1
1,1-Dichloroethene	75-35-4	1,2-Dibromethane	106-93-4
Carbon Disulfide *	75-15-0	Tetrachloroethylene	127-18-4
Methylene Chloride	75-09-2	Chlorobenzene	108-90-7
Freon-11 3	75-69-4	Ethylbenzene	100-41-4
Trans-1 ,2-Dichloroethene	156-60-5	p-xylene	106-42-3
1,1-Dichloroethane	75-34-3	m-xylene	108-38-3
Methyl Tert Butyl Ether	1634-04-4	Bromoform	75-25-2
Vinyl Acetate	108-05-4	Styrene	100-42-5
Methyl Ethyl Ketone	78-93-3	o-xylene	95-47-6
Cis-1,2-Dichloroethene	156-59-2	1,1,2,2-Tetrachloroethane	79-34-5
Hexane	110-54-3	4-Ethyltoluene	622-96-8
Chloroform	67-66-3	1,3,5-Trimethylbenzene	108-67-8
Ethyl Acetate	141-78-6	1,2,4-Trimethylbenzene	95-63-6
Tetrahydrofuran	109-99-9	1,3-Dichlorobenzene	541-73-1
1,2-Dichloroethane	107-06-2	Benzyl Chloride *	100-44-7
1,1,1-Trichloroethane	71-55-6	1,4-Dichlorobenzene	106-46-7
Benzene	71-43-2	1,2-Dichlorobenzene	95-50-1

Table 8-4 Target compounds associated with the VOC-PT analytical scan

Chemical compound	CAS #	Chemical compound	CAS #
Carbon Tetrachloride	56-23-5	1,2,4-Trichlorobenzene	120-82-1
Cyclohexane	110-82-7	Hexachloro-1,3-Butadiene	87-68-3

NOTES:
64 chemical compounds
The MDL is 0.5 ppb for each compound
* Analytical accuracy is ± 10%



THREE CREEKS MONITORING

Location of Canister Sites

Acknowledgements: Original Drawing By Stantec, Basedata: Altalis, Canvec, National Road Network

PREPARED BY

Stantec

FIGURE NO.

8-1

Last Modified: 4/2/2014 By: csteiner

8.2 GRAB SAMPLE REVIEW

Table 8-5 provides a summary of the associated grab sample collection. The 24 grab samples were collected over the period July 7 2010 to August 29 2010. Depending on the sample, different analytical scans were undertaken. When all the samples are considered, a total of 211 target and non-target compounds were identified at least once in the 22 grab samples. There are 108 compounds where the maximum measured concentrations are greater than 0.5 ppb (the minimum detection level for VOC).

Table 8-6 identifies the number of non-zero concentrations (i.e., detectable) and the sums associated with each sample. The sums exclude methane. On average, 43 non-zero compounds are associated with these samples. Depending on the sample, the individual number of non-zero compounds ranges from 21 to 63. The average sums range from 3 ppb to 704 ppb with an average and median of 84 and 33 ppb, respectively. In general, the number of non-zero compounds increases with higher sums.

Table 8-6 identifies three grab samples with sums that are were greater than 100 ppb. Two of these were collected near residence areas (M and O) and one was collected near the emission source region (U). These three samples and the associated key contributing compounds are identified in Table 8-7. The top-10 compounds varyingly account for 62 to 81% of the measured concentrations. In general, the top contributors are butane, pentane and hexane related compounds. Benzene was in the top-10 for one residence location (M) and methyl ethyl ketone is present for the other residence location (O). Ethane is the main contributor for the sample collected in the source region (U). Note that a different analytical scan was adopted for the sample at Site U.

Table 8-8 compares the overall maximum measured (MM) and the average measured (AM) to the odour thresholds (OT), the most stringent short-term benchmark (STB), and the most stringent long-term benchmark (LTB). The approach for comparing the canister measurements to the appropriate benchmarks is discussed in Section 3.3.

The MM for each compound is based on the highest concentration for that compound based on the 22 samples. The AM for each compound represents the average of all 22 samples. The OT are from the Nagata values provided in Table 3-6, and OT that are within a factor of three of the OTC are flagged. The STB is the most stringent of the AAAQO, AAQC, TCEQ and WHO sub 1-hour or 1-hour benchmarks. The LTB is the most stringent of the AAAQO, AAQC, TCEQ and WHO 24-hour to annual benchmarks. The purpose of comparing to the most stringent benchmark is to be conservative.

The chemical compounds are presented in the order from highest to lowest MM (there are 108 compounds associated with the 22 samples). Seventeen of the 108 compounds were identified in 20 or more of the samples. Forty of the 108 compounds were only identified in 1 or 2 samples. With respect to comparison to the ambient benchmarks, the following are noted:

- The odour threshold was only exceeded for hexanal (or hexylaldehyde) (MM = 7.6 ppb, OT = 0.28 ppb). Hexanal was detected in four of the 22 samples.

- A short-term benchmark was only exceeded for benzene (MM = 18.6 ppb, STB = 9 ppb). Benzene was detected in all 22 samples with concentrations ranging from 0.04 to 18.6 ppb. Out of the 22 samples, only 1 was above the STB of 9 ppb.

- A long-term benchmark was only exceeded for: acrolein (AM = 0.9 ppb, LTB = 0.07 ppb); benzene (AM = 1.1 ppb, LTB =0.1 ppb); and 1-pentanol, 2-methyl (AM = 1.5 ppb, LTB = 0.5 ppb).

Grab sample measurements typically represent near instantaneous samples (i.e., typically less than 1 minute) and the benchmarks typically represent averaging times of 1-hour, 24-hours and 1-year. Despite the averaging time differences between the measurements and the benchmarks, measurement and benchmark comparisons are provided for reference purposes. On this basis, a measurement greater than benchmark does not indicate an "exceedance" in the regulatory sense.

As these grab samples were collected during periods when odours were perceived, it is unexpected that the odour threshold was only exceeded for hexanal (an aldehyde), and that hexanal was only measured in four of the samples. The odour associated with hexanal is typically described as "grassy". ESRD (2010), in their review of the Three Creeks canister data, found that the odour threshold for hexanal was exceeded twice. Hexanal emissions are associated with the paper making processes (Jung and Kappen 2010).

The lack of detecting more compounds above odour thresholds could be associated with one of the following:

- Odour thresholds for a mixture of compounds may have a combined odour threshold that is less than the individual thresholds associated with each compound in the mixture.

- The range in concentration sums associated with the grab samples raises the issue whether canisters were deployed to collect samples representative of the odour complaint. A difference in 10 minutes between when the odour is detected and when the sample is collected could mean the sample is not representative if the wind changed. In addition, if the odour is noticed inside the house and the sample is collected outside the house the ambient indoor-outdoor air quality could be different due to the air exchange factor.

- Inherent limitations with respect to minimum detection limits, sampling, and analytical processes that were adopted could also be a contributing factor.

It would be desirable to have information sheets associated with each grab sample to define the type of odour, intensity and duration to further facilitate interpretation.

Table 8-5 Grab Sample Canister Deployment

Location Description		UTM E	UTM N	Date	Time	Operator	Sample ID	Analytical		
Location "M" (NE 07-84-19-W5M)	**M**	500681	6236131	07/07/2010	5:21	Public	T10-1467	C1C4	RSC	PAMS
				08/16/2010	6:06	Public	T10-1928	C1C4	RSC	PAMS
				08/29/2010	6:19	Public	T10-2073	C1C4	RSC	PAMS
				09/13/2010	6:35	Public	T10-2306	C1C4	RSCWB	PAMS
				10/09/2010	0:04	Public	T10-2617	C1C4	RSCWB	VOC-PT
				11/03/2010	23:55	Public	T10-2919	C1C4	RSCWB	VOC-PT
				11/10/2010	6:55	Public	T10-2941	C1C4	RSCWB	VOC-PT
				11/18/2010	0:09	Public	T10-3002	C1C4	RSCWB	VOC-PT
				11/29/2010	19:05	Public	T10-3167	C1C4	RSCWB	VOC-PT
				12/05/2010	23:45	Public	T10-3205	C1C4	RSCWB	VOC-PT
				12/10/2010	17:15	Public	T10-3277	C1C4	RSCWB	VOC-PT
				12/14/2010	5:50	Public	T10-3329	C1C4	RSCWB	VOC-PT
				12/17/2010	6:10	Public	T10-3330	C1C4	RSCWB	VOC-PT
				12/18/2010	13:22	Public	T10-3346	C1C4	RSCWB	VOC-PT
Location "O" (NW 13-85-20-W5M)	**O**	498663	6247484	08/29/2010	10:12	Public	T10-2072	C1C4	RSC	PAMS
				08/31/2010	8:39	Public	T10-2079	C1C4	RSC	PAMS
				12/06/2010	9:30	Public	T10-3206	C1C4	RSCWB	VOC-PT
Location "N" (SE 18 84 19 W5M)	**N**	500681	6237355	07/20/2010	13:20	Public	T10-1644	C1C4	RSC	PAMS
				07/11/2010	22:45	Public	T10-1526	C1C4	RSC	PAMS
Baytex Corner	**U**	511168	6238473	08/30/2010	13:45	ESRD	T10-2074	C1C4	RSC	PAMS

Table 8-5 Grab Sample Canister Deployment

Location Description		UTM E	UTM N	Date	Time	Operator	Sample ID	Analytical		
Location "P" (~2 km E & 15 of Intersection of RR 200 Twp Rd 842)	**P**	501888	6235974	08/17/2010	8:50	Public	T10-1998	C1C4	RSC	PAMS
Location "Q" (On Twp Rd 842, 6.5 km East of Hwy 688)	**Q**	501362	6236687	08/29/2010	9:15	Public	T10-2075	C1C4	RSC	PAMS

NOTES:
22 samples
UTM location coordinates are referenced to Zone 11 and NAD 83 datum.

Table 8-6 Grab Sample measurements

Location Description		Sample ID	Date	Number of non-zero compounds	Sum (ppb)
Location "M" (NE 07-84-19W5)	**M**	T10-1467	7/7/2010	52	37
		T10-1928	8/16/2010	53	122
		T10-2073	8/29/2010	52	59
		T10-2306	9/13/2010	40	28
		T10-2617	10/9/2010	63	453
		T10-2919	11/3/2010	38	15
		T10-2941	11/10/2010	50	41
		T10-3002	11/18/2010	21	6
		T10-3167	11/29/2010	38	18
		T10-3205	12/5/2010	27	13
		T10-3277	12/10/2010	32	15
		T10-3329	12/14/2010	48	12
		T10-3330	12/17/2010	34	49
		T10-3346	12/18/2010	34	22
		Average		**42**	**64**
Location "O" (NW 13-85-20W5)	**O**	T10-2072	8/29/2010	45	29
		T10-2079	8/31/2010	52	44
		T10-3206	12/6/2010	59	152
		Average		**52**	**75**
Location "N" (SE 18 84 19W5)	**N**	T10-1644	7/20/2010	26	3
		T10-1526	7/11/2010	32	5
		Average		**29**	**4**
Baytex Corner	**U**	T10-2074	8/30/2010	54	704
Location "P" (~2 km E & 15 of Intersection of RR 200 Twp Rd 842)	**P**	T10-1998	8/17/2010	56	71
Location "Q" (On Twp Rd 842, 6.5 km East of Hwy 688)	**Q**	T10-2075	8/29/2010	52	64
Average for all locations				**43**	**84**
Median for all locations				**47**	**33**

NOTES:
22 samples.
Concentrations greater than 100 ppb are shaded.

Table 8-7 Top-10 non-methane compounds for the three Highest Grab Sample sums

Location	M		Location	O		Location	U
Sample	**T10-2617**		**Sample**	**T10-3206**		**Sample**	**T10-2074**
Sum (ppb)	**453**		**Sum (ppb)**	**152**		**Sum (ppb)**	**704**
Isopentane	51.7		Isopentane	19.6		Ethane	300.0
2-Methylpentane	34.1		Isobutane	18.5		Isobutane	61.3
3-Methylpentane	33.3		Butane	15.6		Butane	47.3
Methylcyclohexane	32.3		Pentane	12.4		Isopentane	42.7
Cyclohexane	27.8		2-Methylpentane	10.1		Methylcyclohexane	28.8
Isobutane	23.1		Methylcyclohexane	9.3		Pentane	26.9
Methylcyclopentane	21.7		Cyclohexane	7.6		Cyclohexane	20.4
Pentane	19.8		3-Methylpentane	7.3		2-Methylpentane	16.2
Benzene	18.6		Methylcyclopentane	6.5		Methylcyclopentane	14.0
2,3-Dimethylpentane	16.8		Methyl ethyl ketone	5.2		3-Methylpentane	13.8
Sum for top 10	**279**		**Sum for top 10**	**112**		**Sum for top 10**	**571**
	62%			**74%**			**81%**

Table 8-8 Comparison of Grab Sample measurements (ppb) to ambient criteria (based on 22 samples)

Chemical Compound (Grab Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
Methane	74-82-8	22	58000	-	-	-	-	6095	-	-
Ethane	74-84-0	1	300	-	-	-	-	300	-	-
Isobutane	75-28-5	22	61.3	-	-	9696	**0.006**	7.4	3035	**0.002**
Isopentane	78-78-4	22	51.7	1300	**0.040**	1290	**0.040**	8.7	2411	**0.004**
Butane	106-97-8	22	47.3	1200000	**0.00004**	27822	**0.002**	6.6	3035	**0.002**
2-Methylpentane	107-83-5	21	34.1	7000	**0.005**	995	**0.034**	4.3	100	**0.044**
3-Methylpentane	96-14-0	20	33.3	8900	**0.004**	995	**0.033**	3.9	100	**0.039**
Methylcyclohexane	108-87-2	21	32.3	150	**0.215**	150	**0.216**	5.2	402	**0.013**
Cyclohexane	110-82-7	19	27.8	2500	**0.011**	990	**0.028**	4.4	99	**0.044**
Pentane	109-66-0	20	26.9	1400	**0.019**	1392	**0.019**	5.2	2411	**0.002**
Methylcyclopentane	96-37-7	19	21.7	1700	**0.013**	757	**0.029**	3.4	76	**0.044**
Benzene	71-43-2	22	18.6	2700	**0.007**	9.0	**2.067**	1.1	0.1	**11.349**
2,3-Dimethylpentane	565-59-3	17	16.8	4500	**0.004**	856	**0.020**	2.3	86	**0.027**
Methyl ethyl ketone	78-93-3	8	15.8	440	**0.036**	441	**0.036**	3.0	340	**0.009**
Ethanol	64-17-5	5	12.7	520	**0.024**	1015	**0.013**	4.5	999	**0.005**
3-Heptene, 2,2,4,6,6-pentamethyl-	123-48-8	1	11.7	-	-	-	-	11.7	-	-
2,3-Dimethylbutane	79-29-8	19	11.6	420	**0.028**	421	**0.028**	1.4	100	**0.014**
Hexane	110-54-3	19	10.0	1500	**0.007**	1507	**0.007**	2.0	57	**0.036**
Acetone	67-64-1	10	9.0	42000	**0.0002**	2487	**0.004**	2.6	249	**0.010**
Cyclopentane, 1,2-dimethyl-	2452-99-5	5	8.9	-	-	-	-	2.3	-	-
3-Methylhexane	589-34-4	16	8.3	840	**0.010**	751	**0.011**	1.3	75	**0.017**
Cyclopentane	287-92-3	16	8.2	-	-	1188	**0.007**	1.8	119	**0.015**
Toluene	108-88-3	22	8.1	330	**0.025**	265	**0.031**	1.0	69	**0.014**
Hexanal	66-25-1	3	7.6	0.28	**27.179**	20	**0.389**	3.1	200	**0.016**

Table 8-8 Comparison of Grab Sample measurements (ppb) to ambient criteria (based on 22 samples)

Chemical Compound (Grab Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
Cyclohexane, 1,3-dimethyl-, cis-	638-04-0	8	7.2	-	-	-	-	2.2	-	-
m,p-Xylene	108-38-3	22	7.2	41	**0.176**	79	**0.092**	0.7	42	**0.017**
CYCLOBUTANE, ISOPROPYL-	872-56-0	3	6.8	-	-	-	-	3.0	-	-
2-Methylhexane	591-76-4	16	6.7	420	**0.016**	421	**0.016**	1.0	75	**0.013**
.alpha.-Methylstyrene	98-83-9	1	6.1	-	-	52	**0.119**	6.1	10	**0.617**
Cyclopentane, 1,3-dimethyl-, cis-	2532-58-3	6	5.6	-	-	873	**0.006**	1.4	87	**0.016**
Isopropylcyclobutane	872-56-0	2	5.5	-	-	-	-	3.4	-	-
1-Pentene, 2,4,4-trimethyl-	107-39-1	1	5.1	-	-	393	**0.013**	5.1	39	**0.129**
Cyclohexane, 1,1,3-trimethyl-	3073-66-3	10	4.7	-	-	-	-	1.2	-	-
Cyclopentane, 1,3-dimethyl-	2453-00-1	6	4.6	-	-	-	-	1.5	-	-
Sulfur dioxide	7446-09-5	2	3.9	870	**0.004**	-	-	2.7	0	-
Cyclopentane, 1,2,3-trimethyl-	2815-57-8	1	3.9	-	-	-	-	3.9	-	-
2,2-Dimethylbutane	75-83-2	13	3.8	20000	**0.0002**	995	**0.004**	0.6	100	**0.006**
Cyclohexane, propyl-	1678-92-8	3	3.7	-	-	679	**0.005**	1.5	68	**0.022**
Cyclopentane, 1,3-dimethyl-, trans-	1759-58-6	3	3.5	-	-	873	**0.004**	1.4	87	**0.016**
Cyclopentane, ethyl-	1640-89-7	12	3.4	-	-	4067	**0.001**	0.9	407	**0.002**
Cyclopentane, 1-ethyl-2-methyl-, cis-	930-89-2	2	3.4	-	-	-	-	2.1	-	-
Cyclohexane, 1,2-dimethyl-, trans-	6876-23-9	5	3.4	-	-	-	-	1.1	-	-
Cyclopentane, propyl-	2040-96-2	3	3.3	-	-	764	**0.004**	1.4	76	**0.019**
Ethyl benzene	100-41-4	19	3.3	170	**0.019**	171	**0.019**	0.4	131	**0.003**
1,2,4-Trimethylcyclopentane	2815-58-9	2	3.3	-	-	-	-	1.7	-	-
Cyclohexane, ethyl-	1678-91-7	12	3.2	-	-	4082	**0.001**	0.9	408	**0.002**
Cyclopentane, 1-methyl-2-propyl-	3728-57-2	2	2.9	-	-	-	-	1.6	-	-
1-trans-2-cis-3-trans-trimethylcyclopent	-	3	2.8	-	-	-	-	1.3	-	-

Table 8-8 Comparison of Grab Sample measurements (ppb) to ambient criteria (based on 22 samples)

Chemical Compound (Grab Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
Cyclopentane, 1,1-dimethyl-	1638-26-2	3	2.7	-	-	-	-	1.2	-	-
o-Xylene	95-47-6	19	2.6	380	**0.007**	381	**0.007**	0.3	42	**0.007**
Cyclopentane, 1,2,4-trimethyl-, (1.alpha	16883-48-0	3	2.4	-	-	-	-	1.0	-	-
Cycloheptane, methyl-	4126-78-7	4	2.4	-	-	-	-	0.9	-	-
Hexane, 2,4-dimethyl-	589-43-5	5	2.3	-	-	-	-	0.7	-	-
Cyclopentane, 1-ethyl-2-methyl-	3726-46-3	3	2.1	-	-	-	-	0.8	-	-
Carbonyl sulphide	463-58-1	19	2.0	55	**0.037**	55	**0.037**	0.8	1	**0.780**
Isoprene	78-79-5	12	2.0	48	**0.041**	22	**0.091**	0.7	2	**0.325**
Cyclohexane, 1,3,5-trimethyl-	1839-63-0	1	2.0	-	-	-	-	2.0	-	-
m-Ethyltoluene	620-14-4	13	1.9	18	**0.107**	18	**0.106**	0.3	25	**0.010**
Heptane	142-82-5	9	1.7	670	**0.003**	672	**0.003**	0.5	86	**0.006**
.ALPHA.-PINENE, (-)-	80-56-8	5	1.6	18	**0.091**	18	**0.091**	1.0	63	**0.015**
1-No-nol	143-08-8	2	1.6	-	-	17	**0.092**	0.9	46	**0.019**
1-Pentanol, 2-methyl-	105-30-6	1	1.5	-	-	4.8	**0.319**	1.5	0.5	**3.188**
Sulfur dioxide(DOT)	7446-09-5	1	1.5	870	**0.002**	-	-	1.5	0	-
Cyclohexane, 1-ethyl-2-methyl-, trans- $	4923-78-8	1	1.5	-	-	-	-	1.5	-	-
Cyclobutane, 1,2-diethyl-	61141-83-1	1	1.5	-	-	-	-	1.5	-	-
Cyclohexane, 1-ethyl-2-methyl-	3728-54-9	1	1.5	-	-	-	-	1.5	-	-
Pentane, 2,2-dimethyl-	590-35-2	1	1.4	-	-	856	**0.002**	1.4	86	**0.017**
Hexane, 2,5-dimethyl-	592-13-2	1	1.3	-	-	-	-	1.3	-	-
Cyclohexane, 1,3-dimethyl-,	638-04-0	1	1.3	-	-	-	-	1.3	-	-
1,2,3-Trimethylbenzene	526-73-8	11	1.3	-	-	255	**0.005**	0.2	25	**0.007**
1-Hexene	592-41-6	2	1.3	-	-	140	**0.009**	0.8	49	**0.016**
1,3,5-Trimethylbenzene	108-67-8	12	1.3	170	**0.007**	255	**0.005**	0.2	25	**0.007**

Table 8-8 Comparison of Grab Sample measurements (ppb) to ambient criteria (based on 22 samples)

Chemical Compound (Grab Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
o-Ethyltoluene	611-14-3	10	1.3	74	**0.017**	73	**0.017**	0.2	25	**0.008**
Heptane, 4-methyl-	589-53-7	2	1.2	1700	**0.001**	751	**0.002**	0.7	75	**0.010**
Cyclohexane, 1,1,3-trimethy	3073-66-3	1	1.2	-	-	-	-	1.2	-	-
Cyclohexane, 1,1-dimethyl-	590-66-9	3	1.2	-	-	-	-	0.5	-	-
.DELTA. 3 CARENE	13466-78-9	2	1.1	-	-	201	**0.006**	0.7	20	**0.037**
Decane	124-18-5	6	1.09	620	**0.002**	622	**0.002**	0.3	172	**0.002**
Cyclopentane, 1,2-dimethyl-, cis-	1192-18-3	3	1.06	-	-	-	-	0.5	-	-
Cyclohexane, 1-methyl-2-pentyl-	54411-01-7	1	1.05	-	-	-	-	1.1	-	-
1-Butene	106-98-9	6	0.94	360	**0.003**	358	**0.003**	0.4	0	-
3-Methylheptane	589-81-1	7	0.93	1500	**0.001**	751	**0.001**	0.4	75	**0.006**
Cyclopentane, 1,2-dimethyl-, trans-	822-50-4	3	0.88	-	-	873	**0.001**	0.6	87	**0.007**
Acrolein	107-02-8	1	0.88	3.6	**0.243**	1.4	**0.626**	0.9	0.1	**12.514**
CYCLOPENTANE, 1,2,3-TRIMETHYL-, CIS,CIS,	15890-40-1	1	0.76	-	-	-	-	0.8	-	-
1,2,4-Trimethylbenzene	95-63-6	13	0.75	120	**0.006**	143	**0.005**	0.2	25	**0.008**
Cyclohexane, 1,2-dimethyl- (cis/trans) $	583-57-3	2	0.73	-	-	-	-	0.5	-	-
n-Propylbenzene	103-65-1	8	0.73	3.8	**0.192**	47	**0.016**	0.1	51	**0.003**
Cyclohexane, 1,2-dimethyl-,	6876-23-9	1	0.73	-	-	-	-	0.7	-	-
Hexane, 2-methyl-4-methylene-	3404-80-6	1	0.73	-	-	-	-	0.7	-	-
p-Ethyltoluene	622-96-8	11	0.68	8.3	**0.082**	8	**0.082**	0.1	25	**0.005**
Cyclohexane, 1-methyl-3-pentyl-	54411-02-8	1	0.68	-	-	-	-	0.7	-	-
Nonane	111-84-2	4	0.67	2200	**0.0003**	2006	**0.0003**	0.2	201	**0.001**
Carbon disulphide	75-15-0	7	0.66	210	**0.003**	10	**0.068**	0.2	1	**0.222**
Cyclopentane, 1,2,4-trimeth	2815-58-9	1	0.65	-	-	-	-	0.6	-	-
cis-1-Methyl-2-ethylcyclopentane	-	3	0.64	-	-	-	-	0.5	-	-

Table 8-8 Comparison of Grab Sample measurements (ppb) to ambient criteria (based on 22 samples)

Chemical Compound (Grab Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
ETHYL-2 HEXENE-1	37266-23-2	1	0.62	-	-	-	-	0.6	-	-
Freon-11	75-69-4	10	0.59	-	-	4997	**0.0001**	0.3	500	**0.001**
Undecane	1120-21-4	4	0.55	870	**0.001**	549	**0.001**	0.2	55	**0.004**
Cyclohexane, 1,4-dimethyl-,	2207-04-7	1	0.54	-	-	-	-	0.5	-	-
TRANS DIMETHYL-2,2 HEPTENE-3	19550-75-5	1	0.54	-	-	-	-	0.5	-	-
Cyclopentane, 1-ethyl-2-met	3726-46-3	1	0.53	-	-	-	-	0.5	-	-
Cyclopropane, 1-hexyl-2-propyl-, cis-	74630-58-3	1	0.51	-	-	-	-	0.5	-	-
(-)-.beta.-Pinene	18172-67-3	1	0.508	-	-	-	-	0.5	-	-
Cyclooctane, 1,4-dimethyl-, cis-	13151-99-0	2	0.505	-	-	-	-	0.3	-	-

NOTES:
MM = maximum measured
OT = odour threshold
STB = short-term benchmark
AM = average measured
LTB = long-term benchmark

All concentrations and benchmarks are in units of ppb, unless otherwise indicated.
Only compounds where the maximum is greater than 0.5 ppb are shown.
The maximum number of samples is 24.
Short-term benchmarks refer to the most stringent of the sub-1-h and 1-h benchmarks referenced in Section 3.
Long-term benchmarks refer to the most stringent of the 24-h or greater benchmarks referenced in section 3.
Measured values that exceed ambient benchmarks, or are within a factor of 3 of the odour threshold are shaded.

8.3 INTEGRATED SAMPLE REVIEW

Table 8-9 provides a summary of the associated integrated sample collection. The 12 integrated samples were collected over the same period as the grab samples (i.e., July 7 2010 to August 29 2010). Depending on the sample, different analytical scans were undertaken; this may complicate comparison of the different scans. When all the samples are considered, a total of 158 target and non-target compounds were identified at least once in the scans. There are 90 compounds where the maximum measured concentrations are greater than 0.5 ppb (the minimum detection level for VOC).

Table 8-10 identifies the number of non-zero concentrations (i.e., detectable) and the sums associated with each sample. The sums exclude methane. On average, 42 non-zero compounds are associated with these samples. Depending on the sample, the individual number of non-zero compounds ranges from 10 to 59. The average sums range from 2 ppb to 222 ppb with an average and median of 56 and 42 ppb, respectively. The 222 sum refers to a grab sample where the associated 1-hour sum is 89 ppb collected at Site C. The two Site C samples are further discussed in Section 9.1.2. In general, the number of non-zero concentrations increases with higher sums.

Table 8-10 identifies one sample with a sum that is greater than 100 ppb at Site C, which is near the emission source region. The associated key contributing compounds for this and two other samples are identified in Table 8-11. The top-10 compounds varyingly account for 72 to 89% of the measured concentrations. In general, the top contributors are butane, pentane and hexane related compounds. Acetone was in the top-10 for Highway 986b and Site M and methyl isobutyl ketone is present for Highway 986a.

Table 8-12 compares the overall maximum measured (MM) and the average measured (AM) to the odour thresholds (OT), the most stringent short-term benchmark (STB), and the most stringent long-term benchmark (LTB). The approach for comparing the canister measurements to the appropriate benchmarks is discussed in Section 3.3.

The chemical compounds are presented in the order from highest to lowest MM (there are 90 compounds and 12 samples). Fourteen of the 90 compounds were identified in 10 or more of the samples. Thirty of the 90 compounds were only identified in 1 sample. With respect to comparison to the ambient benchmarks, the following are noted:

- The odour threshold was not exceeded for any compounds.
- A short-term benchmark was not exceeded for any of the compounds.
- A long-term benchmark was only exceeded for benzene (AM = 0.4 ppb, LTB = 0.1 ppb).

The number of compounds and the average sums are somewhat similar to those associated with the grab samples. As some of the integrated samples were collected during periods when odours were perceived (as indicated in the tables by "affected"), it is unexpected that no odour thresholds were exceeded. The lack of detecting compounds above the odour threshold was discussed in the previous section.

Table 8-9 Integrated Sample Canister Deployment

Location and Description		UTM E	UTM N	Date	Time	Operator	Sample ID	Analytical		
N-36-84-17-W5M (affected; 1-hour and grab; light wind from the north)	C	527959.713	6243106.6	3/7/2010	0918	ESRD	T10-0400	C1C4	RSCWB	VOC
				3/7/2010	0858	ESRD	T10-0401	C1C4	RSCWB	VOC
PAD1-34 01-35-84-17-W5M (affected; 1-hour; low wind, variable)	E	527151.088	6241895.5	3/5/2010	0852	ESRD	T10-0402	C1C4	RSCWB	VOC
SW-23-83-21-W5M (background or reference; grab; moderate wind from the west)	F	487251.984	6229394.1	3/5/2010	1142	ESRD	T10-0403	C1C4	RSCWB	VOC
4-20-84-18-W5M (affected; 1-hour)	G	511253.94	6238586.1	4/11/2010	0900	ESRD	T10-0627	-	-	VOC
5-24-83-21-W5M (affected; 1-hour)	H	488476.81	6229389.3	4/11/2010	1050	ESRD	T10-0628	-	-	VOC
Highway 986a Site		499764	6247262	11/21/2010	1200	ESRD	T10-3186	C1C4	RSC	VOC-PT
				12/6/2010	1000	ESRD	T10-3187	C1C5	RSC	VOC-PT
NE 7-84-19-5	M	500691.226	6236134.7	12/10/2010	1715	ESRD	T10-3277	C1C6	RSC	VOC-PT
				12/14/2010	0550	ESRD	T10-3329	C1C7	RSC	VOC-PT
				12/17/2010	0610	ESRD	T10-3330	C1C8	RSC	VOC-PT
				12/18/2010	1322	ESRD	T10-3346	C1C9	RSC	VOC-PT

NOTES:
12 samples
Sample T10-400 is included in this table since it is taken at the same time as T101-0401.
Description in parentheses are based on ESRD (2010).
UTM location coordinates are referenced to Zone 11 and NAD 83 datum.

Table 8-10 Integrated Sample measurements

Location Description		Sample ID	Date	Number of non-zero compounds	Sum (ppb)
N-36-84-17-W5M (affected; 1-hour and grab; light wind from the north)	C	T10-0400	3/7/2010	58	89
		T10-0401	3/7/2010	57	222
		Average		**58**	**155**
PAD1-34 01-35-84-17-W5M (affected; 1-hour; low wind, variable)	E	T10-0402	3/5/2010	55	47
SW-23-83-21-W5M (background or reference; grab; moderate wind from the west)	F	T10-0403	3/5/2010	19	4
4-20-84-18-W5M (affected; 1-hour)	G	T10-0627	4/11/2010	63	52
5-24-83-21-W5M (affected; 1-hour)	H	T10-0628	4/11/2010	10	2
Highway 986a		T10-3186	11/21/2010	47	95
		T10-3187	12/6/2010	59	90
		Average		**53**	**93**
NE 7-84-19-5	M	T10-3277	12/10/2010	26	12
		T10-3329	12/14/2010	32	10
		T10-3330	12/17/2010	48	38
		T10-3346	12/18/2010	34	16
		Average		**32**	**19**
Average for all locations				**42**	**56**
Median for all locations				**48**	**42**

NOTES:
12 samples.
Concentrations greater than 100 ppb are shaded (this for a grab sample).

Table 8-11 Top-10 non-methane compounds for the three Integrated Sample sums

Location	C	Location	Highway 986a	Location	M
Sample	**T10-0401**	**Sample**	**T10-3186**	**Sample**	**T10-3330**
Sum (ppb)	**222**	**Sum (ppb)**	**95**	**Sum (ppb)**	**38**
Isopentane	30.9	3-Heptene, 2,2,4,6,6-pentamethyl-	42.5	Isopentane	6.4
Methylcyclohexane	24.5	2-Propanol, 2-methyl-	8.6	Isobutane	5.3
Cyclohexane	22.6	Decane	6.3	Butane	4.7
Butane	18.6	Acetone	6.3	Ethanol	3.7
Isobutane	15.9	Butane	4.0	Pentane	3.0
3-Methylpentane	10.5	Isopentane	3.5	2-Methylpentane	2.6
2-Methyl-1-pentene	10.4	1-Pentene, 2,4,4-trimethyl-	3.5	Methylcyclohexane	2.6
2,3-Dimethylbutane	9.5	Isobutane	3.4	3-Methylpentane	2.1
Cyclohexane, 1,3-dimethyl-, cis-	9.0	Pentane	2.6	Cyclohexane	1.8
2,3-Dimethylpentane	8.4	Methyl isobutyl ketone	2.0	Acetone	1.8
Sum for top 10	**160**	**Sum for top 10**	**83**	**Sum for top 10**	**34**
	72%		**87%**		**89%**

Table 8-12 Comparison of Integrated Sample measurements (ppb) to ambient benchmarks (based on 12 samples)

Chemical Compound (Integrated Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
Methane	74-82-8	10	19600	-	-	-	-	6940	-	-
3-Heptene, 2,2,4,6,6-pentamethyl-	123-48-8	2	42.5	-	-	-	-	25.1	-	-
Isopentane	78-78-4	12	30.9	1300	**0.02**	1290.4	**0.02**	7.1	2411.0	**0.003**
Methylcyclohexane	108-87-2	11	24.5	150	**0.16**	149.7	**0.16**	4.9	401.7	**0.01**
Cyclohexane	110-82-7	10	22.6	2500	**0.01**	989.6	**0.02**	4.8	99.0	**0.05**
Butane	106-97-8	12	18.6	1200000	**0.00002**	27822.4	**0.0007**	5.5	3035.2	**0.002**
Isobutane	75-28-5	12	15.9	-	-	9695.7	**0.002**	4.7	3035.2	**0.002**
3-Methyl-1-butene	563-45-1	1	11.0	-	-	251.5	**0.04**	11.0	778.9	**0.01**
3-Methylpentane	96-14-0	10	10.5	8900	**0.001**	995.1	**0.01**	2.8	99.5	**0.03**
2-Methyl-1-pentene	763-29-1	4	10.4	-	-	139.7	**0.07**	4.0	49.5	**0.08**
Pentane	109-66-0	12	9.7	1400	**0.01**	1392.3	**0.007**	3.3	2411.0	**0.001**
2,3-Dimethylbutane	79-29-8	10	9.5	420	**0.02**	420.8	**0.02**	1.8	99.5	**0.02**
Cyclohexane, 1,3-dimethyl-, cis-	638-04-0	6	9.0	-	-	-	-	2.7	-	-
2-Propanol, 2-methyl-	75-65-0	2	8.6	4500	**0.002**	204.9	**0.04**	4.9	20.5	**0.2**
2,3-Dimethylpentane	565-59-3	8	8.4	4500	**0.002**	855.8	**0.01**	2.2	85.6	**0.03**
2-Methylpentane	107-83-5	9	8.2	7000	**0.001**	995.1	**0.008**	3.2	99.5	**0.03**
Methylcyclopentane	96-37-7	10	8.1	1700	**0.005**	756.8	**0.01**	2.3	75.7	**0.03**
Decane	124-18-5	3	6.3	620	**0.01**	621.6	**0.01**	2.5	172.2	**0.01**
Acetone	67-64-1	7	6.3	42000	**0.0001**	2487.2	**0.003**	2.6	248.7	**0.01**
3-Methylhexane	589-34-4	9	6.0	840	**0.01**	750.6	**0.008**	1.4	75.1	**0.02**
Cyclohexane, 1,1,3-trimethyl-	3073-66-3	6	5.7	-	-	-	-	1.7	-	-
Ethanol	64-17-5	4	4.9	520	**0.01**	1015.2	**0.005**	2.5	999.3	**0.003**
Cyclopentane, 1,3-dimethyl-	2453-00-1	4	4.7	-	-	-	-	2.2	-	-
Cyclopentane, 1,2-dimethyl-, cis-	1192-18-3	1	4.3	-	-	-	-	4.3	-	-

Table 8-12 Comparison of Integrated Sample measurements (ppb) to ambient benchmarks (based on 12 samples)

Chemical Compound (Integrated Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
Methyl ethyl ketone	78-93-3	5	4.1	440	**0.01**	441.5	**0.009**	1.2	339.6	**0.004**
Cyclohexane, 1,2-dimethyl-, trans-	6876-23-9	4	4.1	-	-	-	-	1.7	-	-
Cyclopentane, 1,2,3-trimethyl-, (1.alpha	15890-40-1	1	4.0	-	-	-	-	4.0	-	-
Hexane	110-54-3	9	3.7	1500	**0.002**	1506.8	**0.002**	1.2	56.9	**0.02**
Cyclopentane, 1,2,4-trimethyl-	2815-58-9	2	3.5	-	-	-	-	2.0	-	-
1-Pentene, 2,4,4-trimethyl-	107-39-1	1	3.5	-	-	393.0	**0.009**	3.5	39.3	**0.09**
Cyclopentane, 1,3-dimethyl-, cis-	2532-58-3	4	3.4	-	-	873.2	**0.004**	1.7	87.3	**0.02**
1-methyl-2-ethylcyclopentane isomer 1	NA	1	3.2	-	-	-	-	3.2	-	-
Cyclopentane	287-92-3	9	3.1	-	-	1187.6	**0.003**	1.1	118.8	**0.009**
2,2-Dimethylbutane	75-83-2	6	2.7	20000	**0.0001**	995.1	**0.003**	0.8	99.5	**0.008**
Cyclohexane, 1,1-dimethyl-	590-66-9	3	2.7	-	-	-	-	1.2	-	-
2,3-Dimethyl-3-heptene	NA	1	2.3	-	-	-	-	2.3	-	-
Cyclooctane, methyl-	1502-38-1	3	2.2	-	-	-	-	1.1	-	-
Cyclohexane, 1,2,4-trimethyl-, (1.alpha.	7667-60-9	2	2.0	-	-	-	-	1.3	-	-
Methyl isobutyl ketone	108-10-1	1	2.0	170	**0.01**	171.2	**0.01**	2.0	20.1	**0.1**
Isopropylcyclobutane	872-56-0	2	1.9	-	-	-	-	1.5	-	-
Cyclohexane, ethyl-	1678-91-7	6	1.9	-	-	4082.3	**0.0005**	0.8	408.2	**0.002**
1-Hexanol, 2-ethyl-	104-76-7	1	1.9	-	-	75.2	**0.02**	1.9	30.1	**0.06**
1,1,2,3-Tetramethylcyclohexane	71186-28-2	3	1.8	-	-	-	-	0.9	-	-
Cyclohexane, 2-propenyl-	2114-42-3	1	1.6	-	-	-	-	1.6	-	-
(1S)-2,6,6-Trimethylbicyclo[3.1.1]hept-2	7785-26-4	1	1.6	-	-	-	-	1.6	-	-
Methyl Tert Butyl Ether	1634-04-4	1	1.5	-	-	125.0	**0.01**	1.5	50.0	**0.03**
Sulfur dioxide(DOT)	7446-09-5	1	1.5	870	**0.002**	-	-	1.5	0.0	-
1-trans-2-cis-3-trans-trimethylcyclopent	NA	2	1.5	-	-	-	-	1.0	-	-

Table 8-12 Comparison of Integrated Sample measurements (ppb) to ambient benchmarks (based on 12 samples)

Chemical Compound (Integrated Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
Cyclopentane, ethyl-	1640-89-7	7	1.5	-	-	4066.7	**0.0004**	0.6	406.7	**0.001**
Cyclohexane, 1-ethyl-2-methyl-	3728-54-9	3	1.4	-	-	-	-	0.6	-	-
Benzenemethanol, .alpha.,.alpha.-dimethy	617-94-7	1	1.4	-	-	107.9	**0.01**	1.4	10.8	**0.1**
Cyclohexane, 1-ethyl-4-methyl-, trans-	6236-88-0	2	1.4	-	-	-	-	0.9	-	-
Cyclobutane, Isopropyl-	872-56-0	2	1.4	-	-	-	-	1.2	-	-
Benzene, (1-methylethenyl)-	98-83-9	2	1.4	-	-	51.8	**0.03**	1.2	10.0	**0.1**
Cyclohexane, 1,4-dimethyl-	589-90-2	2	1.3	-	-	-	-	0.8	-	-
2-Methylhexane	591-76-4	10	1.3	420	**0.003**	420.5	**0.003**	0.5	75.1	**0.007**
1,2,4-Trimethyl-Cyclopentane	4850-28-6	2	1.3	-	-	-	-	1.0	-	-
1-Butene	3748-13-8	6	1.3	-	-	-	-	0.9	-	-
Benzene, 1,3-bis(1-methylethenyl)-	106-98-9	1	1.3	360	**0.004**	358.0	**0.004**	1.3	0.0	-
1-Hexene	592-41-6	2	1.3	-	-	139.7	**0.009**	0.8	49.5	**0.02**
1-Ethyl-4-methylcyclohexane	3728-56-1	1	1.2	-	-	-	-	1.2	-	-
Hexane, 2,4-dimethyl-	589-43-5	5	1.2	-	-	-	-	0.5	-	-
Cyclopentane, 1-ethyl-2-methyl-	3726-46-3	1	1.2	-	-	-	-	1.2	-	-
Hexane, 2,3-dimethyl-	584-94-1	3	1.2	-	-	-	-	0.6	-	-
Toluene	108-88-3	11	1.1	330	**0.003**	265.4	**0.004**	0.4	68.99	**0.006**
2,4-(d2)menth-2-ene	5256-68-8	1	1.1	-	-	-	-	1.1	-	-
Cyclooctane	292-64-8	2	1.1	-	-	764.1	**0.001**	0.6	76.4	**0.008**
Benzene	71-43-2	12	1.0	2700	**0.0004**	9.0	**0.11**	0.4	0.1	**4.4**
Carbonyl sulphide	463-58-1	6	1.0	55	**0.02**	55.0	**0.02**	0.7	1.1	**0.6**
Cycloheptane, methyl-	4126-78-7	1	1.0	-	-	-	-	1.0	-	-
Cyclopentane, 1,3-dimethyl-, trans-	1759-58-6	1	0.9	-	-	873.2	**0.001**	0.9	87.3	**0.01**
1,2,4-Trimethylbenzene	95-63-6	6	0.9	120	**0.01**	142.6	**0.006**	0.3	25.5	**0.01**

Table 8-12 Comparison of Integrated Sample measurements (ppb) to ambient benchmarks (based on 12 samples)

Chemical Compound (Integrated Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
2-Butanone	78-93-3	2	0.8	440	**0.002**	441.5	**0.002**	0.5	339.6	**0.002**
1,3,6-Octatriene, 3,7-dimethyl-, (E)- (C	3779-61-1	1	0.8	-	**-**	-	**-**	0.8	-	**-**
cyclopentane, 1,2,3-trimethyl-, cis,cis,	15890-40-1	1	0.8	-	**-**	-	**-**	0.8	-	**-**
Hexane, 3-ethyl-	619-99-8	2	0.8	-	**-**	750.7	**0.001**	0.5	75.1	**0.007**
1-Octanol, 2-butyl-	3913-02-8	3	0.8	-	**-**	-	**-**	0.3	-	**-**
Pentane, 3-ethyl-2-methyl-	609-26-7	3	0.8	-	**-**	750.7	**0.001**	0.4	75.1	**0.005**
Trans Nonene-3	20063-92-7	1	0.8	-	**-**	-	**-**	0.8	-	**-**
1-Propene, 2-methyl-, trimer	7756-94-7	1	0.7	-	**-**	262.0	**0.003**	0.7	26.2	**0.03**
m,p-Xylene	108-38-3	10	0.7	41	**0.02**	78.7	**0.009**	0.3	41.5	**0.007**
Cyclohexane, 1,1'-[1,2-bis(1,1-dimethyle	65149-85-1	1	0.7	-	**-**	-	**-**	0.7	-	**-**
Cyclopentane, 1,2-dimethyl-, trans-	822-50-4	1	0.6	-	**-**	873.2	**0.0007**	0.6	87.3	**0.007**
cis-1-Methyl-2-ethylcyclopentane	NA	2	0.6	-	**-**	-	**-**	0.5	-	**-**
1-Heptene, 5-methyl-	13151-04-7	1	0.6	-	**-**	-	**-**	0.6	-	**-**
1-Heptene, 3-methyl-	4810-09-7	1	0.5	-	**-**	-	**-**	0.5	-	**-**
Cyclopentane, 1-ethyl-3-methyl-	3726-47-4	1	0.5	-	**-**	-	**-**	0.5	-	**-**
Cyclopentane, propyl-	2040-96-2	1	0.5	-	**-**	764.1	**0.0007**	0.5	76.4	**0.007**

Table 8-12 Comparison of Integrated Sample measurements (ppb) to ambient benchmarks (based on 12 samples)

Chemical Compound (Integrated Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
Cyclopropane, 1-hexyl-2-propyl-, cis-	74630-58-3	2	0.5	-	**-**	-	**-**	0.4	-	**-**
Benzene, 1-ethyl-3-methyl-	620-14-4	1	0.5	18	**0.03**	18.1	**0.03**	0.5	25.5	**0.02**

NOTES:
MM = maximum measured
OT = odour threshold
STB = short-term benchmark
AM = average measured
LTB = long-term benchmark

All concentrations and benchmarks are in units of ppb, unless otherwise indicated.
Only compounds where the maximum is greater than 0.5 ppb are shown.
The maximum number of samples is 12.
Short-term benchmarks refer to the most stringent of the sub-1-h and 1-h benchmarks referenced in Section 3.
Long-term benchmarks refer to the most stringent of the 24-h or greater benchmarks referenced in section 3.
Measured values that exceed an ambient benchmark or are within a factor of 3 of the odour threshold are shaded.

8.4 CAMPAIGN SAMPLE REVIEW

Table 8-13 provides a summary of the associated sample collection. The 24 campaign samples were collected over the October 25 to 28 2010 period. When all samples are considered, a total of 93 target and non-target compounds were identified at least once in the scans. There are 28 compounds where the maximum measured concentration is greater than 0.5 ppb (the minimum detection level for VOC).

Table 8-14 identifies the number of number of non-zero concentrations (i.e., detectable) and the sums associated with each sample. The sums exclude methane. On average, 21 non-zero compounds are associated with these samples. Depending on the sample, the individual number of non-zero compounds ranges from 8 to 41. The sums range from 4 ppb to 92 ppb with an average and median of 18 and 9 ppb, respectively. In general, the number of non-zero concentrations and the sums are less than those associated with the grab or integrated samples. This is expected as the grab sample (and to some extent the integrated sample) collection is biased to periods associated with odours and therefore high concentrations. In contrast, the campaign samples are “random” and hence more likely to be associated with a typical period without peaks.

Table 8-15 identifies three grab samples and associated sums: Site A near the Highway 986b site; Reference site H to the SW of the area of interest; and Site K near the Highway 842 station. The associated key contributing compounds for each of these samples are also provided in Table 8-15. The top-10 compounds varyingly account for 77 to 91% of the measured concentrations. Butane and pentane compounds are present for Sites A and H, sulphur containing compounds occur at higher concentration at Site K. Acetone is a significant contributor at Site H.

Table 8-16 compares the overall maximum measured (MM) and the average measured (AM) to the odour thresholds (OT), the most stringent short-term benchmark (STB), and the most stringent long-term benchmark (LTB). The approach for comparing the canister measurements to the appropriate benchmarks is discussed in Section 3.3.

The chemical compounds are presented in the order from highest to lowest MM (there are 28 compounds associated with 24 samples). Six of the 28 compounds were identified in 18 or more of the samples. Seven of the 28 compounds were only identified in 1 or 2 samples. With respect to comparison to the ambient benchmarks, the following are noted:

- The odour threshold was exceeded only for hydrogen sulphide (MM = 4.3 ppb, OT = 0.41 ppb) and nonanal (MM= 1.1 ppb, OT = 0.34 ppb). Hydrogen sulphide and nonanal were identified in 9 and 4 of the samples, respectively.

- No short-term benchmarks were exceeded.

- A long-term benchmarks was exceeded for carbonyl sulphide (AM = 1.5 ppb, LTB = 1.1 ppb). Carbonyl sulphide was detected in all 24 samples.

The odour associated with hydrogen sulphide is typically described as “rotten egg” and the odour associated with nonanal is typically described as “rosy citrus”. ESRD (2010), in their review of the Three Creeks data, found that the odour threshold for nonanal was exceeded once. Hydrogen sulphide emissions are associated the oil and gas industry and nonanal emissions are associated with the paper making processes (Jung and Kappen 2010).

The high acetone concentration of 51.3 ppb (Sample T10-2799) at Site H was taken on October 26 2010 at 2355. The wind directions and wind speeds during and proceeding this time (3 hours) were in the 88 to 94° range, and in the 7.9 to 13.2 km/h range, respectively. This suggests a source direction to the south (S) of Site H.

The high sulphur compound concentrations (Sample T10-2775) at Site K were taken on October 25 2010 at 0437. The wind directions and wind speeds during and proceeding this time (3 hours) were in the 17 to 29 ° range, and in the 3.4 to 3.7 km/h range, respectively. This suggests a source direction to the NNE of Site K.

Table 8-13 Campaign Sample Canister Deployment

Location		UTM E	UTM N	Date	Time	Sample ID	Analytical		
Location "A" Hwy 986	A	503396	6247649	10/25/2010	0129	T10-2773	C1C4	RSC	VOC-PT
				10/26/2010	0003	T10-2780	C1C4	RSC	VOC-PT
				10/27/2010	0412	T10-2833	C1C4	RSC	VOC-PT
				10/27/2010	2253	T10-2830	C1C4	RSC	VOC-PT
				10/28/2010	0003	T10-2831	C1C4	RSC	VOC-PT
Location "B" McKinney Hall	B	494925.8	6238386	10/25/2010	0006	T10-2772	C1C4	RSC	VOC-PT
				10/26/2010	0120	T10-2781	C1C4	RSC	VOC-PT
				10/27/2010	0115	T10-2800	C1C4	RSC	VOC-PT
Location "H" Reference	H	487901	6228436	10/24/2010	2240	T10-2771	C1C4	RSC	VOC-PT
				10/26/2010	0508	T10-2784	C1C4	RSC	VOC-PT
				10/26/2010	2355	T10-2799	C1C4	RSC	VOC-PT
				10/28/2010	0428	T10-2836	C1C4	RSC	VOC-PT
Location "J" Simon Lakes	J	518551	6259865	10/25/2010	0257	T10-2774	C1C4	RSC	VOC-PT
				10/25/2010	2240	T10-2779	C1C4	RSC	VOC-PT
				10/27/2010	0250	T10-2832	C1C4	RSC	VOC-PT
				10/28/2010	0131	T10-2834	C1C4	RSC	VOC-PT
Location "K" ATCO Power Station	K	501475	6236888	10/25/2010	0437	T10-2775	C1C4	RSC	VOC-PT
				10/26/2010	0242	T10-2782	C1C4	RSC	VOC-PT
				10/26/2010	2109	T10-2797	C1C4	RSC	VOC-PT
				10/28/2010	0551	T10-2837	C1C4	RSC	VOC-PT

Table 8-13 Campaign Sample Canister Deployment

Location		UTM E	UTM N	Date	Time	Sample ID	Analytical		
Location "L" RR202 & TWP 844	L	496287	6239874	10/25/2010	0602	T10-2776	C1C4	RSC	VOC-PT
				10/26/2010	0350	T10-2783	C1C4	RSC	VOC-PT
				10/26/2010	2230	T10-2798	C1C4	RSC	VOC-PT
				10/28/2010	0308	T10-2835	C1C4	RSC	VOC-PT

NOTES:
24 samples
UTM location coordinates are referenced to Zone 11 and NAD 83 datum.

Table 8-14 Campaign Sample measurements

Location		Date	Sample ID	Number of non-zero compounds	Sum (ppb)
Location "A" Hwy 986	**A**	10/25/2010	T10-2773	8	4
		10/26/2010	T10-2780	20	15
		10/27/2010	T10-2833	29	24
		10/27/2010	T10-2830	26	26
		10/28/2010	T10-2831	40	22
		Average		**25**	**18**
Location "B" McKinney Hall	**B**	10/25/2010	T10-2772	19	21
		10/26/2010	T10-2781	22	7
		10/27/2010	T10-2800	21	8
		Average		**21**	**12**
Location "H" Reference	**H**	10/24/2010	T10-2771	13	5
		10/26/2010	T10-2784	13	7
		10/26/2010	T10-2799	20	60
		10/28/2010	T10-2836	21	7
		Average		**17**	**20**
Location "J" Simon Lakes	**J**	10/25/2010	T10-2774	11	5
		10/25/2010	T10-2779	15	5
		10/27/2010	T10-2832	22	9
		10/28/2010	T10-2834	31	20
		Average		**20**	**10**
Location "K" ATCO Power Station	**K**	10/25/2010	T10-2775	41	92
		10/26/2010	T10-2782	24	42
		10/26/2010	T10-2797	20	9
		10/28/2010	T10-2837	15	4
		Average		**25**	**37**
Location "L" RR202 & TWP 844	**L**	10/25/2010	T10-2776	12	5
		10/26/2010	T10-2783	19	16
		10/26/2010	T10-2798	33	21
		10/28/2010	T10-2835	18	4
		Average		**21**	**11**
Average for all sites				**21**	**18**
Median for all sites				**20**	**9**

NOTE:
24 samples

Table 8-15 Top-10 non-methane compounds for three Campaign Sample sums

Site	A		Site	H		Site	K
Sample	**T10-2830**		**Sample**	**T10-2799**		**Sample**	**T10-2775**
Sum (ppb)	**26**		**Sum (ppb)**	**60**		**Sum (ppb)**	**92**
Isopentane	3.1		Acetone	51.3		Sulfur dioxide	63.2
Acetone	3.1		Isopentane	2.2		Carbonyl sulphide	6.8
Butane	2.8		Butane	1.6		Acetone	5.0
Isobutane	2.2		Carbonyl sulphide	1.1		1,4-Dioxane	2.3
Carbonyl sulphide	1.7		Nonanal	0.91		Carbon disulphide	1.6
Pentane	1.7		Isobutane	0.51		2-Pentenal, 2-methyl-	1.4
2-Methylpentane	1.5		3-Buten-2-one	0.36		Dimethyl disulphide	1.3
Methylcyclohexane	1.5		3-Methylpentane	0.25		2-Pyridylthiomethyl methyl ether	1.2
3-Methylpentane	1.2		2-Methylpentane	0.25		Butane	0.78
Cyclohexane	0.9		Freon-11	0.25		Octane	0.65
Sum for top-10	**20**		**Sum for top-10**	**59**		**Sum for top-10**	**84**
	77%			**98%**			**91%**

Table 8-16 Comparison of Campaign Sample measurements to ambient benchmarks (all 24 samples)

Chemical Compound (Campaign Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
Methane	74-82-8	24	5200.0	-	-	-	-	2958.3	0.0	-
Sulfur dioxide	7446-09-5	5	63.2	870	**0.07**	172	**0.37**	23.2	0.0	-
Acetone	67-64-1	23	51.3	42000	**0.001**	2487	**0.02**	4.5	249	**0.0**
Carbonyl sulphide	463-58-1	24	6.8	55	**0.1**	55	**0.1**	1.5	1.1	**1.4**
Butane	106-97-8	19	5.7	1200000	**0.000005**	27822	**0.0002**	1.6	3035	**0.0**
Hydrogen sulphide	7783-06-4	9	4.3	0.41	**10.6**	10	**0.43**	1.2	0.0	-
Isopentane	78-78-4	18	3.4	1300	**0.003**	1290	**0.003**	1.4	2411	**0.0**
Pentane	109-66-0	14	2.5	1400	**0.002**	1392	**0.002**	0.9	2411	**0.0**
1,4-Dioxane	123-91-1	2	2.3	-	-	250	**0.01**	1.6	25	**0.1**
Isobutane	75-28-5	16	2.3	-	-	9696	**0.0002**	0.8	3035	**0.0**
Carbon disulphide	75-15-0	16	1.6	210	**0.01**	9.7	**0.2**	0.4	1.0	**0.4**
2-Methylpentane	107-83-5	15	1.5	7000	**0.0002**	995	**0.001**	0.5	100	**0.0**
Methylcyclohexane	108-87-2	12	1.5	150	**0.01**	150	**0.01**	0.4	402	**0.0**
Unknown Sulphur (MW=32)	NA	1	1.4	-	-	-	-	1.4	-	-
2-Pentenal, 2-methyl-	623-36-9	1	1.4	-	-	92	**0.02**	1.4	9.2	**0.2**
Dimethyl disulphide	624-92-0	6	1.3	2.2	**0.6**	5.2	**0.3**	0.6	3.6	**0.2**
3-Methylpentane	96-14-0	13	1.2	8900	**0.0001**	995	**0.001**	0.4	100	**0.0**
2-Pyridylthiomethyl methyl ether	NA	1	1.2	-	-	-	-	1.2	-	-
Nonanal	124-19-6	4	1.1	0.34	**3.3**	258	**0.004**	0.8	26	**0.0**
Cyclohexane	110-82-7	8	0.9	2500	**0.0004**	990	**0.001**	0.5	99	**0.0**
Methylcyclopentane	96-37-7	11	0.9	1700	**0.001**	757	**0.001**	0.3	76	**0.0**
Benzene, 1-methyl-4-(1-methylethyl)-	99-87-6	1	0.8	-	-	502	**0.002**	0.8	50	**0.0**
Hexane	110-54-3	12	0.7	1500	**0.0005**	1507	**0.0005**	0.3	57	**0.0**
Acetophenone	98-86-2	1	0.7	-	-	100	**0.01**	0.7	10	**0.1**

Table 8-16 Comparison of Campaign Sample measurements to ambient benchmarks (all 24 samples)

Chemical Compound (Campaign Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
Octane	111-65-9	3	0.6	1700	**0.0004**	751	**0.001**	0.3	75	**0.0**
2,3-Dimethylpentane	565-59-3	5	0.6	4500	**0.0001**	856	**0.001**	0.3	86	**0.0**
Dimethyldisulfide	624-92-0	2	0.6	2.2	**0.3**	5.2	**0.1**	0.5	3.6	**0.1**
Freon-11	75-69-4	24	0.5	-	**-**	4997	**0.0001**	0.2	500	**0.0**

NOTES:
MM = maximum measured
OT = odour threshold
STB = short-term benchmarks
AM = average measured
LTB = long-term benchmarks

All concentrations and benchmarks are in units of ppb, unless otherwise indicated.
Only compounds where the maximum is greater than 0.5 ppb are shown.
The maximum number of samples is 24.
Short-term benchmarks refer to the most stringent of the sub-1-h and 1-h benchmarks referenced in Section 3.
Long-term benchmarks refer to the most stringent of the 24-h or greater benchmarks referenced in section 3.
Measured values that exceed an ambient benchmark, or are within a factor of 3 of the odour threshold are shaded.

8.5 TRIGGERED SAMPLE REVIEW

The triggered samples are grouped and assessed according to the year the samples were collected. Tables 8-17 to 8-20 identify the Sample ID, the collection date and time, and the received dates for 2010, 2011, 2012 and 2013 samples, respectively. Virtually all samples were collected at the Highway 986a site (11 in 2010, and 16 in 2011) and Highway 986b site (17 in 2011, 52 in 2012 and 20 in 2013). When all 118 samples are considered, a total of 556 target and non-target compounds were identified at least once in the scans. There are 311 compounds where the maximum measured concentration is greater than 0.5 ppb (the minimum detection level for VOC). The analysis of the data follows a similar format as those for the analysis for the previous samples.

The tables also identify the number of non-zero compounds and the total concentrations associated with each sample for the respective years. The total concentration values include all hydrocarbon and reduced sulphur compounds (both target and non-target compounds). Some analysis included nitrogen, oxygen and carbon dioxide concentrations. The sums in these tables have removed these compounds and methane.

The number of non-zero compounds in the samples range from 13 to 81, with averages for each year that range from 40 to 43. The average numbers of compounds for each year are similar to those associated with the grab and the integrated samples; with all being greater than those associated with the campaign samples.

The concentration sums range from 11 ppb to 899 ppb. The average triggered sums for each year are 144 ppb (2010), 99 ppb (2011), 130 ppb (2012) and 166 ppb (2013). This compares to the NMHC analyzer trigger points that range from 50 ppb to 300 ppb. The numbers of compounds that are detected are roughly correlated to the concentration sums, which is to be expected. The average sums for each year are greater than those associated with the grab samples, the integrated samples, and the campaign samples.

Table 8-21 identifies triggered samples with the six highest sums (they are in the 419 to 899 ppb range). Two of these were collected at the Highway 986a site in 2010, and four were collected at the Highway 986b site (three in 2012 and one in 2013). The top-10 compounds for each of these samples are identified in Table 8-21. The top-10 compounds varyingly account for 75 to 99% of the measured concentrations. The key compounds are:

- Acetone is a significant compound for two of the samples (T10-3137 and T12-2346). Sample T10-3137 was taken on December 3 2010 at 0830. The wind direction and wind speed during this time were in 195° and 0 km/h range. For the previous 3 hours, the wind directions and wind speeds were in the 263 to 340° range, and in the 0.1 to 1.5 km/h range, respectively. This suggests a source direction to the W or NW of the Highway 986a site. Sample T12-2346 was taken on July 25 2010 at 0955. The wind directions and wind speeds during and proceeding this time (3 hours) were in the 222 to 248° range, and in the 5.0 to 5.5 km/h range, respectively. This suggests a source direction to the SW of the Highway 986b site.

- Vinyl acetate is a significant compound for one sample (T12-2147). This sample was taken on July 10 2012 at 1215. The wind directions and wind speeds during and proceeding this time (3 hours) were in the 309 to 8 (or 368)° range, and in the 2.5 to 3.9 km/h range, respectively. This suggests a source direction to the N of the Highway 986b site.

- Methyl alcohol is a significant contributor for one sample (T13-0846). This sample was taken on March 26 2013 at 0730. The wind directions and wind speeds during and proceeding this time (3 hours) were in the 120 to 125° range, and in the 3.1 to 4.5 km/h range, respectively. This suggests a source direction to the ESE of the Highway 986b site.

Table 8-22 compares the overall maximum measured (MM) and the average measured (AM) to the odour thresholds (OT), the most stringent short-term benchmark (STB), and the most stringent long-term benchmark (LTB). The approach for comparing the canister measurements to the appropriate benchmarks is discussed in Section 3.3.

The chemical compounds are presented in the order from highest to lowest MM (there are 311 compounds associated with the 118 samples). Eighteen of the 311 compounds were identified in 90 or more of the samples, and 174 of the 311 compounds were only identified in 1 or 2 samples. With respect to comparison to the ambient benchmarks, the following are noted:

- The maximum concentration was within a factor of three for 21 compounds (Table 8-23). In some cases, the compounds occurred frequently (e.g., carbonyl sulphide and toluene). In other cases, the compound was only measured once in the 118 samples.

- A short-term benchmark was only exceeded for 16 compounds (Table 8-24). In some cases, the compounds occurred frequently (e.g., benzene and carbonyl sulphide). In other cases, a compound was only measured once in the 118 samples.

- A long-term benchmark was only exceeded for 26 compounds (Table 8-25). In some cases, the compounds occurred frequently (e.g., benzene and carbonyl sulphide). In other cases, the compound was only measured once in the 118 samples.

The compounds in the Tables 8-23, 8-24 and 8-25 include sulphur containing compounds as well as non-sulphur hydrocarbon compounds.

Figures 8-2 to 8-4 present what is essentially a times series (or more accurately a sample series) of concentrations for selected compounds. There are 118 samples collected over the period July 16 2010 to August 15 2013. The results are presented as:

- Figure 8-2 focuses on frequently occurring hydrocarbon compounds. In some cases, all the indicated compounds are similar for a particular sample. For a few cases, one compound appears anomalous relative to the other samples. The high toluene concentration of 125 ppb associated with Sample ID T13-0570 (Sample 102 on the plot) is an example of an anomalous value.

- Figure 8-3 focuses on frequently occurring reduced sulphur compounds. The high peaks tend to be intermittent. For example, the carbonyl sulphide concentration of 68 ppb associated with Sample ID T12-2346 (Sample 70 on the plot) is an example of an anomalous value.

- Figure 8-4 focuses on the infrequently occurring maximum concentration values. There was only one vinyl acetate measurement (472 ppb) out of the 118 samples (Sample ID T12-2147 (Sample 65 on the plot). High isobutane (48.5 ppb) and butane (16.2 ppb) concentrations are also associated with this sample. The highest acetone concentration of 375 ppb is associated with Sample ID T12-2346 (Sample 70 on the plot). This is the sample that has the high carbonyl sulphide concentrations (see previous bullet).

These time series plots demonstrate a correlation between measured concentrations in a sample.

Figure 8-5 shows the wind directions and wind speeds associated with each Triggered Sample. Based on the Highway 986a site, the samples are most frequently associated with winds from the E, SSW, W and NW. In contrast, the Highway 986b samples are most frequently associated with winds from the ESE and S. As indicated in Section 4, a greater level-of-confidence is placed with the Highway 986b site winds being more representative of regional airflow than those at the Highway 986a site. Both sites indicate that most of the samples are associated with low wind speeds.

Table 8-17 Triggered Sample measurements (2010)

Station	Sample ID	Sampling Date	Sampling Time	Rec Date	Number of non-zero compounds	Total (ppb)
986a	T10-1598	7/14/2010	-	7/16/2010	61	578
986a	T10-2863	-	-	11/2/2010	68	187
986a	T10-2921	-	-	11/8/2010	24	14
986a	T10-2940	-	-	11/12/2010	45	23
986a	T10-3015	11/8/2010	1500	11/22/2010	38	23
986a	T10-2947	-	-	11/15/2010	15	11
986a	T10-3016	11/12/2010	1100	11/22/2010	27	18
986a	T10-3137	11/15/2010	0830	12/3/2010	40	419
986a	T10-3138	11/19/2010	1530	12/3/2010	24	72
986a	T10-3186	11/21/2010	1200	12/7/2010	45	108
986a	T10-3187	12/6/2010	1000	12/7/2010	57	127
Count	**11**			**Average**	**40**	**144**

NOTES:

11 samples.

Dates with a * are received dates, all other dates are sampling date

Concentrations greater than 100 ppb are shaded.

The NMHC analyzer trigger points were set as follows:

- October 6, 2010: 50 ppb
- November 16, 2010: 150 ppb
- December 6, 2010: 300 ppb
- December 8, 2010: 150 ppb.

Table 8-18 Triggered Sample measurements (2011)

Station	Sample ID	Sampling Date	Sampling Time	Rec Date	Number of non-zero compounds	Total (ppb)
986a	T11-0279	-	-	2/14/2011	30	29
986a	T11-0280	-	-	2/14/2011	54	136
986a	T11-0281	-	-	2/14/2011	54	117
986a	T11-0282	-	-	2/14/2011	55	131
986a	T11-0581	-	-	3/4/2011	60	218
986a	T11-0598	-	-	3/10/2011	64	152
986a	T11-0599	-	-	3/10/2011	32	146
986a	T11-0600	-	-	3/10/2011	52	78
986a	T11-0643	-	-	3/16/2011	20	12
986a	T11-0644	-	-	3/16/2011	63	107
986a	T11-0645	-	-	3/16/2011	81	228
986a	T11-0876	4/13/2011	1115	4/14/2011	54	98
986a	T11-0877	4/3/2011	1540	4/14/2011	58	168
986a	T11-1082	4/29/2011	1515	5/6/2011	50	124
986a	T11-1422	5/24/2011	0909	6/3/2011	61	211
986a	T11-1423	5/31/2011	1024	6/3/2011	26	16
986b	T11-2784	-	-	9/2/2011	13	24
986b	T11-2798	-	-	9/2/2011	44	287
986b	T11-2799	-	-	9/2/2011	26	65
986b	T11-2800	-	-	9/2/2011	15	41
986b	T11-3435	10/15/2011	0820	10/19/2011	39	45
986b	T11-3436	10/10/2011	1243	10/19/2011	20	152
986b	T11-3527	10/21/2011	0300	10/27/2011	39	58
986b	T11-3528	10/22/2011	2100	10/27/2011	39	59
986b	T11-3668	11/8/2011	0340	11/14/2011	26	52
986b	T11-3728	11/22/2011	0820	11/23/2011	13	34
986b	T11-3729	11/15/2011	1345	11/23/2011	17	31
986b	T11-3730	11/20/2011	2315	11/23/2011	19	18
986b	T11-3787	11/30/2011	0836	12/1/2011	32	29
986b	T11-3944	12/8/2011	0830	12/19/2011	28	47
986b	T11-3945	12/8/2011	1410	12/19/2011	36	86

Table 8-18 Triggered Sample measurements (2011)

Station	Sample ID	Sampling Date	Sampling Time	Rec Date	Number of non-zero compounds	Total (ppb)
986b	T11-3946	12/15/2011	0941	12/19/2011	39	78
986b	T12-0015	12/29/2011	0854	1/3/2012	46	180
Count	**33**			**Average**	**40**	**99**

NOTES:
33 samples.
Dates with a * are received dates, all other dates are sampling date
Concentrations greater than 100 ppb are shaded.
The NMHC analyzer trigger points were set as follows:

- December 8, 2010: 150 ppb.

Table 8-19 Triggered Sample measurements (2012)

Station	Sample ID	Sampling Date	Sampling Time	Rec Date	Number of non-zero compounds	Total (ppb)
986b	T12-0411	2/5/2012	1400	2/8/2012	53	92
986b	T12-0469	2/8/2012	1158	2/14/2012	31	116
986b	T12-0526	2/10/2012	0924	2/17/2012	34	40
986b	T12-0533	2/16/2012	1320	2/21/2012	62	94
986b	T12-0615	3/2/2012	0850	3/5/2012	50	104
986b	T12-0907	3/25/2012	0730	3/29/2012	35	95
986b	T12-0908	3/24/2012	1130	3/29/2012	36	152
986b	T12-0955	3/27/2012	0828	4/11/2012	37	118
986b	T12-0956	3/27/2012	0828	4/11/2012	27	87
986b	T12-1150	4/22/2012	1054	5/3/2012	40	129
986b	T12-1151	4/30/2012	0945	5/3/2012	50	104
986b	T12-1232	5/2/2012	-	5/10/2012	36	82
986b	T12-1339	5/8/2012	0653	5/24/2012	41	180
986b	T12-1422	5/20/2012	0913	5/29/2012	16	29
986b	T12-1957	7/7/2012	1026	7/11/2012	23	41
986b	T12-1958	7/8/2012	1023	7/11/2012	35	76
986b	T12-1959	7/3/2012	1052	7/11/2012	24	55
986b	T12-1960	6/13/2012	0908	7/11/2012	32	101
986b	T12-2038	7/9/2012	0645	7/12/2012	80	516
986b	T12-2039	7/9/2012	1443	7/12/2012	34	276
986b	T12-2147	7/10/2012	1215	7/17/2012	42	642
986b	T12-2169	7/13/2012	1130	7/18/2012	31	107
986b	T12-2246	7/16/2012	1003	7/24/2012	37	271
986b	T12-2258	7/20/2012	1105	7/25/2012	42	168
986b	T12-2345	7/23/2012	1111	7/30/2012	29	215
986b	T12-2346	7/25/2012	0955	7/30/2012	54	899
986b	T12-2415	7/27/2012	0957	8/2/2012	53	83
986b	T12-2416	7/26/2012	1018	8/2/2012	44	143
986b	T12-2502	7/28/2012	1105	8/10/2012	23	41
986b	T12-2540	8/8/2012	0913	8/14/2012	43	57
986b	T12-2870	8/12/2012	1345	9/5/2012	41	76
986b	T12-3246	9/1/2012	1005	9/24/2012	44	72
986b	T12-3264	9/19/2012	0958	9/25/2012	43	65
986b	T12-3265	9/22/2012	1240	9/25/2012	41	49

Table 8-19 Triggered Sample measurements (2012)

Station	Sample ID	Sampling Date	Sampling Time	Rec Date	Number of non-zero compounds	Total (ppb)
986b	T12-3277	-	-	9/26/2012	48	52
986b	T12-3278	9/24/2012	0652	9/26/2012	24	18
986b	T12-3435	10/4/2012	0955	10/11/2012	49	72
986b	T12-3436	10/4/2012	0957	10/11/2012	38	38
986b	T12-3437	10/6/2012	1850	10/11/2012	47	77
986b	T12-3593	10/9/2012	1009	10/18/2012	41	67
986b	T12-3717	10/16/2012	0935	10/23/2012	45	363
986b	T12-4297	11/12/2012	1210	12/10/2012	34	35
986b	T12-4298	12/6/2012	1101	12/10/2012	39	47
986b	T12-4299	10/31/2012	1006	12/10/2012	48	77
986b	T12-4300	10/19/2012	0956	12/10/2012	51	89
986b	T12-4422	12/7/2012	1000	12/19/2012	38	64
986b	T12-4423	12/9/2012	1215	12/19/2012	32	45
986b	T12-4450	12/16/2012	1226	12/21/2012	41	45
986b	T12-4465	12/19/2012	1127	12/31/2012	50	58
986b	T13-0005	12/28/2011	1035	12/31/2012	58	100
986b	T13-0006	12/27/2012	1023	12/31/2012	56	100
986b	T13-0027	12/30/2012	1028	1/8/2013	63	60
Count	**52**			**Average**	**41**	**130**

NOTES:
52 samples.
Dates with a * are received dates, all other dates are sampling date
Concentrations greater than 100 ppb are shaded.
The NMHC analyzer trigger points were set as follows:

- December 8, 2010: 150 ppb.

Table 8-20 Triggered Sample measurements (2013)

Station	Sample ID	Sampling Date	Sampling Time	Rec Date	Number of non-zero compounds	Total (ppb)
986b	T13-0028	1/4/2013	1231	1/8/2013	69	102
986b	T13-0069	1/6/2013	1010	1/11/2013	45	77
986b	T13-0343	1/9/2013	1632	2/4/2013	45	76
986b	T13-0434	2/1/2013	0855	2/13/2013	49	69
986b	T13-0535	2/10/2013	0948	2/21/2013	51	100
986b	T13-0570	2/25/2013	0355	2/27/2013	61	236
986b	T13-0578	2/20/2013	1004	2/27/2013	46	66
986b	T13-0593	2/25/2013	0945	2/28/2013	43	49
986b	T13-0639	2/26/2013	1345	3/5/2013	58	384
986b	T13-0846	3/26/2013	0730	3/28/2013	35	814
986b	T13-0858	3/3/2013	1918	4/2/2013	29	351
986b	T13-0869	4/1/2013	-	4/3/2013	37	69
986b	T13-1108	3/26/2013	1030	4/17/2013	37	46
986b	T13-1400	4/12/2013	1100	5/16/2013	41	134
986b	T13-1474	5/17/2013	1325	5/22/2013	60	239
986b	T13-2079	6/24/2013	1125	6/25/2013	49	233
842b	T13-2171	6/24/2013	1125	7/3/2013	42	65
986b	T13-2172	6/29/2013	1030	7/3/2013	43	50
986b	T13-2930	7/21/2013	1035	7/23/2013	48	328
986b	T13-3071	-	-	8/8/2013	33	118
842b	T13-3076	-	-	8/9/2013	19	37
842b	T13-3349	-	-	8/15/2013	15	17
Count	**22**			**Average**	**43**	**166**

NOTES:

22 samples.

Dates with a * are received dates, all other dates are sampling date

Concentrations greater than 100 ppb are shaded.

The 986b NMHC analyzer trigger points were set as follows:

- December 8, 2010: 150 ppb
- June 20, 2013: 300 ppb.

The 842b NMHC analyzer trigger points were set as follows:

- November 7, 2012: 150 ppb
- June 20, 2013: 300 ppb.

Table 8-21 Top-10 non-methane compounds for six Highest Triggered Sample sums

Date	7/14/2010		Date	11/15/2010		Date	7/9/2012
Sample	**T10-1598**		**Sample**	**T10-3137**		**Sample**	**T12-2038**
Sum (ppb)	**578**		**Sum (ppb)**	**419**		**Sum (ppb)**	**516**
1-Butene	192		Acetone	333		Ethanol	158
Carbonyl sulphide	118		Acetic Acid	31.4		Methyl ethyl ketone	66.2
Bromomethane	54.3		3-Heptene, 2,2,4,6,6-pentamethyl-	25.8		Hydrogen sulphide	45.4
3-Heptene, 2,2,4,6,6-pentamethyl-	53.9		2-Propanol, 2-methyl-	3.7		Unknown Sulphurs (MW=32)	28.1
Acetone	43.7		1-Butene	2.4		Acetone	23.1
Carbon disulphide	16.6		1-Pentene, 2,4,4-trimethyl-	2.3		Butane	21.5
Methyl isobutyl ketone	14.3		Benzenemethanol, .alpha.,.alpha.-dimethy	1.8		Toluene	17.8
Hexane	10.5		3-Undecene, 6-methyl-, (E)-	1.7		2-Methylpentane	9.1
2-Pentanone, 4,4-dimethyl-	9.3		Butane	1.7		Isopentane	8.9
Methyl Tert Butyl Ether	8.5		Methyl isobutyl ketone	1.5		Sulfur dioxide	8.8
Sum for top 10	**473**		**Sum for top 10**	**405**		**Sum for top 10**	**387**
	82%			**97%**			**75%**

Table 8-21 Top-10 non-methane compounds for six Highest Triggered Sample sums (concluded)

Date	7/10/2012		Date	7/25/2012		Date	3/26/2013
Sample	**T12-2147**		**Sample**	**T12-2346**		**Sample**	**T13-0846**
Sum (ppb)	**642**		**Sum (ppb)**	**899**		**Sum (ppb)**	**814**
Vinyl Acetate	472		Acetone	375		Methyl Alcohol	621
Isobutane	48.5		Sulfur dioxide	122		Chloromethane	117
Acetone	34.3		Methyl ethyl ketone	108		Toluene	23.4
Butane	16.2		Carbonyl sulphide	68		Freon-113	18.5
Isopentane	13.3		Isopentane	22.3		Acetone	6.8
Pentane	9.2		Isobutane	19.2		Butane	4.3
2-Methylpentane	5.7		Butane	18.6		Isobutane	4.3
3-Methylpentane	4.2		Benzene	13.2		Isopentane	4.1
Isoprene	4.2		trans-2-Butene	10.3		Pentane	2.7
Methylcyclohexane	3.8		2-Methylpentane	9.5		Carbon disulphide	2.0
Sum for top 10	**611**		**Sum for top 10**	**766**		**Sum for top 10**	**804**
	95%			**85%**			**99%**

Table 8-22 Comparison of Trigged Sample measurements to ambient benchmarks (118 samples)

Chemical Compound (Triggered Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
Methane	74-82-8	118	13000	-	-	-	-	5062	-	-
Methyl Alcohol	67-56-1	12	621	33000	0.02	2000	0.3	62.4	200	0.3
Vinyl Acetate	108-05-4	1	472	-	-	43	11.1	472	4.3	111
Acetone	67-64-1	90	375	42000	0.009	2400	0.2	18.5	249	0.07
Ethane	74-84-0	6	300	-	-	-	-	217	-	-
1-Butene	106-98-9	50	192	360	0.5	358	0.5	8.5	-	-
Ethanol	64-17-5	12	158	520	0.3	1015	0.2	18.2	999	0.02
Toluene	108-88-3	109	125	330	0.4	265	0.5	3.6	69	0.05
Sulfur dioxide	7446-09-5	9	122	870	0.1	191	0.6	20.2	7.6	2.6
Carbonyl sulphide	463-58-1	116	118	55	2.1	55	2.1	4.2	1.1	4.0
Chloromethane	74-87-3	15	117	-	-	504	0.2	8.4	50	0.17
Methyl ethyl ketone	78-93-3	8	108	440	0.2	441	0.2	23.1	340	0.07
Naphthalene	91-20-3	13	83.8	-	-	-	-	9.4	4.3	2.2
Freon-113	76-13-1	85	78.5	-	-	4968	0.02	3.3	497	0.007
3-Heptene, 2,2,4,6,6-pentamethyl-	123-48-8	91	69.7	-	-	-	-	11.7	-	-
Trisulfide, dimethyl	3658-80-8	4	65.9	-	-	-	-	18.2	-	-
Bromomethane	74-83-9	1	54.3	-	-	31	1.8	54.3	3.1	18
Unknown Sulphurs (MW=32)	0	3	51.7	-	-	-	-	24.8	-	-
Isobutane	75-28-5	109	48.5	-	-	-	-	7.8	3035	0.003
Hydrogen sulphide	7783-06-4	41	45.4	0.41	111	5	9.0	2.7	3.0	0.9
Dimethyl trisulphide	3658-80-8	3	42.5	-	-	-	-	15.7	-	-
Benzene	71-43-2	114	42.3	2700	0.02	9	4.7	1.5	0.1	11
Decane	124-18-5	29	42.0	620.0	0.07	622	0.07	4.3	172	0.02
Trichloroethylene	79-01-6	3	41.2	3900	0.01	101	0.4	13.9	0.4	32

Table 8-22 Comparison of Trigged Sample measurements to ambient benchmarks (118 samples)

Chemical Compound (Triggered Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
2-Pentene, 2,4,4-trimethyl-	107-40-4	2	40.0	-	-	393	0.1	21.4	39	0.5
Disulfide, dimethyl	624-92-0	3	39.9	2.2	18	5	7.7	15.9	3.6	4.4
Isopentane	78-78-4	107	36.3	1300	0.03	-	-	7.9	2411	0.003
Dimethyl disulphide	624-92-0	14	33.3	2.2	15	5	6.4	3.7	3.6	1.0
Acetic Acid	64-19-7	2	31.4	6	5.2	6	5.1	16.3	10	1.6
Butane	106-97-8	110	30.4	1200000	0.00003	27822	0.001	7.7	3035	0.003
Pentane	109-66-0	85	26.9	1400	0.02	-	-	6.1	2411	0.003
Unknown Sulfur	0	8	25.9	-	-	-	-	5.6	-	-
2 ETHYL HEXANOL	104-76-7	1	23.9	-	-	75	0.3	23.9	30	0.8
Heptane, 2,2,6,6-tetramethyl-4-methylene	141-70-8	27	19.9	-	-	-	-	3.3	-	-
Heptafluorobutyric anhydride	336-59-4	1	18.9	-	-	-	-	18.9	-	-
Sulfur dioxide(DOT)	7446-09-5	1	18.3	870	0.02	191	0.1	18.3	7.6	2.4
Carbon disulphide	75-15-0	57	16.6	210	0.08	10	1.7	1.4	1.0	1.4
2-Methylpentane	107-83-5	98	15.8	7000	0.002	995	0.02	3.6	100	0.04
Benzene, 1,3-bis(1-methylethenyl)-	3748-13-8	12	14.5	-	-	-	-	2.1	-	-
Methyl isobutyl ketone	108-10-1	35	14.3	170	0.1	171	0.08	2.4	20	0.12
2-Propanol, 2-methyl-	75-65-0	16	13.6	4500	0.003	205	0.07	4.5	20	0.22
Naphthalene, 1,2,3,4-tetrahydro-6,7-dime	1076-61-5	1	12.1	-	-	-	-	12.1	-	-
Benzene, (1-methylethenyl)-	98-83-9	22	11.0	-	-	52	0.2	1.7	10	0.17
1-Pentene	109-67-1	5	10.9	100	0.1	101	0.1	4.2	-	-
Hexane	110-54-3	103	10.5	1500.0	0.007	1507	0.007	1.9	57	0.03
trans-2-Butene	624-64-6	6	10.3	-	-	2096	0.005	2.7	-	-
3-Methylpentane	96-14-0	98	9.4	8900	0.001	995	0.009	2.3	100	0.02
2-Pentanone, 4,4-dimethyl-	590-50-1	8	9.3	-	-	-	-	2.0	-	-

Table 8-22 Comparison of Trigged Sample measurements to ambient benchmarks (118 samples)

Chemical Compound (Triggered Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
Acrolein	107-02-8	3	9.1	3.6	**2.5**	1	**6.5**	5.3	0.1	**81**
Isoprene	78-79-5	35	8.8	48	**0.2**	22	**0.4**	2.1	2.2	**1.0**
Methyl Tert Butyl Ether	1634-04-4	9	8.5	-	-	-	-	2.0	50	**0.04**
1-Heptene, 2-methyl-	15870-10-7	8	8.2	-	-	-	-	2.8	-	-
Cyclohexanone	108-94-1	2	7.8	-	-	120	**0.07**	4.3	20	**0.22**
Methylcyclohexane	108-87-2	97	7.6	150	**0.05**	150	**0.05**	2.8	402	**0.007**
3-Cyclohexen-1-ol, 3-methyl-	53783-91-8	2	7.3	-	-	-	-	4.6	-	-
2H-Pyran-2-one	504-31-4	1	7.2	-	-	-	-	7.2	-	-
Cyclohexane, 1-methyl-2-pentyl-	54411-01-7	13	7.0	-	-	-	-	1.6	-	-
.alpha.-Methylstyrene	98-83-9	5	7.0	-	-	52	**0.1**	2.9	10	**0.3**
Cyclohexane	110-82-7	99	6.8	2500	**0.003**	990	**0.007**	2.2	99	**0.02**
m,p-Xylene	108-38-3	87	6.5	41	**0.2**	80	**0.08**	0.7	42	**0.02**
5-Hepten-2-one	6714-00-7	1	6.5	-	-	-	-	6.5	-	-
Methanol	67-56-1	10	6.2	33000	**0.0002**	2000	**0.003**	1.8	200	**0.009**
3-Ethyl-2-hexene	620-00-8	1	6.1	-	-	-	-	6.1	-	-
n-Propyl sec-butyl disulphide	59849-54-6	1	6.0	-	-	-	-	6.0	-	-
Methylcyclopentane	96-37-7	99	5.7	1700	**0.003**	-	-	2.0	76	**0.03**
2,3-Dimethylbutane	79-29-8	88	5.4	420	**0.01**	421	**0.01**	0.9	100	**0.009**
Ethyl n-propyl disulfide	30453-31-7	1	5.2	-	-	-	-	5.2	-	-
Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	1	5.2	-	-	503	**0.01**	5.2	50	**0.10**
Isopropyl Alcohol	67-63-0	4	4.9	26000	**0.0002**	-	-	2.8	200	**0.01**
5-Thiazoleethanol, 4-methyl-	137-00-8	1	4.8	-	-	-	-	4.8	-	-
3-Butene-1,2-diol, 1-(2-furanyl)-3-methy	21141-71-9	2	4.8	-	-	-	-	2.7	-	-
cis-2-Butene	590-18-1	6	4.6	-	-	2096	**0.002**	1.4	-	-

Table 8-22 Comparison of Trigged Sample measurements to ambient benchmarks (118 samples)

Chemical Compound (Triggered Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
Cyclopentane	287-92-3	90	4.6	-	-	1188	**0.004**	1.1	119	**0.009**
2-Ethyl-1-hexyl propionate	6293-37-4	2	4.6	-	-	-	-	3.6	-	-
2,2,4,4,5,5,7,7-Octamethyloctane	5171-85-7	2	4.5	-	-	-	-	2.9	-	-
Acetic acid ethenyl ester	108-05-4	1	4.5	-	-	43	**0.1**	4.5	4.3	**1.0**
2,3-Dimethylpentane	565-59-3	79	4.5	4500	**0.001**	856	**0.005**	0.7	86	**0.008**
Carbonyl sulfide	463-58-1	1	4.5	55	**0.08**	55	**0.08**	4.5	1.1	**4.2**
1,2,4-Trimethylbenzene	95-63-6	38	4.4	120	**0.04**	143	**0.03**	0.4	25	**0.02**
Disulfide, dipropyl	629-19-6	1	4.4	-	-	15	**0.3**	4.4	1.5	**2.9**
Undecane	1120-21-4	11	4.2	870	**0.005**	549	**0.008**	1.0	55	**0.02**
Disulfide, bis(1-methylethyl)	4253-89-8	2	4.2	-	-	-	-	2.2	-	-
METHYL PROPYL TRISULFIDE	17619-36-2	1	4.1	-	-	-	-	4.1	-	-
Nonane, 2,2,4,4,6,8,8-heptamethyl-	4390-04-9	11	4.0	-	-	-	-	1.0	-	-
3-Methylhexane	589-34-4	90	3.9	840	**0.005**	751	**0.005**	1.2	75	**0.02**
1,3,5,7-Tetraazatricyclo[3.3.1.1(3,7)]de	100-97-0	1	3.8	-	-	30	**0.1**	3.8	3.0	**1.3**
Tetrahydro thiophene	110-01-0	1	3.7	0.62	**6.0**	1	**6.1**	3.7	2.8	**1.3**
2-Hexene, 5,5-dimethyl-, (Z)-	39761-61-0	4	3.7	-	-	218	**0.02**	2.0	22	**0.09**
Benzene, 1-chloro-4-(trifluoromethyl)- $	98-56-6	2	3.6	-	-	249	**0.01**	3.2	25	**0.13**
Cyclohexane, 1-methyl-3-pentyl-	54411-02-8	3	3.6	-	-	-	-	1.8	-	-
Methyl mercaptan	74-93-1	3	3.6	0.07	**52**	-	-	1.6	0.5	**3.2**
1,3-Pentadiene, (E)-	2004-70-8	1	3.5	-	-	-	-	3.5	-	-
Heptane	142-82-5	54	3.5	670	**0.005**	672	**0.005**	0.5	86	**0.005**
Disulfide, methyl propyl	2179-60-4	4	3.5	-	-	-	-	1.5	-	-
1-Pentene, 2,4,4-trimethyl-	107-39-1	19	3.5	-	-	393	**0.009**	0.9	39	**0.02**
2-Butanone, 3-methyl-	563-80-4	2	3.5	500	**0.007**	500	**0.007**	2.1	200	**0.01**

Table 8-22 Comparison of Trigged Sample measurements to ambient benchmarks (118 samples)

Chemical Compound (Triggered Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
Silane, difluorodimethyl-	353-66-2	1	3.4	-	-	-	-	3.4	-	-
Propene	115-07-1	1	3.3	13000.0	**0.0003**	-	-	3.3	2329	**0.001**
1-Propene, 2-methyl-, trimer	7756-94-7	9	3.2	-	-	262	**0.01**	1.4	26	**0.05**
1-Propene, 2-methyl-, tetramer	15220-85-6	1	3.1	-	-	-	-	3.1	-	-
3,3,7,7-Tetramethyl-1,5-diazabicyclo[3.3	2940-98-9	1	3.1	-	-	-	-	3.1	-	-
1-Hexene, 5,5-dimethyl-	7116-86-1	9	3.1	-	-	-	-	1.0	-	-
1,2,3-Trimethylbenzene	526-73-8	21	3.1	-	-	255	**0.01**	0.4	25	**0.01**
1-Butanol, 3-methyl-, propanoate	105-68-0	3	3.1	-	-	-	-	2.3	-	-
Heptane, 2,4-dimethyl-	2213-23-2	2	3.0	-	-	-	-	1.6	-	-
Naphthalene, decahydro-, trans-	493-02-7	1	2.9	-	-	-	-	2.9	-	-
m-Diethylbenzene	141-93-5	1	2.9	70	**0.04**	-	-	2.9	46	**0.06**
Propanenitrile, 2-methyl-	78-82-0	1	2.8	-	-	-	-	2.8	7.8	**0.4**
Ethanone, 1-[4-(1-methylethenyl)phenyl]-	5359-04-6	2	2.8	-	-	-	-	2.6	-	-
2-Heptene, 3-methyl-	3404-75-9	2	2.8	-	-	-	-	1.4	-	-
Methyl ethyl disulphide	20333-39-5	5	2.8	-	-	-	-	1.4	3.2	**0.5**
4,4-Dimethyl-2-pentenal	926-37-4	1	2.7	-	-	-	-	2.7	-	-
2-Butanethiol, 3-methyl-	2084-18-6	1	2.7	-	-	-	-	2.7	-	-
1,2-Cyclohexanediol	931-17-9	5	2.7	-	-	53	**0.05**	0.8	5.3	**0.16**
Acetaldehyde	75-07-0	7	2.7	1.5	**1.8**	8	**0.3**	0.9	25	**0.04**
2-Pentanone	107-87-9	1	2.7	28	**0.1**	28	**0.09**	2.7	151	**0.02**
Phenol, 4-(methylthio)-	1073-72-9	1	2.6	-	-	-	-	2.6	-	-
Disulfide, ethyl 1-methylpropyl	54166-53-9	1	2.5	-	-	-	-	2.5	-	-
Benzene, 1,2,3,5-tetramethyl-	527-53-7	2	2.4	-	-	228	**0.01**	1.3	23	**0.06**
Naphthalene, 1-methyl-	90-12-0	1	2.4	-	-	-	-	2.4	0.5	**4.7**

Table 8-22 Comparison of Trigged Sample measurements to ambient benchmarks (118 samples)

Chemical Compound (Triggered Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
o-Ethyltoluene	611-14-3	22	2.4	74	**0.03**	-	-	0.3	25	**0.01**
m-Ethyltoluene	620-14-4	41	2.4	18	**0.1**	-	-	0.3	25	**0.01**
Methane, trifluoro-	75-46-7	1	2.4	-	-	-	-	2.4	499	**0.005**
1-Propene, 2-methyl-	115-11-7	1	2.4	10000	**0.0002**	1310	**0.002**	2.4	13971	**0.000**
4,7-Methano-1H-indene, 3a,4,7,7a-tetrahy	77-73-6	2	2.4	-	-	11	**0.2**	1.6	5.0	**0.3**
1-Hexanol, 2-ethyl-	104-76-7	6	2.3	-	-	75	**0.03**	1.3	30	**0.04**
Cyclopentane, 1,3-dimethyl-	2453-00-1	26	2.3	-	-	-	-	0.5	-	-
2-Methylhexane	591-76-4	86	2.3	420	**0.005**	421	**0.005**	0.5	75	**0.007**
2,2-Dimethylbutane	75-83-2	55	2.2	20000	**0.0001**	995	**0.002**	0.3	100	**0.003**
Freon-12	75-71-8	68	2.2	-	-	10103	**0.0002**	0.4	1010	**0.0004**
Cyclohexane, isothiocyanato-	1122-82-3	1	2.1	-	-	-	-	2.1	-	-
Dimethyl sulphide	75-18-3	3	2.1	3	**0.7**	3	**0.7**	1.2	10	**0.12**
o-Xylene	95-47-6	70	2.1	380	**0.006**	-	-	0.3	42	**0.007**
Benzene, 1-chloro-4-(trifluoromethyl)-	98-56-6	4	2.1	-	-	249	**0.008**	1.0	25	**0.04**
Ethanamine, N-ethyl-N-nitroso-	55-18-5	1	2.0	-	-	0	**8.4**	2.0	0.02	**84**
Methyl Butyl Ketone	591-78-6	2	2.0	24	**0.08**	-	-	1.3	1.0	**1.4**
3-Hexene, 2,2-dimethyl-, (E)-	690-93-7	2	2.0	-	-	-	-	1.1	-	-
1-Hexanone, 1-phenyl-	942-92-7	1	1.9	-	-	-	-	1.9	-	-
Benzene, 1,4-bis(1-methylethenyl)-	1605-18-1	2	1.9	-	-	-	-	1.1	-	-
1,3,6-Octatriene, 3,7-dimethyl-, (E)- (C	3779-61-1	3	1.9	-	-	-	-	1.1	-	-
4-Cyanocyclohexene	100-45-8	6	1.9	-	-	13	**0.1**	1.0	1.3	**0.8**
Cyclodecene, 1-methyl-	66633-38-3	1	1.9	-	-	-	-	1.9	-	-
2-Hexenal, (E)-	6728-26-3	2	1.9	-	-	-	-	1.0	-	-
Butanal	123-72-8	1	1.9	0.67	**2.8**	5	**0.4**	1.9	25	**0.07**

Table 8-22 Comparison of Trigged Sample measurements to ambient benchmarks (118 samples)

Chemical Compound (Triggered Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
Hexatriacontane	630-06-8	1	1.8	-	-	-	-	1.8	-	-
2-methyl Thiophene	554-14-3	2	1.8	-	-	25	**0.07**	1.6	2.5	**0.6**
2-Pentanol, 3-chloro-2-methyl-	74685-49-7	1	1.8	-	-	-	-	1.8	-	-
Disulfide, ethyl hexyl	67421-86-7	2	1.8	-	-	-	-	1.2	-	-
2,2,4-Trimethylpentane	540-84-1	7	1.8	670	**0.003**	671	**0.003**	0.3	75	**0.005**
Benzenemethanol, .alpha.,.alpha.-dimethy	617-94-7	2	1.8	-	-	108	**0.02**	1.6	11	**0.15**
Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	1	1.7	-	-	467	**0.004**	1.7	47	**0.04**
3-Undecene, 6-methyl-, (E)-	74630-52-7	1	1.7	-	-	-	-	1.7	-	-
Disulfide, ethyl 1-methylethyl	53966-36-2	1	1.7	-	-	-	-	1.7	-	-
Ethyl benzene	100-41-4	75	1.7	170	**0.01**	171	**0.01**	0.3	131	**0.002**
Cyclohexane, 1,3-dimethyl-, cis-	638-04-0	24	1.7	-	-	-	-	0.5	-	-
p-Diethylbenzene	105-05-5	1	1.7	0.39	**4.4**	-	-	1.7	46	**0.04**
2-Hexene, 3,4,4-trimethyl-	53941-19-8	1	1.7	-	-	-	-	1.7	-	-
Benzene, 1-(2-butenyl)-2,3-dimethyl-	54340-85-1	1	1.7	-	-	-	-	1.7	-	-
Naphthalene, 2-methyl-	91-57-6	2	1.7	-	-	-	-	1.2	0.5	**2.4**
2,3,4-trimethyl-1-pentanol	NA	1	1.7	-	-	-	-	1.7	-	-
CYCLOBUTANE, ISOPROPYL-	872-56-0	6	1.7	-	-	-	-	1.0	-	-
Dodecane, 2,6,10-trimethyl-	3891-98-3	1	1.7	-	-	404	**0.004**	1.7	40	**0.04**
Cyclohexene, 3-methyl-6-(1-methylethyl)-	5256-65-5	1	1.7	-	-	-	-	1.7	-	-
Benzene, 1-methyl-3-(1-methylethyl)-	535-77-3	3	1.7	-	-	-	-	0.9	-	-
.ALPHA.-PINENE, (-)-	80-56-8	11	1.7	18	**0.1**	18	**0.09**	0.7	63	**0.01**
Naphthalene, decahydro-2-methyl-	2958-76-1	1	1.6	-	-	-	-	1.6	-	-
1-METHYL-4-N-PENTYLCYCLOHEXANE (CIS+TRAN	NA	2	1.6	-	-	-	-	1.1	-	-
2-Hexene, (Z)-	7688-21-3	2	1.6	-	-	140	**0.01**	1.5	49	**0.03**

Table 8-22 Comparison of Trigged Sample measurements to ambient benchmarks (118 samples)

Chemical Compound (Triggered Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
Cyclohexane, 1,1,3-trimethyl-	3073-66-3	41	1.6	-	-	-	-	0.5	-	-
Butane, 1-ethoxy-	628-81-9	1	1.6	-	-	561	**0.003**	1.6	56	**0.03**
Thiophene, tetrahydro-	110-01-0	1	1.6	0.62	**2.5**	1	**2.5**	1.6	2.8	**0.6**
Diethyl disulfide	110-81-6	1	1.5	2	**0.8**	2	**0.8**	1.5	2.8	**0.5**
2-Pentene, 3,4,4-trimethyl-	598-96-9	1	1.5	-	-	-	-	1.5	-	-
2,5-Cyclohexadiene-1,4-dione, 2,6-bis(1,	719-22-2	1	1.5	-	-	-	-	1.5	-	-
Benzene, 1,2,3,5-tetrachloro-4,6-difluor	1198-56-7	1	1.5	-	-	-	-	1.5	-	-
Octane	111-65-9	16	1.5	1700	**0.0009**	13254	**0.0001**	0.4	75	**0.005**
Thiophene, tetrahydro-2-methyl-	1795-09-1	1	1.4	-	-	-	-	1.4	-	-
3-Cyclohexen-1-ol	822-66-2	1	1.4	-	-	-	-	1.4	-	-
Disulfide, dibutyl	629-45-8	2	1.4	-	-	-	-	0.8	-	-
cis-2-Pentene	627-20-3	4	1.4	-	-	2620	**0.0005**	0.8	-	-
Methane, thiobis-	75-18-3	1	1.4	3	**0.5**	3	**0.5**	1.4	10	**0.14**
Trisulfide, dipropyl	6028-61-1	1	1.4	-	-	-	-	1.4	-	-
Dodecane	112-40-3	8	1.4	110.0	**0.01**	111	**0.01**	0.6	50	**0.01**
Cyclohexanone, 2-chloro-	822-87-7	1	1.4	-	-	-	-	1.4	-	-
2-Butenoic acid, methyl ester	18707-60-3	1	1.3	-	-	-	-	1.3	-	-
Indene	95-13-6	1	1.3	-	-	-	-	1.3	5.1	**0.3**
Cyclohexane, 1-methyl-2-propyl-	4291-79-6	2	1.3	-	-	611	**0.002**	1.2	61	**0.02**
DIMETHYLDISULFIDE	624-92-0	2	1.3	2.2	**0.6**	5	**0.2**	0.9	3.6	**0.25**
Cyclohexane, ethyl-	1678-91-7	48	1.3	-	-	4082	**0.0003**	0.4	408	**0.0009**
Diisopropyl trisulfide	5943-34-0	1	1.3	-	-	-	-	1.3	-	-
Freon-11	75-69-4	108	1.3	-	-	4997	**0.0003**	0.3	500	**0.0005**
4-Pentenal	2100-17-6	3	1.3	-	-	-	-	0.7	-	-

Table 8-22 Comparison of Trigged Sample measurements to ambient benchmarks (118 samples)

Chemical Compound (Triggered Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
2-Butenal	4170-30-3	1	1.3	-	-	3	**0.4**	1.3	0.3	**4.0**
1-Propanone, 1-(2-furanyl)-	3194-15-8	1	1.2	-	-	-	-	1.2	-	-
Hexane, 1,1,1,2,2,3,3,4,4,5,6,6,6-tridec	1998-54-5	1	1.2	-	-	-	-	1.2	-	-
Allyl sulphide	592-88-1	1	1.2	0.22	**5.6**	0	**5.8**	1.2	3.0	**0.4**
2,2-Dichloro-3,3,4,4-tetramethylcyclobut	66239-90-5	1	1.2	-	-	-	-	1.2	-	-
Benzene, 1-methyl-2-(1-methylethyl)- (CA	527-84-4	2	1.2	-	-	-	-	0.7	-	-
Cyclopentanecarboxaldehyde	872-53-7	1	1.2	-	-	-	-	1.2	-	-
trans-2-Pentene	646-04-8	3	1.2	-	-	2620	**0.0005**	0.7	-	-
Camphene	79-92-5	5	1.2	-	-	9	**0.1**	0.5	0.9	**0.5**
Benzaldehyde	100-52-7	9	1.2	-	-	21	**0.06**	0.5	2.1	**0.25**
Benzene, 1,2,4,5-tetramethyl-	95-93-2	1	1.2	-	-	228	**0.005**	1.2	23	**0.05**
Cyclohexane, 1,1'-[1,2-bis(1,1-dimethyle	65149-85-1	7	1.18	-	-	-	-	0.7	-	-
Cyclopentane, 1,2-dimethyl-	2452-99-5	11	1.18	-	-	-	-	0.6	-	-
1-Heptanol	111-70-6	3	1.18	4.8	**0.2**	400	**0.003**	0.8	57	**0.01**
Dimethyl tetrasulphide	5756-24-1	1	1.17	-	-	-	-	1.2	-	-
1-Heptylcyclohexene	15232-86-7	1	1.16	-	-	-	-	1.2	-	-
2-Hexene, 3,5,5-trimethyl-	26456-76-8	7	1.16	-	-	-	-	0.7	-	-
2-Octene, (E)-	13389-42-9	1	1.15	-	-	-	-	1.2	-	-
Cyclopentane, (2-methylpropyl)-	3788-32-7	1	1.15	-	-	-	-	1.2	-	-
p-Ethyltoluene	622-96-8	19	1.15	8.3	**0.1**	-	-	0.2	25	**0.01**
Cyclotetradecane	295-17-0	1	1.14	-	-	-	-	1.1	-	-
2-Butanol, 2-methyl-	75-85-4	1	1.14	88	**0.01**	89	**0.01**	1.1	56	**0.02**
Ethyl mercaptan	75-08-1	1	1.11	0.0087	**128**	0	**3.5**	1.1	0.5	**2.2**
Cyclopentane, 1,3-dimethyl-, cis-	2532-58-3	17	1.10	-	-	873	**0.001**	0.5	87	**0.006**

Table 8-22 Comparison of Trigged Sample measurements to ambient benchmarks (118 samples)

Chemical Compound (Triggered Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
2-Cyclohexen-1-one	930-68-7	1	1.08	-	-	-	-	1.1	-	-
Thiophene, 2-isohexyl-	4861-59-0	1	1.08	-	-	-	-	1.1	-	-
Heptane, 2-iodo-	18589-29-2	1	1.06	-	-	-	-	1.1	-	-
Formaldehyde	50-00-0	2	1.05	500	**0.002**	12	**0.09**	0.7	2.7	**0.24**
4-Hepten-3-one, 2,6-dimethyl-	56259-14-4	1	1.04	-	-	-	-	1.0	-	-
Cyclohexanol, 2-methyl-	583-59-5	1	1.04	-	-	-	-	1.0	-	-
3-Hexene, (Z)-	7642-09-3	1	1.02	-	-	-	-	1.0	-	-
Cyclohexane, 1,3-dimethyl-, trans-	2207-03-6	12	1.02	-	-	-	-	0.5	-	-
2,4-Dimethylpentane	108-08-7	7	1.02	940	**0.001**	856	**0.001**	0.6	86	**0.007**
1,3,5-Trimethylbenzene	108-67-8	14	1.02	170	**0.006**	255	**0.004**	0.2	25	**0.007**
Styrene	100-42-5	17	1.01	35	**0.03**	16	**0.06**	0.3	33	**0.009**
Isopropylcyclobutane	872-56-0	12	1.00	-	-	-	-	0.5	-	-
Cyclopentene	142-29-0	2	0.98	-	-	2912	**0.0003**	0.9	291	**0.003**
Acetophenone	98-86-2	3	0.96	-	-	100	**0.01**	0.4	10	**0.04**
Cyclohexane, 1,4-dimethyl-2-(2-methylpro	54411-17-5	1	0.95	-	-	-	-	1.0	-	-
Hexane, tetradecafluoro-	355-42-0	1	0.95	-	-	-	-	0.9	-	-
Ethanone, 1-cyclohexyl-	823-76-7	1	0.95	-	-	-	-	0.9	-	-
1-Heptene, 5-methyl-	13151-04-7	4	0.93	-	-	-	-	0.5	-	-
Cyclopentane, 1,3-dimethyl-, trans-	1759-58-6	5	0.93	-	-	873	**0.001**	0.6	87	**0.006**
Bicyclo[3.1.0]hexan-2-ol	NA	1	0.92	-	-	-	-	0.9	-	-
Benzene, (1-methylethyl)-	98-82-8	1	0.91	8.4	**0.1**	47	**0.02**	0.9	51	**0.02**
1,3-Cyclopentadiene	542-92-7	2	0.91	-	-	741	**0.001**	0.8	74	**0.01**
Cyclopentane, 1,2-dimethyl-, trans-	822-50-4	13	0.90	-	-	873	**0.001**	0.4	87	**0.005**
2-Heptenal, (E)-	18829-55-5	2	0.89	-	-	-	-	0.7	-	-

Table 8-22 Comparison of Trigged Sample measurements to ambient benchmarks (118 samples)

Chemical Compound (Triggered Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
Nonane	111-84-2	14	0.88	2200	**0.0004**	-	-	0.3	201	**0.001**
cis-3-Hexene	7642-09-3	1	0.88	-	-	-	-	0.9	-	-
Cyclohexane, 1,4-dimethyl-	589-90-2	18	0.88	-	-	-	-	0.3	-	-
Nonanal	124-19-6	3	0.88	0.34	**2.6**	-	-	0.4	26	**0.02**
3-Methylheptane	589-81-1	32	0.87	1500	**0.0006**	751	**0.001**	0.2	75	**0.003**
2-Methylheptane	592-27-8	11	0.87	110	**0.008**	109	**0.008**	0.3	75	**0.003**
Cyclopentane, 1,2-dimethyl-, cis-	1192-18-3	10	0.86	-	-	-	-	0.6	-	-
1-Pentene, 3-methyl-	760-20-3	2	0.85	-	-	-	-	0.5	-	-
1-Decanol, 2-hexyl-	2425-77-6	5	0.84	-	-	10	**0.08**	0.3	1.0	**0.3**
4,7-Methano-1H-indene, octahydro-	6004-38-2	1	0.83	-	-	-	-	0.8	-	-
2-Pentenal, (E)-	1576-87-0	1	0.81	-	-	-	-	0.8	-	-
Decane, 4-methyl-	2847-72-5	1	0.81	-	-	-	-	0.8	-	-
3-Octene, 2,6-dimethyl-	6874-28-8	1	0.81	-	-	-	-	0.8	-	-
Undecane, 5-cyclohexyl-	13151-80-9	1	0.81	-	-	-	-	0.8	-	-
Pyrimidine, 5-bromo-2,4-bis(methylthio)-	60186-81-4	1	0.80	-	-	-	-	0.8	-	-
1-Propene, 1,1,3,3,3-pentafluoro-	690-27-7	2	0.80	-	-	-	-	0.4	-	-
Methane, chlorodifluoro-	75-45-6	1	0.80	-	-	-	-	0.8	512	**0.002**
Ethanone, 1-cyclopropyl-	765-43-5	1	0.80	-	-	-	-	0.8	-	-
3-Pentanol	584-02-1	2	0.79	-	-	289	**0.003**	0.7	56	**0.01**
1,4-Dioxane	123-91-1	1	0.78	-	-	250	**0.003**	0.8	25	**0.03**
Benzene, 1-chloro-4-(trifluoromethyl)- (	98-56-6	1	0.76	-	-	249	**0.003**	0.8	25	**0.03**
Hexane, 1-(hexyloxy)-4-methyl-	74421-20-8	1	0.76	-	-	-	-	0.8	-	-
Cyclohexane, 1,2-dimethyl-, trans-	6876-23-9	9	0.75	-	-	-	-	0.4	-	-
Cyclopropane, 1-ethyl-1-methyl-	53778-43-1	1	0.75	-	-	-	-	0.7	-	-

Table 8-22 Comparison of Trigged Sample measurements to ambient benchmarks (118 samples)

Chemical Compound (Triggered Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
Cyclopentane, decyl-	1795-21-7	1	0.74	-	-	-	-	0.7	-	-
Acetaldehyde, chloro-	107-20-0	1	0.74	-	-	9	**0.08**	0.7	0.9	**0.8**
2-Propenoic acid, 2-ethylhexyl ester (CA	103-11-7	1	0.74	-	-	47	**0.02**	0.7	4.7	**0.16**
1-Heptene	592-41-7	3	0.73	-	-	-	-	0.7	-	-
2-Hexanone, 5-methyl-	110-12-3	5	0.73	-	-	12	**0.06**	0.5	10	**0.05**
2-Cyclohexen-1-ol	822-67-3	8	0.72	-	-	-	-	0.5	-	-
2,6-HEPTADIONE	13505-34-5	1	0.72	-	-	-	-	0.7	-	-
Cycloheptane	291-64-5	2	0.69	-	-	848	**0.0008**	0.5	85	**0.005**
Acetaldehyde, 2-butenylhydrazone	75268-07-4	1	0.68	-	-	-	-	0.7	-	-
2,3-Pentanedione	600-14-6	1	0.68	-	-	-	-	0.7	-	-
2,3,4-Trimethylpentane	565-75-3	6	0.68	-	-	751	**0.0009**	0.2	75	**0.002**
Octane, 2-chloro-	628-61-5	1	0.67	-	-	-	-	0.7	-	-
Cyclobutanone, 2,2-dimethyl-	1192-14-9	2	0.67	-	-	-	-	0.4	-	-
Cyclooctane, butyl-	16538-93-5	2	0.66	-	-	-	-	0.6	-	-
Hexane, 1,6-dicyclohexyl-	1610-23-7	1	0.66	-	-	-	-	0.7	-	-
2-Heptanone	110-43-0	1	0.66	6.8	**0.1**	7	**0.1**	0.7	180	**0.004**
5-Hexyn-1-ol	928-90-5	1	0.65	-	-	-	-	0.6	-	-
Cyclopentane, ethyl-	1640-89-7	29	0.65	-	-	4067	**0.0002**	0.3	407	**0.0008**
Cyclohexane, 1-propenyl-	5364-83-0	1	0.65	-	-	-	-	0.6	-	-
Thiophene, 2-ethyl-	872-55-9	3	0.64	-	-	22	**0.03**	0.4	2.2	**0.19**
2-Hexenal	505-57-7	1	0.64	-	-	-	-	0.6	-	-
1-Propanol, 2,2-dimethyl-	75-84-3	1	0.63	-	-	422	**0.001**	0.6	42	**0.01**
cis-1-Decalone	4832-16-0	1	0.62	-	-	-	-	0.6	-	-
Cyclohexane, 1,4-dimethyl-, trans-	2207-04-7	5	0.60	-	-	-	-	0.3	-	-

Table 8-22 Comparison of Trigged Sample measurements to ambient benchmarks (118 samples)

Chemical Compound (Triggered Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
2-Butanone	78-93-3	1	0.60	440	**0.001**	441	**0.001**	0.6	340	**0.002**
Tridecane	629-50-5	1	0.59	-	-	465	**0.001**	0.6	47	**0.01**
Freon-114	76-14-2	7	0.58	-	-	10068	**0.0001**	0.3	1007	**0.0003**
dl-Limonene	138-86-3	2	0.58	38	**0.02**	38	**0.02**	0.4	20	**0.02**
Cyclohexane, 1-ethyl-1,4-dimethyl-, tran	62238-32-8	1	0.58	-	-	-	-	0.6	-	-
Cyclohexane, isocyanato-	3173-53-3	1	0.58	-	-	0	**4.2**	0.6	0.02	**29**
Cyclohexane, 1,2-dimethyl-, cis-	2207-01-4	4	0.57	-	-	-	-	0.4	-	-
4-Octene, (E)-	14850-23-8	1	0.57	-	-	-	-	0.6	-	-
Cyclopentane, 1,2,4-trimethyl-	2815-58-9	7	0.56	-	-	-	-	0.3	-	-
Tetradecane	629-59-4	1	0.56	-	-	432	**0.001**	0.6	43	**0.01**
Cyclohexane, 1-ethyl-2-methyl-, cis-	4923-77-7	1	0.55	-	-	-	-	0.5	-	-
2-Dodecanol, 2-methyl-	1653-37-8	1	0.55	-	-	-	-	0.5	-	-
2-Cyclopenten-1-one, 3-methyl-	2758-18-1	1	0.54	-	-	-	-	0.5	-	-
Thiophene, 3-methyl-	616-44-4	1	0.54	-	-	25	**0.02**	0.5	2.5	**0.22**
Ethene, 1,1-difluoro-	75-38-7	1	0.54	-	-	10	**0.05**	0.5	1.0	**0.5**
Dodecane, 4-cyclohexyl-	13151-84-3	1	0.53	-	-	-	-	0.5	-	-
Cyclohexane, 1,2-dimethyl- (cis/trans) $	583-57-3	12	0.53	-	-	-	-	0.4	-	-
1-Heptene, 3-methyl-	4810-09-7	3	0.53	-	-	-	-	0.3	-	-
2-Hexene, 2,5,5-trimethyl-	40467-04-7	2	0.52	-	-	-	-	0.4	-	-
Cycloheptane, methyl-	4126-78-7	7	0.52	-	-	-	-	0.3	-	-
1-Hexene, 3-methyl-	3404-61-3	2	0.52	-	-	-	-	0.4	-	-

Table 8-22 Comparison of Trigged Sample measurements to ambient benchmarks (118 samples)

Chemical Compound (Triggered Samples)	CAS #	Count	MM	OT	MM/OT	STB	MM/STB	AM	LTB	MM/LTB
6-Tridecene, 2,2,4,10,12,12-hexamethyl-7	55255-73-7	1	0.51	-	-	-	-	0.508	-	-
Cyclopropane, 1-ethyl-2-heptyl-	74663-86-8	2	0.51	-	-	-	-	0.4	-	-

NOTES:
MM = maximum measured
OT = odour threshold
STB = short-term benchmarks
AM = average measured
LTB = long-term benchmarks
The MM is the same as the AM when there is only one measurement (i.e., the count = 1)

All concentrations and benchmarks are in units of ppb, unless otherwise indicated.
Only compounds where the maximum is greater than 0.5 ppb are shown.
The maximum number of samples is 118.
Short-term benchmarks refer to the most stringent of the sub-1-h and 1-h benchmarks referenced in Section 3.
Long-term benchmarks refer to the most stringent of the 24-h or greater benchmarks referenced in section 3.
Measured values that exceed an ambient benchmark, or are within a factor of 3 of the odour threshold are shaded.

Table 8-23 Triggered Sample compounds that are within a factor of 3 of the odour threshold

Chemical Compound	CAS #	Count	MM	OT	MM/OT
Ethyl mercaptan	75-08-1	1	1.11	0.0087	**128**
Hydrogen sulphide	7783-06-4	41	45.4	0.41	**111**
Methyl mercaptan	74-93-1	3	3.6	0.07	**52**
Dimethyl disulphide	624-92-0	17	39.9	2.2	**18**
Tetrahydro thiophene	110-01-0	1	3.7	0.62	**6.0**
Allyl sulphide	592-88-1	1	1.2	0.22	**5.6**
Acetic Acid	64-19-7	2	31.4	6	**5.2**
p-Diethylbenzene	105-05-5	1	1.7	0.39	**4.4**
Butanal	123-72-8	1	1.9	0.67	**2.8**
Nonanal	124-19-6	3	0.88	0.34	**2.6**
Acrolein	107-02-8	3	9.1	3.6	**2.5**
Thiophene, tetrahydro-	110-01-0	1	1.6	0.62	**2.5**
Carbonyl sulphide	463-58-1	116	118	55	**2.1**
Acetaldehyde	75-07-0	7	2.7	1.5	**1.8**
Diethyl disulfide	110-81-6	1	1.5	2	**0.8**
Dimethyl sulphide	75-18-3	3	2.1	3	**0.7**
Dimethyldisulfide	624-92-0	2	1.3	2.2	**0.6**
1-Butene	106-98-9	50	192	360	**0.5**
Methane, thiobis-	75-18-3	1	1.4	3	**0.5**
Toluene	108-88-3	109	125	330	**0.4**

NOTES:
MM = maximum measured
OT = odour threshold
Sulphur containing compounds are highlighted

Table 8-24 Triggered Sample compounds that are greater than the most stringent short-term benchmark

Chemical Compound	CAS #	Count	MM	STB	MM/STB
Vinyl Acetate	108-05-4	1	472	43	**11.1**
Hydrogen sulphide	7783-06-4	41	45.4	5	**9.0**
Ethanamine, N-ethyl-N-nitroso-	55-18-5	1	2.0	0	**8.4**
Disulfide, dimethyl	624-92-0	17	39.9	5	**7.7**
Acrolein	107-02-8	3	9.1	1	**6.5**
Tetrahydro thiophene	110-01-0	1	3.7	1	**6.1**
Allyl sulphide	592-88-1	1	1.2	0	**5.8**
Acetic Acid	64-19-7	2	31.4	6	**5.1**
Benzene	71-43-2	114	42.3	9	**4.7**
Cyclohexane, isocyanato-	3173-53-3	1	0.58	0	**4.2**
Ethyl mercaptan	75-08-1	1	1.11	0	**3.5**
Thiophene, tetrahydro-	110-01-0	1	1.6	1	**2.5**
Carbonyl sulphide	463-58-1	116	118	55	**2.1**
Bromomethane	74-83-9	1	54.3	31	**1.8**
Carbon disulphide	75-15-0	57	16.6	10	**1.7**

NOTES:
MM = maximum measured
STB = short-term benchmark
Sulphur containing compounds are highlighted

Table 8-25 Triggered Sample compounds that are greater than the most stringent long-term benchmark (LTB)

Chemical Compound	CAS #	Count	AM	LTB	MM/LTB
Vinyl Acetate	108-05-4	1	472	4.3	**111**
Ethanamine, N-ethyl-N-nitroso-	55-18-5	1	2.0	0.02	**84**
Acrolein	107-02-8	3	5.3	0.1	**81**
Trichloroethylene	79-01-6	3	13.9	0.4	**32**
Cyclohexane, isocyanato-	3173-53-3	1	0.6	0.02	**29**
Bromomethane	74-83-9	1	54.3	3.1	**18**
Benzene	71-43-2	114	1.5	0.1	**11**
Naphthalene, 1-methyl-	90-12-0	1	2.4	0.5	**4.7**
Carbonyl sulfide	463-58-1	1	4.5	1.1	**4.2**
2-Butenal	4170-30-3	1	1.3	0.3	**4.0**
Carbonyl sulphide	463-58-1	116	4.2	1.1	**4.0**
Methyl mercaptan	74-93-1	3	1.6	0.5	**3.2**
Disulfide, dipropyl	629-19-6	1	4.4	1.5	**2.9**
Sulfur dioxide	7446-09-5	9	20.2	7.6	**2.6**
Sulfur dioxide(DOT)	7446-09-5	1	18.3	7.6	**2.4**
Naphthalene, 2-methyl-	91-57-6	2	1.2	0.5	**2.4**
Naphthalene	91-20-3	13	9.4	4.3	**2.2**
Ethyl mercaptan	75-08-1	1	1.1	0.5	**2.2**
Disulfide, dimethyl	624-92-0	17	5.8	3.6	**1.6**
Acetic Acid	64-19-7	2	16.3	10	**1.6**
Carbon disulphide	75-15-0	57	1.4	1.0	**1.4**
Methyl Butyl Ketone	591-78-6	2	1.3	1.0	**1.4**
Tetrahydro thiophene	110-01-0	1	3.7	2.8	**1.3**
1,3,5,7-Tetraazatricyclo[3.3.1.1(3,7)]de	100-97-0	1	3.8	3.0	**1.3**
Acetic acid ethenyl ester	108-05-4	1	4.5	4.3	**1.0**

NOTES:
MM = maximum measured
LTB = long-term benchmark
Sulphur containing compounds are highlighted

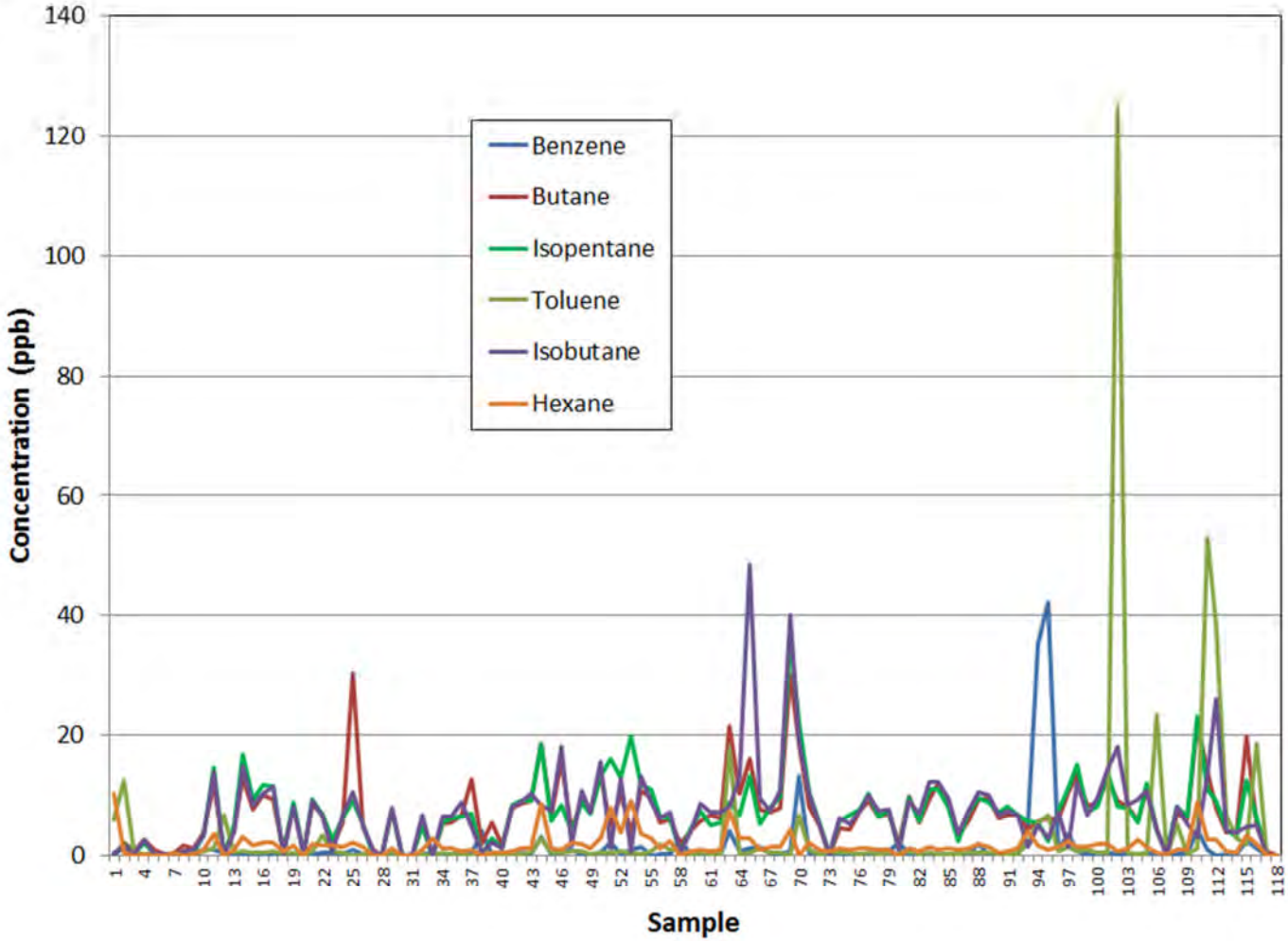


Figure 8-2 Triggered Sample series plot for selected hydrocarbon compounds

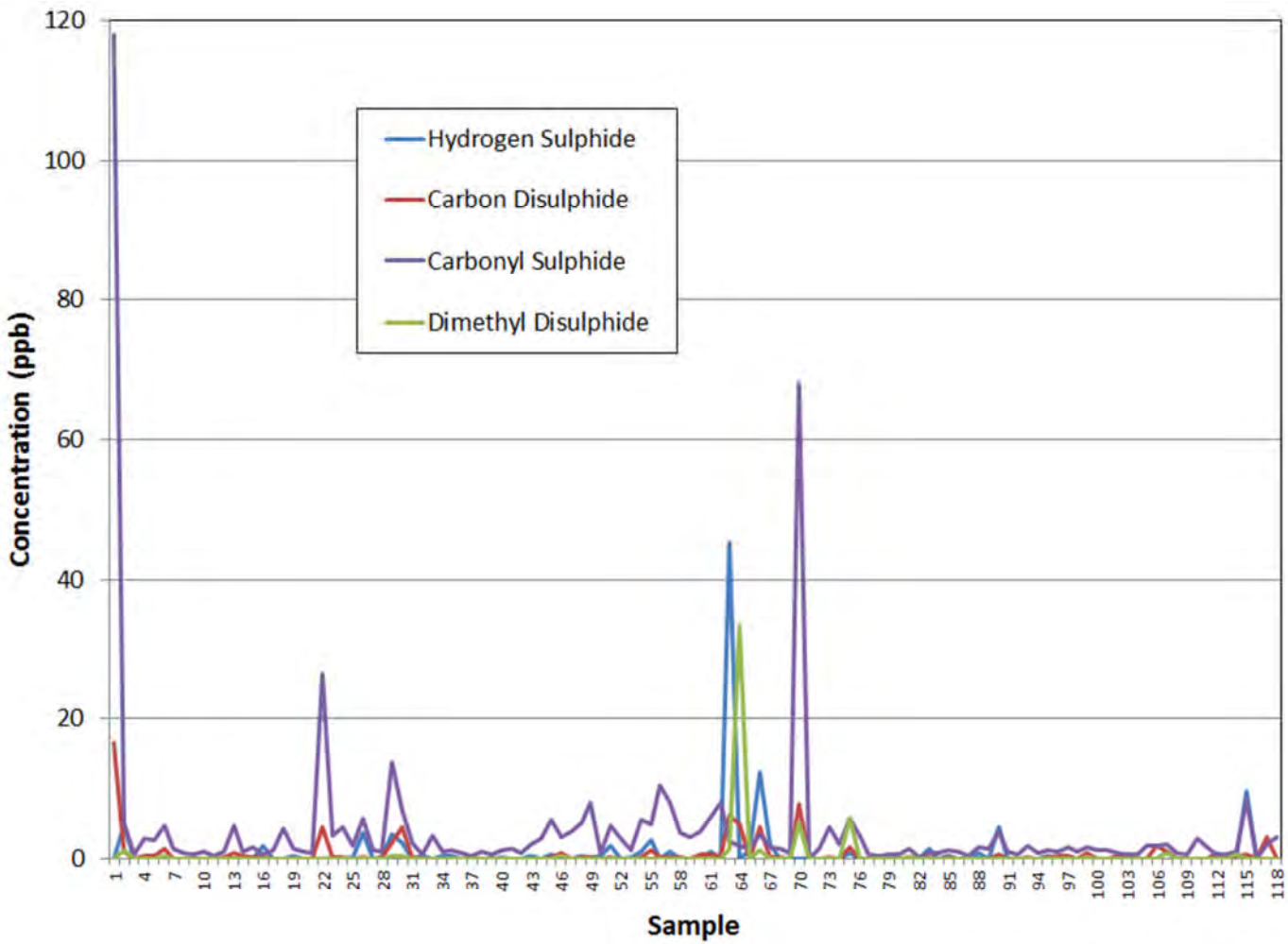


Figure 8-3 Triggered Sample series plot for selected hydrocarbon compounds

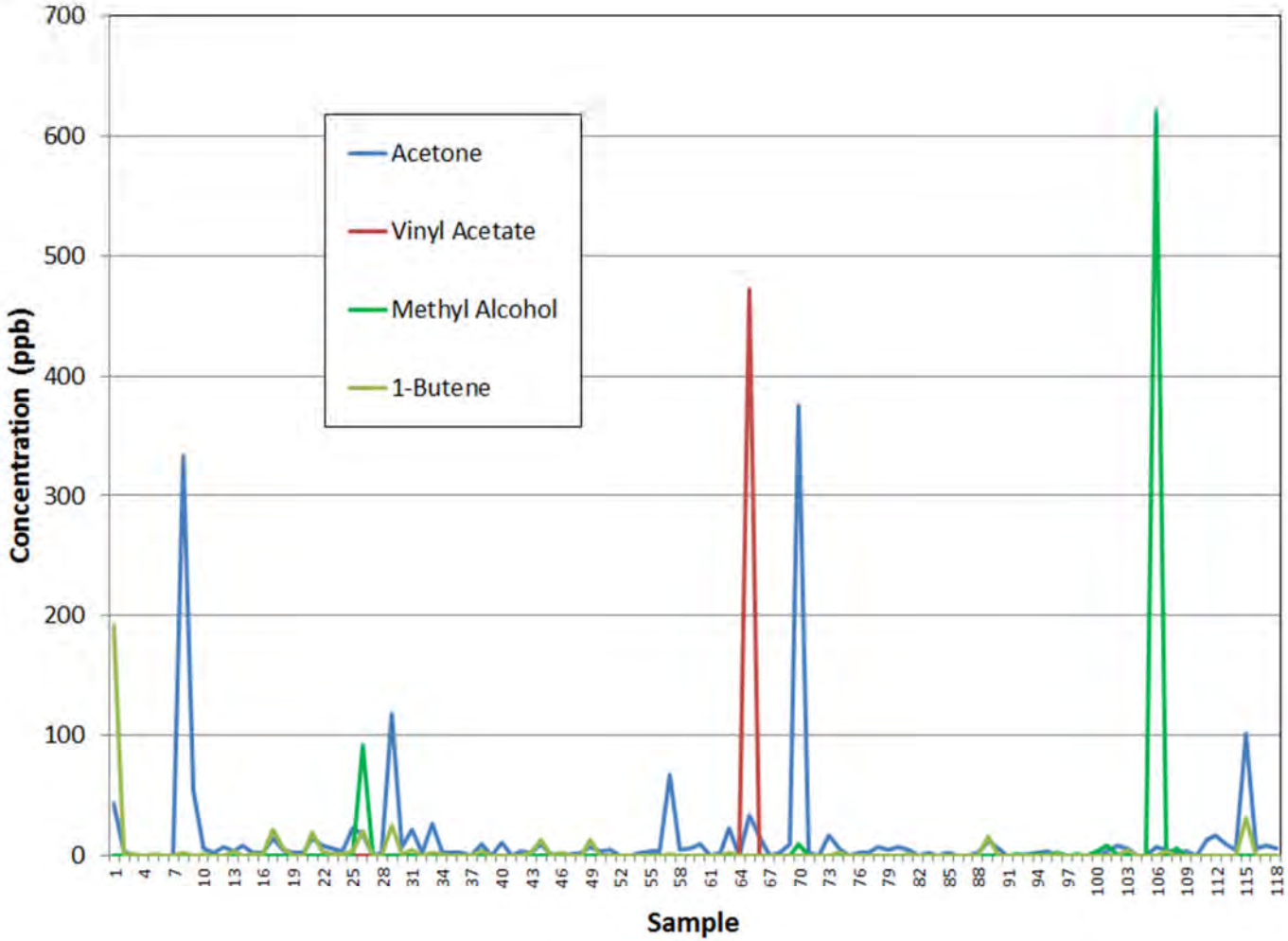
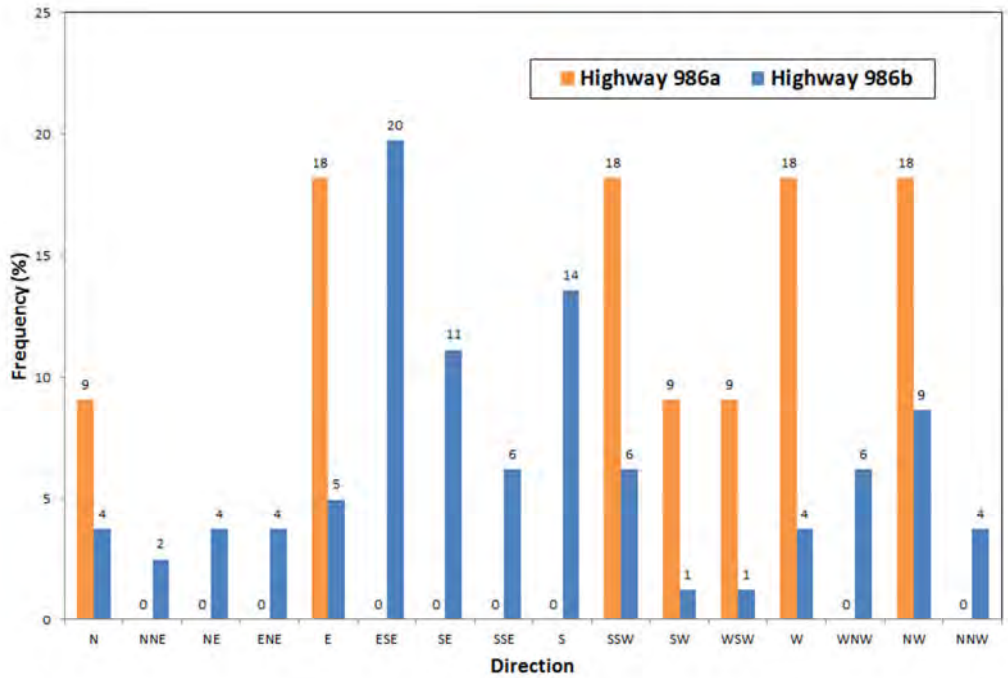


Figure 8-4 Triggered Sample series plot for selected intermittent compounds



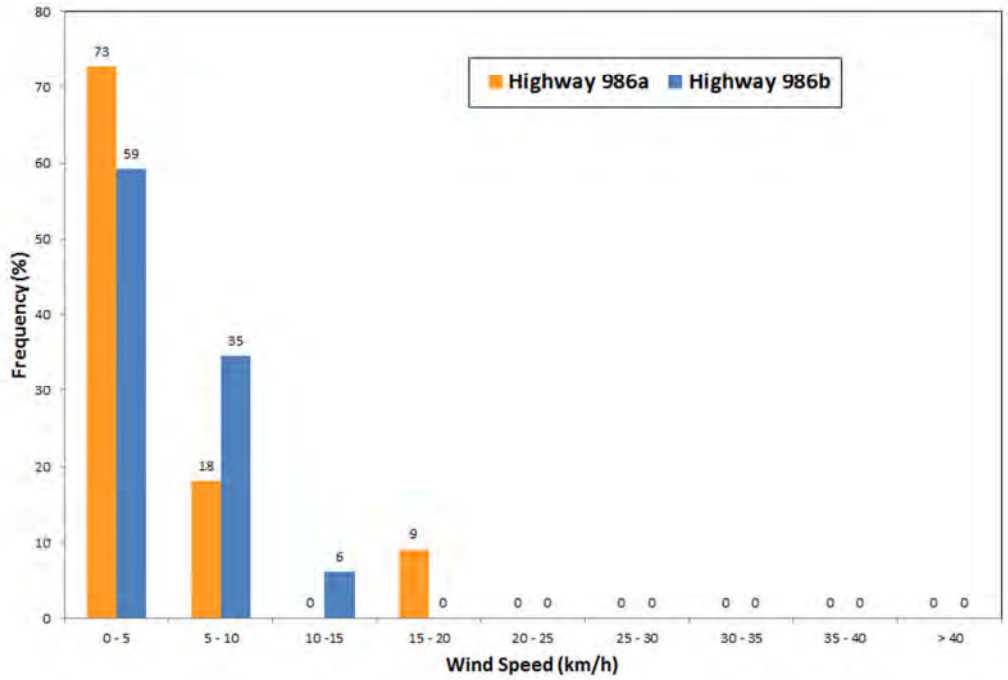


Figure 8-5 Wind direction and wind speed trends associated with the Triggered Samples

8.6 FINDINGS

The canister sampling approach is effectively the only way to determine a more complete speciation of hydrocarbons and reduced sulphur compounds in the atmosphere. This sampling greatly enhances the information base and complements other sampling. An examination of the canister ambient air quality data collected indicates the following:

- The highest Grab Samples indicated that the top contributors were butane, pentane and hexane related compounds. A casual review of the source sample analysis provided in ESRD (2010) indicates that these compounds are present and there appears to be a correlation between the grab sample and the emission source profiles associated with the heavy oil extraction operations.

- It is surprising that ambient concentrations were not greater than the odour thresholds more frequently or for more compounds since the grab sample collection was biased to occur when odour complaints occurred. Minimum detection limit, sample and analytical limitations, exposure to multiple odourants, and individual sensitivity considerations could account for this apparent contradiction.

- The findings associated with the Integrated Samples are similar to those associated with the Grab Samples.

- The Campaign Samples were collected at random, and generally were associated with lower concentrations than those associated with the Grab Samples or the Integrated Samples.

- The Triggered Sample collection was the most comprehensive in terms of number of samples, and the length of record. Similar to the Grab sample collection, it would be biased to high concentration events. The Triggered Sample collection indicted 21 compounds within a factor of three of the odour threshold, 16 compounds that were greater than short-term benchmarks and 26 compounds that were greater than long-term benchmarks.

- For all sample collection types, there were compounds that showed up frequently, while for other compounds, they only showed up a few times (e.g., methanol, vinyl acetate, and acetone). High concentrations associated with an infrequently occurring compound may provide a “signature” indicator that could help identify the emission source.

The canister analysis can be further examined to examine time series for selected compounds and to more formally relate the maximum concentrations of all samples to wind directions to determine upwind source directions. As with the odour complaint assessment and the high continuous measurements, back trajectory analysis can also be used to help identify upwind source directions associated with the canisters.

8.7 GAPS AND RECOMMENDATIONS

Based on the examination of the data, the following gaps and recommendations have been identified:

Gap/Recommendation V1: A key component with any field sample collection program is the establishing and maintaining a robust chain of custody system. The chain of custody system unambiguously defines the time and location associated with each measured value from the sample collection to the reporting of the measurement in the final report. The samples that were collected and analyzed did not appear to have followed a chain of custody approach. Examples include:

- Sample locations were missing in some cases.
- Locations were sometimes provided in the DLS Section, Range, Township system. In some cases, the range and township values were interchanged, in some cases the samples were stated as being collected west of the 6th meridian, which puts the sample collection location in B.C.
- Sample collection times were not always indicated.
- No information was provided with the grab samples to document how and where they were collected and what the associated odour conditions were.

Attempts were made to resolve the ambiguity, but some samples were not included in this review, and some of the samples may have been miss-categorized. A review of this assessment by field staff is required to confirm that the samples are appropriately included and categorized (i.e., can the chain of custody be re-created?).

Gap/Recommendation V2: As indicated in Section 3.0, the provided minimum detection limits were greater than the odour threshold for several compounds; mostly for the aldehydes, the phenols, and the reduced sulphur compounds. Alternate analytical methods need to be examined to reduce the detection limits. This should be discussed with AITF, the laboratory contractor.

Gap/Recommendation V3: The AIFT provided minimum detection limits (MDLs) of 50 ppb for the C1C4 scan, 1 ppb for the RSC scan, 0.5 ppb for the PAMS scan, and 0.5 ppb for most compounds associated with the VOC-PT scan. It was not stated if these MDLs are associated with analytical limitations or with the whole sampling approach. The analysis of several duplicate and blank samples would provide an indicator of the uncertainty that could be associated with each measurement, and the analysis of several field blanks would help confirm the MDLs.

Gap/Recommendation V4: Coupled with the meteorology Gap/Recommendation M3 to install another wind instrument in the emission source area, and with the continuous monitoring Gap/Recommendation C3 to locate another monitoring station in the emission source area, the

collection of triggered samples in the source region would help define potential emission sources.

Gap/Recommendation V5: Different NMHC trigger levels were adopted for the Triggered Sample collection. In many cases the sum of hydrocarbon and reduced sulphur compounds were much less than the trigger threshold. Therefore it is difficult to recommend a specific threshold level. The three most frequently occurring odour complaint sites identified an average of 54 events per year for each site. The numbers of triggered samples collected were 33 in 2011 and 52 in 2012. To determine trends and relationships associated with high concentration events, at least 50 to 60 samples per year are desirable.

Gap/Recommendation V6: T There is a considerable amount of information associated with the analysis of the canisters. This report and the associated ESRD reports do not make full use of this data. Further analysis of the data is recommended in the future after additional quality control and recommendations outlined herein have been undertaken.

9.0 ESRD Reports and PAH Sampling

The ESRD obtained measurements in the Three Creeks region with their Mobile Air Monitoring Laboratory (MAML). In addition, other ambient air quality samples were collected and analyzed. The ambient air quality data collected by ESRD are summarized in two ESRD reports:

- Three Creeks Odour Issue: A report on Air Quality Monitoring Conducted between February and May 2010 (ESRD 2010)

- *A Report on Air Quality Monitoring conducted in the Three Creeks Area (Phase II)* (ESRD 2011). The second report examines data collected between April and December 2010.

Section 9.1 provides a summary of the key findings associated with the 2010 report, and Section 9.2 provides a summary of key findings associated with the 2011 report. The reanalysis of the canister samples coordinated by ESRD were presented in Section 8 of this report. Additional PAH sample measurements that are not included in the two referenced ESRD reports are discussed in Section 9.3.

9.1 ESRD (2010) REPORT SUMMARY

9.1.1 Monitoring Activities

The monitoring for the February to May 2010 period focuses on two categories of monitoring: community and industrial source. Community monitoring involved ambient measurements at resident and other locations. The community sampling involved:

- The deployment of canisters to collect grab and integrated average samples. These are described in Section 8.

- The collection of continuous air quality measurements using a monitoring station identified as Site I in the ESRD report. This is the same as the Highway 986a monitoring station identified in Section 7.

- The deployment of canisters triggered by the THC analyzer at the Highway 986a location. These are referred to as the Triggered samples discussed in Section 8.3.

Industrial monitoring involved the collection of 10-min samples from potential emission source locations, and it involved 8 Shell site samples, 6 Baytex site samples, 6 Husky site samples, 4 Penn West site samples and 2 CCS Midstream Services Engineering site samples. As these are source related samples, the review of these data are not in scope with the ambient air quality monitoring review. Therefore only the ambient community sampling discussed in the ESRD (2010) report are discussed.

9.1.2 ESRD (2010) Report Findings

Based on the examination of the ambient air quality monitoring data, the ESRD report identified the following conclusions (with our comments):

- Higher ambient concentrations tend to occur at locations experiencing an odour complaint than at background locations where no odours are perceived. One-hour average VOC concentration during odour complaints ranged from 41 to 521 ppb. At background locations, the corresponding range is from 2 to 13 ppb.

- The odour thresholds were exceeded for hexanal (hexylaldehyde)(2 times) and nonal (nonylaldehyde)(1 time). Odours occurred during times when threshold values were not exceeded. ESRD speculated that this could be attributed to odour thresholds associated with a mixture of compounds being less than the odour thresholds associated with individual compounds.

  – While this may be true, Stantec notes that the minimum detection level for the RSC are 1 ppb and the minimum detection level for the VOC are 0.5 ppb (See section 8-1). Out of the 23 RSC identified in Table 3-5, the odour thresholds are less than 1 ppb for 17 RSC. There also several hydrocarbon compounds associated with odour thresholds less than 0.5 ppm (e.g., some aldehydes, phenols, organic acids, nitriles, aromatics, butyrates, valerates and acryrates (see Table 3-5).

- ESRD compared simultaneous grab and 1-h average samples collected at Site C (see Table 7 in ESRD 2010). The grab sample was collected at the beginning of the 1-h sample period when an odour was most noticeable. Due to dispersion processes in the atmosphere, higher peak concentrations would be associated with the shorter period grab sample. ESRD found that the grab sample concentrations were a factor of two or more greater than the 1-h values.

  – A more rigorous analysis of the ESRD Table 7 values is provided by Stantec in Table 9-1 and shows the average and median ratios of the Grab Sample to 1-h average samples to be 2.9 and 3.0 respectively. This supports the use of a peak to mean ratio of three as indicated in Section 3.2.

- Comparison of ambient concentration measurements to the source concentration measurements indicated different chemical compound profiles. The source profiles were characterized by light chemical compounds. The community sites included oxygenated VOCs that were not found in the source profiles. ESRD speculates that chemical transformation processes in the atmosphere could limit the use of chemical fingerprinting.

  – Stantec notes that the comparison of the community and source profiles can be confounded by the minimum detection level of 50 ppb for the lighter C1 to C4 analyses and the minimum detection level of 0.5 ppb for the heaver C4+ compounds. This

detection limitation may influence the measurement of the lighter compounds in the community.

- Where applicable, the ESRD compared the measured concentrations to the AAAQO. In all cases, the measured values were less than the respective AAAQO. This comment refers to the continuous measurements at the Highway 986a station and the canister samples.
  - Stantec notes that given the limited number of compounds associated with an AAAQO, meeting the AAAQO does not necessarily infer there are no potential adverse effects.

9.2 ESRD (2011) REPORT SUMMARY

9.2.1 Monitoring Activities

The monitoring for the April to December 2010 period focuses on the following activities:

- The installation of an ambient air quality monitoring station that is referred to as Site I in the ESRD report. This is the Highway 986a site that was examined in Section 7.0 of this report (i.e., the Three Creeks Industry Air Quality Working Group (TCIAQWG) report).

- The deployment of the MAML at six sites over the period of four evenings in October 2010. The data collected by the MAML were supplemented by the deployment of canister air samples which are identified in this report (i.e., the TCIAQWG report) as Campaign Samples (Section 8.2).

- Air samples were collected over a three week period and analysed for PAHs. These results are re-examined in Section 9.3.

9.2.2 Ambient Air Quality Station (Highway 986a)

The ESRD examination of the air quality measurements associated with this station for the period April to December 2010 indicates:

- Ambient THC concentrations were found to occur in two “clusters”. A peak in the 1.9 to 2.0 ppm, and peaks in the 2.1 to 2.3 ppm range. Although not identified, the first peak would be associated with global background methane concentrations.

- Most of the high THC concentrations were associated with wind speeds less than 6 km/h. The wind direction data inferred upwind source region to the east of the monitoring site.

- Most of the high THC concentration events occurred during the night.

9.2.3 MAML Survey

Over the period October 24 to October 28 2010 (4 days), six 1-hour measurements per day were taken at each of six sites. These sites (A, B, H, J, K and L) are identified as the Campaign Sample in Table 8-13, and the maximum and median CO, NO_X, SO_2 and THC concentrations are presented in Figure 9-1. Higher CO and NO_X concentration were measured near Sites A and B, and these higher values were attributed nearby roadway combustion sources. The maximum 1-h CO, NO_X and SO_2 concentrations are all much less than the associated 1-h AAAQO (13 ppm for CO, 0.212 ppm for NO_2, and 0.172 ppm for SO_2).

9.2.4 Canister Sampling

The ESRD report identifies three types of sampling that correspond to three types identified in Section 8.0 of this report: Grab samples, Campaign Samples and Triggered Samples.

9.2.4.1 Grab Samples

Twenty-two grab samples were collected at sites M, N, O, P and Q by residents during odour complaints. These sites and associated samples are identified in Table 8-5. The ESRD report indicates for following for the targeted compounds:

- Of the 65 target compounds identified, the most abundant were methane, carbonyl sulphide, carbon disulphide, acetone, benzene, trimethylbenzenes, toluene, and a large abundance of pentanes, butanes and hexanes.

- Pentanes, butanes, and hexanes detected in these grab samples were far more abundant than the Highway 986a and MAML samples.

- For most of the detected compounds the maximum concentrations were observed in the sample collected on October 9th (12:04 AM) at the Site M. The compounds in greatest abundance were aromatic and non-aromatic hydrocarbons, which is similar to the samples collected at the Highway 986a site.

For the non-targeted compounds:

- One hundred and thirteen non-target compounds were detected: Most of the detected compounds have mid to heavy molecular weights; the heavy compounds were mostly hydrocarbons, alkanes in the form of cyclohexanes, heptanes, hexanes, pentanes, octanes and propanes.

- Most non-target compounds were detected less than 4 times. Cyclohexanes and cyclopentanes were consistently detected at different sites during the period of August 16th to August 31st.

The total VOC, excluding methane, concentrations from grab samples collected at local residences ranged from 3 to 453 ppb, which is similar to samples collected at the Highway 986a site.

9.2.4.2 Campaign Samples

Twenty four 1-h air samples were collected at the Campaign Sample sites (sites A, B, H, J, K and L). These sites and associated samples are identified in Table 8-13. One sample from each day for each site was collected. The ESRD report indicates for following for the targeted compounds:

- Fifty-two target compounds were detected with the most abundant being: methane, carbonyl sulphide, carbon disulphide, acetone, pentanes, benzene, alkanes, cyclohexanes, hexanes, and toluene.

- The highest total concentration was measured on October 26, 2010 at Site H (reference site). At this time the wind speed was 8.5 km/h and the prevailing wind direction was from the east.

For the non-targeted compounds:

- There were thirty-eight non-target compounds that were detected. Most of the detected compounds have mid to heavy molecular weights; the heavy compounds were mostly alcohols and alkenes.

The 1-h average total VOC concentrations ranged from 2 to 84 ppb. The median THC concentrations at the various MAML sites were comparable to concentrations measured at background sites (~2 ppm). The MAML survey was designed to provide a “snap shot” of VOC concentrations during the sample time and place.

9.2.4.3 Triggered Samples (Highway 986a)

At the highway 986a site (identified as Site I by ESRD) 10-min air samples were collected when the continuous hydrocarbon analyzer detected a preset concentration. The set trigger level was exceeded 11 times in 2010. The ESRD report indicates the following for the targeted compounds:

- A total of sixty target compounds were detected. The most abundant were methane, carbonyl sulphide, carbon disulphide, acetone, pentanes, benzenes, cyclohexanes, hexanes, toluenes, and xylenes.

- There was one air sample that contained 333 ppb of Acetone. This concentration is an order of magnitude higher than other samples with detectable acetone concentrations.

The 10-min average total VOC concentrations for samples analyzed ranged from 5 to 413 ppb. For the non-targeted compounds:

- A total of 102 non-targeted compounds were detected. There was a great deal of variability in the type of non-target VOCs detected between samples. The detected non-target compounds included alcohols, ketones, alkanes, alkenes, and cycloalkanes.

- Three compounds were detected more than 3 times: 2-methyl- 2-propanol, 1-methylethenyl-benzene, and 2,2,4,6,6-pentamethyl-3-heptene.

- Contribution of non-target compounds to total detected sample varied, composing 8 to 82% of the total analyzed VOC mass.

The Highway 986a samples detected significantly more aromatic hydrocarbons such as xylenes and trimethylbenzenes than the MAML Campaign Samples. As the Highway 986a samples during elevated hydrocarbon events and the MAML samples were taken at random, it is possible that aromatic hydrocarbons were more prevalent during periods of high hydrocarbons.

Table 9-1 Comparison of simultaneous 1-h and grab sample concentrations at Site C (based on Table 7, ESRD 2010)

	Name	Formula	MW	1-h	Grab	Grab/1-h
1	Methane	CH4	16	14200	19600	1.4
2	Ethane	C2H6	30	bdl	bdl	-
3	1-Butene	C4H8	56	bdl	1.2	-
4	cis-2-Butene	C4H8	56	bdl	bdl	
5	Butane	C4H10	58	8.23	18.6	2.3
6	Isobutane	C4H10	58	5.15	15.9	3.1
7	2-Methyl-2-butene	C5H10	70	bdl	bdl	-
8	3-Methyl-1-butene	C5H10	70	11	bdl	-
9	cis-2-Pentene	C5H10	70	bdl	bdl	-
10	Cyclopentane	C5H10	70	0.75	3.1	4.1
11	trans-2-Pentene	C5H10	70	bdl	bdl	-
12	Isopentane	C5H12	72	11.2	30.9	2.8
13	Pentane	C5H12	72	3.69	6.83	1.9
14	Benzene	C6H6	78	0.45	0.51	1.1
15	2-Methyl-1-pentene	C6H12	84	3.46	10.4	3.0
16	cis-2-Hexene	C6H12	84	bdl	bdl	-
17	Cyclohexane	C6H12	84	7.9	22.6	2.9
18	Methylcyclopentane	C6H12	84	2.82	8.14	2.9
19	2,2-Dimethylbutane	C6H14	86	0.75	2.72	3.6
20	2,3-Dimethylbutane	C6H14	86	2.76	9.48	3.4
21	2-Methylpentane	C6H14	86	2.63	8.15	3.1

Table 9-1 Comparison of simultaneous 1-h and grab sample concentrations at Site C (based on Table 7, ESRD 2010)

	Name	Formula	MW	1-h	Grab	Grab/1-h
22	3-Methylpentane	C6H14	86	3.44	10.5	3.1
23	Hexane	C6H14	86	0.65	1.92	3.0
24	Toluene	C7H8	92	0.19	0.21	1.1
25	Methylcyclohexane	C7H14	98	8.25	24.5	3.0
26	2,3-Dimethylpentane	C7H16	100	2.46	8.37	3.4
27	2-Methylhexane	C7H16	100	0.38	1.33	3.5
28	3-Methylhexane	C7H16	100	1.7	6.02	3.5
29	Heptane	C7H16	100	0.14	0.43	3.1
30	Styrene	C8H8	104	bdl	bdl	-
31	Ethylbenzene	C8H10	106	0.07	0.13	1.9
32	m,p-Xylene	C8H10	106	0.19	0.52	2.7
33	o-Xylene	C8H10	106	0.07	0.18	2.6
34	3-Methylheptane	C8H18	114	bdl	bdl	-
35	1,2,4-Trimethylbenzene	C9H12	120	0.25	0.87	3.5
36	1,3,5-Trimethylbenzene	C9H12	120	0.13	0.46	3.5
37	Isopropylbenzene	C9H12	120	bdl	bdl	-
38	n-Propylbenzene	C9H12	120	bdl	bdl	-
39	Nonane	C9H20	128	bdl	bdl	-
40	alpha pinene	C10H16	136	bdl	bdl	-
41	beta pinene	C10H16	136	bdl	bdl	-
46	Carbonyl sulphide	COS	60	0.87	bdl	-
All (w/o methane)		**Sum**		**79.6**	**194.0**	
All (w/o methane)		**Average**				**2.9**
All (w/o methane)		**median**				**3.0**

NOTES:
bdl = below detection limit
The 1-hour values are assumed to be based on Sample ID T10-0400.
The grab sample values are assumed to be based on Sample ID T10-0401.

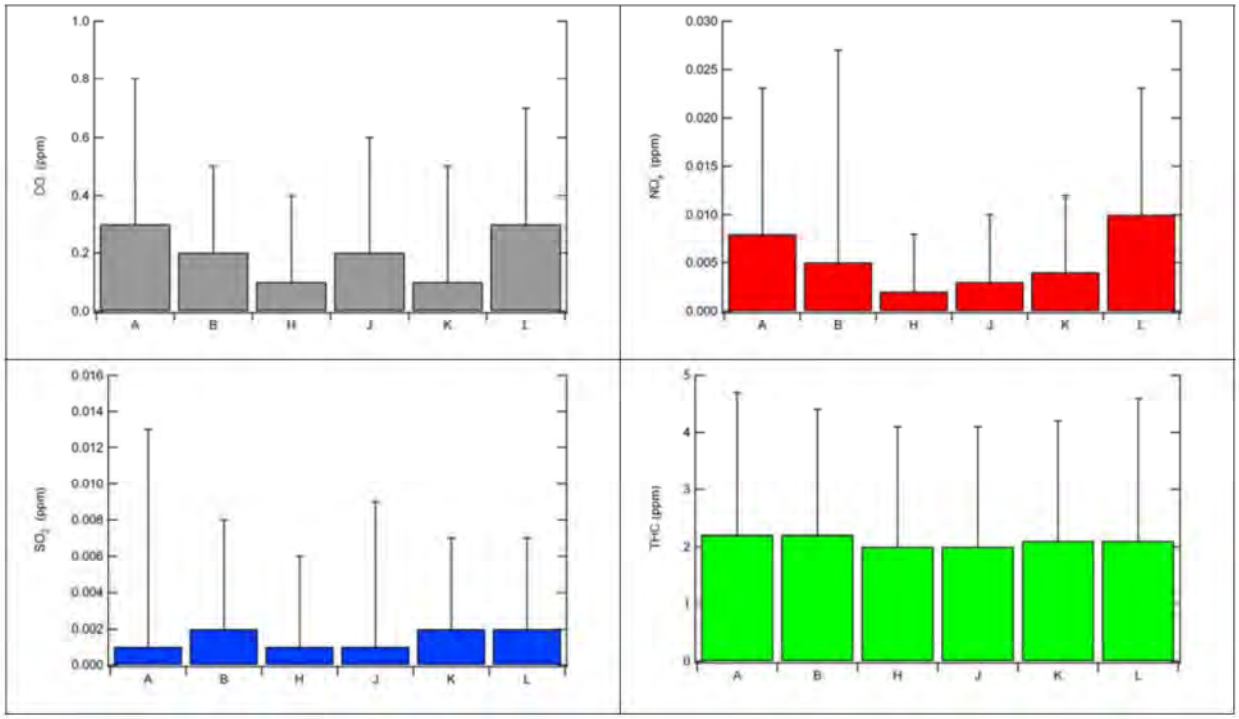


Figure 9-1 Box plots of CO, NO_X, SO_2 and THC from the MAML survey. The bars show the 1-h median concentrations and the whisker shows the maximum 1-h concentration (from Figure 6, ESRD 2011).

9.3 PAH MEASUREMNTS

9.3.1 Approach

PAH samples were taken at the six sites indicated in Table 9-2 and Figure 9-2. One of these sites (H) is the same reference site identified as part of the Campaign Sample collection and the MAML continuous measurements. PAH samples were collected over a period of 24 hours (midnight to midnight) on a six-day cycle for three cycles. The sampling schedule is in accordance with the National Air Pollution Surveillance (NAPS) calendar. Specifically, the samples were collected on November 10, November 16, and November 22, 2010.

For all three days of sampling, average wind speeds were at or less than 4 km/h, indicating near stagnant conditions. The collection and analysis was also undertaken in accordance with the NAPS methodology. Hi-Volume filter-PUF sampling units were used to collect PAHs and the samples were sent to the Environment Canada Air Quality Laboratory in Ottawa for analysis.

9.3.2 ESRD Analysis

The ESRD analysis indicates that maximum concentrations (for many PAH compounds) at the reference site were equal to or greater than the PAH concentrations measured at the other sample sites. The lowest total PAH concentration was 3.5 ng/m^3 at the Site VI on November 10 and the highest total PAH concentration was 41.6 ng/m^3 at the Site II site on November 22.

9.3.3 Additional Analysis

Table 9-3 presents the maximum PAH concentration measurements at each monitoring site. Each value is therefore the maximum of three samples at each site. The highest maximum PAH concentrations were measured at Site II (41.6 ng/m^3) and at Site IV (40.0 ng/m^3). The lowest maximum PAH concentrations were at Site H (29 ng/m^3), Site III (28.8 ng/m^3) and Site V (26.8 ng/m^3).

Table 9-4 presents the maximum PAH concentrations associated with each day. The maximum PAH concentration of 41.6 ng/m^3 on November 22 is substantively greater than the corresponding values for the other days (8.6 ng/m^3 for November 10 and 87.7 ng/m^3 for November 16. The day-to-day variation is much greater than the site-to-site variation. This suggests these PAH concentrations were not strongly influenced by local sources, and are influenced by more distant sources.

On November 10, the average winds from 0000 to 0900 were 2.8 km/h and 80° (from the E). From 1000 to 2300, they were 3.0 km/h and 214° (from the SW). On November 16, the average winds were 3.5 km/h and 361° (from the N). On November 22, the average winds from 000 to 0600 were 4.5 km/h and 11° (from the N). From 1000 to 2300, the winds were 4.7 km/h and 212° (from the SW). Based on wind direction, there is no reason for the November 22 values to be greater than those for the other two days.

Table 9-5 presents the overall mean and the overall maximum PAH concentrations and compares them to the short-term and long-term ambient air quality benchmarks. For all PAH compounds, the measured values are much less than the respective benchmarks.

9.4 FINDINGS

The ESRD findings are based on a subset of the data analyzed in this report. Both the ESRD reports and this report flagged the maximum hexanal and nonanal concentrations as being greater than the Nagata odour thresholds. This report found other compounds that were greater than the respective odour thresholds as it included a larger database than the ESRD reports.

The examination of the PAH concentration measurements for three days indicated very low values relative to the associated ambient benchmarks.

9.5 GAPS AND RECOMMENDATIONS

The gaps and recommendations are divided into two sets: one related to the ESRD reports, and the other related to the PAH measurements. The following identifies gaps and recommendations associated with the ESRD reports:

- **Gap/Recommendation E1:** The canister Gap/Recommendation V1 identified a chain of custody challenge. This challenge extends to the reports. We view it as desirable for the report analysis to have the link back to the Sample ID. This will allow reviewers to confirm the findings. In addition, all sampling locations should be geo-referenced to UTM coordinates or to latitude/longitude coordinates and not be shown as a "dot on a map".

- **Gap/Recommendation E2:** We recognize that comparing ambient concentrations to odour thresholds helps place the ambient air quality measurements in perspective. Industry, regulator, and community stakeholders, however, need to be aware that there are uncertainties with respect to correlating measurements to odours..

The following identifies gaps and recommendations associated with the PAH monitoring:

- **Gap/Recommendation H1:** The ESRD PAH monitoring only focused on three days. While the values are low relative to the ambient air quality benchmarks, they may not necessarily be representative of the highest values that could occur in the area. The NAPS schedule of sampling every sixth day produces about 60 to 61 samples per year. Having 60 samples per year provides a better indicator of conditions than three samples. Like the campaign sampling, the air quality that is measured is random and the limited samples collected are unlikely to have occurred on days characterized by poor air quality.

- **Gap/Recommendation H2:** Information about the PAH data in terms of minimum detection levels or uncertainty were not provided by ESRD. Field blanks and duplicate data samples in future studies by ESRD would provide an indicator of measurement quality.

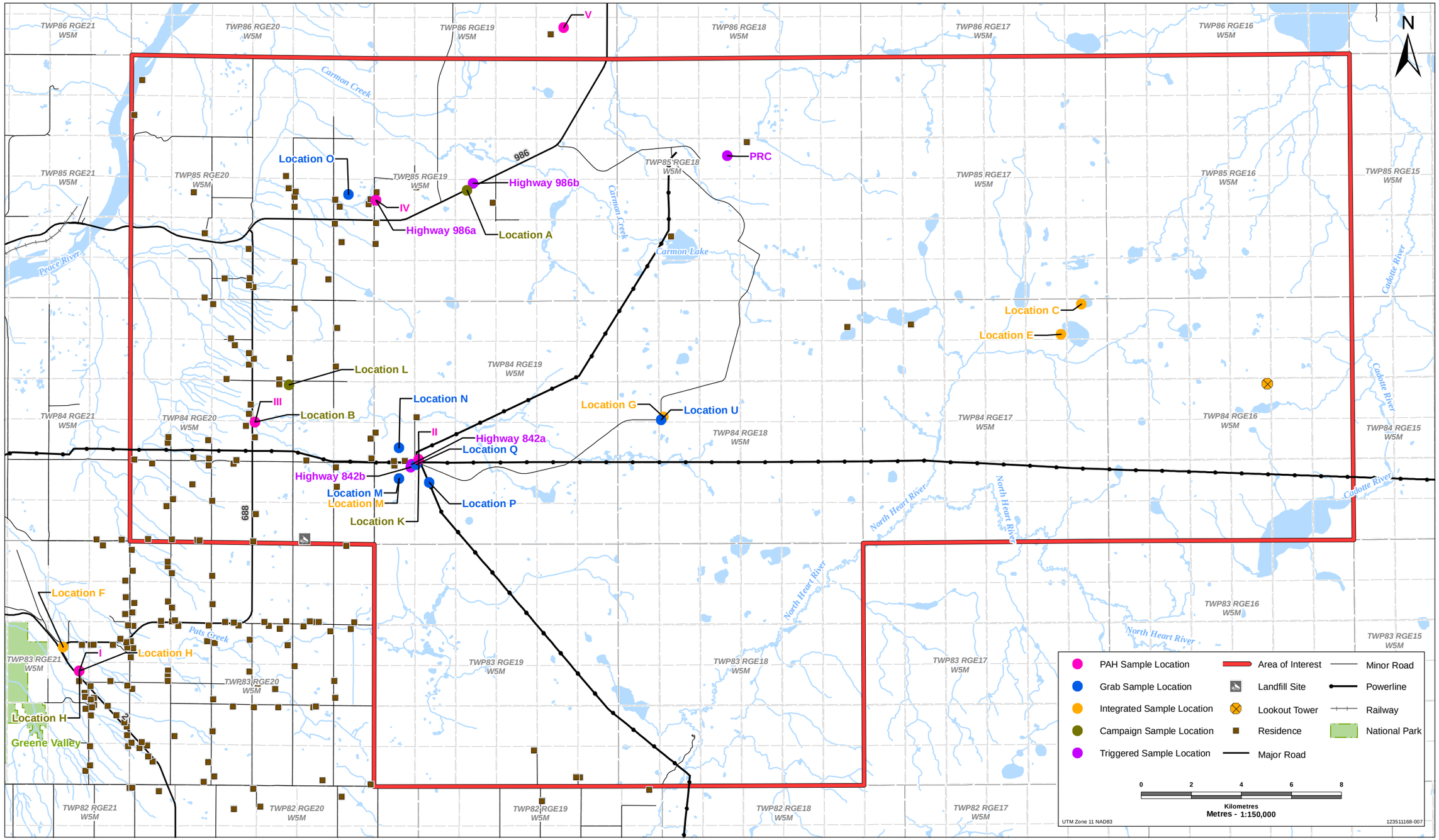
Table 9-2 Location of the PAH sample collection sites

Site ID	ESRD Site ID	ESRD Description	UTM E	UTM N
H	H	Reference	6228436	487901
II	II	Donna	6236888	501475
III	III	McKinnley	6238386	494926
IV	IV	Dzien	6247262	499764
V	V	Three Creeks	6254158	507263
J	VI	J	6259865	518551

NOTE:
UTM location coordinates are referenced to Zone 11 and NAD 83 datum.

Table 9-3 Maximum PAH concentrations (ng/m³) at each site

	H (Reference)	II (Donna)	III (McKinnley)	IV (Dzien)	V (Three Creeks)	VI (J)
Napthalene	11.35	13.31	9.76	13.14	13.66	10.95
Acenaphthylene	0.38	0.22	0.24	0.36	0.20	0.14
Acenaphthene	0.78	0.77	0.57	0.75	0.45	0.48
Fluorene	3.10	1.25	1.07	1.18	1.02	0.81
2-me-fluorene	1.24	0.41	0.34	0.41	0.31	0.29
Phehanthrene	4.51	4.38	3.35	4.33	2.66	3.45
Anthracene	0.79	0.18	0.11	0.18	0.10	0.14
Fluoranthene	0.87	1.69	0.93	1.57	0.75	1.29
Pyrene	0.80	1.32	0.73	1.29	0.62	1.06
Retene	7.76	13.76	9.51	12.99	5.13	13.14
Benzo[a]fluorene	0.24	0.30	0.15	0.29	0.13	0.23
Benzo[b]fluorene	0.11	0.16	0.08	0.15	0.07	0.12
1-me-pyrene	0.20	0.24	0.11	0.23	0.11	0.18
Benzo[g,h,i]fluoranthene	0.14	0.25	0.15	0.24	0.12	0.21
Benz[a]anthracene	0.21	0.45	0.24	0.42	0.20	0.35
Triphenylene	0.15	0.21	0.11	0.17	0.09	0.15
Chrysene	0.49	1.05	0.51	0.97	0.39	0.76
7-me-benz[a]anthracene	0.01	0.02	0.01	-	-	-
Benzo[b]fluoranthene	0.26	0.47	0.27	0.45	0.23	0.38
Benzo[k]fluoranthene	0.06	0.12	0.07	0.10	0.05	0.09
Benzo[e]pyrene	0.17	0.27	0.15	0.26	0.13	0.21
Benzo[a]pyrene	0.11	0.25	0.13	0.24	0.12	0.19
Perylene	0.01	0.02	0.02	0.03	0.02	0.03
Indeno[1,2,3-cd]fluoranthene	0.02	0.04	0.02	0.04	0.00	0.03
Indeno[1,2,3-cd]pyrene	0.09	0.16	0.10	0.15	0.08	0.13
Dibenz[a,h]anthracene	0.02	0.03	0.02	0.03	0.01	0.02
Benzo[b]chrysene	0.01	0.03	0.01	0.02	0.01	0.02
Benzo[g,h,i]perylene	0.09	0.15	0.09	0.14	0.08	0.12
Anthanthrene	-	-	0.02	0.03	0.02	0.02
Total PAH	**29.0**	**41. 6**	**28.8**	**40.0**	**26.8**	35.0



THREE CREEKS MONITORING

Location of PAH Sampling Sites

Acknowledgements: Original Drawing By Stantec, Basedata: Altalis, Canvec, National Road Network

PREPARED BY

Stantec

FIGURE NO.

9-2

Last Modified: 4/2/2014 By: cstelner

Table 9-4 Maximum PAH concentrations (ng/m³) for each day

Sampling Date	10-Nov-2010	16-Nov-2010	22-Nov-2010
Napthalene	3.59	1.88	13.66
Acenaphthylene	0.36	0.14	0.24
Acenaphthene	0.33	0.36	0.77
Fluorene	0.92	0.73	1.25
2-me-fluorene	0.30	0.24	0.41
Phehanthrene	1.23	2.21	4.38
Anthracene	0.09	0.06	0.18
Fluoranthene	0.22	0.34	1.69
Pyrene	0.19	0.25	1.32
Retene	0.91	2.41	13.76
Benzo[a]fluorene	0.04	0.04	0.30
Benzo[b]fluorene	0.02	0.02	0.16
1-me-pyrene	0.04	0.04	0.24
Benzo[g,h,i]fluoranthene	0.04	0.05	0.25
Benz[a]anthracene	0.04	0.06	0.45
Triphenylene	0.07	0.05	0.21
Chrysene	0.12	0.19	1.05
7-me-benz[a]anthracene	-	0.00	0.02
Benzo[b]fluoranthene	0.12	0.12	0.47
Benzo[k]fluoranthene	0.03	0.03	0.12
Benzo[e]pyrene	0.06	0.06	0.27
Benzo[a]pyrene	0.03	0.03	0.25
Perylene	-	0.00	0.03
Indeno[1,2,3-cd]fluoranthene	0.01	0.00	0.04
Indeno[1,2,3-cd]pyrene	0.04	0.04	0.16
Dibenz[a,h]anthracene	0.01	0.01	0.03
Benzo[b]chrysene	-	0.00	0.03
Benzo[g,h,i]perylene	0.04	0.04	0.15
Anthanthrene	-	-	0.03
Total PAH	**8.6**	**8.7**	**41.6**

Table 9-5 Comparison of mean and maximum PAH concentrations (ng/m³) to ambient air quality benchmarks

	Mean	Max	Short-term benchmark	Long-term benchmark
Napthalene	5.33	13.66	**200000**	**50000**
Acenaphthylene	0.15	0.36	**1000**	**100**
Acenaphthene	0.37	0.77	**1000**	**100**
Fluorene	0.74	1.25	**10000**	**1000**
2-me-fluorene	0.25	0.41	**-**	**-**
Phehanthrene	1.99	4.38	**500**	**50**
Anthracene	0.08	0.18	**500**	**50**
Fluoranthene	0.54	1.69	**500**	**50**
Pyrene	0.43	1.32	**500**	**50**
Retene	4.42	13.76	**-**	**-**
Benzo[a]fluorene	0.09	0.30	**-**	**-**
Benzo[b]fluorene	0.05	0.16	**500**	**50**
1-me-pyrene	0.07	0.24	**-**	**-**
Benzo[g,h,i]fluoranthene	0.09	0.25	**-**	**-**
Benz[a]anthracene	0.13	0.45	**500**	**50**
Triphenylene	0.07	0.21	**-**	**-**
Chrysene	0.32	1.05	**500**	**50**
7-me-benz[a]anthracene	0.02	0.02	**-**	**-**
Benzo[b]fluoranthene	0.18	0.47	**500**	**50**
Benzo[k]fluoranthene	0.04	0.12	**500**	**50**
Benzo[e]pyrene	0.10	0.27	**500**	**50**
Benzo[a]pyrene	0.08	0.25	**30**	
Perylene	0.02	0.03	**500**	**50**
3-me-cholanthrene	-	-	**20**	**2**
Indeno[1,2,3-cd]fluoranthene	0.03	0.04	**-**	**-**
Indeno[1,2,3-cd]pyrene	0.06	0.16	**500**	**50**
Dibenz[a,h]anthracene	0.02	0.03	**500**	**50**
Benzo[b]chrysene	0.02	0.03	**-**	**-**
Benzo[g,h,i]perylene	0.06	0.15	**500**	**50**
Anthanthrene	0.02	0.03	**-**	**-**
Total PAH	**15.66**	**41.56**		

10.0 Bibliography

AAAQO. (2013). *Alberta Ambient Air Quality Objectives and Guidelines Summary*. Government of Alberta.

AIHA. (1989). *Odor thresholds for chemicals with established occupational health standards*. Fairfax, VA: American Industrial Hygiene Association.

Amoore, J. E. (1985). *The perception of hydrogen sulfide odor in relation to setting an ambient standard*. Berkeley, CA: Olfacto-Labs: Prepared for the California Air Resources Board.

Clearstone. (2013). *Title to be to added*.

Cometto-Muñiz, J. Enrique, and Michael H. Abraham. (2010). Odor Detection by Humans of Lineal Aliphatic Aldehydes and Helional as Gauged by Dose–Response Functions. *Chemical senses 35.4*, 289-299.

Davies, M., Prasad, S., Geini, W., Vandeheyan, M., Vatcher, C., Whiteley, S., Bhardwaj, S. (2006). Ai-Concentration Monitoring Technology, Methods and Overview. *Western Interprovincial Scientific Studies Association (WISSA)*, 3.1-3.61.

ESRD. (2010). *THREE CREEKS ODOUR ISSUE:A REPORT ON AIR QUALITY MONITORING CONDUCTED BETWEEN FEBRUARY AND MAY 2010*. Government of Alberta.

ESRD. (2011). *A REPORT ON AIR QUALITY MONITORING CONDUCTED IN THE THREE CREEKS AREA (PHASE II)*. Government of Alberta.

Nagata, Y. (2003). Measurement of Odor Threshold by Triangle Odor Bag Method . *Odor measurement review*, 118-127.

NPRI. (2013, 08 05). *Environment Canada*. Retrieved 12 1, 2013, from National Pollutant Realease Inventory: http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=4A577BB9-1

OME. (2012). *ONTARIO'S AMBIENT AIR QUALITY CRITERIA*. STANDARDS DEVELOPMENT BRANCH ONTARIO MINISTRY of the ENVIRONMENT.

Ruijten, M. W. M. M., R. van Doorn, and AP van Harreveld. (2009). *Assessment of odour annoyance in chemical emergency management*. RIVM rapport 609200001.

Schiffman, Susan S., Jeanette L. Bennett, and James H. Raymer. (2001). Quantification of odors and odorants from swine operations in North Carolina. *Agricultural and Forest Meteorology 108.3*, 213-240.

TCEQ. (2013, 2 1). *The Texas Commission on Environmental Quality*. Retrieved 12 2, 2013, from http://www.tceq.texas.gov/toxicology/esl/list_main.html/#esl_1

WHO. (2000). *Air Quality Guidlines for Europe*. Copenhagen: World Health Organization Regional Office for Europe.

Wilby, F. V. (1969). Variation in recognition odor threshold of a panel. *Journal of the Air Pollution Control Association 19.2*, 96-100.

10.1 PERSONAL COMMUNICATION

Candace MacDonald, Grande Prairie Team Leader, Field and Operations Branch, Alberta Energy Regulator, to Mervyn Davies, Stantec Consulting Inc. Nov/13/2013.

Bibliography
May 2014