

Community Assessment Project Final Report

Evaluation of the Impact of Airport Emissions on Ambient Levels of Air Toxics, Particularly Toxic Particulate Matter, in Neighborhoods Abutting TF Green Airport

October 2012

Introduction

In 2004, the Rhode Island Department of Environmental Management (RI DEM), Office of Air Resources, received a Community Assessments grant from EPA's National Air Toxics Monitoring Program to study air quality in neighborhoods abutting TF Green Airport, a medium hub airport located in Warwick, Rhode Island. In that study, RI DEM, working with the Rhode Island Department of Health (RIDOH) Air Pollution Laboratory, monitored volatile organic compounds (VOCs), carbonyls, fine particulate matter (PM_{2.5}) and black carbon (BC) from April 2005 to September 2006 at five Warwick sites. The site locations for the 2004 study are shown in Figure 1. Pollutant levels measured were compared to health benchmarks and to concurrent measurements at urban, suburban and rural comparison sites in Rhode Island. RI DEM also conducted an extensive analysis of the monitoring data, along with meteorological, emissions inventory and airport operations data to investigate the impact of airport emissions on neighborhood pollutant levels. A final report on the project was submitted to the EPA in April 2008.

The main conclusions of that study were as follows:

- Average concentrations of five VOCs and two carbonyls were above health benchmarks corresponding to a one in one million cancer risk at one or more of the sites. Those pollutants are:
 - Formaldehyde
 - Carbon tetrachloride
 - Benzene
 - Chloroform
 - Acetaldehyde
 - 1,3-butadiene
 - Tetrachloroethylene
- Concentrations of tetrachloroethylene were higher at the Lydick site, northeast of the Airport, than at the other Warwick and the comparison sites. Concentrations of trichloroethylene and dichloromethane were elevated at the Fire Station site, northwest of the Airport. The elevated concentrations of these industrial/commercial chlorinated solvents were not linked to Airport operations.
- Concentrations of gasoline constituents, including the BTEX compounds, tended to be higher at the Field View site, the site closest to the Airport, than at the other Warwick sites but were lower at all Warwick sites than at the urban comparison sites. It was not possible to definitively link the higher gasoline constituent levels at Field View with Airport operations.

- Concentrations of formaldehyde at Field View were substantially (approximately 1 ppb) higher than at the other Warwick sites and the comparison sites on almost every day with a maximum ambient temperature of 60°F or higher. Sampler bias was ruled out as the cause of this elevation, but it was not possible to determine whether the elevated levels were due to an on-site source or to an offsite source, such as the Airport.
- Black carbon (BC) levels, measured with Aethalometers, at the four sites closest to the Airport were significantly impacted by Airport operations. BC concentrations were also influenced by wind speed and by other sources, such as vehicle traffic. Since BC is an indicator of toxic particulate matter species but does not itself have a health benchmark, it was not possible to quantify the health significance of the Airport impacts of this pollutant.
- Concentrations of fine particulate matter (PM_{2.5}) at the Warwick sites were similar to those at comparison sites and did not appear to be significantly influenced by Airport operations.

RI DEM identified two issues needing follow up investigation:

1. Were the somewhat elevated levels of gasoline constituents and substantially elevated levels of formaldehyde observed at the Field View site influenced by Airport operations or by other (e.g. on-site) sources? Since the residence at the Field View site, which was occupied during the study, was demolished soon after the monitoring was completed, further monitoring of those pollutants at that site would be useful for establishing the contribution of on-site sources to the pollutant elevations.
2. What is the health significance of the Airport impact on neighborhood BC levels and which parameters should be monitored in the future to best characterize and track those impacts?

In April 2007, RI DEM applied for a second Community Assessment grant to address the latter issue. The proposed project, which was approved by the EPA, included further monitoring for BC and for other particulate parameters, such as particle-bound polycyclic aromatic hydrocarbons (PAH) and ultra-fine particles (UFP), around TF Green and at comparison sites in the State.

However, in 2007, the Rhode Island General Assembly approved legislation requiring the Rhode Island Airport Corporation (RIAC), the quasi-governmental agency that operates TF Green, to establish and operate a long-term air monitoring network around the Airport. To comply with that law, RIAC began monitoring VOC; carbonyls; semi-volatile organic compounds (SVOC), including PAH; PM_{2.5}; BC, particle-bound PAH and UFP in early 2008 at four sites in the neighborhoods surrounding the Airport, including three of the sites from the original RI DEM study. RIAC is not required to analyze or interpret the data collected but must supply all data collected to RI DEM. The locations of the long-term RIAC air monitoring sites are shown in Figure 2.

In April 2008 RI DEM submitted a revised grant application to the EPA that removed elements of the original proposal that overlap with the RIAC monitoring requirements from the project plan. The revised application, which was approved by the EPA, reduced the allocation requested for the project from \$468,730 to \$209,716. This report summarizes the outcomes of the revised second phase project.

Project Objectives

The main objectives of the modified second phase project were to provide an analysis of the first year of RIAC’s monitoring data and to maximize the quality and utility of the RIAC monitoring data by ensuring:

1. That RIAC data meet data quality objectives,
2. That comparison data for monitored pollutants are collected at other sites in the State to provide a context for the Warwick results,
3. That data are stored in a user-friendly format and are available for further study, and
4. That the first year of the RIAC data are analyzed and interpreted.

Objective 1 – Evaluate the Quality of RIAC Data

Prior to initiating operation of the long-term monitoring network, RIAC prepared a Quality Assurance Project Plan (QAPP), which was modeled on RI DEM’s QAPP for the original TF Green study. RI DEM and the RIDOH Air Pollution Laboratory reviewed and commented on drafts of the RIAC QAPP. A copy of the RIAC QAPP is attached as Appendix B. As part of the current project, RI DEM reviewed RIAC results, as well the results of duplicate samples analyzed by the RIDOH Air Pollution Laboratory, and compared the precision/accuracy of those data with the benchmarks established in the QAPP. The results of this review are discussed below.

Objective 2 - Comparison Sites

Comparison data from sites in other areas of Rhode Island are useful in the interpretation of monitoring data collected in the vicinity of the Airport. Comparison data were collected during the study period at the Rhode Island locations listed in Table 1.

Table 1 Rhode Island Comparison Sites

| Pollutant | Site |
|------------------|---|
| VOC | W. Greenwich – rural, upwind of metropolitan area E. Providence – suburban, downwind of metropolitan area Providence (Urban League) – urban, National Air Toxics Trends (NATTS) site Pawtucket – urban, adjacent to I-95 |
| Carbonyls | E. Providence – suburban, downwind of metropolitan area Providence (Urban League) – urban, NATTS site |
| SVOC (TO-13a) | Providence (Urban League) – urban, NATTS site |

| | |
|------------------------------|--|
| PM _{2.5} (FRM/FEM) | W. Greenwich – rural, upwind of metropolitan area E. Providence – suburban, downwind of metropolitan area Providence (Urban League) – urban, NATTS site Providence (Eddy) – urban, near I-95 Pawtucket – urban, adjacent to I-95 |
| BC | E. Providence – suburban, downwind of metropolitan area Providence (Urban League) – urban, NATTS site |
| Particle-Bound PAH | E. Providence – suburban, downwind of metropolitan area Providence (Urban League) – urban, NATTS site |
| Particle count (UFP measure) | E. Providence – suburban, downwind of metropolitan area Providence (Urban League) – urban, NATTS site |

Note that the VOC, carbonyl, PM_{2.5} and BC comparison data were collected throughout the study period (2008 – present) as part of RI DEM’s ongoing ambient air monitoring network. SVOC data collection at the Urban League, Providence site began in July 2008, pursuant to NATTS requirements. Particle-bound PAH and particle count comparison data were collected for several months in 2011 in conjunction with this study using equipment purchased with project funds.

Objective 3 – Establish a Framework for Storing and Analyzing Data

RI DEM developed an Access database to store and analyze monitoring and related data as part of the first RI DEM TF Green study. In this study, RI DEM further developed this database to accommodate the monitoring data collected at the RIAC sites and the RI DEM comparison sites, including co-located monitor data. Additional information necessary to interpret the monitoring data including health benchmarks, chemical properties, meteorology and airport activity (flights) are also stored in this database. The database is updated as data are received from RIAC.

Objective 4 - Data Analysis and Reporting

RI DEM used the data in the database described above to analyze the data collected by RIAC from 2008 through mid-2011. The data analysis included the following:

Health Effects

- Health benchmarks for acute and chronic exposures were established for the first phase of RI DEM TF Green study. Health benchmarks were updated and the list of chemicals with benchmarks was extended to include pollutants not monitored in the earlier study. Updated VOC and carbonyl health benchmarks are listed in Table 2.
- Mean concentrations of all pollutants were compared to chronic health benchmarks and maximum concentrations to acute health benchmarks, where available. Cancer risks associated with mean concentrations were calculated for carcinogens.
- Data will be made available to RI DOH for use in ongoing and future health studies.

Table 2 VOC and Carbonyl Health Benchmarks (ppb)

| CHEMICAL NAME | Acute Benchmark | Chronic Benchmark (Non-cancer) | Chronic Benchmark (All health effects) |
|---------------------------|---------------------|--------------------------------|--|
| acetaldehyde | 260 ^A | 5 ^F | 0.3 ^M |
| acetone | 26000 ^B | 13000 ^G | 13000 ^G |
| acrolein | 1 ^A | 0.009 ^F | 0.009 ^F |
| acrylonitrile | 100 ^B | 0.9 ^F | 0.004 ^M |
| benzene | 9 ^B | 3 ^G | 0.04 ^M |
| benzyl chloride | 46 ^A | 0.4 ^H | 0.004 ^M |
| 1,3-butadiene | 1000 ^C | 0.9 ^F | 0.015 ^M |
| carbon disulfide | 1000 ^E | 200 ^F | 200 ^F |
| carbon tetrachloride | 300 ^A | 16 ^F | 0.03 ^M |
| chlorobenzene | 10000 ^D | 200 ^I | 200 ^I |
| chloroform | 30 ^A | 20 ^G | 0.008 ^M |
| chloromethane | 500 ^B | 40 ^F | 40 ^F |
| cyclohexane | 300000 ^D | 1700 ^F | 1700 ^F |
| 1,2-dibromoethane | 45 ^D | 1 ^F | 0.0003 ^M |
| p-dichlorobenzene | 2000 ^B | 10 ^G | 10 ^G |
| 1,1-dichloroethane | 100000 ^D | 60 ^J | 0.6 ^N |
| 1,2-dichloroethane | 1000 ^D | 600 ^G | 0.01 ^M |
| 1,1-dichloroethene | 5000 ^E | 20 ^K | 20 ^K |
| dichloromethane | 600 ^B | 600 ^{GK} | 30 ^M |
| 1,2-dichloropropane | 50 ^B | 0.9 ^F | 0.02 ^N |
| 1,3-dichloropropene | 1000 ^D | 4 ^F | 0.04 ^M |
| ethylbenzene | 5000 ^B | 60 ^F | 60 ^F |
| formaldehyde | 40 ^B | 8 ^G | 0.06 ^M |
| hexachlorobutadiene | | | 0.05 ^M |
| n-hexane | 50000 ^D | 200 ^F | 200 ^F |
| 2-hexanone | 1000 ^C | 7 ^F | 7 ^F |
| isopropylbenzene | 50000 ^D | 80 ^F | 80 ^F |
| methyl ethyl ketone | 4000 ^A | 1700 ^{FK} | 1700 ^F |
| Methyl-t-butyl-ether | 2000 ^B | 700 ^G | 4 ^N |
| styrene | 5000 ^B | 60 ^G | 60 ^G |
| 1,1,2,2-tetrachloroethane | 1000 ^D | 0.2 ^H | 0.002 ^M |
| tetrachloroethylene | 200 ^B | 40 ^G | 0.025 ^N |
| toluene | 1000 ^B | 80 ^G | 80 ^G |
| 1,1,1-trichloroethane | 2000 ^B | 900 ^F | 900 ^F |
| trichloroethylene | 2000 ^B | 0.35 ^F | 0.04 ^M |
| 2,2,4-trimethylpentane | | 200 ^L | 200 ^L |
| vinyl acetate | 4000 ^D | 10 ^K | 10 ^K |
| vinyl chloride | 500 ^B | 30 ^K | 0.09 ^M |
| xylene | 2000 ^B | 20 ^F | 20 ^F |

Basis for benchmarks

- A – California Acute Reference Exposure Level
- B - ATSDR Acute Minimal Risk Level
- C – OSHA Permissible Exposure Level
- D – NIOSH Recommended Exposure Limit
- E – ACGIH Threshold Limit Value
- F – US EPA Inhalation Reference Concentration (RfC)

G – ATSDR Chronic Minimal Risk Level
H – US EPA Potency Factor – Level corresponding to 10^{-4} risk
I – California Chronic Reference Exposure Level
J - California Cancer Potency Factor – Level corresponding to 10^{-4} risk
K – ATSDR Intermediate Minimal Risk Level
L – New York Annual Guideline Concentration
M - US EPA Potency Factor – Level corresponding to 10^{-6} risk
N- California Cancer Potency Factor – Level corresponding to 10^{-6} risk

Identification of Sources and Trends

- Pollutant concentrations measured at Warwick sites were compared to concurrent measurements at the other Warwick sites and at the comparison sites listed above.
- Concentration data were correlated with airport activity data (e.g. number of takeoffs per runway per hour) and meteorological parameters, particularly wind direction.
- Correlations in measured levels of pollutants, particularly VOCs, were studied in an attempt to characterize plume signatures to aid in identifying sources.
- Data from continuous measurements of PM-related parameters (BC, particle bound PAH and particle count (PC)) were studied in detail. For each parameter, the analysis included correlations with wind direction and other meteorological parameters as well as with airport activity and other available data to determine conditions (e.g. meteorology, time of day, airport activity) that impact those levels. This information will be useful for better defining source contributions and health impacts as well as for making recommendations about long-term monitoring.

Project Results

VOCs and Carbonyls

Data Quality – VOCs and Carbonyls

RIAC collected 24-hour VOC and carbonyl samples every 6th day at each of the four sites during 2008 and 2009. VOC and carbonyl samples are collected with ATEC samplers according to EPA Method TO-15 and TO-11a, respectively. Duplicate samples for quality assurance purposes are collected using the ATEC samplers' second channel. Sampling frequency was reduced to one sample per month per site in late 2009.

In February and March of 2008, RIAC temporarily sited one of the ATEC samplers purchased for the TF Green network alongside the VOC and carbonyl samplers at RI DEM's East Providence site. Initial measurements showed significant differences between RI DEM and RIAC measurements for both VOCs and carbonyls; those discrepancies were largely resolved by the adjustment of RIAC sampler flow rates. In addition, it was determined that the RIAC ATEC

unit was significantly contaminated with several VOCs, including toluene, and, as a result, the ATEC samplers were returned to the manufacturer for cleaning and replacement of the contaminated parts.

The RIAC QAPP requires the collection of one duplicate VOC sample and one duplicate carbonyl sample at each site each calendar quarter to assess the precision and accuracy of the measurements. The QAPP specifies that, for the precision to be acceptable, the relative percent difference in duplicate measurements must be less than or equal to 30% at concentrations of at least five times the MDL. The accuracy/bias is acceptable if the co-located measurement is within 25% of the corresponding initial measurement for commonly observed substances, such as benzene, toluene and the xylenes, and within 50% of the initial value for other compounds. One duplicate VOC and one duplicate carbonyl sample are analyzed by the RIDOH Air Pollution Laboratory each quarter.

RI DEM evaluated the results of the duplicate VOC and carbonyl samples collected by RIAC to determine whether the precision and accuracy goals identified in the QAPP were met and whether the RIAC analysis is comparable to that conducted by the RIDOH laboratory. This QA/QC analysis focused on the VOC and carbonyls that were identified in RI DEM's initial TF Green study as posing a cancer risk above one in one million at one or more of the study sites, substances that are of potential concern due to noncancer risk, and other substances that may be used as markers for mobile source emissions. Those substances are listed in Table 3.

Table 3 VOC and Carbonyls Evaluated for Quality Assurance

| Target Substances | Reason for Inclusion |
|----------------------|---|
| VOC | |
| carbon tetrachloride | cancer risk |
| benzene | cancer risk, mobile source emissions |
| chloroform | cancer risk |
| 1,3-butadiene | cancer risk, mobile source emissions |
| tetrachloroethylene | cancer risk |
| acrolein | noncancer risk, mobile source emissions |
| hexane | mobile source emissions |
| toluene | mobile source emissions |
| ethyl benzene | mobile source emissions |
| xylenes (m and o,p) | mobile source emissions |
| Carbonyls | |
| formaldehyde | cancer risk, mobile source emissions |
| acetaldehyde | cancer risk, mobile source emissions |

Between March 2008 and September 2011, 42 valid co-located VOC samples were analyzed by the RIAC contractor. Figure 3 shows the distribution of the relative errors for the target pollutants in the co-located samples. For comparison purposes, the distribution of relative error for those pollutants in 52 co-located samples collected at RI DEM's East Providence monitoring site in 2011 are displayed on the same graphs.

As shown in that figure, the third quartile relative error for the RI DOH East Providence samples was at or below 20% for all pollutants except for acrolein, a substance with known monitoring accuracy issues. In contrast, the only substance for which the third quartile of the RIAC relative errors was below 30%, the precision target in the RIAC QAPP, was carbon tetrachloride. RIAC's third quartile relative errors for 1,3-butadiene and benzene, the most significant mobile source- related carcinogenic VOCs, were 60% and 53%, respectively.

During the same time period, March 2008- September 2011, the RIAC contractor collected 17 duplicate samples that were sent to the RIDOH laboratory for analysis. For most of the pollutants, the distributions of relative errors for the RIAC-analyzed and RIDOH-analyzed pairs were similar to those in the RIAC-RIAC duplicates discussed above. This suggests that the variability is largely associated with sampling issues, such as contamination of the samplers and/or canisters, rather than in the laboratory analysis. Note that the RIDOH laboratory advised the RIAC contractor that the canisters should be steam cleaned to minimize contamination, but it is not clear whether that was done in a timely manner. The high relative error must be considered when interpreting subtle inter-site differences in VOC results reported by RIAC. Note that RIAC has since hired a new contractor, who is working with the RIDOH laboratory in an effort to improve data quality.

In contrast, virtually all of the acetaldehyde and formaldehyde co-located samples, both those in which both samples were analyzed by a RIAC contractor and those in which the duplicate was analyzed by DOH, had relative errors below 30%. See Figure 4 below.

Health Effects and Source Identification – VOCs and Carbonyls

Health Effects

Mean concentrations of target VOCs and carbonyls were compared to chronic health benchmarks and maximum concentrations to acute health benchmarks, where available. Cancer risks associated with mean concentrations were calculated for carcinogens. The last 12 months during which VOC samples were collected every sixth day, December 1, 2009 – November 30, 2010, were used for calculating an annual average for comparison to the chronic health benchmarks.

With the exception of acrolein, maximum levels of VOC and carbonyls measured at the Warwick sites were lower than the corresponding acute health benchmarks and average levels were lower than the corresponding non-cancer chronic benchmarks. Acrolein levels measured at the airport sites tended to be higher than those at the comparison sites. However, since, as discussed above, the relative error associated with RIAC's measurements of that pollutant were very high and since there are known problems with producing accurate acrolein measurements, those results are not definitive.

Average levels of six VOCs and two carbonyls exceeded the cancer benchmark, which is associated with a lifetime cancer risk of one in one million (10^{-6}), at one or more site. Those pollutants are:

- 1,2-Dichloroethane (Ethylene dichloride). Reported average levels of this pollutant were similar and were slightly higher than the cancer benchmark at all of the Warwick sites. Average levels at all Warwick sites were lower than those at the comparison sites, including the rural Alton Jones site. Note that the RIAC minimum detection level (MDL) was twice the cancer benchmark and many of the reported concentrations were below the MDL. A concentration of one-half of the MDL (equivalent to the cancer benchmark) was used for those samples in the calculation of the average.
- 1,3-Butadiene. This pollutant is a component of exhaust from stationary and mobile combustion sources, including aircraft and automobiles. Mean levels of 1,3-butadiene were higher than the cancer benchmark at all Warwick sites and at all of the comparison sites except for Alton Jones. Levels were highest (approximately 5 times the cancer benchmark) at the Vernon Street, Pawtucket comparison site, which is adjacent to I-95, and second highest (3 times the benchmark) at the Urban League, Providence comparison site. Levels at the Warwick sites and the East Providence comparison site were approximately twice the benchmark. 1,3-Butadiene levels at the Pembroke site, east of the airport, tended to be slightly higher than those at the other Warwick sites.
- Benzene. Average levels of this mobile source pollutant were highest at the Vernon Street and Urban League comparison sites (8 and 7 times the benchmark, respectively). The mean level at the East Providence site (5.5 times the benchmark) was also slightly higher than those reported for the Warwick sites. All of the Warwick sites recorded average benzene levels between 4 and 5 times the benchmark, with Pembroke (east of the airport) and Fire Station (west of the airport) slightly higher than Lydick (northeast) and Field View (southwest). The average level at Alton Jones was lower than at the other sites, but was twice the cancer benchmark. Note that, in the early RI DEM study, benzene levels at the Field View site tended to be higher than at the other Warwick sites, but the RIAC results do not show an elevation of that pollutant at that location.
- Carbon tetrachloride. The average levels of this pollutant, which is no longer used but, due to its persistence, is present throughout the United States in background air, were virtually the same at all Warwick and comparison sites, approximately three times the cancer benchmark.
- Chloroform. The average levels of this pollutant were approximately 2- 3 times the cancer benchmark at all Warwick and comparison sites, including Alton Jones.
- Tetrachloroethylene (perchloroethylene). Average levels of this pollutant, which is primarily used by dry cleaners, were approximately equal to the cancer benchmark at all Warwick and comparison sites. The highest level (1.6 times the benchmark) recorded was at the Fire Station site and the lowest level at the Alton Jones comparison site (40% of the benchmark). Since the Fire Station levels were frequently higher than at the other Warwick sites, it appears likely that the perchloroethylene air levels at that site are affected by a nearby dry cleaning source. Note that, in the previous study, levels of this pollutant tended to be elevated at the Lydick site.

- Acetaldehyde. Average levels of this pollutant exceeded the cancer benchmarks at all of the Warwick sites and at both of the carbonyl comparison sites (East Providence and Urban League). Average levels at the Lydick, Fire Station and Field View sites were similar (approximately twice the benchmark) and were lower than at the comparison sites (3 times the benchmark at Urban league and 4 times the benchmark at the East Providence site). However, acetaldehyde levels recorded at the Pembroke site frequently were elevated during the period June 1, 2009 – February 1, 2010, resulting in an average concentration approximately 6 times the cancer benchmark at that site. The elevations during this period do not correspond to particular weather conditions or runway use. Formaldehyde concentrations were not elevated at Pembroke during that period. However, on August 22, 2008, levels of both acetaldehyde and formaldehyde were unusually elevated at the Pembroke site. On that day, winds were from the SE in the morning, switching to SW in the afternoon, and an unusually high number of take-offs from Runway 16 occurred.
- Formaldehyde. Average levels of this pollutant were substantially above (28 – 48 times higher than) the cancer benchmark at all Warwick and comparison sites. Levels were, on average, higher at the comparison sites than at the Lydick, Field View and Fire Station sites. Average formaldehyde levels at Pembroke (48 times the benchmark) were slightly higher than at the comparison sites (42 times the benchmark). However, if the August 22, 2008 outlier concentration discussed above is excluded, concentrations at the Pembroke site are consistent with those at the other airport sites and tend to be lower than at the comparison sites. The distribution of formaldehyde levels at the airport and comparison sites is displayed in Figure 5.

Mobile Source Pollutant Patterns

The concentrations of the BTEX compounds (benzene, toluene, ethyl benzene and xylenes), the aromatic pollutants generally associated with mobile source emissions, at the comparison sites tend to be highest at the Vernon Street, Pawtucket site, which is adjacent to I-95, second highest at the Urban League site, which is located in an urban area of Providence, next highest at the suburban East Providence site, which is often downwind of the Providence metropolitan area, and lowest at the Alton Jones site, which is in a rural area of West Greenwich. As shown in Figure 6, concentrations of these pollutants at the Warwick sites were, in most cases, similar to or lower than the concentrations at the East Providence site, although concentrations of the xylenes and ethyl benzene at the Pembroke site tend to be higher than those at the other Warwick sites and higher than those in East Providence. Benzene and toluene levels at Pembroke were similar to those at the other Warwick sites. Concentrations of the BTEX pollutants at the Field View site were generally slightly lower than at the other airport sites, in contrast to the results of the early RI DEM study.

Mobile source fuels also contain a range of other hydrocarbons. The preponderance of the hydrocarbons in jet fuel has 9 – 16 carbons. Unfortunately, hydrocarbons in that range are not generally targeted in the VOC analytical method used for measuring ambient VOC (EPA Method TO-15) and are not reported in the RIAC VOC analysis results. RIAC does report results for hexane (6 carbons) and heptane (7 carbons), constituents of gasoline that are present

in lower concentrations in jet fuel. As shown in Figure 6, heptane concentration distributions were similar to those seen with the BTEX compounds - concentrations of heptane at the Warwick sites tended to be slightly lower than those at the East Providence site, with the Field View site concentrations the lowest.

For hexane, however, the pattern was different. Hexane levels at the Pembroke site on many sampling days were substantially higher than those at the other Warwick sites and the comparison sites. These very high concentrations, along with the fact that hexane levels at the Pembroke site don't correlate well with the other mobile source pollutants measured at that site suggest that there may be a stationary hexane emissions source near that site. Since the VOC samples are taken over a 24-hour period and wind directions vary over the course of a day, it is not possible to definitively determine where such a source would be located relative to the monitor. It does appear, however, that winds were frequently from the south or southwest on the days that the elevated levels occurred. RI DEM identified two potential sources, a maintenance facility that is located approximately 0.1 miles to the southwest and a printing company located about 0.5 miles south- southwest of the monitor. However, since neither of these facilities report significant use of hexane, this issue is still under investigation. Note that there was no correlation between number of take-off events on any of the runways per day and hexane levels at the Pembroke site.

Quality assurance issues also may have influenced the hexane levels measured at Pembroke. Hexane levels at all of the Warwick sites correlated relatively poorly with levels of other mobile source pollutants, while hexane levels at all of the comparison sites correlate quite well with those pollutants. This was not true in the 2005-06 RI DEM Airport study, in which hexane levels at all Warwick sites correlated well with those of other mobile source pollutants. Moreover, as shown in Figure 7, the relative error for hexane in duplicate samples taken at Pembroke (median 64%) was substantially greater than that at the other Warwick sites (16% - 29%). The median relative error for duplicate hexane samples taken during the same time period at RI DEM's East Providence site was 3%. Therefore, the elevations in hexane levels measured at the Pembroke site may be at least partially explained by contamination or other quality assurance issues.

Due to the quality assurance concerns, it is impossible to be definitive about the patterns of mobile source pollutants at the Warwick sites, except that levels of all of the mobile source pollutants except for hexane seem to be within the range of those seen elsewhere in the State. The high hexane levels seen at the Pembroke site may be at least partially explained by contamination or other quality assurance issues; however, these levels bear continued surveillance and, if hexane levels at that site continue to be high, further investigation.

SVOC

Data Quality – SVOC

24-hour SVOC samples have been collected every 6th day at each of the four RIAC sites since January 2008. Samples are collected with Tisch TE-1000 high volume air samplers on quartz

filters followed by a polyurethane foam (PUF) plug and XAD resin, according to EPA Method TO-13a. Since duplicate SVOC samples are not collected, precision and accuracy cannot be assessed for those pollutants. SVOC concentrations measured at the Warwick sites were compared with those measured at RI DEM's Urban League site in Providence. Since RI DEM operates only one SVOC site, comparisons with levels measured in Boston, Massachusetts were also included. Annual mean concentrations were calculated for three time periods, October 2008 – September 2009, October 2009 – September 2010, and October 2010 – September 2011.

Health Effects and Source Identification – SVOC

Health Effects

Concentrations of twenty SVOC PAH species are measured at the Warwick sites. The toxicity of naphthalene, the most volatile of these species, is generally evaluated separately from that of the other SVOCs. For the purpose of this evaluation, naphthalene concentrations measured at the Warwick sites and at the Providence and Boston SVOC sites were compared to the EPA Inhalation Reference Concentration (RfC) for non-cancer effects associated with that pollutant, $3 \mu\text{g}/\text{m}^3$, and the concentration corresponding to a 10^{-6} cancer risk, $0.03 \mu\text{g}/\text{m}^3$, derived from California OEHHA's inhalation cancer potency factor for naphthalene.

Concentrations of naphthalene at the Warwick and comparison sites for each of the three years evaluated are shown in Figure 8. Mean concentrations for all sites and all time periods were substantially lower than the non-cancer benchmark. Naphthalene concentrations at all of the Warwick sites were approximately 1.5 times the cancer benchmark for the first two time periods evaluated (October 2008 – September 2009 and October 2009 – September 2010) and were approximately equal to the cancer benchmark in the third year (October 2010 – September 2011). Concentrations at both of the comparison sites were higher than those at the Warwick sites in each of the three years (annual means at the Providence site were approximately three times and at the Boston site were $2 - 2 \frac{1}{2}$ the cancer benchmark).

RI DEM's Office of Air Resources generally evaluates the cancer risk of other polycyclic aromatic hydrocarbons (PAH) cumulatively using weighting factors derived from California OEHHA inhalation cancer potencies and by the World Health Organization. Weighting factors are keyed to the cancer potency of benzo(a)pyrene (BaP), so a PAH species with a cancer potency that is ten times lower than that of BaP would have a weighting factor of 0.1. The concentration of each PAH species is multiplied by the corresponding weighting factor and those products are summed to determine the concentration in "BaP equivalents." A concentration of $0.00009 \mu\text{g}/\text{m}^3$ ($0.09 \text{ ng}/\text{m}^3$) BaP equivalents is associated with a 10^{-6} cancer risk, as derived from the OEHHA cancer potency for BaP.

Weighting factors are available for 9 of the PAHs measured. The PAHs measured and the weighting factors used for this analysis are listed in Table 4.

Table 4 PAH Species Reported by RIAC and Corresponding Cancer Weighting Factors

| PAH SPECIES | WEIGHTING FACTORS | BASIS |
|------------------------|-------------------|-------|
| 1-METHYLNAPHTHALENE | | |
| 2-METHYLNAPHTHALENE | | |
| ACENAPHTHENE | | |
| ACENAPHTHYLENE | | |
| ANTHRACENE | 0.3 | WHO |
| BENZO(A)ANTHRACENE | 0.1 | OEHHA |
| BENZO(A)PYRENE | 1 | OEHHA |
| BENZO(B)FLUORANTHENE | 0.1 | OEHHA |
| BENZO(E)PYRENE | | |
| BENZO(G,H,I)PERYLENE | | |
| BENZO(K)FLUORANTHENE | 0.1 | OEHHA |
| CHRYSENE | 0.01 | OEHHA |
| DIBENZO(A,H)ANTHRACENE | 1.1 | OEHHA |
| FLUORANTHENE | 0.1 | WHO |
| FLUORENE | | |
| INDENO(1,2,3-CD)PYRENE | 0.1 | OEHHA |
| NAPHTHALENE | | |
| PERYLENE | | |
| PHENANTHRENE | | |
| PYRENE | | |

As shown in Figure 9, PAH concentrations at all Warwick and comparison sites were above the 10^{-6} cancer risk health benchmark for BaP equivalents (0.09 ng/m^3). In the first two years analyzed, October 2008 – September 2009 and October 2009 – September 2010, BaP equivalent concentrations at the Warwick sites were 9 – 13 times higher than the cancer benchmark. Concentrations at the Warwick sites were, on average, highest at the Fire Station location and lowest at Pembroke. The BaP equivalent levels measured those years at the Providence comparison site were 9 – 10 times the benchmark, roughly equal to the Pembroke levels and lower than the levels at the other Warwick sites.

In the third year, mean BaP equivalent concentrations at all of the Rhode Island sites dropped considerably. That year, October 2010 – September 2011, concentrations were similar at all of the Warwick sites, 6 – 7 times the benchmark, and were slightly lower at the Warwick sites than the concentration at the Providence site, which was 8 times the benchmark. This statewide reduction in PAH levels may have been related to weather conditions during that year.

Interestingly, BaP equivalent levels at the Boston site were lower than at the Rhode Island locations in all three years. More analysis would be required to determine the reason for this difference.

PAH are emitted primarily by combustion sources. A variety of factors, including the material combusted and the temperature and efficiency of the combustion process, affect the relative concentrations of various PAH species generated. As shown in Figure 9, although the weighting factor approach discussed above allows for a calculation of cumulative risk, the mixture of species that contribute to that risk varies from site to site. A more thorough analysis of the

differences in the PAH profiles at the Warwick and comparison sites may shed some light on the relative contribution of various mobile and stationary combustion sources on ambient PAH levels.

PARTICULATE MATTER SPECIES AND INDICATORS

RIAC operates four types of monitors that measure particulate matter species and indicators. Federal Reference Method (FRM) PM_{2.5} monitors are run at all sites every 6th day. The other three types of particulate monitors, particle counters, Aethalometers measuring black carbon and particle bound-PAH monitors, are scheduled to run continuously at all sites. Note that the SVOC monitors discussed previously capture semi volatile pollutants in both particulate and vapor forms and reports the total concentrations of each pollutant.

Data Quality – Particulate Matter Measurements

24-hour PM_{2.5} samples have been collected every 6th day at each of the four sites since January 2008. Samples are collected on pre-weighed filters using ThermoFisher Partisol-FRM 2000 low volume air samplers equipped with size-segregating cyclones and are analyzed gravimetrically. Although there are no co-located measurements, one trip blank and one field blank have been analyzed during most sampling rounds since mid-2008. Mass increases that would correspond to concentrations of 2 – 25 µg/m³ were observed in 15 of the 22 field blanks and 7 of the 15 trip blanks collected before October 2009, as shown in Figure 10. RI DEM and RI DOH met with RIAC's contractor during that period and the contractor agreed to adjust filter handling procedures to reduce the potential for contamination and to allow for equilibration of humidity. No levels above RIAC's detection level (50.5 µg, which corresponds to a concentration of approximately 2 µg/m³) were reported in subsequent blanks. Therefore, this report will consider PM_{2.5} FRM data reported by RIAC only for the two year period from October 2009 – September 2011.

Particle-bound PAH is measured continuously at each RIAC site with a Desktop Photoelectric Aerosol Sensor (PAS) 2000, manufactured by EcoChem Analytics. Particle count, an indicator of ultrafine particulate matter (UFPM) concentration, is measured continuously at each site with a TSI water-based condensation particle counter (CPC) equipped with an inlet cyclone to screen out particles larger than 3 µm. The RIAC network originally employed TSI Model 3781 particle counters but, due to the lack of reliability of those monitors, purchased two TSI Model 3793 units. Optically-absorbing black carbon (BC) aerosol particles, which are characteristic of diesel and jet exhaust, are continuously measured by a Magee Scientific Model AE-22 dual channel Aethalometer equipped with a PM_{2.5} inlet.

RIAC does not operate co-located PAS monitors, so the ability to assess data quality for these instruments is limited. RI DEM purchased two PAS monitors with funds from this grant but, due to administrative difficulties, was not able to acquire that equipment until 2011. RI DEM/RI DOH has been operating those monitors at two sites in the State monitoring network since early 2011 in order to obtain comparison data for this study. When RIAC's new contractor took over in the 4th quarter of 2011, RIAC's PAS monitors, as well as the Aethalometers and particle

counters, were taken out of service for maintenance. In 2nd quarter 2012 those monitors were returned to service, and RI DEM plans to co-locate one of its PAS monitors at a RIAC site for some period of time in the near future in order to establish data compatibility.

Although RIAC purchased an extra CPC unit and RIAC's QAPP calls for the operation of a co-located CPC at one site, the CPC units proved to be unreliable and the extra unit was required to replace primary units when equipment failures occurred. RI DEM/RI DOH owns two Model 3781 CPC units, which similarly have been subject to frequent equipment reliability issues, and purchased two Model 3783 units with funds from the project. As with the PAS monitors, RI DEM/RI DOH has been operating the CPC monitors at two sites in the State network in order to collect comparison data, but plans to co-locate one of its CPC monitors at a RIAC site for some period of time in the near future in order to establish data compatibility.

RIAC operated a single channel Aethalometer borrowed from RI DEM as a co-located monitor at the Pembroke site from February 2008 through December 2010. The median absolute relative error for hourly average readings during the period that the co-located monitor was operating was 20%; 90% of the readings had a relative error less than 40%. As shown in Figure 11, the absolute relative error in 2008 was very low in 2008 (median approximately 10%), but doubled in subsequent years. As can be seen in Figure 12, while there was little bias between the readings of the two monitors in 2008; in 2009 and 2010, the RI DEM co-located machine tended to read more than 20% higher than the primary monitor.

Health Effects and Source Identification – Particulate species

Health Effects

As discussed above, due to significant blank concentrations in many of the PM_{2.5} FRM sample rounds prior to October 2009, results are presented here only for the two subsequent years for which data are available, October 2009 – September 2010 and October 2010 – September 2011. PM_{2.5} concentrations for each of those years at each Warwick site and the concentrations measured on the same days at the RI DEM comparison sites are listed in Table 5 and shown graphically in Figure 13. All concentrations measured are lower than the corresponding annual and short-term National Ambient Air Quality Standards (NAAQS) for this pollutant. Annual average PM_{2.5} concentrations at the Warwick sites were similar to those seen at RI DEM's Vernon Street, Pawtucket site, which is in a residential area adjacent to I-95 north of Providence and is generally the site that records the highest PM_{2.5} levels in RI DEM's monitoring network.

98th percentile values tended to be somewhat higher at the Warwick sites than at the comparison sites in the first year and slightly higher at the Warwick sites than at the comparison sites in the second year. The exception to this trend was the Field View, which had a 98th percentile value lower than those at all of the other Warwick sites and similar to those at the comparison sites in the first year and substantially higher than those at all of the Warwick and comparison sites in the second year.

Although the blank measurements during these two years were in the non-detect range, it is not clear that RIAC's PM_{2.5} measurements are accurate enough to conclude that these differences reflect actual elevations in ambient PM_{2.5} levels. Further, due to variations in wind direction during the 24-hour periods that the samples are collected, it is not possible to definitively determine possible sources of elevated levels.

However, the possibility that the airport has an impact on measured PM_{2.5} levels cannot be ruled out. Figures 14a and 14b show the daily concentrations observed at the Warwick sites and the Urban League, Providence site during the study period. Concentrations at the Lydick site, which is downwind of the airport when winds are from the SW, were substantially elevated and substantially higher than at the other sites on January 9, 2009 and February 14, 2011. On the first of these days, winds were from the S – SSW for a large portion of the day and, on the second, the winds were from the SW for most of the day. Therefore, the airport may have contributed to the PM_{2.5} elevations on those days.

On February 14, 2010, PM_{2.5} levels were elevated at the Pembroke and Fire Station sites. Winds were variable that day. The Pembroke site was not downwind of the airport that day and the Fire Station was downwind for short periods. Levels at the Field View site, which was downwind of the airport for much of that day, were not elevated. Concentrations were also elevated at the Fire Station site on April 8, 2010. Wind directions ranged from the NE to the SSE that day. Again, the Fire Station was not downwind of the airport for most of the day and PM_{2.5} levels at the Field View site, which was downwind, were not elevated.

Field View levels were elevated on November 16, 2010 and July 20, 2011. On both of these days, the wind direction varied somewhat through the day, but the site was downwind of the airport for portions of the day.

Therefore, although it is impossible to be definitive, the airport may affect measured PM_{2.5} levels on certain days, particularly at the Lydick and Field View sites, which are on opposite ends of the main runway.

Table 5 PM_{2.5} Concentrations (µg/m³)

| Annual Mean (Annual NAAQS = 15 µg/m ³ , 3-year average) | | |
|--|---------------------|---------------------|
| Site | Oct 2009 - Sep 2010 | Oct 2010 - Sep 2011 |
| Field View | 8.5 | 9.8 |
| Fire Station | 8.9 | 9.2 |
| Lydick | 8.7 | 9.2 |
| Pembroke | 9.1 | 9.3 |
| Vernon St | 8.9 | 9.2 |
| Urban League | 7.9 | 7.8 |
| Eddy St | 8.2 | 8.2 |
| E Providence | 7.5 | 7.9 |
| Alton Jones | 6.7 | 6.9 |
| | | |
| | | |
| 98th Percentile (Short-term NAAQS = 35 µg/m ³ , 3-year average) | | |
| | Oct 2009 - Sep 2010 | Oct 2010 - Sep 2011 |
| Fieldview | 19.6 | 27.2 |
| Fire Station | 33.9 | 22.8 |
| Lydick | 26.6 | 21.7 |
| Pembroke | 25.4 | 20.4 |
| Vernon St | 20.5 | 19.4 |
| Urban League | 19.8 | 17.4 |
| Eddy St | 19.5 | 18.0 |
| E Providence | 20.8 | 16.8 |
| Alton Jones | 15.7 | 16.6 |

A more detailed analysis is possible for the other three particulate measures, particle-bound PAH, particle count (PC) and BC, because the continuous measurements enable a more direct comparison of elevated levels to concurrent weather conditions and airport activity.

The distribution of hourly average concentrations of BC, particle-bound PAH and PC for hours that all RIAC monitors were operating are displayed in Figures 15, 16a and 17a. Since there are no health benchmarks available for these pollutants, these data are useful only for inter-site comparisons. On average, BC and PAH were higher at the Fire Station site and Lydick sites than at the Field View and Pembroke sites, while the reverse is true for PC. Note that the particle counters broke down much more frequently than the other monitors, so there are considerably fewer hours with data for all four sites for PC than for BC and PAH (7,021 hours versus 19,469 and 25,179 hours, respectively). However, when the PC analysis was repeated with the 13,713 hours with data available for at least three of the Warwick sites, the results were similar.

Comparisons with data collected concurrently at the East Providence and Urban League comparison sites are presented in the Figures 15, 16b and 17b. Since BC was collected at the comparison sites throughout the study period, the comparisons with those data are most robust. Average BC concentrations at the Fire Station and Lydick sites were 10% and 5% higher, respectively, than at the Urban League site. This difference may not be significant (note the earlier discussion of the approximately 20% median relative error between the primary and co-located BC monitor at the Pembroke site). The average BC concentration at Field View was similar to that at Urban League and the average at Pembroke was similar to the (lower) concentration at the East Providence site.

Operation of the particle-bound PAH monitors at the comparison sites did not begin until March 2011, so the data presented in Figure 16b represent only the March – September 2011 time period. Patterns may be different in colder months. During the months that measurements were taken, the Urban League particle-bound PAH measurements were, on average, considerably higher than those at all of the other sites. Average PAH concentrations at the Warwick sites were similar to or lower than those at the East Providence comparison site.

The PC comparison data are even less robust, because the RIAC PC monitors were operating very sporadically by March 2011, when Urban League and East Providence PC data collection began, and there were no RIAC PC data collected after June 2011. Figure 17b shows that the mean PC concentration at the Field View site during that time was higher than that at the comparison sites, while the average concentrations at the other sites were lower than at the comparison sites, but it is not known whether the relative concentrations would be similar if more data were available.

In an effort to determine sources of these pollutants, the data were analyzed to determine diurnal patterns of pollutant concentrations. Graphs showing average concentrations of each of these pollutants by hour of day (local time) for weekday and weekend days are shown in Figures 18 – 20. As can be seen in those graphs:

- Average weekday BC and PAH levels peak during the hour that begins at 7:00 AM at all of the Warwick sites and at the Urban League site. This is a phenomenon that is commonly observed at other locations, and is due to emissions from rush hour traffic during a time of the day when the meteorological conditions are often not conducive to dispersion and mixing. As has been noticed in earlier studies, the weekday levels at the East Providence site tend to peak in the 8:00 AM hour, probably that site is at an elementary schools and school buses and other vehicles are present at that hour.
- Similarly, weekday PC tends to peak at 7:00 at most of the sites. However, at Pembroke and Field View, weekday PC peaks at 6:00 AM. Since TF Green take-offs begin at 6:00 AM, it is likely that elevated PC levels at those sites before the typical morning rush hour are related to airport activity.

- Average concentrations on weekend days for all three pollutants tend to be lower than on the weekdays, particularly during the morning rush hour. It is interesting to note that, on the weekends at the Pembroke site, there continues to be a significant PC peak at 6:00 and BC and PAH levels also show a small peak at that hour. This again is consistent with the effect of aircraft emissions on this site; that effect is more apparent for BC and PAH on weekends because of reduced early morning vehicular traffic on those days.

A variety of meteorological conditions can also affect particulate pollutant levels. As can be seen in Figures 21 – 23, average concentrations for all three continuous particulate measurements were highest when wind speeds were low. This is consistent with the discussion above concerning the contribution of poor dispersion conditions to early morning peak concentrations. This pattern was true on both weekday and weekend days, but the concentrations were higher on weekdays, due to the higher level of emissions on those days.

Note that the RIAC Aethalometers are dual channel monitors that measure black carbon levels at two wave lengths, one in the infrared (IR) region, and one in the ultraviolet (UV) region. Both of these measurements are presented in these figures and are represented at BC-1 and BC-2. RI DEM similarly originally operated its Aethalometers in a dual mode but, due to instability of measurements noted in the earlier Airport study, the UV channel was disconnected.

Although average PC concentrations, like those for BC and particle-bound PAH, decrease with wind speed, that decrease is more gradual, as shown in Figure 23. In particular, the levels at the Field View site decreased less than those at the other sites with increasing wind speed. This may be partially due to the fact that PC levels are decrease more rapidly than the other measures with distance and time from a source, as small particles agglomerate and disperse. Therefore, elevated PC levels measured at the RIAC sites are likely due to sources that are quite close to the monitors and these levels may be affected less by wind speed than the other measurements, which are more likely to be influenced by more distant sources.

The relationship between temperature and particulate measures is less clear. As shown in Figures 24a and 24b, average BC-2 levels seem to be somewhat higher when temperatures are below 40°F than with higher temperatures, but that relationship is not evident with BC-1. This may be because BC-2 is a more sensitive measure of fresh combustion products, and combustion sources tend to operate less efficiently initially at colder temperatures upon startup. BC-2 also is a more sensitive measure of wood smoke, and wood stoves in the area likely are operated more in colder temperatures. These two factors may also explain the higher average levels of particle-bound PAH seen at colder temperatures, as shown in Figure 25. Note that Figure 26 shows no evident relationship between average PC levels and temperature at the Warwick sites.

The meteorological parameter that has the potential for providing the most information about potential sources of the particulate pollutants is wind direction. As shown in Figure 29, the influence of wind direction on PC levels is much more distinct than for the other particulate measures (Figures 27a, 27b and 28). Specifically, average levels of PC at the Field View site are elevated relative to those at the other Warwick sites when wind have an easterly component (NNE – ESE), PC levels are elevated at the Lydick site with SW winds, and PC levels at Pembroke are higher than at the other sites when winds are from the WSW – NW. PC levels at the Fire Station tend to be lower than at the other sites, but are slightly favored with S-SSE winds. In all cases, these wind directions are consistent with the sites being downwind of the Airport.

Although BC and particle-bound PAH show similar trends, the relationship of levels of those measures with wind directions is less clear. As discussed above, this is probably at least partially due to the fact that those pollutant levels are affected by a variety of sources in an area, while PC tends to be highly dominated by proximate sources. For this reason, PC is a better indicator of airport emissions than the other two parameters at locations immediately adjacent to the facility. However, BC and PAH levels provide useful clues about sources of elevated levels.

Figures 30 a-d and 31 a-d show the hourly concentrations of BC-1, BC-2, PAH and PC during two days. On May 23, 2008, the wind was from the NW most of the day, so the Pembroke site was downwind of the airport that day. All of the measures show significant peak concentrations at the Pembroke site at 6:00 AM, when the first morning flights take off at the Airport. Smaller peaks are seen at Pembroke later in the day. Similar peaks are not seen at the other sites, which are not downwind. On that day, all of these parameters clearly show a relationship between particulate concentrations and aircraft emissions downwind of the airport.

The picture is somewhat different on August 13, 2009. On that day, the wind was from the NNE for much of the day, so the Field View site was downwind of the airport. PC levels were substantially elevated at that site throughout the day, particularly in the 6:00 AM hour. However, the levels of the other pollutants do not show as clear a relationship, at least partially because levels of those pollutants at the other sites appear to be affected by other sources. Therefore, on that day, PC is the only parameter that clearly shows the effect of airport emissions on surrounding air quality.

The continuous monitors generate a tremendous amount of data, and there are many issues that could be explored with a more detailed evaluation of those data.

Conclusions and Next Steps

RI DEM has concluded the following, based on an analysis of RIAC data collected between 1/1/08 and 9/30/11:

- The relative errors for VOC are higher than the target levels in the QAPP and considerably higher than the relative errors for RI DEM's network. Because of this variability, interpretation of subtle inter-site differences in VOC levels is difficult. RI DEM is working with RIAC's new contractor in an effort to improve VOC data reliability.
- Relative errors for the carbonyls (formaldehyde and acetaldehyde) are consistent with targets.
- RIAC operated a second Aethalometer, borrowed from RI DEM, as a co-located monitor at the Pembroke site from February 2008 – 2010. In the first year, the two units agreed well. In 2009 and 2010, however, the co-located monitor tended to read more than 20% higher than the primary monitor. The correlation between the results of the two monitors continued to be acceptable (median absolute relative error approximately 20%).
- Since no co-located monitors have been operated for the remaining parameters (PM_{2.5}, SVOC, particle-bound PAH and PC), opportunities for quality assurance/quality control of those measurements are limited. RI DEM plans to co-locate a PAS unit (measuring particle-bound PAH) and a particle counter (measuring PC) at a RIAC site during 2013.
- Levels of all VOCs and carbonyls, with the exception of acrolein, were below acute and chronic health benchmarks. Acrolein levels at all Warwick sites tended to be considerably higher than at all comparison sites, although the very high relative error and the known analytical problems for that pollutant add uncertainty to this finding. Maximum reported acrolein levels at the Warwick sites were above the acute health benchmark and mean reported acrolein levels for all Warwick and comparison sites were higher than the chronic noncancer benchmark.
- Mean levels of six VOC and two carbonyls were higher than the corresponding cancer health benchmarks, which are based on a risk level of 10⁻⁶. In general, these levels were consistent with those seen at comparison sites and do not seem to be linked to airport operations.

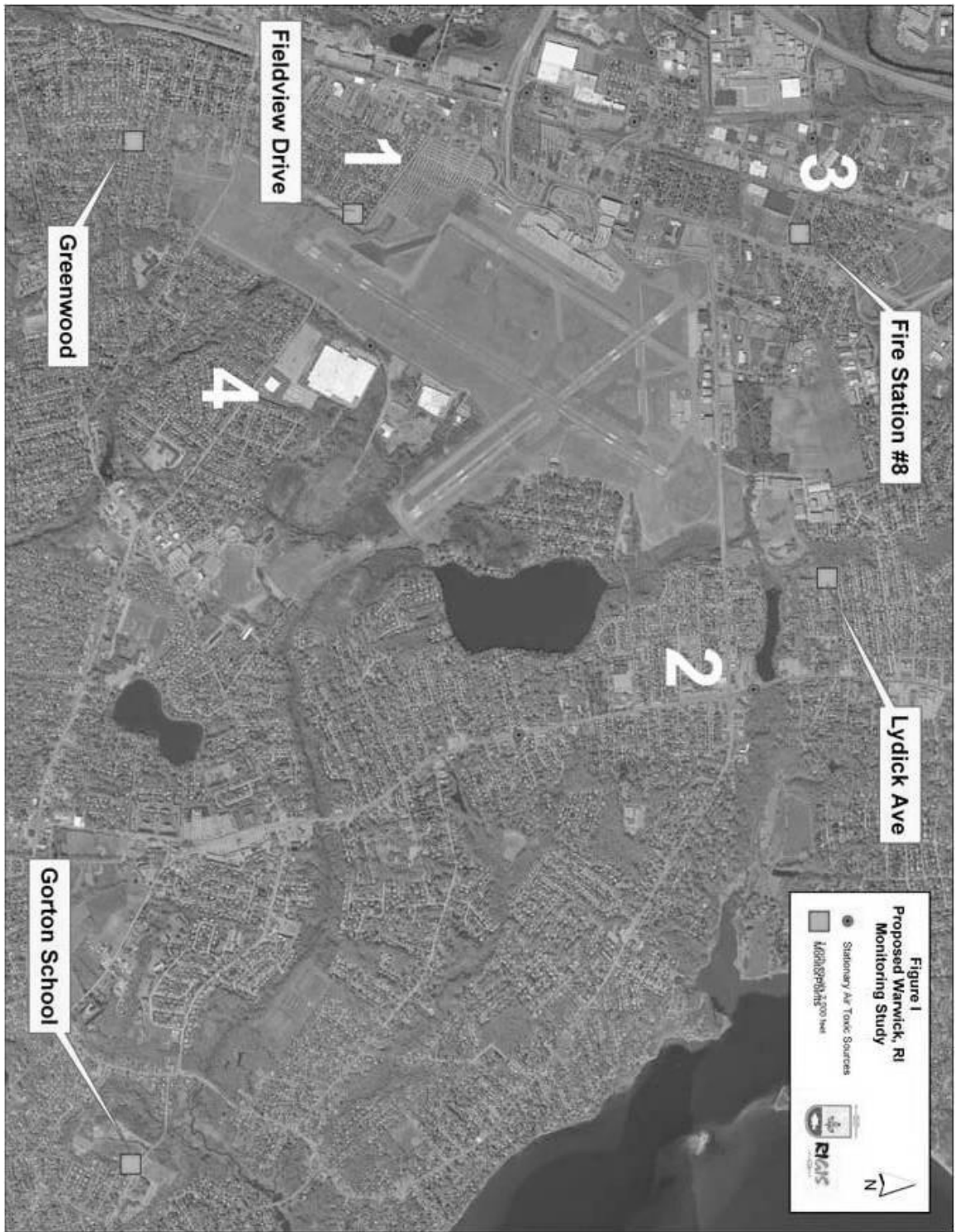
- Average levels of several mobile source pollutants, including 1,3-butadiene, benzene, xylenes and ethyl benzene were slightly higher at Pembroke than at the other Warwick sites. The average benzene level at the Fire Station was also slightly higher than at the Lydick and Field View sites. In general, the concentrations of mobile source pollutants at the Warwick sites were similar to those at the East Providence comparison site. In the earlier RI DEM Warwick study, concentrations of these pollutants were slightly elevated at Field View, but this was not the case with the RIAC measurements. The earlier elevations may have been due to sources on the Field View property before the residence was razed. As discussed previously, data quality issues associated with the RIAC VOC samples cast uncertainty on subtle inter-site differences in levels of those pollutants observed at the Warwick sites.
- Average levels of tetrachloroethylene (perchloroethylene) were similar at all Warwick and comparison sites, but it appears that a source near the Fire Station may contribute to slightly elevated levels at that site on some days. Note that, in the previous study, tetrachloroethylene levels were sometimes elevated at the Lydick site, but that finding was not observed in the RIAC data.
- Acetaldehyde levels at the Pembroke site were frequently elevated during the period June 1, 2009 – February 1, 2010. The source of these elevations has not been determined. Note that formaldehyde levels were similar at all Warwick and comparison sites. The elevated Field View formaldehyde levels seen in the earlier RI DEM study were not evident in the RIAC data and may have been caused by local sources on the Field View property.
- Hexane levels were frequently elevated at the Pembroke site, although these levels were considerably below the health benchmark for that pollutant. It appears that a source that is south or southwest of the site may contribute to these levels, but that source has not been identified. Since hexane levels at that site do not correlate with concentrations of BTEX substances, it is unlikely that these elevations are caused by mobile sources.
- Naphthalene levels were similar at all of the Warwick sites (slightly higher than the 10^{-6} cancer risk benchmark) and were lower at the Warwick sites than at the Urban League, Providence SVOC comparison site. Concentrations of the other SVOC PAHs, in BaP equivalents, were highest at the Fire Station and higher at all Warwick sites than at the Providence sites during the first two years evaluated (10/08 – 9/09 and 10/09 – 9/10). In the third year (10/10 – 9/11), concentrations at all Rhode Island sites dropped considerably, and levels at the Warwick sites were lower than at the Providence site. The profile of PAH species varied from site to site and from year to year. Further evaluation of those profiles and other factors may yield more information about the relative impacts of various mobile and stationary combustion sources on ambient PAH levels in Rhode Island. Note that no co-located SVOC samples are taken, so the significance of inter-site variations in PAH levels reported by RIAC cannot be determined.

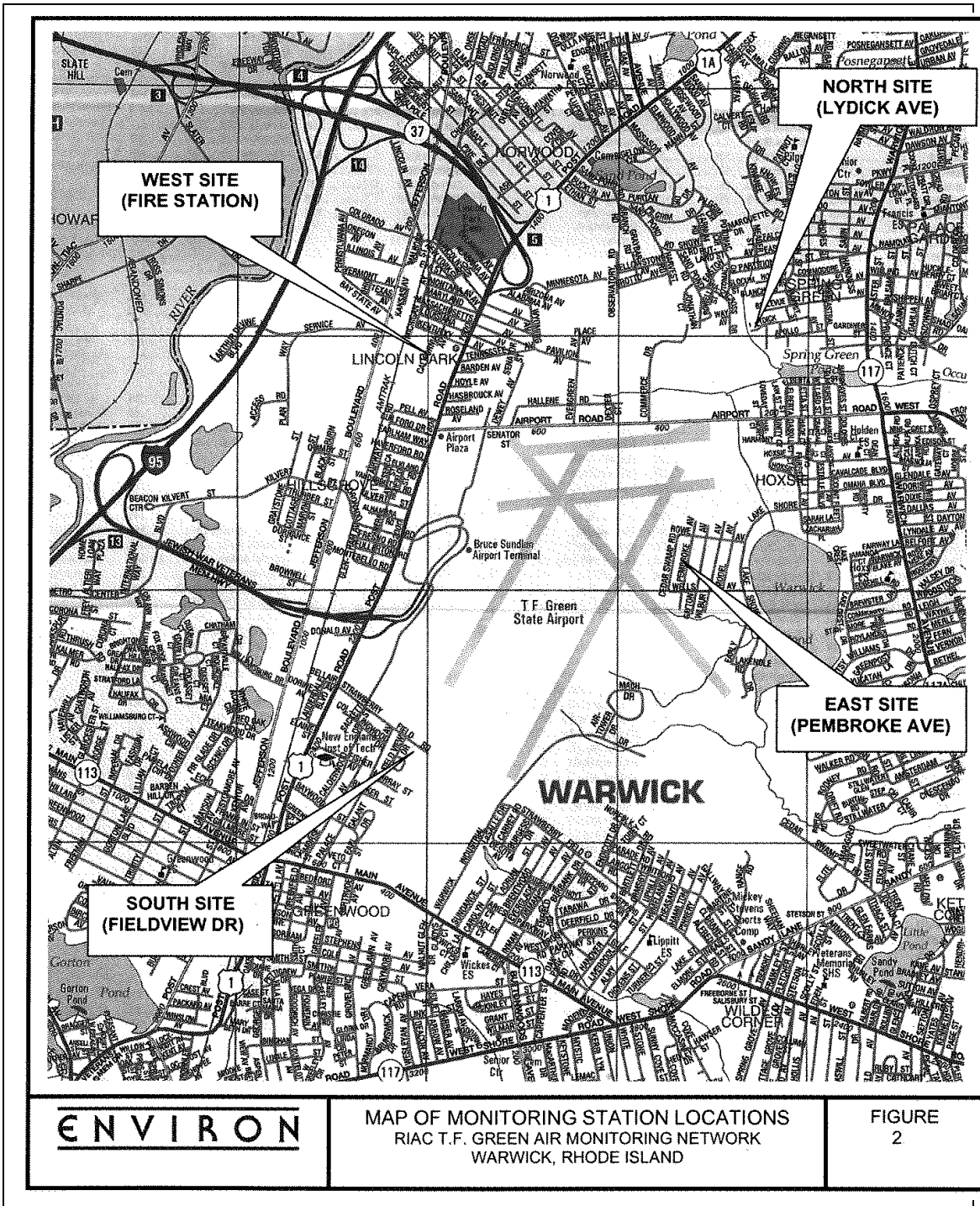
- Due to quality assurance/quality control concerns, PM_{2.5} FRM samples taken prior to October 2009 were not considered in the analysis. At all the Warwick sites, 98th percentile PM_{2.5} levels were lower than the 24-hour PM_{2.5} NAAQS and annual average PM_{2.5} levels were lower than the annual average PM_{2.5} NAAQS for each of the two years with valid measurements. The 98th percentile levels at the Warwick sites were higher than at the comparison sites, but since no co-located samples were taken, the significance of this difference cannot be determined. The possibility that airport activities may impact Warwick PM_{2.5} levels cannot be ruled out. RI DEM is considering collecting a small number of co-located PM_{2.5} samples at a RIAC location to further evaluate those findings.
- BC and particle-bound PAH levels, on average, were higher at the Fire Station and Lydick sites than at the Pembroke and Field View sites, while the reverse was true for PC. RI DEM conjectures that this is the case because the Fire Station and Lydick sites are located in more heavily traveled, more heavily populated areas than the other sites and are thus more impacted by vehicular traffic and stationary source combustion sources (e.g. residential and industrial heating) that contribute to BC and particle-bound PAH levels. Field View and Pembroke are closest to the opposite ends of the main runway, and are thus more likely to be impacted at close range by aircraft emissions. Ultrafine particles are emitted in very high quantities by aircraft, and concentrations of particle counts drop off rapidly with distance and time from the source as the particles agglomerate and disperse, so the monitors in the closest proximity to the runway would be the most heavily impacted by that source. Although BC and particle-bound PAH are also emitted by aircraft, measurements of those pollutants, which are reported in mass concentrations units, are reduced with distance only by dispersion, not by the reduction in particle number caused by agglomeration of small particles. Therefore, the impacts of emissions from aircraft and other sources on those parameters are seen at farther distances and for greater time periods than is the case with PC.
- Average BC levels at the Fire Station and Lydick sites were slightly higher than concurrent measurements at the Urban League comparison sites. However, it is not clear that this difference is significant. There are not enough concurrent data available to accurately compare PC and particle-bound PAH levels at the comparison sites with those at the Warwick sites.
- Average BC and particle-bound PAH levels at all Warwick sites and at the Providence comparison sites peak at the hour that begins at 7:00 AM, due to increased emissions associated with morning rush hour, combined with the poor dispersion conditions that are generally present at that hour.
- Average PC levels at the Fire Station and Lydick sites also peak in the 7:00 AM hour, but levels at the Field View and Pembroke sites peak in the 6:00 AM hour, when commercial aircraft flight activity begins.

- Average levels of BC, particle-bound PAH and PC levels are highest when wind speeds are low. Drop off of concentrations with wind speed is less dramatic for PC than for the other pollutants, probably because high particle counts are generally associated with nearby sources.
- BC-2 (black carbon measured using light in the UV range, commonly associated with fresh PAH emissions) and particle-bound PAH levels tend to be highest when temperatures are low, probably because of the inefficiency of startup of combustion processes and the increased use of wood stoves and other heating sources during cold weather conditions. PC and BC-1 do not show a clear relationship with temperature.
- Average PC levels are clearly linked to wind direction; at each Warwick site, average PC levels are higher than at the other Warwick sites when that site is downwind of the Airport. This is less evident for the Fire Station site, which is not as close to the ends of the main runway as are the other sites. This Airport effect is also seen for BC and particle bound-PAH measurements, but the impact of other sources on those measures largely obscure this effect.
- Levels of PC at the Warwick sites, particularly Field View and Pembroke, tend to show significant peaks beginning in the 6:00 AM hour on days that the site is downwind of the Airport. On some days, especially at Pembroke, clear peaks of BC and particle-bound PAH can also be seen at that hour, but on other days any elevations of BC and/or particle-bound PAH that may be associated with aircraft emissions are obscured by impacts of those pollutants from other sources.
- While PC is clearly the best indicator of local impacts from aircraft, BC and particle-bound PAH also provide useful information for evaluating sources and composition of particulate matter in the area. Due to the large amount of these data that have been collected, there is considerable opportunity available for a more detailed analysis of those impacts.
- This report and the database, which contains all monitoring data as well as meteorological and airport activity data and information on the pollutants measured, will be made available to the RI DOH and to any other interested entity for further study and evaluation.

Appendix A

Figures





From the "TF Green Airport Long Term Air Monitoring System Quality Assurance Plan," prepared by Environ International Corp., 2008.

Figure 3 Distribution of Relative Error in 2008-2011 RIAC Duplicates from Warwick Sites and in 2011 RI DOH Duplicates from East Providence (EP) Site

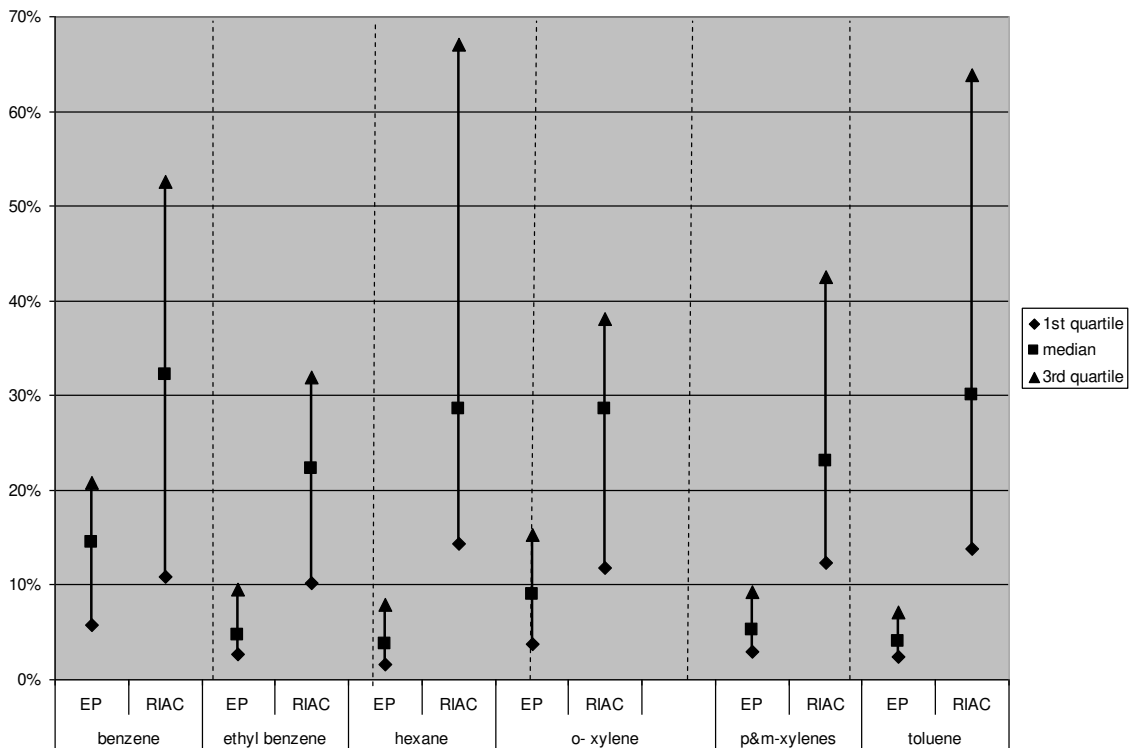
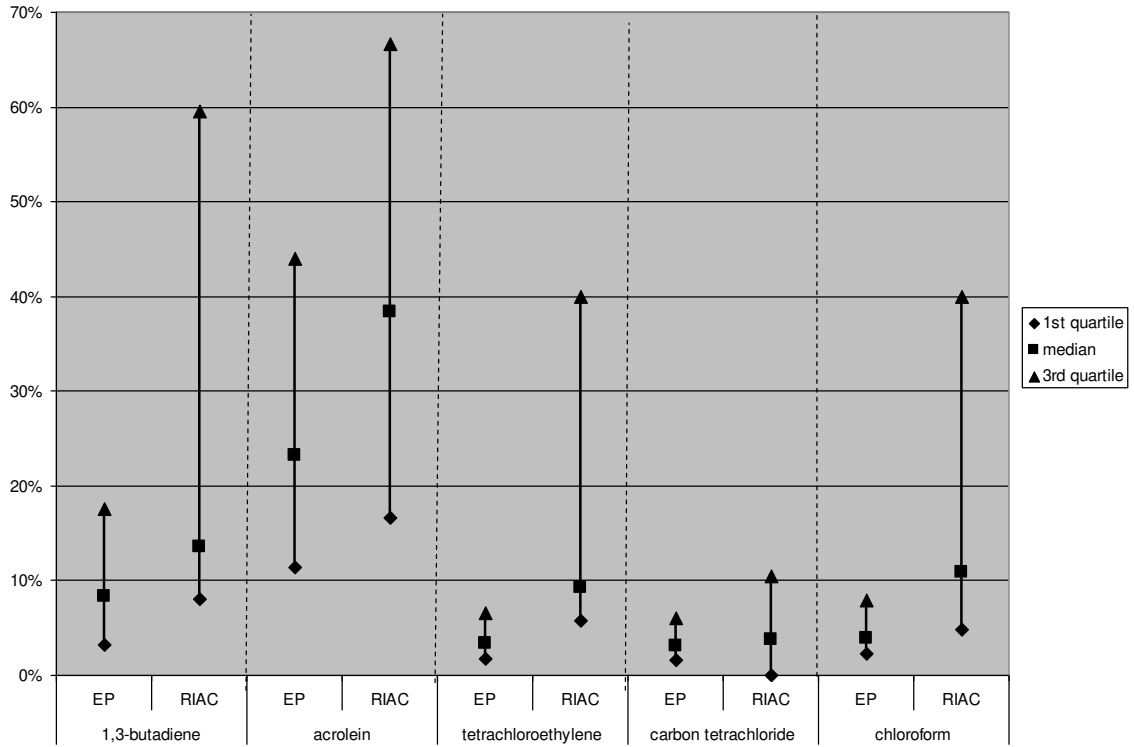


Figure 4 Distribution of Relative Error in 2008-2011 Warwick Carbonyl Samples: Duplicates Analyzed by RIAC Contractor (RIAC-RIAC Comparisons) and by RIDOH (RIAC-RIDOH Comparisons)

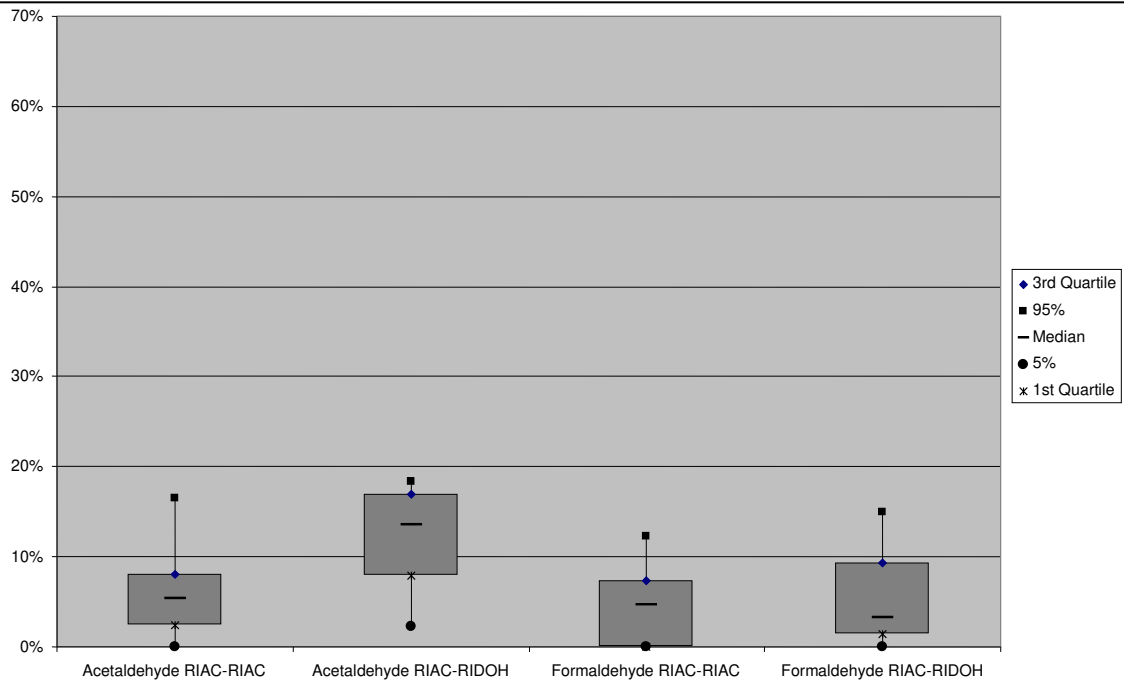
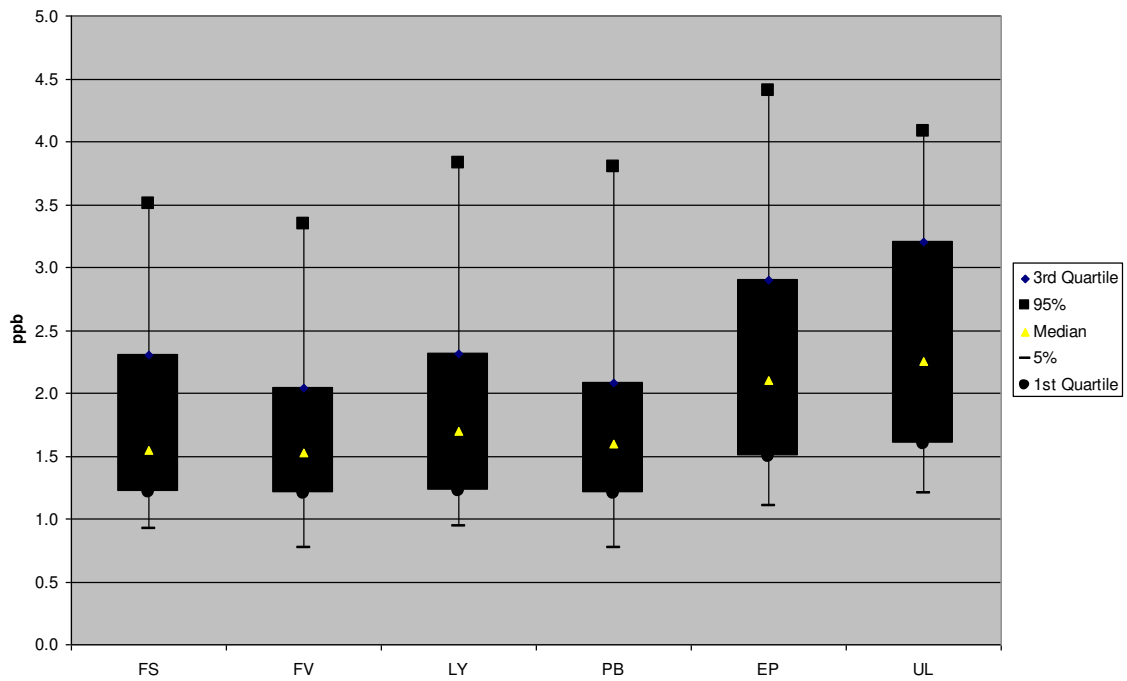


Figure 5 Distribution of Formaldehyde Concentrations



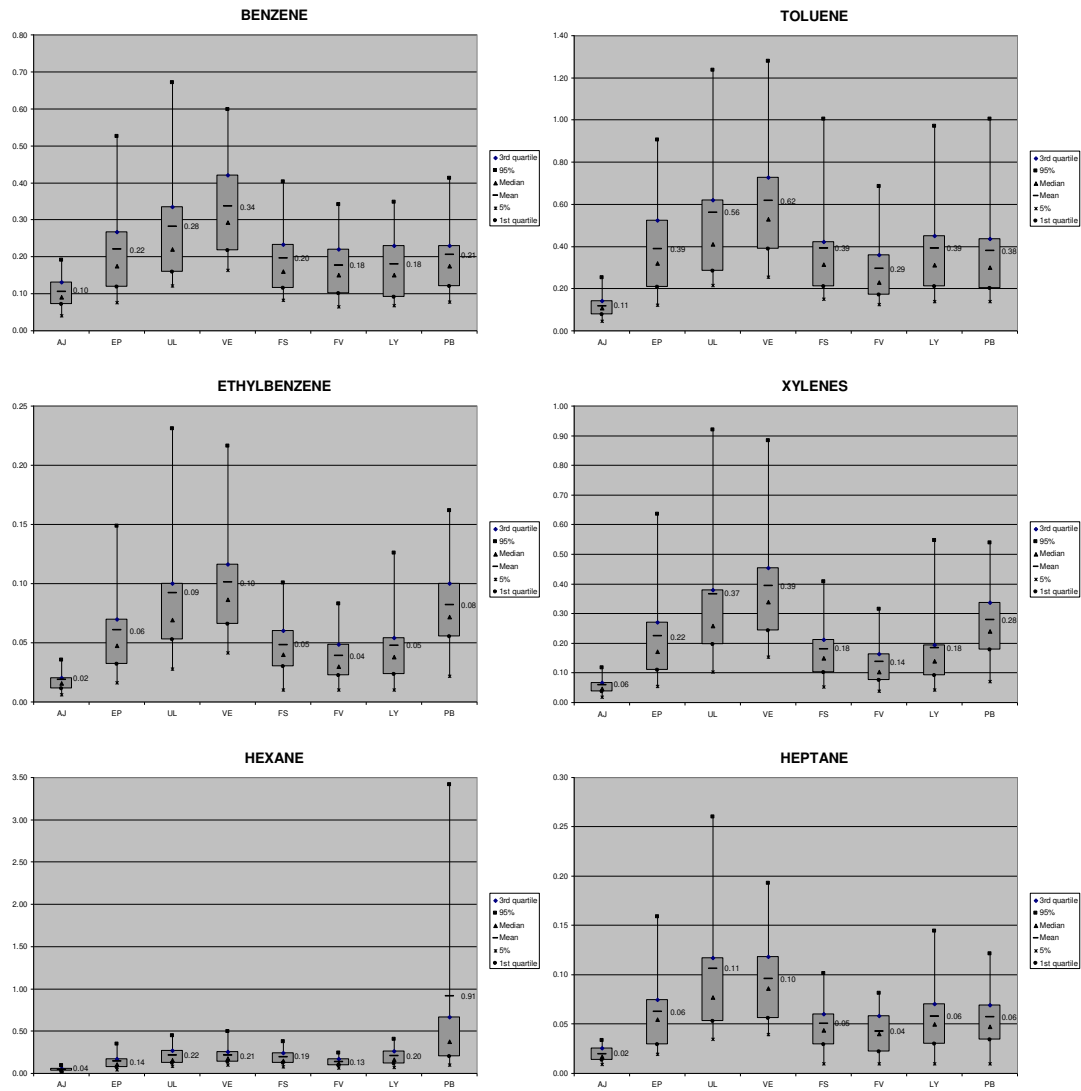


Figure 6 Mobile Source Pollutant Concentration Distributions for Comparison Sites; Alton Jones (AJ), East Providence (EP), Urban League (UL) and Vernon St. (VE) and Airport Sites; Fire Station (FS), Field View (FV), Lydick (LY) and Pembroke (PB)

Figure 7 Relative Error for Hexane at Warwick and East Providence Sites

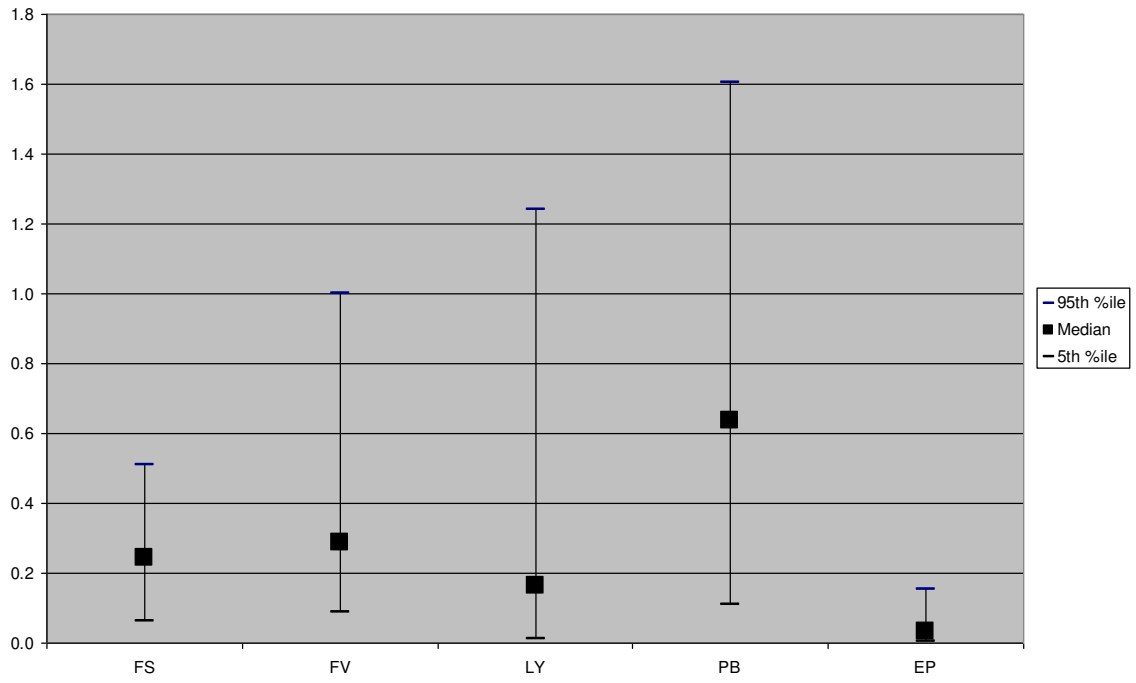


Figure 8 NAPHTHALENE CONCENTRATIONS (Mean +/- SD)

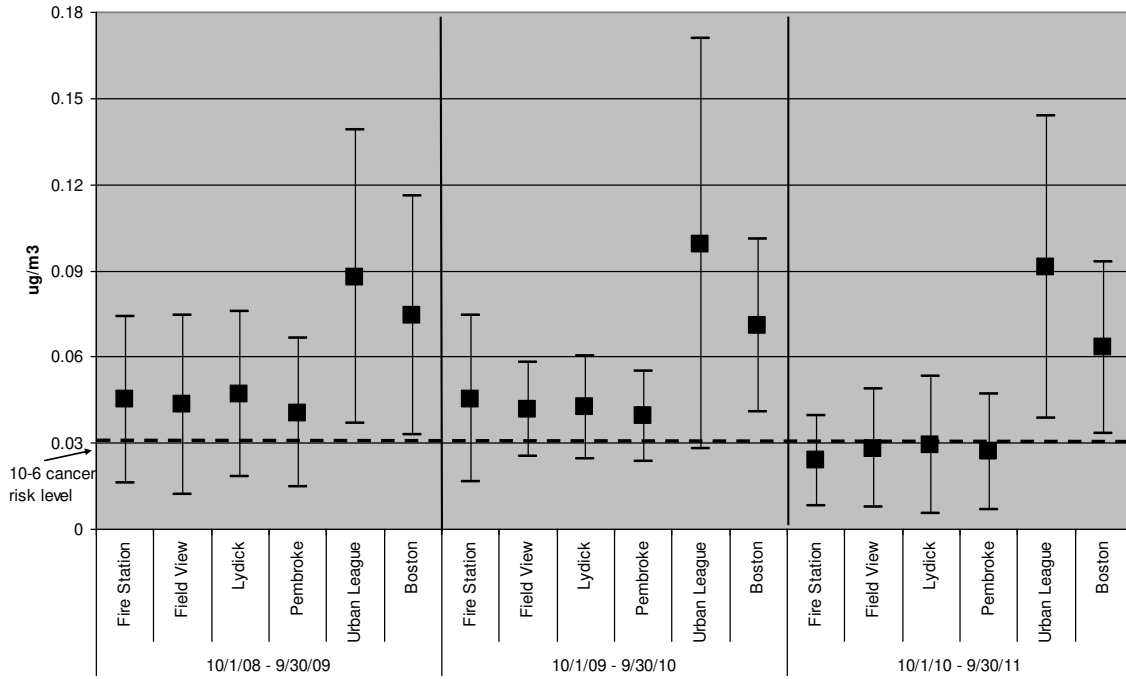


FIGURE 9 BENZO(A)PYRENE EQUIVALENTS

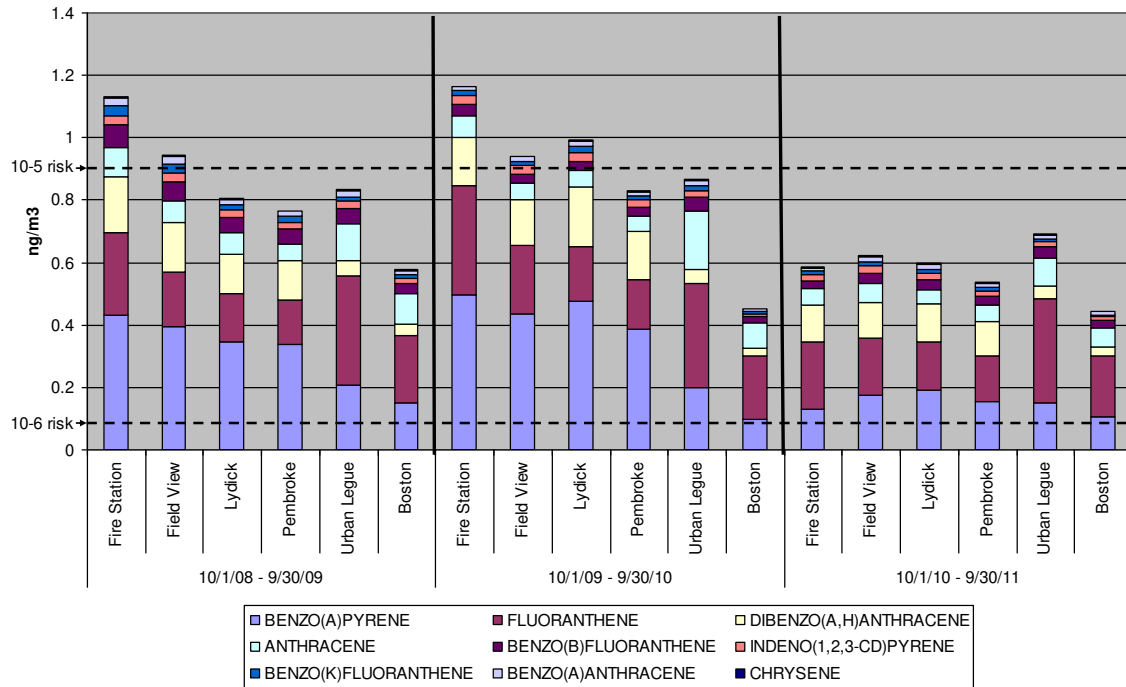


Figure 10 PM2.5 Field and Trip Blanks 6/08 - 9/11

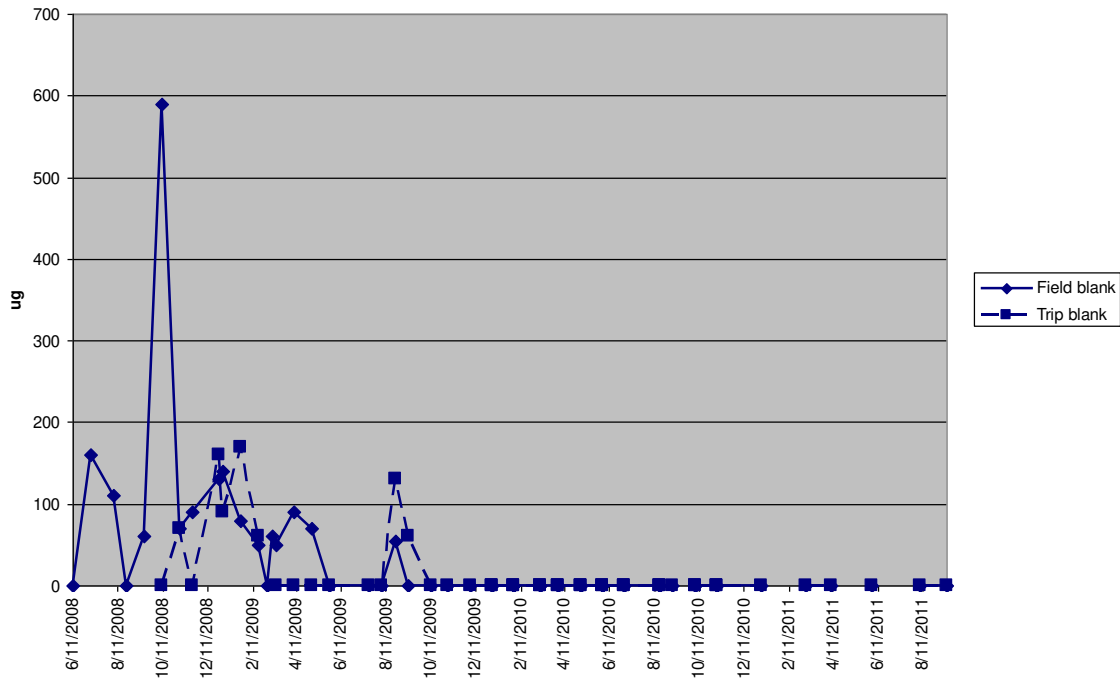


Figure 11 Absolute Relative Error - Black Carbon Primary & Colo - Pembroke Site

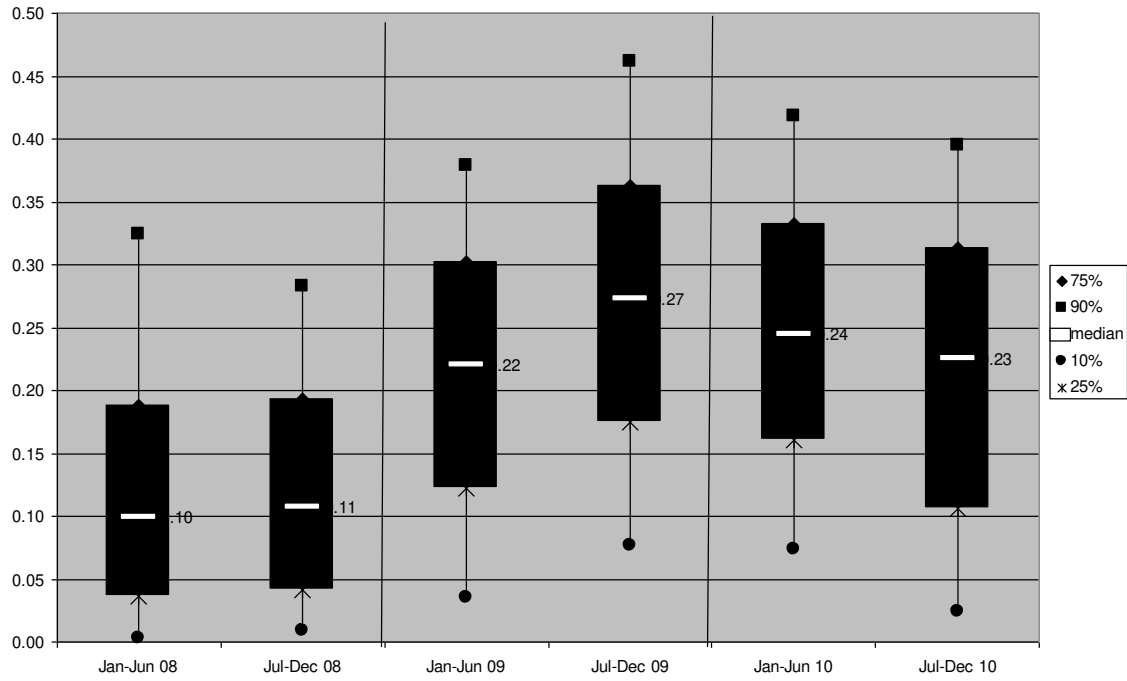


Figure 12 Relative Error - Black Carbon Primary & Colo at Pembroke Site
Positive value indicates that colo is reading higher than primary

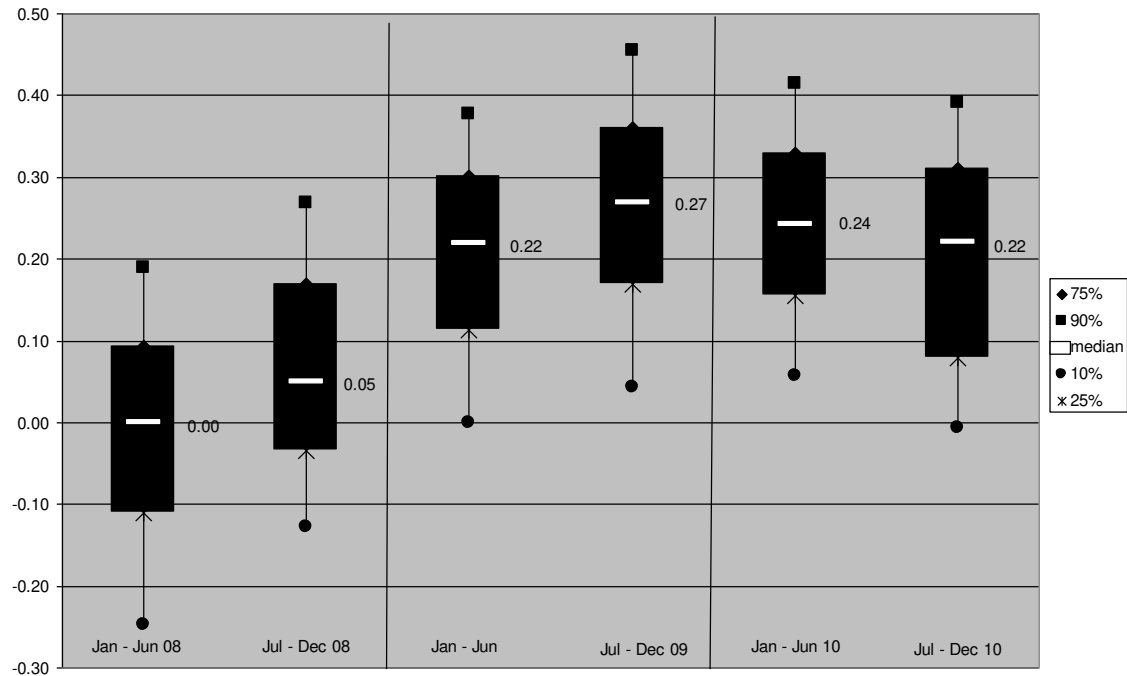


Figure 13 Annual Mean and 98th Percentile PM2.5 Concentrations
 Short-term NAAQS = 35 ug/m3, 98th percentile value, averaged over 3 years
 Long-term NAAQS = 15 ug/m3, annual mean, averaged over 3 years

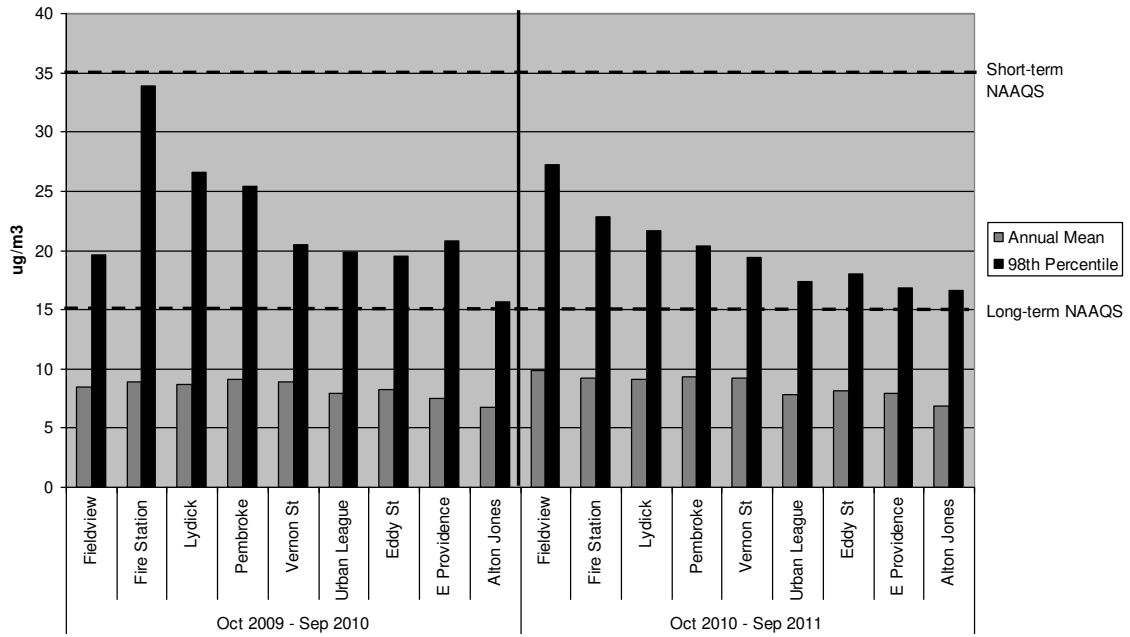


Figure 14a PM2.5 Concentrations October 2009 - November 2010

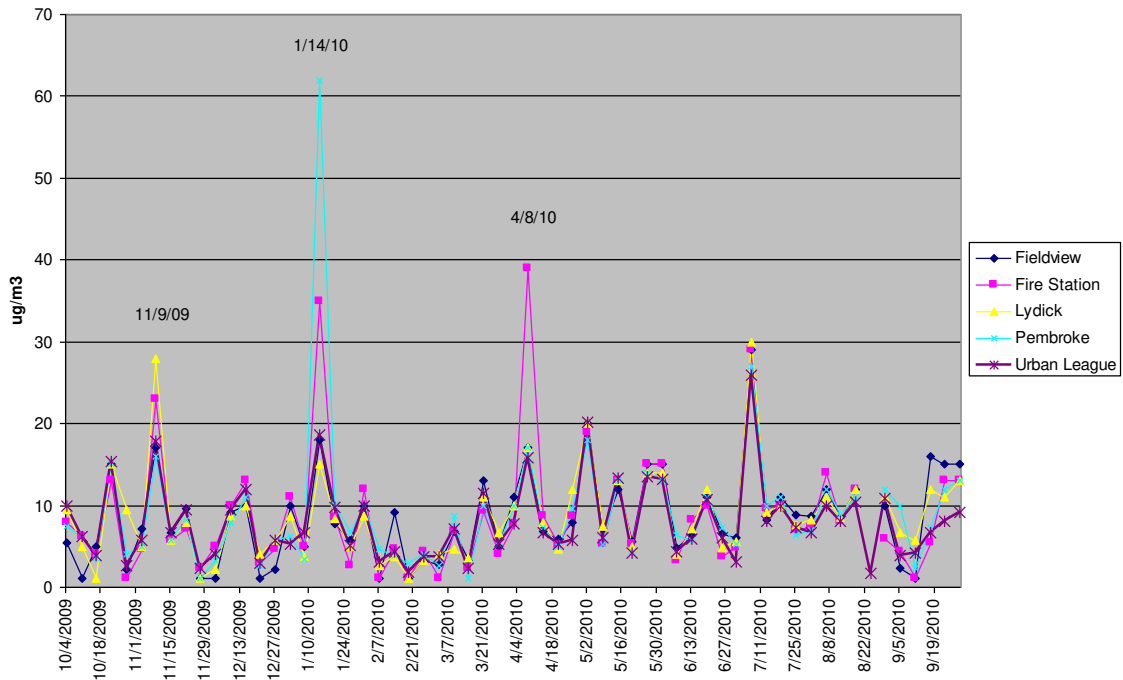


Figure 14 b PM2.5 Concentrations October 2010 - September 2011

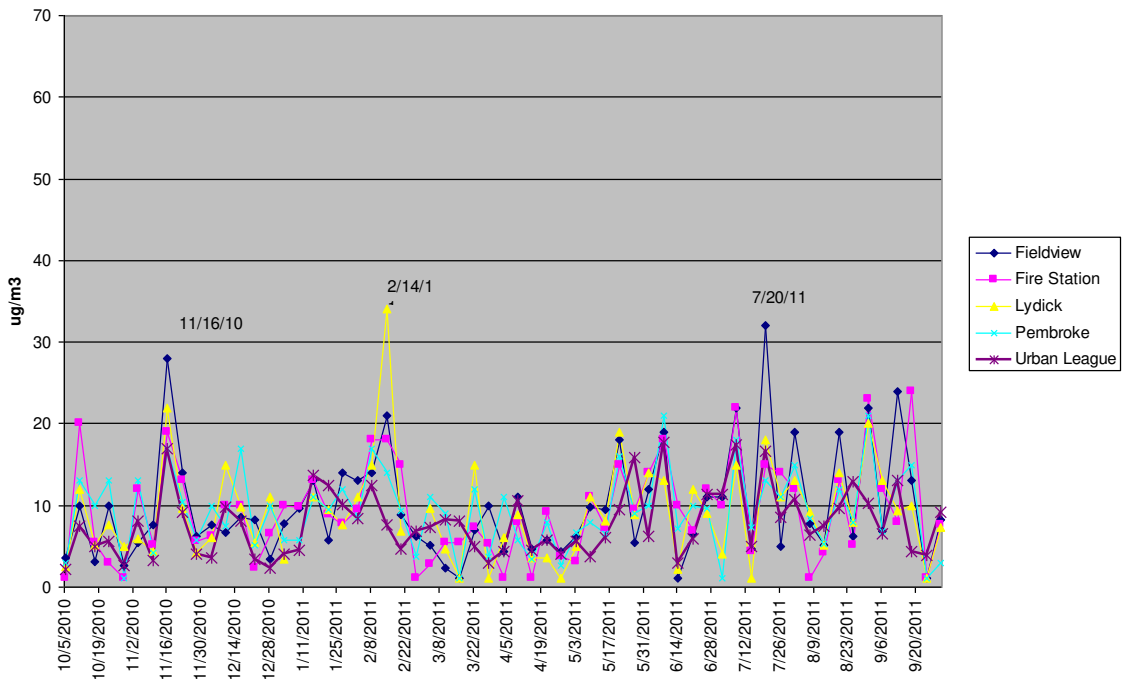


Figure 15 Black Carbon Concentrations for Hours with Data at All Warwick Sites.

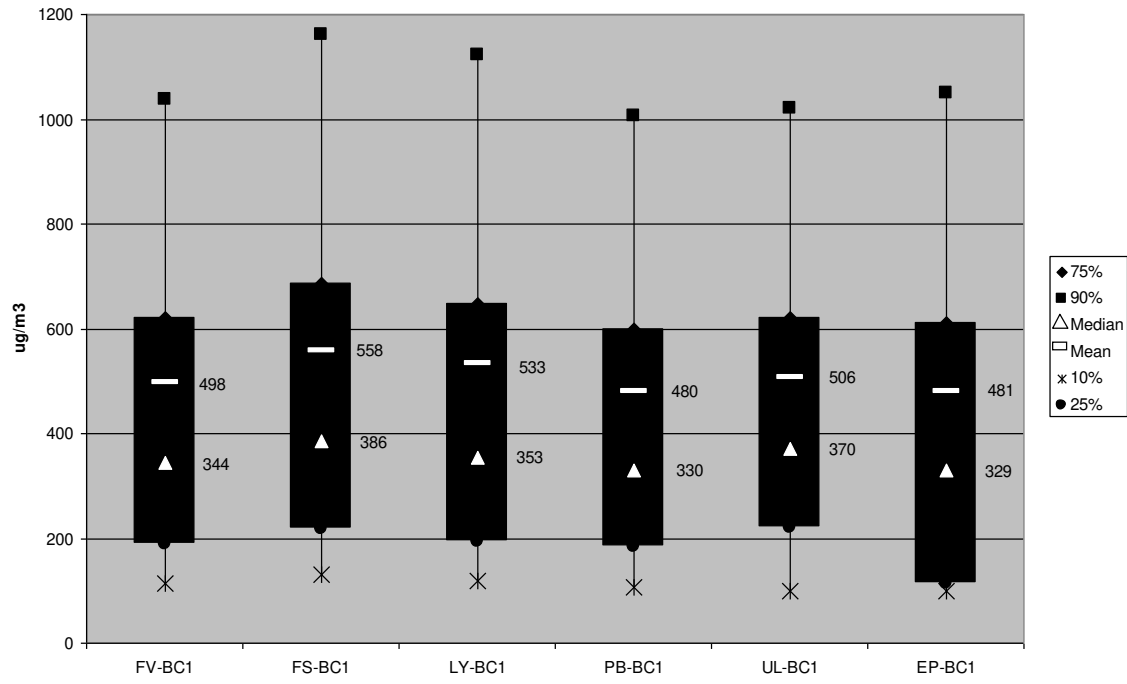


Figure 16a Particle-Bound PAH Concentrations for Hours with Data at All Warwick Sites.

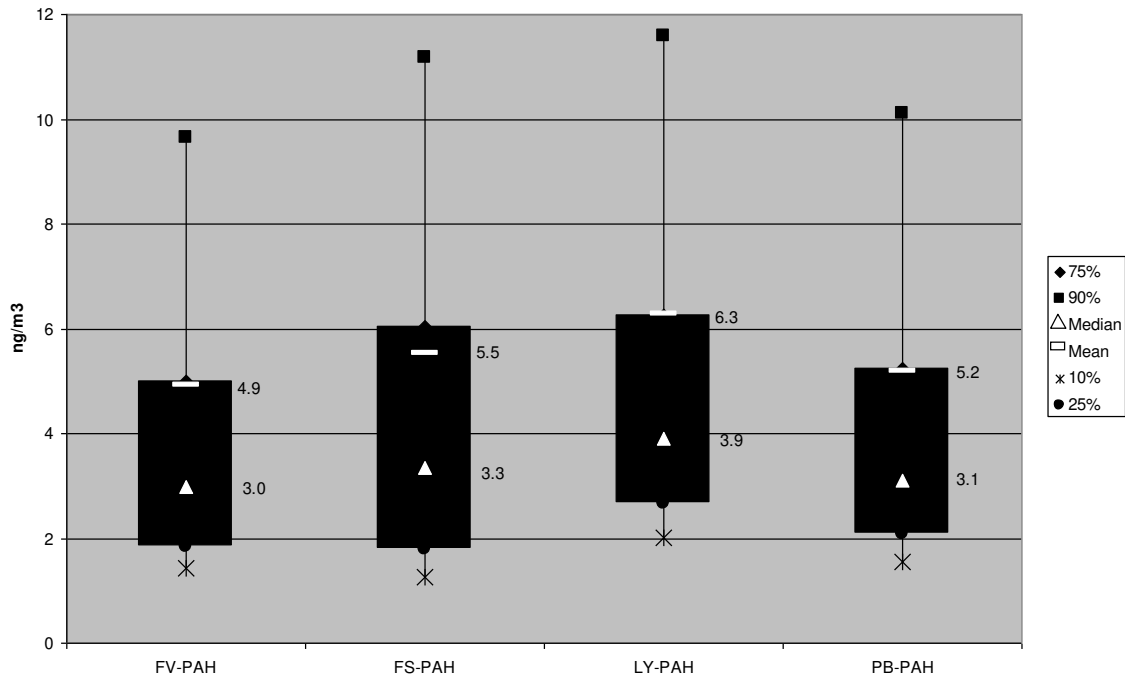


Figure 16b Particle-Bound PAH Concentrations for Hours with Data at E Providence and/or Urban League Comparison Site

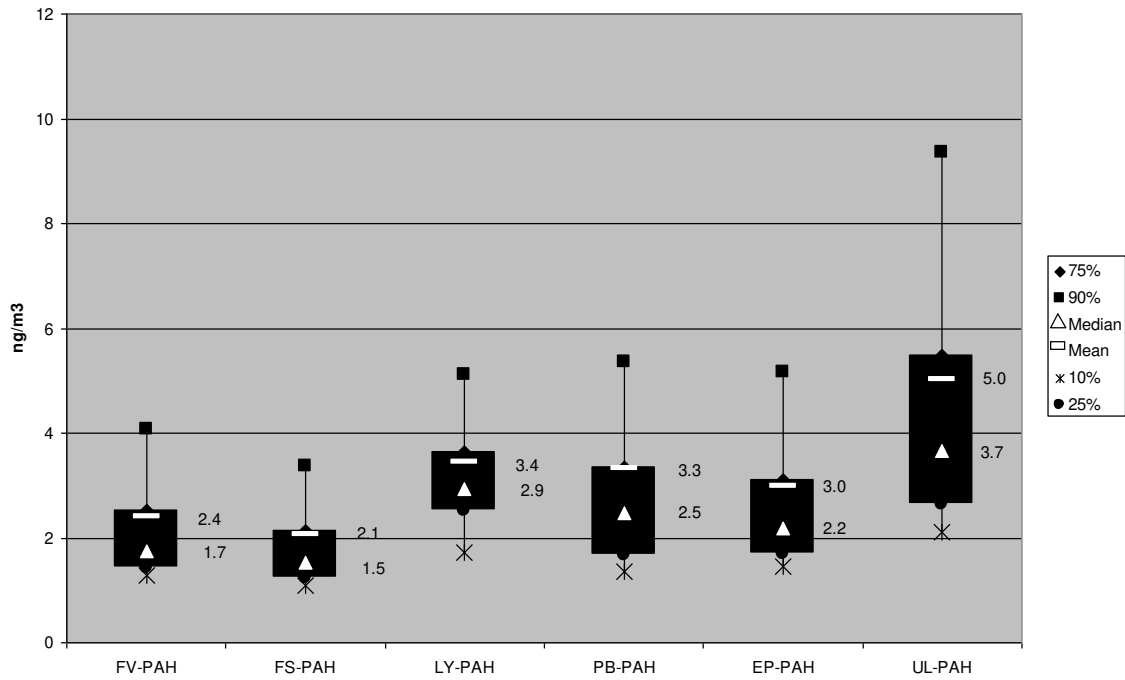


Figure 17a Particle Counts for Hours with Data at all Warwick Sites

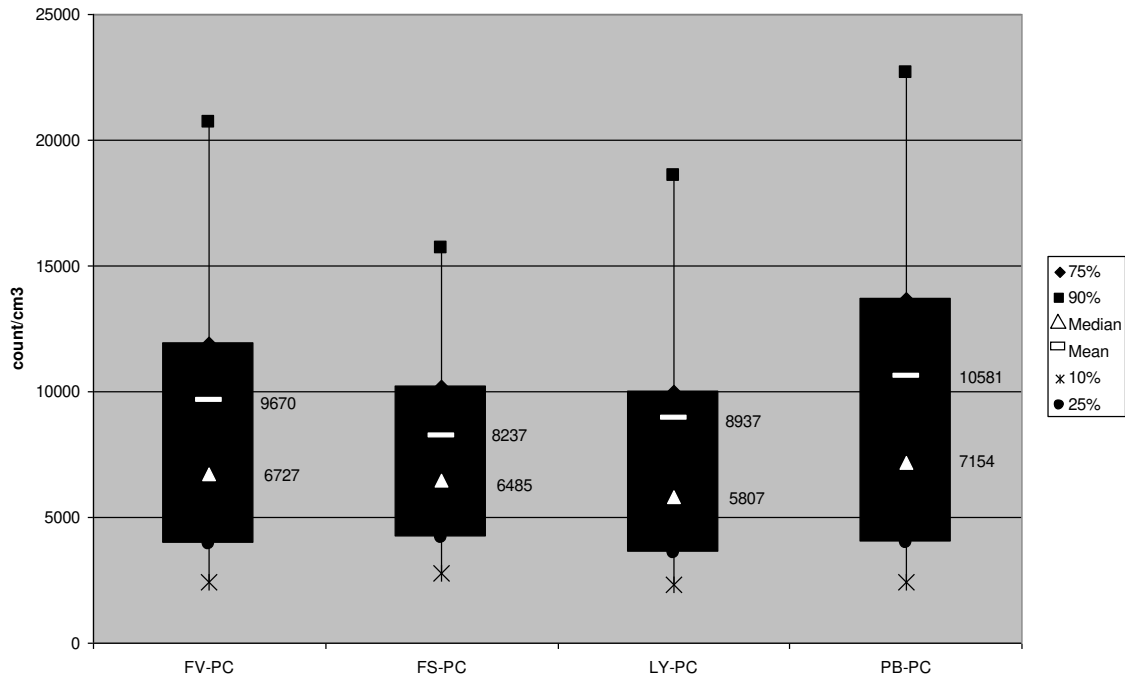


Figure 17b Particle Counts for Hours with Data at E Providence and/or Urban League Comparison Site

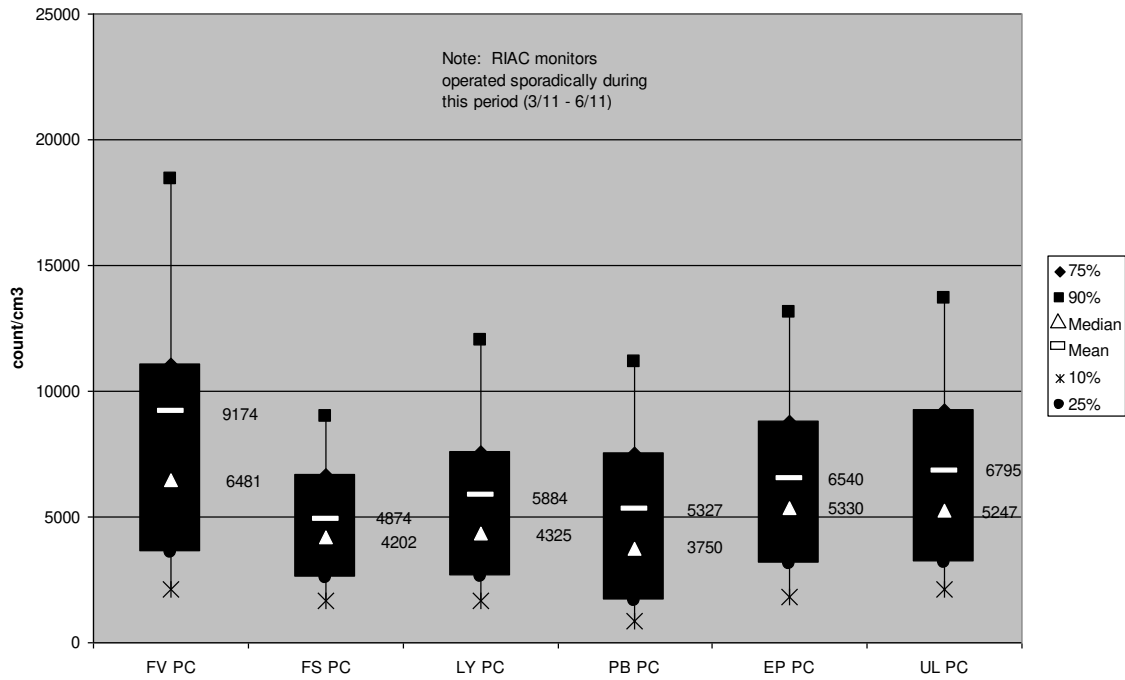


Figure 18a Average Weekday Black Carbon Levels by Time of Day

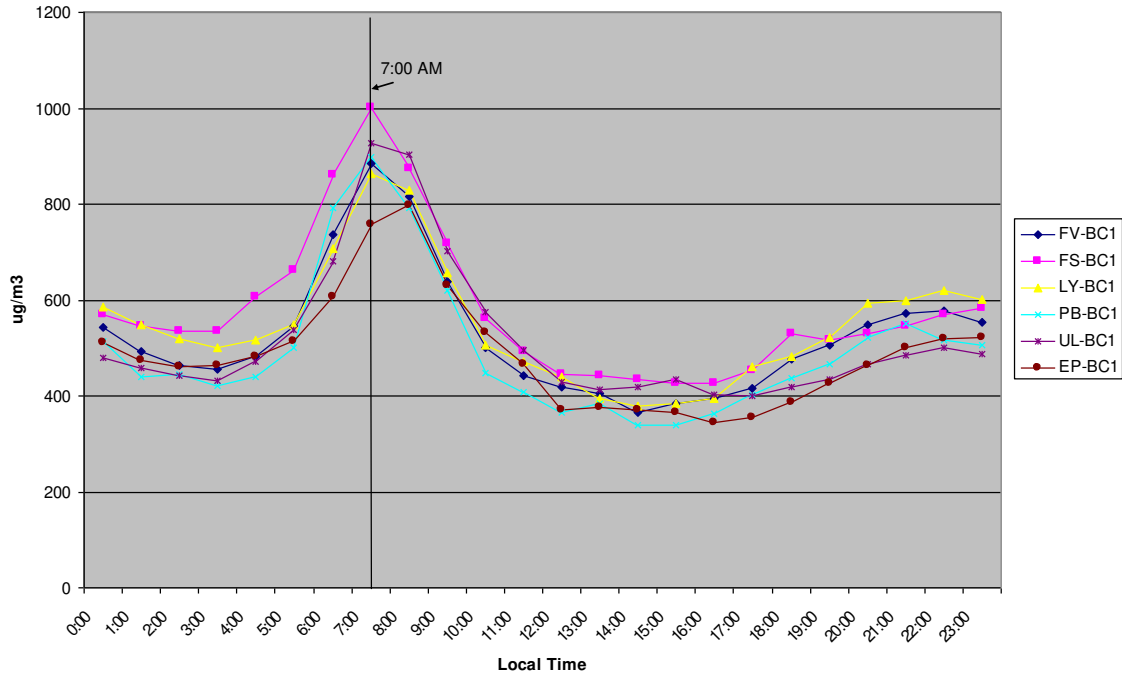


Figure 18b Average Weekend Black Carbon Levels by Time of Day

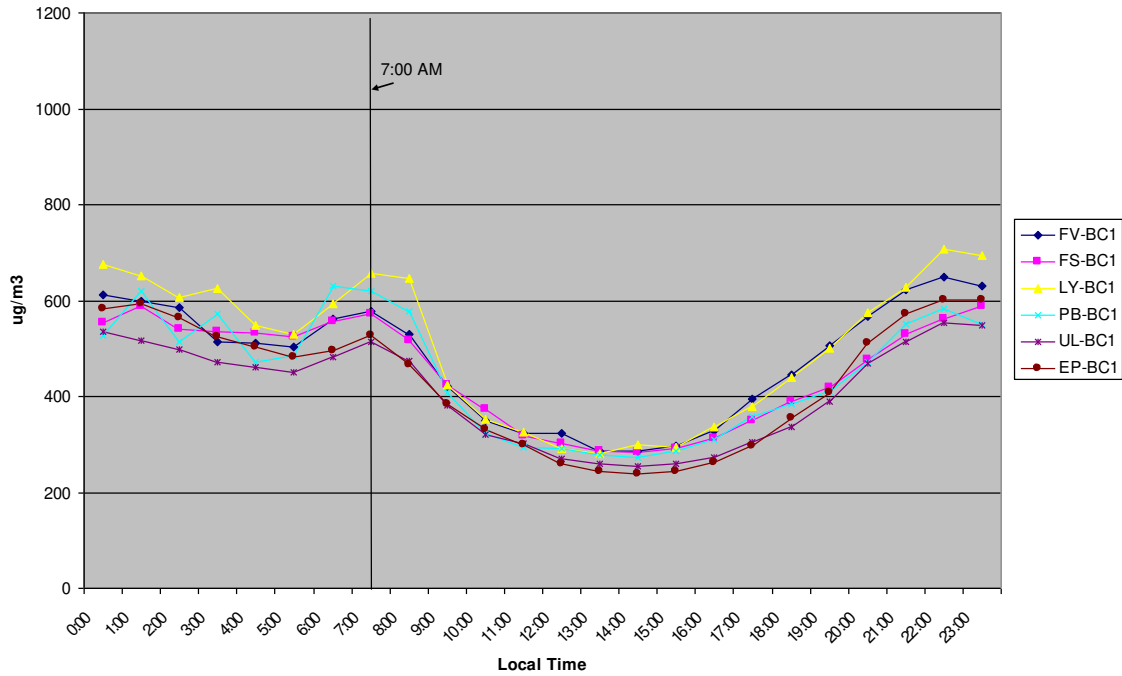


Figure 19a Average Weekday Particle-bound PAH by Time of Day

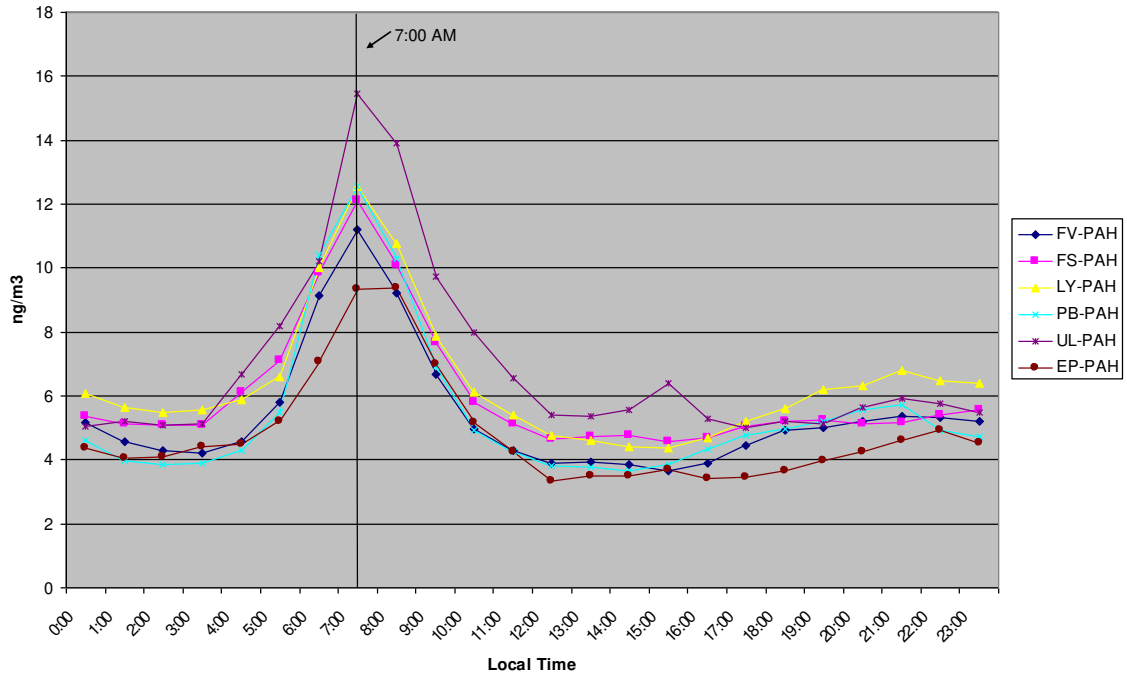


Figure 19b Average Weekend Particle-bound PAH by Time of Day

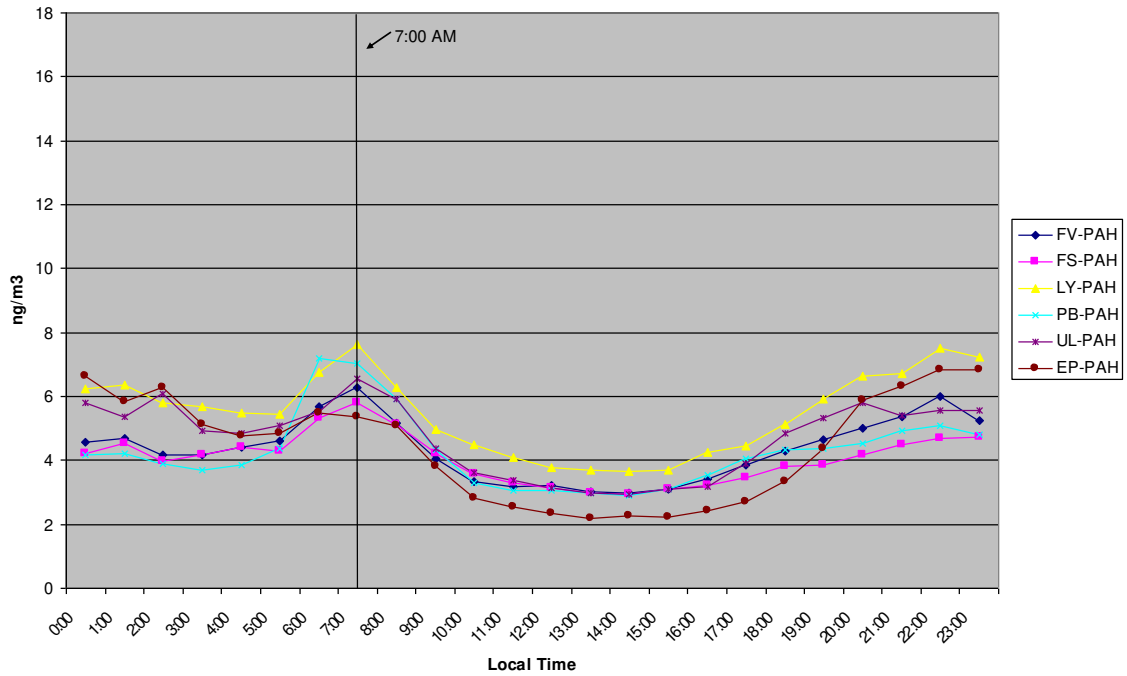


Figure 20a Average Weekday Particle Count by Time of Day

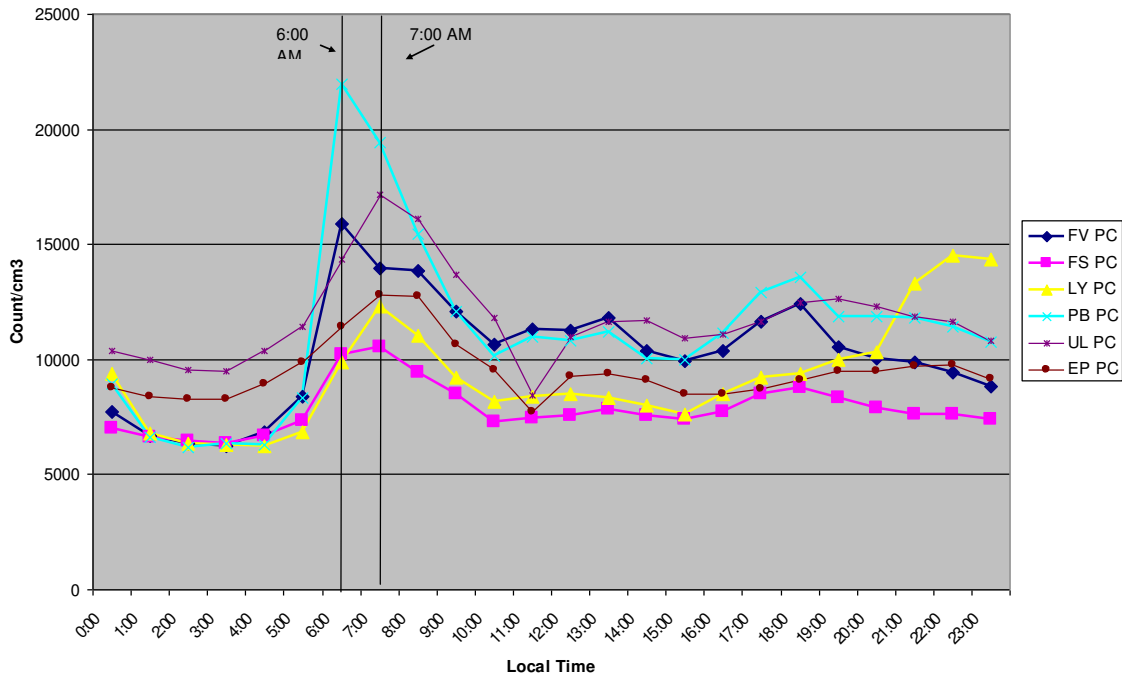


Figure 20b Average Weekend Particle Count by Time of Day

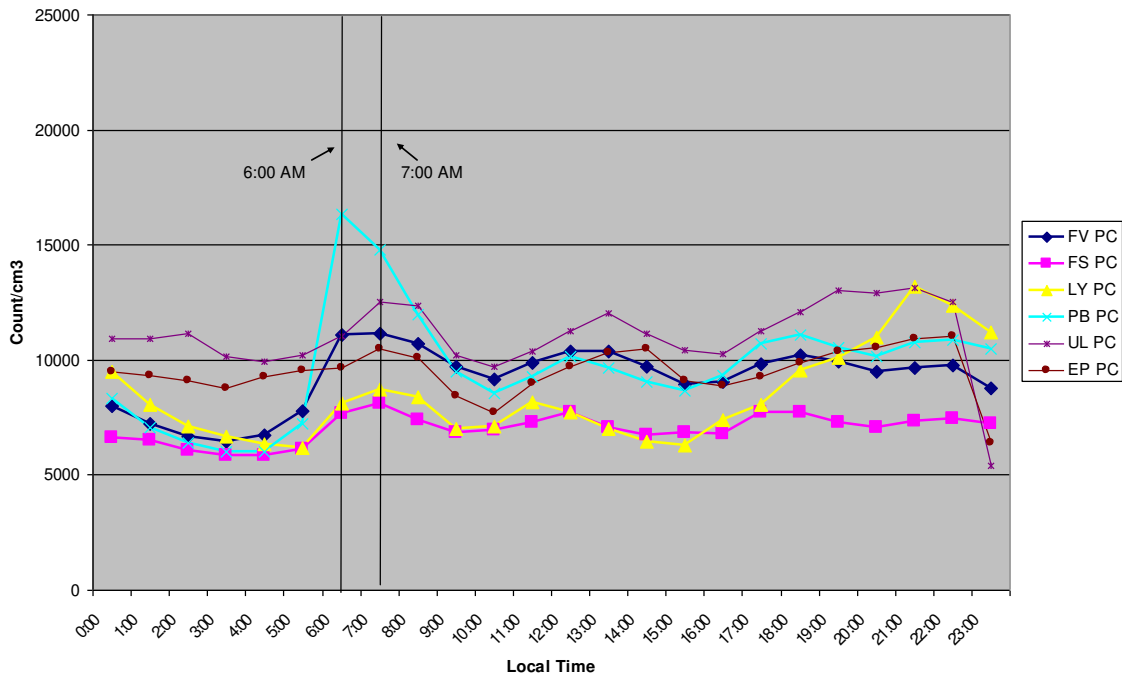


Figure 21a Average Black Carbon-1 by Wind Speed

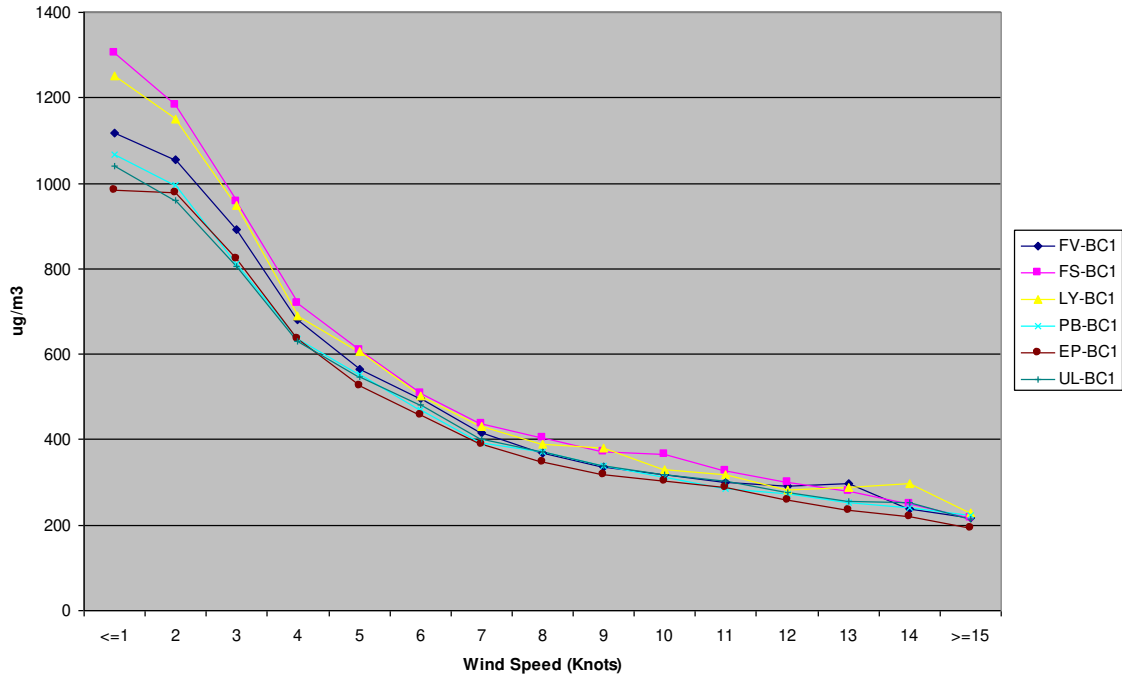


Figure 21b Average Black Carbon-2 by Wind Speed

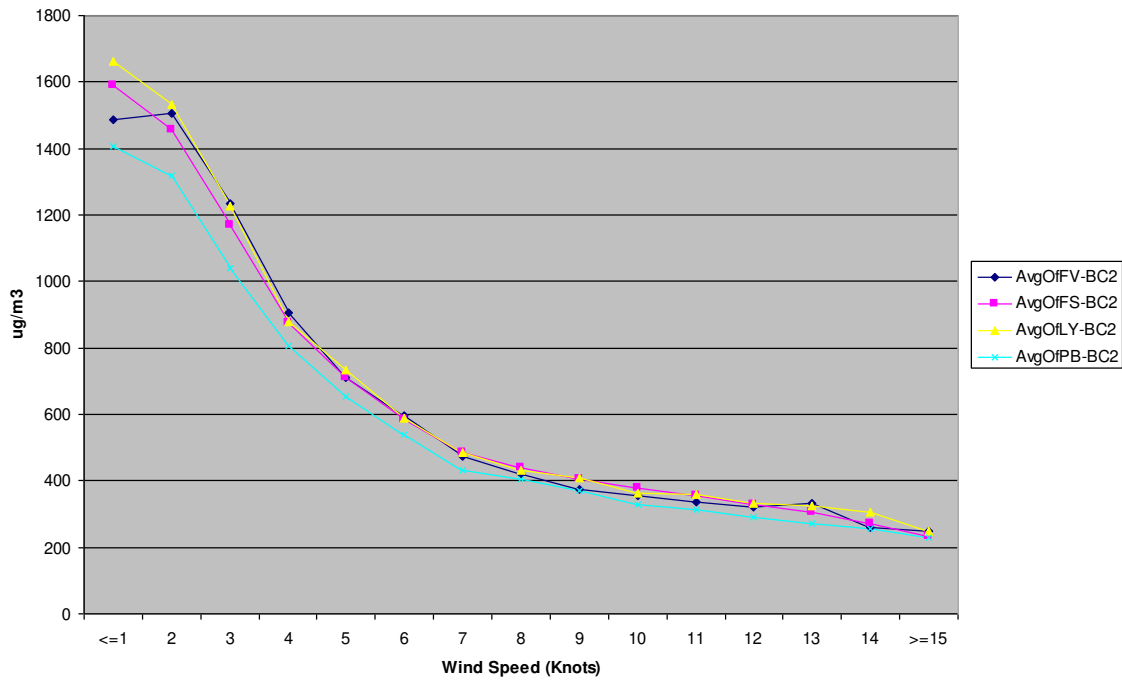


Figure 22 Average Particle-Bound PAH by Wind Speed

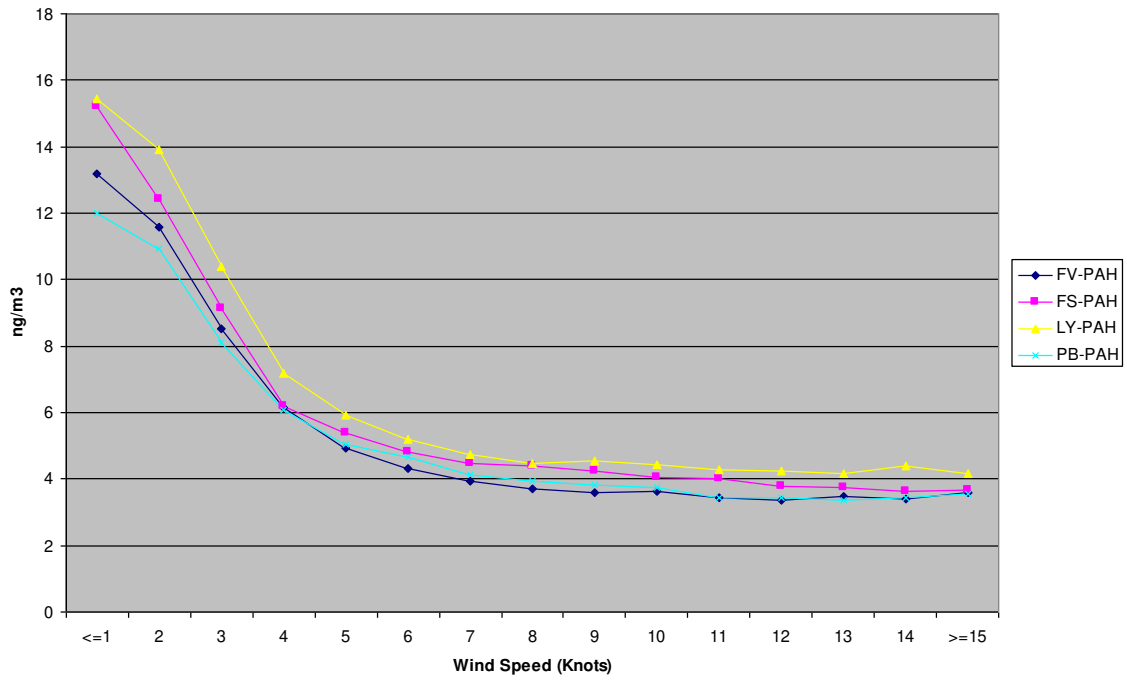


Figure 23 Average Particle Count by Wind Speed

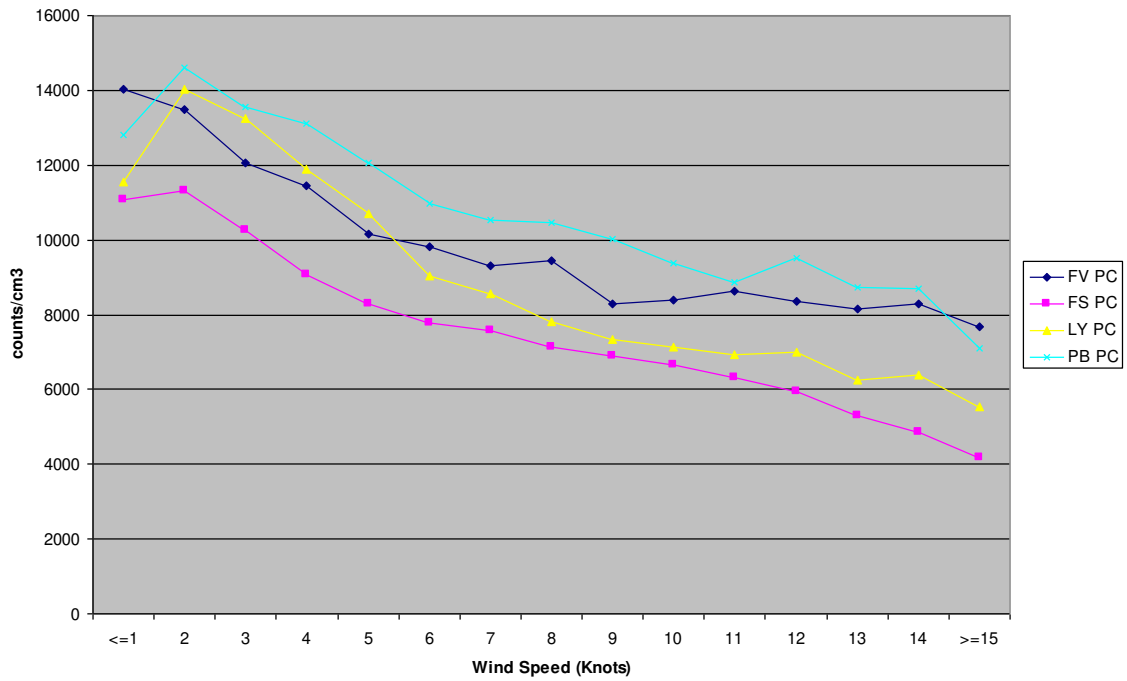


Figure 24a Average Black Carbon-1 by Temperature

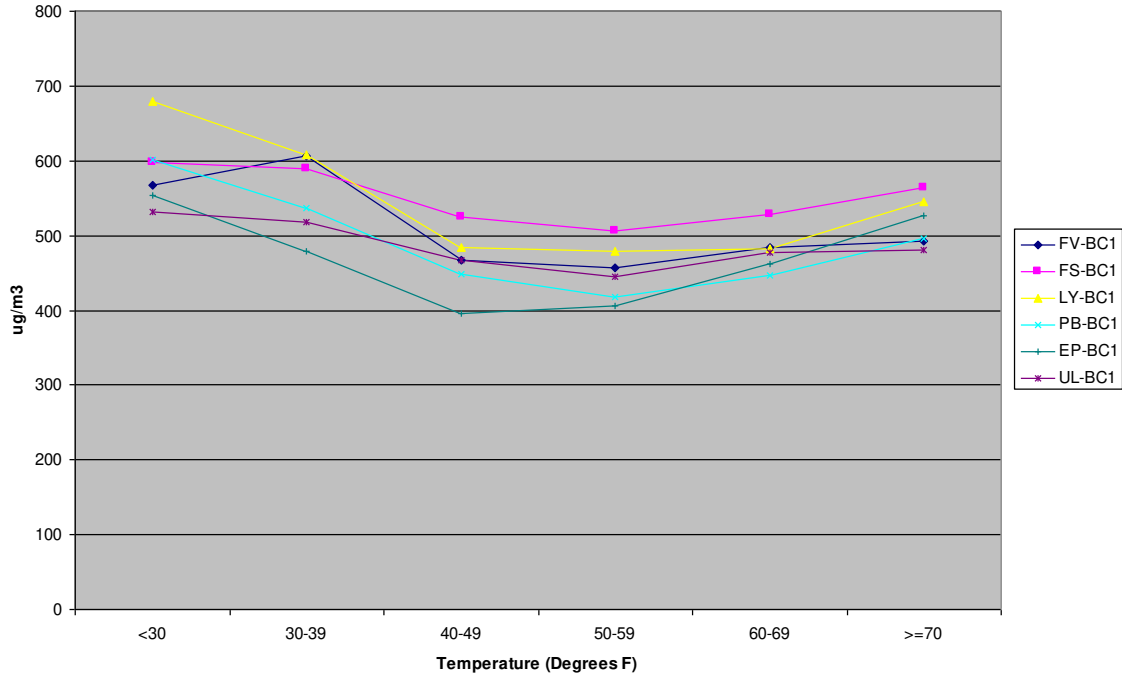


Figure 24b Average Black Carbon-2 by Temperature

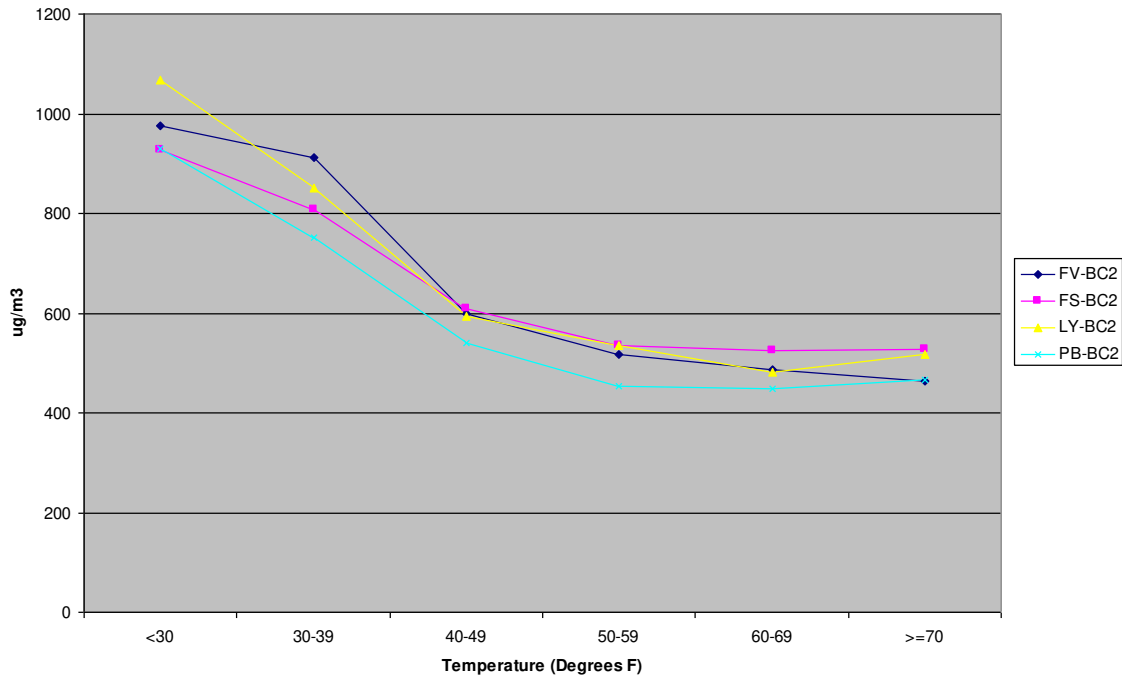


Figure 25 Average Particle-Bound PAH by Temperature

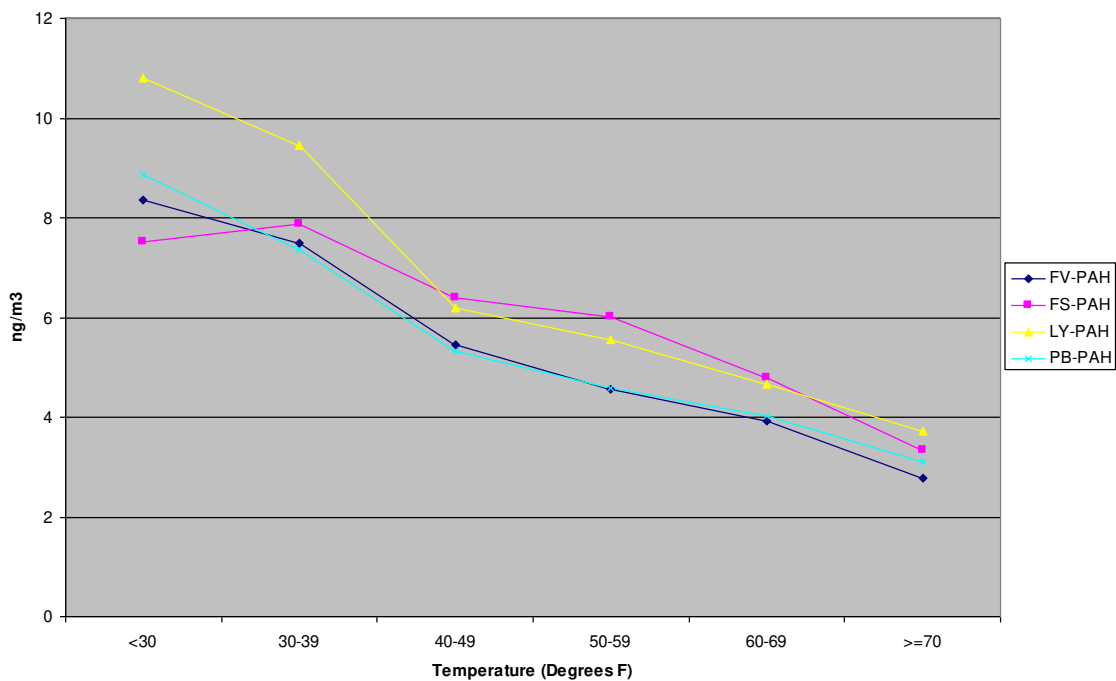


Figure 26 Average Particle Count by Temperature

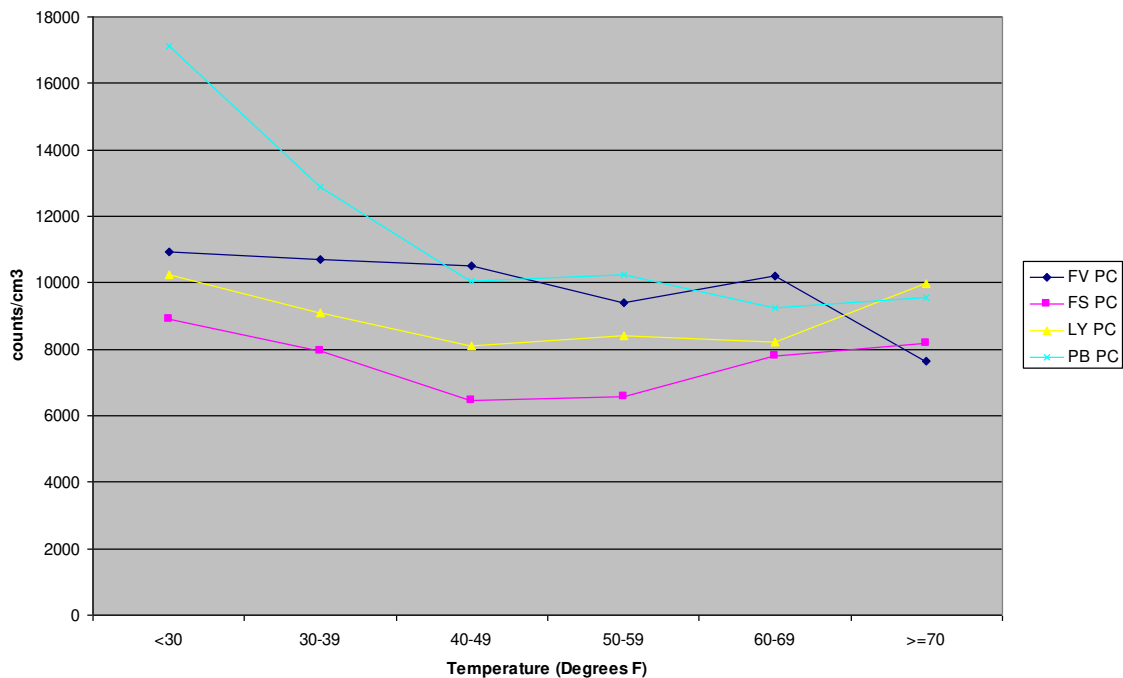


Figure 27a Average Black Carbon -1 by Wind Direction

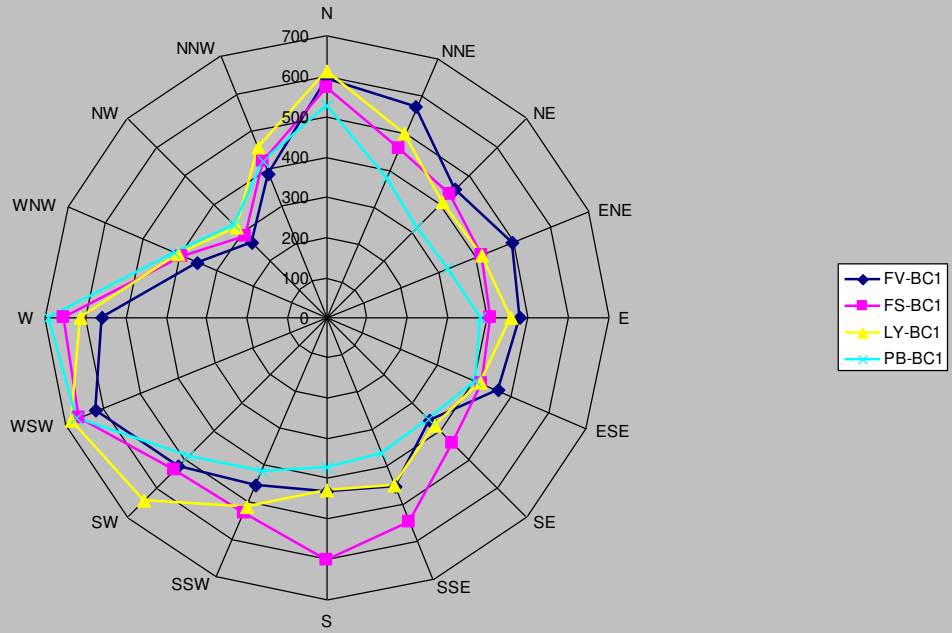


Figure 27b Average Black Carbon-2 by Wind Direction

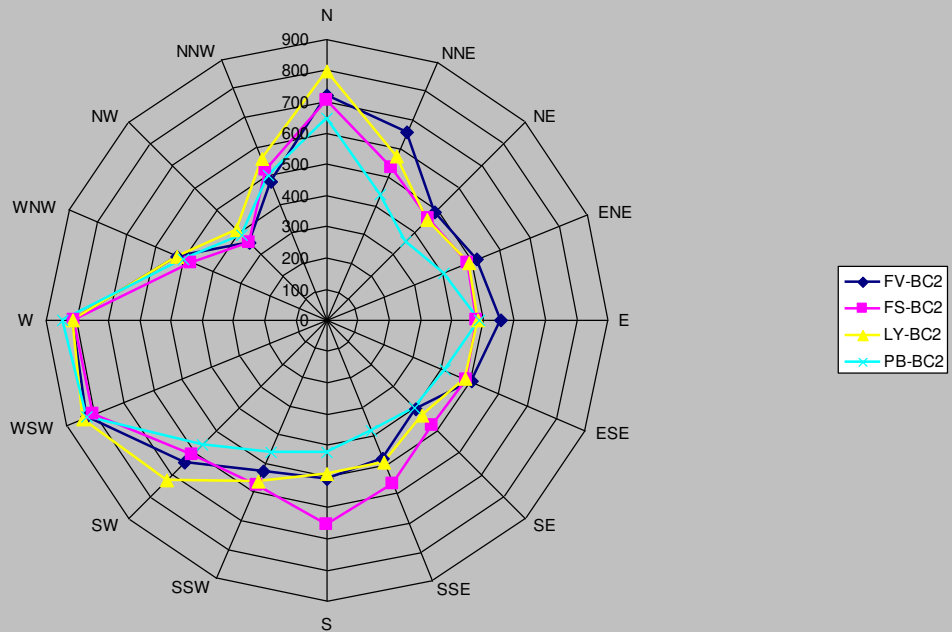


Figure 28 Average Particle-Bound PAH by Wind Direction

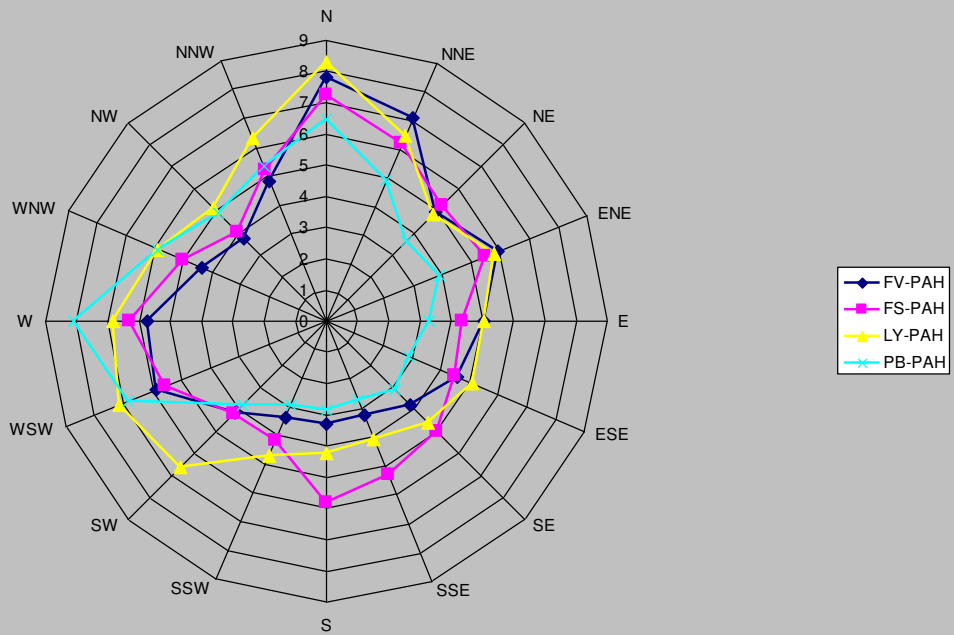
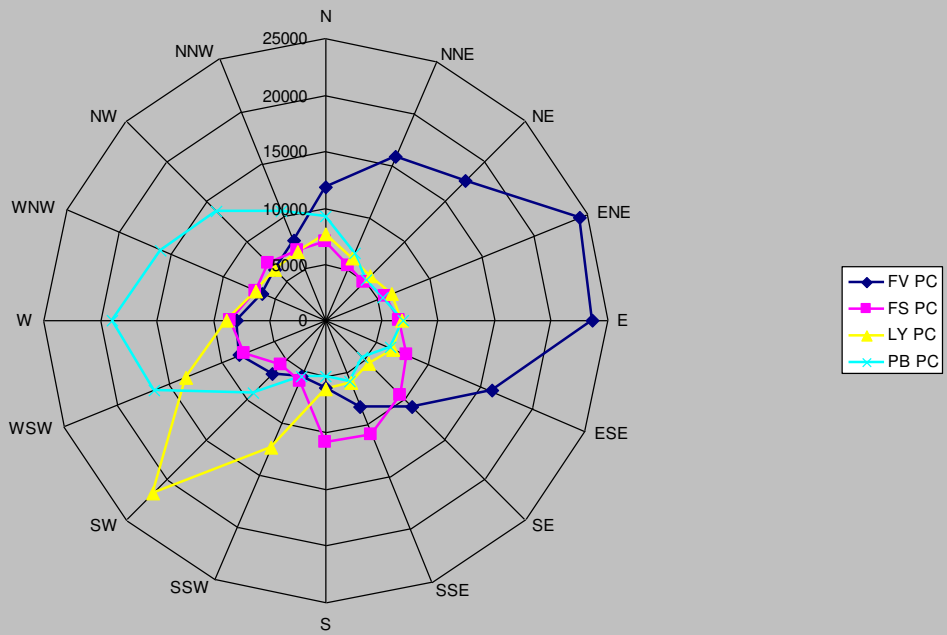


Figure 29 Average Particle Count by Wind Direction



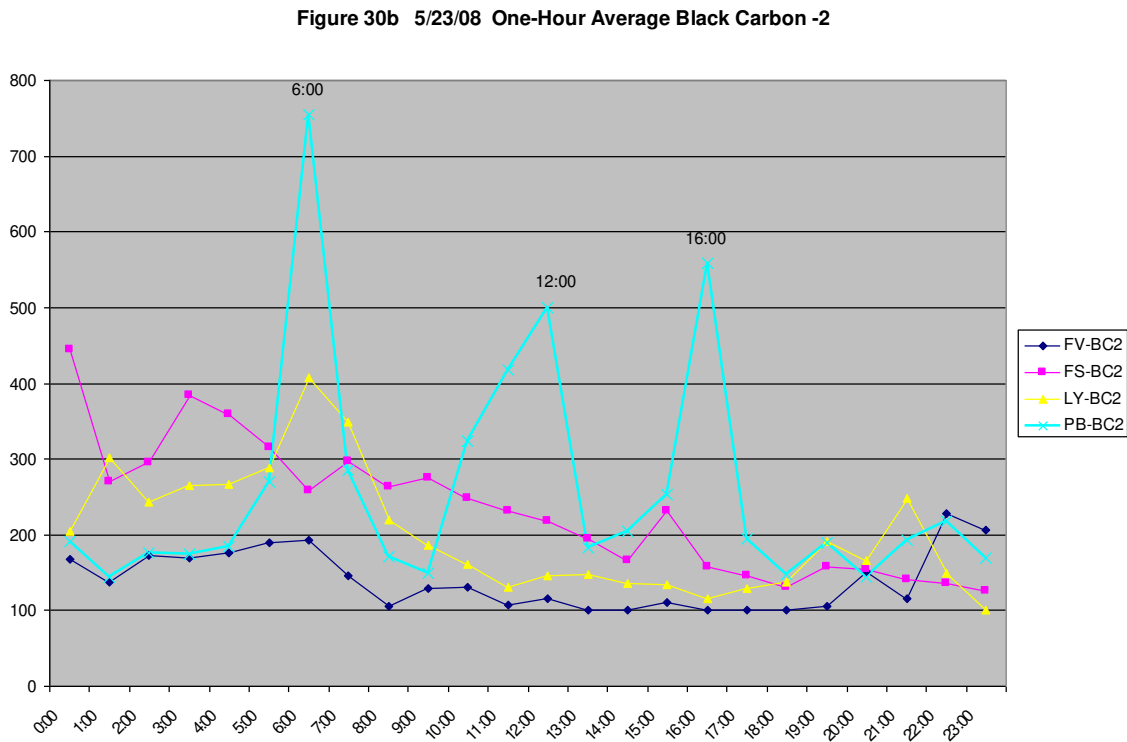
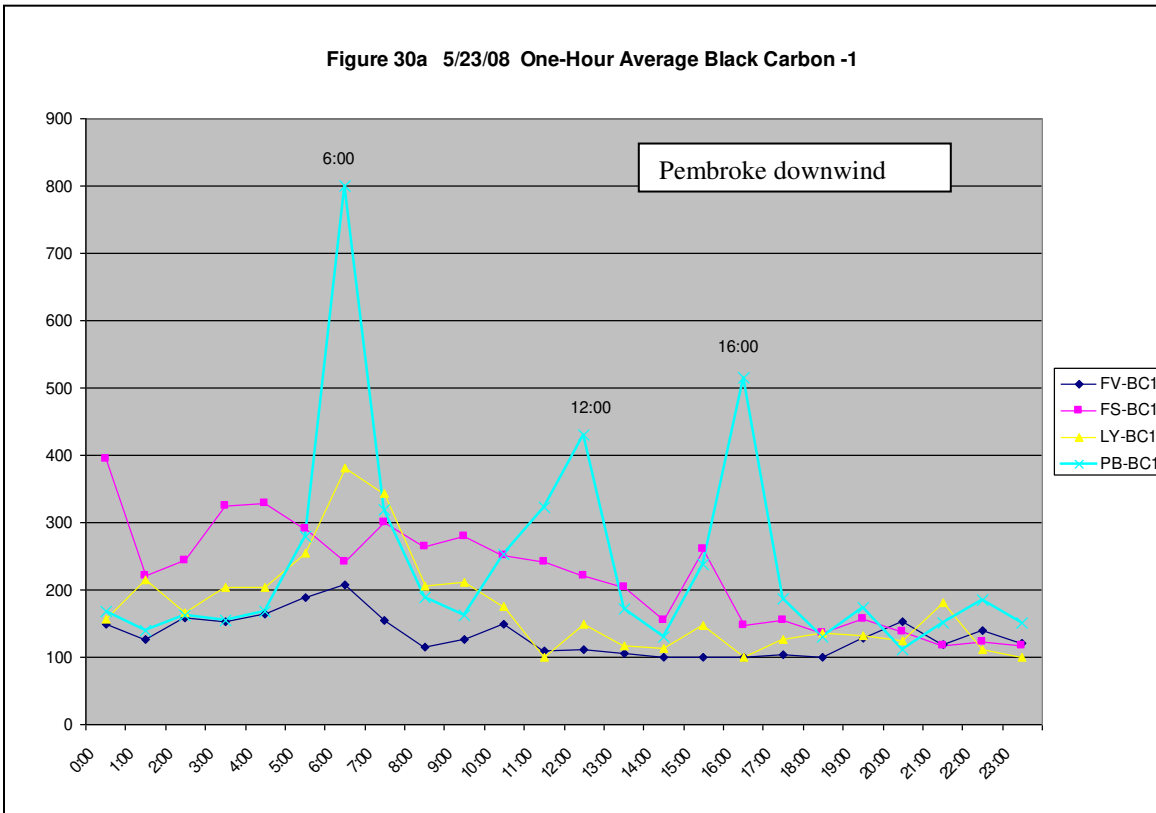


Figure 30c 5/23/08 One-Hour Average Particle-Bound PAH

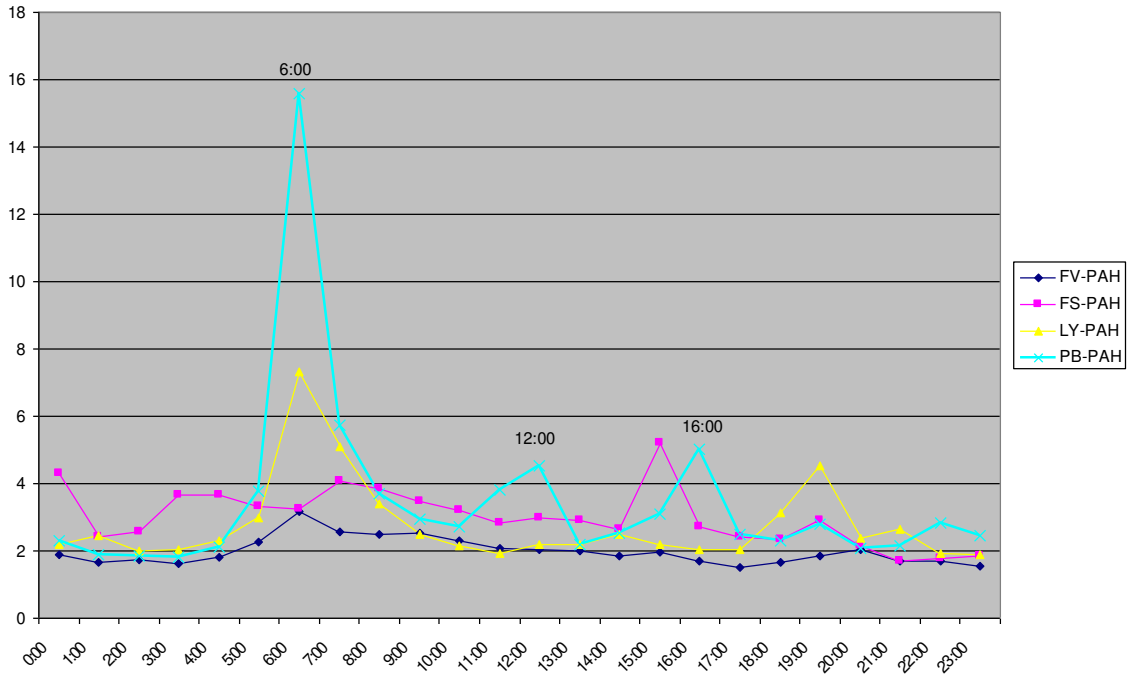


Figure 30d 5/23/08 One-Hour Average Particle Count

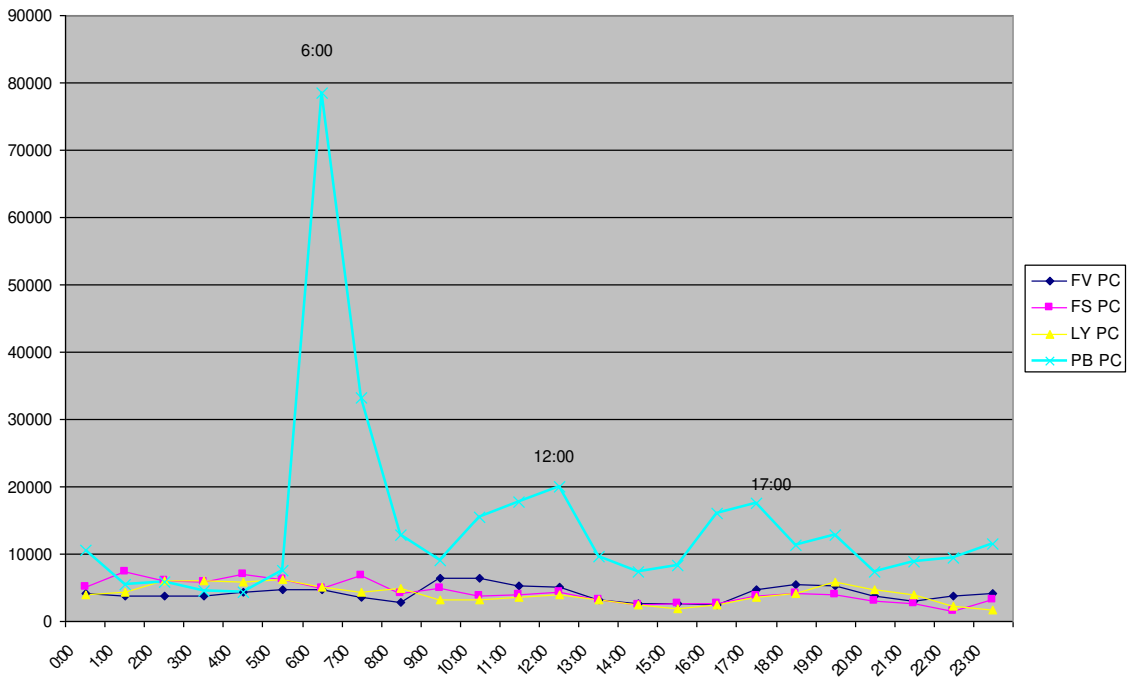


Figure 31a Hourly Average Black Carbon-1 8/13/09

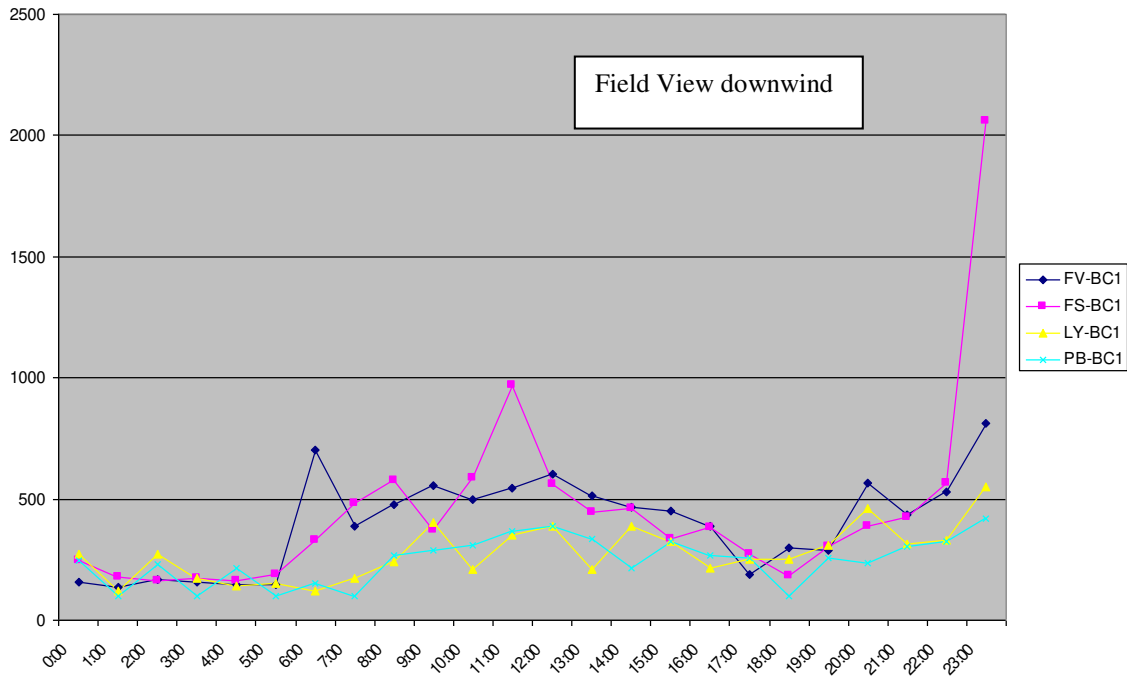


Figure 31b Hourly Average Black Carbon-2 8/13/09

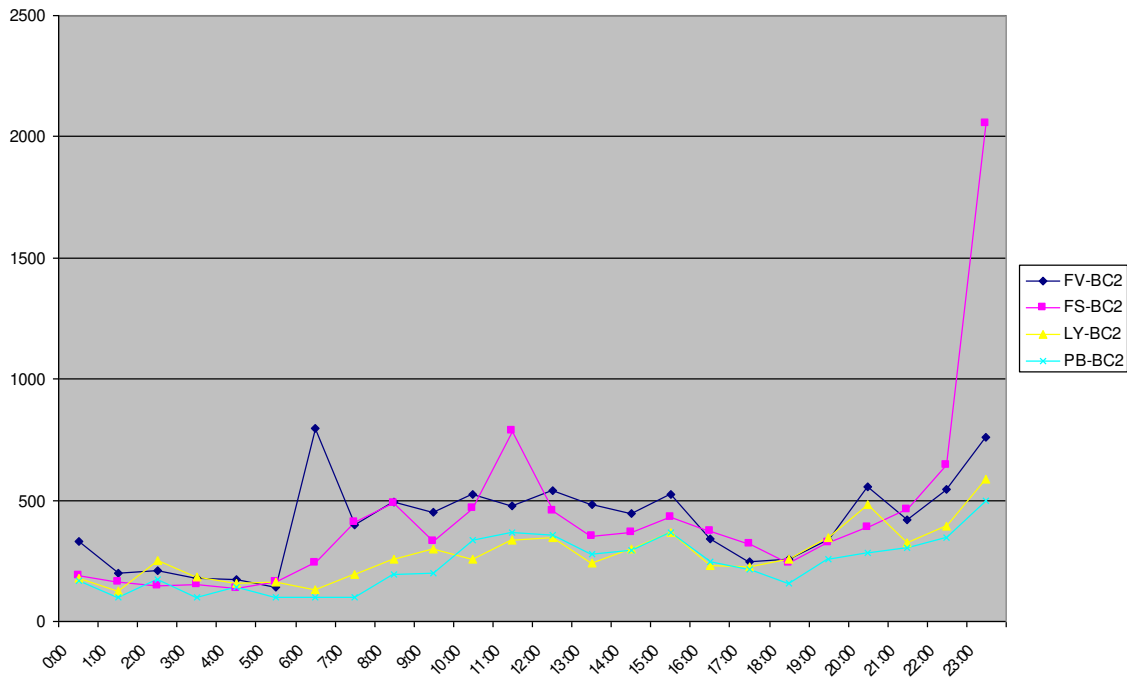


Figure 31c Hourly Average Particle-Bound PAH 8/13/09

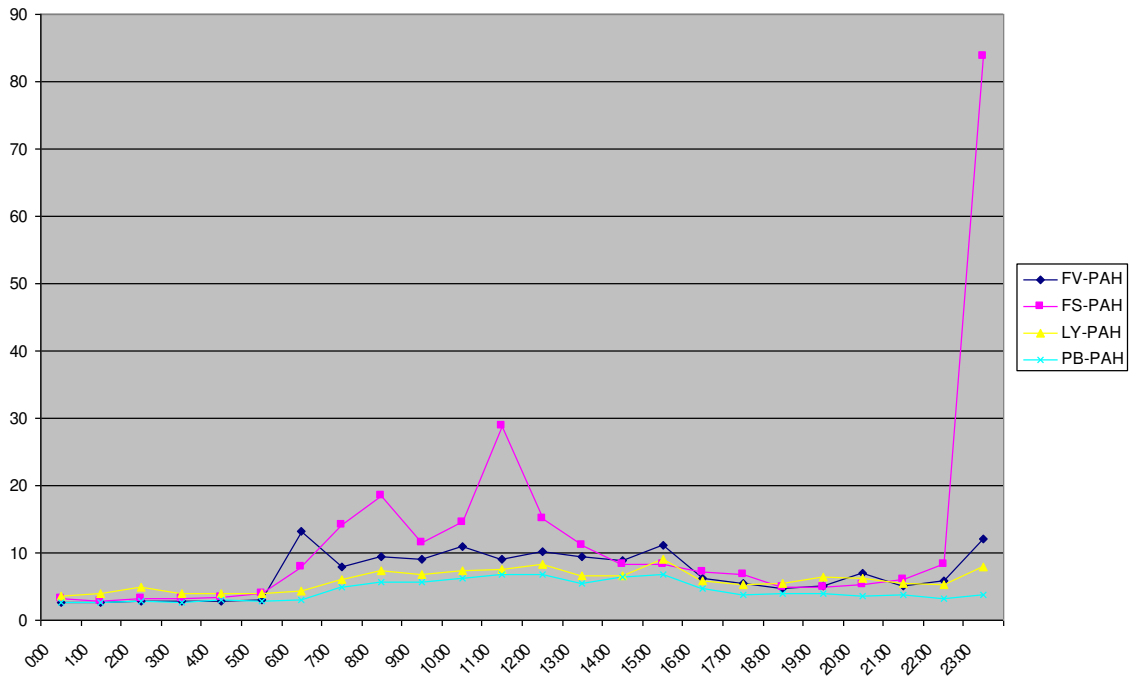
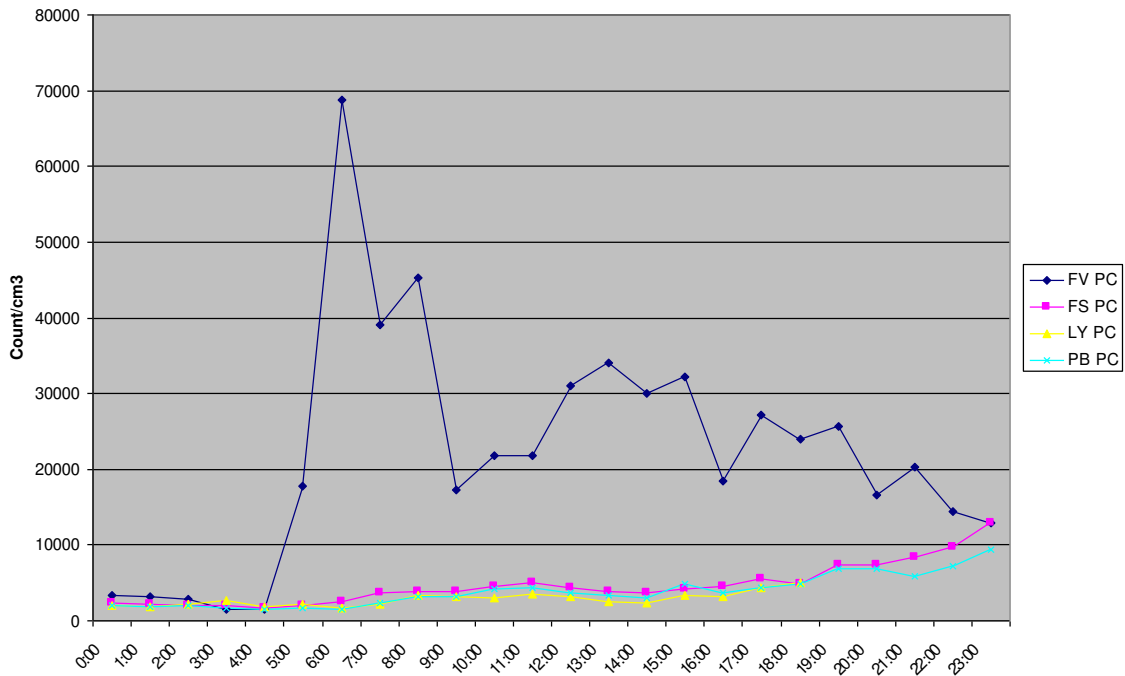


Figure 31d Hourly Average Particle Count 8/13/09



Appendix B

RIAC Quality Assurance Project Plan (QAPP)