Teterboro Airport
Teterboro, New Jersey
Detailed Air Quality Evaluation

Prepared for:
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Trenton, New Jersey

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FINAL REPORT

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Acronyms

ATL	Air Toxics Laboratory
BAM	beta attenuation monitor
BC	black carbon
BTEX	benzene, toluene, ethylbenzene, and xylenes
CAS	Columbia Analytical Services
CAS #	Chemical Abstract Service Chemical Registry Number
CO	carbon monoxide
DOAS	differential optical absorption spectroscopy
DUV	deep ultraviolet
EC/OC	elemental carbon/organic carbon
FAA	Federal Aviation Authority
FRM	Federal Reference Method
GC/MS	gas chromatograph with mass spectrometry
HI	hazard index
HPLC	high performance liquid chromatography
HQ	hazard quotient
LTO	landing and takeoff
MTBE	methyl *tertiary*-butyl ether
NAAQS	National Ambient Air Quality Standard
NJDEP	New Jersey Department of Environmental Protection
NO_2	nitrogen dioxide
NOx	nitrogen oxides
NWS	National Weather Service
PAH	polycyclic aromatic hydrocarbon
PANYNJ	Port Authority of New York and New Jersey
PM2.5	fine particulate matter (aerodynamic diameter <2.5 µm)
RfC	reference concentration
RIDEM	Rhode Island Department of Environmental Management
RIDOH	Rhode Island Department of Health
SVOC	semivolatile organic compound
TEB	Teterboro Airport
TEOM	tapered element oscillating microbalance
TPH	total petroleum hydrocarbons
UCL	upper confidence limit
URF	unit risk factor
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound

1.0 Executive Summary

1.1 Background and Study Objectives

As the oldest operating airport in the New York/New Jersey metropolitan area, Teterboro Airport (TEB) has grown into one of the busiest General Aviation airports in the United States, with over 200,000 arrivals and departures per year. The 827-acre airport consists of a two-runway configuration:

- Runway 1-19 (North/South) is 7,000 feet long and 150 feet wide
- Runway 6-24 (NE/SW) is 6,015 feet long and 150 feet wide

The airport is located in Bergen County, New Jersey, within the municipalities of Teterboro and Moonachie, and is bordered by Hasbrouck Heights and Wood-Ridge to the west; Moonachie to the south; Little Ferry to the east; and South Hackensack to the north. Other nearby municipalities include Bogota, Carlstadt, East Rutherford, Hackensack, Maywood, Oradell, Rutherford, and Teaneck.

The general purpose of this study is to evaluate the potential air quality and health risks associated with operations of Teterboro Airport. This study is designed to provide data to meet the following objectives:

- Assess long-term ambient concentrations of selected air toxics (including chemicals regulated as hazardous air pollutants [HAPs]) in the immediate vicinity of the airport and the associated risks to human health;
- Provide monitoring results consistent with other data being collected by the New Jersey Department of Environmental Protection (NJDEP), which would allow for a comparison of the Teterboro results to data collected for other locations in New Jersey (including Camden, Chester, New Brunswick, and Elizabeth); and
- Evaluate whether contributions from airport emissions can be discerned from the contributions of other background sources.

1.2 Description of Monitoring Network

Four sampling and monitoring stations were established at the airport fenceline near each of the runways, and equipment was set up to monitor:

- Volatile organic compounds (VOCs) and carbonyls
- Fine particulate matter ($PM_{2.5}$)
- Black carbon (BC)
- Meteorological conditions (wind speed and direction)
- Traffic
- Aircraft activity
- Continuous gaseous compounds (using DUV-based open path monitors)

1.3 Air Sampling and Monitoring Results

1.3.1 VOCs and Carbonyls

Among the individual VOCs and carbonyls that were evaluated throughout the study, 16 compounds were consistently detected in the canister/cartridge samples (detected in greater than 70% of the samples) around Teterboro Airport:

- **2-Butanone (MEK) (77%)**
- **Acetone (99%)**
- **Benzene (86%)**
- Dichlorodifluoromethane (75%)
- **Ethylbenzene (73%)**
- **Methylene chloride (82%)**
- **Toluene (98%)**
- Trichlorofluoromethane (81%)
- **Xylenes (73-88%)**
- Acetaldehyde (100%)
- **Benzaldehyde (91%)**
- **Butyraldehyde (79%)**
- **Formaldehyde (100%)**
- **Hexaldehyde (77%)**
- **Propionaldehyde (96%)**
- **Valeraldehyde (75%)**

Note: Compounds in **bold** were higher around Teterboro than all other NJ monitoring stations

Among these 16 compounds, all except for three of these compounds had higher median, mean, 95th percentile, and maximum concentrations than all of the other NJDEP monitoring stations, including the mobile source-dominated Elizabeth station. For some compounds (e.g., benzene, acetaldehyde), the concentrations measured around Teterboro Airport are only slightly higher than or comparable to those measured at other NJDEP locations (e.g., Elizabeth). However, for others (e.g., formaldehyde, ethylbenzene, toluene, xylenes, methylene chloride, 2-butanone), the concentrations measured around Teterboro Airport are greater than a four-fold higher than other NJDEP locations.

To provide some context for understanding the implications of these monitoring data, ENVIRON conducted a conservative screening risk assessment in accordance with NJDEP procedures. These screening assessments include multiple safety and uncertainty factors, and are designed to overstate risks to be health protective.

- The concentrations of the compounds consistently detected around Teterboro Airport are associated with total cancer risks that are up to five times higher at parts of Teterboro Airport than the other NJDEP locations. The risks at all locations are largely associated with formaldehyde, which accounts for 75% to 87% of the risk around Teterboro Airport and 71% to 78% of the risk at the other NJDEP locations.

- The concentrations of the compounds consistently detected around Teterboro Airport are associated with noncancer HI values that are up to two times higher at parts of Teterboro Airport than the other NJDEP locations. Again, the risks at all locations are largely associated with formaldehyde, which accounts for 75% to 88% of the risk around Teterboro Airport and 67% to 79% of the risk at the other NJDEP locations.

It is important to recognize that these risks are not necessarily associated with the airport operations. Nor is the observation that the concentrations detected around Teterboro are higher than the other NJDEP locations for certain compounds intended to suggest that these are the highest concentrations in the state. The comparisons of air concentrations and associated risks presented in this report are provided as a point of reference based on available data. The observation that the detected concentrations were elevated compared to "typical" urban, suburban, or mobile source-dominated locations suggests that additional study may be warranted for the Teterboro Airport vicinity to characterize the sources of certain detected compounds, such as formaldehyde.

1.3.2 Fine Particulate Matter and Black Carbon

Continuous $PM_{2.5}$ data were collected at two of the monitoring stations using a beta attenuation monitor (BAM). $PM_{2.5}$ concentrations were observed to follow an inverse pattern with wind speed, with higher concentrations occurring when wind speeds are low. To evaluate the contributions to ambient $PM_{2.5}$ concentrations from the airport and roadways, ENVIRON screened the $PM_{2.5}$ data based on wind direction. This analysis indicated several very sharp and distinct spikes occurring when winds were blowing from the airport runway toward the $PM_{2.5}$ monitor. Similarly, several sharp and distinct spikes were also observed when winds were blowing from the roadway toward the $PM_{2.5}$ monitor (i.e., away from the airport runway). The magnitude of the $PM_{2.5}$ concentration spikes are roughly equivalent, suggesting that both the airport and roadway activities appear be associated with similar ambient $PM_{2.5}$ concentrations.

Continuous BC data were also collected at two of the monitoring stations. Similar to $PM_{2.5}$, BC concentrations appear to follow an inverse pattern with wind speed, with higher concentrations occurring when wind speeds are low. To evaluate the contributions to ambient BC concentrations from the airport and roadways, ENVIRON screened the BC data based on wind direction. Several distinct spikes were observed that occur when winds were blowing from the airport runway toward the BC monitor, but not as sharp as the spikes observed for $PM_{2.5}$. Similarly, several distinct spikes were also observed when winds were blowing from the roadway toward the BC monitor (i.e., away from the airport runway), again not as sharp as the spikes observed for $PM_{2.5}$. The magnitude of the BC concentration spikes are roughly equivalent, suggesting that both the airport and roadway activities appear be associated with similar ambient BC concentrations. However, because the spikes were not as sharp, this suggests that the quantities of BC emitted by the sources were less than for $PM_{2.5}$.

1.3.3 Open Path Monitoring Results

One novel aspect of this study was the application of open path optical techniques for airport monitoring. These types of techniques are an active field of research within USEPA for Near Road studies of mobile sources. Among the various open path techniques currently being developed and evaluated by USEPA is a Deep UltraViolet Differential Optical Absorption Spectroscopy (DUV-DOAS) system, which measures the absorption of atmospheric constituents in selected regions in the ultraviolet (UV) and visible light spectrum. The DOAS technology used in this study specifically measures absorption in the deep UV spectrum, which generally refers to wavelengths between 200 and 300 nanometers (nm). The metric used in this study is an aggregate measure of the intensity at which compounds absorb in the DUV range, referred to as "DUV Intensity".

To evaluate whether the DUV intensity readings could be related to airport activity or traffic on adjacent roadways, ENVIRON screened the DUV intensity data based on wind direction, as was

performed for $PM_{2.5}$ and BC. Several very sharp and distinct spikes were observed to occur when winds were blowing from the airport runway toward the DUV-DOAS system. Similarly, several sharp and distinct spikes were also observed when winds were blowing from the roadway toward the DUV-DOAS system. The magnitude of the DUV intensity spikes are roughly equivalent, suggesting that both the airport and roadway activities appear be associated with similar DUV intensity readings.

As an additional analysis, the times of the DUV intensity measurements were compared with the time elapsed since the most recent airplane landing and takeoff (LTO). The highest DUV intensity values occur when the time elapsed since the most recent LTO is very brief. As the amount of time since the most recent LTO increases, the DUV intensity values approach a steady background level. These analyses suggest a relationship between high DUV intensity and LTO activity.

Finally, for additional confirmation that the DUV intensity readings could be related to airport activity, ENVIRON reviewed the video footage for certain periods of time when high DUV intensity spikes were observed. Numerous examples were identified in which a spike in DUV intensity occurred at a time when multiple airplanes were observed to be queued on the runway and idling, whereas more constant DUV intensity readings corresponded to the general pattern of planes departing without a significant amount of idling on the runway.

It is important to note that the use of this technology is still in the research and development phase. This approach has not been officially validated or approved by USEPA, NJDEP, or other regulatory agencies. The definition of DUV Intensity used in this study is an initial effort at quantifying DUV-DOAS readings with respect to aircraft and motor vehicle emissions, but other methods of interpreting these data are a recommended area of future study.

1.4 Conclusions and Recommendations

Based on the results of this study, the following conclusions were reached:

- Certain VOCs were detected around Teterboro Airport at higher concentrations than other locations in New Jersey (e.g., formaldehyde, toluene); other VOCs (e.g., benzene, acetaldehyde) were comparable to other “representative” New Jersey locations.

- Risks associated with the concentrations of VOCs consistently detected at parts of Teterboro Airport are higher than other “representative” locations in New Jersey (based on conservative risk screening calculations intended to overestimate exposures and be health protective).

- Similar to other locations in New Jersey, risks around Teterboro Airport exceed health benchmarks. These exceedances are typical of urban areas in the U.S.

- $PM_{2.5}$ measured around Teterboro Airport appears to be higher than other New Jersey monitoring locations in 2006, although the method used to measure $PM_{2.5}$ around Teterboro Airport in this study typically yields higher results than the Federal Reference Method and procedures used at the other New Jersey locations.

- $PM_{2.5}$ and DUV intensity signal were observed to come from both roadways and the airport. Black carbon was also observed to come from both roadways and the airport

operations, although to a lesser extent. These conclusions are supported by temporal and wind direction-filtered analyses, as well as review of videotapes.

- Although the data indicate that airport activities have a measurable effect on local air quality, the data were insufficient to quantify the contribution from airport activities. However, the prevalence of these measurable impacts suggests that the airport is not an insignificant source with respect to the local air quality.

- Airport contributions appear to be highly dependent on wind direction and wind speed, as well as airport activity.

ENVIRON provides the following recommendations for additional study:

- Additional study is needed to identify and quantify potential emission sources of certain detected VOCs and carbonyls, such as formaldehyde. In particular, the summertime increase in formaldehyde concentrations should be further evaluated to understand why it was elevated at P1 but not at other locations. Acrolein concentrations in the airport vicinity should be characterized.

- $PM_{2.5}$ and black carbon concentrations and emission sources should be further evaluated.

- The DUV-DOAS open path system appears to be a promising tool for evaluating airport impacts on local air quality; more research is needed to develop this technology and to characterize DUV compounds.

- Additional study is needed to understand the impact of airport operations on the local community. Perimeter monitoring around the airport coupled with neighborhood monitoring, particularly at times when jet fuel odors are apparent, would be useful in evaluating potential exposures to the surrounding population. Short-term sampling (e.g., three hours or less) when winds are steady would be useful in quantifying upwind and downwind concentrations.

This additional study may improve our ability to quantify the contributions from airport activities to local air quality.

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2.0 Introduction

2.1 Background

As the oldest operating airport in the New York/New Jersey metropolitan area, Teterboro Airport (TEB) has grown into one of the busiest General Aviation airports in the United States, with over 200,000 arrivals and departures per year. The first flight from the present airport site was made in 1919. The Port Authority of New York and New Jersey (PANYNJ) purchased the site on April 1, 1949 from Fred L. Wehran, a private owner and later leased it to Pan American World Airways, and then to its successor organization, Johnson Controls, for 30 years until December 1, 2000, when PANYNJ assumed full responsibility for the operation of TEB. The 827-acre airport consists of a two-runway configuration (Figure 2-1):

- Runway 1-19 (North/South) is 7,000 feet long and 150 feet wide
- Runway 6-24 (NE/SW) is 6,015 feet long and 150 feet wide

In addition to these runways, the airport contains approximately 4.2 miles of taxiways. The airport is bordered by U.S. Route 46 to the north, Fred Wehran Drive to the northeast, Redneck Avenue to the southeast, Moonachie Avenue to the south, and Industrial Avenue to the west. The airport is located in Bergen County, New Jersey, within the municipalities of Teterboro and Moonachie, and is bordered by Hasbrouck Heights and Wood-Ridge to the west; Moonachie to the south; Little Ferry to the east; and South Hackensack to the north. Other nearby municipalities include Bogota, Carlstadt, East Rutherford, Hackensack, Maywood, Oradell, Rutherford, and Teaneck.

In 2001, ENVIRON conducted a screening-level evaluation of potential air quality impacts associated with operations of the Teterboro Airport, which consisted of two parts – a screening-level air sampling and analysis study (conducted over a 48-hour period during June 27-29, 2001) and a preliminary risk evaluation (ENVIRON 2001) (“Screening Study”). The overall results of the Screening Study indicate that airport operations may be affecting ambient air quality in the immediate vicinity. Some of the specific findings of the Screening Study include the following:

- Concentrations of fuel-related compounds such as benzene, toluene, ethylbenzene, xylenes, 1,3-butadiene, and trimethylbenzene were measured in air near Teterboro Airport that were higher than annual average levels that have been reported in Camden and Elizabeth, New Jersey by the New Jersey Department of Environmental Protection (NJDEP). In contrast, concentrations of non-fuel related air toxics such as carbon tetrachloride, chloromethane, and methylene chloride were similar in magnitude at the three sites. The Screening Study recognized that the sampling results represented a single point in time and thus may not reflect long-term conditions.
- Concentrations of a number of air toxics were elevated downwind from the airport, compared to background levels measured upwind from the airport. These chemicals include benzene, toluene, ethylbenzene, xylenes, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, and 4-ethyltoluene, all of which are fuel related compounds.

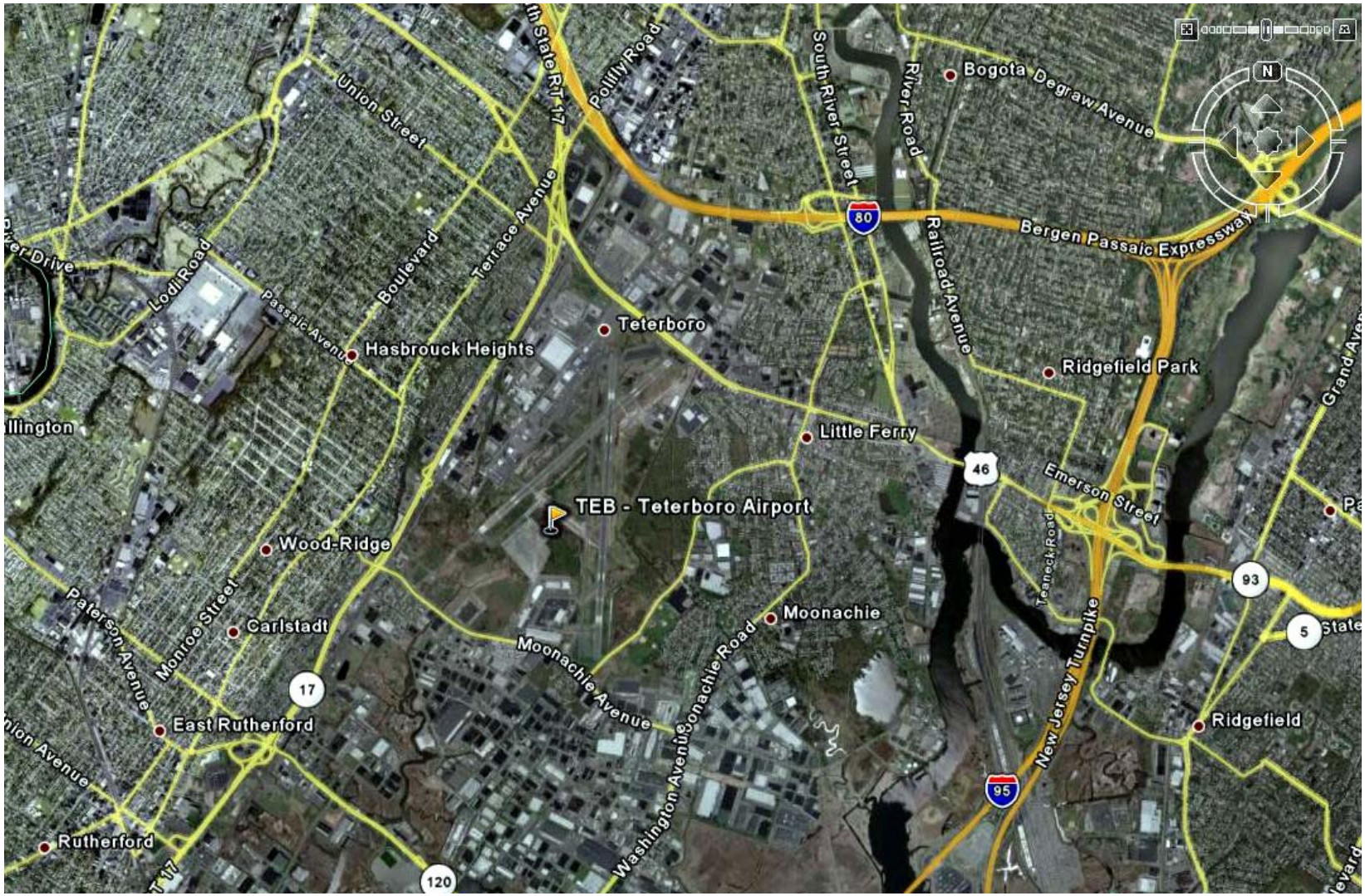

Figure 2-1 Teterboro Airport and Vicinity

- At locations in predominantly downwind directions relative to the airport, a greater number of air toxics were detected at higher concentrations downwind from the airport than upwind of the airport.

- A preliminary risk screening was conducted based on the air sampling results. Assuming long-term exposure to the concentrations measured during the study period, risks to human health (both cancer and noncancer health effects) were evaluated. Carcinogenic risks ranging from 80 in one million (8E-5) to 900 in one million (9E-4) were calculated for an adult receptor using the average air concentration data collected from the airport fenceline. The primary chemicals driving cancer risk are benzene and 1,3-butadiene, which are both fuel-related compounds. Screening-level assessments that indicate cancer risks of greater than approximately 1 in one million (1E-6) generally suggest that a more refined analysis may be required. Thus, the preliminary risk results exceed the regulatory benchmark (1E-6) by two orders of magnitude, and a more refined analysis is warranted. This assessment also identified noncarcinogenic hazard indices that are up to five times higher than screening levels based on regulatory guidance. The primary chemicals driving noncancer risk are benzene and toluene, which are also fuel-related compounds. Again, such results would suggest that a more refined analysis is warranted.

Based on the results of the Screening Study and a recognition that the sampling results represented a single point in time and thus may not reflect long-term conditions, a more extensive study was recommended.

Subsequent to the 2001 Screening Study, a modeling study was conducted by the Environmental and Occupational Health Sciences Institute (EOHSI) (Georgopoulos et al. 2003) to estimate the impact of TEB operations on local air quality. The EOHSI study concluded the following:

- The relative contribution of Teterboro airport operations to the ambient concentrations of air toxics in the modeled area is minor, due to the presence of multiple other mobile, area, and point sources.

- The Teterboro airport contribution to ambient air toxics levels at 51 of the 53 census tracts within a 5 km radius from the airport is less than 1%. Naphthalene is an exception; however, its levels are very low.

- The contributions of airport operations to air toxics levels in the Moonachie and Teterboro census tracts are generally on the order of 1-5% (except naphthalene).

Insufficient long-term monitoring data are publicly available to evaluate the accuracy of the EOSHI modeling results.

2.2 Study Objectives

The general purpose of the Detailed Study is to evaluate the potential air quality and health risks associated with operations of Teterboro Airport.

This study is designed to provide data to meet the following objectives:

- Assess long-term ambient concentrations of selected air toxics (including chemicals regulated as hazardous air pollutants [HAPs]) in the immediate vicinity of the airport and the associated risks to human health;

- Provide monitoring results consistent with other data being collected by NJDEP, which would allow for a comparison of the Teterboro results to data collected for other locations in New Jersey; and

- Evaluate whether contributions from airport emissions can be discerned from the contributions of other background sources.

To meet the above objectives, the focus of this study was on the compounds known to be emitted by mobile sources (e.g., cars, trucks, and aircraft), with particular attention being placed on those compounds associated with aircraft operations (e.g., takeoff, landing, refueling, idling, and maintenance).

2.3 Previous Work at Other Airports

Much of the previous work to characterize air quality near airports has consisted of short-term studies, typically a few days or several weeks in duration. Selected previous monitoring studies are summarized in Table 2-1.

One notable exception is a recent long-term study that was completed at T.F. Green Airport in Warwick, Rhode Island (Morin and Vandeslice 2007). This study was designed to evaluate the concentrations of air toxics in Warwick neighborhoods and evaluate their associated health risks. Over the course of the one year study, five sites in Warwick (four near the airport and one at a distant location) were monitored for volatile organic compounds (VOCs), carbonyls, black carbon (BC), and fine particulate matter ($PM_{2.5}$). Twenty-four hour VOC and carbonyl samples were collected from each site every six days, and BC and $PM_{2.5}$ were monitored continuously. Key findings of the T.F Green study are summarized below:

- **Black Carbon.** The study found that average BC concentrations varied with wind direction in a pattern consistent with airport influence (e.g., average concentrations were generally higher at downwind locations).

- **$PM_{2.5}$.** Although a correlation between wind direction and $PM_{2.5}$ was identified, the correlation did not suggest airport influence (e.g., elevated concentrations were not generally higher at downwind locations)

- **VOCs and carbonyls.** The study did not identify any VOCs that exceeded the acute or chronic benchmarks for noncancer effects; however, the average concentration of five VOCs, including benzene, 1,3-butadiene, chloroform, carbon tetrachloride, and tetrachloroethylene, exceeded the benchmark for 1 in one million cancer risk. In addition, two carbonyls, including formaldehyde and acetaldehyde exceeded applicable cancer benchmarks. The study found no correlation between wind speed and VOC or carbonyl concentrations; however, concentrations of many of the mobile source VOCs (e.g., toluene, ethylbenzene, xylenes, and MTBE) and formaldehyde were on average slightly higher at the site closest to the airport. The airport contribution to the elevated VOCs at this station could not be quantified.

The study recommended continued investigation to better understand the health impact of air quality in the area.

Table 2-1 Summary of Previous Airport Air Quality Studies

Reference	Date of Study	Monitoring Duration	Parameters Monitored	Key Findings/Notes
Los Angeles International Airport, Los Angeles, California				
Eden 2000; Barbosa 2000	June - September 1999	Two weeks and three days	• PM_{10} • EC/OC • VOCs	• Elevated concentrations of soot found at airport • Key pollutants identified were CO, benzene, 1,3-butadiene, and EC • Elevated concentrations of key pollutants were found at terminals • Elevated concentrations of key pollutants were found during Thanksgiving week
O'Hare International Airport, Chicago, Illinois				
Mosardi-Platt 2000; ENVIRON 2000b	September – November 1999	Five days plus two grab samples	• PM • Carbonyls • VOCs • SVOCs • PAHs	• Elevated concentrations of $PM_{2.5}$, aldehydes, and VOCs were identified downwind of the airport • Hypothetical lifetime incremental cancer risks associated with concentrations measured at the airport fenceline were five-fold higher than "background" air quality in Naperville, Illinois
Illinois EPA 2002	June-December 2000	16 Days (12 day interval)	• VOCs • Carbonyls • SVOCs • Particulate metals	• Elevated concentrations of benzene, chloroform, chromium, lead, manganese, PAH, dioxins, formaldehyde, nickel, and toluene identified at the airport
Seattle-Tacoma International Airport, Seattle, Washington				
McCulley et. al. 1995; DesMarais 1995	October - December 1993	Four days	• VOCs • TPH • CO	• Airport contributes to elevated benzene concentrations

Reference	Date of Study	Monitoring Duration	Parameters Monitored	Key Findings/Notes
TF Green Airport, Warwick, Rhode Island				
Morin and Vanderslice 2007	April 2005 – May 2006	One year	• VOCs • Carbonyls • Black carbon • $PM_{2.5}$	• Average concentration of black carbon varied with wind direction in a pattern consistent with airport influence (e.g., average concentrations were generally higher at downwind locations). • Average concentration of five VOCs (benzene, 1,3-butadiene, chloroform, carbon tetrachloride, and Tetrachloroethylene) exceeded the benchmark for one in one million cancer risk • Concentration of two carbonyls (formaldehyde and acetaldehyde) exceeded applicable cancer benchmarks. • Concentrations of many of the mobile source VOCs (e.g., toluene, ethyl benzene, xylenes, and MTBE) and formaldehyde were on average slightly higher at the site closest to the airport.
Budapest Airport, Budapest, Hungary				
Schurmann et. al. 2006	April 12, 2005 - April 27, 2005	15 days	• CO • CO_2 • NO • NO_2 • PM_{10}	• Highest concentrations were found during low wind speed conditions downwind of the airport • Inverse dispersion modeling results showed that overall, emissions from taxiing aircrafts was the most important source of NOx in the vicinity of one of the airport terminals during the measurement campaign
Heathrow Airport, London, England				
United Kingdom Department of Transport 2006	Various	Various	• NO_x • NO_2 • $PM_{2.5}$ • PM_{10} • Ozone	• Compilation of several data sets • NO, NO_x, and PM 10 were identified as key pollutants
Schiphol Airport, Amsterdam, Netherlands				
Netherlands Organization for Applied Science Research 2000 (referenced in CDM 2003)	Not identified	Not identified	• VOCs • PAHs	• Airport contribution to regional concentrations of benzene, toluene, phenanthrene, and benzo(a)pyrene determined to be 3.3, 4.0, 5.4, and 4.0 percent, respectively

Reference	Date of Study	Monitoring Duration	Parameters Monitored	Key Findings/Notes
Zurich Airport, Zurich, Switzerland				
Schurmann et. al. 2007	June 30, 2004 - July 15, 2004	15 days	• NO • NO_2 • CO • CO_2 • VOCs	• CO concentrations in the vicinity of the terminals were found to be highly dependent on aircraft movement • NO concentrations were dominated by emissions from ground support vehicles • The measured emission indices for aircraft showed a strong dependence upon engine type • Isoprene, a VOC commonly associated with biogenic emissions, was found in aircraft exhaust
Notes: Only monitoring studies have been included in this table; modeling and emissions studies were excluded.				

2.4 Document Organization

Following the Executive Summary (Chapter 1) and this Introduction (Chapter 2), the Teterboro Airport Detailed Air Quality Evaluation is presented into the following additional chapters of this report:

- ***Chapter 3 – Methodology*** provides a summary of the sample collection and analytical methods used for sampling and monitoring program;
- ***Chapter 4 – Airport and Local Traffic Activity*** provides a summary of the aircraft and local motor vehicle traffic during the study period;
- ***Chapter 5 – Air Sampling and Monitoring Results*** describes the results of the air quality data collected, and compares these data with those collected by NJDEP in other areas of New Jersey; in addition, conservative estimate of risks to human health associated with the levels of constituents measured in the airport vicinity during the study period is presented, as well as a comparison with risks for other areas of New Jersey;
- ***Chapter 6 – Open Path Monitoring Results*** presents the air quality data collected using a state-of-the-art, continuous open path method;
- ***Chapter 7 – Conclusions and Recommendations*** provides a summary of the key conclusions of the study, along with recommendations for additional areas of research; and
- ***Chapter 8 – References*** provides all references cited in this report.

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3.0 Methodology

This chapter provides a description of the study monitoring network, including the selection of monitoring locations and sampling/monitoring equipment.

3.1 Description of Monitoring Network

3.1.1 Sampling Locations

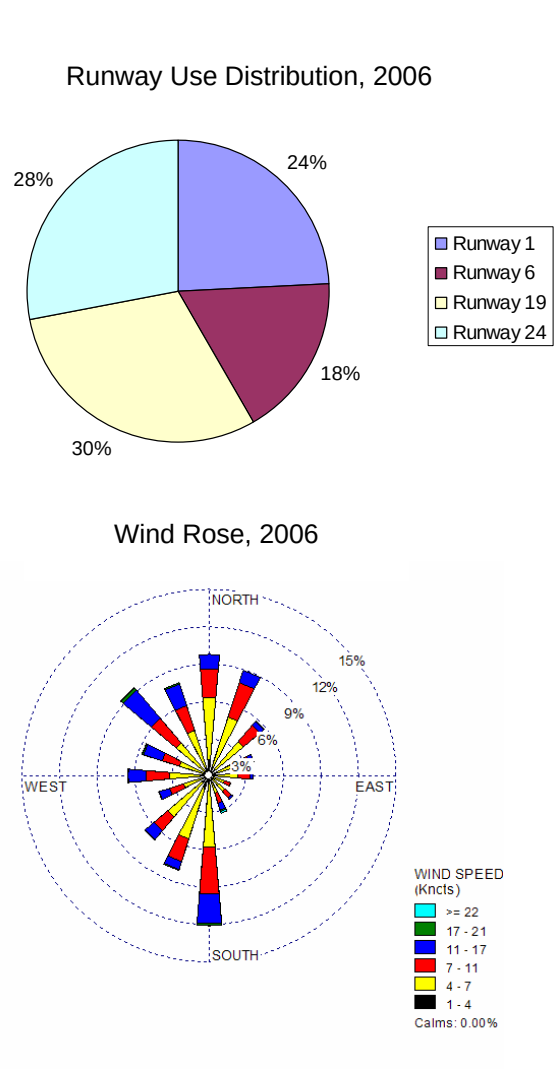
Based on the available resources for the study, ENVIRON focused its efforts on characterizing the air quality in the immediate vicinity of the airport, i.e., at the fenceline. The air monitoring program consisted of two Primary Sampling Sites and two Secondary Sampling Sites (total of four sampling locations). The differences between the Primary and Secondary Sampling Sites are discussed in Section 3.1.2. Selection of the four monitoring sites was based on various factors, including a review of historical meteorological data for Teterboro Airport, proximity to the airport operations, and site accessibility (see Figure 3-1).

The four sampling locations are described below (see Figures 3-2 through 3-4):

- **Primary Sampling Site #1 – Industrial Avenue and U.S. Route 46.** The airport is bordered to the northwest by Industrial Avenue and to the north by U.S. Route 46. Runway 19 is located in this northern corner of the airport. A sampling trailer was placed between a landscaped area retaining wall at the intersection of Industrial Avenue and U.S. Route 46 and a NJ Transit Bus Stop. The sample location was outside of the perimeter fence along the shoulder of U.S. Route 46 East and was situated both in one of the downwind directions and one of the upwind directions of aircraft taxiing for Runway 19. Primary Sampling Site #1 contained a full-set of sampling and monitoring equipment, with the open path transmitter located approximately 600 feet (190 m) to the east along the airport fenceline. The open path transmitter was located approximately 20 feet inside the perimeter fence on the airfield.

- **Primary Sampling Site #2 – Moonachie Avenue and Redneck Avenue.** Redneck Avenue borders the southeastern edge of the airport, near Runway 1 and extends in a northward direction from Moonachie Avenue, which is the southern border of the airport. A sampling trailer was placed on Moonachie Avenue within the fenced portion of this corner of the airport. The Primary Sampling Site #2 location is situated in one of the downwind directions of aircraft taxiing for Runway 1, and is situated between the airport and the nearby trailer park. This station contained a full-set of sampling and monitoring equipment, with the open path transmitter located approximately 590 feet (188 m) to the northeast at the northerly end of a jet exhaust blast fence along Redneck Avenue.

- **Secondary Sampling Site #1 – U.S. Route 46.** Runway 24 is located near the intersection of U.S. Route 46 and Fred Wehren Drive. A sampler has been placed near the portion of the perimeter fencing where an access gate and utility pole currently exist, near Runway 24. This station only contained sampling equipment for VOCs.



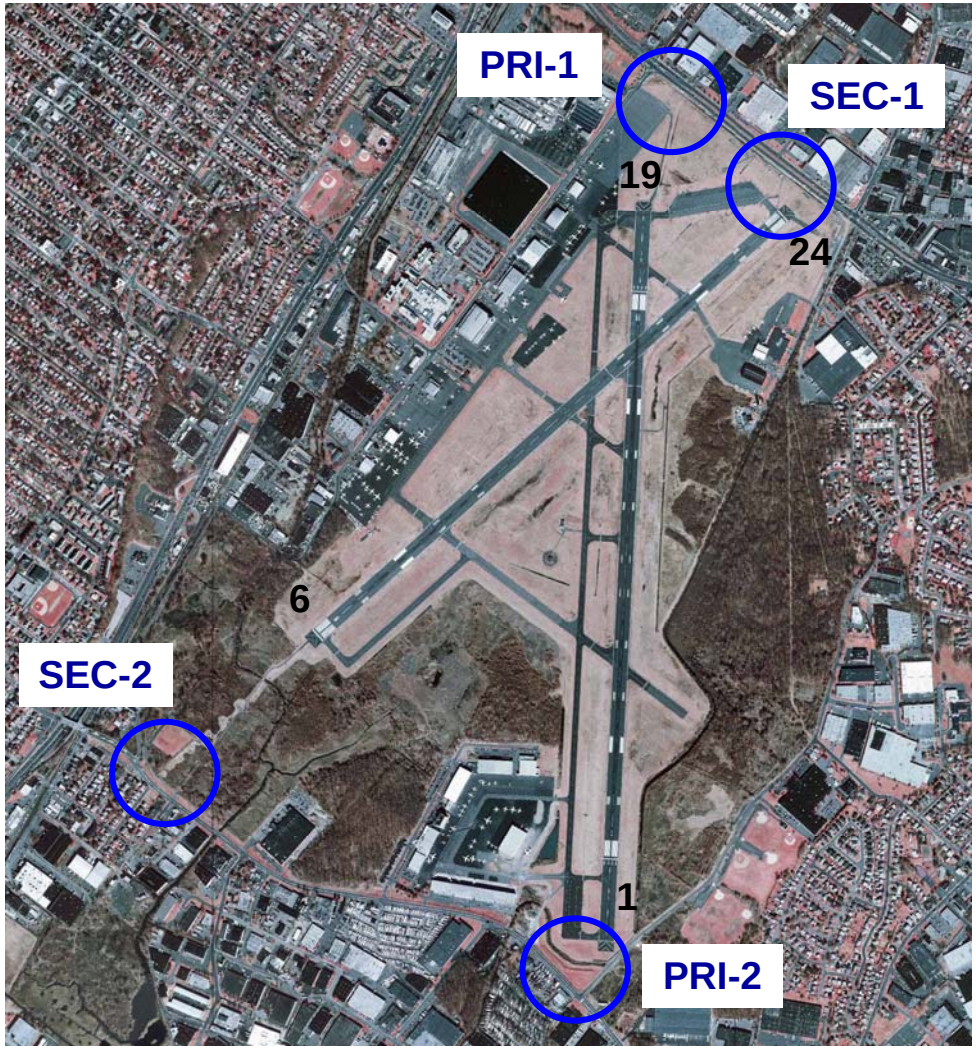


Figure 3-1 Location of Sampling Sites, Runway Use Distribution, and Wind Rose Diagram for Study Period (2006)

Figure 3-2 Primary Sampling Site #1, located on U.S. Route 46 East near Runway 19

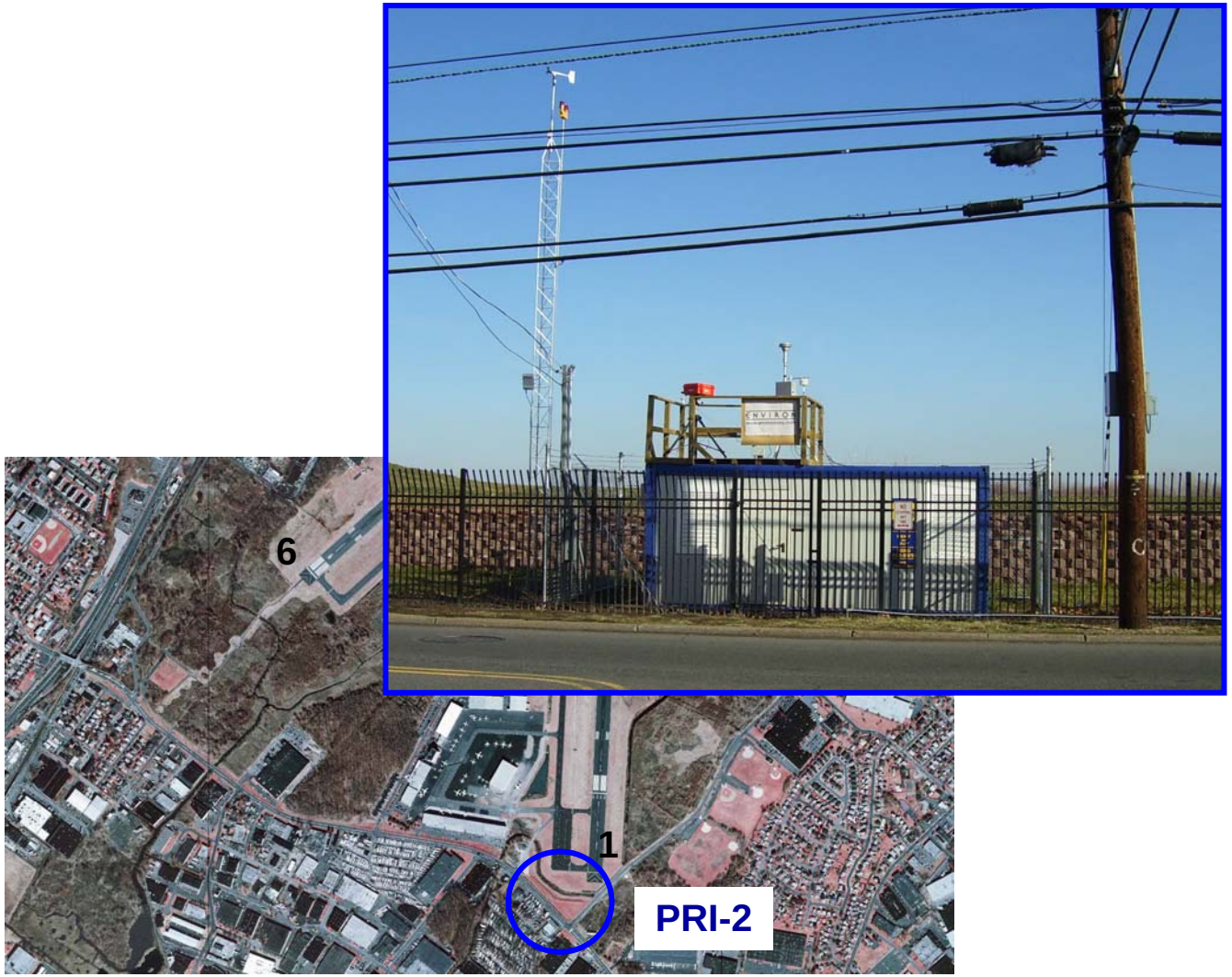


Figure 3-3 Primary Sampling Site #2, located at the intersection of Redneck Avenue and Moonachie Avenue near Runway 1

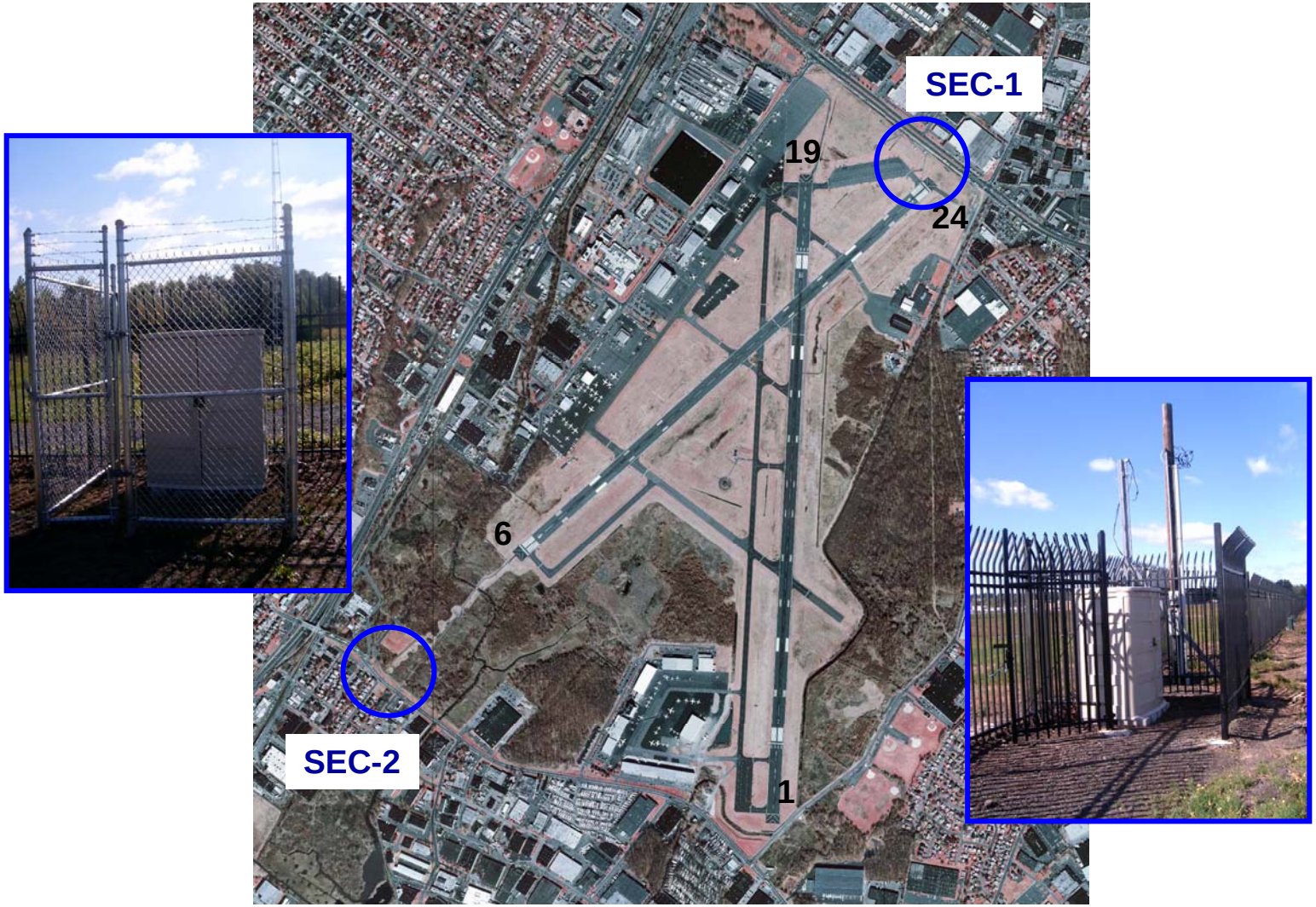


Figure 3-4 Secondary Sampling Site #1, located on U.S. Route 46 East near Runway 24 and Secondary Sampling Site #2 on Moonachie Avenue near Runway 6

- **Secondary Sampling Site #2 – Moonachie Avenue.** Moonachie Avenue borders the airport to the south, near Runways 6 and 1. A VOC sampler has been placed near the perimeter fencing beneath the approach path to Runway 6 near Union Street (along the access road for the Wright Brothers athletic field). This southwestern location is situated both in one of the downwind directions and one of the upwind directions of aircraft taxiing for Runway 6. This station only contained sampling equipment for VOCs.

Each of the locations described above is situated on airport property, outside of the Object Free Areas but within Runway Protection Zones. ENVIRON worked with TEB personnel to secure approvals for these sampling site locations from the Federal Aviation Authority (FAA), National Weather Service (NWS), PANYNJ, and TEB.

3.1.2 Sampling and Monitoring Equipment

Based on a review of recent evaluations of air quality in the vicinity of airports (Barbosa 2000; Eden 2000; ENVIRON 2000a, 2000b; IEPA 2002; McCulley Frick 1995), along with other emission inventories (ERG 1999; Hayes 2003), chemicals associated with aircraft operations include various VOCs (including carbonyls) and particulate matter. When emitted from aircraft, these and other air toxics will first enter the atmosphere, where they can affect overall air quality. Certain of the air toxics may then deposit onto soil, surface water, vegetation, and other environmental media.

The following sampling and monitoring equipment were used:

- **VOCs and Carbonyls (Primary Sites #1 and #2)** – VOC samples were collected in six-liter stainless steel SUMMA® canisters. Carbonyl (e.g., formaldehyde, acetaldehyde) samples were collected on a Waters Corporation Sep-Pak cartridge coated with 2,4-dinitrophenylhydrazine (DNHP). These samples were collected using a Model 2200-2 Toxic Air Sampler manufactured by Atmospheric Technology (ATEC) of Malibu, California, which has the capability of simultaneously collecting air samples into canisters (for VOCs) and sorbent cartridges (for carbonyls) (see Appendix A-1 for more information on this sampler). The samplers recorded start and stop times, final canister pressure, and temporal canister pressure data, which were downloaded after each run. The samplers also recorded the cartridge flow rate and temporal sample volume for the carbonyl samples.

- **VOCs only (Secondary Sites #1 and #2)** – At the two Secondary Sampling Sites, VOC samples were collected, but carbonyl samples were not. The VOC samples were collected using a Model 2200-1 Toxic Air Sampler manufactured by ATEC, which was configured to allow the collection of 24-hour VOC samples. The samplers recorded start and stop times, final canister pressure, and temporal canister pressure data, which were downloaded after each run.

- **Gaseous Compounds (Primary Sites #1 and #2)** – Continuous, path-integrated gas measurements were collected using a UVSentry Differential Optical Absorbance System (DOAS) manufactured by CEREX Environmental Systems of Atlanta, Georgia (see Appendix A-2). The UVSentry samplers recorded raw spectrum data for each sample collected.

- **Black Carbon (Primary Sites #1 and #2)** – Continuous BC measurements were collected using a Model AE-16 single beam aethelometer manufactured by Magee

Scientific Company of Berkeley, California (see Appendix A-3). The aethelometer allows real-time measurement of optically-absorbing BC aerosol particles, which are characteristic of diesel and jet exhaust.

- **Fine Particulate Matter ($PM_{2.5}$) (Primary Sites #1 and #2)** – Continuous $PM_{2.5}$ measurements were collected using an E-BAM mass monitor manufactured by Met One Instruments of Grants Pass, Oregon (see Appendix A-4). The E-BAM is a portable, real-time beta attenuation monitor suitable for automated and continuous sampling and reporting of $PM_{2.5}$ concentrations.

- **Traffic Data (Primary Site #1 and Primary Site #2)** – A Smart Sensor Model 105 radar device manufactured by Wavetronix of Linden, Utah was used to collect traffic data on U.S. Route 46 and Moonachie Avenue (see Appendix A-5). The Smart Sensor is a non-intrusive traffic monitoring and classification system that was mounted approximately 20 feet above the surface of the road on the meteorological towers to record number of vehicles, average speed, occupancy (percent of the sample that a vehicle occupied the travel lanes), and perform a limited classification of the vehicles (classified as small, medium, and large vehicle).

- **Meteorology (Primary Site #2 and Secondary Site #1)** – A Model 05305 Wind Monitor-AQ wind sensor manufactured by RM Young Company of Traverse City, Michigan was used to collect wind direction and wind speed data. The wind speed and direction sensors were located at a height of 10 meters above grade and, to the extent possible, away from the influence of any nearby buildings or trees.

- **Surveillance Camera (all sites)** – A visual spectrum video camera was mounted on top of each sampling trailer and shed for Primary 1, Primary 2, and Secondary 2. The cameras took digital pictures at a frame rate of approximately one frame every eight seconds and were connected to a digital video recorder to archive the images. The intent of this camera system was to observe how many planes were taxiing to the runway or idling on the holding aprons at any given time. The resolution of the images was not sufficient to observe identifying markings of individual planes, only the presence of the planes themselves.

Due to budget constraints, no measurements of metals or PAHs were performed, although both are known to be emitted from airport operations.

All sampling and monitoring equipment was housed on the roof of or within a trailer (Primary Sites) or sampling shed (Secondary Sites) or aluminum meteorological tower. The sampling inlets were all situated at an elevation of between three and five meters. To the extent possible, the sampling locations were intended to meet USEPA siting criteria (40 CFR Part 58, Appendix E), and were situated away from the influence of any nearby buildings or trees. The primary siting criteria that the locations did not meet was their proximity to roadways.

The trailers and sheds were provided with electricity, and equipped with heating and air conditioning to maintain relatively constant environmental conditions throughout the year. Each trailer and shed was also provided with security fencing, with access restricted to ENVIRON field staff and airport operations staff (for emergency access only).

3.1.3 Sampling Events

Two types of air sampling events were included in the Detailed Study:

- **Discrete Sampling Events.** The goal of the Discrete Sampling Events is to collect integrated samples that can be used for assessing long term exposure, which can be compared with other areas of the state. Calendar day samples (24-hour integrated samples) were collected on a once every six day schedule for a period of one year. The sampling schedule coincided with the six-day sampling schedule being utilized by NJDEP (and USEPA) for its state-wide monitoring network. Based on this sampling schedule, a maximum of 61 samples were collected from each location. There were 8-9 samples for each day of the week, and 15-16 samples for each season.

- **Continuous Sampling.** In addition to the routine discrete sampling described above, several continuous monitoring instruments were operational throughout the course of the project (i.e., continuously over a one year period), which provided temporal data on the concentrations of the measured pollutants. These data, together with continuous meteorological data and local vehicular traffic counts, were evaluated on a regular basis to evaluate trends in concentrations as a function of airport activity and local traffic patterns.

3.2 Laboratory Methods and Data Validation

This Detailed Study utilized several sampling and analytical methods developed by USEPA to evaluate the presence of VOCs, aldehydes, and particulate matter in ambient air, as described below.

3.2.1 Volatile Organic Compounds

Equipment used to collect all air samples for VOCs followed USEPA guidelines outlined in *Compendium Method TO-15: Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS)*. Integrated samples were collected in six-liter stainless steel SUMMA® canisters, which were cleaned, individually certified, and evacuated by either ENSR Air Toxics Laboratory (ENSR ATL) of Harvard, MA or Alpha Woods Hole Laboratory (Alpha Labs) of Westborough, Massachusetts[1] in accordance with Method TO-15. Using flow controllers, ambient air was pumped into the canisters at a constant flow rate over the duration of the sampling period. These whole air samples were subsequently analyzed by ENSR ATL or Alpha Labs for target VOCs by GC/MS.

In addition to the standard TO-15 suite of target VOCs, Pleil et al. (2000) noted that jet fuel tends to have higher concentrations of n-alkanes in the C9 to C12 range than automotive fuel. Thus, these higher level alkanes may serve as indicator species of airport influences. The list of target VOCs was expanded beyond the standard TO-15 target VOCs to include octane, nonane, decane, undecane, and dodecane.

[1] The analytical lab used at the beginning of this project was ENSR ATL. Partway through the project, in March 2006, ENSR ATL was acquired by Alpha Labs, and the analytical work was transferred to Alpha Labs.

The VOCs analyzed for in the canister samples are listed in Table 3-1, along with the method reporting limits (MRLs). In Table 3-1, data flagged with a U or ND qualifier were not detected at the specified method detection limit. Compounds that were detected at concentrations lower than the MRLs were flagged with a J qualifier, and treated as unqualified data in the data analysis. Data flagged with a B qualifier were detected in a field or lab blank; data with a B-flag were only used if the detected value was more than five times the blank contamination. No data substitutions were made for missing data.

Table 3-1 VOCs Analyzed by Method TO-15

CAS #	Compound	Method Reporting Limit	
		ppbV	µg/m³
67-64-1	Acetone	1.0 / 2.0	2.4 / 4.8
71-43-2	Benzene	0.5	1.6
100-44-7	Benzyl Chloride	0.5	2.6
75-27-4	Bromodichloromethane	0.5	3.4
75-25-2	Bromoform	0.5	5.2
74-83-9	Bromomethane	0.5	1.9
106-99-0	Butadiene,1,3-	0.5	1.1
78-93-3	Butanone, 2- (methyl ethyl ketone, MEK)	0.5	1.5
75-15-0	Carbon Disulfide	0.5	1.6
56-23-5	Carbon Tetrachloride	0.5	3.1
108-90-7	Chlorobenzene	0.5	2.3
75-00-3	Chloroethane	1.0	1.3
67-66-3	Chloroform	0.5	2.4
74-87-3	Chloromethane	0.5	1.0
107-05-1	Chloropropene, 3-	0.5	1.6
110-82-7	Cyclohexane	0.5	1.7
124-18-5	Decane, n-	0.5	2.9
124-48-1	Dibromochloromethane	0.5	4.3
106-93-4	Dibromoethane, 1,2-	0.5	3.8
76-14-2	Dichloro-1,1,2,2-tetrafluoroethane, 1,2- (CFC 114)	0.5	3.5
95-50-1	Dichlorobenzene, 1,2-	0.5	3.0
541-73-1	Dichlorobenzene, 1,3-	0.5	3.0
106-46-7	Dichlorobenzene, 1,4-	0.5	3.0
75-71-8	Dichlorodifluoromethane (CFC 12)	0.5 / 1.0	2.5 / 4.9
75-34-3	Dichloroethane, 1,1-	0.5	2.0
107-06-2	Dichloroethane, 1,2-	0.5	2.0
75-35-4	Dichloroethene, 1,1-	0.5	2.0
156-59-2	Dichloroethene, cis-1,2-	0.5	2.0
156-60-5	Dichloroethene, trans-1,2-	0.5	2.0
78-87-5	Dichloropropane, 1,2-	0.5	2.3
10061-01-5	Dichloropropene, cis-1,3-	0.5	2.3
10061-02-6	Dichloropropene, trans-1,3-	0.5	2.3
123-91-1	Dioxane, 1,4-	0.5 / 1.0	1.8 / 3.6

CAS #	Compound	Method Reporting Limit	
		ppbV	µg/m³
112-40-3	Dodecane, n-	0.5	3.5
64-17-5	Ethanol	2.0	3.8
141-78-6	Ethyl acetate	0.5	1.8
100-41-4	Ethylbenzene	0.5	2.2
622-96-8	Ethyltoluene, 4-	0.5	2.5
142-82-5	Heptane, n-	0.5	2.1
87-68-3	Hexachlorobutadiene	0.5	5.3
110-54-3	Hexane, n-	0.5 / 1.0	1.8 / 3.5
591-78-6	Hexanone, 2-	0.5	2.1
67-63-0	Isopropyl Alcohol	0.5 / 1.0	1.2 / 2.5
1634-04-4	Methyl tert-Butyl Ether (MTBE)	0.5	1.8
108-10-1	Methyl-2-pentanone, 4- (methyl isobutyl ketone, MIBK)	0.5	2.1
75-09-2	Methylene chloride	1.0	3.5
111-84-2	Nonane, n-	0.5	2.6
111-65-9	Octane, n-	0.5	2.3
115-7-1	Propylene	0.5 / 1.0	0.9 / 1.7
100-42-5	Styrene	0.5	2.1
79-34-5	Tetrachloroethane, 1,1,2,2-	0.5	3.4
127-18-4	Tetrachloroethene	0.5	3.4
109-99-9	Tetrahydrofuran	0.5	1.5
108-88-3	Toluene	0.5	1.9
120-82-1	Trichlorobenzene, 1,2,4-	0.5	3.7
71-55-6	Trichloroethane, 1,1,1-	0.5	2.7
79-00-5	Trichloroethane, 1,1,2-	0.5	2.7
79-01-6	Trichloroethene	0.5	2.7
75-69-4	Trichlorofluoromethane	0.5	2.8
76-13-1	Trichloro-1,2,2-trifluoroethane, 1,1,2- (CFC 113)	0.5	3.8
95-63-6	Trimethylbenzene, 1,2,4-	0.5	2.5
108-67-8	Trimethylbenzene, 1,3,5-	0.5	2.5
123-91-1	Trimethylpentane, 2,2,4-	0.5	2.3
1120-21-4	Undecane, n-	0.5	3.2
108-05-4	Vinyl Acetate	0.5	1.8
593-60-2	Vinyl Bromide	0.5	2.2
75-01-4	Vinyl Chloride	0.5	1.3
95-47-6	Xylene, o-	0.5	2.2
136777-61-2	Xylenes, m,p-	1.0	4.3
Notes: Compounds that have two MRLs listed above had different limits when the laboratory analytical work was transferred from ENSR ATL to Alpha Labs.			

3.2.2 Carbonyls

Carbonyls (e.g., formaldehyde, acetaldehyde) were sampled in accordance with *Compendium Method TO-11A: Determination of Formaldehyde in Ambient Air Using Adsorbent Cartridge Followed by High Performance Liquid Chromatography (HPLC)*. Air samples were pumped

through a Waters Corporation Sep-Pak cartridge coated with DNPH. The cartridges were analyzed by Columbia Analytical Services, Inc. (CAS) of Simi Valley, California. Samples were shipped on ice via overnight delivery to CAS's laboratory for analysis. The carbonyls analyzed for in the cartridge samples are listed in Table 3-2.

Table 3-2 Carbonyls Analyzed by Method TO-11A

CAS #	Compound	Method Reporting Limit	
		ppbV	µg/m³
75-07-0	Acetaldehyde	0.12	0.21
100-52-7	Benzaldehyde	0.071	0.21
123-72-8	Butyraldehyde	0.073	0.21
5779-94-2	Dimethyl Benzaldehyde, 2,5-	0.038	0.21
50-00-0	Formaldehyde	0.17	0.21
66-25-1	Hexaldehyde	0.051	0.21
590-86-3	Isovaleraldehyde	0.048	0.21
123-38-6	Propionaldehyde	0.088	0.21
620-23-5 104-87-0	Tolualdehyde, m- + Tolualdehyde, p-	0.085	0.42
529-20-4	Tolualdehyde, o-	0.043	0.21
110-62-3	Valeraldehyde	0.059	0.21

Quality assurance activities included trip blanks and duplicate sampling. A separate Quality Assurance Project Plan (QAPP) was developed for use with this project, which is included in Appendix B.

3.3 Preliminary Comparison Testing

To ensure that the results from this study are comparable with the data being collected separately by NJDEP on a routine basis, ENVIRON collected three VOC and carbonyl samples at NJDEP's Elizabeth air monitoring station located at Exit 13 of the New Jersey Turnpike using one of the ATEC Model 2200 samplers that was used in this study. These samples were collected on September 1, 7, and 15, 2005 and were compared with samples simultaneously collected by NJDEP at that air monitoring station. NJDEP's samples for September 1st were voided due to a canister leak.

Table 3-3 presents a comparison of ENVIRON's and NJDEP's samples for the September 7 and 15 events. Since the Elizabeth station is located next to the New Jersey Turnpike, the primary constituents expected would be associated with mobile source emissions. As such, the levels of benzene, toluene, ethylbenzene, and xylenes (BTEX) are of greatest interest among the VOCs. Because of differences in the detection limits of the laboratories used by NJDEP and ENVIRON, there is uncertainty with comparing the results for some of the non-BTEX constituents. Agreement between the NJDEP and ENVIRON results for BTEX was considered to be reasonable (i.e., within factor of two). Similarly, with the exception of acetaldehyde, agreement between the NJDEP and ENVIRON results for carbonyls was considered to be reasonable. Acetaldehyde concentrations measured by ENVIRON were three to four times lower than the NJDEP data.

Table 3-3 Comparison of BTEX and Aldehyde Concentrations Measured by ENVIRON and NJDEP

Compound	9/1/05 ENVIRON	9/7/05 ENVIRON	9/7/05 ENVIRON DUP	9/7/05 ENVIRON AVG	9/7/05 NJDEP	9/13/05 ENVIRON	9/13/05 NJDEP
Benzene	0.50	0.63	0.86	0.75	0.71	1.10	1.06
Ethylbenzene	0.50	0.53	0.50 U	0.28	0.30	0.61	0.39
o-Xylene	0.50 U	0.50 U	0.53	0.39	0.34	0.79	0.46
p & m-Xylene	1.30	1.30	1.40	1.35	0.75	2.10	0.99
Toluene	4.80	4.40	4.80	4.60	1.83	5.20	2.62
Acetaldehyde	0.88	1.2	---	1.2	6.05	1.9	8.34
Benzaldehyde	0.054	0.061	---	0.061	0.055	0.12	0.07
Butyraldehyde	0.088	0.091	---	0.091	0.106	0.28	0.469
Formaldehyde	2.9	2.7	---	2.7	4.4	8.8	8.9
Hexaldehyde	0.079	0.065	---	0.065	0.017	0.13	0.081
Propionaldehyde	0.17	0.21	---	0.21	0.161	0.72	0.529
Valeraldehyde	0.11	0.087	---	0.087	0.025	0.31	0.452

Notes:
All concentrations are in ppbv
No data collected by NJDEP on 9/1/05

ENVIRON also operated one of the E-BAM units at the Elizabeth station from August 16 to 25 for comparison against NJDEP's $PM_{2.5}$ results, which are measured using the Federal Reference Method (FRM) for $PM_{2.5}$. These data are summarized in Figure 3-5. Agreement between the NJDEP and ENVIRON results for $PM_{2.5}$ was considered to be reasonable, although the E-BAM data appear to overestimate the FRM results. Based on a linear regression, the ENVIRON data were approximately 16% higher than the NJDEP data, which is equivalent to an overestimate of approximately 2-3 $\mu g/m^3$ at concentrations of 15 to 20 $\mu g/m^3$.

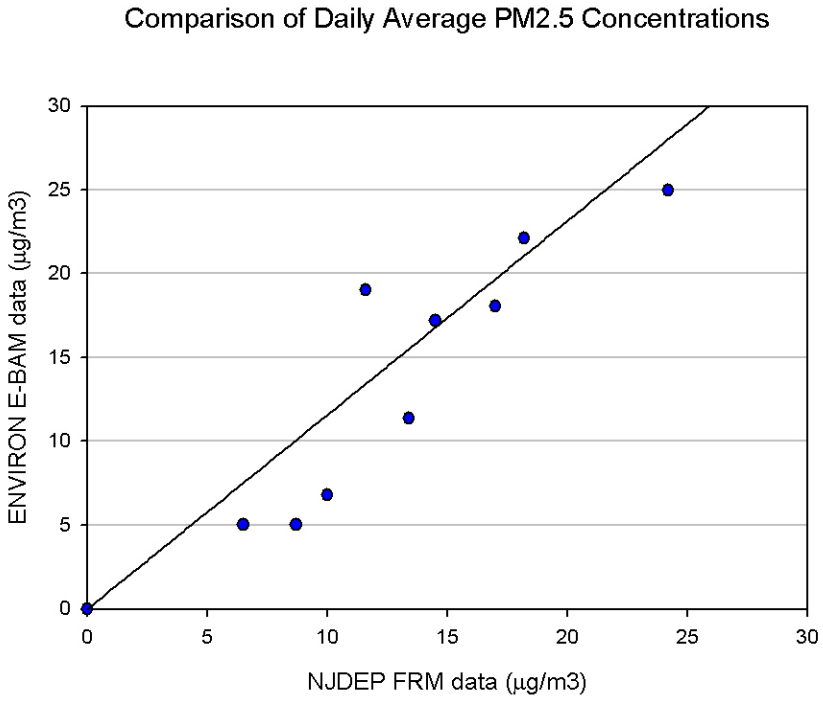


Figure 3-5 Comparison of daily average $PM_{2.5}$ concentration data collected by ENVIRON (E-BAM) and NJDEP (FRM), Elizabeth monitoring station, August 16-25, 2005. Linear regression results in ENVIRON data being 16% higher than NJDEP data (i.e., y=1.16x), with an r^2 value of 0.82 and a standard error of the slope of 0.087.

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4.0 Aircraft and Local Traffic Activity

In this chapter, temporal patterns of aircraft and motor vehicles on local roads are compared. As discussed below, the two types of emissions sources have different temporal patterns, which will assist us in differentiating between the contributions to local air quality of the different sources.

4.1 Landings and Take-Offs

Records of airport landing and take-off (LTO) events were provided to ENVIRON by airport operations personnel on a monthly basis. PANYNJ developed and operates a proprietary LTO event recording system to track the airport activity. It should be noted that the LTO records log the date and time when the aircraft lifts off the runway or touches down. This data set does not provide an indication of overall airport activity such as aircraft starting engines, taxiing on taxiways, or idling on holding aprons for clearance to take-off or move around the airport/cross runways. To verify airport activity such as idling aircraft, the video recording system described in Section 3.1.2 was utilized.

The LTO data provided to ENVIRON consisted of the date and time of the LTO event, runway number and the type of event (landing/arrival, take-off/departure, missed approach, or touch and go). The records also contained a code corresponding to the type of aircraft or helicopter.[2] Figure 4-1 shows a summary of the distribution of LTO by time of day for 2006. During the weekdays, airport activity is low but constant in the early morning, increases steadily beginning around 6:00 AM, levels off after 8:00 AM, begins increasing again in the early afternoon, peaking between 4:00 and 6:00 PM, then decreases steadily into the evening. The afternoon peak levels were between 35 and 50 LTOs per hour. On Sundays, the peak also occurred around 4:00 PM, at a peak level comparable to the weekday levels. The lowest amount of aircraft activity occurred on Saturdays, with a late morning peak of around 20 LTOs per hour.

4.2 Traffic Volumes

Traffic data were collected on a continuous basis at one-minute intervals at Primary 1 along U.S. Route 46 (US46), a six lane highway with a grass median and at Primary 2 along Moonachie Avenue, a two lane secondary road.

Figure 4-2 shows a summary of the distribution of the traffic volume data by time of day for 2006. The total traffic data were separated into small, medium, and large vehicle length subsets. Figures 4-3 and 4-4 show, respectively, the small vehicle and large vehicle subsets of the total traffic volume data. At Primary 1, which is situated on Route 46, a clear bimodal pattern was observed for both total traffic and small vehicles on weekdays, with peaks at 7:00 AM and 4:00 PM corresponding to the morning and evening rush hours. Large vehicle traffic (i.e., trucks), however, displayed a more unimodal pattern with a peak extending from 8:00 AM through 4:00 PM. Unimodal patterns with afternoon peaks were observed for total traffic and small vehicles on the weekend, with a higher level of traffic on Saturdays than on Sundays. For large vehicles on weekends, a unimodal pattern was also observed on Saturdays, but with a morning peak rather than an afternoon peak; no significant peaks were observed on Sundays. The weekday peaks corresponded with traffic counts of around 3,500 to 4,000 total vehicles per

[2] Taken primarily from the Federal Aviation Administration's Air Traffic Publication 7110.65P Appendix A

hour; Saturday and Sunday peaks corresponded with traffic counts of approximately 3,000 and 2,200 total vehicles per hour, respectively.

At Primary 2, which is situated on Moonachie Avenue, a bimodal to trimodal pattern was observed for both total traffic and small vehicles on weekdays, with stronger peaks at 7:00 AM and 4:00 PM and a weaker peak around noon. Weekday peak levels were between 900 and 1,000 total vehicles per hour. For large vehicles on weekdays, a bimodal patter was observed, with a stronger morning peak at 7:00 AM and a secondary mid-afternoon peak around 2:00 PM. Saturday and Sunday traffic patterns were comparable for both total traffic and small vehicles at this location, with a single peak between late morning and late afternoon of around 400 to 500 total vehicles per hour. For large vehicles on weekends at Primary 2, no significant peaks were observed.

New Jersey Route 17 (NJ17) is located a few blocks to the west of TEB (see Figure 2-1). Although no traffic data were collected by ENVIRON along NJ17, traffic volume data were collected during 2006 by the New Jersey Department of Transportation and the Federal Highway Administration (NJDOT/FHA) between Moonachie Avenue and Henry Street (Milepost 7.40) (see Appendix E). Figure 4-5 shows a comparison of the daily traffic volumes for NJ17 compared with the data collected at Primary 1 and Primary 2. Based on these data, it appears that NJ17 has approximately double the traffic volume of US46, the highway on which Primary 1 is situated. Based on the higher traffic volumes and its close proximity to TEB, it would be expected that motor vehicles on NJ17 could affect air quality in the vicinity of the airport

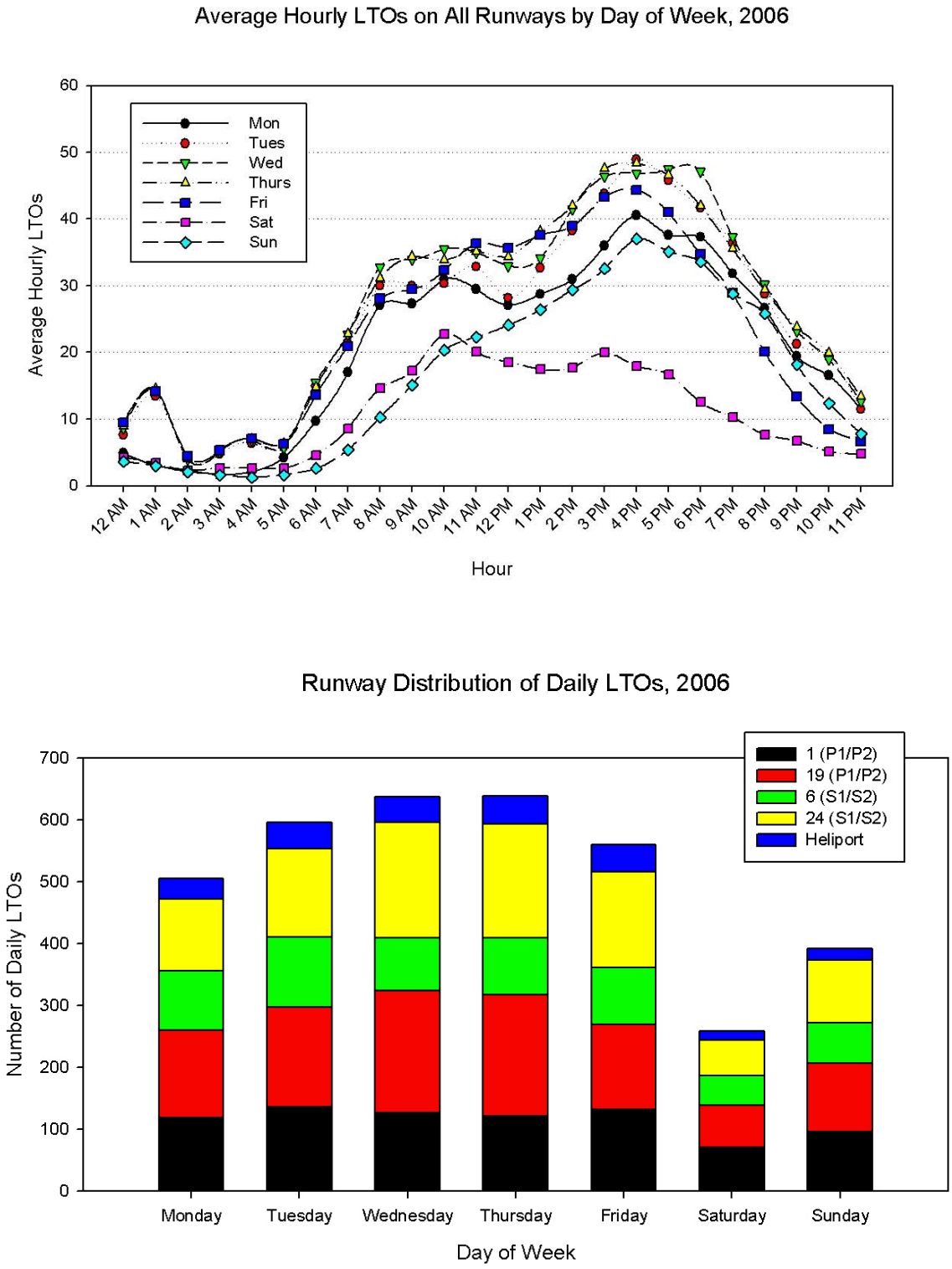

Figure 4-1 Distribution of LTOs Across Time of Day and Day of Week

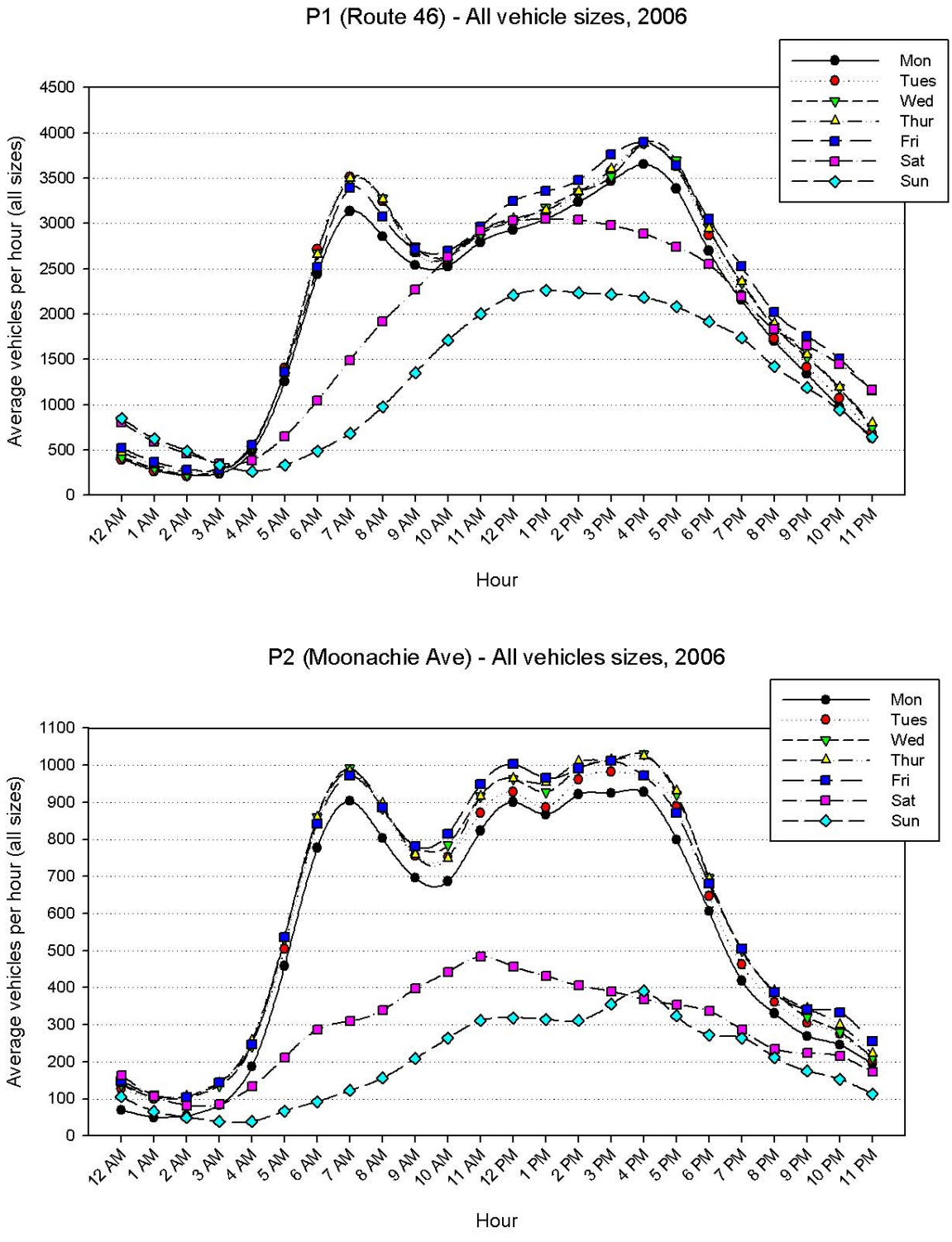

Figure 4-2 Distribution of Total Traffic Volumes Across Time of Day and Day of Week

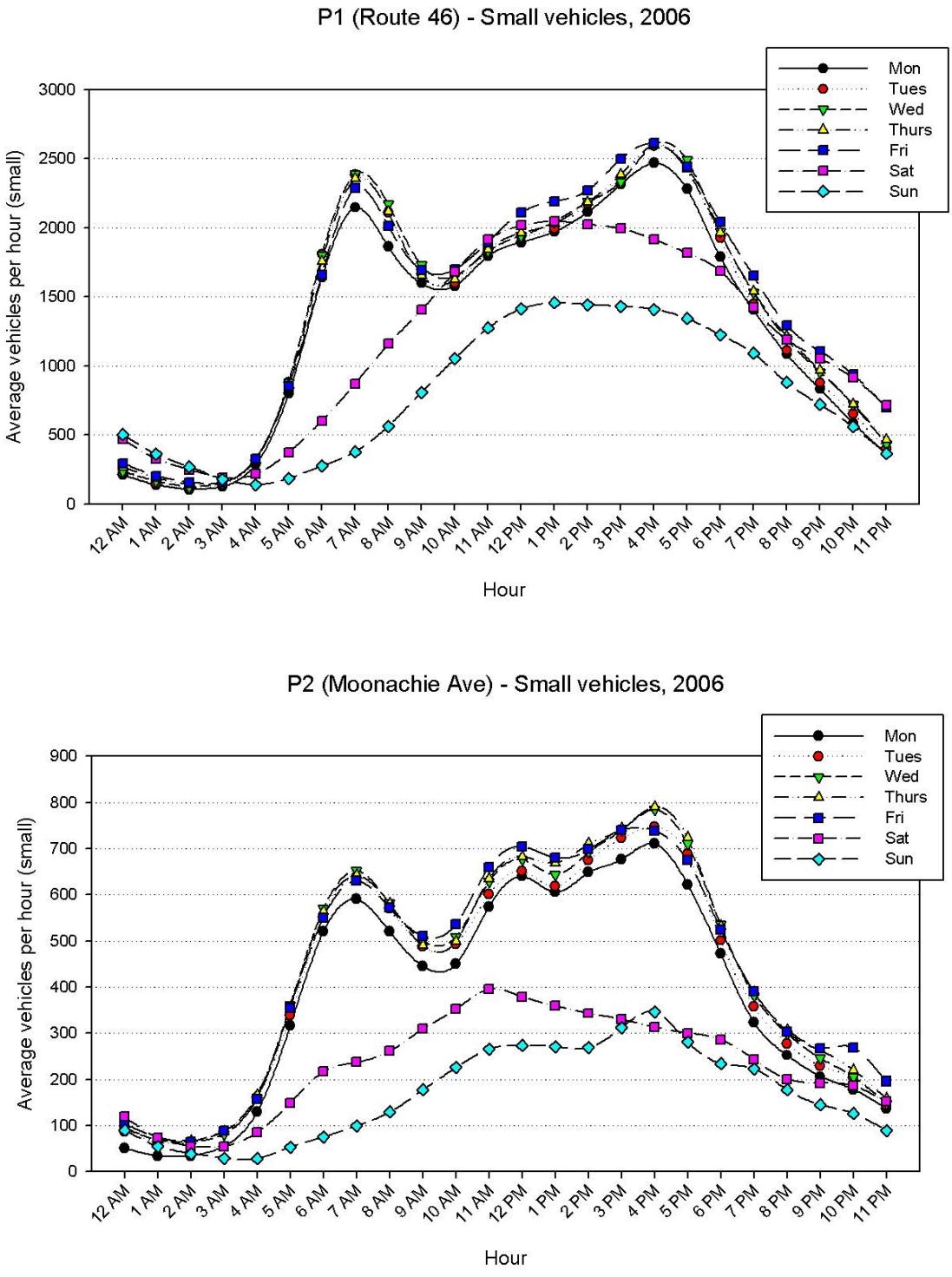

Figure 4-3 Distribution of Small Vehicle Traffic Volumes Across Time of Day and Day of Week

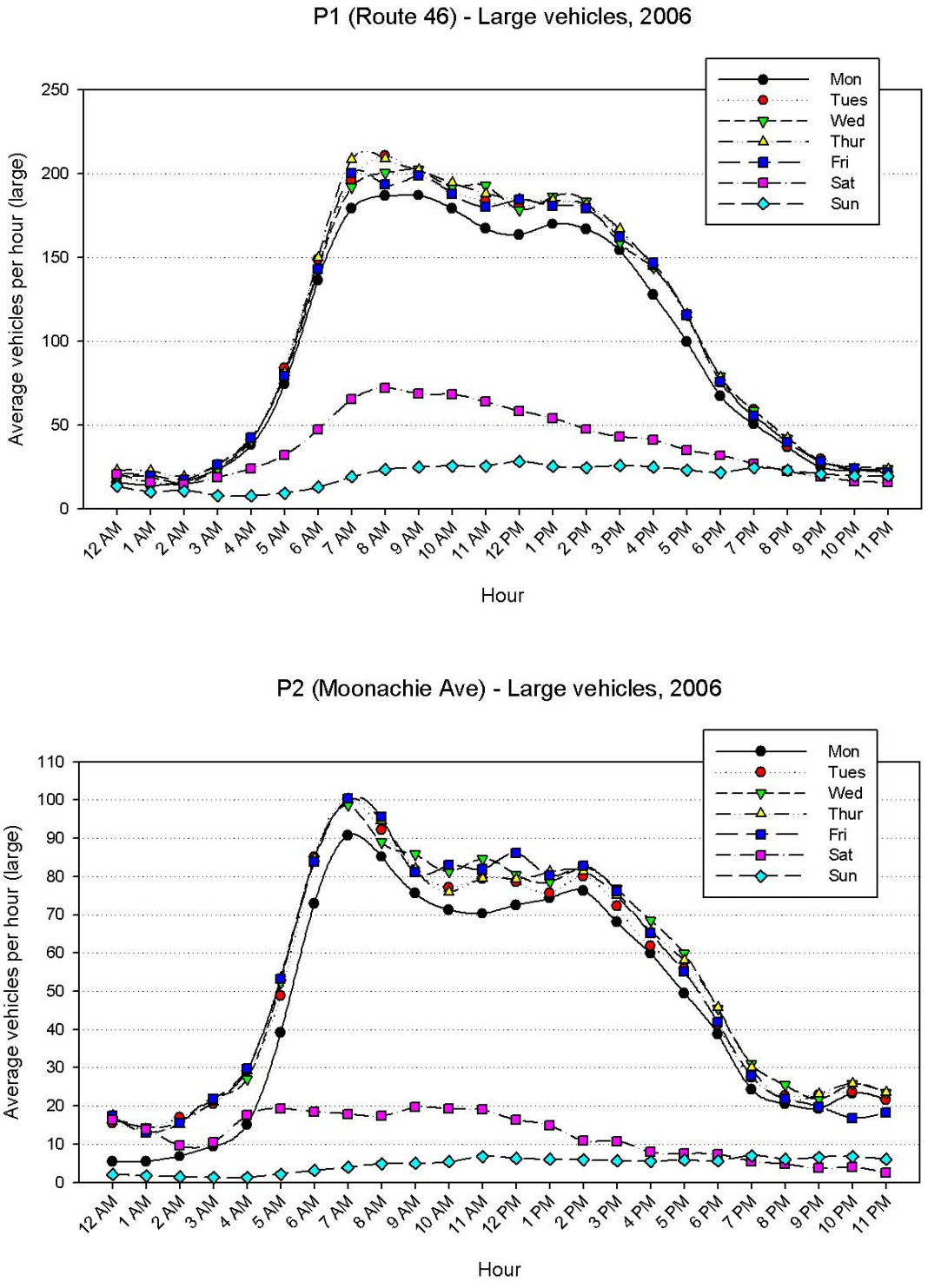

Figure 4-4 Distribution of Large Vehicle Traffic Volumes Across Time of Day and Day of Week

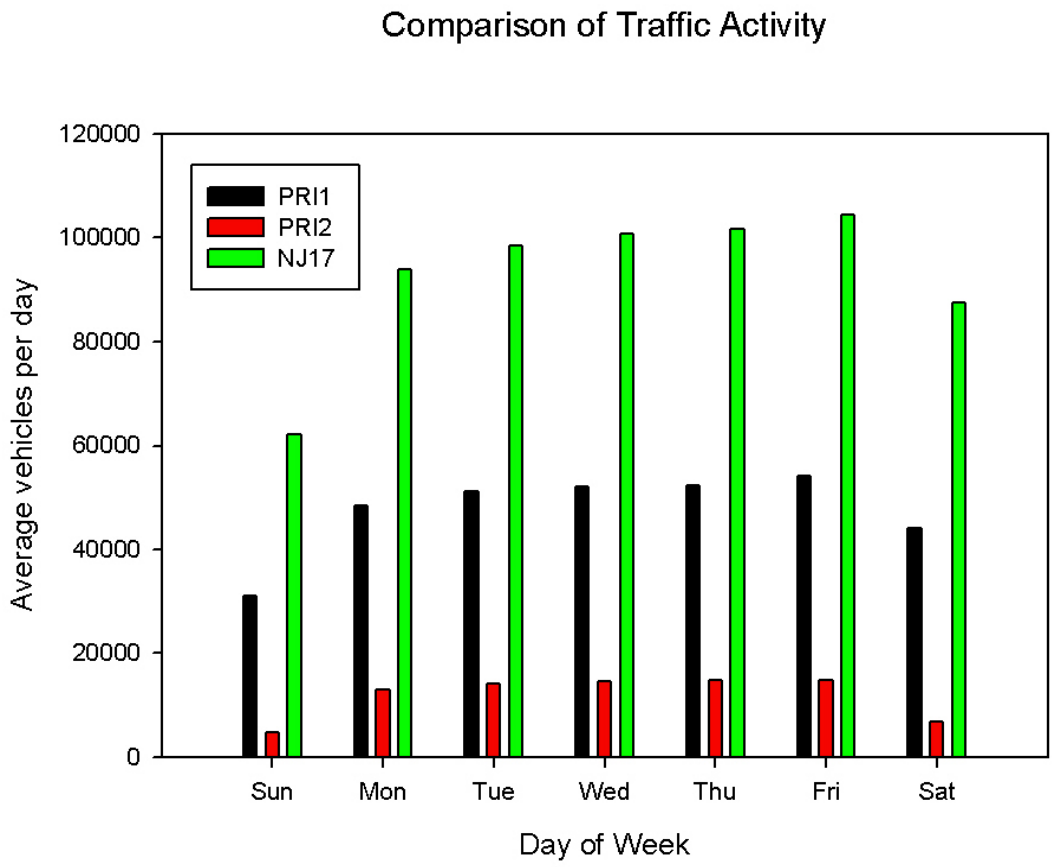

Figure 4-5 Comparison of Traffic Volumes for Primary 1, Primary 2, and NJ17

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5.0 Air Sampling and Monitoring Results

This chapter presents the results of the air sampling and monitoring performed during 2006. The meteorological conditions for the year are first presented, followed by a summary of the discrete sampling and continuous monitoring results.

5.1 Meteorological Conditions

Wind speed and direction data were collected at five-second intervals at Primary 1 and Primary 2. Figure 5-1 presents a wind rose of the data collected from both stations combined, which indicates that the predominant wind direction in 2006 was from the south. Figure 5-2 shows how the average hourly wind speed varied over the course of the day. Wind speeds were relatively constant in the night, beginning to rise steadily around 6:00 to 7:00 AM, peaking in the middle of the afternoon around 3:00 or 4:00 PM, then decreasing steadily throughout the later afternoon and evening.

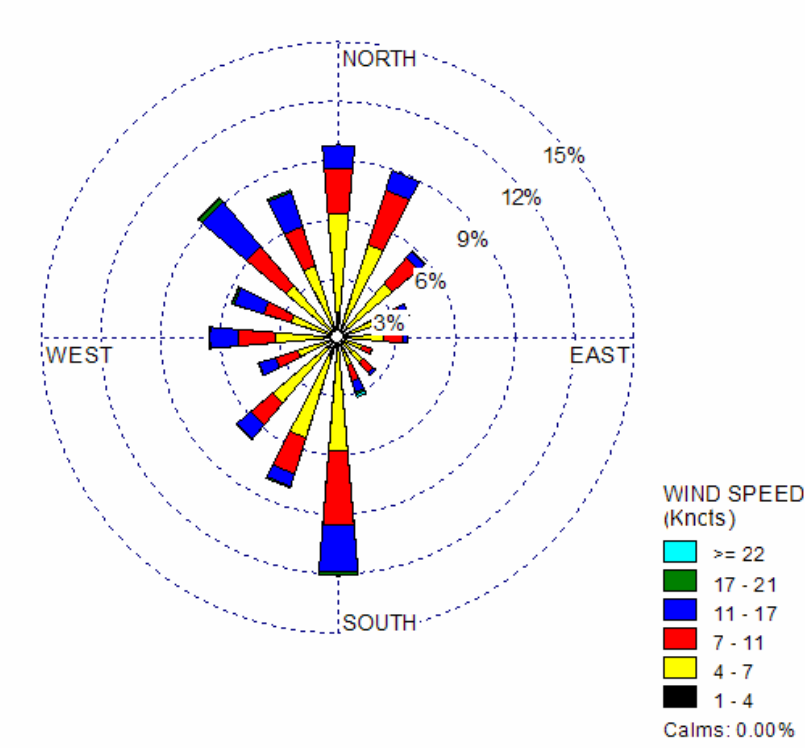


Figure 5-1 Wind rose for Primary 1 and Primary 2 stations combined. Predominant wind direction is from the south.

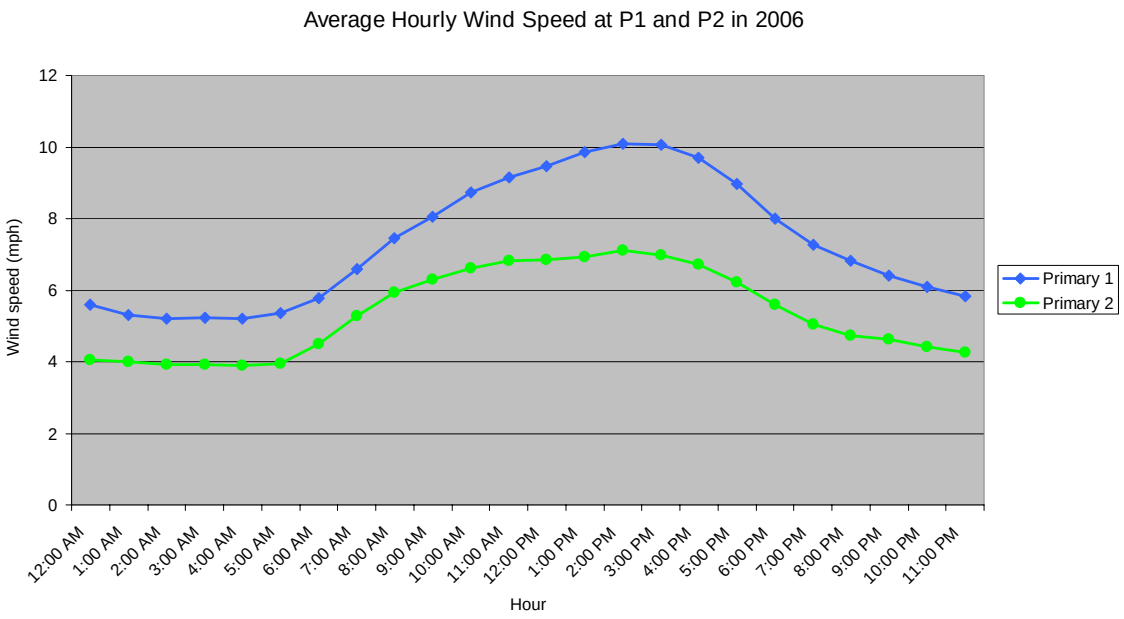


Figure 5-2 Relationship of Average Hourly Wind Speed and Time of Day

5.2 Volatile Organic Compounds and Carbonyls

VOC samples were collected at all four sampling locations; carbonyls were measured at the two Primary sites only.

5.2.1 Teterboro Airport and Other New Jersey Locations

The following 16 compounds were consistently detected in the canister/cartridge samples (i.e., a detectable concentration found in greater than 70% of the samples collected) around Teterboro Airport:

- **2-Butanone (MEK) (77%)**
- **Acetone (99%)**
- **Benzene (86%)**
- Dichlorodifluoromethane (75%)
- **Ethylbenzene (73%)**
- **Methylene chloride (82%)**
- **Toluene (98%)**
- Trichlorofluoromethane (81%)
- **Xylenes (73-88%)**
- Acetaldehyde (100%)
- **Benzaldehyde (91%)**
- **Butyraldehyde (79%)**
- **Formaldehyde (100%)**
- **Hexaldehyde (77%)**
- **Propionaldehyde (96%)**
- **Valeraldehyde (75%)**

Note: Compounds in **bold** were higher around Teterboro than all other NJ stations (discussed in Section 5.2.1); percentage of samples with detected concentration shown in parentheses.

Table 5-1 provides summary statistics for the concentrations measured for these 16 compounds. A complete summary of the VOC sampling results from the canisters and cartridges, along with temporal and box plots of the concentration data and wind roses during each of the sampling days, is provided in Appendix C. Table 5-1 also compares the VOC results for samples collected around Teterboro Airport with those collected at four other NJDEP monitoring stations, located in Camden, Chester, New Brunswick, and Elizabeth (Figure 5-3). These four stations comprise the NJDEP Air Toxics Monitoring network. Each of these stations was selected by NJDEP in order to provide "general population" air quality data that are representative of the following regional environments:

- Camden – Urban
- Chester – Background
- New Brunswick – Suburban
- Elizabeth (New Jersey Turnpike, Exit 13) – Mobile Source Dominated

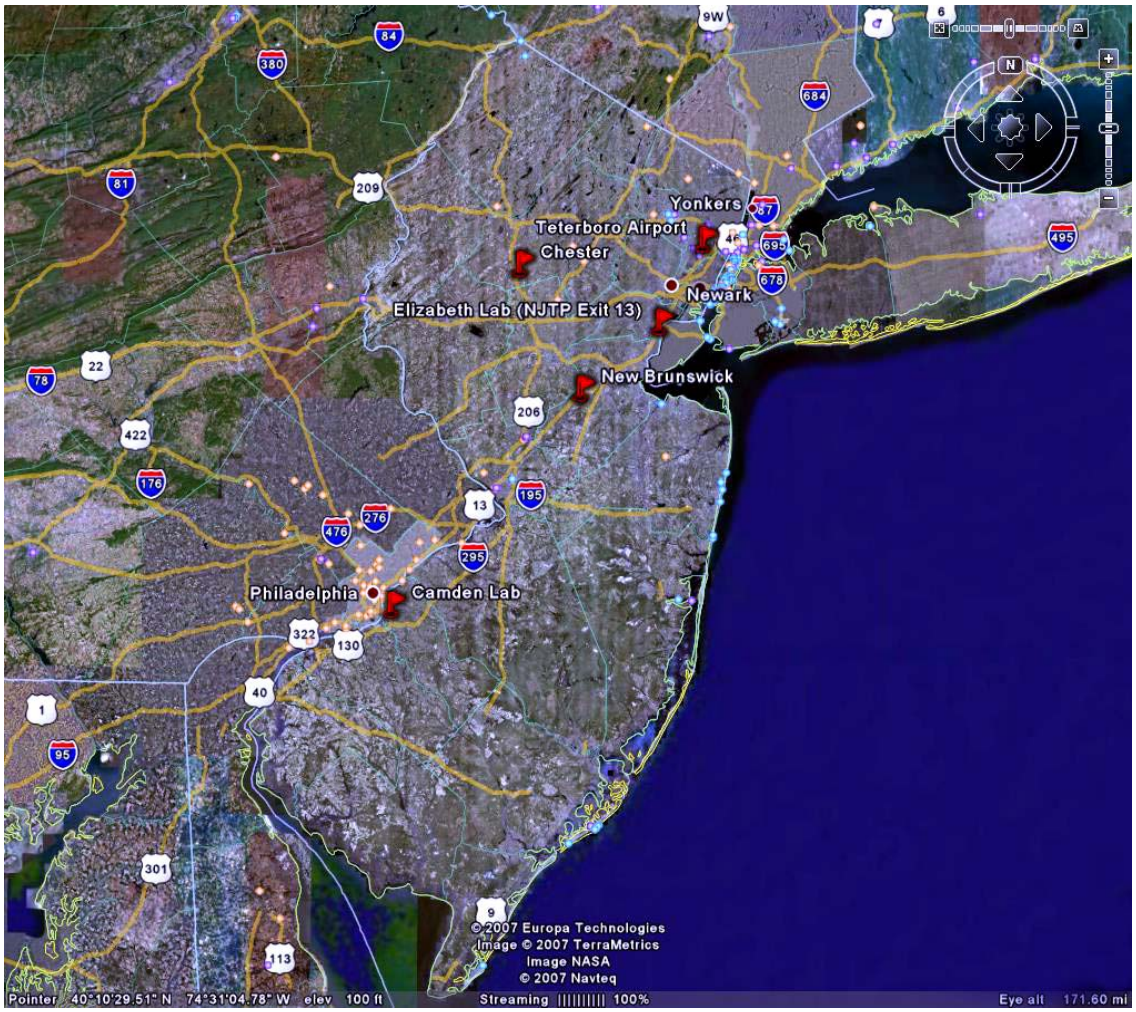


Figure 5-3 Location of NJDEP Monitoring Stations

Because the intent of these stations is to provide *representative* data (as opposed to "worst case") for general population exposure monitoring, there are likely similar areas within the state that have air quality that may be better or worse than these stations.

Based on a data validation review of the reasonableness of the data, the data collected for one day (August 27) was observed to be unusually high for numerous compounds compared to the data collected for the remainder of the year, and much higher than would be expected, even in urban environments. Because there was no obvious explanation for the high values, and they appeared to be an isolated event, the data collected on this day were eliminated as an outlier.

Among the 16 compounds discussed in Section 5.2.1 that were detected in greater than 70% of the samples, all except for three of these compounds (i.e., 13) had higher median, mean, 95th percentile, and maximum concentrations than all of the other NJDEP monitoring stations, including the mobile source-dominated Elizabeth station. Among these 13 compounds, the increased concentrations measured around Teterboro Airport for one (benzene) compared to those measured at Elizabeth were not statistically significant, based on a t-test.

For some compounds (e.g., benzene, acetaldehyde), the concentrations measured around Teterboro Airport are only slightly higher than or comparable to those measured at other NJDEP locations (e.g., Elizabeth). However, for others (e.g., formaldehyde, ethylbenzene, toluene, xylenes, methylene chloride, 2-butanone), the concentrations measured around Teterboro Airport are greater than a four-fold higher than other "representative" NJDEP locations. Box plots for selected compounds are shown in Figure 5-4; a complete set of box plots is provided in Appendix C.

No significant concentrations of n-alkanes in the C9 to C12 range (i.e., octane, nonane, decane, undecane, and dodecane) were detected. Thus, it is unclear whether these compounds are a good marker of jet fuel at Teterboro Airport.

Table 5-1 Statistics for Subset of Detected Compounds

Compound	Statistic	Teterboro (P1)	Teterboro (P2)	Teterboro (S1)	Teterboro (S2)	Teterboro (all)	Chester	Elizabeth	New Brunswick	Camden
2-Butanone	% detect	72%	79%	79%	79%	77%	97%	98%	94%	100%
	Median	0.97	1.10	1.08	0.83	**0.97**	0.36	0.40	0.36	0.39
	Mean	1.35	1.82	2.20	1.31	**1.67**	0.41	0.46	0.43	0.40
	95%ile	3.48	6.76	4.91	4.81	**5.17**	1.31	1.04	0.93	0.66
	Max	19.20	13.90	48.00	11.00	**48.00**	2.74	1.43	2.08	1.41
Acetaldehyde	% detect	100%	100%	---	---	100%	100%	100%	100%	100%
	Median	1.70	1.40	---	---	1.40	0.59	**2.87**	1.74	0.95
	Mean	1.83	1.62	---	---	1.72	0.66	**3.14**	1.85	1.14
	95%ile	4.20	2.89	---	---	4.01	1.22	**6.28**	3.76	2.15
	Max	4.60	5.50	---	---	5.50	1.71	**7.21**	4.25	2.38
Acetone	% detect	100%	98%	100%	96%	99%	100%	100%	100%	100%
	Median	6.79	8.66	9.64	7.80	**7.80**	0.80	1.02	0.89	0.96
	Mean	9.08	12.02	14.99	12.36	**12.12**	0.87	1.17	0.98	1.04
	95%ile	21.13	38.63	40.02	39.76	**37.71**	1.75	2.24	2.07	2.10
	Max	40.30	52.10	141.00	110.00	**141.00**	2.37	3.80	3.01	2.65
Benzaldehyde	% detect	88%	93%	---	---	91%	100%	100%	100%	100%
	Median	0.31	0.08	---	---	**0.10**	0.02	0.04	0.02	0.06
	Mean	1.37	0.09	---	---	**0.73**	0.02	0.04	0.02	0.06
	95%ile	5.95	0.18	---	---	**4.81**	0.04	0.08	0.04	0.10
	Max	8.30	0.49	---	---	**8.30**	0.07	0.09	0.12	0.11
Benzene	% detect	88%	88%	88%	82%	86%	100%	100%	100%	100%
	Median	0.39	0.38	0.41	0.28	**0.36**	0.14	0.35	0.18	0.32
	Mean	0.41	0.42	0.49	0.35	**0.42**	0.16	0.41	0.21	0.36
	95%ile	0.90	0.86	1.21	0.97	**1.12**	0.30	0.95	0.41	0.66
	Max	1.50	1.50	1.50	1.40	**1.50**	0.35	1.40	0.55	0.94
Butyraldehyde	% detect	73%	85%	---	---	79%	100%	100%	100%	100%
	Median	0.13	0.10	---	---	**0.12**	0.07	0.09	0.06	0.11
	Mean	0.34	0.11	---	---	**0.23**	0.07	0.14	0.08	0.11
	95%ile	1.52	0.24	---	---	**1.21**	0.11	0.35	0.17	0.18
	Max	1.70	0.33	---	---	**1.70**	0.15	0.63	0.31	0.19
Dichlorodifluoro-methane	% detect	77%	71%	76%	75%	75%	100%	100%	100%	100%
	Median	0.43	0.39	0.41	0.42	0.41	0.54	**0.55**	0.53	0.54
	Mean	0.36	0.33	0.35	0.35	0.35	0.54	**0.56**	0.54	0.55
	95%ile	0.61	0.60	0.63	0.58	0.63	0.62	**0.76**	0.71	0.68
	Max	0.68	0.70	0.70	0.69	0.70	0.97	**1.17**	0.75	0.77
Ethylbenzene	% detect	75%	75%	71%	71%	73%	100%	100%	100%	100%
	Median	0.11	0.15	0.09	0.10	**0.11**	0.03	0.10	0.06	0.07
	Mean	0.17	0.26	0.18	0.13	**0.19**	0.03	0.12	0.06	0.09

Compound	Statistic	Teterboro (P1)	Teterboro (P2)	Teterboro (S1)	Teterboro (S2)	Teterboro (all)	Chester	Elizabeth	New Brunswick	Camden
	95%ile	0.84	0.84	0.60	0.33	**0.82**	0.05	0.32	0.12	0.18
	Max	1.02	1.82	1.40	0.81	**1.82**	0.10	0.47	0.15	0.28
Formaldehyde	% detect	100%	100%	---	---	100%	100%	100%	98%	100%
	Median	3.90	3.50	---	---	**3.75**	1.24	3.50	1.78	2.38
	Mean	8.48	4.21	---	---	**6.37**	1.56	3.67	2.10	2.88
	95%ile	30.02	8.63	---	---	**26.15**	3.23	7.32	3.71	6.18
	Max	39.00	10.00	---	---	**39.00**	4.36	8.60	17.70	6.65
Hexaldehyde	% detect	78%	77%	---	---	78%	100%	100%	98%	100%
	Median	0.11	0.08	---	---	**0.10**	0.02	0.03	0.02	0.04
	Mean	0.33	0.09	---	---	**0.21**	0.03	0.04	0.03	0.05
	95%ile	1.42	0.21	---	---	**1.21**	0.04	0.08	0.04	0.09
	Max	1.70	0.35	---	---	**1.70**	0.06	0.15	0.56	0.12
Methylene chloride	% detect	82%	86%	81%	80%	82%	95%	100%	100%	100%
	Median	0.67	0.66	0.72	0.59	**0.67**	0.07	0.16	0.11	0.10
	Mean	0.92	1.11	1.88	0.77	**1.18**	0.10	0.23	0.12	0.28
	95%ile	2.72	2.33	3.70	2.21	**3.27**	0.21	0.53	0.23	0.82
	Max	7.42	15.50	39.80	4.31	**39.80**	0.46	1.14	0.48	5.42
o-Xylene	% detect	74%	71%	72%	75%	73%	97%	100%	100%	100%
	Median	0.10	0.13	0.09	0.08	**0.10**	0.03	0.11	0.06	0.07
	Mean	0.19	0.24	0.20	0.16	**0.20**	0.03	0.13	0.07	0.09
	95%ile	0.84	0.78	0.77	0.57	**0.79**	0.05	0.34	0.15	0.18
	Max	1.20	1.80	1.50	0.86	**1.80**	0.10	0.58	0.18	0.26
p & m-Xylene	% detect	91%	89%	81%	89%	88%	100%	100%	100%	100%
	Median	0.41	0.59	0.38	0.30	**0.41**	0.06	0.26	0.14	0.18
	Mean	0.68	0.88	0.64	0.53	**0.68**	0.07	0.35	0.17	0.23
	95%ile	2.22	2.70	2.27	1.68	**2.58**	0.15	1.09	0.37	0.61
	Max	4.40	4.10	2.97	2.80	**4.40**	0.26	1.52	0.54	0.82
Propionaldehyde	% detect	93%	98%	---	---	96%	100%	100%	100%	100%
	Median	0.25	0.23	---	---	**0.24**	0.08	0.10	0.06	0.12
	Mean	0.30	0.30	---	---	**0.30**	0.09	0.14	0.07	0.14
	95%ile	0.70	0.57	---	---	**0.69**	0.14	0.37	0.16	0.29
	Max	1.00	0.86	---	---	**1.00**	0.21	0.59	0.27	0.33
Toluene	% detect	98%	96%	97%	100%	98%	100%	100%	100%	100%
	Median	1.29	2.22	1.40	1.01	**1.35**	0.14	0.67	0.29	0.52
	Mean	2.23	2.79	1.78	1.62	**2.10**	0.18	0.83	0.34	0.66
	95%ile	6.27	8.04	4.64	4.13	**7.81**	0.32	2.50	0.64	1.39
	Max	12.10	12.10	9.96	17.60	**17.60**	0.84	3.26	1.01	4.06
Trichlorofluoro-methane	% detect	86%	79%	79%	79%	81%	100%	100%	100%	100%
	Median	0.25	0.24	0.24	0.23	0.24	0.26	0.26	0.26	**0.30**
	Mean	0.25	0.25	0.22	0.22	0.24	0.26	0.27	0.27	**0.30**

Compound	Statistic	Teterboro (P1)	Teterboro (P2)	Teterboro (S1)	Teterboro (S2)	Teterboro (all)	Chester	Elizabeth	New Brunswick	Camden
	95%ile	0.51	0.63	0.51	0.52	**0.54**	0.32	0.36	0.35	0.38
	Max	0.78	0.91	0.62	0.56	**0.91**	0.52	0.49	0.37	0.42
Valeraldehyde	% detect	75%	75%	---	---	75%	100%	100%	96%	100%
	Median	0.11	0.13	---	---	**0.12**	0.02	0.05	0.02	0.05
	Mean	0.27	0.23	---	---	**0.25**	0.02	0.11	0.04	0.05
	95%ile	1.22	0.82	---	---	**1.01**	0.04	0.39	0.08	0.08
	Max	1.50	1.00	---	---	**1.50**	0.05	0.90	0.33	0.09

Notes:
1. Maximum for each chemical and parameter is shown in **bold shading**
2. All concentrations are in ppbv
3. Statistics for “Teterboro (all)” samples are based on two locations for aldehydes and four locations for other VOCs; other NJ data are from one location each
4. Detection limits used by NJDEP are lower than those used at Teterboro Airport, which explains why the NJDEP data have a higher percentage of samples with detects.
5. Data collected on August 27 were unusually high, and were excluded as an outlier.

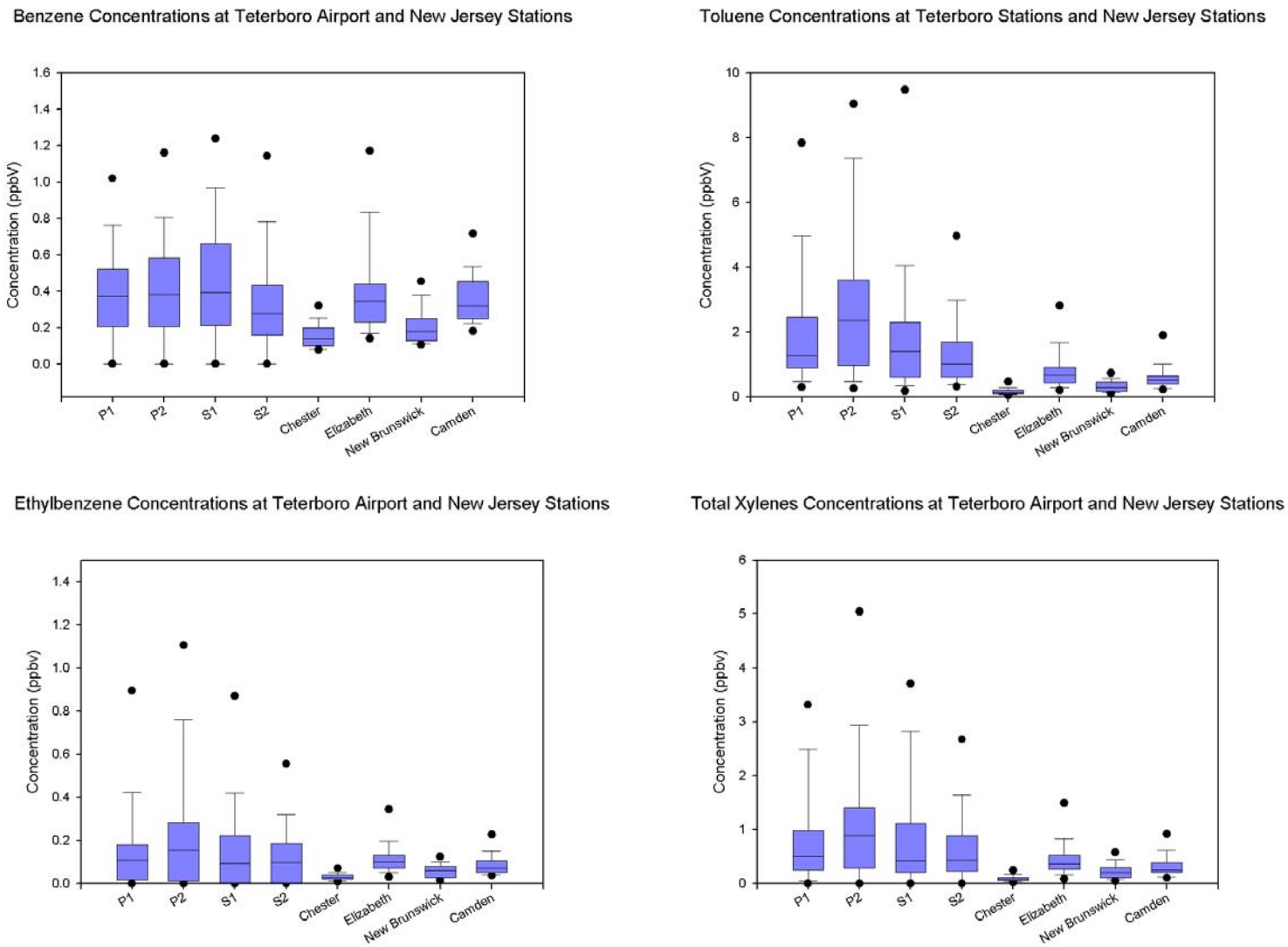


Figure 5-4 Box plots of selected VOC concentrations measured around Teterboro and other NJDEP monitoring locations. Boxes indicate the 25%, 50%, and 75% values; bars represent the 10% and 90% values; circles represent the 5% and 95% values.

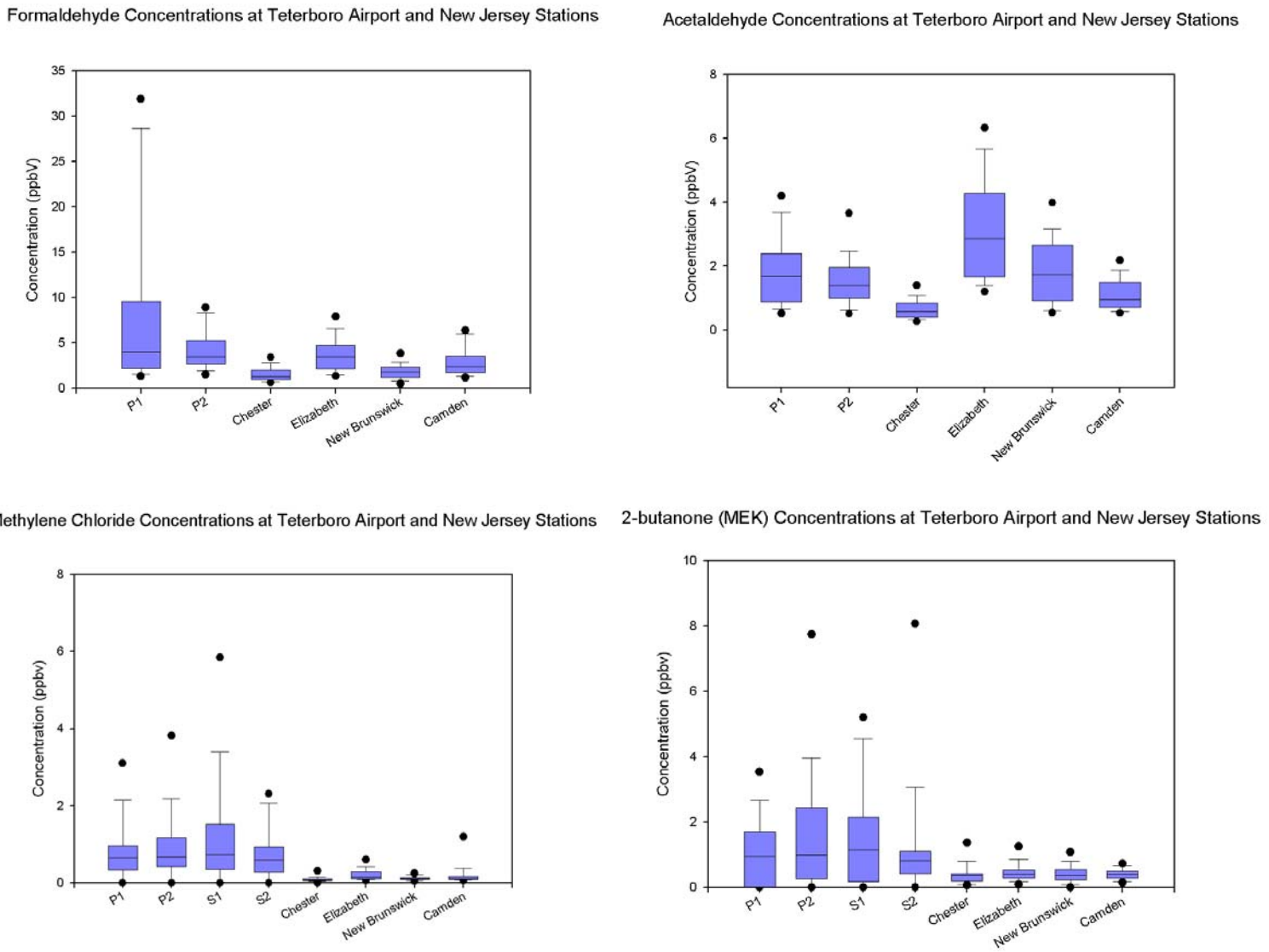
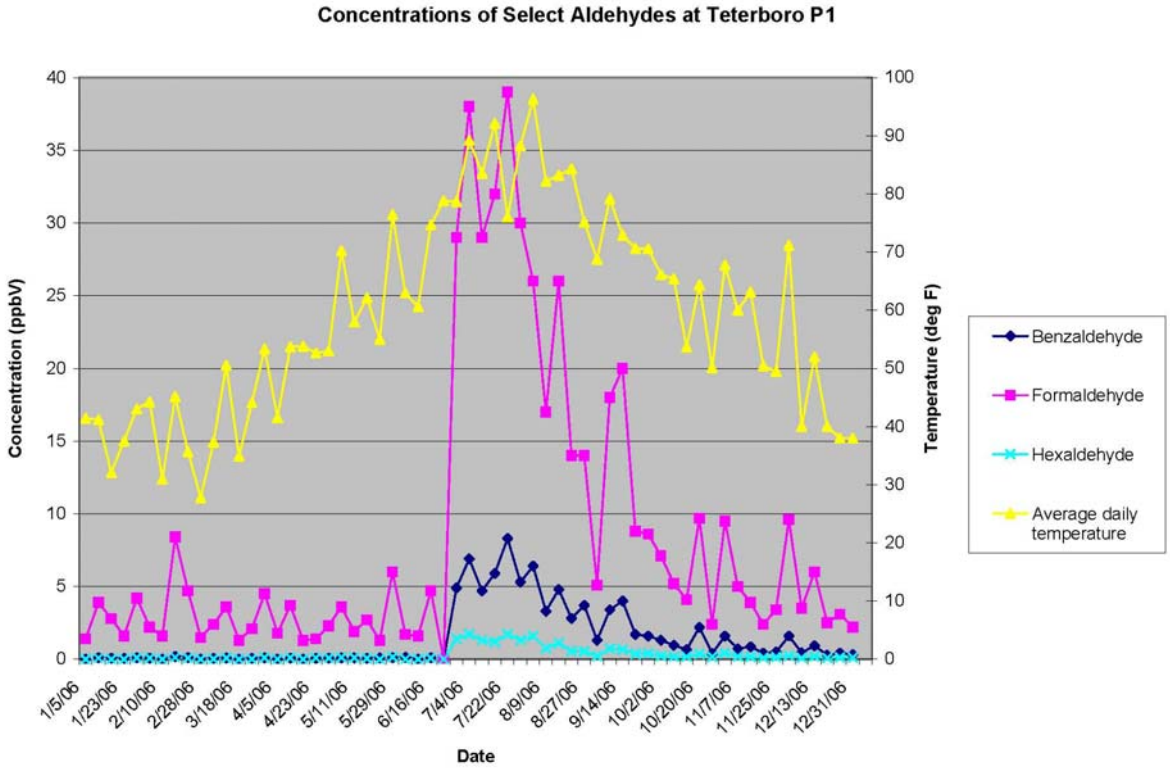


Figure 5-4 (cont.) Box plots of selected VOC concentrations measured around Teterboro and other NJDEP monitoring locations. Boxes indicate the 25%, 50%, and 75% values; bars represent the 10% and 90% values; circles represent the 5% and 95% values.

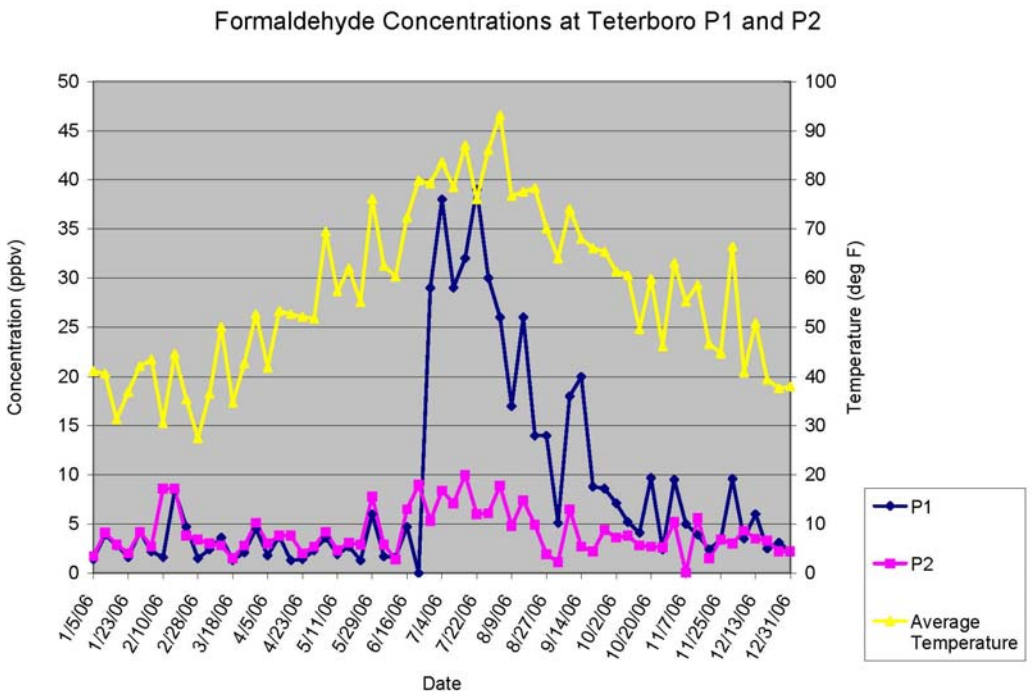
Several additional noteworthy trends were observed for certain VOCs. Some aldehydes, such as formaldehyde, are produced through photochemical reactions in the atmosphere (Kao 1994), which are more prevalent at higher temperatures. As shown in Figure 5-5(a), the concentrations of formaldehyde and other aldehydes at Primary 1 were observed to be relatively consistent throughout the first half of the year, increasing sharply in the summer months, and decreasing again during the last months of the year. This summertime increase corresponds to a gradual increase in average daily temperature, which peaks in the summer months before decreasing again for the rest of the year. This trend was not observed, however, at P2, as shown in Figure 5-5(b).

Due to the steep increase in formaldehyde beginning in July, compared to the more gradual increase in temperature throughout the first six months of the year, this summertime increase is likely not entirely due to increasing temperatures. It is likely that direct emission sources of formaldehyde have contributed to the higher concentrations in the summer months.

To evaluate the reasons for this difference between the two locations would require additional investigation into potential sources of formaldehyde in the airport vicinity, which was beyond the scope of this study.



(a)



(b)

Figure 5-5 Summertime Increase in Concentrations of Selected Aldehydes. Summertime increase in formaldehyde was not as pronounced at P2 as in P1.

Another noteworthy trend was the change in concentrations of methyl tert-butyl ether (MTBE) over the course of the year. MTBE was widely used as a gasoline additive during winter months to reduce the amount of carbon monoxide (CO) and unburned hydrocarbons in motor vehicle exhaust. MTBE is not used in jet fuel, so it is a useful indicator of motor vehicle emissions. Due to concerns regarding ground water contamination, many gas stations in New Jersey and the rest of the U.S. eliminated the use of MTBE as an additive in the first half of 2006. Figure 5-6 shows atmospheric concentrations of MTBE present during the first quarter of the year, and primarily nondetect readings for the remainder of the year. This indicates that emissions from motor vehicles are present in the collected samples, and some of the VOCs detected in the samples collected around Teterboro Airport can be attributed to motor vehicles.

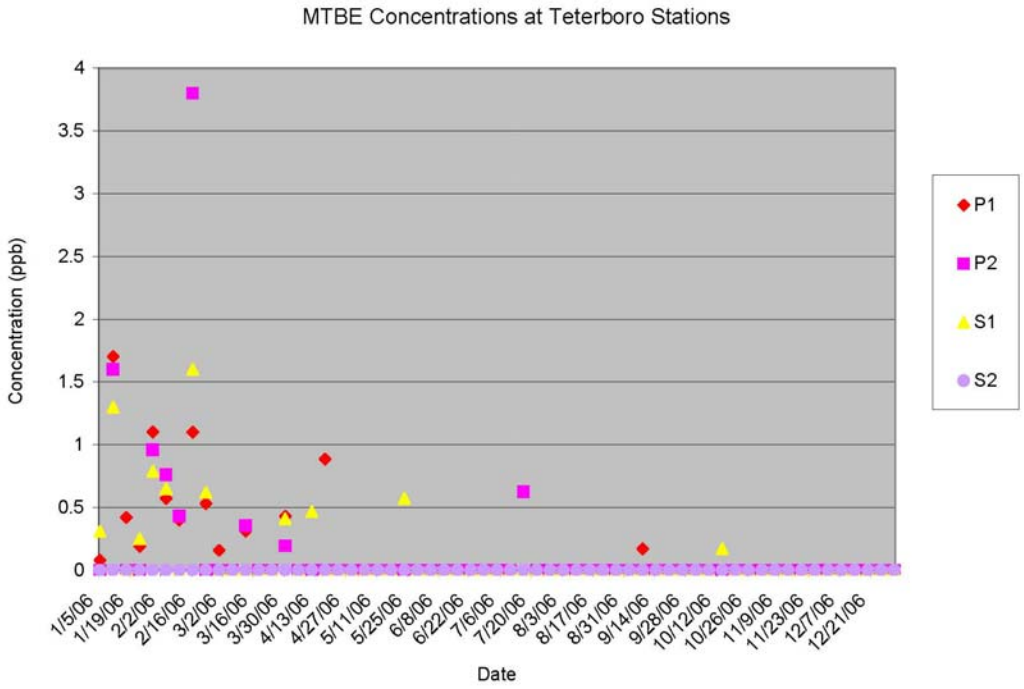


Figure 5-6 Concentrations of MTBE More Prevalent During First Quarter of 2006

5.2.2 Risk Screening

To provide some context for understanding the implications of the monitoring data collected during this study, ENVIRON conducted a conservative screening risk assessment. This risk screening was performed in accordance with NJDEP procedures (NJDEP 2004, 2007).

Among the 16 compounds consistently detected in the samples collected around Teterboro Airport, five are associated with potential carcinogenic health effects – acetaldehyde, benzene, ethylbenzene, formaldehyde, and methylene chloride. Nine of these 16 compounds are associated with non-carcinogenic health effects – acetaldehyde, acetone, benzene, dichlorodifluoromethane, formaldehyde, methylene chloride, toluene, trichlorofluoromethane, and xylenes. In order to compare the relative risks of these compounds among Teterboro Airport data and the other NJDEP monitoring station locations, unit risk factors and reference concentrations compiled by NJDEP (2007) were used to estimate both cancer and noncancer risks.

Cancer risks are expressed as a probability of an incremental cancer case occurring based on lifetime exposure to a chemical under specific conditions of exposure. For example, an upper bound cancer risk of one in one million (1E-6) indicates that, under certain conservative standard exposure assumptions that are designed to overestimate risks, there is a one in one million chance of an additional cancer case above background.[3] For regulatory purposes, NJDEP considers a risk of less than one in one million to be negligible. As shown in Figure 5-7

[3] In the U.S., men have about a 1 in 2 lifetime risk of developing cancer and women have about a 1 in 3 lifetime risk. The calculated cancer risks are the probability of an additional cancer case above these background levels.

and Table 5-2, the concentrations of the compounds consistently detected around Teterboro Airport are associated with total cancer risks ranging from 9E-5 to 2E-4 (90 in one million to 200 in one million), whereas the concentrations of these same compounds measured at the other NJDEP monitoring stations range from 3E-5 to 8E-5 (30 in one million to 80 in one million). Thus, the cancer risks associated with these compounds are up to five times higher at parts of Teterboro Airport than the other NJDEP locations. The cancer risks calculated for Elizabeth are approximately equivalent to those calculated for P2, but approximately half the values calculated for P1. The risks at all locations are largely associated with formaldehyde, which accounts for 76% to 87% of the risk around Teterboro Airport and 71% to 78% of the risk at the other NJDEP locations. The large contribution of formaldehyde to total cancer risk is consistent with the findings of the 1999 National-Scale Air Toxics Assessment (NATA).[4]

Noncancer risks for individual compounds are expressed in terms of a "hazard quotient" (HQ), and for multiple compounds in terms of a "hazard index" (HI). A hazard quotient is the ratio of an estimated average exposure concentration and a long term "reference concentration" (RfC), which is a concentration which, even over a long period of time, is not expected to have any negative effect on health. According to USEPA and NJDEP guidance, the risk associated with inhalation exposures to noncarcinogens is considered negligible if the long term HI is less than or equal to one. As shown in Figure 5-8 and Table 5-3, the concentrations of the compounds consistently detected around Teterboro Airport are associated with long term HI values ranging from 2.2 to 4.0, whereas the HI values associated with the concentrations of these same compounds measured at the other NJDEP monitoring stations range from 0.8 to 2.2. Thus, the noncancer HI values associated with these compounds are up to two times higher at parts of Teterboro Airport than the other NJDEP locations. Similar to the cancer risk results, the noncancer risks calculated for Elizabeth are approximately equivalent to those calculated for P2, but approximately half the values calculated for P1. Again, the risks at all locations are largely associated with formaldehyde, which accounts for 78% to 88% of the risk around Teterboro Airport and 67% to 79% of the risk at the other NJDEP locations.

With respect to noncancer risks, one notable compound that is not included in these calculations is acrolein. It has been reported that acrolein may be an important contributor to noncancer risk associated with airports (Hayes 2003). However, acrolein is a difficult compound to measure consistently. Recently, ERG developed for USEPA a procedure for measuring acrolein (ERG 2006); however, this procedure was not available during the course of this study. It is recommended that acrolein be included as a target compound for any future monitoring studies.

[4] See http://www.state.nj.us/dep/airmon/airtoxics/bergen.htm for NATA risk results for Bergen County.

Table 5-2 Cancer Risks Associated with Subset of Detected Compounds

Compound	TEB-P1	TEB-P2	CHE	ELIZ	NB	CAM
Acetaldehyde	7.2E-6	6.4E-6	2.6E-6	1.2E-5	7.3E-6	4.5E-6
Benzene	1.0E-5	1.0E-5	3.9E-6	1.0E-5	5.2E-6	9.0E-6
Ethylbenzene	1.9E-6	2.8E-6	3.3E-7	1.3E-6	6.5E-7	9.4E-7
Formaldehyde	1.4E-4	6.7E-5	2.5E-5	5.9E-5	3.4E-5	4.6E-5
Methylene chloride	1.5E-6	1.8E-6	1.6E-7	3.7E-7	2.0E-7	4.5E-7
Total Cancer Risk	**1.6E-4**	**8.9E-5**	**3.2E-5**	**8.3E-5**	**4.7E-5**	**6.1E-5**
% Associated with Formaldehyde	87%	76%	78%	71%	71%	76%
TEB-P1 = Teterboro Primary Site #1, TEB-P2 = Teterboro Primary Site #2, CHE = Chester, ELIZ = Elizabeth, NB = New Brunswick, CAM = Camden						

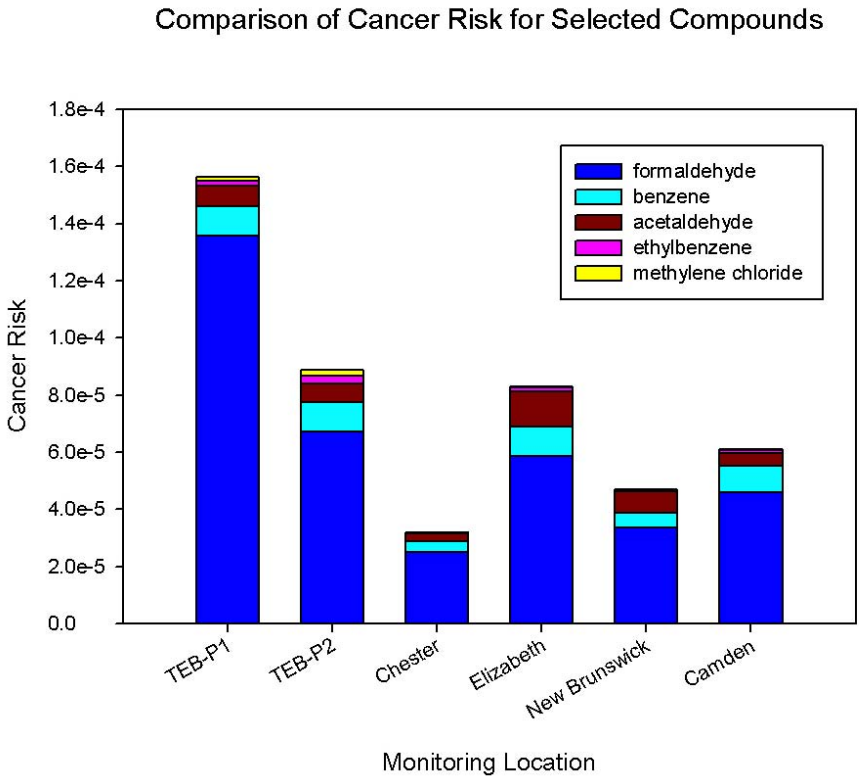


Figure 5-7 Cancer Risks Associated with Subset of Detected Compounds. Risks at all locations exceed the health benchmark of 1E-6, which is a typical occurrence for urban locations in the U.S.

Table 5-3 Noncancer Risks Associated with Subset of Detected Compounds

Compound	TEB-P1	TEB-P2	CHE	ELIZ	NB	CAM
Acetaldehyde	0.36	0.32	0.13	0.63	0.37	0.23
Acetone	0.0007	0.0009	6.7E-5	8.9E-5	7.5E-5	8.0E-5
Benzene	0.044	0.044	0.017	0.043	0.022	0.039
Dichlorodifluoromethane	0.009	0.0082	0.013	0.014	0.013	0.013
Formaldehyde	3.5	1.7	0.64	1.5	0.86	1.2
Methylene chloride	0.0079	0.0096	0.0008	0.002	0.0011	0.0024
Toluene	0.028	0.035	0.0023	0.010	0.0042	0.0083
Trichlorofluoromethane	0.002	0.002	0.0021	0.0022	0.0021	0.0024
Xylenes, o-	0.0083	0.011	0.0012	0.0056	0.0030	0.0038
Xylenes, p/m-	0.030	0.038	0.0029	0.015	0.0071	0.0099
Total Hazard Index	**4.0**	**2.2**	**0.8**	**2.2**	**1.3**	**1.5**
% Associated with Formaldehyde	88%	78%	79%	68%	67%	79%
TEB-P1 = Teterboro Primary Site #1, TEB-P2 = Teterboro Primary Site #2, CHE = Chester, ELIZ = Elizabeth, NB = New Brunswick, CAM = Camden						

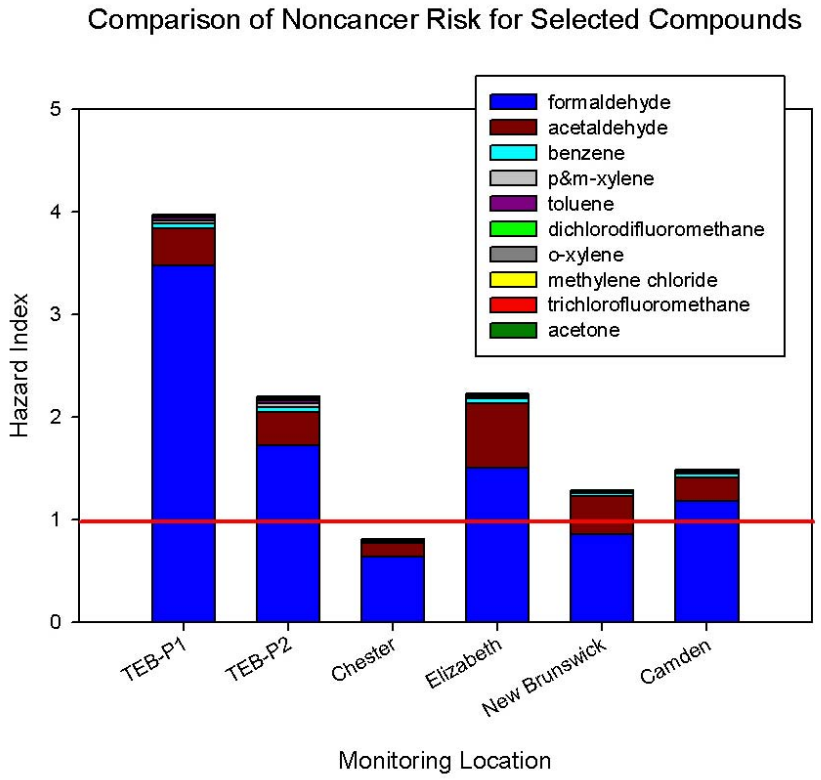


Figure 5-8 Noncancer Risks Associated with Subset of Detected Compounds. Hazard indices at all locations except Chester exceed the health benchmark of 1, which is a typical occurrence for urban locations in the U.S.

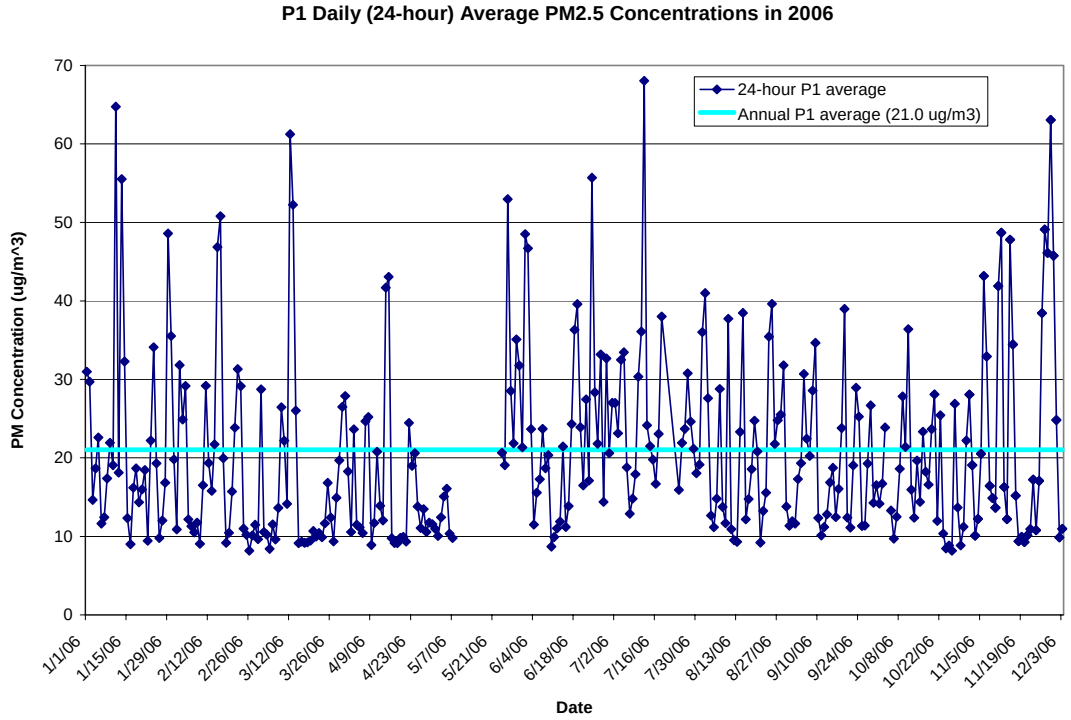
It is important to recognize that the risks calculated in this study are based on air quality data collected at the ends of the airport runways, and no data were collected from within the surrounding neighborhoods. The NJDEP air quality data, on the other hand, are collected at stations that have been sited to be representative of where various exposure populations work or live. Thus, the risks calculated based on the airport data collected in this study likely overestimate (to an unknown extent) the potential risks to the surrounding communities. It is also important to recognize that these risks are not necessarily associated with the airport operations. Nor is the observation that the concentrations detected around Teterboro are higher than the other NJDEP locations for certain compounds intended to suggest that these are the highest concentrations in the state. The comparisons of air concentrations and associated risks presented in this report are provided as a point of reference based on available data. The observation that the detected concentrations were elevated compared to "typical" urban, suburban, or mobile source-dominated locations suggests that additional study may be warranted for the Teterboro Airport vicinity to characterize the sources of certain detected compounds, such as formaldehyde.

5.3 Fine Particulate Matter

Continuous $PM_{2.5}$ data were collected at Primary 1 and Primary 2. Samples were collected at each station at one minute intervals, except when maintenance was being performed on the E-BAM instruments.

Based on the continuous data collected, ENVIRON calculated the average concentration for each 24-hour period, as well as the annual average for 2006. These 24-hour and annual average concentrations are shown in Figure 5-9 The annual average concentrations were 21 and 18 $\mu g/m^3$ at Primary 1 and Primary 2, respectively.

Figure 5-10 compares the annual average $PM_{2.5}$ concentrations measured around Teterboro Airport with NAAQS compliance data collected at other NJDEP monitoring stations. As shown in this figure, the annual concentrations for 2006 around Teterboro Airport are higher than the 2006 average concentrations at the other NJDEP locations. However, it is important to recognize that the Teterboro Airport data are not directly comparable with the NJDEP data due to the difference in measurement methods. The continuous monitors used in this study typically result in higher readings than would be expected using the filter-based Federal Reference Method (FRM) that was used to generate the NJDEP data. The reason that the continuous instruments were used for this study instead of the FRM was to allow temporal trends to be evaluated. Figure 5-11 shows the average hourly $PM_{2.5}$ concentrations for the year, separated by day of week. As these figures show, $PM_{2.5}$ concentrations tended to reach a peak between 4:00 and 6:00 AM, decrease to a minimum by mid-day, and increase to a second peak in the late evening.



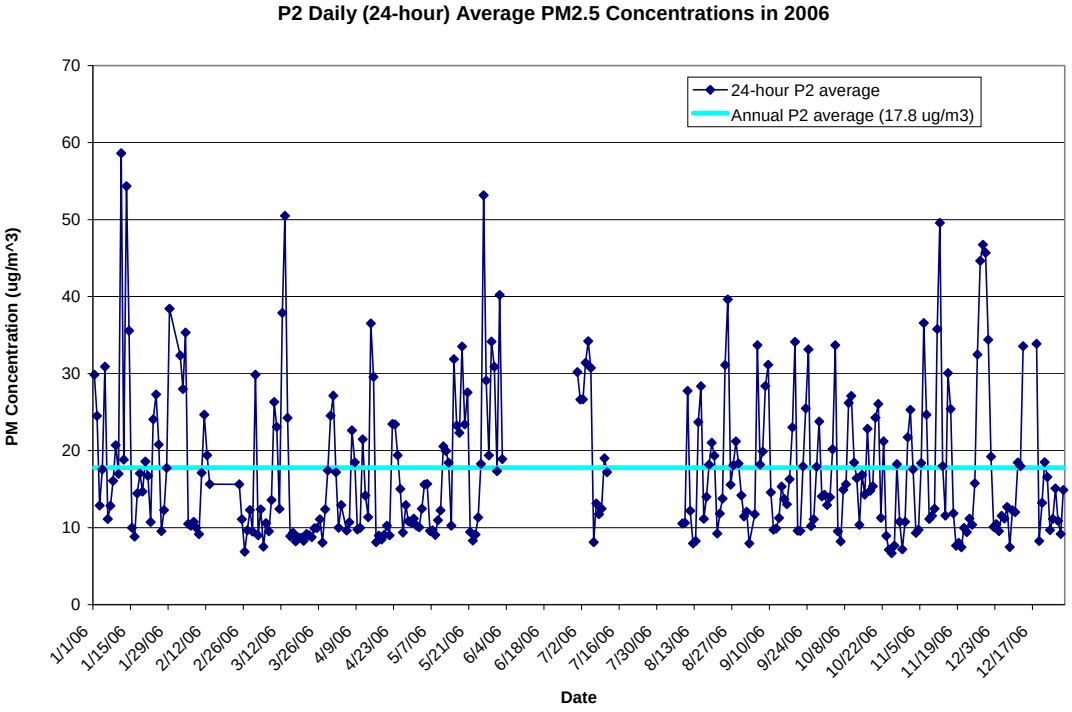


Figure 5-9 Average Daily $PM_{2.5}$ Concentrations Measured around Teterboro Airport

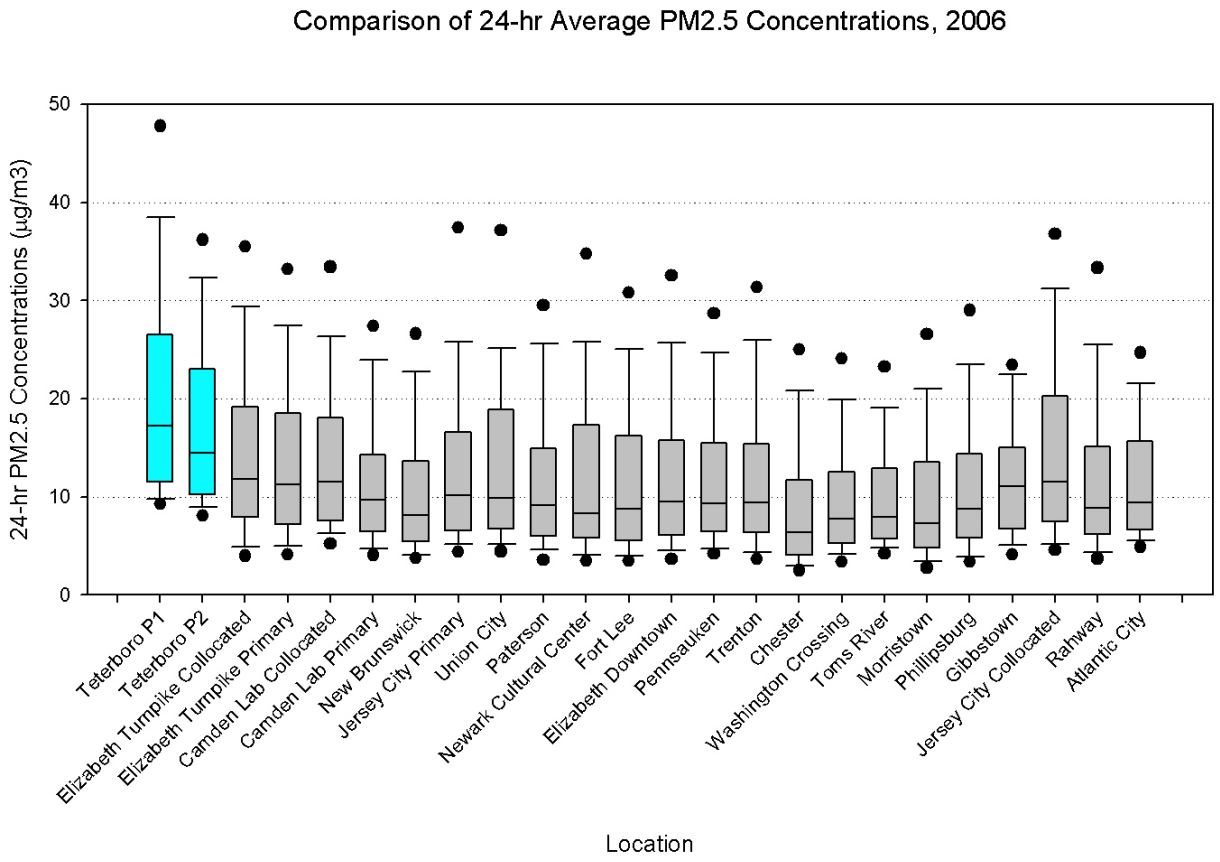


Figure 5-10 Box Plot Comparison of Annual Average $PM_{2.5}$ Concentrations Measured around Teterboro Airport with Data Collected at Other NJDEP Monitoring Stations. Note that the data for Teterboro were collected using a different method than is used by NJDEP, and is likely biased upward by as much as 16%. Boxes indicate the 25%, 50%, and 75% values; bars represent the 10% and 90% values; circles represent the 5% and 95% values.

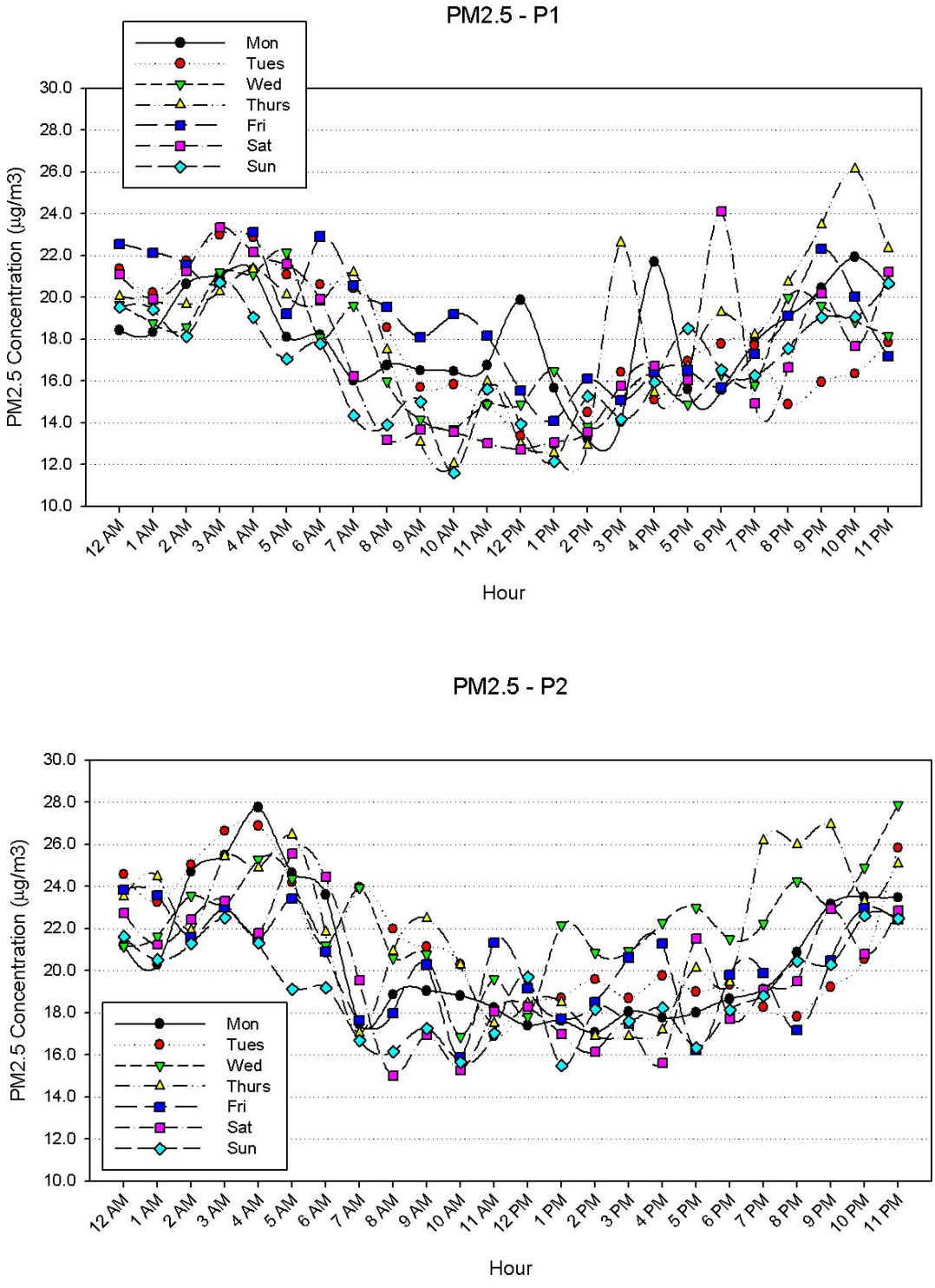


Figure 5-11 Average Hourly $PM_{2.5}$ Concentrations, Separated by Day of Week

Comparing these plots with Figure 5-2, the $PM_{2.5}$ concentrations follow an inverse pattern with wind speed. This relationship is further seen in Figure 5-12, which shows that higher $PM_{2.5}$ concentrations occur when wind speeds are low.

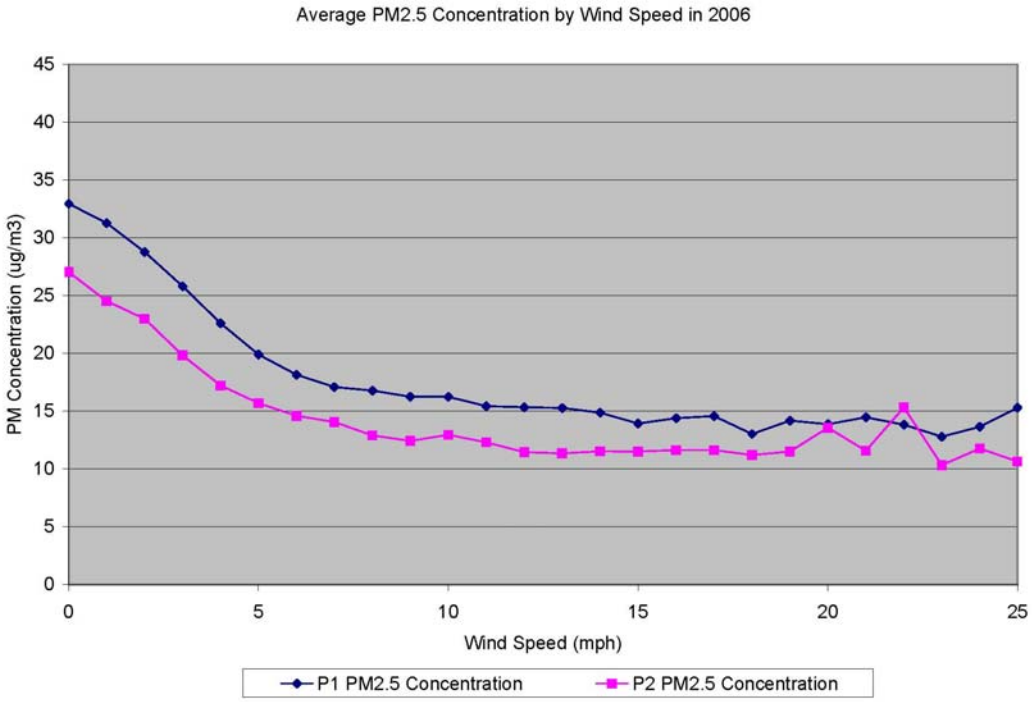


Figure 5-12 Relationship Between $PM_{2.5}$ Concentration and Wind Speed. Highest $PM_{2.5}$ concentrations observed at lowest wind speeds.

To evaluate the contributions to ambient $PM_{2.5}$ concentrations from the airport and roadways, ENVIRON screened the $PM_{2.5}$ data based on wind direction. Figure 5-13 shows an example of the wind direction-filtered data for the month of September 2006. Comparable plots for other months are provided in Appendix D. The plot for September 2006 shows several very sharp and distinct spikes that occur when winds were blowing from the airport runway toward the $PM_{2.5}$ monitor (shown in blue). Similarly, several sharp and distinct spikes were also observed when winds were blowing from the roadway toward the $PM_{2.5}$ monitor (i.e., away from the airport runway) (shown in pink). The magnitude of the $PM_{2.5}$ concentration spikes are roughly equivalent, suggesting that both the airport and roadway activities appear be associated with similar ambient $PM_{2.5}$ concentrations.

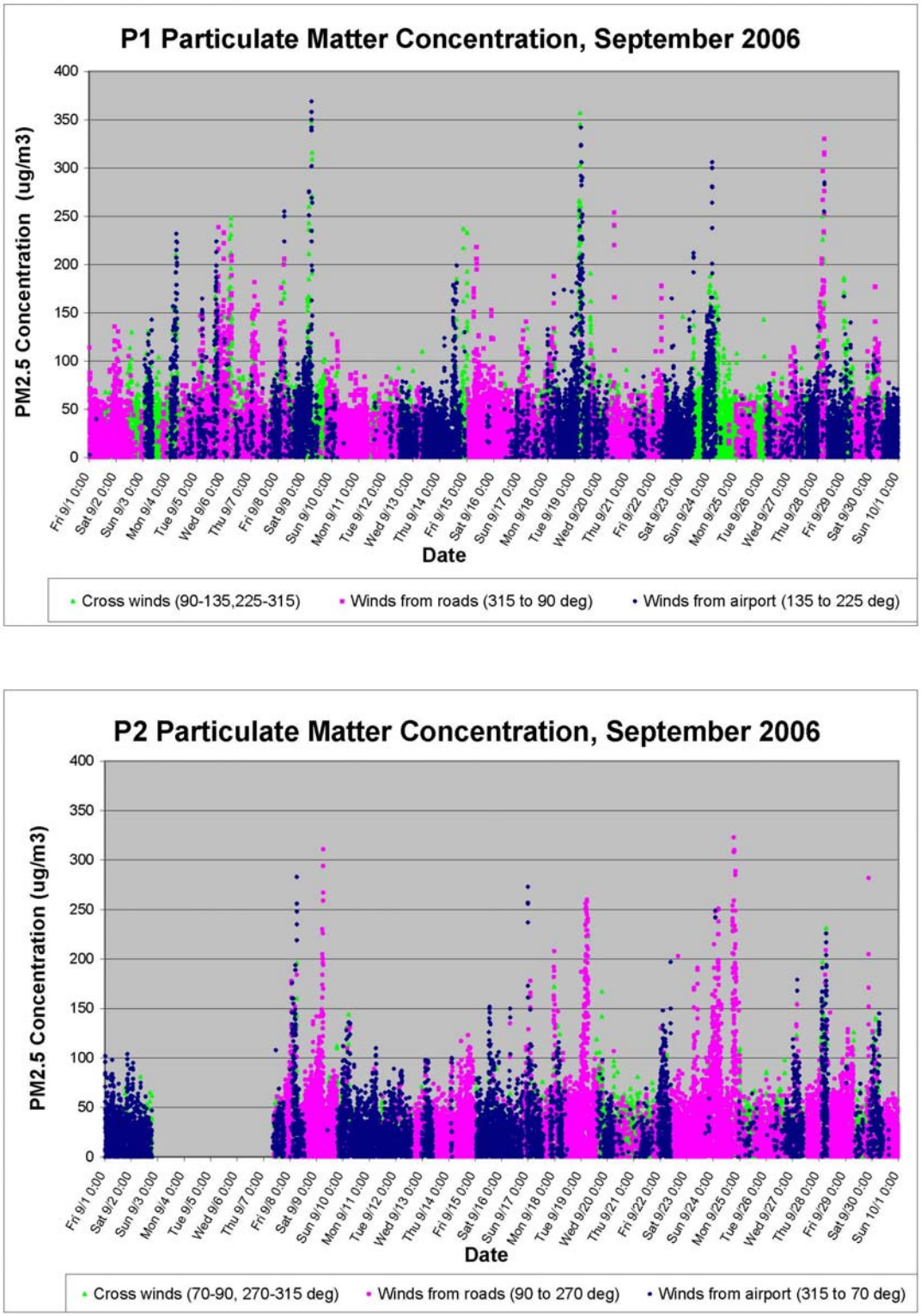


Figure 5-13 Wind Direction-Filtered $PM_{2.5}$ Concentrations (Blue=wind blowing from airport to monitor, pink=wind blowing from roads to monitor), September 2006

5.4 Black Carbon

Continuous BC data were collected at Primary 1 and Primary 2. Samples were collected at each station at one minute intervals, except when maintenance was being performed on the instruments. Figure 5-14 shows the average hourly BC concentrations for 2006, separated by day of week. As these figures show, on weekdays, BC concentrations tended to reach a peak between 6:00 to 7:00 am, and steadily decline and level off over the remainder of the day. On weekends, overall BC levels are lower than during the week, with no strong peaks observed.

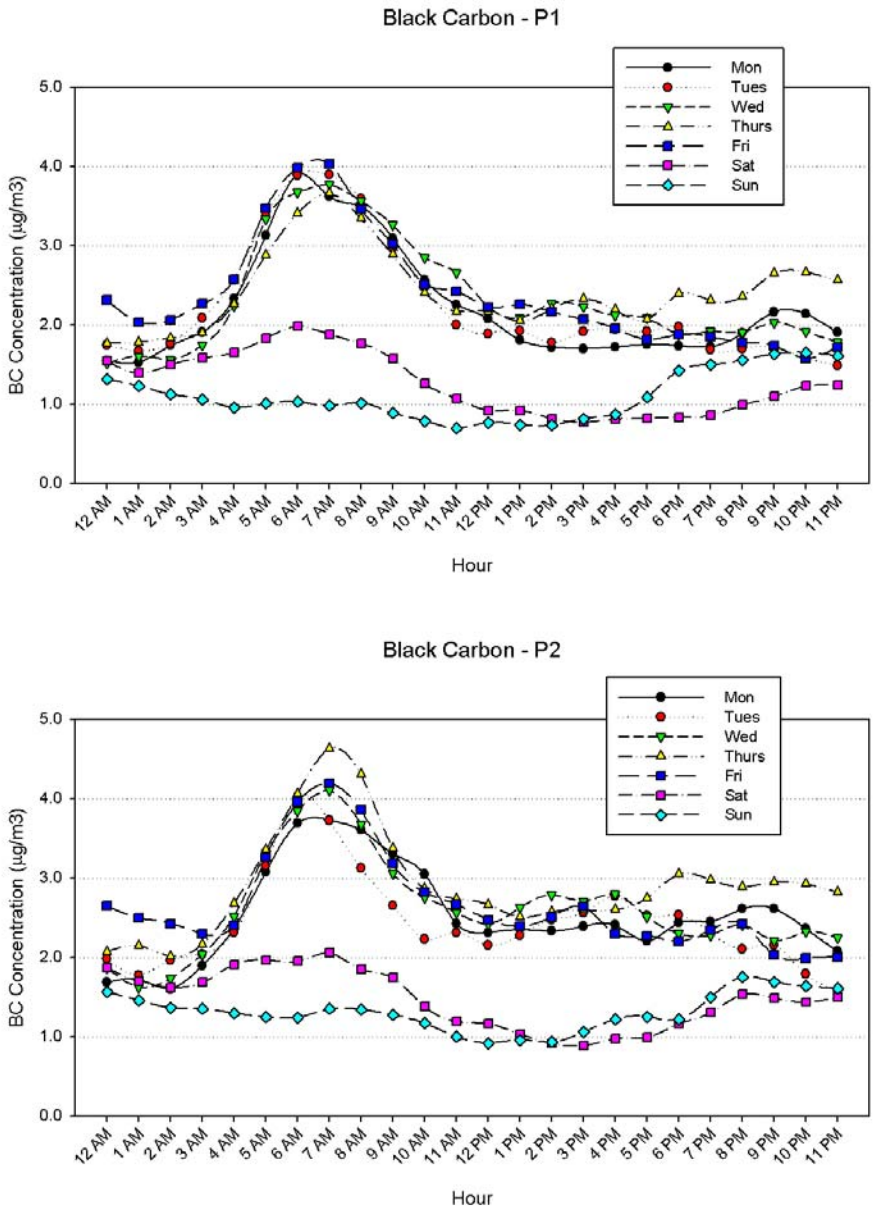


Figure 5-14 Average Hourly Black Carbon Concentrations By Day of Week

These temporal trends appear to resemble the traffic activity patterns for large vehicles (Figure 4-4) more closely than the traffic activity patterns for total vehicles (Figure 4-2) or small vehicles (Figure 4-3) or aircraft LTOs (Figure 4-1). This suggests that trucks may have been the largest contributor to ambient BC concentrations.

Similar to $PM_{2.5}$, BC concentrations appear to follow an inverse pattern with wind speed. This relationship is further seen in Figure 5-15, which shows that higher BC concentrations occur when wind speeds are low.

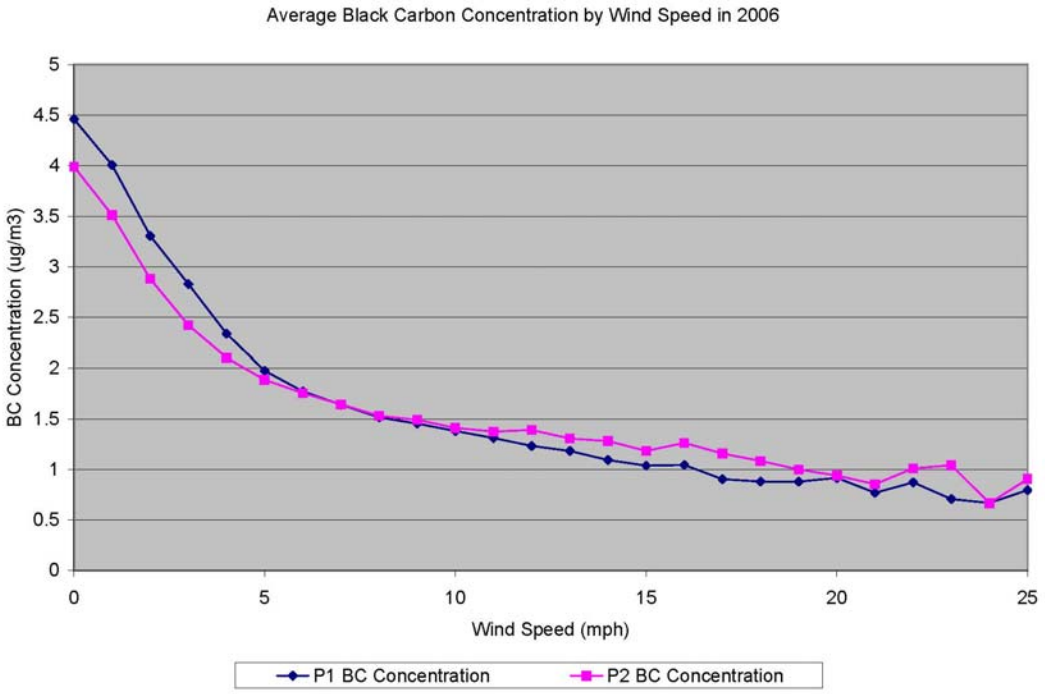


Figure 5-15 Relationship Between BC Concentration and Wind Speed. Highest BC concentrations observed at lowest wind speeds.

To evaluate the contributions to ambient BC concentrations from the airport and roadways, ENVIRON screened the BC data based on wind direction. Figure 5-16 shows an example of the wind direction-filtered data for the month of September 2006. Comparable plots for other months are provided in Appendix D. The plots for September 2006 shows several distinct spikes that occur when winds were blowing from the airport runway toward the BC monitor (shown in blue), but not as sharp as the spikes observed for $PM_{2.5}$. Similarly, several distinct spikes were also observed when winds were blowing from the roadway toward the BC monitor (i.e., away from the airport runway) (shown in pink), again not as sharp as the spikes observed for $PM_{2.5}$. The magnitude of the BC concentration spikes are roughly equivalent, suggesting that both the airport and roadway activities appear be associated with similar ambient BC concentrations. Because the spikes do not appear to be as sharp, this suggests that the quantities of BC emitted by the sources may be less than for $PM_{2.5}$. However, this may also be a function of the difference in scale between the BC and $PM_{2.5}$ plots.

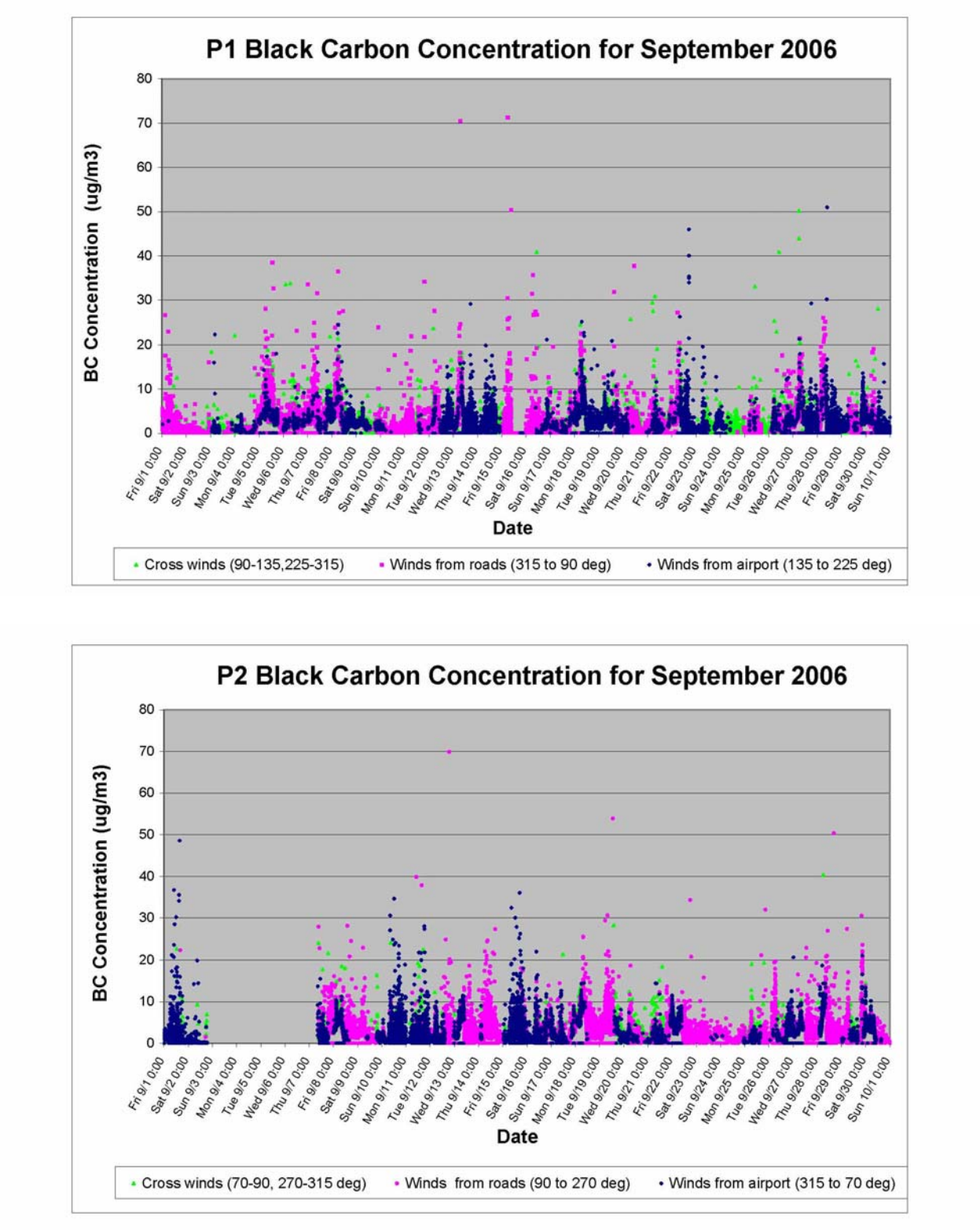


Figure 5-16 Wind Direction-Filtered BC Concentrations (Blue=wind blowing from airport to monitor, pink=wind blowing from roads to monitor), September 2006

6.0 Open Path Monitoring Results

Open path optical techniques for spatiotemporal-resolved measurement of air pollutants is an active field of research within USEPA. Among the various open path techniques currently being developed and evaluated by USEPA is a Deep UltraViolet Differential Optical Absorption Spectroscopy (DUV-DOAS) system (Thoma et al. 2006).

DOAS is a method of quantifying the concentrations of gases by measuring their absorption in selected regions in the ultraviolet (UV) and visible spectra. The DOAS technology in the UV Sentry system specifically measures absorption in the deep UV spectrum, which generally refers to wavelengths between 200 and 300 nanometers (nm).

6.1 System Configuration

The open path DUV-DOAS spectrometer system used for this project is the UV Sentry manufactured by CEREX Environmental Services of Atlanta, GA. The system used in this study was equipped with a deuterium source light bulb.

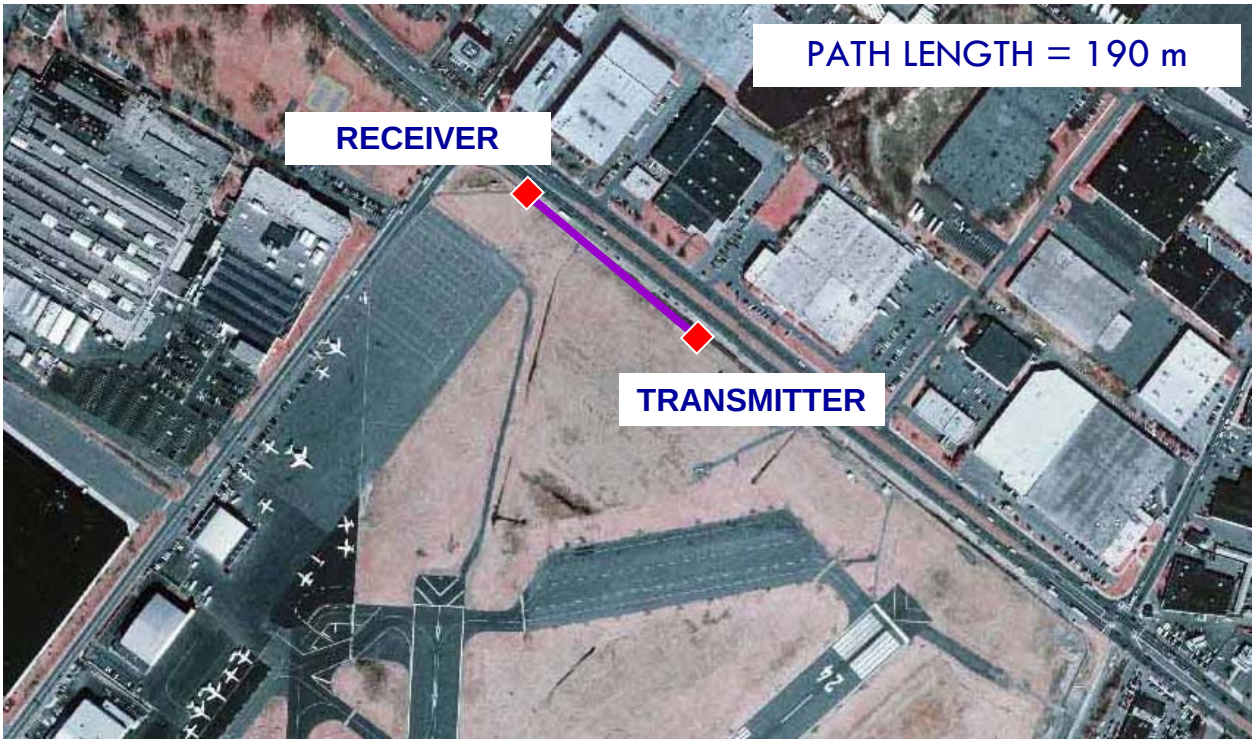
6.1.1 Data Collection

The UV Sentry system consists of two components – a transmitter and a receiver. The transmitter sends a column of UV light (light beam) to the receiver, which focuses the UV light onto an optical fiber sensor. The light is then transmitted to a spectrometer and a raw spectra file is generated and recorded on a personal computer connected to the UV Sentry receiver. The raw spectra file contains header information about the sample number, date, time, sample site, path length and signal strength. In addition, the raw spectra file contains the light intensity at over 2,000 specific wavelengths between 180 and 320 nm (CEREX 2006). At Primary 1 and Primary 2, the transmitter and receiver were approximately 190 meters apart, as recommended by the manufacturer (see Figures 6-1 and 6-2).

To perform any quantitative analysis on collected data spectra, a “clean air” background spectrum must also be generated, when none of the absorbing gases are present or are minimized. The background spectrum is subtracted from a given data spectrum.

$$Absorbance = \log\left(\frac{Background\_Intensity}{Data\_Intensity}\right)$$

The background spectra file may be generated in advance, or selected during data processing at a time period that is expected to be free of absorbing gases to the extent possible. Using the UV Sentry control software, the user has the option of manually selecting a background file or setting the software to automatically select the previous record as the background file. The UV Sentry system was typically configured to record data at one minute intervals except for a one-week period in August and a two-day period in December when it was configured to record data every five seconds.



(a) Primary 1

(b) Receiver

(c) Transmitter

Figure 6-1 DUV-DOAS system configuration, Primary 1

(b) Primary 2

(b) Receiver

(c) Transmitter

Figure 6-2 DUV-DOAS system configuration, Primary 2

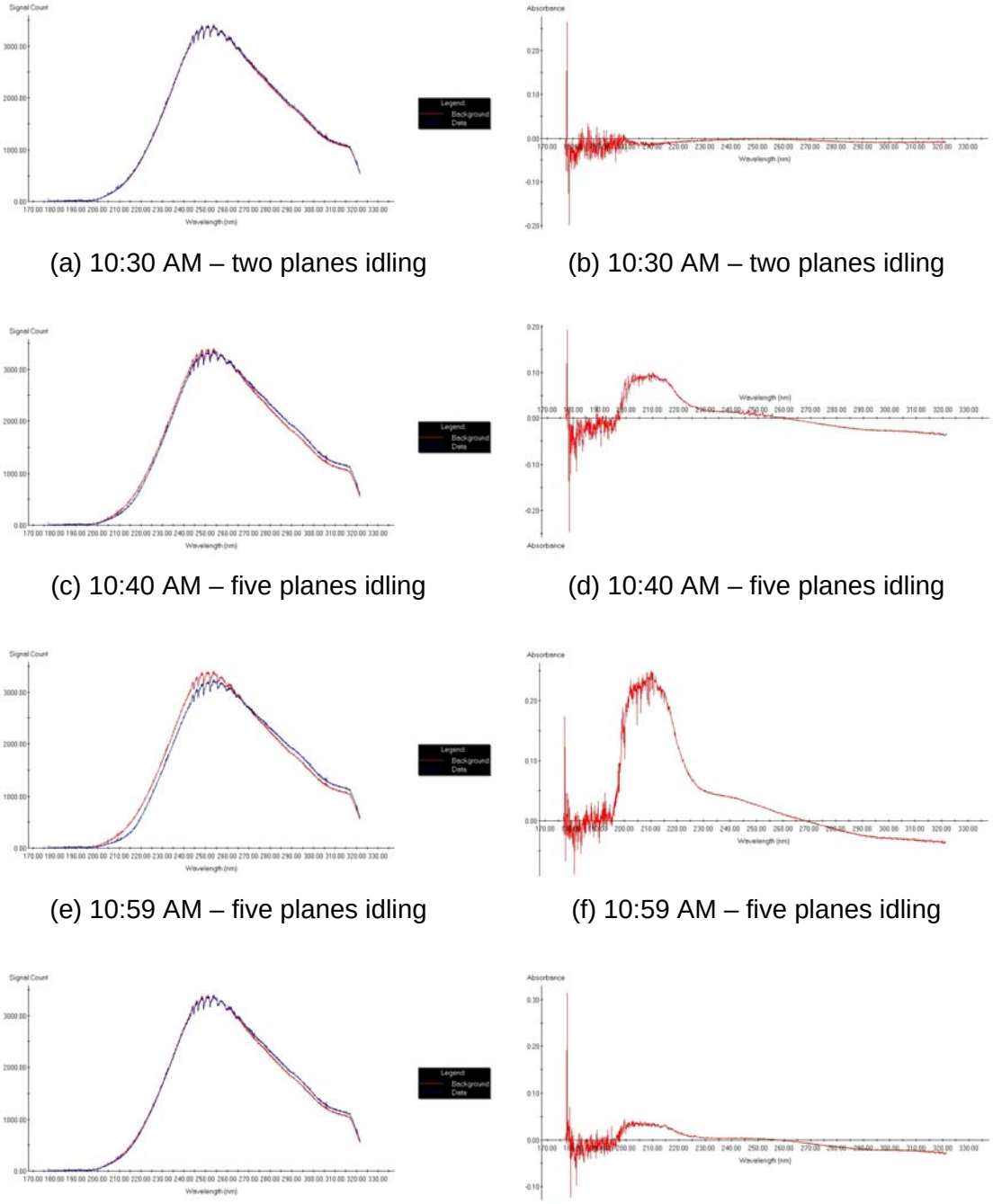
6.1.2 Data Processing

The raw spectra files were processed to estimate the intensity of UV absorption in the DUV range associated with several compounds, including VOCs. While many VOCs absorb in the UV range, some of their spectral features are similar, making them difficult to distinguish and attribute to one compound. Many compounds exhibit strong peaks between 180 and 220 nm, but the need to distinguish them requires the search for distinct spectral features beyond 220 nm. According to CEREX, these features may be difficult to detect unless the compound is present at high concentrations. For the purposes of the results presented in this report, a program developed in Matlab was used to calculate an aggregate measure of the intensity at which compounds absorb in the DUV range (referred to as "DUV Intensity").

Figure 6-3 shows an example of the absorption in the DUV range observed during high aircraft emission events in this study in September 2006. This figure shows plots of a series of readings from the DUV-DOAS system as a function of wavelength, which were measured during a time when the number of aircraft idling on the runway increased and decreased over time. The plots on the left hand column are the signal readings observed; both a background signal (red) and the ambient measurement (blue) are shown at different time intervals. The plot in Figure 6-3(a) shows the ambient measurement to be generally equivalent to the background reading. In Figures 6-3(c) and (e), the number of idling planes increased, and the ambient signal is observed to be lower than background, reflecting the absorbance at those wavelengths. Finally, in Figure 6-3(g), the ambient signal is observed to return to background, as the number of idling aircraft decreases.

The plots on the right hand column show a measure of the difference (UV absorbance) between the ambient and background readings. Figure 6-3(b) shows the two signals to be similar, with little difference. In Figures 6-3(d) and (f), the differences between the two signals increase, and a clear peak can be seen at wavelengths between 180 and 220 nm, which then decreases in Figure 6-3(h). This series of plots shows a strong relationship between the airport emissions and DUV Intensity.

USEPA researchers have observed similar absorbance in the DUV range with motor vehicle emissions from near roadway studies using these same DUV-DOAS systems. To quantify a measure of the DUV Intensity, based on discussions with USEPA researchers, absorption around 201 to 207 nm has been observed to be associated with high emission events, with better sensitivity at 207 nm (Thoma, personal communication). On the other hand, there is little change in absorption around 280 nm, making that wavelength a good candidate for an equipment-based baseline. Differences in readings at 280 nm over time are likely associated with shifts in the alignment of the equipment rather than variations in concentrations of atmospheric constituents. The Matlab program uses the raw spectra files generated by the UV Sentry system and calculates the logarithms of the absorption measurements at 207 and 280 nm. The difference in the logarithms of the measurements at 207 and 280 nm is referred to in this study as "DUV Intensity." The calculation performed by the Matlab program is sensitive to the signal strength of the UV Sentry system, which fluctuated throughout the study. As a result, the calculated "DUV Intensity" value is a relative, not absolute, indicator of absorption in the DUV range.



(a) 10:30 AM – two planes idling

(b) 10:30 AM – two planes idling

(c) 10:40 AM – five planes idling

(d) 10:40 AM – five planes idling

(e) 10:59 AM – five planes idling

(f) 10:59 AM – five planes idling

(g) 11:07 AM – one plane idling

(h) 11:07 AM – one plane idling

Figure 6-3 Example absorbance spectra during high emissions event on September 14, 2006, Primary 1, between 10:30 and 11:07 AM. Plots (a), (c), (e), and (g) are signal counts observed at the receiver, while plots (b), (d), (f), and (h) are the absorbance spectra. High absorbance between wavelengths of 180 and 220 nm observed during emissions event.

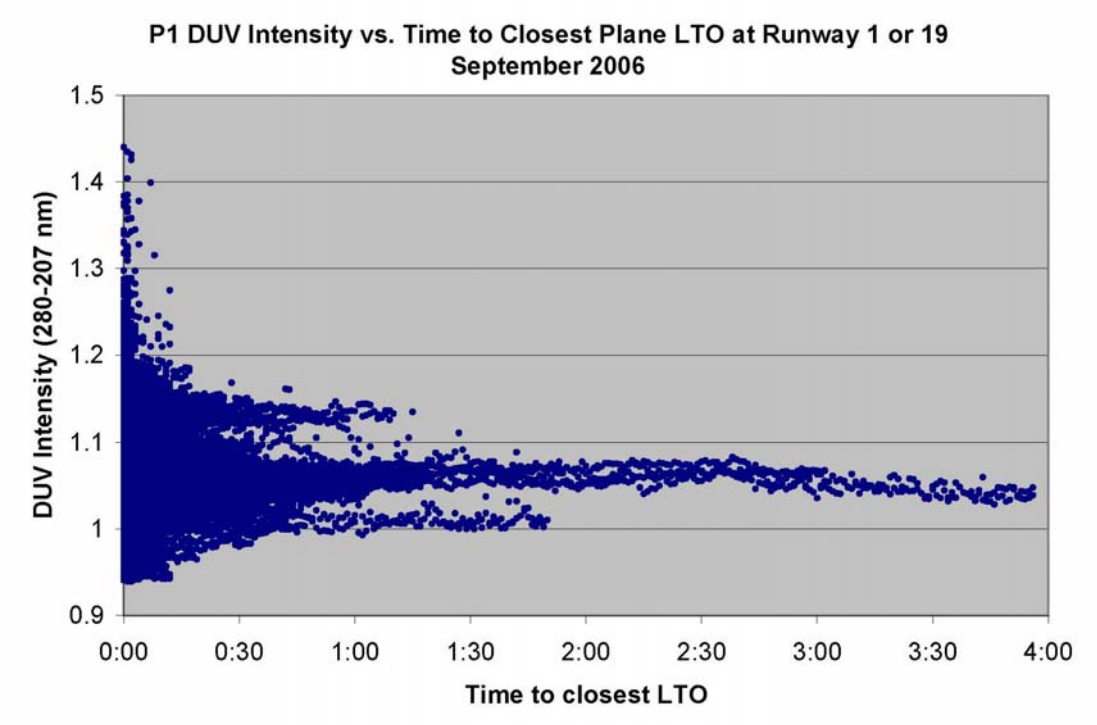
It is important to note that the use of this technology is still in the research and development phase. This approach has not been officially validated or approved by USEPA, NJDEP, or other regulatory agencies. The definition of DUV Intensity used in this study is an initial effort at quantifying DUV-DOAS readings with respect to aircraft and motor vehicle emissions, but other methods of interpreting these data are a recommended area of future study.

6.2 Open Path Results

As discussed previously, DUV intensity, defined for the purposes of this study as the difference between the signal at 280 and the signal at 207, was used as an aggregate indicator of chemicals that absorb in the DUV range.

6.2.1 Time Elapsed Since Most Recent LTO

To evaluate whether the DUV intensity readings could be related to airport activity, ENVIRON evaluated a subset of the DUV data collected when the winds were blowing from the airport runway toward the DUV-DOAS system. The times of the DUV intensity measurements were compared with the time elapsed since the most recent airplane LTO (helicopter LTO activity was excluded). Figure 6-4 shows an example of these comparisons for the month of September 2006. Comparable plots for other months are provided in Appendix D. These plots indicate that the highest DUV intensity values occur when the time elapsed since the most recent LTO is very brief. As the amount of time since the most recent LTO increases, the DUV intensity values approach a steady background level. Certain background levels are higher than others, which tend to be associated with calm wind conditions. These plots suggest a relationship between high DUV intensity and LTO activity.



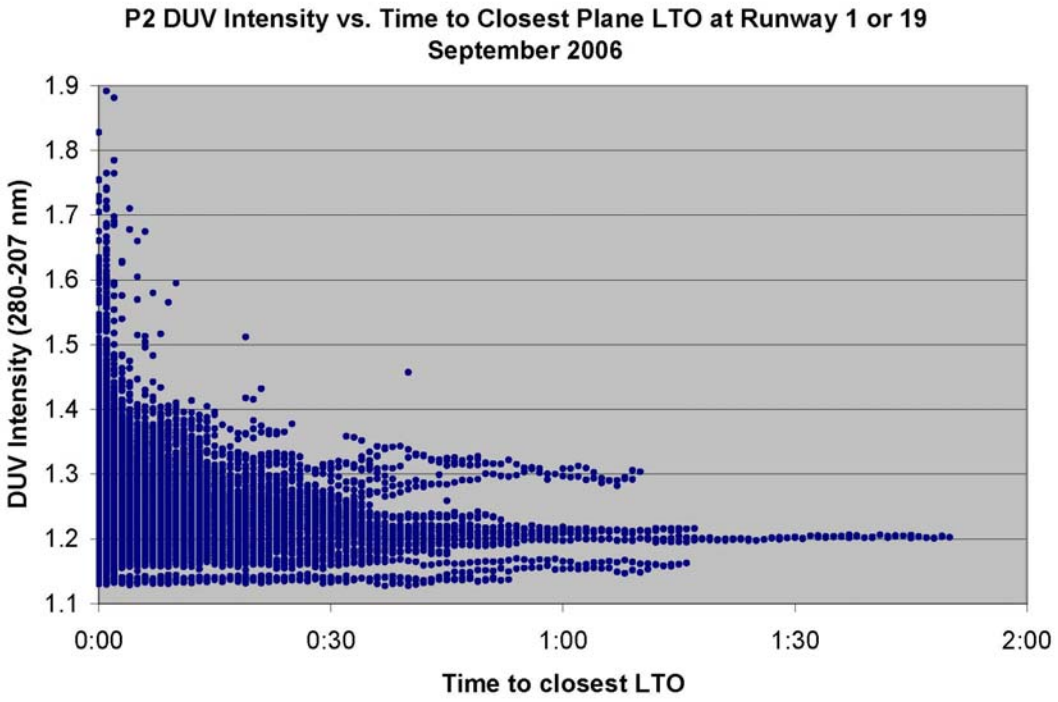
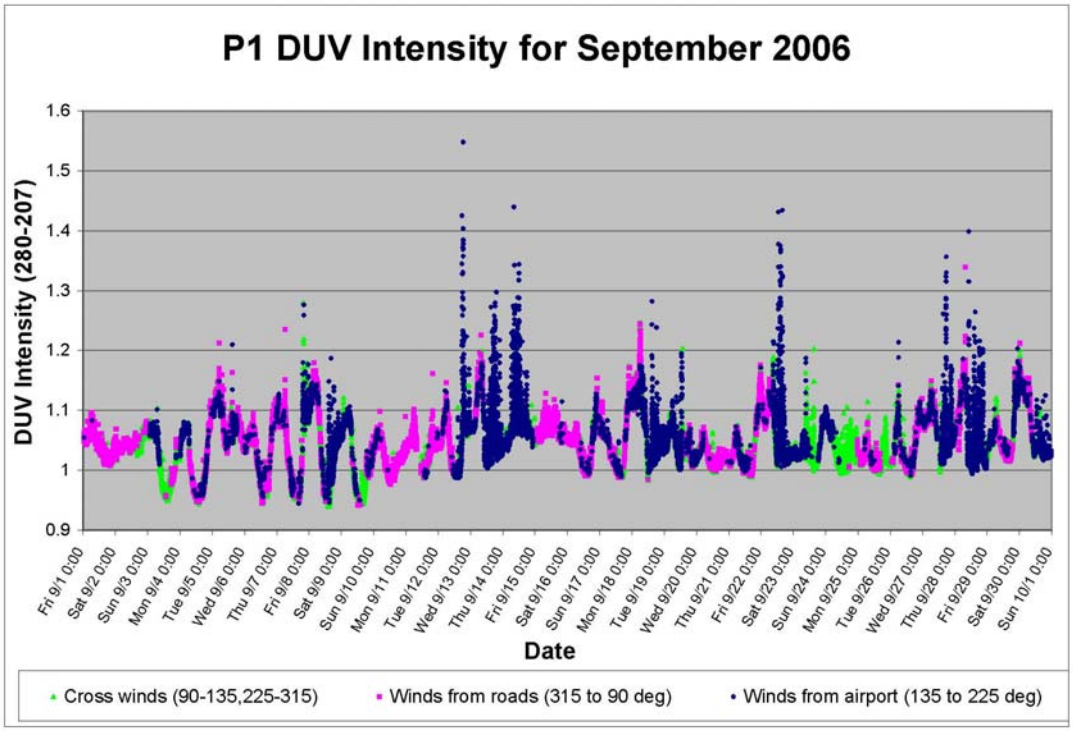


Figure 6-4 Relationship Between DUV Intensity at P1/P2 and Time to Closest LTO. Highest DUV Intensity values observed when time to closest LTO is short; DUV intensity values reach a baseline as time to closest LTO increases; higher baselines were generally associated with low or calm winds.

6.2.2 Wind Direction-Filtered Analysis

To evaluate the separate contributions to DUV intensity from the airport and roadways, ENVIRON screened the DUV intensity data based on wind direction, as was performed for $PM_{2.5}$ and BC. Figure 6-5 shows an example of the wind direction-filtered DUV data for the month of September 2006. Comparable plots for other months are provided in Appendix D. The plot for September 2006 shows several very sharp and distinct spikes that occur when winds were blowing from the airport runway toward the DUV-DOAS system (shown in blue). Similarly, several sharp and distinct spikes were also observed when winds were blowing from the roadway toward the DUV-DOAS system (i.e., away from the airport runway) (shown in pink). The magnitude of the DUV intensity spikes are roughly equivalent, suggesting that both the airport and roadway activities appear be associated with similar DUV intensity readings.



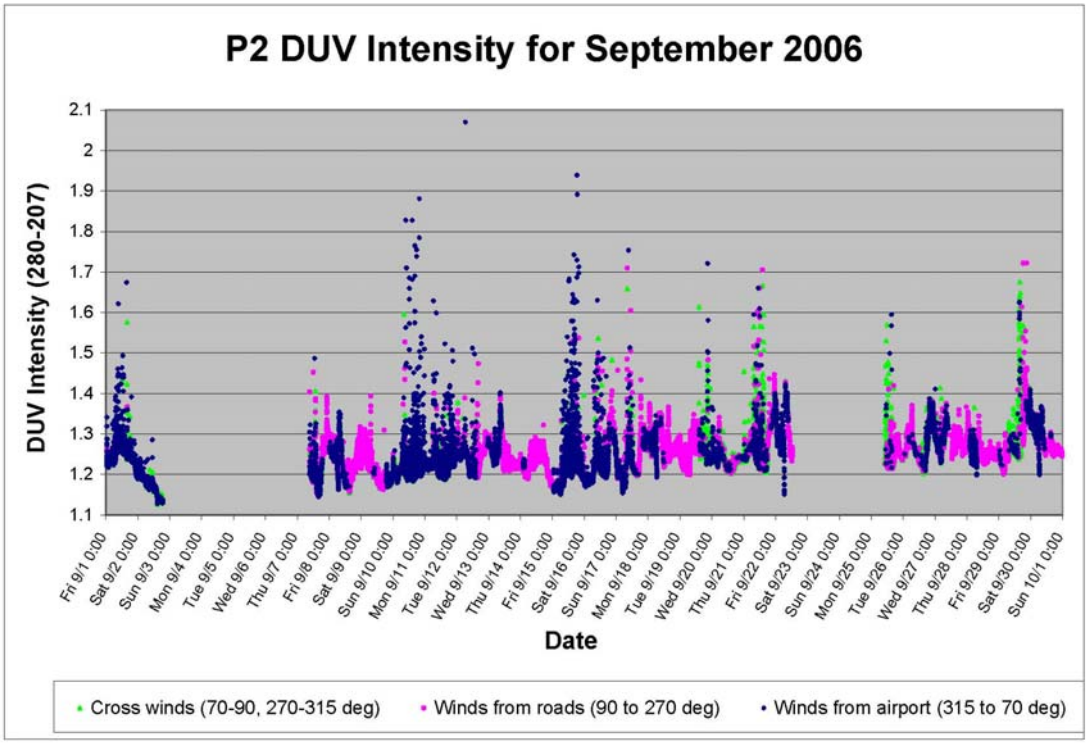


Figure 6-5 Wind Direction-Filtered DUV Intensity Levels (Blue=wind blowing from airport to monitor, pink=wind blowing from roads to monitor), September 2006

6.2.3 Comparison with Video Footage

For additional confirmation that the DUV intensity readings could be related to airport activity, ENVIRON reviewed the video footage for certain periods of time when high DUV intensity spikes were observed and the wind was blowing from the runway in the direction of the open path system.

6.2.3.1 September 14, 2006, Primary 1, 10:30 to 11:07 AM

For the time period associated with the absorbance spectra shown in Figures 6-3 and 6-6, a steady increase in DUV intensity was observed between 10:30 and 10:59 AM, decreasing by 11:07 AM. As shown in the photographs in Figure 6-7, there were two aircraft queued and idling on the runway at 10:30 AM. By 10:40 AM, the number of idling aircraft increased to five and remained at this level through 10:59. By 11:07 AM, the number of aircraft on the runway decreased to one. The wind was blowing from the runway in the direction of the open path system throughout this time interval.

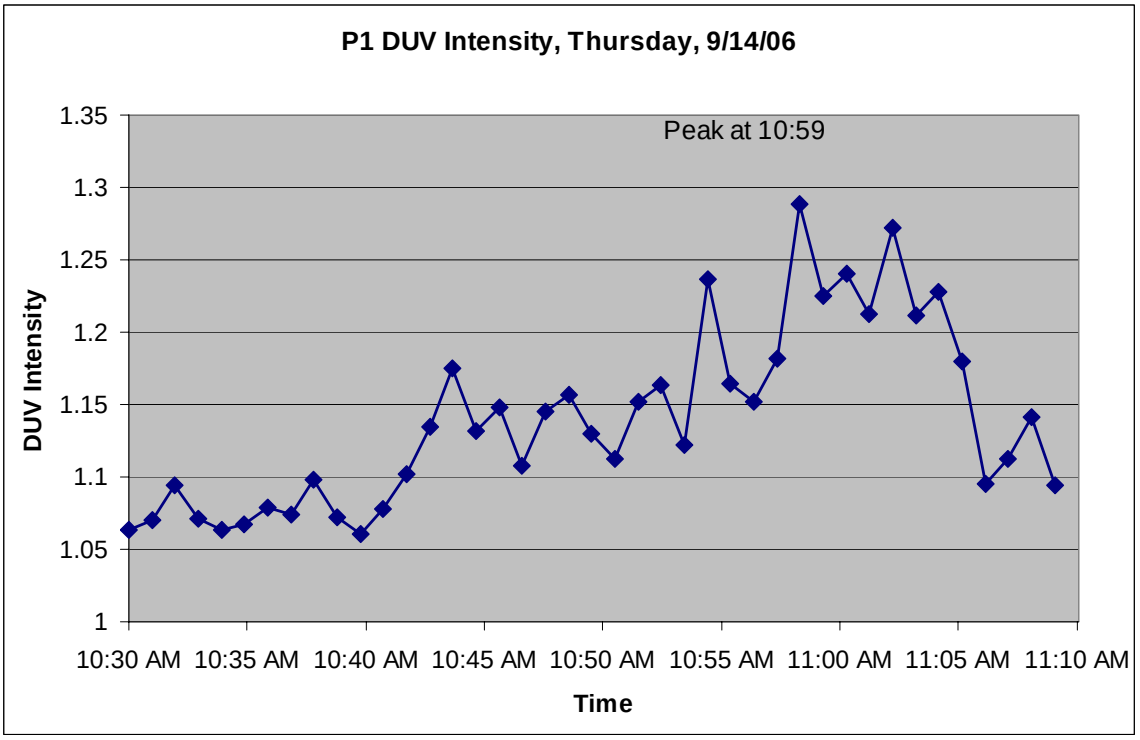


Figure 6-6 DUV Intensity at Primary 1 for the late morning of September 14, 2006

(a) 10:30 AM

(b) 10:40 AM

(c) 10:59 AM

d) 11:07 AM

Figure 6-7 Video footage of runway activity at Primary 1 between 10:30 and 11:07 AM on September 14, 2006. Five planes queued on runway holding apron and idling for more than a 20-minute period.

6.2.3.2 August 30, 2006, Primary 2, 7:50 to 7:55 AM

For the time period associated with the absorbance spectra shown in Figure 6-8, a brief spike in DUV intensity was observed between 7:50 and 7:55 AM. Between 7:45 and 7:50 AM, a steady pattern of aircraft takeoffs was observed from the video footage, with one plane taxiing and departing at a time at approximately one minute intervals. As shown in the photographs in Figure 6-9, between 7:50 and 7:53 AM, three aircraft were queued and idling on the runway at the same time. Around 7:53 AM, the first of these three queued airplanes took off, followed by the other two over the next two minutes. After 7:55 AM, the steady pattern of aircraft takeoffs resumed with one plane taxiing and departing at a time at approximately one minute intervals. The wind was blowing from the runway in the direction of the open path system throughout this time interval.

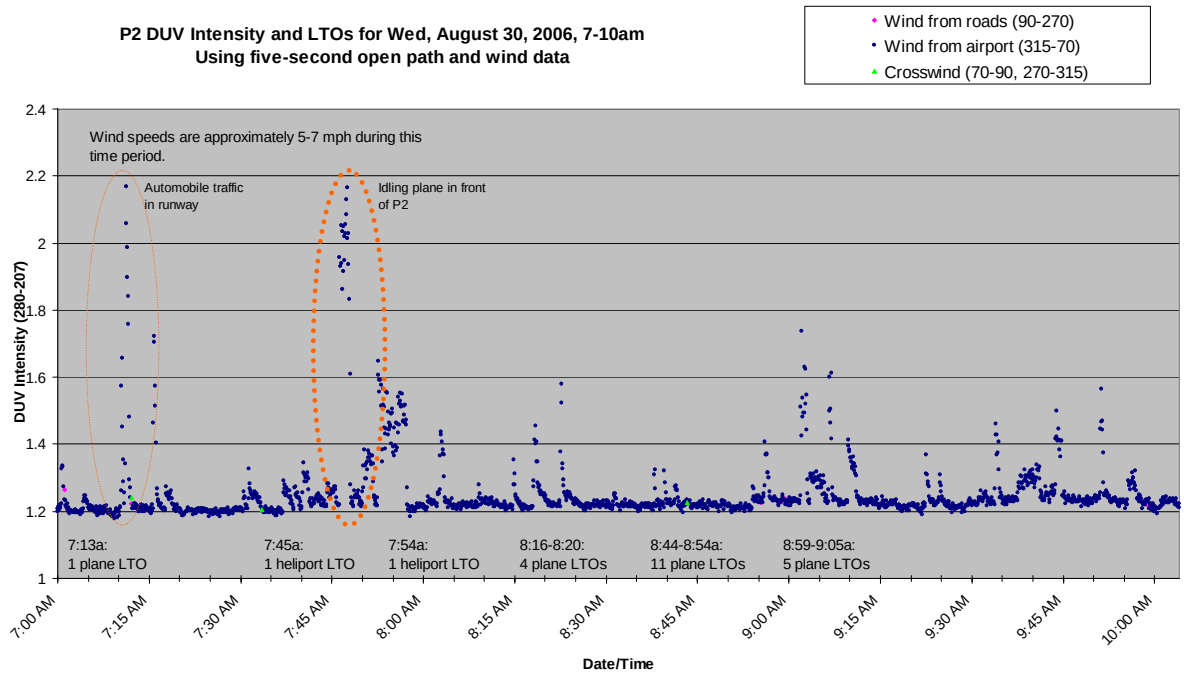


Figure 6-8 DUV Intensity at Primary 2 for the morning of August 30, 2006. Spike in DUV Intensity between 7:50 and 7:53 AM corresponds to a period when three airplanes were queued on the runway holding apron and idling.

Figure 6-9 Video footage of runway activity at Primary 2 between 7:49 and 7:55 AM on August 30, 2006. Between 7:50 and 7:53 AM, three airplanes were queued on the runway holding apron and idling.

6.2.3.3 August 30, 2006, Primary 2, 11:00 to 11:05 AM

A third example occurred on August 30, 2006 between 11:00 and 11:00 AM. As shown below in Figure 6-10, high DUV intensity levels were observed during the latter half of this time interval. Video footage during the initial half of this time interval shows a series of planes taxiing toward Runway 1. A series of five planes are queued on Runway 1 at 11:00 AM, as shown in Figure 6-11(a). Five minutes later, these same planes are still in the same location, as shown in Figure 6-11(b), indicating a period of time when emissions during idling occurred. The wind was blowing from the runway in the direction of the open path system throughout this time interval.

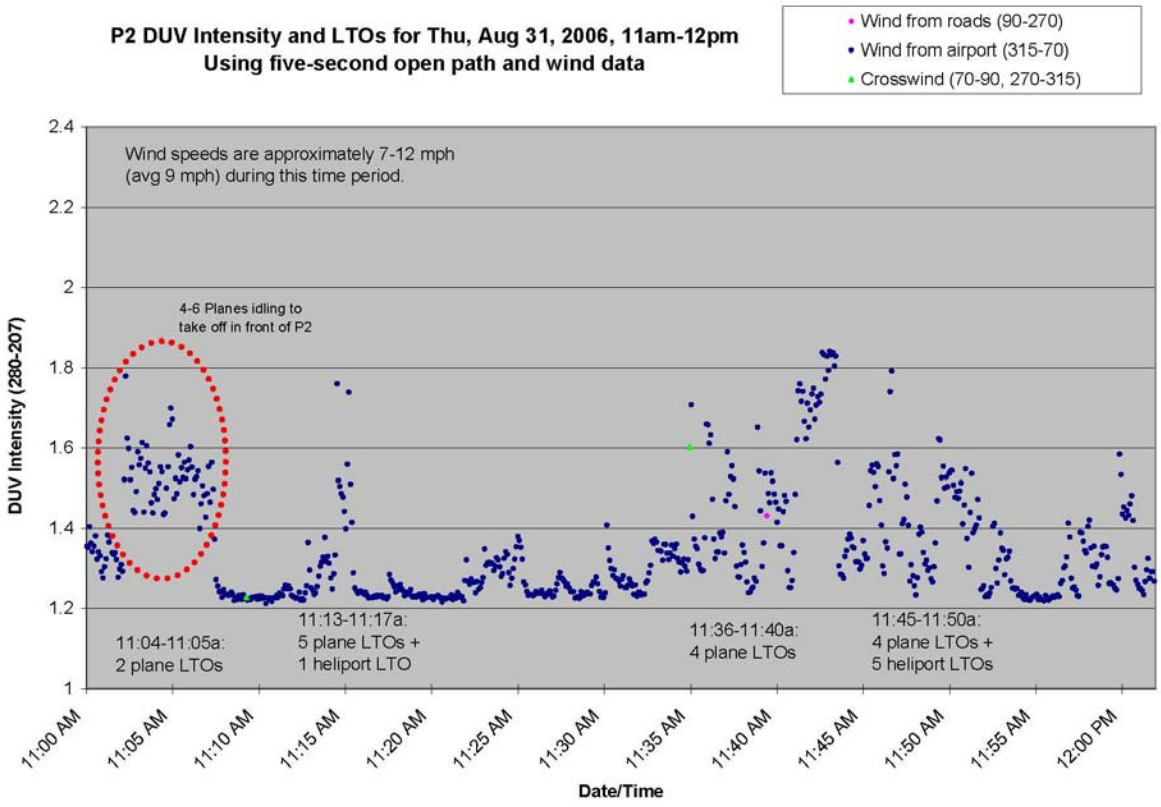
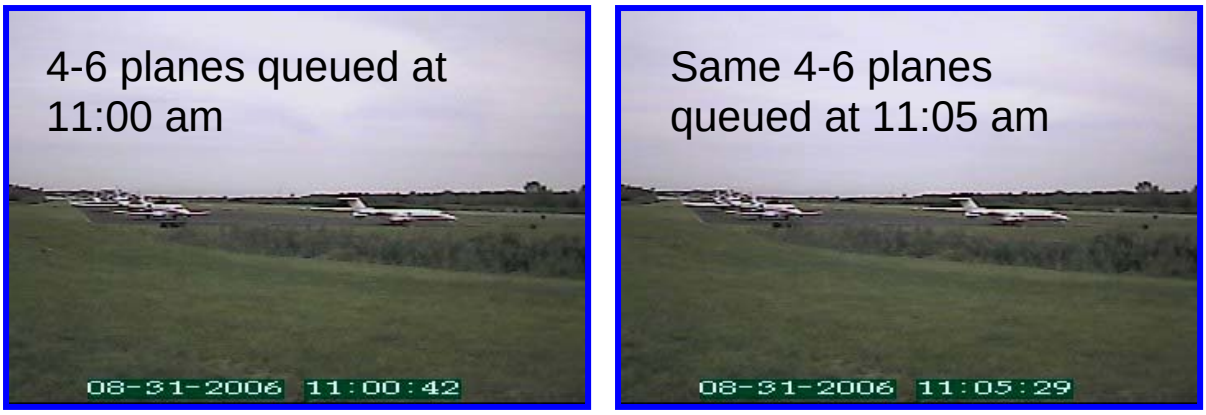


Figure 6-10 DUV Intensity at Primary 2 for the late morning of August 31, 2006. Spike in DUV Intensity between 11:00 and 11:05 AM corresponds to a period when 4-6 airplanes were queued on the runway and idling.



(a) (b)

Figure 6-11 Video footage of runway activity at Primary 2 between 11:00 and 11:05 AM on August 31, 2006. Four to six airplanes were queued on the runway holding apron and idling during this period.

6.2.3.4 August 30, 2006, Primary 2, 11:30 to 11:40 AM

A final example occurred on August 30, 2006 between 11:30 and 11:40 AM. As shown below in Figure 6-12, high DUV intensity levels were observed during the latter half of this time interval. Video footage during the initial half of this time interval shows a series of planes taxiing toward Runway 1. From 11:30 to 11:31 AM, a dark plume of smoke can be seen in the distance near where the planes were taxiing. The plume of smoke grows darker and spreads wider over the course of the next minute before it gradually dissipates (Figures 6-13 (a) to (j)). These visible emissions correspond to a spike in the DUV intensity several minutes later, which may be due to the amount of time for the plume to be transported from the distant taxiway to the DUV-DOAS system. The wind was blowing from the runway in the direction of the open path system throughout this time interval.

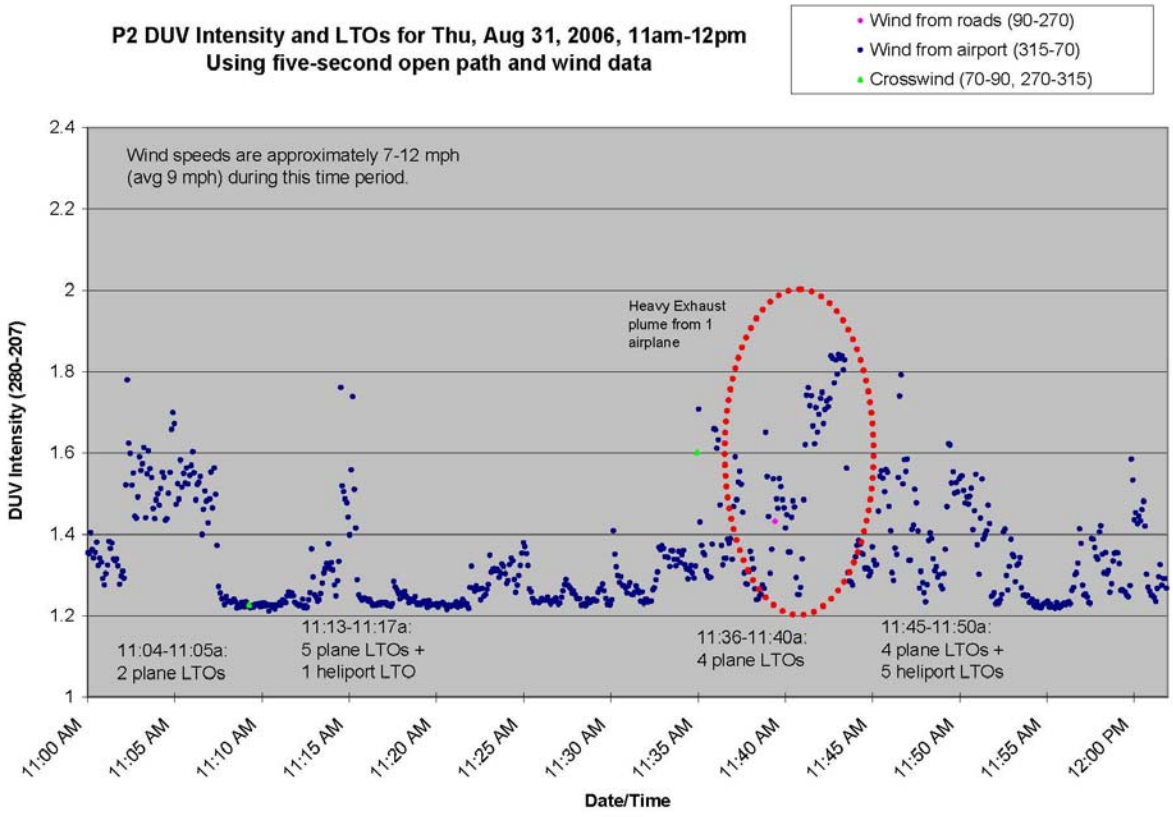
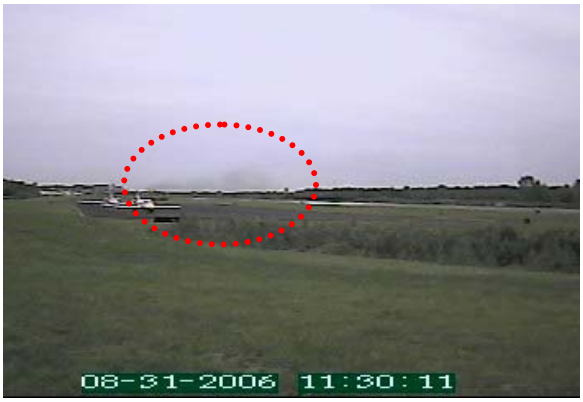


Figure 6-12 DUV Intensity at Primary 2 for the late morning of August 31, 2006. Spike in DUV Intensity around 11:35 AM corresponds to a period when a visible plume of heavy exhaust from a plane near the rear of the runway was observed.


08-31-2006 11:29:54

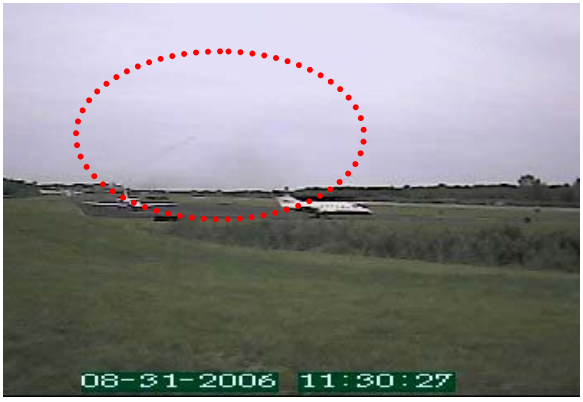
(a)


08-31-2006 11:30:11

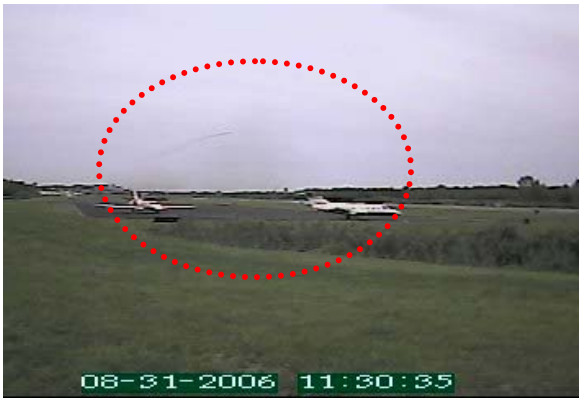
(b)


08-31-2006 11:30:19

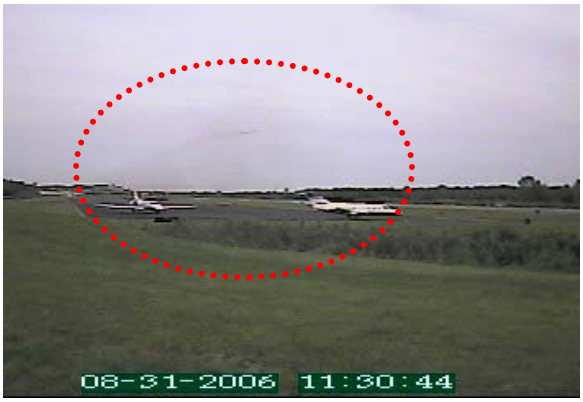
(c)


08-31-2006 11:30:27

(d)


08-31-2006 11:30:35

(e)


08-31-2006 11:30:44

(f)

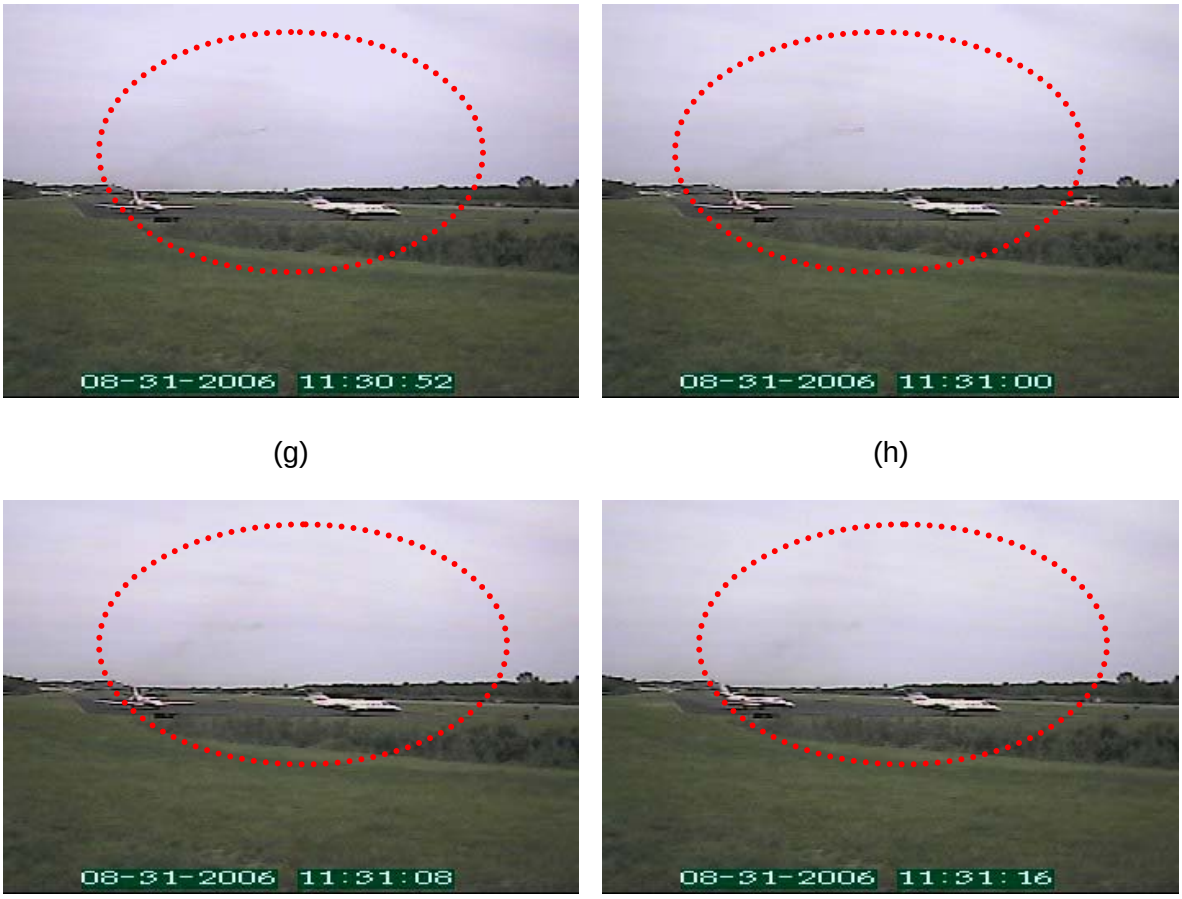


Figure 6-13 Video footage of heavy exhaust observed from airplane on distant taxiway at Primary 2 on August 31, 2006.

These examples provide additional support to the use of DUV intensity as an indicator of airport-related influences on local air quality. However, additional research is needed to further evaluate these relationships between aircraft activity and DUV intensity. Further analysis may also allow the presence of individual constituents to be extracted from the DUV absorbance measurements.

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7.0 Conclusions and Recommendations

Based on the results of this study, the following conclusions were reached:

- Certain VOCs were detected at parts of Teterboro Airport at higher concentrations than other locations in New Jersey (e.g., formaldehyde, toluene); other VOCs (e.g., benzene, acetaldehyde) were comparable to other "representative" New Jersey locations.

- Risks associated with the concentrations of VOCs consistently detected at parts of Teterboro Airport are higher than other "representative" locations in New Jersey (based on conservative risk screening calculations intended to overestimate exposures and be health protective).

- Similar to other locations in New Jersey, risks around Teterboro Airport exceed health benchmarks. These exceedances are typical of urban areas in the U.S.

- $PM_{2.5}$ measured around Teterboro Airport appears to be higher than other New Jersey monitoring locations in 2006, although the method used to measure $PM_{2.5}$ around Teterboro Airport in this study typically yields higher results than the Federal Reference Method and procedures used at the other New Jersey locations.

- $PM_{2.5}$ and DUV intensity signal were observed to come from both roadways and the airport. Black carbon was also observed to come from both roadways and the airport operations, although to a lesser extent. These conclusions are supported by temporal and wind direction-filtered analyses, as well as review of videotapes.

- Although the data indicate that airport activities have a measurable effect on local air quality, the data were insufficient to quantify the contribution from airport activities. However, the prevalence of these measurable impacts suggests that the airport is not an insignificant source with respect to the local air quality.

- Airport contributions appear to be highly dependent on wind direction and wind speed, as well as airport activity.

ENVIRON provides the following recommendations for additional study:

- Additional study is needed to identify and quantify potential emission sources of certain detected VOCs and carbonyls, such as formaldehyde. In particular, the summertime increase in formaldehyde concentrations should be further evaluated to understand why it was elevated at P1 but not at other locations. Acrolein concentrations in the airport vicinity should be characterized.

- $PM_{2.5}$ and black carbon concentrations and emission sources should be further evaluated.

- The DUV-DOAS open path system appears to be a promising tool for evaluating airport impacts on local air quality; more research is needed to develop this technology and to characterize DUV compounds.

- Additional study is needed to understand the impact of airport operations on the local community. Perimeter monitoring around the airport coupled with neighborhood

monitoring, particularly at times when jet fuel odors are apparent, would be useful in evaluating potential exposures to the surrounding population. Short-term sampling (e.g., three hours or less) when winds are steady would be useful in quantifying upwind and downwind concentrations.

This additional study may improve our ability to quantify the contributions from airport activities to local air quality.

8.0 References

Barbosa, S. 2000. *Air monitoring study at Los Angeles international airport terminals*. Prepared by South Coast Air Quality Management District. April.

CDM. 2003. *Toxic air pollutants near airports – national experience*. Presentation to City of Warwick, prepared for Rhode Island Airport Corporation Board. September 29.

DesMarais, D.L. 1995. *Review of the McCulley, Frick and Gilman air quality study for Sea-Tac Airport and summary of the available information on air pollution from jet aircraft*. May.

Eastern Research Group, Inc. (ERG). 1999. *Documentation for the 1996 base year national toxics inventory for aircraft sources*. Prepared for Emission Factor and Inventory Group, United States Environmental Protection Agency, Research Triangle Park, NC. September 30.

ERG. 2006. *Procedure for the determination of acrolein and other volatile organic compounds (VOCs) in air collected in canisters and analyzed by gas chromatography/mass spectrometry (GC/MS) using selective ion monitoring (SIM).* Prepared for Office of Air Quality Planning and Standards, United States Environmental Protection Agency, Research Triangle Park, NC. November.

Eden, R. 2000. *Air monitoring study in the area of Los Angeles international airport*. Prepared by South Coast Air Quality Management District. April.

ENVIRON International Corporation (ENVIRON). 2000a. *Preliminary study and analysis of toxic air pollutant emissions from O'Hare International Airport and the resulting health risks created by these toxic emissions in surrounding residential communities. Volume II. Preliminary modeling evaluation of risks associated with emissions from Chicago O'Hare airport*. Prepared for City of Park Ridge, Illinois. Project No. 02-8733A. August.

ENVIRON. 2000b. *Preliminary study and analysis of toxic air pollutant emissions from O'Hare International Airport and the resulting health risks created by these toxic emissions in surrounding residential communities. Volume IV. Preliminary risk evaluation of Mostardi-Platt Park Ridge project data monitoring adjacent to O'Hare airport*. Prepared for City of Park Ridge, Illinois. Project No. 02-8733A. August.

ENVIRON. 2001. *Screening air quality evaluation of Teterboro Airport, Teterboro, New Jersey*. Prepared for Coalition for Public Health and Safety. October 12.

Georgopoulos, P.G., S.W. Wang, C. Efstathiou, S. Tong, and P.J. Lioy. 2003. Investigation of the impact of airport operations on local air quality, Teterboro Airport (Bergen County, NJ). Presentation by Environmental and Occupational Health Sciences Institute (EOHSI), Exposure Measurement and Assessment Division. July 23.

Hayes, S.R. 2003. Characterizing air toxics composition of jet exhaust for airport health risk assessments. Presented at 96th Annual Meeting, Air & Waste Management Association. Paper #81121.

Illinois Environmental Protection Agency (IEPA). 2002. *Final Report, Chicago O'Hare Airport Air Toxic Monitoring Program, June-December, 2000*. Bureau of Air. May.

Kao, A.S. 1994. Formation and removal reactions of hazardous air pollutants. *J. Air & Waste Manage. Assoc.* **44:**683-696.

McCulley, Frick & Gilman (McCulley Frick). 1995. *Final report. Air quality survey, Seattle-Tacoma international airport*. Prepared for Port of Seattle Aviation Planning Department. Job No. 9029. January.

Morin, B.M. and R. Vanderslice. 2007. TF Green air monitoring study. Final presentation. June 13.

Mostardi-Platt Associates, Inc. (Mostardi-Platt). 2000. *Preliminary study and analysis of toxic air pollutant emissions from O'Hare International Airport and the resulting health risks created by these toxic emissions in surrounding residential communities. Volume III. Preliminary downwind site sampling investigation for air toxic emissions from O'Hare International airport*. Prepared for City of Park Ridge, Illinois. August.

New Jersey Department of Environmental Protection (NJDEP). 2004. Guidance on preparing a risk assessment for air contaminant emissions (revised). Technical Manual 1003. Air Quality Permitting Program, Bureau of Air Quality Evaluation. December.

NJDEP. 2007a. Unit risk factors for inhalation. Division of Air Quality, Bureau of Technical Services, Air Quality Evaluation Section. May.

NJDEP. 2007b. Reference concentrations for inhalation. Division of Air Quality, Bureau of Technical Services, Air Quality Evaluation Section. May.

NJDEP. 2007c. Risk screening policy and second-level risk screening. Division of Air Quality, Bureau of Technical Services, Air Quality Evaluation Section. June 8.

Pleil, J.D., L.B. Smith, and S.D. Zelnick. 2000. Personal exposure to JP-8 jet fuel vapors and exhaust at air force bases. *Environ. Health Perspect.* **108**(3):183-192.

Schürmann, G., K. Schäfer, J. Carsten, H. Hoffmann, V. Groma, S. Török, and S. Emeis. 2006. Airport air quality and emission studies by remote sensing and inverse dispersion modeling. *Remote Sensing of Clouds and the Atmosphere XI*, J. R. Slusser, K. Schäfer, and A. Comerón (Eds.). Proc. Of SPIE, **6362**: 63621E-1 – E-12.

Schürmann, G., K. Schäfer, J. Carsten, H. Hoffmann, M. Bauerfeind, E. Fleuti, and B. Rappenglück. 2007. The impact of NOx, CO and VOC emissions on the air quality of Zurich airport. *Atmos. Environ.*, **41**: 103-118.

Thoma, E.D., R.C. Shores, V. Isakov, R.W. Baldauf, T.R. Long, R.F. Snow, E.D. Morris, and T.L. Balicki. 2007. Measurement of near road nitric oxide using DUV-DOAS. *Proceedings of the 100th Annual Conference of the Air & Waste Management Association, Pittsburgh, PA, June 26-28, 2007*. Paper AO-1a-824.

Thoma, E.D., E.L. Thompson, R.C. Shores, and D.B. Harris. 2006. Measurement of low level air toxics with modified UV DOAS. *Proceedings of the 99th Annual Conference of the Air*

& Waste Management Association, New Orleans, LA, June 20-23, 2006. Paper AO-1b-270.

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