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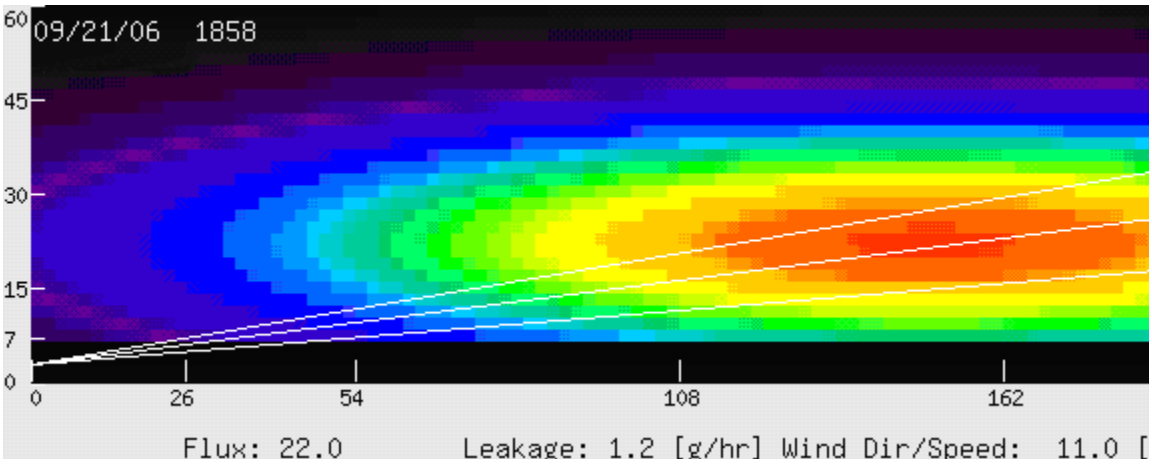
July 2007

Measurement of Total Site Mercury Emissions for a Chlor-alkali Plant Using Open-Path UV-DOAS



Example Plume Map

EPA/R-07/077
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Measurement of Total Site Mercury Emissions from a Chlor-alkali Plant Using Open-Path UV-DOAS

Final Report to OAQPS

Category II/Support for Development of Environmental Regulations and Standards

by

ARCADIS U.S., Inc.

Contract No. EP-C-04-023
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Foreword

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

Sally Gutierrez, Director
National Risk Management Research Laboratory

Notice

The U.S. Environmental Protection Agency through its Office of
Research and Development funded and managed the research described here under contract number EP-C-04-023 to Arcadis U.S., Inc. It has been subjected to the Agency`s review and has been approved for publication as an EPA document.

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List of Acronyms

APPCD	Air Pollution Prevention and Control Division
ASOS	Automated Surface Observation System
CCF	Concordance Correlation Factor
DQI	Data Quality Indicators
ECPB	Emissions Characterization and Prevention Branch
EPA	Environmental Protection Agency
MACT	Maximum Achievable Control Technology
MCCAP	Mercury Cell Chlor-Alkali Plants
NESHAP	National Emission Standard for Hazardous Air Pollutants
NIST	National Institute of Standards and Technology
NRDC	National Resources Defense Council
NRMRL	National Risk Management Research Laboratory
OAQPS	Office of Air Quality Planning and Standards
ORD	Office of Research and Development
ORS	Optical Remote Sensing
OTM-10	EPA Other Test Method-10
PAC	Path-Averaged Concentration
PDC	Path-Defining Component
PIC	Path Integrated Concentration
PI-ORS	Path-Integrated Optical Remote Sensing
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RPM	Radial Plume Mapping
RSD	Relative Standard Deviation
SSE	Sum of Squared Errors
TSA	Technical Systems Audit
UV-DOAS	Ultraviolet Differential Absorption Spectroscopy
VC	Vertical Capture Criteria
VRPM	Vertical Radial Plume Mapping

Executive Summary

This test report addresses the ARCADIS portion of the overall OAQPS Project Plan entitled, *Study of Mercury Fugitive Emissions from Cell Rooms and Other Sources at Mercury Cell Chlor-Alkali Plants*, dated September 8, 2005 (Appendix A). The OAQPS project reflects EPA's efforts to obtain additional information regarding fugitive mercury emissions from mercury cell chlor-alkali plants in response to issues raised by the Natural Resources Defense Council (NRDC) on 02/07/04 in its petition for reconsideration of the MACT rule for mercury cell chlor-alkali facilities promulgated on 12/19/03 (68FR70904). Presented in this report are total site mercury emissions data acquired at Occidental Chemical's Muscle Shoals, Alabama chlor-alkali plant from September 21, 2006 through November 12, 2006. The mercury emission data presented here will be used by OAQPS to determine if the fugitive cell room elemental mercury emissions are on the order of historical assumptions (1,300 g/day) or on the order of 2002 levels of unaccounted for mercury (approximately 10,000 g/day). This work was performed by ARCADIS U.S., Inc. (ARCADIS), under contract to the National Risk Management Research Laboratory (NRMRL) of EPA's Office of Research and Development (ORD). The report is limited to presentation of data associated with the measurements conducted by ARCADIS/NRMRL during this campaign. Synthesis of data from other sources separately acquired, analysis of maintenance activities, and comparisons of emissions to historical results will be conducted by OAQPS as part of the overall project summary.

To accomplish the goal of total site elemental mercury emission measurement, the monitoring systems were set up outside and downwind of the cell room building, as well as downwind of all ancillary processes both inside and outside the cell room building. Potential sources of emissions include: cell room sources (stacks, roof ventilation systems, and building leaks); leaks of mercury-contaminated brine in the brine treatment area; the wastewater system; the handling and storage of mercury contaminated wastes; and process vent stacks. OAQPS will also use the results here along with separate cell room and point source mercury emissions data for the same time period to estimate whether there are significant fugitive mercury sources outside the cell room.

The measurement approach used a Vertical Radial Plume Mapping (VRPM) measurement configuration employing three open-path ultraviolet differential optical absorption spectroscopy (UV-DOAS) instruments for elemental mercury concentration measurements, in conjunction with multipoint ground level mercury measurements with a Lumex mercury analyzer. The measurement systems operated on a 24-hour, 7-day

per week basis for the 53 day campaign. Full details on the measurement campaign are contained in the EPA quality assurance project plan entitled, *Measurement of Total Site Mercury Emissions from a Chlor-alkali Plant Using Open-Path UV-DOAS* (rev. 0.3 September, 2006).

The 3-beam VRPM configuration used to estimate elemental mercury emissions from the facility was located at a fixed position and fixed orientation on site for the duration of the project. Calculations of mercury flux through the VRPM plane were conducted only when specific data quality indicators involving wind speed, wind direction, path averaged concentration ratios and instrument operation were met. Out of the 53 day deployment, VRPM mercury flux values were calculated for 23 days of the measurement campaign. Data is presented as 20 minute moving averages consisting of a sequential collection of 4 minute measurement cycles. A total of 1170 mercury emission flux estimates were produced for 20 minute time periods. The 24 hour extrapolated mercury emission rate values ranged from 18 to 1210 grams per day, with an average of 410 grams per day. The extrapolated emission rate is summarized in the figure below. Overall measurement uncertainty is estimated to be within +/-20% which is sufficient to meet the order of magnitude data quality objective for this project.

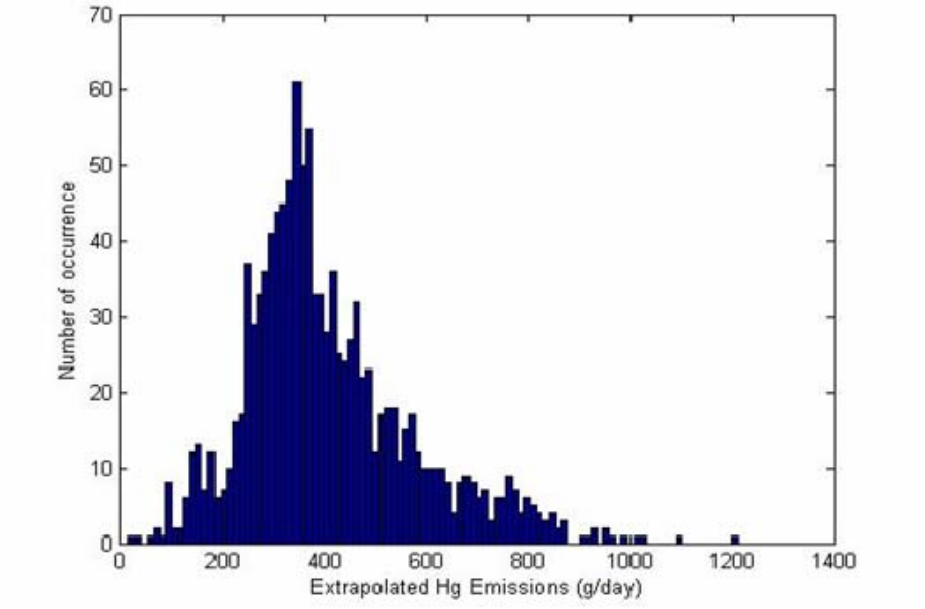

Figure E-1. Summary of 24-hour extrapolated fugitive mercury site emission values (by VRPM).

1. Introduction

1.1 Background

In December 2003, the EPA promulgated the National Emission Standard for Hazardous Air Pollutants (NESHAP) for mercury cell chlor-alkali plants (40 CFR 63 Subpart IIIII) *(Federal Register Summary: 68 FR 70903, Federal Register Vol. 68 No. 244, Friday, December 19, 2003; Pp. 70903-70946 Regulation: 40 CFR Part 63).*

In February 2004, the Natural Resources Defense Council (NRDC) filed petitions on the final rule in U.S. district court citing among other issues, uncertainty associated with EPA fugitive mercury emission estimates and the inability of mercury cell industry to fully account for mercury added to their processes to make up for losses via wastes, product and emissions.

For example, according to the EPA's 2002 Toxic Release Inventory, approximately 7 Mg of mercury was released by the nine operating mercury cell chlor-alkali plants (MCCAPs) in the U.S. Approximately 4.5 Mg was estimated to be air emissions with 89% (4 Mg) assumed to be fugitive emissions (non-stack emissions). Industry estimates indicate that approximately 33 Mg of Hg was "used" by the operating plants indicating that 25.5 Mg was unaccounted for. NRDC and other interested parties maintain that the majority of unaccounted for Hg must be lost through fugitive emissions and that recognition of this fact would have affected decisions made in developing and promulgating the Mercury Cell MACT rule.

In April 2004, EPA agreed to reconsider aspects of the rulemaking which led to planning and execution of emission measurement projects designed to reduce uncertainty in fugitive emissions of Hg from MCCAPs. An OAQPS project plan describing these measurement efforts along, with additional history of this topic and physical descriptions of the mercury cell chlor-alkali process, is contained in Appendix A: *Study of Mercury Fugitive Emissions from Cell Rooms and Other Sources at Mercury Cell Chlor-Alkali Plants*, dated September 8, 2005, prepared for OAQPS, Sector Policies and Programs Division by EC/R (ECR) Incorporated.

As an overall project goal, OAQPS will use the total site mercury emission data presented in this report, in conjunction with cell room vent monitoring, stack emission, and maintenance activity data from this and other facilities acquired by OAQPS under other parts of the Project Plan, to determine if the elemental mercury cell room fugitive emissions from the observed facilities are on the order of historical assumptions (1,300

g/day) or on the order of 2002 levels of unaccounted for mercury (approximately 10,000 g/day). This test report only addresses the ARCADIS/NRMRL subproject area of the OAQPS plan presenting site elemental mercury emission data from the Occidental Chemical's Muscle Shoals facility acquired during a continuous monitoring campaign from September 21, 2006 to November 12, 2006 using an ORS/VRPM measurement configuration.

As part of the overall OAQPS project, Occidental Chemical was responsible for documenting plant process and maintenance activities that occurred during the sampling period. This information included production levels, waste-handling activities, thermal mercury recovery activity, maintenance activities, and housekeeping activities. Records of any major malfunctions or other circumstances that resulted in large mercury emission episodes were also maintained by Occidental Chemical and provided to OAQPS. The purpose of the ARCADIS/NRMRL total site mercury emissions monitoring and the Occidental Chemical recordkeeping is to allow OAQPS to draw correlations between these activities and short-term mercury emission rates. OAQPS will use this information, in concert with the stack monitoring and point source data (from the cell room monitored roof ventilation systems) provided by others, to determine the order of magnitude of the unaccounted mercury air emissions.

In addition to the cell room, there is the possibility that fugitive mercury emissions could occur from sources outside the cell rooms. The ARCADIS/NRMRL test in Muscle Shoals, Alabama, was a short-term measurement study designed to estimate the total elemental mercury emission from the site. These data will be used by OAQPS in combination with cell room roof vent monitoring data to determine if sources outside the cell room could be significant sources of fugitive mercury emissions for this plant. To accomplish the goal of total site elemental mercury emission measurement, the monitoring systems were set up outside and downwind of the of the cell room building, as well as downwind of all ancillary processes both inside and outside the cell room building. OAQPS will use these results along with the cell room and point source mercury emissions data for the same time period to estimate whether there are significant fugitive mercury sources outside the cell room.

After all the test programs and monitoring data collection activities are complete, OAQPS will analyze the information obtained to determine if an improvement can be made to the previous estimation of fugitive mercury emissions for the industry. EPA will then consider this estimation in the reconsideration of the MACT rule, as requested by NRDC's petition. As relevant, EPA will publish a notice in the Federal Register summarizing any plans for changes to the current MACT rule.

Additional information on the subproject area addressed in this test report can be found in the EPA ORD Quality Assurance Project Plan, *Measurement of Total Site Mercury Emissions from a Chlor-alkali Plant Using Open-Path UV-DOAS*, Rev. 0.3, September 2006.

1.2 Project Description

To estimate the total site elemental mercury emissions from the Occidental Chemical Muscle Shoals, Alabama plant, two measurement systems were deployed on site downwind from the cell room and other potential mercury sources. The primary measurement system, described in Section 2.1, consists of an Optical Remote Sensing/Vertical Radial Plume Mapping (ORS/VRPM) flux measurement configuration utilizing UltraViolet Differential Optical Absorption spectroscopy (UV-DOAS) instruments for path-integrated elemental mercury concentration measurements. The ORS/VRPM data were augmented by a multi-point ground level elemental mercury point monitor measurement system described in Section 2.2. Together these data provide an estimate of total site mercury emission from the facility of sufficient certainty to meet the data quality objective for the project.

The field study was seven weeks (53 days) in duration, conducted from September 21, 2006 through November 12, 2006. Although the original schedule was for a six-week study, instrumentation problems encountered with the Climatronics meteorological head (discussed in detail in Section 3.2.3) and unfavorable wind conditions during the initial weeks of the campaign resulted in the 11 day extension. For this project, ARCADIS was responsible for collecting and analyzing all data. Cary Secrest of EPA's Office of Enforcement and Compliance Assurance supported the measurement campaign by operating the UV-DOAS instrumentation.

The sampling configuration for this study was placed so as to maximize the capture of mercury emissions from the site. Potential sources of these total emissions could include: cell room sources (stacks, roof ventilation systems, and building leaks); leaks of mercury-contaminated brine in the brine treatment area; the wastewater system; the handling and storage of mercury contaminated wastes; and process vent stacks.

The following data was collected on a 24-hour, 7-day per week basis as part of the measurement campaign:

- Path-averaged concentration (PAC) of elemental mercury using the three independent UV-DOAS instruments arranged in vertical VRPM flux plane.

- Ground level elemental mercury point monitoring using the Lumex Mercury Analyzer.

- Meteorological data

These data were combined as detailed in Section 3 to yield average elemental mercury emission flux estimates for 20 minute time periods throughout the study. Flux emission estimates were calculated only for those time periods which met specific data acceptance criteria discussed in Section 3 and the quality assurance project plan.

2. Description of Measurement Methods and Site Deployment

The following section describes the measurement methods, site deployment, and calculations used to obtain elemental mercury flux information from the acquired data. Section 2.1 describes the ORS/VRPM method used to assess mass emission flux of elemental mercury from the site. Section 2.2 describes the multipoint Lumex measurement providing ground level mercury data in the area under the VRPM flux plane. Section 2.3 describes the site deployment, the emission flux measurement calculation and averaging periods are described in Section 3.

2.1 Vertical Radial Plume Mapping Method

The ORS/VRPM method was the primary means used to estimate mercury emission from the site. The Radial Plume Mapping method (RPM) was developed at the University of Washington in the mid-1990s. The method uses positional scanning or multiple single-beam ORS instruments to collect path-integrated concentration data along multiple beam paths in the configuration deployed in the survey area. The beam paths can be configured in a horizontal plane (Horizontal Radial Plume Mapping) to produce surface concentration contour maps, or, as used in this project, in a vertical plane deployed downwind of the survey area (Vertical Radial Plume Mapping) to map the downwind plume from the site. By including meteorological data collected concurrently with the ORS measurements, the Vertical Radial Plume Mapping (VRPM) method can be used to calculate the downwind emission flux from the site. This leads to a direct, measurement-based estimate of the emission rate from the survey area. A more detailed discussion of the RPM methodology and of the VRPM configuration can be found in EPA's Other Test Method 10 (OTM-10) entitled, "Optical Remote Sensing for Emission Characterization from Non-point Sources" and can be found on EPA's website at www.epa.gov/ttn/emc/tmethods.html.

Two different beam configurations of the VRPM methodology are recommended: the five-beam (or more) and the three-beam VRPM configuration. The three-beam configuration is used to provide flux calculations downwind of an area source, but does not provide crosswind spatial information on the plume. This configuration is typically used downwind of area sources that are suspected to be homogenous in nature and the collection of spatial information is not necessary or desired. For this project, the three-beam configuration provided adequate spatial coverage for measuring the total site mercury emissions.

Figure 2-1 illustrates the setup for the three-beam VRPM configuration. In the three-beam configuration, the PI-ORS instrument would typically scan over the three PDCs (pathlength-defining components) sequentially. However, for this project which utilized three independent UV-DOAS instruments, the data were collected simultaneously along each optical path. The UV-DOAS systems used for this study were bistatic in configuration having separate transmitters (UV light sources) and receivers. The transmitters were mounted on a water tower present on site (shown as PDCs in Figure 2-1), and the UV-DOAS receivers were placed together, indicated as the PI-ORS Instrument in Figure 2-1. The lowest beam of the VRPM configuration is usually at ground level. Due to site constraints, an elevated VRPM plane was utilized for this project. The UV-DOAS receivers were mounted to specially constructed concrete piers at a height of approximately 3 m above ground level. The lowest transmitter on the water tower was mounted at 18 m above ground level making the average height of the lowest beam at approximately 10 m above the ground. This will be discussed further in subsequent sections.

The VRPM computer algorithm uses a smooth basis function minimization routine of a bivarate Gaussian function to generate mass emission flux information from species concentration and wind data. To derive the bivariate Gaussian function, it is convenient to express the generic bivariate function G in polar coordinates r and θ:

$$G(r,\theta)=\frac{A}{2\pi\sigma_y\sigma_z\sqrt{1-\rho_{12}^2}}\exp\left\{-\frac{1}{2\left(1-\rho_{12}^2\right)}\left[\frac{(r\cdot\cos\theta-m_y)^2}{\sigma_y^2}-\frac{2\rho_{12}\left(r\cdot\cos\theta-m_y\right)\left(r\cdot\sin\theta-m_z\right)}{\sigma_y\sigma_z}+\frac{\left(r\cdot\sin\theta-m_z\right)^2}{\sigma_z^2}\right]\right\} \quad (1)$$

The bivariate Gaussian has six unknown independent parameters:

- A = normalizing coefficient which adjusts for the peak value of the bivariate surface;
- ρ_{12} = correlation coefficient which defines the direction of the distribution-independent variations in relation to the Cartesian directions y and z (ρ_{12}=0 means that the distribution variations overlap the Cartesian coordinates);
- m_y and m_z = peak locations in Cartesian coordinates; and
- σ_y and σ_z = standard deviations in Cartesian coordinates.

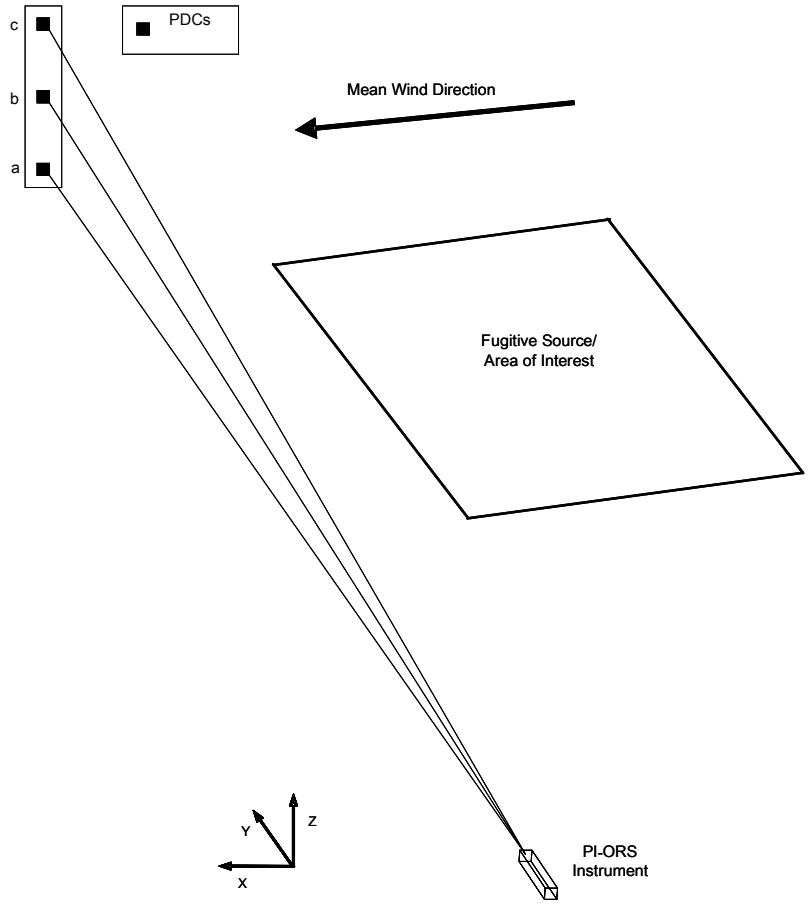

Figure 2-1. Example of a Vertical Radial Plume Mapping configuration setup.

Six independent beam paths are sufficient to determine one bivariate Gaussian that has six independent unknown parameters. Some reasonable assumptions are made when applying the VRPM methodology to this problem, to reduce the number of unknown parameters. The first is setting the correlation parameter ρ_{12} equal to zero. This assumes that the reconstructed bivariate Gaussian is limited only to changes in the vertical and crosswind directions. In this case, Equation 1 reduces into Equation 2:

$$G(r,\theta) = \frac{A}{2\pi\sigma_y\sigma_z}\exp\left\{-\frac{1}{2}\left[\frac{(r\cdot\cos\theta - m_y)^2}{\sigma_y^2} + \frac{(r\cdot\sin\theta - m_z)^2}{\sigma_z^2}\right]\right\} \quad (2)$$

When the VRPM configuration consists only of three beam paths, the width of the plume can be arbitrarily assigned to be very wide, compared to the longest beam path. Therefore, the three-beam VRPM configuration is most suitable for area sources or for sources with a series of point and fugitive sources that are known to be distributed across the upwind area. The standard deviation in the crosswind direction is typically assumed to be about four times that of the ground level beam path (length of vertical plane). If r_1 represents the length of the vertical plane, the bivariate Gaussian would be as follows:

$$G(A,\sigma_z,m_z)=\frac{A}{2\pi(4r_1)\sigma_z}\exp\left\{-\frac{1}{2}\left[\frac{(r\cdot\cos\theta-\tfrac{1}{2}r_1)^2}{(4r_1)^2}+\frac{(r\cdot\sin\theta-m_z)^2}{\sigma_z^2}\right]\right\} \quad (3)$$

A, m_z, and σ_z are the unknown parameters to be retrieved in this case of the fitting procedure. An error function (SSE) for minimization is defined for this phase in a similar manner. The SSE function for the second phase is defined as:

$$SSE(A,\sigma_z,m_z)=\sum_i\left(PAC_i-\int_0^{r_i}G(r_i,\theta_i,A,\sigma_{m_z})dr/r_i\right)^2 \quad (4)$$

Where PAC_i is the measured PAC value for the I^{th} beam. The SSE function is minimized using the Simplex method to solve for the three unknown parameters.

This process is for determining the vertical gradient in concentration. It allows an accurate integration of concentrations across the vertical plane as the long-beam ground-level PAC provides a direct integration of concentration at the lowest level.

Once the parameters of the function are found for a specific run, the VRPM procedure calculates the concentration values for every square elementary unit in a vertical plane. Then, the VRPM procedure integrates the values, incorporating wind speed data at each height level to compute the flux. This enables the direct calculation of the flux in grams per day (g/day), using wind speed data in meters per second (m/s).

As described in earlier studies (Hashmonay et al., 2001), the concordance correlation factor (CCF) was used to represent the level of fit for the reconstruction in the path-integrated domain (predicted versus measured PAC). CCF is defined as the product of two components:

$$CCF = rA \tag{5}$$

Where:

r = the Pearson correlation coefficient;

A = a correction factor for the shift in population and location.

This shift is a function of the relationship between the averages and standard deviations of the measured and predicted PAC vectors:

$$A = \left[\frac{1}{2} \left(\frac{\sigma_{PAC_P}}{\sigma_{PAC_M}} + \frac{\sigma_{PAC_M}}{\sigma_{PAC_P}} + \left(\frac{\overline{PAC_P} - \overline{PAC_M}}{\sqrt{\sigma_{PAC_P} \sigma_{PAC_M}}} \right)^2 \right) \right]^{-1} \tag{6}$$

Where:

σ_{PAC_P} = standard deviation of the predicted PIC vector;

σ_{PAC_M} = standard deviation of the measured PIC vector;

$\overline{PAC_P}$ = the mean of the predicted PIC vector; and

$\overline{PAC_M}$ = the mean of the measured PIC vector.

The Pearson correlation coefficient is a good indicator of the quality of fit to the Gaussian mathematical model. In this procedure, typically an r close to 1 will be followed by an A very close to 1. This means that the averages and standard deviations in the two concentration vectors are very similar and the mass is conserved (good flux value). However, when a poor CCF is reported (CCF<0.80) at the end of the fitting procedure it does not directly mean that the mass is not conserved. It could be a case where only a poor fit to the Gaussian function occurred if the correction factor A was still very close to 1 (A>0.90). However, when both r and A are low one can assume that the flux calculation is inaccurate.

2.2 Ground-level Point Sampling

To augment data acquired with the ORS/VRPM technique, elemental mercury concentration measurements were made in areas underneath of the VRPM flux plane. The purpose of these measurements was to establish approximate ground level concentrations coincident with the VRPM flux measurements to understand if significant amounts of mercury emissions were present underneath the VRPM flux plane that may not be accounted for by the VRPM measurement. This was necessary since the VRPM flux plane was elevated for this study and because of the complex ground level air flow caused by the numerous obstructions below the VRPM plane. To estimate the ground level mercury concentration under the VRPM plane, a Lumex mercury analyzer (model RA-915+) was deployed downwind from the cell room, with three sampling tubes deployed outward from the analyzer. The sampling tubes which, were approximately 15 m apart and 4 m above ground level (detailed in Section 2.3), delivered a combined sample to the Lumex analyzer establishing an estimate of average elemental mercury concentration for a 7 m high by 45 m long area underneath the VRPM plane. These data were used in conjunction with free flowing wind speed projections to establish an estimate of uncertainty in the elevated VRPM measurement. Additional information on the ground-level point sampling configuration can be found in the EPA ORD Quality Assurance Project Plan, *Measurement of Total Site Mercury Emissions from a Chlor-alkali Plant Using Open-Path UV-DOAS*, Rev. 0.3, September 2006.

2.3 Site Deployment Description

Figure 2-2 is a site plot showing the locations of the cell room, the water tower supporting UV-DOAS transmitters, the instrument trailer containing the OPSIS analyzers and communication equipment, and the approximate location of the meteorological (met.) station in an open field. The optical beam paths of the VRPM plane are indicated by the gold-colored arrow from the instrument trailer to the water tower. The position of the VRPM plane was chosen to maximize the total capture of fugitive mercury from the site taking into account potential source locations, prevailing wind directions and site constraints.

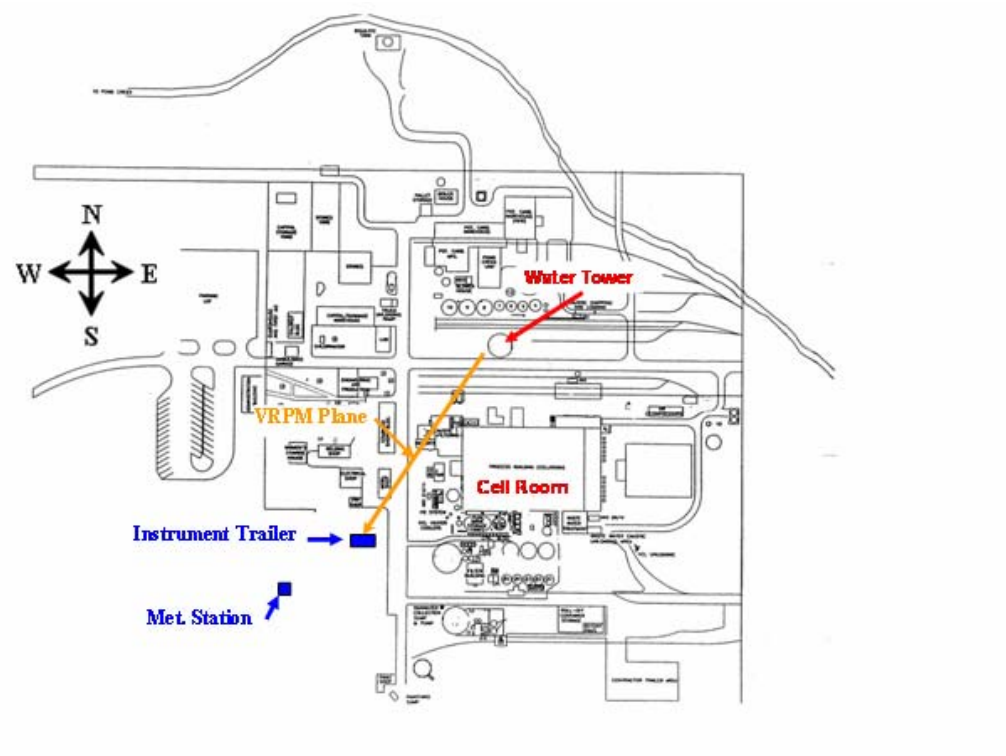

Figure 2-2. Site plot of Occidental Chemical showing cell room, water tower, instrument trailer, meteorological station and Vertical Radial Plume Mapping plane locations.

As part of communications with OAQPS, Occidental Chemical identified four known mercury-emitting sources/discharge points. These included the cell room roof vents and several sources outside the cell room building adjoining its West wall and in the areas in close proximity to the cell room just to West and South West of the building. These sources included: an emergency low-pressure vent stack for the hydrogen compression process, the high pressure hydrogen system vent stack, and the retort vent stack. Additionally the caustic filter operation is attached to the West wall of the cell room building and the brine operations are located just to the south of the cell room building. All of these potential sources were located to the southeast of the VRPM Plane. Since the regional prevailing wind directions were predominately from the southeast during September and October (Figure 2-3), the VRPM configuration was positioned downwind of the potential source with an orientation approximately normal to the expected prevailing wind directions for the study.

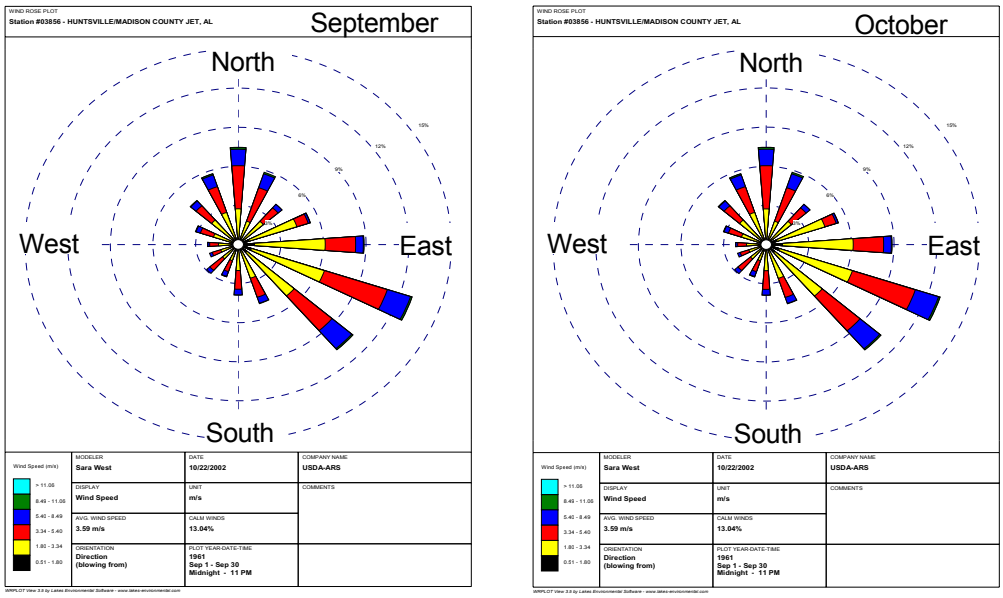

Figure 2-3. Average wind rose data from 1961-1990 for September and October from Huntsville, AL.

Figure 2-4 shows an overhead image of the facility showing the location of the VRPM plane and the Lumex mercury analyzer sampling points. Also shown are the approximate locations of the cell room roof vents which consisted of two rows of induced draft fans (65 fans total). The Lumex analyzer was located in a temperature controlled enclosure that was placed inside of an air-conditioned mechanical room located close to the central sampling location shown in Figure 2-4. The Lumex analyzer sampled from a combined air stream of the three sampling points which were separated by approximately 15 m. The tubing used for the sampling was 25 m lengths of ¼ inch i.d. Teflon and was attached to an overhead pipe rack to allow suspension of the sampling inlets at 4 m above ground level. A three-way Teflon splitter was used to combine the sampling tubes. A heated head Teflon coated pre-sampling pump supplied the combined sample to the Lumex analyzer.

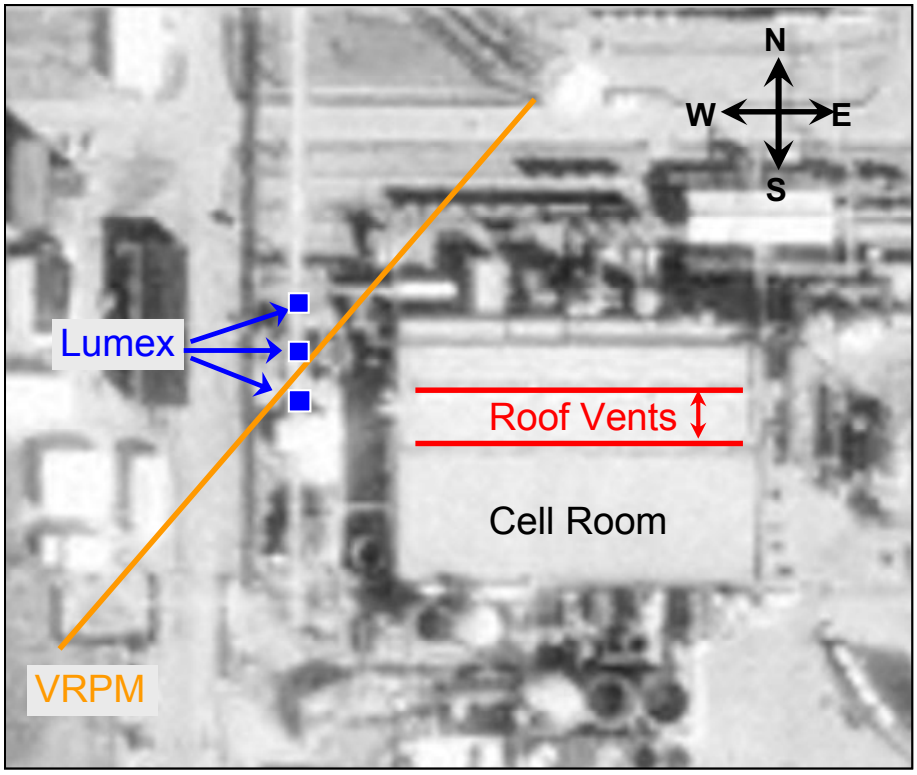

Figure 2-4. Image of site showing Vertical Radial Plume Mapping configuration, Lumex mercury analyzer sampling locations, cell room and cell room roof vents.

For the VRPM configuration, the three UV-DOAS sources (transmitters) were mounted at heights of 18, 28, and 37 meters on the water tower. This resulted in optical pathlengths of 217, 218, and 219 meters from source to receiver. The UV-DOAS receivers were mounted at a height of 3 meters. Accounting for that offset, the source heights in relationship to the receivers were therefore 15, 25, and 34 meters. The Climatronics/R.M. Young meteorological heads were deployed at a height of approximately 12 meters. Figure 2-5 shows an illustrative side view of the VRPM configuration, showing the locations of the three UV-DOAS bistatic sources and the approximate positions of the Lumex analyzer sampling locations.

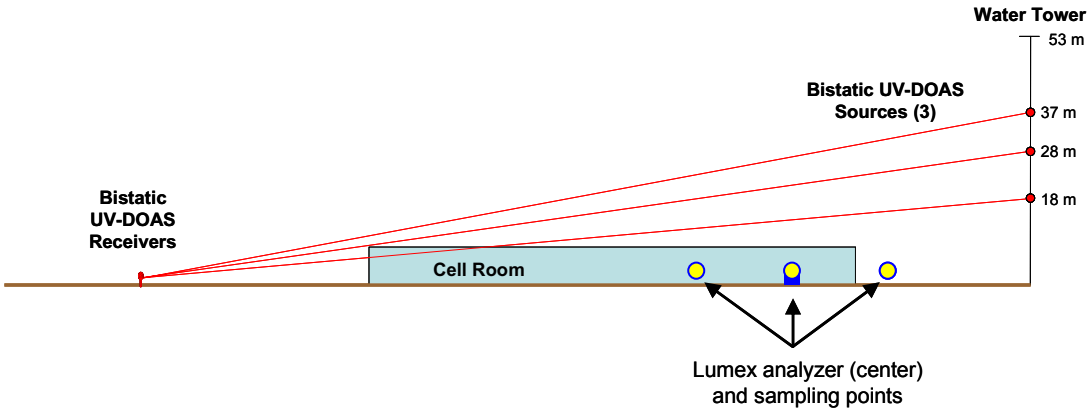

Figure 2-5. Side view of the Vertical Radial Plume Mapping configuration and locations of the Lumex mercury analyzer and its sampling points.

3. Results and Discussion

3.1 Data Averaging and Calculation Description

The individual instruments used in this study had measurement averaging times of either 30 seconds (meteorological instruments and Lumex) or 1-minute (UV-DOAS). Since the instrument measurement times were not fully synchronized, a 4-minute base averaging period for the data from each instrument was established. The 4-minute base averaging period parameters were then used in a 20-minute moving average. Each flux calculation presented consists of a group average of five consecutive 4-minute base periods resulting in an emission flux estimate for a 20-minute time interval, reported at its temporal midpoint. The fundamental units of emission flux produced by the VRPM method are grams per second. For presentation in this test report, each average mercury emission flux value was extrapolated to represent a 24 hour time period by converting from units of grams per second to grams per day. This was accomplished by multiplying each flux result by a factor of 86,400.

For this project, the VRPM flux plane extended from 5 m above ground level to the top boundary of the integration plane, defined as the point where the extrapolated concentration values (in the vertical direction) go to zero. This height was determined when the data was processed in the VRPM algorithm. As discussed previously, the VRPM data was augmented with data acquired by the Lumex analyzer sampling below the VRPM plane. Using the same averaging sequence described above, an approximate maximum flux through the Lumex plane was calculated by multiplying the area represented by the plane (7m height by 45 m length) by the average concentration measured by the Lumex and by the free-flowing wind vector projections on to the Lumex plane which was defined to be parallel to the VRPM plane. The free-flowing wind vector was used since characterization of wind movement in the area of the Lumex plane was known to be complex due to nearby structures, but would be spanned by the magnitude of the free flowing wind projection (positive and negative) when considering flux through the Lumex plane. The Lumex data are represented by the error bars in the presented data with the high value indicating flux through the plane in the same direction as the calculated VRPM flux and low values indicating a potential negative flow through the Lumex plane.

Total mercury flux was calculated when (1) the horizontal plume capture criteria and UV-DOAS and Lumex Mercury Analyzer Data Quality Indicators (DQIs) were met; and (2) the vertical capture criteria were met. When these criteria were met, all total flux calculations are reported, including the emissions leakage through the bottom 5-meters

of the vertical plane based on flux values calculated using data collected with the Lumex Mercury Analyzer.

3.1.1 Acceptable Data Criteria and Emission Flux Correction Factors

Only data which met all of the following criteria were deemed acceptable and included in the data presented in Sections 3.2.1 (the Climatronics data) and 3.2.2 (the R.M. Young data):

1. Prevailing wind speed ≥1 m/s. Table 3-1 shows a summary of the wind rose data where the wind speed was less than 1 m/s. Mercury concentration data collected during periods that the prevailing wind speed was ≤ 1 m/s were excluded from the presented data.

Table 3-1. Data Deemed Unacceptable Based on Wind Rose Data

Total Measurement Campaign (21 September through 12 November 2006)		
Wind Direction	**Percent of Winds from each Direction**	**Wind Speed (m/s)**
N	16.20%	0.2
NE	7.40%	0.5
E	**2.50%**	**0.5**
SE	**10.40%**	**0.6**
S	**3.20%**	**0.4**
SW	5.90%	0.5
W	32.00%	0.4
NW	22.60%	0.5

BOLD values indicate wind data that meet the ±60% horizontal wind criteria.

2. Horizontal plume capture: ±60°.

   Mercury flux values were calculated only during periods when the prevailing wind direction was within ± 60° to perpendicular to the plane of the VRPM configuration. The mercury flux values calculated during these periods are presented as "Unadjusted Flux Values" in the summary tables presented later in the document. In order to provide an assessment of the horizontal plume capture by the VRPM configuration, the project team analyzed the calculated mercury flux values and

prevailing wind direction, with respect to the orientation of the VRPM configuration plane, at the time of the measurements. The assessment was done by plotting the calculated mercury flux values as a function of prevailing wind direction (see Figure 3-1).

A linear fit of the data was performed for prevailing winds from 0° to -60°, and 0° to 60°. The resulting linear regression equations (shown in Figure 3-1) were then used to calculate a mercury flux value adjusted for the prevailing wind direction during the time of the measurements. The adjusted values are presented as "Adjusted Emission Rates" in the summary tables presented later in the document

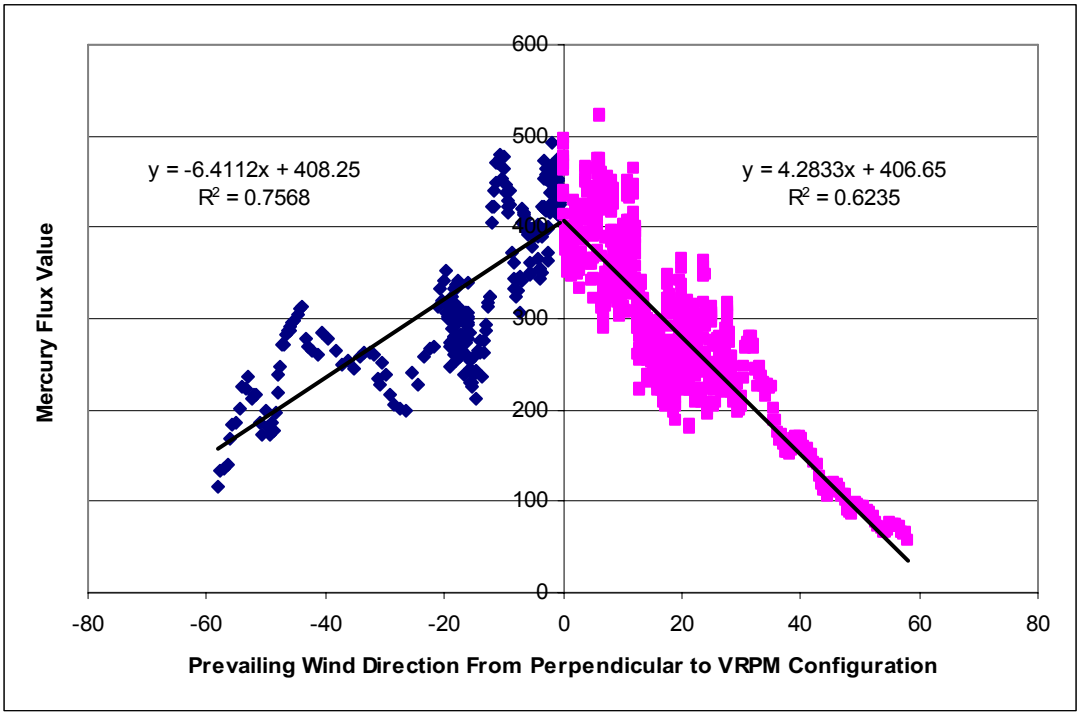

Figure 3-1. Plot of calculated mercury flux values (grams/day) versus prevailing wind direction, with respect to the plane of the Vertical Radial Plume Mapping configuration, during the time of the measurements.

3. Vertical capture criteria (refer to Figure 2-1).

   70% plume capture by VRPM configuration = $\frac{\text{beam 2 conc.} - \text{beam 3 conc.}}{\text{beam 2 conc.}} > 0.1$

   This was the optimum beam capture, and this data is color coded **blue** in the time series of emission rate graphs and in the summary data tables.

   60% plume capture by VRPM configuration: $0 > \frac{\text{beam 2 conc.} - \text{beam 3 conc.}}{\text{beam 2 conc.}} > 0.1$

   Although this data does not meet the original 70% capture goal, the majority of the plume is still being captured by the configuration. Therefore, this data is included below and is color coded **orange** in the time series of emission rate graphs and in the summary data tables.

   The assessment of the vertical plume capture is done by comparing the path-averaged mercury concentration (PAC) data measured along the upper two beam paths of the VRPM configuration, averaged over a 20-minute interval. If the 20-minute average PAC measured along the uppermost beam path is not at least 10 percent lower than the PAC measured along the next lowest beam path, this indicates that the VRPM configuration did not provide an adequate vertical capture of the plume, and data from this particular 20-minute time period was not used for the flux calculation.

4. The CCF must be ≥ 0.80.

As mentioned earlier in the document, the concordance correlation factor (CCF) is used in the VRPM method to represent the level of fit for the reconstruction in the path-integrated domain (predicted versus measured PAC).

Although a poor CCF value (CCF < 0.80) at the end of the fitting procedure does not necessarily indicate an inaccurate flux calculation, for the purposes of this project, mercury flux values are reported only when the corresponding CCF value of the reconstruction is greater than 0.80.

3.2 Data Graphs and Tables

This section presents results form the test campaign. Section 3.2.1 presents data acquired from the first 3 weeks of the project. During this time, a Climatronics meteorological station was employed to collect wind data. Section 3.2.2 presents data from the last 4 weeks of the project which utilized an R.M. Young meteorological station. For each day of sampling, a times series graph of extrapolated emission rates, a summary of results table, and an example plume map are presented. Each data point represents a moving 20-minute average to a 24-hour time basis with the error bars representing the Lumex plane value previously described. The graphically represented data are the "adjusted" values. For each reported average, the following information will be provided: Lumex data, wind speed, wind direction, concordance correlation factors (used to represent the level of fit for the reconstruction in the path-integrated domain, i.e., predicted versus measured path-averaged concentration), the calculated mercury flux values, and the mercury emission rates.

For each of the 53 days of sampling, when all quality control criteria were met, the following data will be presented:

- A graph showing a time series of mercury emission rates,
- An example mercury plume map, and
- A summary table of results including the following for data for the reported average: ground-level flux value based on data from the Lumex mercury analyzer, wind speed, wind direction, CCF (used to represent the level of fit for the reconstruction in the path-integrated domain, i.e., predicted versus measured PAC), the flux values (actual flux values calculated during periods that the prevailing wind direction was from -60° to +60° from perpendicular to the VRPM configuration, but not adjusted for the angle of the prevailing wind direction), and the emission rates (flux values adjusted for the angle of the prevailing wind direction).

3.2.1 Climatronics Meteorological Data

Although the Climatronics monitor had been calibrated prior to field deployment, and had passed the QC checks in the field, some questionable readings were noted during the initial weeks of the measurement campaign. Because of concerns for the reliability of the data being produced by this instrument, it was replaced with the R.M. Young

monitor on 19 October 2006. Table 3-2 shows that the amount of data acquired with the Climatronics was relatively small in comparison to data acquired with the R.M. Young, since wind directions were not favorable during the early part of the study. Since OAQPS requested data reporting to be as complete as possible for this project, the emission flux data taken using corrected values of Climatronics data are included in this report. Assessment descriptions for the Climatronics operation and offset determinations are described subsequently and in Section 4.

Table 3-2. Wind Rose Data for Climatronics Monitor

Total Measurement Campaign (September 21 through November 12, 2006)			**Climatronics Data** (September 21 through October 18, 2006)		
Wind Direction	**Percent of Winds from each Direction**	**Wind Speed (m/s)**	**Wind Direction**	**Percent of Winds from each Direction**	**Wind Speed (m/s)**
N	19.10%	1.9	N	24.30%	1.9
NE	12.80%	2	NE	19.90%	2
E	**3.60%**	**1.7**	**E**	**1.50%**	**1.7**
SE	**16.60%**	**1.6**	**SE**	**3.50%**	**1.6**
S	**4.20%**	**1.6**	**S**	**1.00%**	**1.6**
SW	5.00%	1.3	SW	1.00%	1.3
W	17.40%	1.1	W	24.70%	1.1
NW	21.30%	1.5	NW	24.00%	1.5

BOLD values indicate wind data that meet the ±60% wind criteria.

In order to assess the reliability of the Climatronics wind speed and wind direction data, the data were compared with National Weather Service data obtained from the Automated Surface Observation System (ASOS) at the Northwest Alabama Regional Airport, located approximately two miles from the project site. Based on two minute wind averages, there were four days in which the directional trends matched, but where the wind direction data were offset by a consistent factor. Those days and the correction factors applied are shown in Table 3-3. All other wind direction data and all wind speed data produced by the Climatronics monitor were found to be acceptable. More information on the procedure used to determine the wind direction correction factors presented in Table 3-3 can be found in Section 4.2.3 of this document.

Table 3-3. Correction Factors Applied to Four Days of Climatronics Data

Date	Directional Correction Factor Applied
September 21, 2006	110°
September 22, 2006	110°
September 30, 2006	100°
October 8, 2006	60°

Figures 3-2 through 3-46 and Tables 3-4 through 3-27 present time series graphs of extrapolated emission rates, a summary of results table, and an example plume map for each day of sampling.

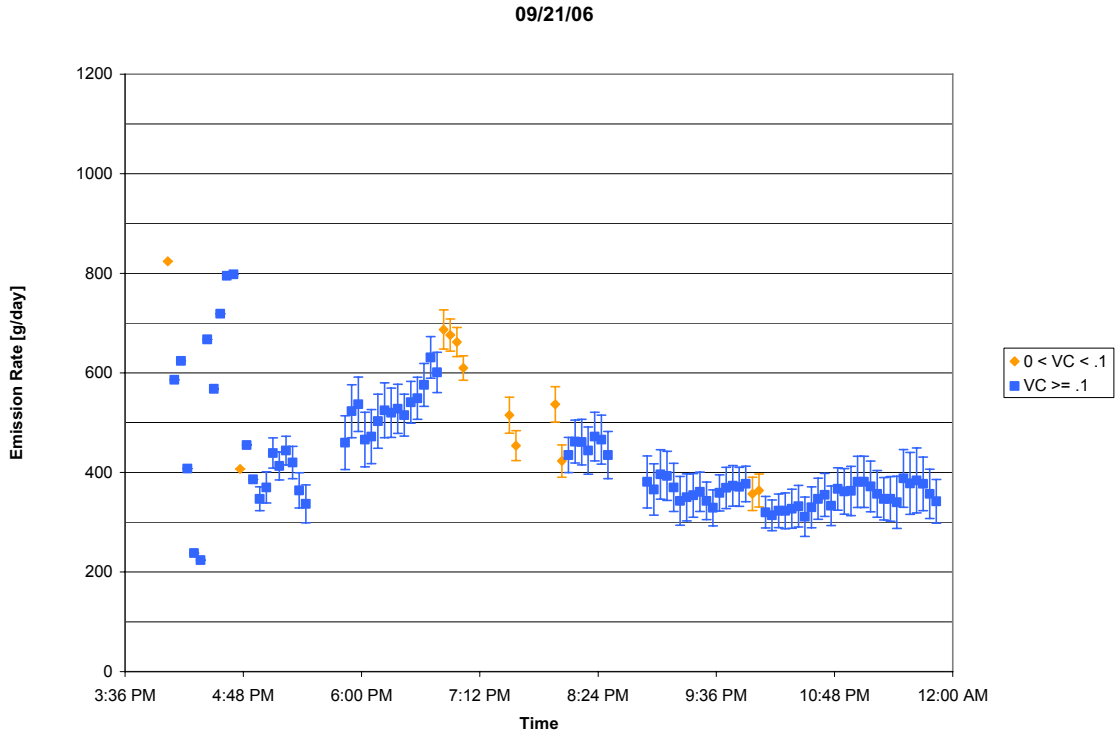

Figure 3-2. Time series of emission rate for September 21, 2006.

Table 3-4. Summary of Results for September 21, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
4:02 PM	0	2.9	34	0.964	384	824
4:06 PM	0	2.8	28	0.984	326	586
4:10 PM	0	2.8	29	0.997	339	624
4:14 PM	0	2.8	25	0.995	245	408
4:18 PM	0	2.7	24	1	147	238
4:22 PM	0	2.6	28	1	126	224
4:26 PM	0	2.7	32	1	329	667
4:30 PM	0	2.8	30	1	299	568
4:34 PM	0	2.9	32	1	360	719
4:38 PM	0	3	32	0.999	402	795
4:42 PM	-1	3.2	28	1	451	798
4:46 PM	5	3.1	24	0.954	254	407
4:50 PM	11	3.2	25	0.982	275	455
4:54 PM	18	3.2	25	0.988	235	386
4:58 PM	24	3.2	26	0.994	208	347
5:02 PM	31	3.1	29	0.991	200	370
5:06 PM	30	3	30	0.988	230	439
5:10 PM	28	2.8	28	0.982	234	413
5:14 PM	29	2.7	25	0.99	268	444
5:18 PM	32	2.8	21	0.998	281	420
5:22 PM	35	2.8	16	0.995	273	364
5:26 PM	38	3.1	14	0.996	261	337
5:50 PM	54	2.8	10	1	386	460
5:54 PM	53	2.7	7	1	466	523
5:58 PM	55	2.6	7	1	481	537
6:02 PM	55	2.5	6	1	425	466
6:06 PM	54	2.3	7	1	420	472
6:10 PM	54	2.2	4	1	469	503
6:14 PM	55	2.1	5	1	482	525
6:18 PM	50	1.9	7	1	460	520
6:22 PM	49	1.9	6	1	475	528
6:26 PM	42	1.8	8	1	452	515
6:30 PM	42	1.9	10	1	454	541

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
6:34 PM	42	1.9	13	1	441	549
6:38 PM	43	2	11	1	477	576
6:42 PM	42	2	12	1	512	631
6:46 PM	41	1.9	12	1	490	601
6:50 PM	39	1.9	13	1	547	687
6:54 PM	32	1.7	11	1	561	676
6:58 PM	29	1.6	11	1	547	662
7:02 PM	25	1.4	11	1	502	610
7:30 PM	36	1.5	0	1	510	515
7:34 PM	30	1.3	3	1	435	454
7:58 PM	36	1.6	-5	1	502	537
8:02 PM	32	1.5	3	1	403	423
8:06 PM	35	1.6	11	1	363	435
8:10 PM	43	1.9	11	1	384	462
8:14 PM	46	2	11	1	384	461
8:18 PM	47	2	11	1	368	444
8:22 PM	49	2.1	12	1	387	472
8:26 PM	49	2.1	12	1	376	466
8:30 PM	47	2	12	1	353	435
8:54 PM	52	2.2	8	1	335	381
8:58 PM	52	2.3	10	1	309	366
9:02 PM	50	2.4	13	1	318	396
9:06 PM	49	2.5	11	0.997	323	393
9:10 PM	48	2.4	9	1	317	370
9:14 PM	49	2.4	11	1	287	343
9:18 PM	48	2.4	10	1	296	350
9:22 PM	44	2.4	9	1	305	354
9:26 PM	40	2.3	10	1	307	361
9:30 PM	38	2.2	10	1	292	343
9:34 PM	36	2.2	8	1	285	329
9:38 PM	36	2.2	9	1	308	359
9:42 PM	41	2.2	8	1	324	369
9:46 PM	41	2.1	7	1	333	373
9:50 PM	39	2	8	1	325	371
9:54 PM	36	1.9	7	1	333	377

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
9:58 PM	34	1.8	5	1	329	357
10:02 PM	33	1.9	7	1	325	364
10:06 PM	32	1.9	8	1	280	320
10:10 PM	31	1.9	7	1	282	314
10:14 PM	34	2	7	1	286	323
10:18 PM	36	2.1	7	1	288	323
10:22 PM	39	2.2	7	1	291	327
10:26 PM	42	2.3	6	1	302	332
10:30 PM	40	2.2	5	1	286	311
10:34 PM	41	2.3	5	1	303	330
10:38 PM	41	2.3	6	1	316	347
10:42 PM	43	2.3	4	1	333	355
10:46 PM	40	2.1	4	1	314	333
10:50 PM	42	2.2	3	1	352	367
10:54 PM	46	2.2	1	1	356	362
10:58 PM	49	2.2	0	1	360	363
11:02 PM	51	2.3	0	1	377	381
11:06 PM	51	2.4	1	1	374	381
11:10 PM	51	2.5	3	1	354	372
11:14 PM	47	2.5	4	1	335	357
11:18 PM	42	2.6	5	1	319	347
11:22 PM	45	2.8	3	1	332	347
11:26 PM	53	3.1	1	1	336	340
11:30 PM	58	3.2	2	1	377	388
11:34 PM	62	3.2	2	0.999	367	378
11:38 PM	65	3.2	0	0.999	384	384
11:42 PM	54	2.9	3	1	358	377
11:46 PM	49	2.7	5	1	331	357
11:50 PM	44	2.4	4	1	321	342

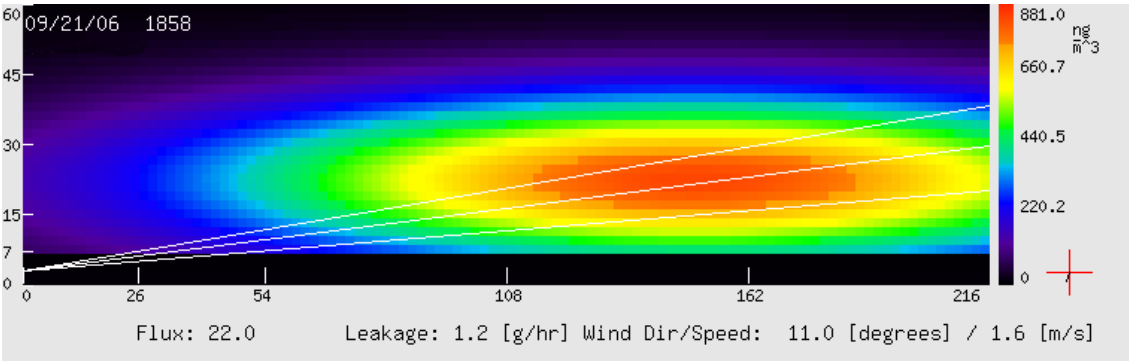

Figure 3-3. Example plume map for September 21, 2006.

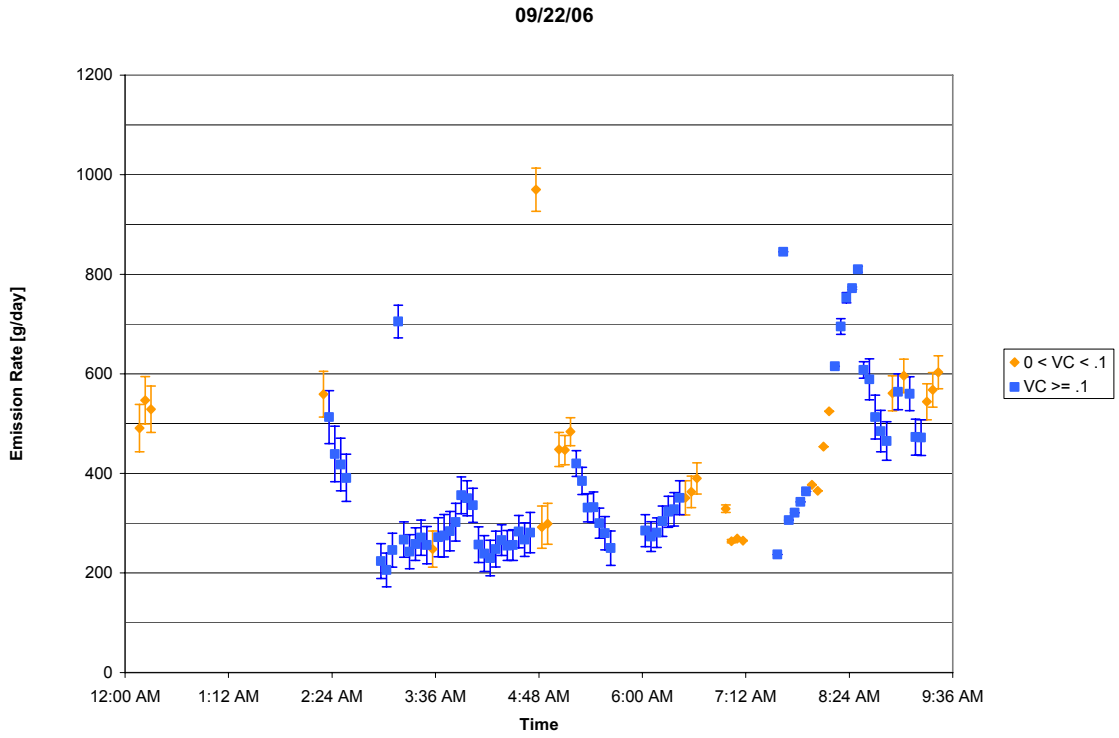

Figure 3-4. Time series of emission rate for September 22, 2006.

Table 3-5. Summary of Results for September 22, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
12:10 AM	48	2.1	-4	1	465	491
12:14 AM	48	2.1	-6	1	509	547
12:18 AM	47	2.1	-6	1	492	529
2:18 AM	46	2	-8	1	508	559
2:22 AM	53	2.1	-4	1	488	513
2:26 AM	56	2.2	1	1	430	439
2:30 AM	53	2.3	7	1	375	418
2:34 AM	47	2.4	10	1	328	391
2:58 AM	35	3.1	21	0.991	149	224
3:02 AM	34	3	23	0.987	133	206
3:06 AM	34	3.1	23	0.99	158	246
3:14 AM	36	3.2	20	0.992	185	267
3:18 AM	34	3.2	19	0.989	172	243
3:22 AM	33	3.2	17	0.987	187	258
3:26 AM	35	3.5	20	0.978	188	271
3:30 AM	37	3.8	23	0.977	164	256
3:34 AM	36	3.8	23	0.972	158	248
3:38 AM	39	3.9	24	0.987	172	272
3:42 AM	42	4	23	0.994	175	275
3:46 AM	39	3.6	21	1	192	284
3:50 AM	38	3.4	17	1	220	302
3:54 AM	37	3.3	16	0.999	265	356
3:58 AM	35	3.2	14	0.999	271	350
4:02 AM	34	3.1	14	0.999	264	336
4:06 AM	36	3.2	13	1	206	257
4:10 AM	36	3.1	12	1	196	239
4:14 AM	36	3.1	11	0.996	189	230
4:18 AM	36	3.2	13	0.995	196	248
4:22 AM	31	3.1	16	0.991	201	266
4:26 AM	30	3.1	17	0.994	188	255
4:30 AM	31	3.1	17	0.996	190	256
4:34 AM	32	3.3	21	0.994	190	283
4:38 AM	34	3.4	22	0.989	175	267
4:42 AM	40	3.8	23	0.989	181	281

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
4:50 AM	42	4.7	29	0.964	158	292
4:54 AM	41	4.7	30	0.944	158	299
5:02 AM	34	4.4	29	0.924	245	448
5:06 AM	30	3.8	28	0.931	253	447
5:10 AM	28	3.4	25	0.953	291	484
5:14 AM	26	3.1	21	0.994	282	420
5:18 AM	27	3	20	1	266	385
5:22 AM	28	3	18	1	235	331
5:26 AM	30	3.2	18	1	239	332
5:30 AM	30	3.2	17	1	222	300
5:34 AM	33	3.3	16	1	208	280
5:38 AM	35	3.4	16	1	186	250
6:02 AM	32	3.3	18	0.998	205	285
6:06 AM	30	3.2	18	1	198	273
6:10 AM	30	3.2	19	0.998	197	281
6:14 AM	30	3.4	20	0.996	211	304
6:18 AM	31	3.7	21	0.994	218	323
6:22 AM	33	3.8	21	0.991	218	328
6:26 AM	34	3.9	23	0.976	226	351
6:30 AM	34	4	23	0.973	227	351
6:34 AM	32	3.7	25	0.953	220	363
6:38 AM	31	3.7	26	0.935	228	390
6:58 AM	8	4.2	30	0.926	173	329
7:02 AM	4	3.9	30	0.946	140	264
7:06 AM	0	3.7	29	0.942	146	269
7:10 AM	0	3.6	29	0.955	146	265
7:34 AM	0	3.2	21	0.991	157	237
7:42 AM	0	3.1	20	0.995	209	306
7:46 AM	0	3.1	21	0.994	213	321
7:50 AM	0	3.2	21	0.995	231	343
7:54 AM	0	3.3	20	0.988	251	364
7:58 AM	0	3.4	23	0.977	241	377
8:02 AM	0	3.3	23	0.971	234	365
8:06 AM	0	3.4	24	0.959	286	454
8:10 AM	0	3.5	26	0.903	310	525

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
8:14 AM	0	3.5	27	1	350	615
8:18 AM	-15	3.6	26	1	407	695
8:22 AM	-9	3.7	28	1	423	753
8:26 AM	-1	3.7	25	1	467	772
8:30 AM	6	3.8	23	1	519	810
8:34 AM	17	3.7	22	1	399	608
8:38 AM	41	3.6	21	1	397	589
8:42 AM	44	3.5	20	1	355	513
8:46 AM	42	3.4	20	1	330	485
8:50 AM	39	3.2	21	0.998	315	465
8:54 AM	35	3.2	22	0.979	367	561
8:58 AM	36	3.3	23	0.992	361	564
9:02 AM	34	3.3	23	0.984	382	596
9:06 AM	34	3.3	24	0.988	353	560
9:10 AM	36	3.4	25	0.98	288	473
9:14 AM	36	3.3	29	0.987	261	472
9:18 AM	36	3.4	30	0.957	291	544
9:22 AM	35	3.4	29	0.957	307	568
9:26 AM	33	3.4	31	0.912	313	603

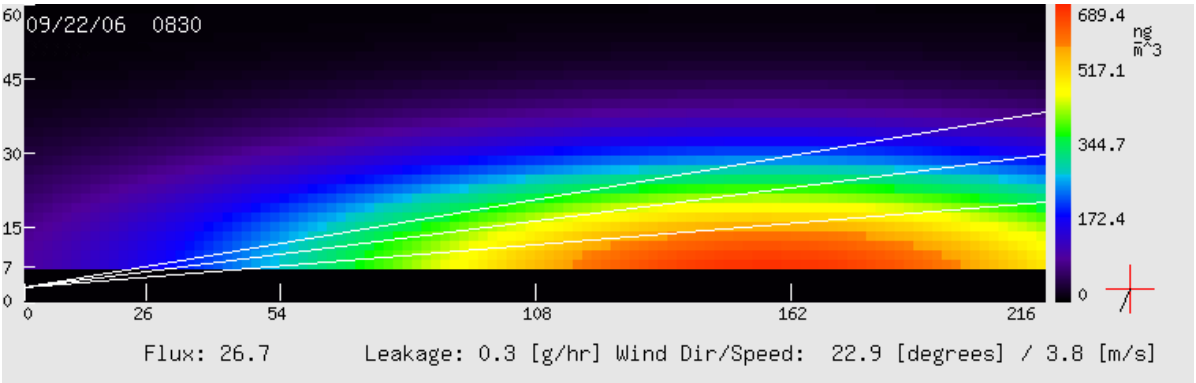

Figure 3-5. Example plume map for September 22, 2006.

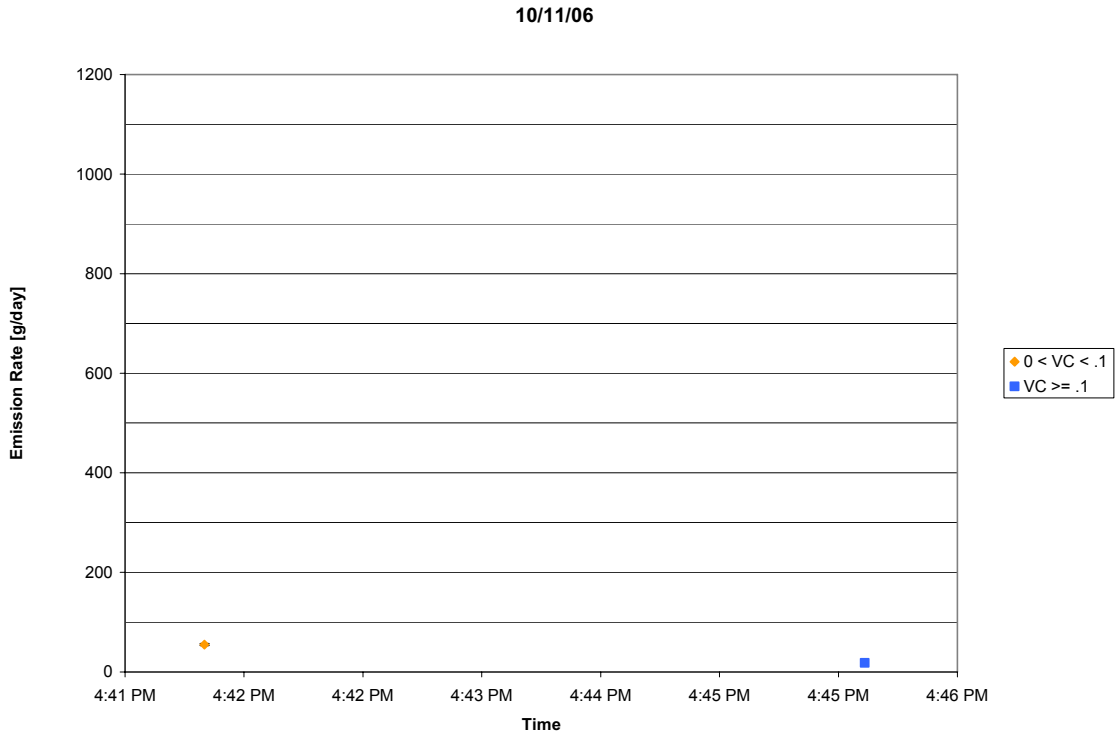

Figure 3-6. Time series of emission rate for October 11, 2006.

Table 3-6. Summary of Results for October 11, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
4:42 PM	2	4	-13	1	47	55
4:46 PM	1	1.5	-12	1	16	18

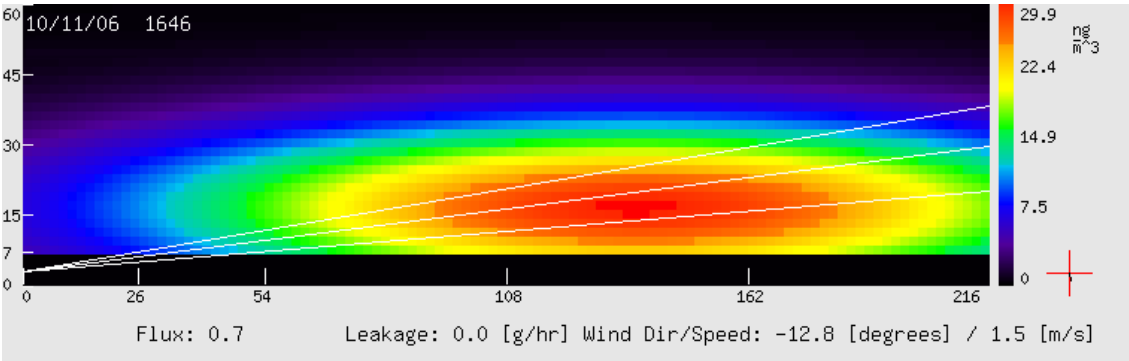

Figure 3-7. Example plume map for October 11, 2006.

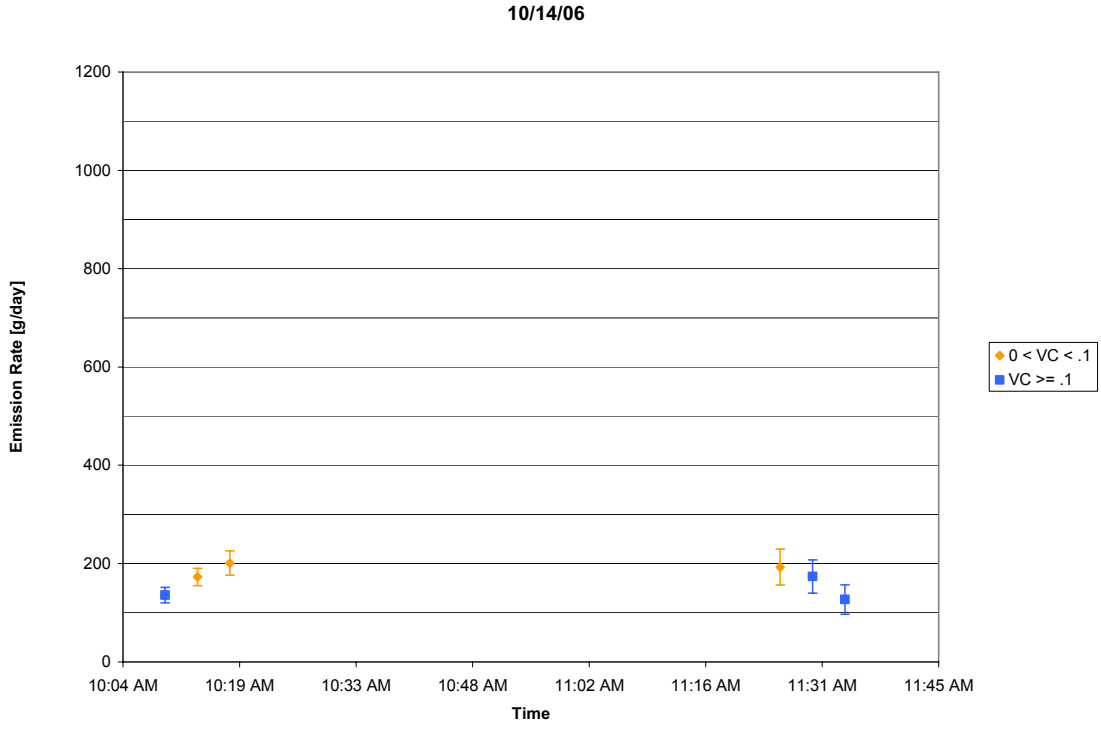

Figure 3-8. Time series of emission rate for October 14, 2006.

Table 3-7. Summary of Results for October 14, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
10:10 AM	16	2.5	-54	1	58	136
10:14 AM	18	2.4	-48	1	84	173
10:18 AM	25	2.4	-46	1	101	201
11:26 AM	36	1.8	-49	0.995	92	193
11:30 AM	34	1.9	-58	1	67	174
11:34 AM	30	1.8	-59	1	47	127

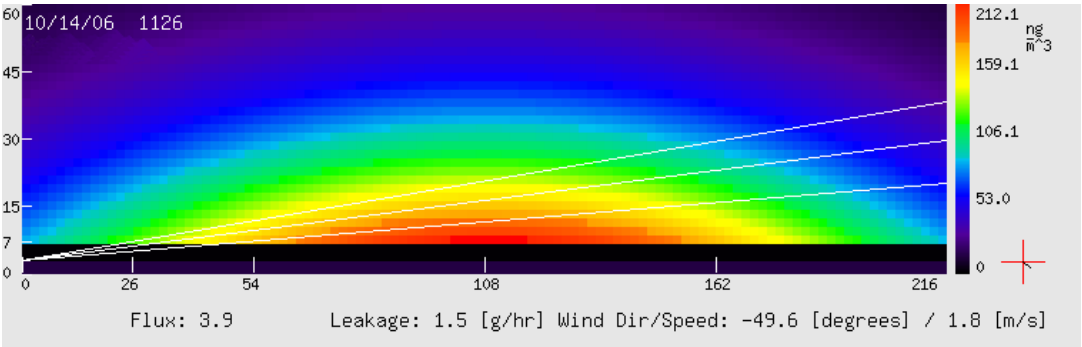

Figure 3-9. Example plume map for October 14, 2006.

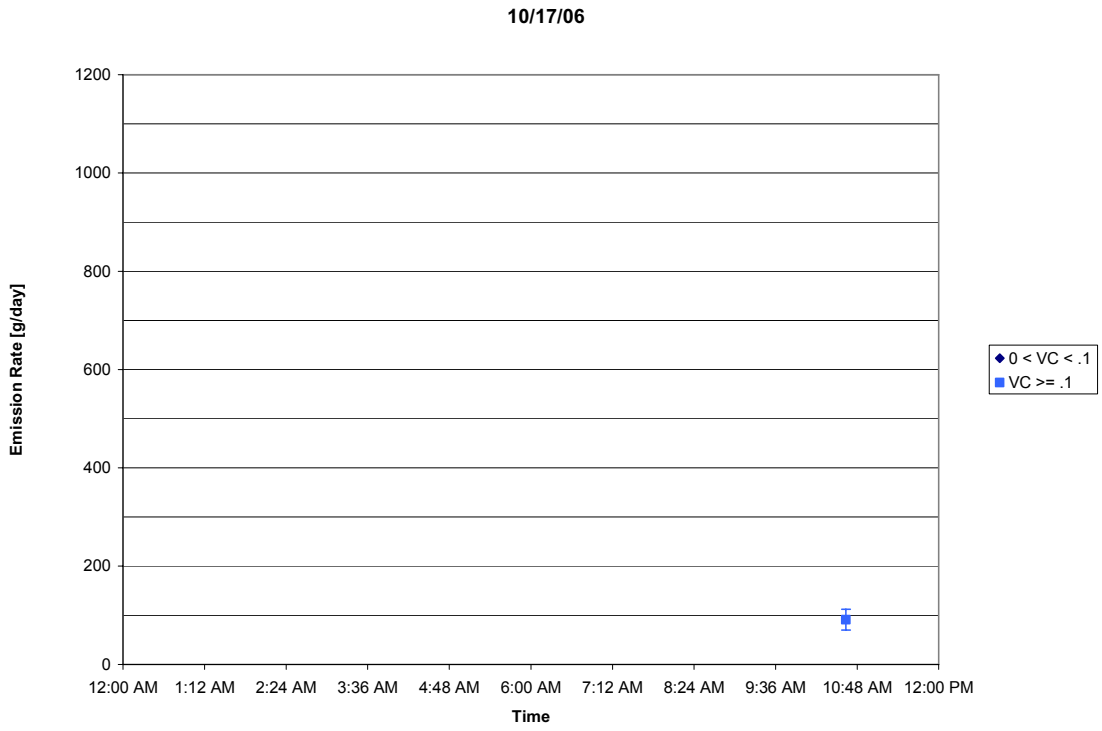

Figure 3-10. Time series of emission rate for October 17, 2006.

Table 3-8. Summary of Results for October 17, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
10:38 AM	21	5	-39	0.99	52	91

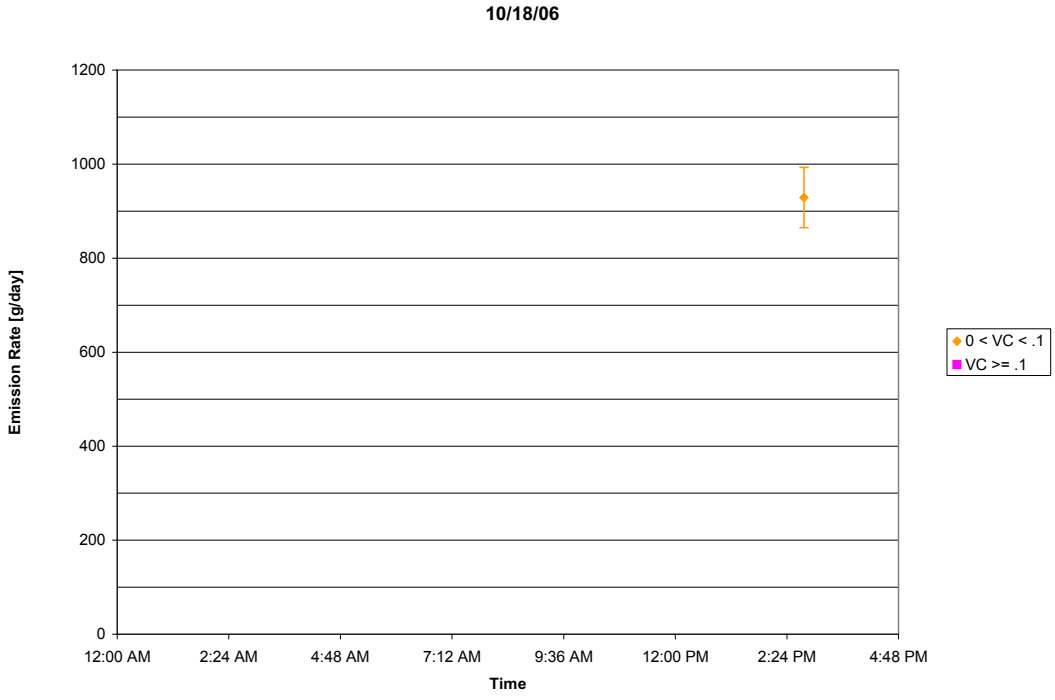

Figure 3-11. Time series of emission rate for October 18, 2006.

Table 3-9. Summary of Results for October 18, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
2:46 PM	64	1.6	-20	1	727	929

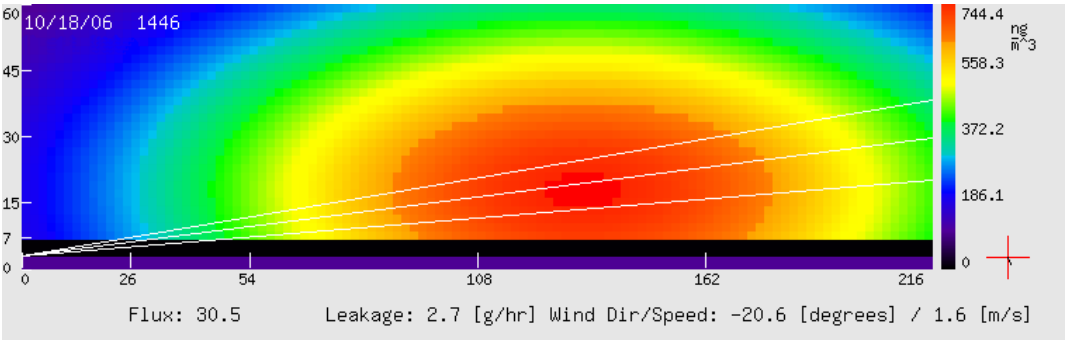

Figure 3-12. Example plume map for October 18, 2006.

3.2.2 R.M. Young Meteorological Data

The following R.M. Young meteorological data was collected October 19 through November 13, 2006.

Table 3-10. Wind Rose Data for R.M. Young Monitor

Total Measurement Campaign (September 21 through November 12, 2006)			**R.M. Young Data** (October 18 through November 12, 2006)		
Wind Direction	**Percent of Winds from each Direction**	**Wind Speed (m/s)**	**Wind Direction**	**Percent of Winds from each Direction**	**Wind Speed (m/s)**
N	19.10%	1.9	N	14.10%	2.3
NE	12.80%	2	NE	6.00%	2.1
E	**3.60%**	**1.7**	**E**	**5.60%**	**1.4**
SE	**16.60%**	**1.6**	**SE**	**29.00%**	**1.5**
S	**4.20%**	**1.6**	**S**	**7.30%**	**1.4**
SW	5.00%	1.3	SW	8.70%	1.1
W	17.40%	1.1	W	10.40%	0.9
NW	21.30%	1.5	NW	18.80%	1.5

BOLD values indicate wind data that meet the ±60% wind criteria.

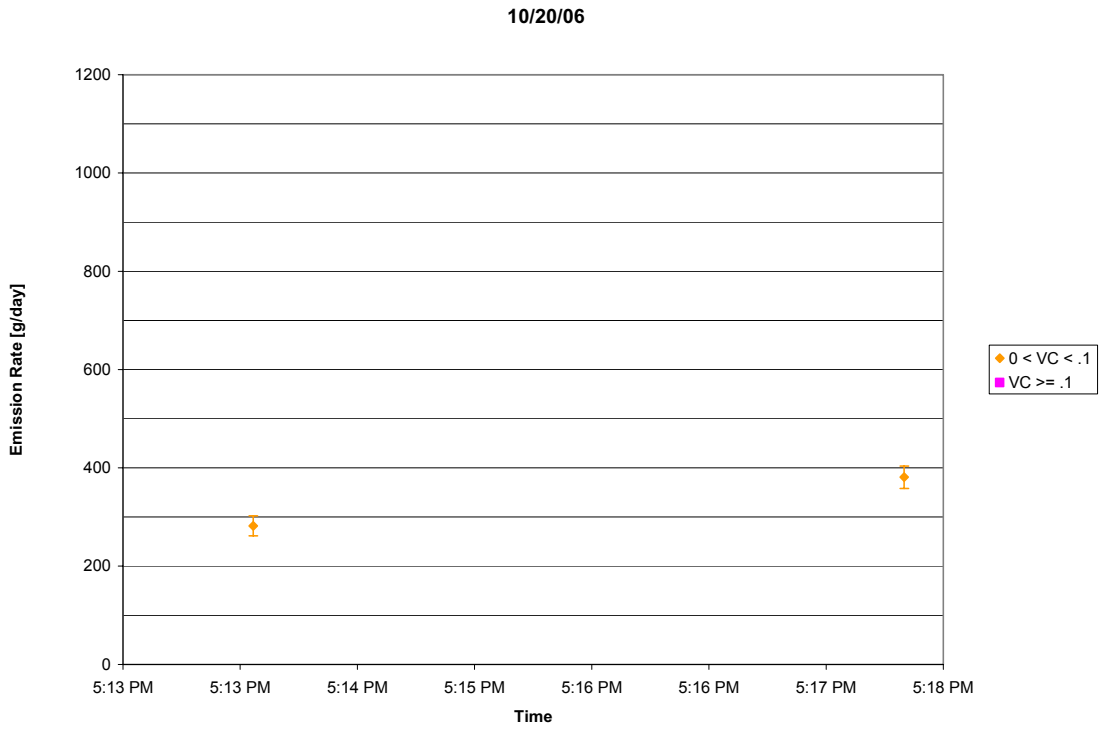

Figure 3-13. Time series of emission rate for October, 20 2006.

Table 3-11. Summary of Results for October 20, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
5:14 PM	20	1.4	-15	1	235	282
5:18 PM	23	1.5	-16	1	312	381

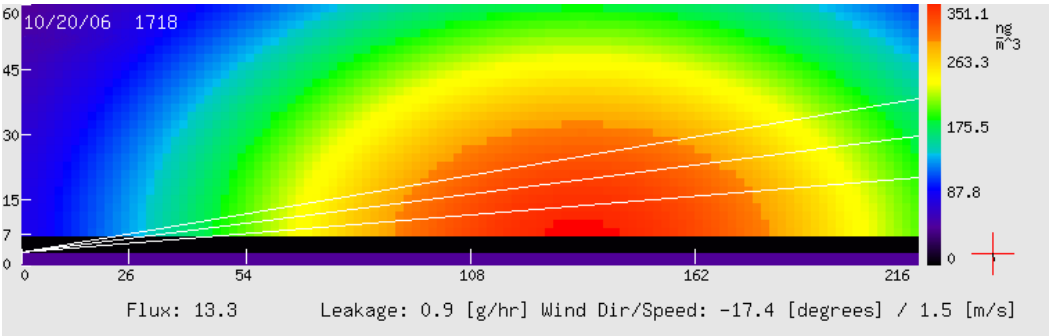

Figure 3-14. Example plume map for October 20, 2006.

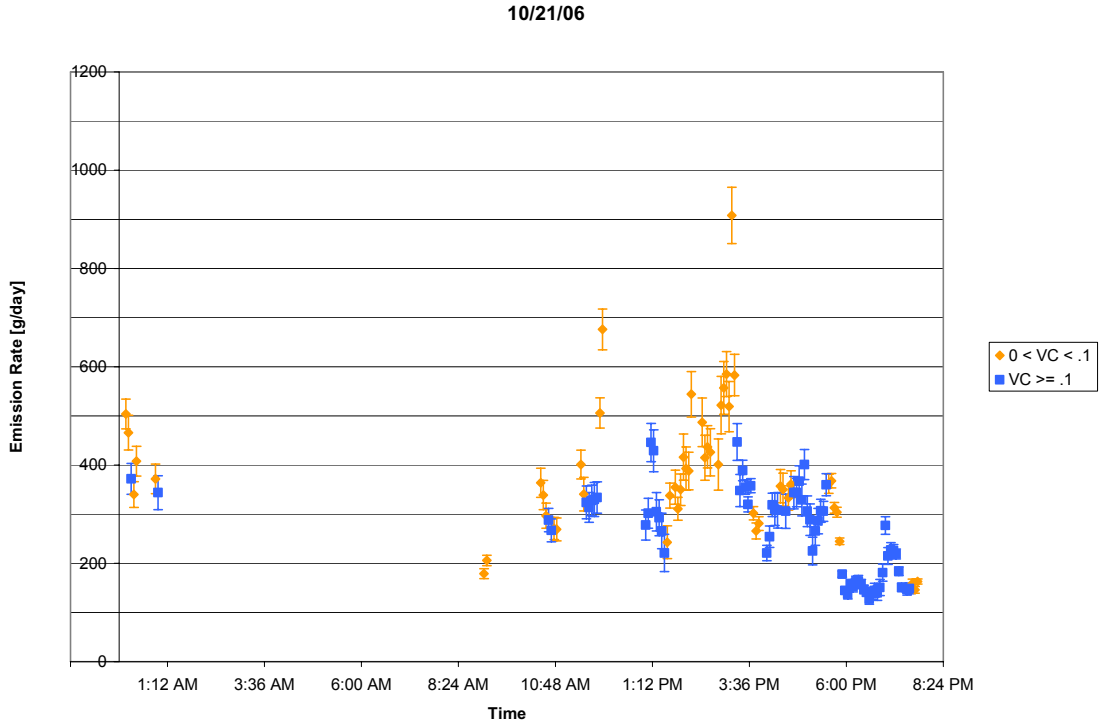

Figure 3-15. Time series of emission rate for October 21, 2006.

Table 3-12. Summary of Results for October 21, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
9:02 AM	10	1.4	6	1	162	179
9:06 AM	11	1.6	15	1	159	206
10:26 AM	30	2.1	-6	1	339	364
10:30 AM	30	2.1	-2	1	330	339
10:34 AM	26	2	1	1	294	297
10:38 AM	24	2	3	1	276	288
10:42 AM	24	1.9	3	1	255	267
10:46 AM	23	1.8	4	1	255	271
10:50 AM	24	1.7	-2	1	262	269
11:26 AM	29	2	-1	1	395	401
11:30 AM	34	1.8	0	1	338	341
11:34 AM	33	1.7	0	1	321	324
11:38 AM	30	1.7	0	1	310	314
11:42 AM	31	1.8	0	1	327	328
11:46 AM	35	1.8	0	1	328	330
11:50 AM	32	1.9	-1	1	327	334
11:54 AM	31	1.9	-9	1	454	506
11:58 AM	42	2.1	-17	1	545	676
12:10 AM	30	1.8	-17	1	410	504
12:14 AM	35	1.8	-13	1	399	466
12:18 AM	31	1.6	-8	1	338	372
12:22 AM	26	1.4	-6	1	315	340
12:26 AM	30	1.5	-3	1	389	408
12:54 AM	30	1.4	6	0.988	337	372
12:58 AM	35	1.5	5	1	315	344
1:02 PM	31	1.4	7	1	247	278
1:06 PM	30	1.5	5	1	280	302
1:10 PM	39	1.8	12	1	359	446
1:14 PM	42	1.9	13	1	343	429
1:18 PM	39	1.8	12	0.999	247	305
1:22 PM	37	1.8	9	0.994	250	293
1:26 PM	36	1.8	10	0.982	224	266
1:30 PM	38	1.7	2	0.987	215	221
1:34 PM	33	1.6	-1	0.973	239	243

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
1:38 PM	25	1.4	-4	1	322	338
1:46 PM	35	1.5	-3	1	342	355
1:50 PM	23	1.3	-4	0.963	293	311
1:54 PM	32	1.4	-12	0.994	301	350
1:58 PM	47	1.6	-12	0.978	359	416
2:02 PM	44	1.5	-15	0.982	326	393
2:06 PM	38	1.5	-15	0.915	322	388
2:10 PM	46	1.6	-9	0.976	486	544
2:26 PM	49	1.7	-11	0.952	427	487
2:30 PM	46	1.6	-11	0.92	364	415
2:34 PM	43	1.7	-16	0.934	360	437
2:38 PM	48	1.8	-6	0.913	395	426
2:50 PM	52	1.9	7	0.931	357	401
2:54 PM	59	1.9	9	0.95	449	522
2:58 PM	54	1.8	12	0.992	452	557
3:02 PM	46	1.6	7	0.995	517	585
3:06 PM	51	1.7	0	0.997	512	519
3:14 PM	42	1.7	17	0.964	430	583
3:18 PM	37	1.8	18	0.985	319	447
3:22 PM	33	1.8	27	0.992	201	348
3:26 PM	21	1.7	44	0.996	123	389
3:30 PM	15	1.6	44	0.994	113	355
3:34 PM	15	1.7	39	0.996	126	320
3:38 PM	14	1.7	45	0.983	104	358
3:42 PM	13	1.7	38	0.967	121	302
3:46 PM	16	1.8	30	0.952	141	266
3:50 PM	14	1.7	26	0.937	165	281
4:02 PM	16	2	22	0.988	146	221
4:06 PM	22	2.2	19	0.992	180	254
4:10 PM	24	2.2	22	0.985	207	319
4:14 PM	33	2.1	19	0.991	217	310
4:18 PM	36	2	21	0.99	206	308
4:22 PM	34	1.9	24	0.967	223	357
4:26 PM	34	1.9	24	0.976	216	350
4:30 PM	35	1.9	25	0.982	188	306

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
4:34 PM	25	1.8	24	0.974	209	333
4:38 PM	28	1.8	19	0.974	253	361
4:42 PM	33	1.9	15	0.988	266	344
4:46 PM	29	1.9	16	0.996	258	344
4:50 PM	31	2	14	1	289	367
4:54 PM	32	2.1	14	1	255	329
4:58 PM	31	2.1	16	1	301	401
5:02 PM	31	2.2	13	1	244	306
5:06 PM	32	2.1	12	0.999	233	289
5:10 PM	28	2	12	0.999	183	225
5:14 PM	29	2.1	14	0.999	207	266
5:18 PM	26	2	15	0.993	219	286
5:22 PM	24	1.9	17	0.995	227	307
5:26 PM	20	1.8	17	0.994	225	306
5:30 PM	22	1.7	16	0.991	267	360
5:34 PM	19	1.5	14	0.965	281	362
5:38 PM	15	1.4	15	0.968	281	368
5:42 PM	11	1.2	16	0.941	236	313
5:46 PM	10	1.2	17	0.95	223	304
5:50 PM	7	1.2	19	0.956	172	245
5:54 PM	6	1.2	22	0.994	118	178
5:58 PM	7	1.3	20	0.998	100	145
6:02 PM	9	1.4	18	1	98	137
6:06 PM	11	1.5	18	1	112	157
6:10 PM	11	1.6	18	1	110	153
6:14 PM	12	1.7	17	1	119	162
6:18 PM	12	1.7	19	1	115	164
6:22 PM	10	1.6	21	0.996	107	158
6:26 PM	9	1.6	20	0.987	100	147
6:30 PM	9	1.6	19	0.991	100	142
6:34 PM	10	1.5	17	0.989	93	127
6:38 PM	12	1.6	15	0.996	106	138
6:42 PM	14	1.7	13	1	115	145
6:46 PM	15	1.7	13	1	112	140
6:50 PM	17	1.8	13	1	121	151

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
6:54 PM	17	1.9	13	1	144	181
6:58 PM	18	1.9	14	1	216	277
7:02 PM	17	1.9	16	0.999	160	215
7:06 PM	15	1.8	19	0.996	160	227
7:10 PM	12	1.6	22	0.996	149	226
7:14 PM	10	1.5	23	0.992	139	219
7:18 PM	9	1.5	24	0.986	114	184
7:22 PM	9	1.5	22	0.979	98	151
7:30 PM	11	1.6	17	0.992	108	147
7:34 PM	11	1.5	17	0.984	109	149
7:38 PM	9	1.4	17	0.977	115	159
7:42 PM	7	1.2	17	0.965	107	146
7:46 PM	5	1.1	18	0.93	118	163

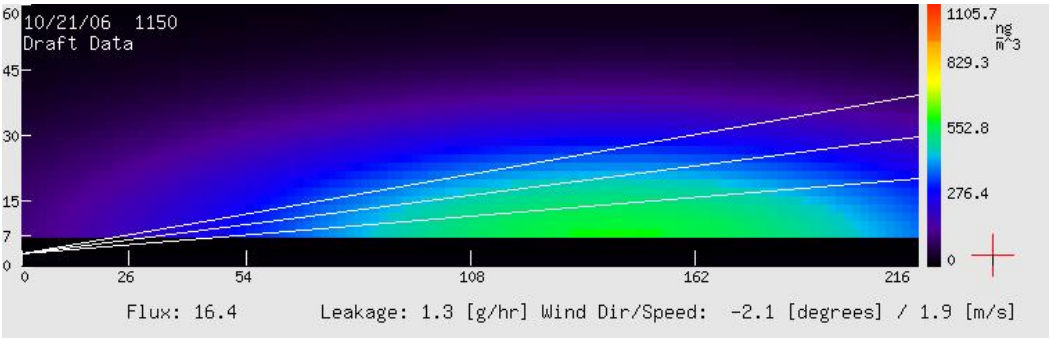

Figure 3-16. Example plume map for October 21, 2006.

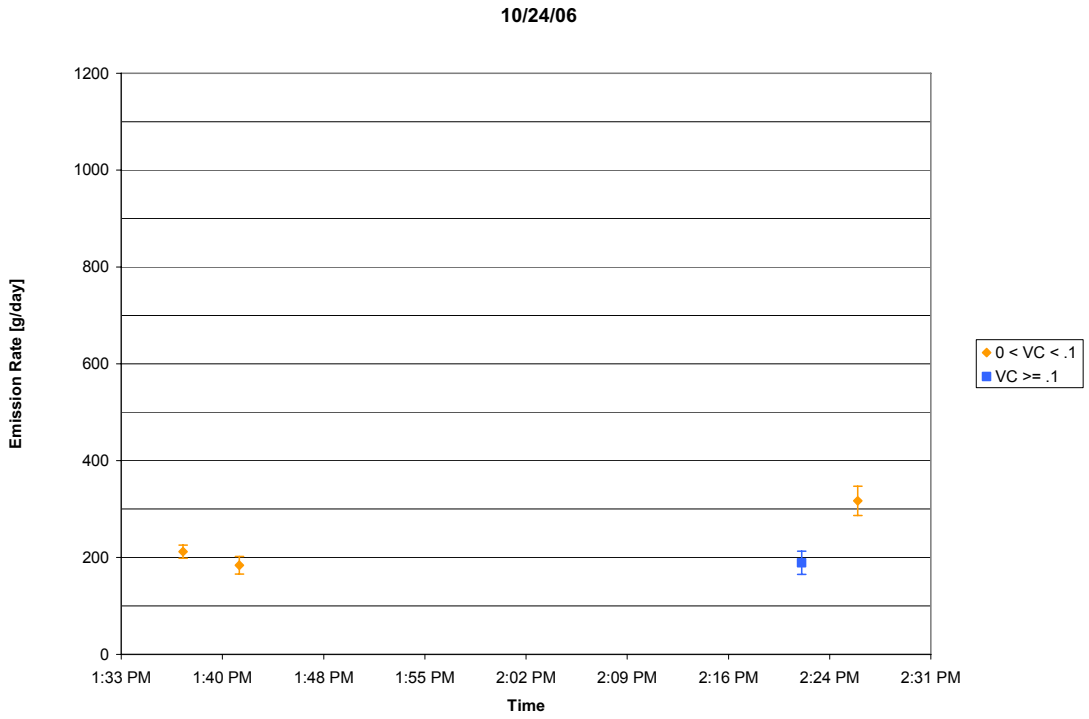

Figure 3-17. Time series of emission rate for October 24, 2006.

Table 3-13. Summary of Results for October 24, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
1:38 PM	14	1.1	-49	0.908	100	212
1:42 PM	18	1.2	-58	0.996	69	184
2:22 PM	24	1.1	-48	1	91	189
2:26 PM	30	1.4	-32	1	208	317

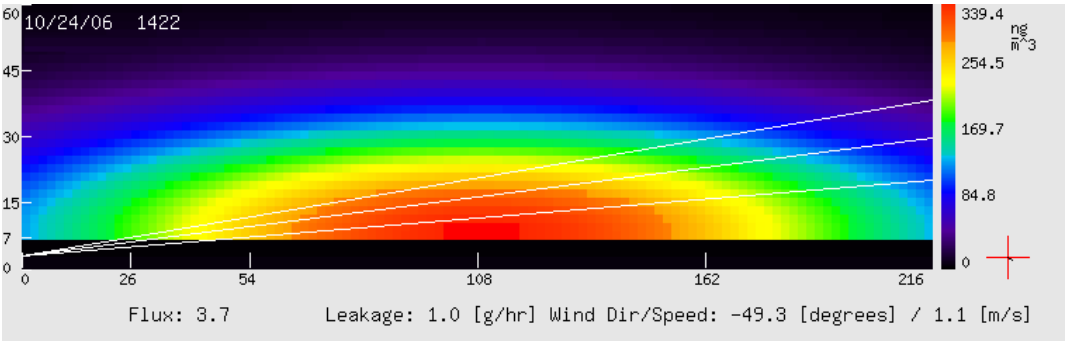

Figure 3-18. Example plume map for October 24, 2006.

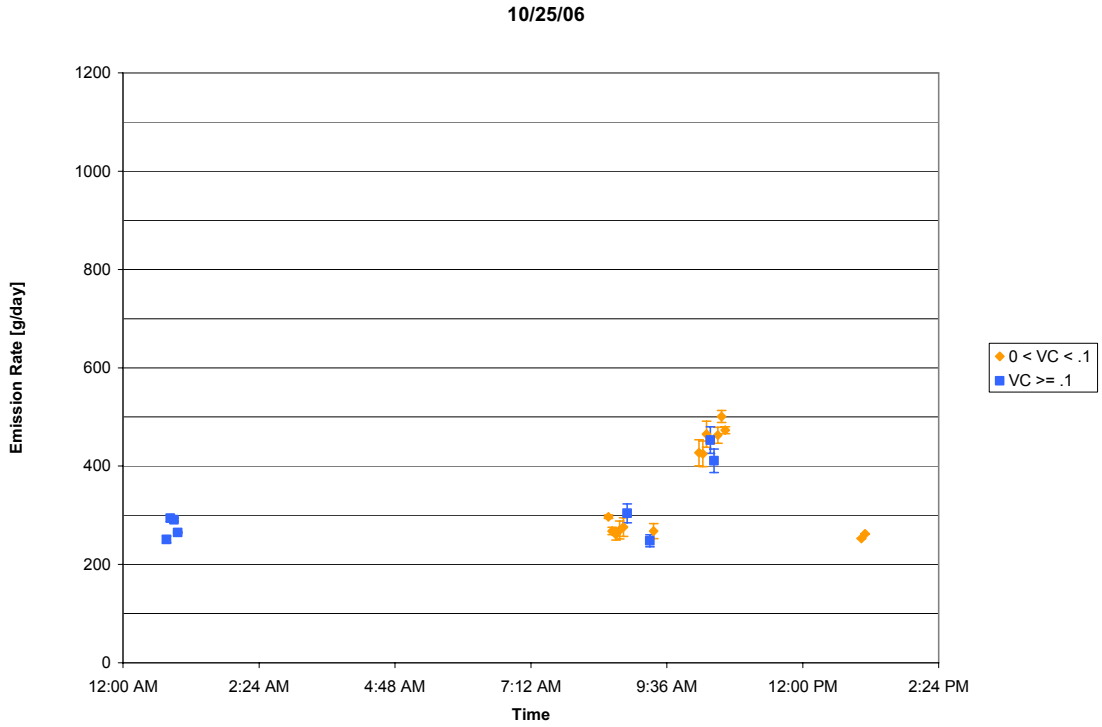

Figure 3-19. Time series of emission rate for October 25, 2006.

Table 3-14. Summary of Results for October 25, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
8:34 AM	3	1.8	4	1	278	297
8:38 AM	7	1.7	3	1	254	268
8:42 AM	11	1.7	4	1	243	261
8:46 AM	18	1.8	6	1	244	270
8:50 AM	19	1.8	10	1	235	276
8:54 AM	19	2	11	1	252	304
9:18 AM	12	1.9	9	1	211	248
9:22 AM	15	1.8	8	1	235	268
10:10 AM	27	2	1	1	423	427
10:14 AM	26	2	1	1	417	425
10:18 AM	26	2.1	4	1	436	465
10:22 AM	27	2.2	6	1	409	453
10:26 AM	24	2.2	9	1	352	411
10:30 AM	16	2	16	1	348	463
10:34 AM	12	2	25	1	305	501
10:38 AM	7	1.8	29	1	257	473
12:46 AM	7	2	11	1	207	251
12:50 AM	7	2	11	1	241	294
12:54 AM	3	1.8	10	1	244	291
12:58 AM	1	1.5	13	1	212	265
1:02 PM	1	1.4	7	1	225	253
1:06 PM	0	1.5	1	1	259	262

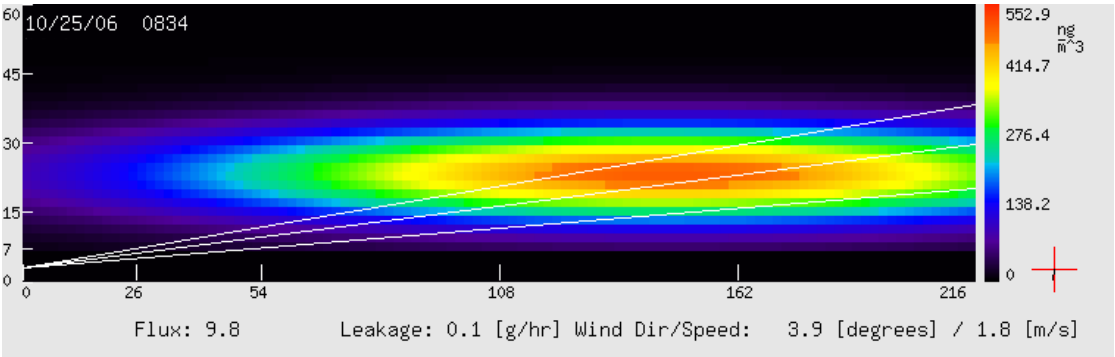

Figure 3-20. Example plume map for October 25, 2006.

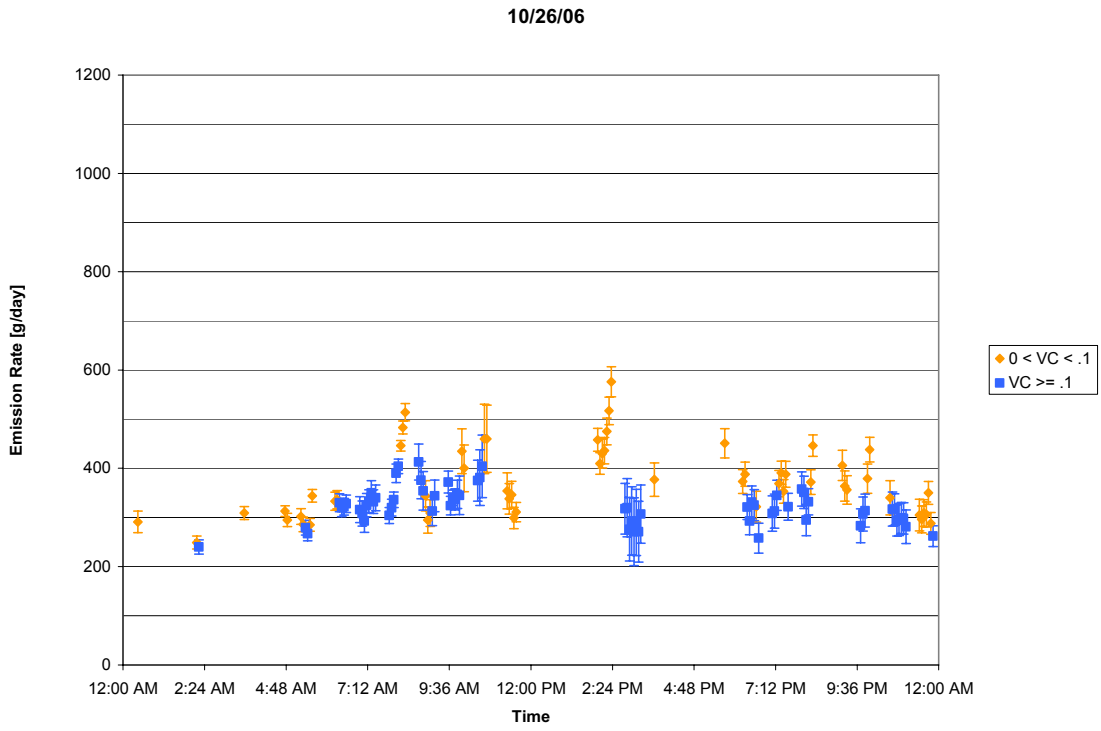

Figure 3-21. Time series of emission rate for October 26, 2006.

Table 3-15. Summary of Results for October 26, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
2:10 AM	13	1.7	14	1	194	249
2:14 AM	14	1.8	15	1	183	240
3:34 AM	13	1.5	7	1	276	309
4:46 AM	11	1.6	21	1	211	313
4:50 AM	13	1.7	19	1	205	295
5:14 AM	16	1.7	13	1	239	302
5:18 AM	15	1.7	16	1	215	286
5:22 AM	15	1.8	17	1	204	279
5:26 AM	14	1.8	19	1	189	267
5:30 AM	13	1.8	18	1	204	285
5:34 AM	13	1.8	16	1	255	344
6:14 AM	18	1.7	9	1	285	333
6:18 AM	18	1.8	15	1	259	336
6:22 AM	18	1.9	18	1	239	330
6:26 AM	18	2.1	18	1	231	320
6:30 AM	17	2.2	16	1	239	322
6:34 AM	18	2.2	16	1	248	328
6:58 AM	26	1.8	7	1	280	316
7:02 AM	26	1.8	8	1	268	308
7:06 AM	23	1.7	8	1	257	293
7:10 AM	24	1.9	9	1	277	325
7:14 AM	23	1.9	11	1	274	333
7:18 AM	25	1.9	14	1	273	350
7:22 AM	24	1.8	15	1	252	332
7:26 AM	26	1.9	16	1	253	340
7:50 AM	16	1.6	17	1	223	304
7:54 AM	17	1.6	13	1	253	320
7:58 AM	16	1.6	9	1	288	336
8:02 AM	19	1.7	9	1	337	390
8:06 AM	15	1.7	8	1	355	404
8:10 AM	11	1.7	9	1	384	446
8:14 AM	13	1.8	8	1	419	483
8:18 AM	18	1.8	9	1	444	514
8:42 AM	36	1.8	25	1	250	413

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
8:46 AM	38	1.8	27	1	219	376
8:50 AM	39	1.7	27	1	204	354
8:54 AM	31	1.5	28	1	192	344
8:58 AM	27	1.4	25	1	181	295
9:02 AM	27	1.5	19	1	217	309
9:06 AM	30	1.6	13	1	249	313
9:10 AM	32	1.7	12	1	282	344
9:34 AM	22	2	19	1	263	372
9:38 AM	19	2	20	1	224	324
9:42 AM	16	2.1	23	1	219	340
9:46 AM	21	2.2	24	1	209	337
9:50 AM	29	2.3	25	0.998	213	347
9:54 AM	39	2.3	25	0.993	208	345
9:58 AM	46	2.3	28	0.976	246	435
10:02 AM	48	2.2	28	0.977	225	400
10:26 AM	42	1.9	12	1	308	375
10:30 AM	57	1.9	10	1	323	381
10:34 AM	63	1.9	7	1	357	404
10:38 AM	71	1.9	6	1	418	460
10:42 AM	68	1.7	8	1	405	460
11:18 AM	37	1.7	14	1	274	354
11:22 AM	31	1.6	14	1	264	338
11:26 AM	28	1.5	14	1	272	346
11:30 AM	22	1.4	14	1	235	299
11:34 AM	20	1.4	13	1	246	311
12:26 AM	22	1.4	19	1	206	291
1:58 PM	23	1.8	18	1	326	458
2:02 PM	22	1.8	19	1	288	410
2:06 PM	30	2	19	1	300	430
2:10 PM	27	2	19	1	307	436
2:14 PM	27	2.1	19	1	332	475
2:18 PM	28	2	18	1	374	517
2:22 PM	31	2	15	0.995	439	576
2:46 PM	52	2.1	13	0.994	251	318
2:50 PM	59	2.2	12	0.997	259	320

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
2:54 PM	65	2.2	9	0.996	237	276
2:58 PM	70	2.3	8	0.995	258	293
3:02 PM	69	2.2	9	1	234	271
3:06 PM	67	2.2	10	1	244	290
3:10 PM	62	2.1	10	1	230	271
3:14 PM	59	2.1	13	1	245	307
3:38 PM	34	1.5	11	1	313	377
5:42 PM	30	1.4	10	0.905	379	451
6:14 PM	24	2.1	23	1	240	373
6:18 PM	25	2.1	22	1	254	388
6:22 PM	25	2.1	20	1	218	321
6:26 PM	28	2.1	19	1	205	293
6:30 PM	33	2.2	19	1	234	331
6:34 PM	31	2.1	20	1	226	325
6:38 PM	31	2.1	19	0.997	224	322
6:42 PM	30	2.2	20	0.992	176	258
7:06 PM	36	2.4	19	1	217	308
7:10 PM	35	2.3	18	1	226	313
7:14 PM	31	2.1	16	1	256	345
7:18 PM	27	2	17	1	273	369
7:22 PM	24	1.9	17	1	288	391
7:26 PM	24	1.9	18	1	255	353
7:30 PM	26	2	17	0.987	286	388
7:34 PM	27	2	17	1	237	322
7:58 PM	35	2.3	19	1	249	358
8:02 PM	33	2.3	20	0.998	240	351
8:06 PM	32	2.2	20	0.999	203	295
8:10 PM	27	2.2	21	0.996	220	332
8:14 PM	25	2.2	22	0.99	246	372
8:18 PM	22	2	20	0.926	305	446
9:10 PM	31	1.9	13	0.97	325	406
9:14 PM	31	2	16	0.977	275	364
9:18 PM	29	2	18	0.997	254	356
9:42 PM	35	2.4	18	0.994	205	283
9:46 PM	35	2.5	18	0.992	219	307

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
9:50 PM	34	2.4	19	0.996	220	314
9:54 PM	30	2.3	19	0.99	264	379
9:58 PM	25	2.1	20	0.971	302	438
10:34 PM	35	2.4	23	0.983	218	340
10:38 PM	35	2.5	22	0.997	209	317
10:42 PM	32	2.4	22	0.998	205	316
10:46 PM	32	2.4	22	0.992	195	294
10:50 PM	32	2.5	20	0.994	202	296
10:54 PM	32	2.6	20	0.997	203	299
10:58 PM	32	2.6	23	0.992	192	298
11:02 PM	34	2.8	22	0.989	184	281
11:26 PM	32	2.6	23	0.975	196	305
11:30 PM	27	2.4	23	0.965	190	296
11:34 PM	27	2.4	24	0.981	193	309
11:38 PM	25	2.3	26	0.985	182	306
11:42 PM	23	2.3	25	0.976	213	350
11:46 PM	22	2.3	26	0.976	172	288
11:50 PM	21	2.2	26	0.993	156	262

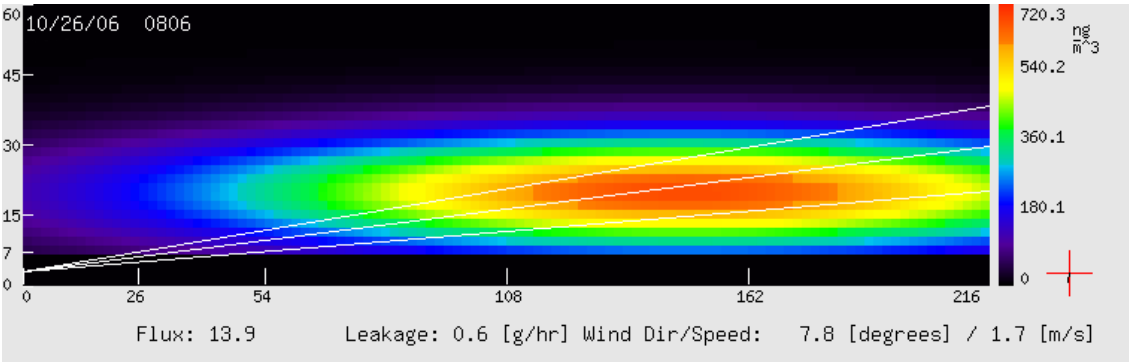

Figure 3-22. Example plume map for October 26, 2006.

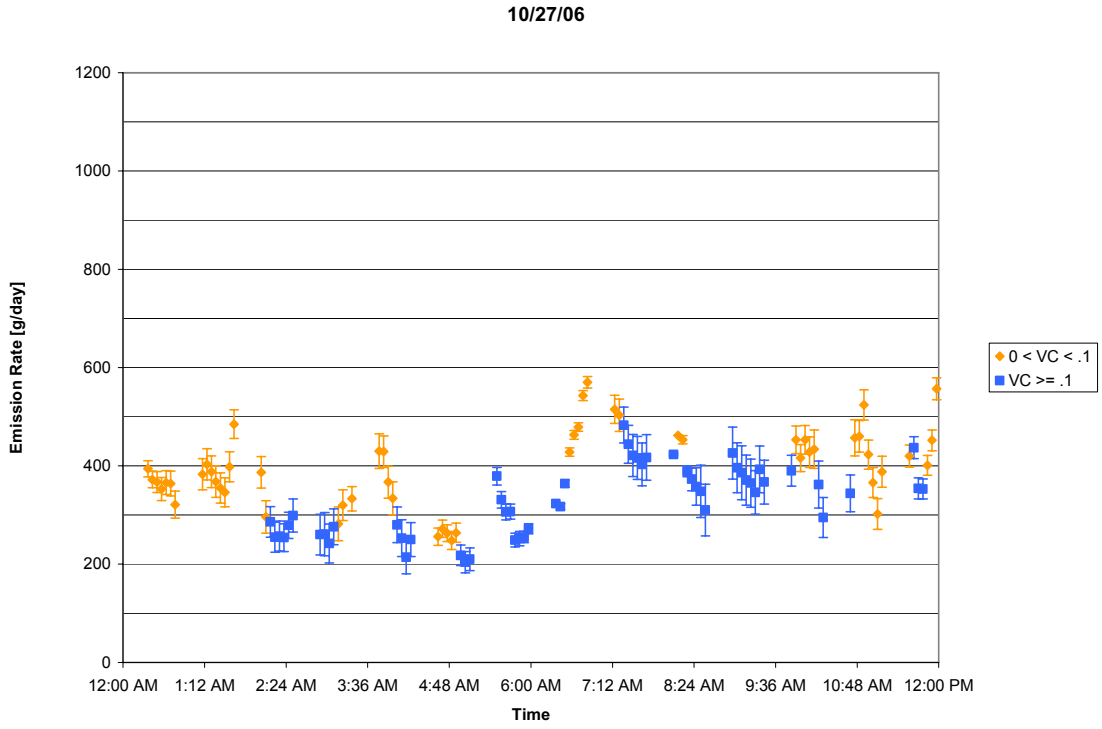

Figure 3-23. Time series of emission rate for October 27, 2006.

Table 3-16. Summary of Results for October 27, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
12:22 AM	17	2	17	0.953	292	394
12:26 AM	17	1.9	16	0.957	279	372
12:30 AM	21	1.9	16	0.915	274	367
12:34 AM	23	1.9	17	0.947	259	353
12:38 AM	24	1.9	17	0.97	271	366
12:42 AM	25	1.9	17	0.998	265	364
12:46 AM	27	1.9	16	0.999	243	321
1:10 AM	32	2.1	10	1	323	383

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
1:14 AM	32	2.1	9	0.996	345	403
1:18 AM	32	2	10	0.983	329	388
1:22 AM	32	2	11	0.973	304	368
1:26 AM	30	2	13	0.998	282	355
1:30 AM	30	2	15	1	263	346
1:34 AM	31	2	16	1	301	398
1:38 AM	29	2	13	1	384	485
2:02 AM	32	2	8	0.994	339	387
2:06 AM	33	2	9	1	255	296
2:10 AM	31	2.1	10	1	242	286
2:14 AM	31	2	11	1	210	255
2:18 AM	30	2.1	14	1	200	257
2:22 AM	28	2.1	17	1	185	254
2:26 AM	27	2.1	17	1	204	279
2:30 AM	34	2.2	16	1	225	299
2:54 AM	42	2.5	15	1	200	260
2:58 AM	44	2.6	14	1	202	261
3:02 AM	40	2.5	15	1	184	242
3:06 AM	36	2.4	16	0.999	208	276
3:10 AM	34	2.3	14	0.984	219	282
3:14 AM	31	2.2	15	0.968	245	320
3:22 AM	25	1.9	12	0.931	269	333
3:46 AM	35	2.4	21	0.993	289	430
3:50 AM	32	2.4	19	0.953	298	429
3:54 AM	32	2.4	17	0.956	269	367
3:58 AM	34	2.4	17	0.971	244	334
4:02 AM	36	2.4	16	0.986	210	280
4:06 AM	37	2.5	16	0.996	191	253
4:10 AM	34	2.6	15	0.999	163	214
4:14 AM	35	2.8	19	0.994	175	250
4:38 AM	18	2.7	26	0.968	152	256
4:42 AM	18	2.8	25	0.969	164	272
4:46 AM	17	2.8	22	0.96	174	263
4:50 AM	18	2.9	21	0.967	166	248
4:54 AM	19	3	21	0.973	178	264

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
4:58 AM	21	2.9	18	0.985	156	218
5:02 AM	22	2.7	17	0.992	151	204
5:06 AM	23	2.6	16	0.998	157	210
5:30 AM	18	2.2	13	1	305	379
5:34 AM	17	2.2	12	1	269	331
5:38 AM	16	2.4	12	0.999	248	306
5:42 AM	15	2.5	14	0.999	237	307
5:46 AM	14	2.4	15	1	190	249
5:50 AM	15	2.4	15	1	192	252
5:54 AM	12	2.3	17	1	186	255
5:58 AM	10	2.3	19	1	189	272
6:22 AM	3	2.2	13	1	255	323
6:26 AM	6	2.1	10	1	266	317
6:30 AM	7	2.1	10	1	307	364
6:34 AM	9	2.1	9	1	368	428
6:38 AM	9	2	11	1	385	463
6:42 AM	9	2	12	1	391	479
6:46 AM	10	1.9	10	1	458	543
6:50 AM	12	1.8	9	0.998	488	570
7:14 AM	29	2.3	1	1	511	515
7:18 AM	33	2.5	0	1	503	503
7:22 AM	36	2.6	1	1	474	483
7:26 AM	38	2.5	2	1	431	444
7:30 AM	43	2.6	3	1	402	421
7:34 AM	44	2.6	6	1	379	416
7:38 AM	44	2.5	8	1	355	403
7:42 AM	46	2.5	8	1	365	417
8:06 AM	2	2.5	5	1	389	423
8:10 AM	0	2.5	3	1	441	462
8:14 AM	8	2.6	0	1	453	453
8:18 AM	11	2.5	1	1	386	389
8:22 AM	24	2.5	2	1	360	373
8:26 AM	38	2.7	3	1	342	358
8:30 AM	53	2.8	3	1	330	348
8:34 AM	53	2.6	6	1	280	310

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
8:58 AM	53	2.7	17	1	310	426
9:02 AM	51	2.6	16	1	295	396
9:06 AM	55	2.9	18	1	277	386
9:10 AM	51	2.9	19	1	259	371
9:14 AM	49	2.9	19	1	255	365
9:18 AM	44	2.8	17	1	253	346
9:22 AM	48	2.9	17	1	288	393
9:26 AM	45	2.6	15	1	282	367
9:50 AM	31	1.8	23	1	250	390
9:54 AM	28	1.8	23	1	289	453
9:58 AM	27	1.8	19	0.948	290	416
10:02 AM	29	2	22	0.986	294	453
10:06 AM	31	2.3	21	0.91	289	428
10:10 AM	39	2.7	17	0.98	318	434
10:14 AM	48	3	19	0.994	252	362
10:18 AM	41	3.1	24	0.994	185	295
10:42 AM	37	3.1	28	0.981	192	344
10:46 AM	37	3.1	28	0.945	254	457
10:50 AM	32	2.8	29	0.946	254	460
10:54 AM	31	2.7	27	0.911	306	524
10:58 AM	30	2.6	27	0.976	247	423
11:02 AM	30	2.5	25	0.969	223	366
11:06 AM	31	2.4	24	0.976	187	302
11:10 AM	31	2.5	26	0.96	228	388
11:34 AM	23	2.1	29	0.993	227	420
11:38 AM	22	2.1	31	1	224	437
11:42 AM	21	2	29	1	193	354
11:46 AM	20	1.9	32	1	175	353
11:50 AM	20	1.9	33	1	191	401
11:54 AM	21	2	36	1	194	452
11:58 AM	22	2.1	39	0.909	215	557

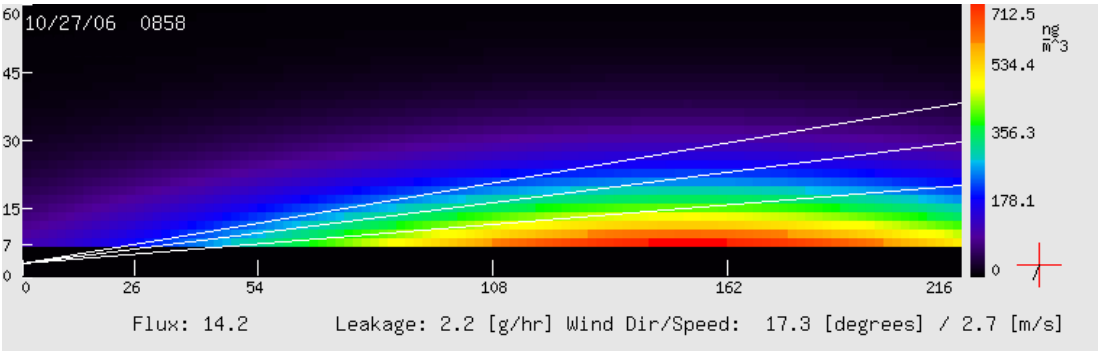

Figure 3-24. Example plume map for October 27, 2006.

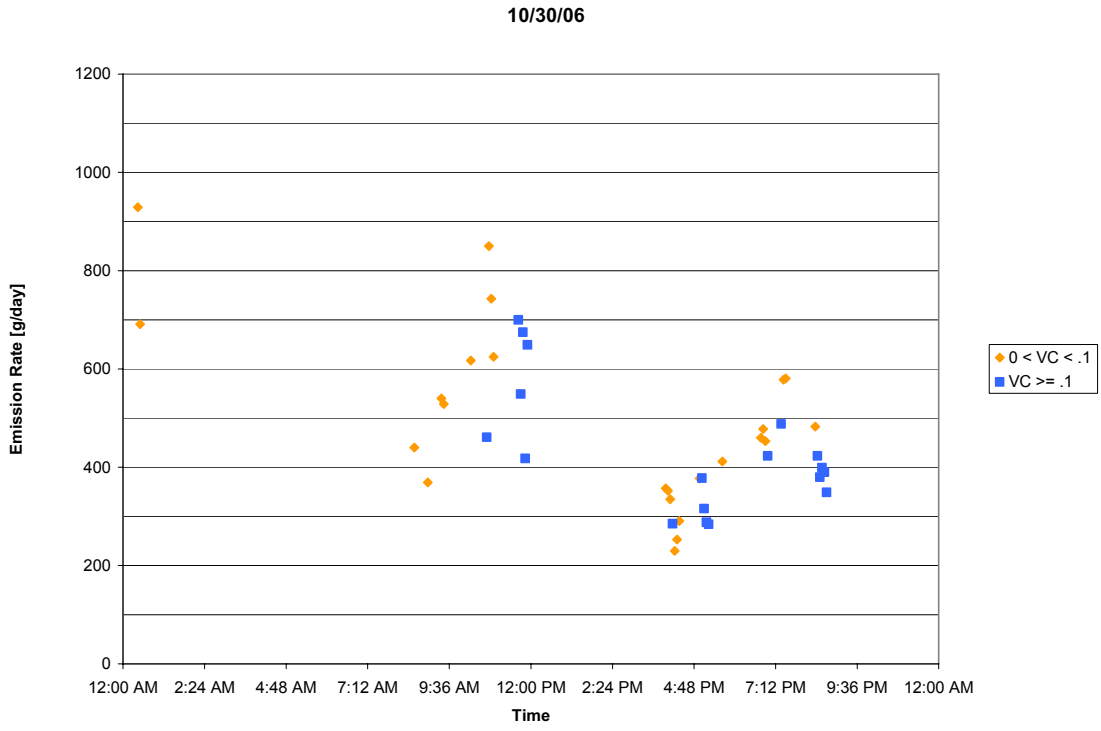

Figure 3-25. Time series of emission rate for October 30, 2006.

Table 3-17. Summary of Results for October 30, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
8:34 AM	0	1.9	28	1	244	440
8:58 AM	0	1.7	21	1	250	369
9:22 AM	0	2.2	32	0.905	273	540
9:26 AM	0	2.2	34	0.967	243	529
10:14 AM	0	2.4	56	0.97	77	617
10:42 AM	0	2.2	55	0.982	62	461
10:46 AM	0	2.2	59	0.964	65	850
10:50 AM	0	2	57	0.949	73	743
10:54 AM	0	1.9	57	0.964	64	625
11:38 AM	0	2.2	55	0.998	94	700
11:42 AM	0	2.1	50	1	121	549
11:46 AM	0	2.2	54	0.997	98	675
11:50 AM	0	2.2	55	0.985	57	418
11:54 AM	0	1.8	59	0.985	51	649
12:26 AM	0	1.9	56	0.951	108	929
12:30 AM	0	1.9	56	0.971	79	691
3:58 PM	0	1.8	48	0.958	88	357
4:02 PM	0	1.9	43	0.968	115	352
4:06 PM	0	1.8	45	0.97	101	335
4:10 PM	0	1.8	44	0.982	87	285
4:14 PM	0	1.8	46	0.975	63	230
4:18 PM	0	1.8	49	0.951	57	253
4:22 PM	0	1.9	51	0.951	59	291
4:58 PM	0	1.3	34	0.969	177	377
5:02 PM	0	1.4	26	0.998	225	378
5:06 PM	0	1.3	19	1	220	316
5:10 PM	0	1.4	16	1	216	288
5:14 PM	0	1.4	15	1	218	284
5:38 PM	0	1.3	7	0.994	370	412
6:46 PM	0	1.2	-3	1	441	460
6:50 PM	0	1.2	-5	1	450	478
6:54 PM	0	1.3	-2	1	438	453
6:58 PM	0	1.3	2	1	411	423
7:22 PM	0	1.5	3	1	465	488

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
7:26 PM	0	1.5	6	1	524	578
7:30 PM	0	1.5	4	1	546	581
8:22 PM	0	1.3	0	1	476	483
8:26 PM	0	1.4	-1	1	415	423
8:30 PM	0	1.5	0	1	380	380
8:34 PM	0	1.7	-1	1	391	399
8:38 PM	0	1.8	0	1	384	390
8:42 PM	0	1.7	-2	1	338	349

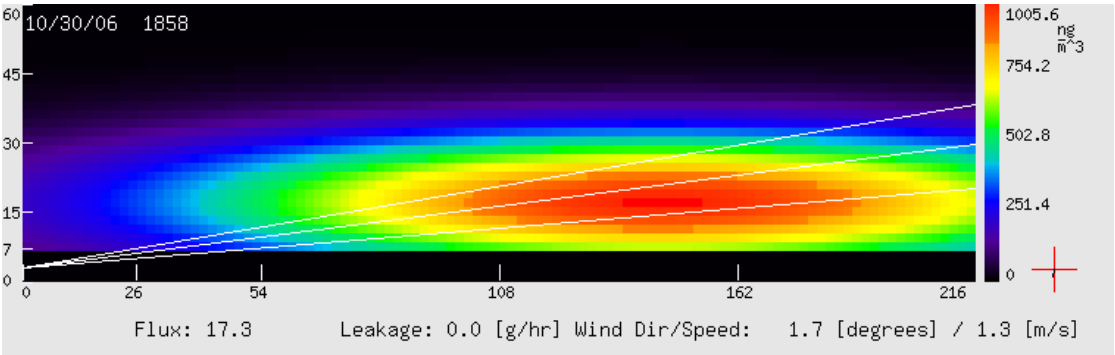

Figure 3-26. Example plume map for October 30, 2006.

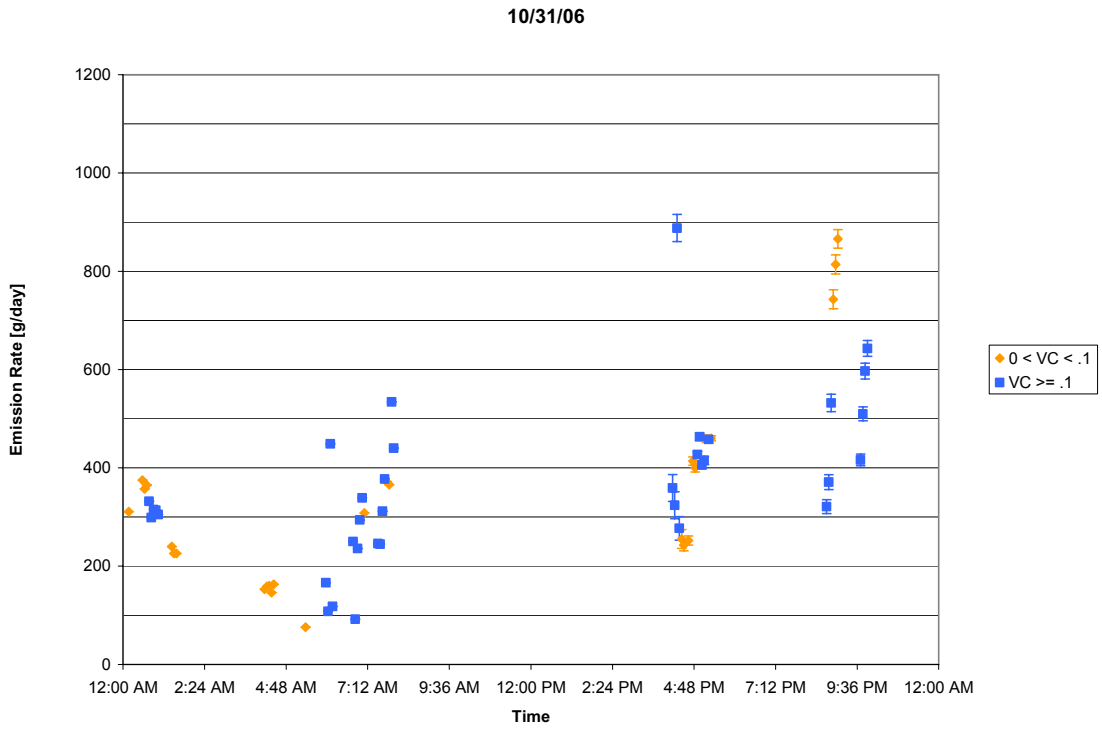

Figure 3-27. Time series of emission rate for October 31, 2006.

Table 3-18. Summary of Results for October 31, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
12:10 AM	0	1.2	-11	1	271	311
12:34 AM	0	1.3	-10	1	332	375
12:38 AM	0	1.3	-9	1	319	357
12:42 AM	0	1.5	-7	1	336	365
12:46 AM	0	1.6	-3	1	319	332
12:50 AM	0	1.7	1	1	295	299
12:54 AM	0	1.8	6	1	284	315
12:58 AM	0	1.8	12	0.994	255	314

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
1:02 AM	0	1.8	17	0.991	224	305
1:26 AM	0	1.2	19	0.953	168	240
1:30 AM	0	1.1	14	0.951	176	226
1:34 AM	0	1.1	13	0.997	180	226
4:10 AM	0	1.2	16	0.939	115	153
4:14 AM	0	1.2	13	0.941	125	159
4:18 AM	0	1.2	11	0.957	133	160
4:22 AM	0	1.2	11	0.957	122	146
4:26 AM	0	1.2	8	0.944	142	163
5:22 AM	0	1.3	7	0.98	68	76
5:58 AM	0	1.3	-1	0.965	162	166
6:02 AM	0	1.3	1	0.986	106	108
6:06 AM	0	1.2	6	0.989	410	449
6:10 AM	0	1.2	10	0.984	100	118
6:46 AM	0	1.2	7	0.991	222	250
6:50 AM	0	1.4	3	0.992	88	92
6:54 AM	0	1.4	0	0.992	235	236
6:58 AM	0	1.4	0	0.99	292	294
7:02 AM	0	1.3	0	0.982	335	339
7:06 AM	0	1.2	1	0.974	303	308
7:30 AM	0	1.7	13	1	195	246
7:34 AM	0	1.6	14	0.996	192	245
7:38 AM	0	1.6	15	0.985	237	312
7:42 AM	0	1.6	15	0.979	290	377
7:46 AM	0	1.4	16	0.965	276	371
7:50 AM	0	1.3	23	0.948	236	366
7:54 AM	0	1.3	33	0.993	254	534
7:58 AM	0	1.1	46	0.989	124	440
4:10 PM	27	2.3	15	1	277	359
4:14 PM	27	2.3	15	1	246	324
4:22 PM	24	2.3	21	0.995	185	277
4:26 PM	19	2.4	23	0.969	163	255
4:30 PM	12	2.2	29	0.974	133	243
4:38 PM	9	2.3	27	0.965	144	252
4:46 PM	8	1.7	28	0.952	230	414

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
4:50 PM	8	1.7	26	0.97	235	400
4:54 PM	7	1.4	24	0.995	268	427
4:58 PM	7	1.4	25	0.994	279	463
5:02 PM	8	1.5	26	1	238	406
5:06 PM	8	1.6	26	1	243	415
5:10 PM	8	1.5	27	1	263	459
5:14 PM	7	1.4	38	1	188	458
5:18 PM	5	1.1	48	0.947	115	460
8:42 PM	14	1.1	1	1	318	321
8:46 PM	15	1.1	8	1	322	371
8:50 PM	18	1.2	16	1	395	532
8:54 PM	19	1.4	18	1	530	743
8:58 PM	19	1.4	20	1	563	814
9:02 PM	19	1.4	20	1	601	866
9:42 PM	12	1.2	7	1	373	416
9:46 PM	14	1.3	9	1	435	510
9:50 PM	16	1.3	14	1	465	597
9:54 PM	16	1.3	17	1	472	643

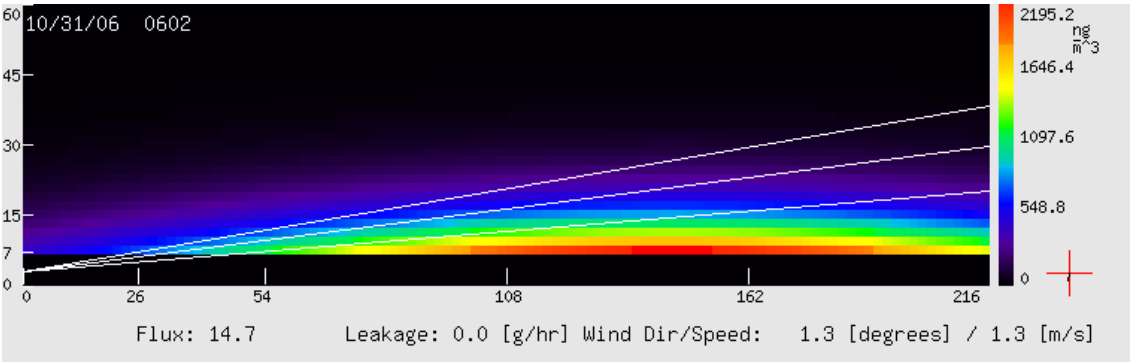

Figure 3-28. Example plume map for October 31, 2006.

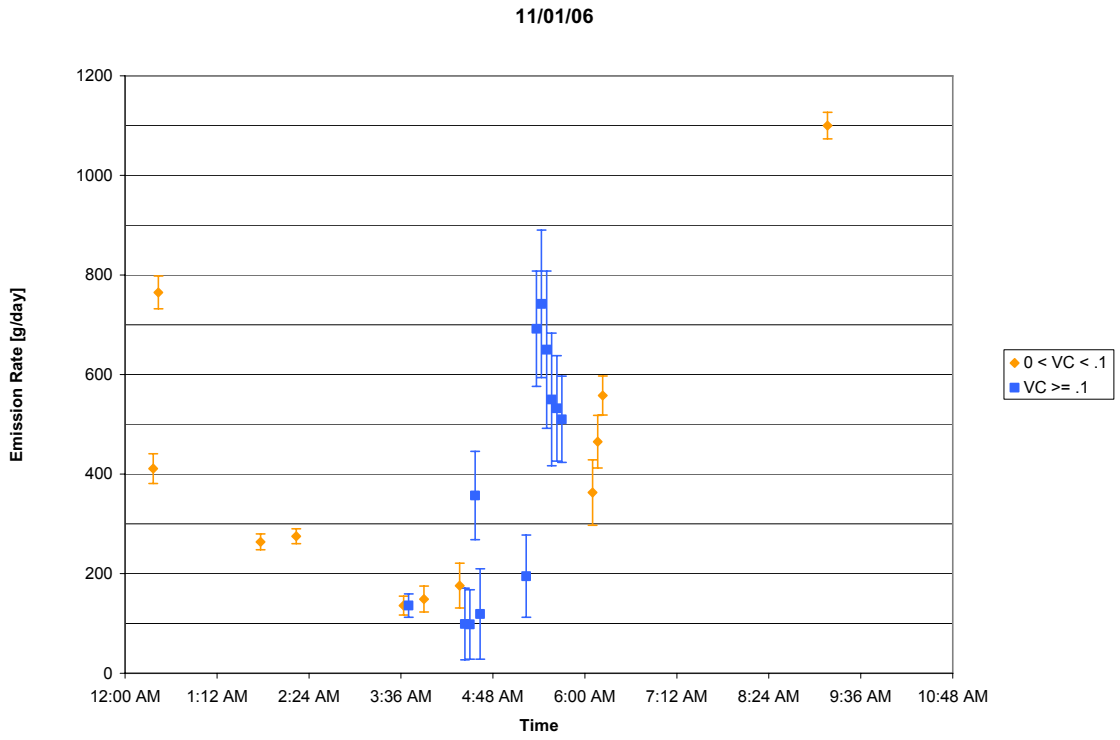

Figure 3-29. Time series of emission rate for November 1, 2006.

Table 3-19. Summary of Results for November 1, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
12:22 AM	30	1.3	-10	0.911	362	411
12:26 AM	33	1.4	-7	1	700	765
1:46 AM	16	1.1	-15	0.925	221	264
2:14 AM	15	1.3	-15	0.932	229	275
3:38 AM	19	1.5	-15	0.961	113	136
3:42 AM	24	1.5	-15	0.95	114	136
3:54 AM	26	1.6	-15	0.963	124	149
4:22 AM	45	1.1	-29	0.98	121	176
4:26 AM	72	1.3	-24	0.99	73	99
4:30 AM	70	1.2	-23	0.995	74	98
4:34 AM	89	1.3	-17	0.985	289	357
4:38 AM	91	1.3	-15	0.975	99	119
5:14 AM	83	1.6	-15	0.956	162	195
5:22 AM	120	1.7	-15	0.944	575	692
5:26 AM	150	1.7	-15	0.932	614	742
5:30 AM	160	1.6	-17	0.942	526	650
5:34 AM	130	1.5	-17	0.97	445	550
5:38 AM	110	1.4	-16	0.974	438	532
5:42 AM	87	1.4	-16	0.975	417	510
6:06 AM	66	1.4	-19	0.965	286	363
6:10 AM	53	1.5	-18	0.919	371	465
6:14 AM	39	1.5	-17	0.915	452	558
9:10 AM	27	1.6	12	1	886	1100

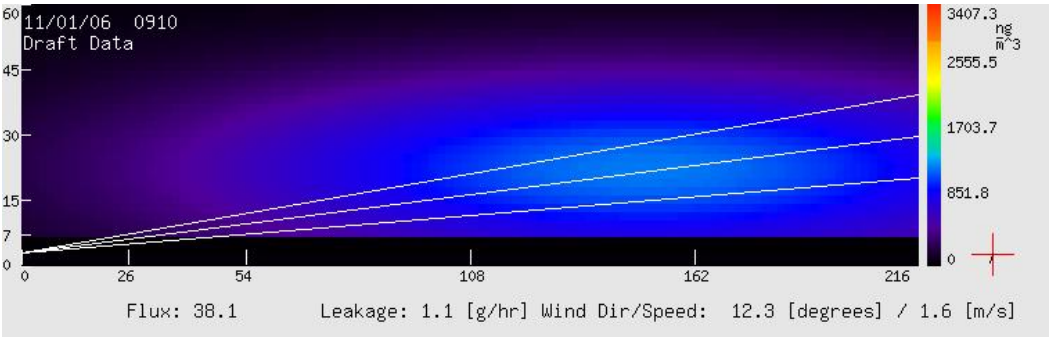

Figure 3-30. Example plume map for November 1, 2006.

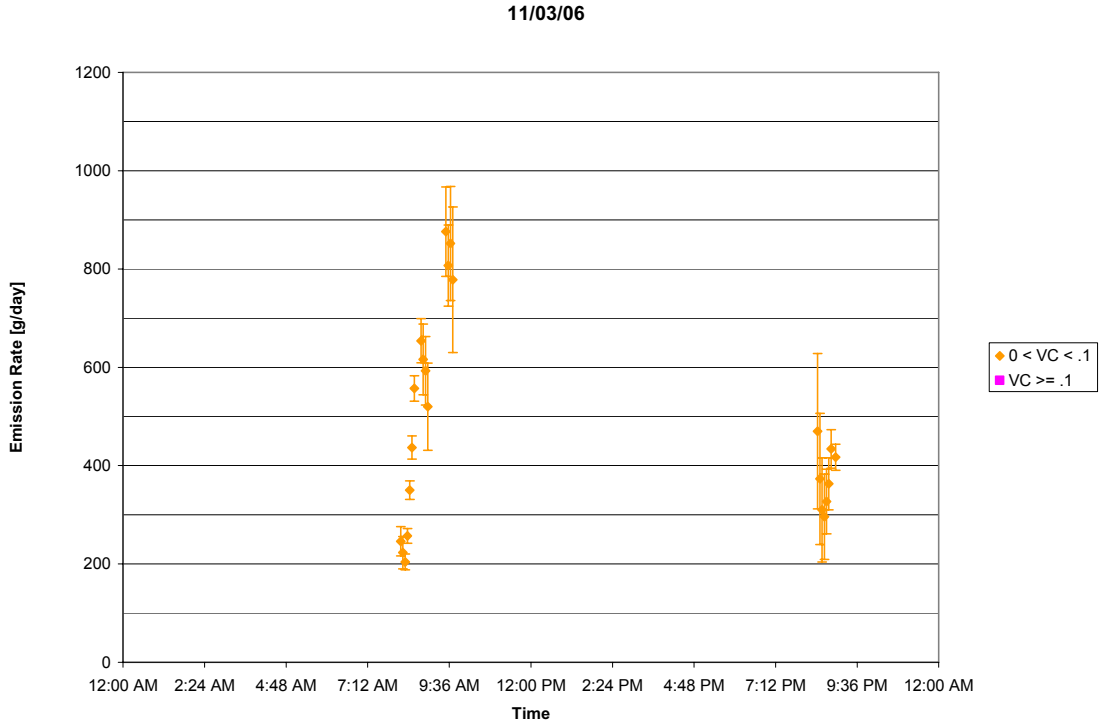

Figure 3-31. Time series of emission rate for November 3, 2006.

Table 3-20. Summary of Results for November 3, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
8:10 AM	20	1.4	-58	1	94	246
8:14 AM	16	1.3	-49	1	105	223
8:18 AM	12	1.3	-54	1	86	204
8:22 AM	8	1.5	-53	1	110	257
8:26 AM	4	1.8	-46	0.995	178	350
8:30 AM	2	2	-36	0.986	265	437
8:34 AM	6	2.2	-37	0.888	334	557
8:46 AM	23	2	-43	0.909	354	654
8:50 AM	31	2	-46	1	311	616
8:54 AM	33	2.1	-44	1	312	593
8:58 AM	35	2.1	-53	1	225	520
9:30 AM	48	2.5	-53	1	378	876
9:34 AM	50	2.4	-48	1	393	807
9:38 AM	47	2.4	-50	1	392	852
9:42 AM	47	2.4	-54	1	327	778
8:26 PM	27	1.8	-30	0.97	319	470
8:30 PM	24	1.8	-29	0.997	254	373
8:34 PM	22	1.7	-29	0.989	214	310
8:38 PM	20	1.6	-30	0.983	199	296
8:42 PM	19	1.6	-30	0.964	220	327
8:46 PM	18	1.6	-30	0.941	244	363
8:50 PM	21	1.6	-31	0.969	289	434
8:58 PM	18	1.5	-32	0.983	274	417

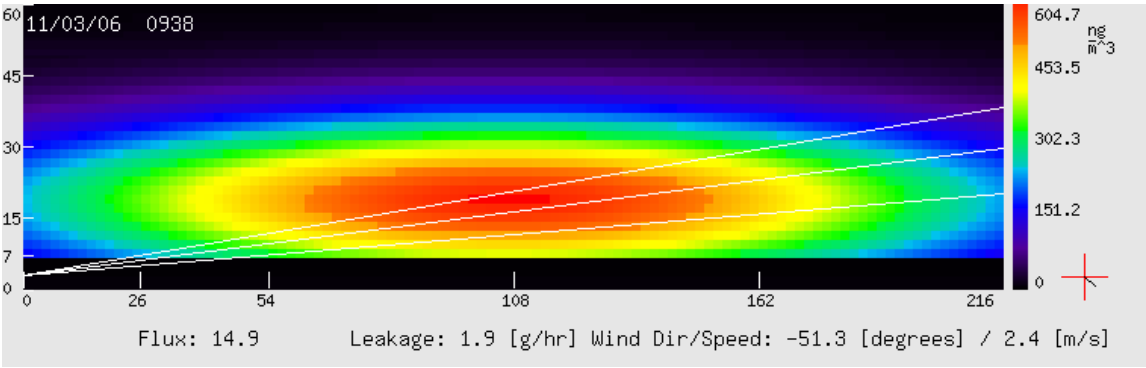

Figure 3-32. Example plume map for November 3, 2006.

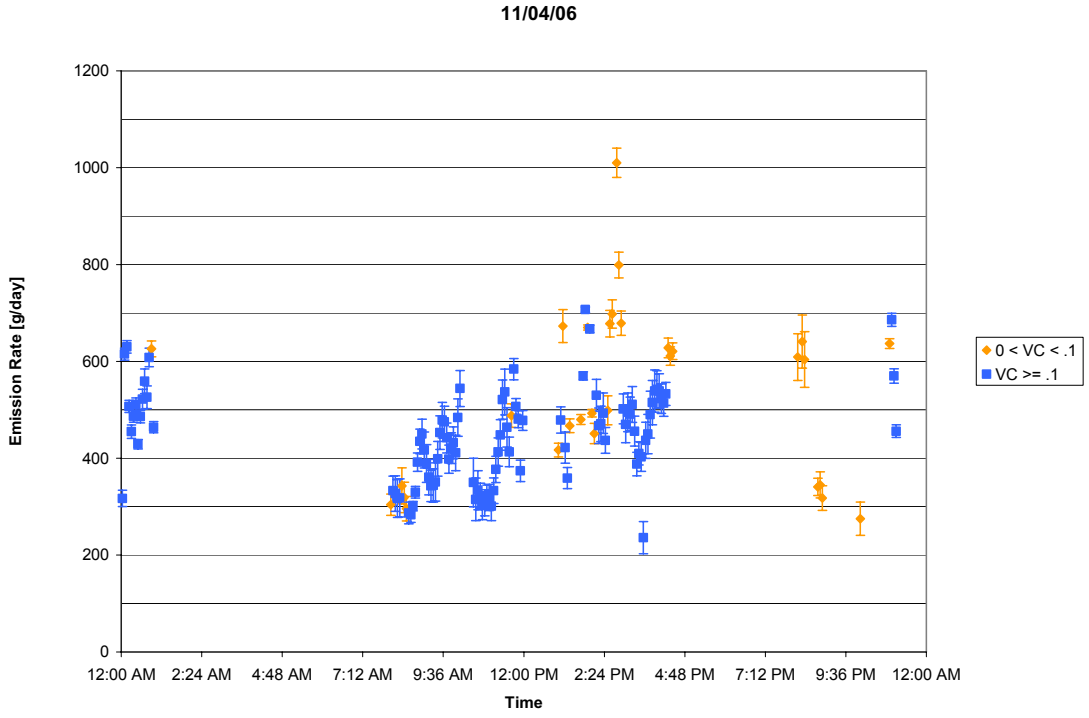

Figure 3-33. Time series of emission rate for November 4, 2006.

Table 3-21. Summary of Results for November 4, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
8:02 AM	22	2.3	1	1	300	304
8:06 AM	30	2.6	1	1	328	333
8:10 AM	37	2.7	0	1	324	327
8:14 AM	39	2.6	-2	1	308	317
8:18 AM	39	2.5	-6	1	296	318
8:22 AM	37	2.4	-6	1	317	343
8:26 AM	31	2.1	-5	1	299	319
8:30 AM	25	2	-5	1	277	296
8:34 AM	23	2.1	-5	1	269	287
8:38 AM	16	2.1	-3	1	271	283
8:42 AM	10	2.3	4	1	281	301
8:46 AM	12	2.4	6	0.998	298	330
8:50 AM	19	2.6	11	0.995	326	392
8:54 AM	25	2.6	16	1	325	435
8:58 AM	31	2.6	22	1	293	450
9:02 AM	37	2.6	19	0.997	296	417
9:06 AM	39	2.6	16	1	291	389
9:10 AM	37	2.6	13	1	286	361
9:14 AM	32	2.6	11	1	285	343
9:18 AM	35	2.5	11	1	286	344
9:22 AM	40	2.4	13	1	281	351
9:26 AM	36	2.5	20	1	276	399
9:30 AM	35	2.6	25	0.997	272	453
9:34 AM	37	2.7	28	0.999	268	479
9:38 AM	33	2.7	30	1	248	475
9:42 AM	31	2.8	28	1	248	442
9:46 AM	29	2.7	24	1	250	398
9:50 AM	32	2.7	25	1	254	421
9:54 AM	33	2.6	25	0.998	265	432
9:58 AM	37	2.4	23	0.974	264	411
10:02 AM	39	2.4	29	0.986	267	484
10:06 AM	37	2.4	32	0.984	267	544
10:30 AM	50	2.4	10	0.971	294	350
10:34 AM	44	2.3	11	0.983	263	315

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
10:38 AM	40	2.3	19	0.985	234	334
10:42 AM	26	2.1	15	0.996	247	322
10:46 AM	29	2	13	1	242	302
10:50 AM	27	1.9	11	1	258	308
10:54 AM	24	1.8	9	1	277	321
10:58 AM	27	1.8	1	1	314	319
11:02 AM	30	1.8	6	1	274	301
11:06 AM	26	1.9	12	1	272	333
11:10 AM	27	2.1	21	1	254	377
11:14 AM	29	2.3	25	0.986	254	413
11:18 AM	31	2.4	27	0.973	255	448
11:22 AM	40	2.6	24	0.988	326	521
11:26 AM	47	2.6	25	0.989	326	537
11:30 AM	41	2.3	28	1	257	464
11:34 AM	31	1.9	39	0.997	163	413
11:38 AM	24	1.9	44	0.968	155	488
11:42 AM	22	1.9	51	0.995	121	584
11:46 AM	16	1.5	45	0.984	149	507
11:50 AM	18	1.5	35	1	218	481
11:54 AM	22	1.8	29	1	204	374
11:58 AM	21	1.7	36	0.999	206	478
12:02 PM	17	1.6	37	1	135	317
12:06 PM	12	1.7	51	0.99	124	615
12:10 PM	13	1.9	50	0.987	137	630
12:14 PM	12	1.6	45	0.999	147	507
12:18 PM	14	1.6	35	0.997	206	455
12:22 PM	12	1.6	36	0.999	209	487
12:26 PM	14	1.7	42	1	173	511
12:30 PM	10	1.3	41	1	151	429
12:34 PM	13	1.3	38	1	194	486
12:38 PM	20	1.3	33	1	253	522
12:42 PM	25	1.5	28	1	313	559
12:46 PM	24	1.4	28	1	292	526
12:50 PM	19	1.4	41	1	217	608
12:54 PM	16	1.5	35	0.997	282	626

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
12:58 PM	12	1.4	27	1	270	464
1:02 PM	14	1.2	23	0.982	269	417
1:06 PM	27	1.6	2	0.998	468	479
1:10 PM	34	1.7	-8	1	608	673
1:14 PM	32	1.5	4	1	399	422
1:18 PM	22	1.2	20	1	249	359
1:22 PM	14	1.1	28	0.998	259	467
1:42 PM	10	1.4	40	0.91	181	480
1:46 PM	8	1.4	47	0.991	152	570
1:50 PM	6	1.3	55	0.986	100	707
1:54 PM	5	1.1	55	0.971	91	670
1:58 PM	8	1.2	50	1	140	667
2:02 PM	8	1.1	33	0.971	237	493
2:06 PM	21	1.5	14	0.981	354	451
2:10 PM	33	1.9	8	1	466	530
2:14 PM	37	1.7	12	1	377	467
2:18 PM	36	1.6	12	1	383	471
2:22 PM	42	1.8	11	1	405	493
2:26 PM	27	1.5	7	0.995	386	437
2:30 PM	30	1.6	0	0.965	499	499
2:34 PM	27	1.7	-2	0.912	658	678
2:38 PM	29	1.7	-2	0.937	676	698
2:46 PM	30	1.8	12	0.977	828	1010
2:50 PM	27	1.7	22	1	519	799
2:54 PM	25	1.7	21	0.995	459	679
2:58 PM	31	1.8	18	1	364	502
3:02 PM	38	1.9	16	1	356	470
3:06 PM	40	2	13	0.998	392	495
3:10 PM	36	2	10	1	412	491
3:14 PM	37	2	11	0.997	426	511
3:18 PM	31	1.9	14	0.999	354	456
3:22 PM	24	1.9	12	0.998	317	388
3:26 PM	24	1.8	10	1	344	410
3:30 PM	30	1.8	8	0.996	353	403
3:34 PM	33	1.9	7	1	211	236

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
3:38 PM	37	1.9	7	0.998	386	437
3:42 PM	41	1.7	10	0.999	378	450
3:46 PM	48	1.9	11	0.993	404	490
3:50 PM	46	2	10	0.994	433	515
3:54 PM	44	2	12	0.989	439	539
3:58 PM	39	2	10	0.993	454	542
4:02 PM	35	2	10	1	457	539
4:06 PM	30	1.9	10	1	444	523
4:10 PM	27	1.7	10	1	437	514
4:14 PM	24	1.5	9	1	462	533
4:18 PM	20	1.4	9	1	538	628
4:22 PM	19	1.3	9	1	522	611
4:26 PM	17	1.2	9	1	532	621
8:10 PM	48	1.2	-17	0.937	495	609
8:18 PM	55	1.5	-19	0.962	507	641
8:22 PM	57	1.5	-19	0.959	476	604
8:46 PM	18	1.4	-18	0.937	273	341
8:50 PM	27	1.5	-19	0.948	274	345
8:54 PM	25	1.4	-17	0.93	257	318
10:02 PM	34	1.3	-14	0.946	233	275
10:54 PM	10	1.2	18	1	462	637
10:58 PM	13	1.3	18	1	493	686
11:02 PM	15	1.2	15	1	434	570
11:06 PM	13	1.1	13	1	363	456

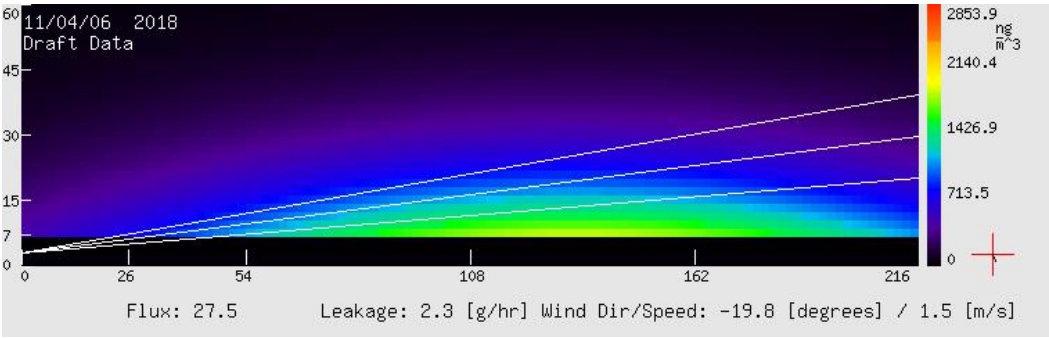

Figure 3-34. Example plume map for November 4, 2006.

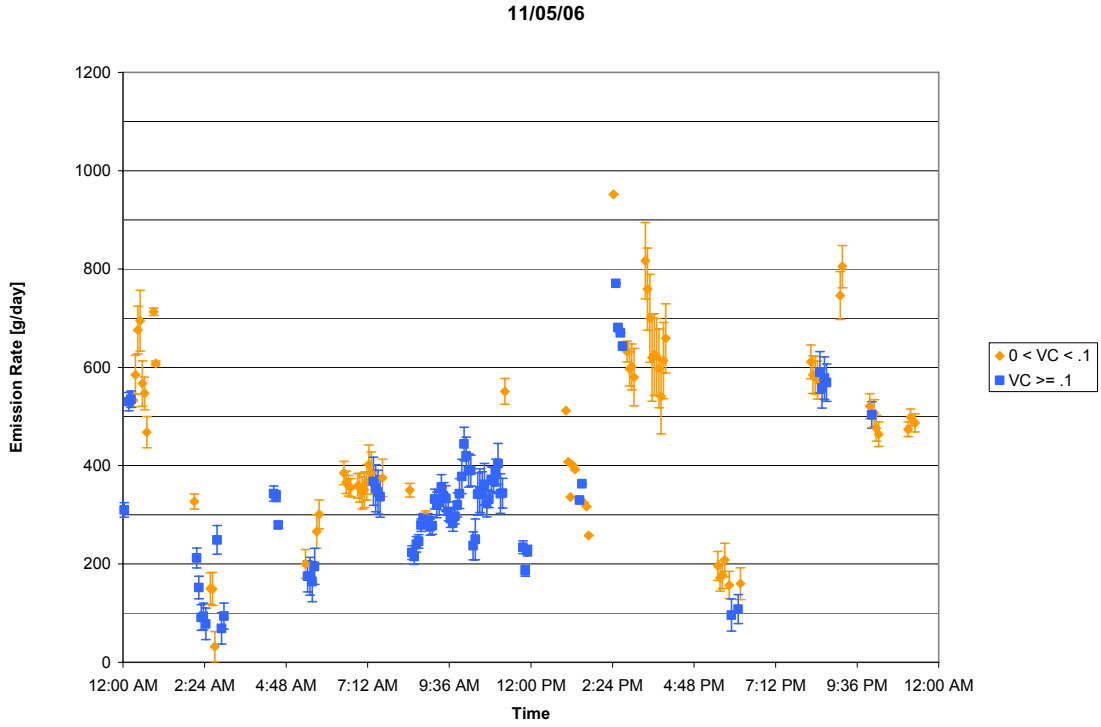

Figure 3-35. Time series of emission rate for November 5, 2006.

Table 3-22. Summary of Results for November 5, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
12:10 AM	18	1.2	9	1	452	530
12:14 AM	17	1.2	5	1	490	535
12:18 AM	13	1.2	1	1	522	533
2:06 AM	15	1.4	-18	0.993	262	327
2:10 AM	20	1.3	-18	1	170	212
2:14 AM	23	1.2	-17	0.997	123	152
2:18 AM	26	1.2	-17	0.987	74	91
2:22 AM	27	1.1	-16	0.981	76	93
2:26 AM	32	1.1	-17	0.989	64	78
2:34 AM	32	1.3	-17	0.974	122	150
2:38 AM	34	1.3	-17	0.967	120	149
2:42 AM	31	1.3	-18	0.983	25	32
2:46 AM	29	1.2	-20	0.974	195	249
2:54 AM	32	1.2	-17	0.982	56	69
2:58 AM	26	1.1	-15	0.992	78	94
4:26 AM	16	1.5	-18	1	275	343
4:30 AM	11	1.4	-17	1	273	338
4:34 AM	6	1.2	-17	1	228	279
5:22 AM	30	1.3	-23	0.957	151	200
5:26 AM	32	1.3	-20	0.994	137	175
5:30 AM	38	1.5	-17	0.998	142	175
5:34 AM	41	1.5	-16	0.993	134	164
5:38 AM	36	1.4	-15	0.992	161	195
5:42 AM	34	1.5	-15	1	222	266
5:46 AM	30	1.5	-14	1	252	301
6:30 AM	24	2	1	1	380	385
6:34 AM	23	1.9	0	1	365	366
6:38 AM	21	1.8	-2	1	348	359
6:42 AM	18	1.7	-7	1	327	355
6:54 AM	25	1.7	-18	1	287	359
6:58 AM	29	1.8	-18	1	286	355
7:02 AM	33	1.8	-17	1	281	345
7:06 AM	36	1.8	-16	1	289	351
7:10 AM	36	1.9	-15	1	304	366
7:14 AM	40	2.1	-13	1	341	402
7:18 AM	43	2.2	-13	1	328	385

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
7:22 AM	49	2.4	-12	1	319	368
7:26 AM	48	2.4	-9	1	317	354
7:30 AM	44	2.4	-5	1	325	346
7:34 AM	42	2.3	-5	1	316	337
7:38 AM	38	2.3	-2	1	364	375
8:26 AM	14	1.9	10	1	298	350
8:30 AM	14	1.9	4	1	210	223
8:34 AM	16	2	1	1	212	215
8:38 AM	16	2.1	3	1	231	240
8:42 AM	14	2.3	1	1	241	246
8:46 AM	13	2.4	1	1	273	279
8:50 AM	12	2.2	5	1	268	291
8:54 AM	11	2.1	5	1	273	297
8:58 AM	13	2.1	5	1	267	289
9:02 AM	17	2.1	4	1	259	275
9:06 AM	18	2	5	1	256	278
9:10 AM	20	2.2	10	1	281	332
9:14 AM	26	2.2	14	1	248	320
9:18 AM	25	2.2	15	1	251	325
9:22 AM	25	2.3	20	1	244	356
9:26 AM	28	2.3	24	1	212	338
9:30 AM	26	2.3	26	1	199	333
9:34 AM	19	2.3	24	1	189	307
9:38 AM	18	2.3	26	1	171	292
9:42 AM	17	2.2	21	1	191	283
9:46 AM	15	2	19	1	210	297
9:50 AM	24	2.2	13	0.993	253	320
9:54 AM	30	2.3	12	0.98	280	343
9:58 AM	35	2.3	16	0.984	281	378
10:02 AM	34	2.3	27	0.967	256	444
10:06 AM	38	2.4	27	0.973	244	420
10:10 AM	34	2.3	29	0.98	215	390
10:14 AM	31	2.2	29	0.996	210	390
10:18 AM	28	2	19	0.994	167	237
10:22 AM	42	2.3	6	1	226	250
10:26 AM	43	2.4	7	1	303	342
10:30 AM	45	2.6	2	1	338	349

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
10:34 AM	44	2.7	0	1	342	344
10:38 AM	42	2.7	2	0.999	350	362
10:42 AM	27	2.4	10	0.988	275	323
10:46 AM	18	2.3	9	0.986	284	332
10:50 AM	25	2.3	13	0.98	298	372
10:54 AM	27	2.1	9	0.967	316	370
10:58 AM	27	2.1	12	0.976	316	386
11:02 AM	41	2.3	7	0.993	362	404
11:06 AM	40	2.2	4	0.997	320	343
11:10 AM	30	2	9	1	297	344
11:14 AM	26	1.9	20	0.916	380	551
11:46 AM	13	1.4	2	1	225	234
11:50 AM	11	1.3	-3	1	179	186
11:54 AM	11	1.3	-8	1	205	227
12:02 AM	15	1.2	-39	1	180	310
12:22 AM	40	1.7	-12	0.904	508	585
12:26 AM	48	1.9	-17	0.992	550	676
12:30 AM	62	1.9	-15	0.982	577	695
12:34 AM	46	1.6	-10	0.988	503	567
12:38 AM	33	1.3	-10	1	485	547
12:42 AM	32	1.4	0	1	464	468
12:54 AM	7	1.4	-16	0.999	582	713
12:58 AM	5	1.7	-15	0.963	508	608
1:02 PM	0	1.7	-14	0.965	431	512
1:06 PM	0	1.6	-8	0.966	371	408
1:10 PM	0	1.6	-4	0.978	319	336
1:14 PM	0	1.8	-3	0.973	385	400
1:18 PM	0	1.8	0	0.942	390	392
1:26 PM	0	1.5	-8	0.998	300	330
1:30 PM	0	1.5	-11	1	316	363
1:34 PM	0	1.3	-18	0.948	259	324
1:38 PM	0	1.3	-31	0.973	210	317
1:42 PM	0	1.2	-44	0.958	136	258
2:26 PM	0	2	-10	0.892	837	952
2:30 PM	0	2.2	-6	1	718	771
2:34 PM	0	2.4	-8	1	613	681
2:38 PM	0	2.4	-10	1	595	670

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
2:42 PM	0	2.5	-18	0.991	518	643
2:46 PM	9	2.4	-28	0.977	445	643
2:50 PM	21	2.5	-36	0.962	389	632
2:54 PM	35	2.4	-41	0.961	333	597
2:58 PM	47	2.4	-46	0.97	303	601
3:02 PM	59	2.4	-57	0.968	226	580
3:22 PM	78	2.9	-51	0.931	370	817
3:26 PM	84	2.9	-44	0.961	396	759
3:30 PM	90	2.9	-44	0.945	368	700
3:34 PM	89	2.7	-45	0.935	321	620
3:38 PM	83	2.4	-47	0.94	313	626
3:42 PM	78	2.4	-47	0.954	308	622
3:46 PM	80	2.5	-46	0.942	302	598
3:50 PM	75	2.6	-44	0.951	282	540
3:54 PM	78	2.7	-42	0.959	334	614
3:58 PM	70	2.6	-41	0.947	365	659
5:30 PM	30	1.2	-20	0.947	152	196
5:34 PM	27	1.1	-14	0.94	145	172
5:38 PM	28	1.2	-12	0.958	155	178
5:42 PM	34	1.3	-14	0.956	177	208
5:50 PM	28	1.2	-16	0.941	129	157
5:54 PM	33	1.3	-16	0.984	79	96
6:06 PM	30	1.1	-7	0.982	99	108
6:10 PM	32	1.2	-7	0.949	147	160
8:14 PM	34	2.2	0	1	611	611
8:18 PM	38	2.2	0	1	580	585
8:22 PM	38	2.2	-1	1	575	584
8:26 PM	39	2.2	-1	1	565	574
8:30 PM	42	2.3	0	1	583	590
8:34 PM	41	2.3	0	1	557	558
8:38 PM	43	2.4	0	1	578	578
8:42 PM	38	2.4	0	1	569	569
9:06 PM	49	2.5	-2	1	722	746
9:10 PM	43	2.4	-1	1	790	805
9:58 PM	25	1.9	1	1	511	521
10:02 PM	27	1.9	2	1	491	503
10:06 PM	27	1.9	1	1	500	507

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
10:10 PM	26	1.8	1	1	471	476
10:14 PM	25	1.7	0	1	460	464
11:06 PM	15	1.3	-9	1	424	474
11:10 PM	17	1.4	-8	1	449	498
11:18 PM	18	1.4	-4	1	462	487

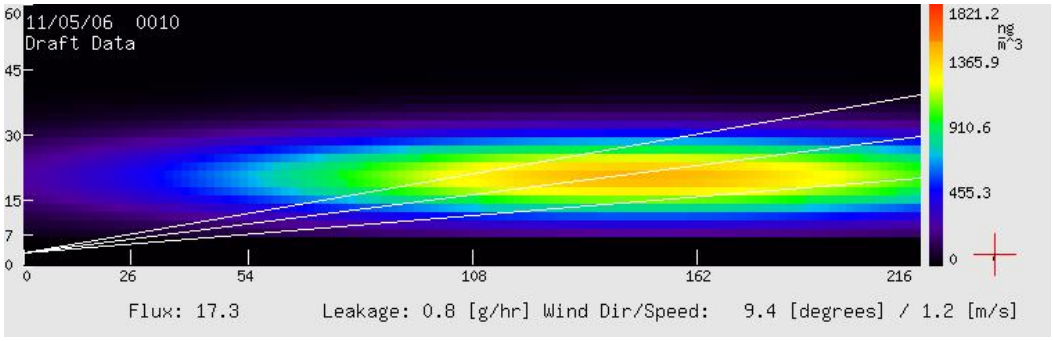

Figure 3-36. Example plume map for November 5, 2006.

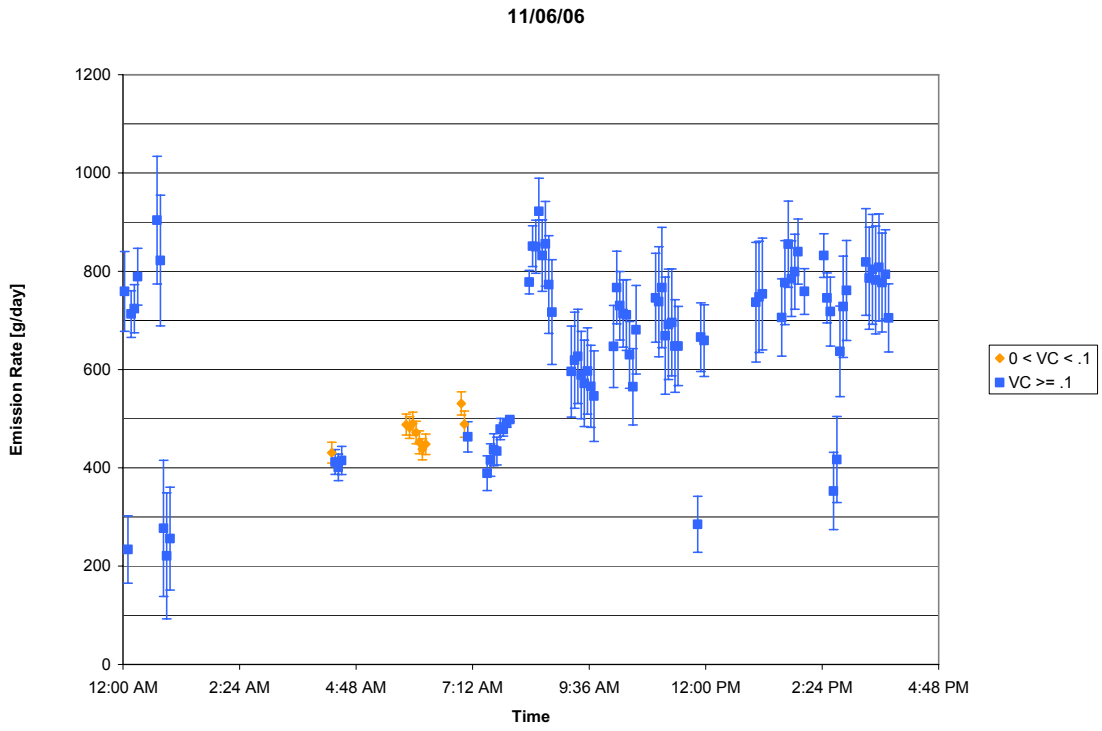

Figure 3-37. Time series of emission rate for November 6, 2006.

Table 3-23. Summary of Results for November 6, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
4:18 AM	21	1.8	-4	1	409	431
4:22 AM	25	1.9	-3	1	395	412
4:26 AM	27	1.9	-3	1	386	401
4:30 AM	29	2	-2	1	403	415
5:50 AM	21	2	0	1	485	488
5:54 AM	22	2	0	1	479	482
5:58 AM	24	2.1	0	1	487	490
6:02 AM	23	2.1	0	1	469	472
6:06 AM	23	2	0	1	450	452
6:10 AM	22	1.9	1	1	434	438
6:14 AM	21	1.9	1	1	443	448
6:58 AM	24	2.2	0	1	531	531
7:02 AM	27	2.2	0	1	484	489
7:06 AM	31	2.3	0	1	463	463
7:30 AM	35	2	4	1	366	389
7:34 AM	33	2	5	1	384	416
7:38 AM	33	2.1	4	1	410	437
7:42 AM	28	2.1	6	1	396	434
7:46 AM	22	2.3	7	1	426	479
7:50 AM	13	2.3	6	1	432	478
7:54 AM	9	2.4	6	1	448	491
7:58 AM	3	2.4	6	0.995	452	498
8:22 AM	24	2.3	8	0.99	675	778
8:26 AM	42	2.3	8	0.996	751	851
8:30 AM	54	2.2	6	0.997	764	850
8:34 AM	67	2.3	6	1	833	922
8:38 AM	73	2.3	2	1	803	832
8:42 AM	86	2.6	-1	1	836	856
8:46 AM	99	2.7	0	0.999	766	773
8:50 AM	110	2.7	0	0.977	715	717
9:14 AM	93	2.9	1	0.959	589	596
9:18 AM	98	3	3	0.974	595	619
9:22 AM	96	3.1	4	0.97	587	627

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
9:26 AM	89	3	6	0.976	536	589
9:30 AM	88	2.9	6	0.989	522	572
9:34 AM	88	2.9	6	0.991	543	597
9:38 AM	84	2.9	4	0.979	534	566
9:42 AM	92	2.9	3	0.974	518	546
10:06 AM	84	2.7	9	0.96	561	647
10:10 AM	74	3	8	0.969	671	767
10:14 AM	70	2.9	10	0.974	613	730
10:18 AM	68	3	10	0.974	607	714
10:22 AM	72	3	10	0.99	599	711
10:26 AM	68	2.9	11	0.986	523	630
10:30 AM	78	2.6	12	0.98	459	565
10:34 AM	90	2.8	11	0.967	564	681
10:58 AM	90	2.7	11	0.985	622	746
11:02 AM	110	2.9	10	0.98	628	738
11:06 AM	120	3.1	11	0.983	636	767
11:10 AM	120	3.1	12	0.981	544	669
11:14 AM	110	3.3	12	0.972	562	692
11:18 AM	110	3.5	13	0.979	553	696
11:22 AM	94	3.6	13	0.967	513	648
11:26 AM	80	3.9	15	0.943	498	648
11:50 AM	57	3	14	0.978	221	285
11:54 AM	70	3.2	14	0.96	525	666
11:58 AM	73	3.3	13	0.947	529	659
12:02 AM	81	3.6	12	0.939	614	759
12:06 AM	69	3.5	12	0.978	189	234
12:10 AM	48	3.1	13	0.981	572	713
12:14 AM	49	3	13	0.992	572	724
12:18 AM	58	2.9	14	0.994	616	789
12:42 AM	130	3.5	6	0.977	813	904
12:46 AM	130	3.5	6	0.986	744	822
12:50 AM	140	3.6	6	0.988	251	277
12:54 AM	130	3.5	9	0.98	189	221
12:58 AM	100	3.5	10	0.979	217	256
1:02 PM	120	3.5	9	0.965	634	737

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
1:06 PM	110	3.4	11	0.971	617	748
1:10 PM	110	3.4	11	0.959	624	754
1:34 PM	79	2.9	15	0.958	540	706
1:38 PM	85	3.3	18	0.956	560	777
1:42 PM	88	3.7	20	0.965	588	855
1:46 PM	77	3.8	21	0.951	527	785
1:50 PM	76	4	24	0.937	501	799
1:54 PM	66	4.3	25	0.963	510	840
2:02 PM	47	4	24	0.951	474	759
2:26 PM	44	3.7	22	0.958	548	832
2:30 PM	51	3.4	16	0.959	556	746
2:34 PM	70	3.1	14	0.967	558	718
2:38 PM	79	3	13	0.977	281	353
2:42 PM	88	2.7	10	0.975	352	417
2:46 PM	92	2.6	12	0.983	519	637
2:50 PM	100	2.7	12	0.985	593	728
2:54 PM	100	2.7	12	0.984	621	761
3:18 PM	110	2.8	9	0.984	710	819
3:22 PM	100	2.6	6	0.983	710	786
3:26 PM	110	2.6	4	0.977	752	804
3:30 PM	110	2.5	4	0.976	735	782
3:34 PM	110	2.5	5	0.973	747	808
3:38 PM	100	2.3	5	0.975	712	777
3:42 PM	91	2.2	6	0.994	722	794
3:46 PM	69	1.9	7	1	623	705

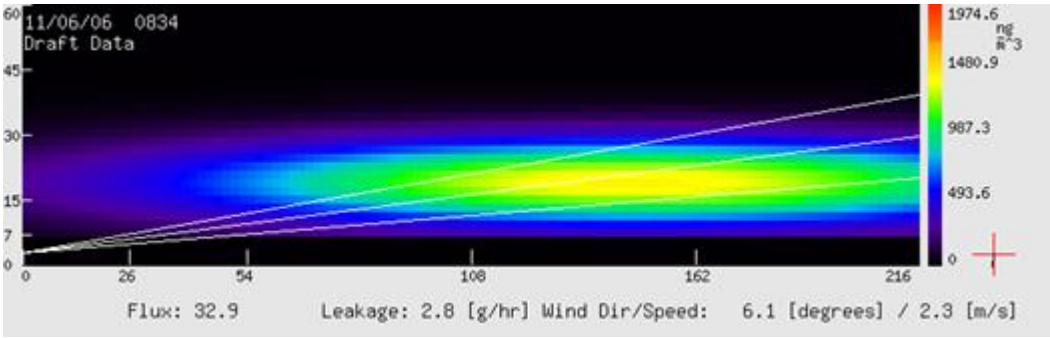

Figure 3-38. Example plume map for November 6, 2006.

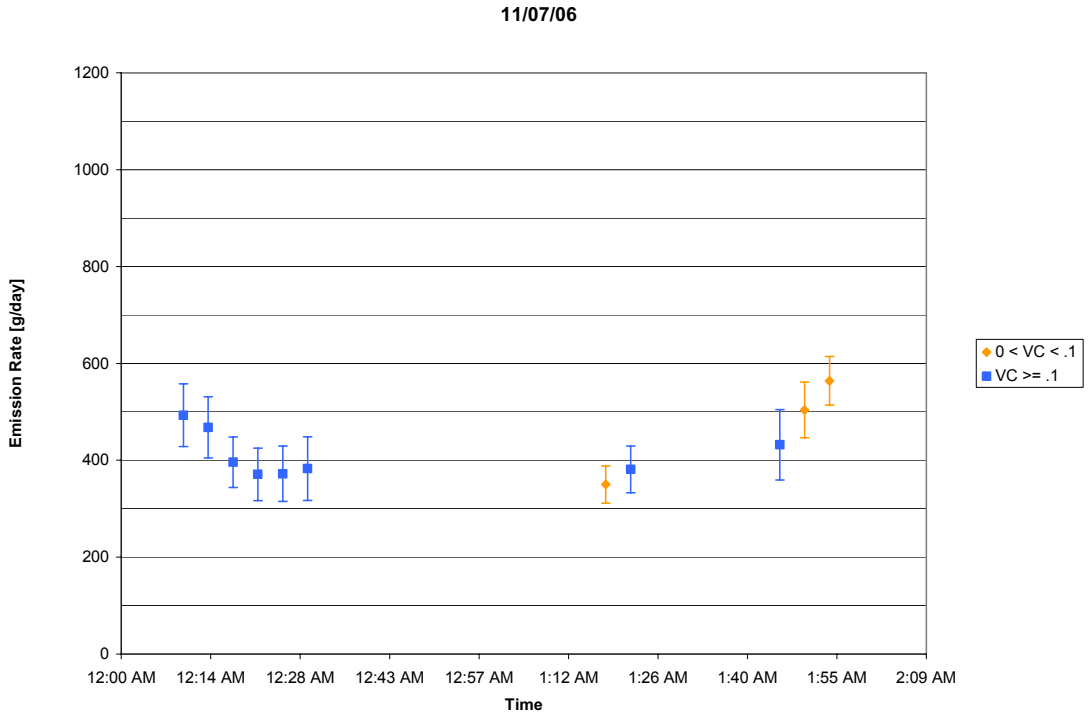

Figure 3-39. Time series of emission rate for November 7, 2006.

Table 3-24. Summary of Results for November 7, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
12:10 AM	65	3.5	-4	1	468	493
12:14 AM	63	3.5	-2	1	453	468
12:18 AM	52	3.1	-1	1	389	396
12:22 AM	54	3.2	2	1	360	371
12:26 AM	57	3.2	1	1	368	372
12:30 AM	66	3.1	0	1	381	383
1:18 AM	39	2.5	-1	0.94	342	350
1:22 AM	48	2.8	0	0.998	377	381
1:46 AM	73	3.6	1	0.996	429	432
1:50 AM	57	3	2	0.979	486	504
1:54 AM	50	2.7	3	0.886	538	564

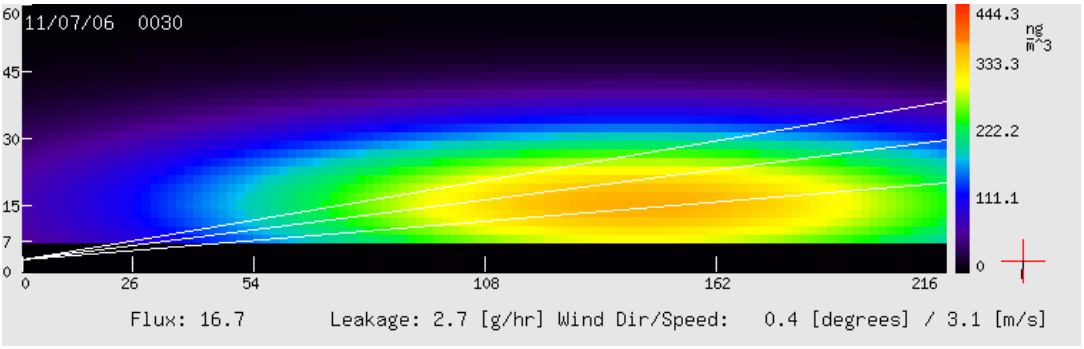

Figure 3-40. Example plume map for November 7, 2006.

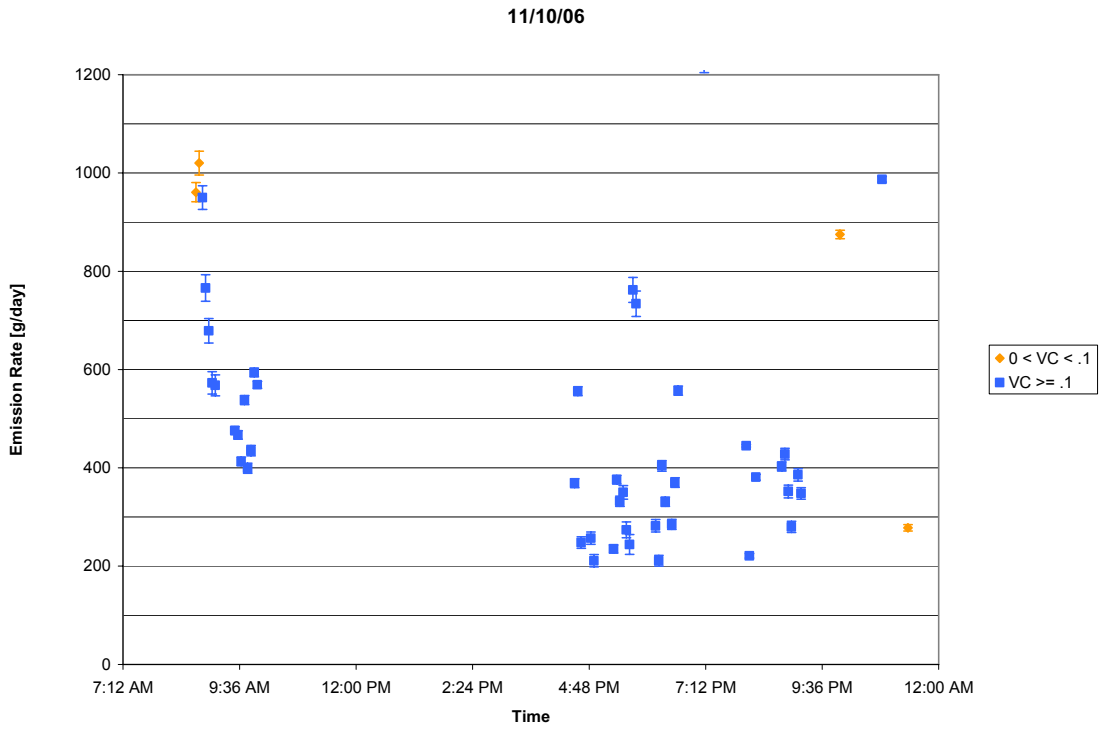

Figure 3-41. Time series of emission rate for November 10, 2006.

Table 3-25. Summary of Results for November 10, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
8:42 AM	20	1.4	18	1	692	961
8:46 AM	24	1.7	21	1	684	1020
8:50 AM	24	1.9	24	1	593	950
8:54 AM	27	1.8	24	0.999	481	766
8:58 AM	25	1.8	24	0.991	424	679
9:02 AM	23	1.7	23	0.994	367	573
9:06 AM	21	1.8	24	0.996	355	568
9:30 AM	8	1.2	49	1	112	476
9:34 AM	9	1.3	39	0.998	184	467
9:38 AM	9	1.3	32	1	204	413
9:42 AM	9	1.3	39	1	211	538
9:46 AM	10	1.3	35	1	182	399
9:50 AM	11	1.2	45	0.999	125	435
9:54 AM	9	1.2	56	1	73	594
9:58 AM	7	1.2	56	0.999	69	569
4:30 PM	9	1.5	48	0.992	90	369
4:34 PM	9	1.6	47	0.995	150	556
4:38 PM	12	1.6	47	0.992	65	248
4:50 PM	12	1.6	49	0.987	59	257
4:54 PM	12	1.5	49	0.984	49	211
5:18 PM	8	1.7	45	0.994	69	235
5:22 PM	9	1.7	44	0.994	114	376
5:26 PM	11	1.7	39	0.999	129	332
5:30 PM	14	1.8	33	0.998	167	350
5:34 PM	16	1.9	30	1	145	274
5:38 PM	20	2.1	27	0.993	140	244
5:42 PM	25	2.3	28	0.985	430	762
5:46 PM	26	2.3	28	0.99	413	734
6:10 PM	13	2.2	37	0.999	117	282
6:14 PM	11	2.1	38	0.998	85	211
6:18 PM	11	1.9	41	0.998	147	404
6:22 PM	10	1.9	39	0.998	126	331
6:30 PM	10	1.8	44	0.997	87	285

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
6:34 PM	10	1.8	45	0.994	110	370
6:38 PM	9	1.9	48	0.995	141	557
7:10 PM	6	1.3	58	0.982	100	1210
8:02 PM	3	1.1	56	0.993	54	445
8:06 PM	5	1.2	53	0.997	36	221
8:14 PM	6	1.2	49	0.989	90	381
8:46 PM	9	1.8	45	0.992	119	403
8:50 PM	12	1.8	46	0.998	118	428
8:54 PM	13	1.8	47	0.998	92	352
8:58 PM	11	1.7	48	0.998	70	280
9:06 PM	13	1.8	51	0.996	75	386
9:10 PM	12	1.9	53	0.989	61	348
9:58 PM	8	1.9	59	0.913	70	875
10:50 PM	6	2	60	0.954	63	987
11:22 PM	6	1.5	59	0.983	20	278

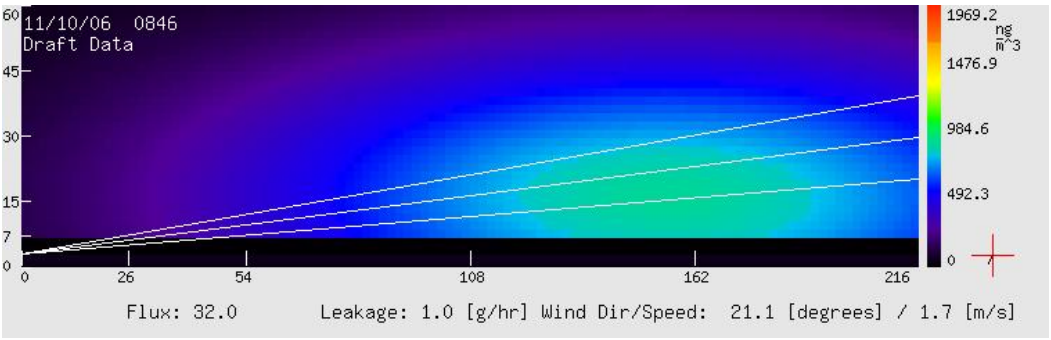

Figure 3-42. Example plume map for November 10, 2006.

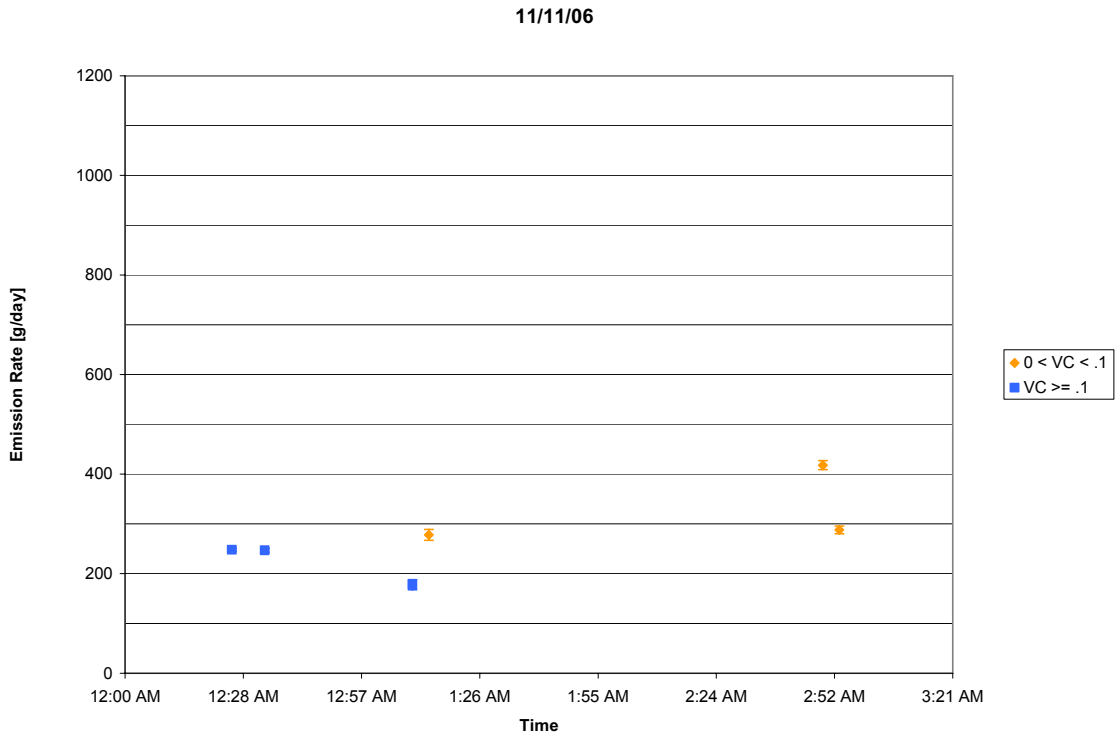

Figure 3-43. Time series of emission rate for November 11, 2006.

Table 3-26. Summary of Results for November 11, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
12:26 AM	3	1.6	59	0.944	20	248
12:34 AM	4	1.6	58	0.93	22	247
1:10 AM	10	2	54	0.94	28	178
1:14 AM	11	2	55	0.938	38	278
2:50 AM	9	1.5	42	0.938	144	418
2:54 AM	8	1.2	35	0.946	130	288

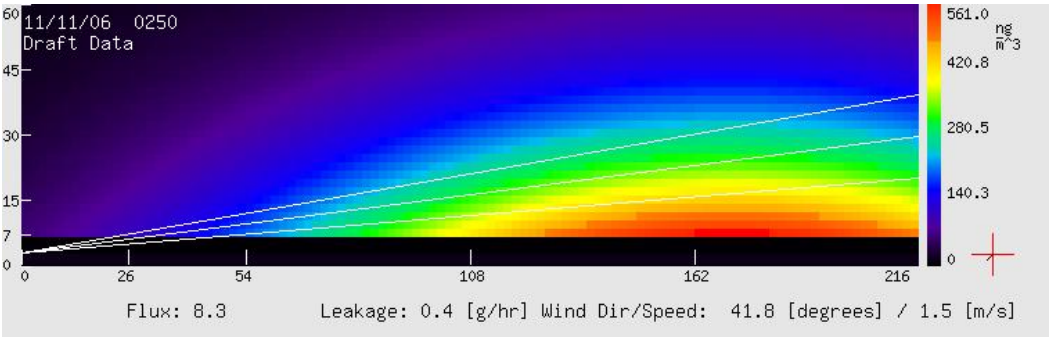

Figure 3-44. Example plume map for November 11, 2006.

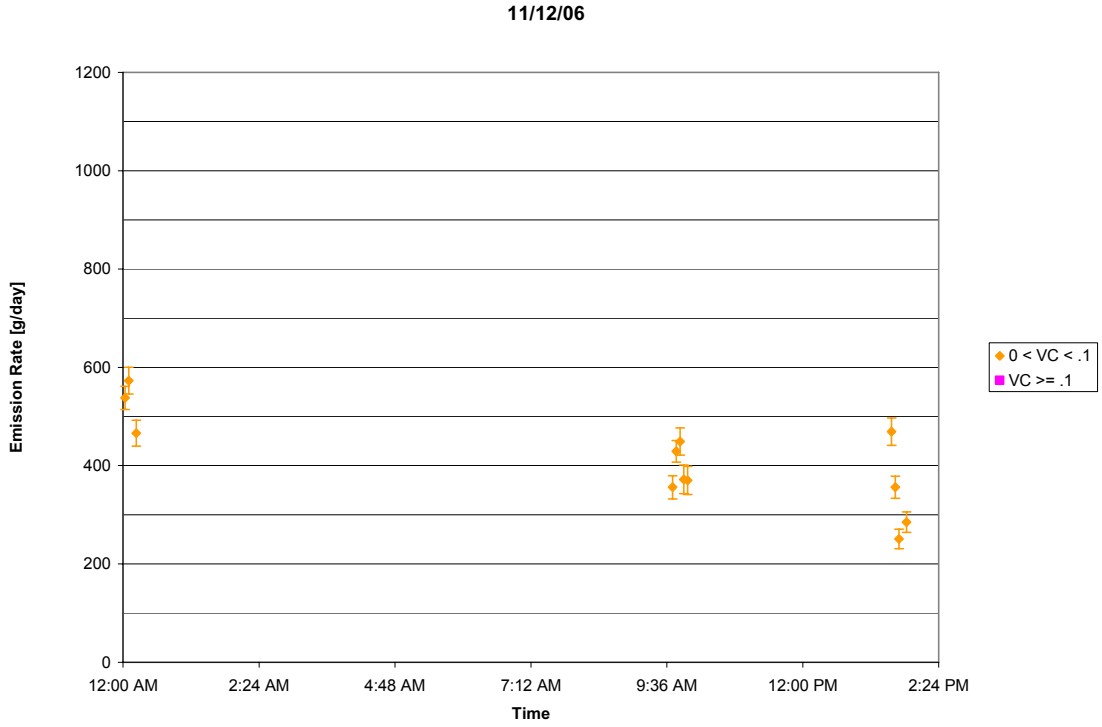

Figure 3-45. Time series of emission rate for November 12, 2006.

Table 3-27. Summary of Results for November 12, 2006

Time	Lumex Flux Value [g/day]	Wind Speed [m/s]	Wind Direction [deg from normal to VRPM config.]	Concordance Correlation Factor	Unadjusted Flux Values [g/day]	Adjusted Emission Rate [g/day]
9:42 AM	24	2.4	-55	0.99	145	356
9:46 AM	22	2.5	-50	0.976	200	429
9:50 AM	28	2.7	-41	0.986	250	449
9:54 AM	29	2.6	-48	1	182	372
9:58 AM	29	2.5	-50	1	171	370
12:02 AM	24	1.5	-19	0.998	423	538
12:06 AM	27	1.6	-12	1	496	573
12:14 AM	26	1.8	0	1	465	466
1:34 PM	28	1.8	-55	0.959	191	469
1:38 PM	23	1.6	-59	0.91	131	356
1:42 PM	20	1.4	-58	0.943	95	251
1:50 PM	21	1.7	-53	0.925	124	285

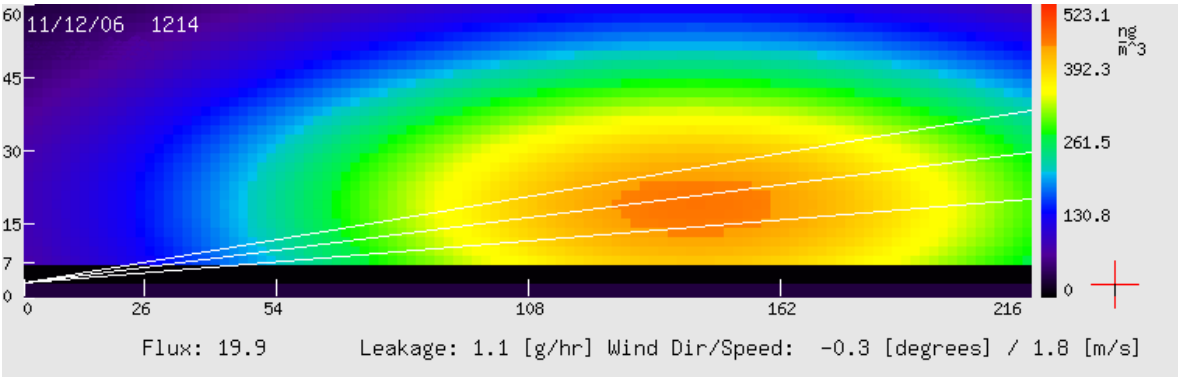

Figure 3-46. Example plume map for November 12, 2006.

3.3 Summary

ARCADIS and EPA ORD conducted one continuous, seven-week (53 day) monitoring study for total site mercury emissions at Occidental Chemical's Muscle Shoals, Alabama plant. The measurement campaign was conducted using a Vertical Radial Plume Mapping (VRPM) measurement configuration, using three bistatic, open-path, Ultra-Violet Differential Optical Absorption Spectroscopy (UV-DOAS) instruments, operated on a 24-hour, 7-day per week basis. Site constraints necessitated the use of an elevated VRPM configuration setup. Additionally, a Lumex Mercury Analyzer was deployed along the ground, downwind from the cell room. The purpose of this instrument was to provide an assessment of any emissions leakage, or emissions not captured by the VRPM calculation due to the complex air flow caused by the numerous obstructions in the vicinity of the lowest five meters of the VRPM configuration.

Mercury flux values were calculated for 23 days of the measurement campaign during instances when the prevailing wind direction was ± 60° from perpendicular to the VRPM configuration and the vertical plume capture criterion was met. Additionally, the mercury emission rate for each period was calculated by applying an adjustment factor to the calculated flux value, considering the plume capture in the horizontal direction. Mercury Flux and emission rate values were also calculated for periods when the vertical plume capture criterion was not met.

A total of 1170 mercury emission flux estimates were produced for 20 minute time periods. The 24 hour extrapolated mercury emission rate values ranged from 18 to 1210 grams per day, with an average of 410 grams per day. The extrapolated emission rate is summarized in figure 3-47. Overall measurement uncertainty is estimated to be within +/-20% which is sufficient to meet the order of magnitude data quality objective for this project.

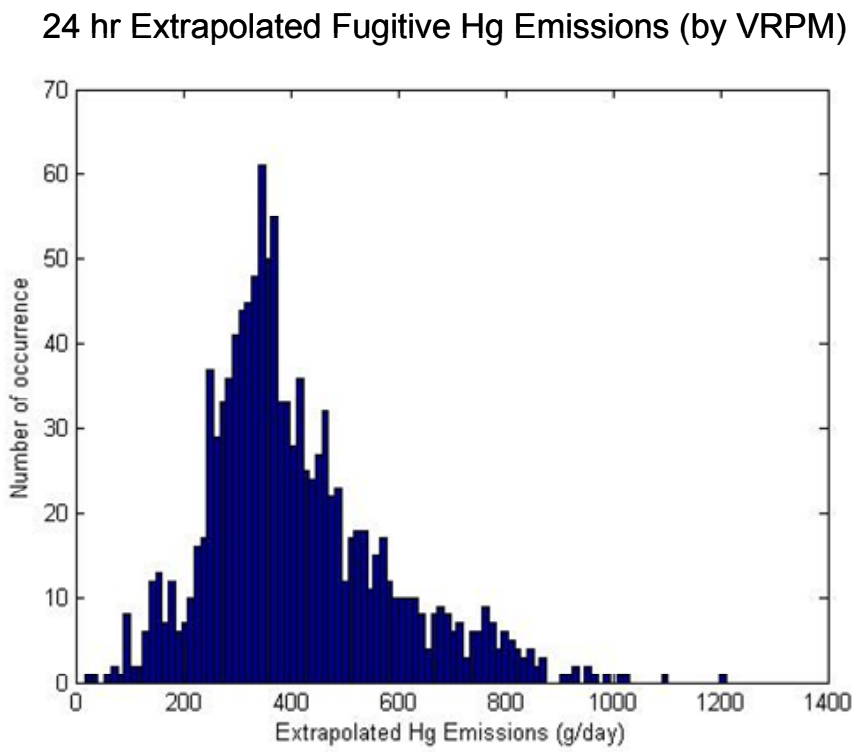

Figure 3-47. Summary of 24-hour extrapolated mercury emission values.

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4. QA/QC

The data collected during this project was intended to provide support for the development of environmental regulations and standards. It is of sufficient scope and substance that these results could be combined with those from other projects of similar scope and substance to provide necessary information for decisions. They are not intended for direct use in enforcement activities, litigation, or human studies. They are not sufficient to make the needed decisions without input from other projects. This project data was collected in conformance with the quality requirements of NRMRL QA Category II.

4.1 Instrument Calibration

All equipment is calibrated annually and/or cal-checked as part of standard operating procedures. Certificates of calibration are kept on file. Maintenance records are kept for any equipment adjustments or repairs in bound project logbooks that include the data and description of maintenance performed. Instrument calibration and QC procedures and frequency are listed in Table 4-1 and are further described in the text.

As part of the preparation for this project, a Category II Quality Assurance Project Plan (QAPP) was prepared and approved for the field campaign.

4.2 Assessment of DQI Goals

The critical measurements associated with this project and the established data quality indicator (DQI) goals in terms of accuracy, precision, and completeness are listed in Table 4-2. More information on the procedures used to assess DQI goals can be found in Section 10 of the *ECPD Optical Remote Sensing Facility Manual* (USEPA, 2004).

Table 4-1. Instrumentation Calibration Frequency and Description

Instrument	Measurement	Calibration Date	Calibration Detail
OPSIS UV-DOAS	Analyte PAC	Pre-deployment and in-field QC Checks	Appendix E and H of this document of project QAPP
Lumex Mercury Analyzer	Mercury concentration	Pre-deployment and in-field checks	Appendix F of project QAPP
Climatronics Model 101990-G1 Meteorological Head	Wind Speed in miles/hour	June 7, 2006	APPCD Metrology Lab Cal. Records on file
Climatronics Model 101990-G1 Meteorological Head	Wind direction in degrees from North	June 7, 2006	APPCD Metrology Lab Cal. Records on file
R.M. Young Meteorological Head	Wind Speed in miles/hour	June 7, 2006	APPCD Metrology Lab Cal. Records on file
R.M. Young Meteorological Head	Wind direction in degrees from North	July 14, 2006	APPCD Metrology Lab Cal. Records on file
Topcon Model GTS-211D Theodolite	Distance Measurement	April 19, 2006	Calibration of distance measurement. Actual distance=19.6 m Measured distance= 19.56 m
Topcon Model GTS-211D Theodolite	Angle Measurement	April 19, 2006	Calibration of angle measurement. Actual angle= 360º Measured angle= 360º28’47”

Table 4-2. DQI Goals for the Project

Measurement Parameter	Analysis Method	Accuracy	Precision	Detection Limit	Completeness
Mercury PAC	UV-DOAS, bistatic	±15%[1]	±15%[1]	~0.003 ppbv[2]	75%
Mercury concentrations	Lumex Mercury Analyzer	±25%[3]	±25%[3]	~0.0002 ppbv	90%
Ambient Wind Speed	Climatronics meteorological head post-field calibration by EPA Metrology Lab	±10% of actual wind speed	±10% of actual wind speed	Not applicable	90%
Ambient Wind Direction	Climatronics meteorological head with clip to North	±10º	±10º	Not applicable	90%
Distance Measurement	Theodolite- Topcon	±1m	±1m	Not applicable	100%
Beam angle	Theodolite- Topcon	±0.1º	±0.1º	Not applicable	100%

1. The QC check procedures for determining the accuracy and precision of the UV-DOAS instruments can be found in Appendix H of the project QAPP.
2. The procedures used for determining the minimum detection limit of the UV-DOAS instruments can be found in Section 5.3 of Appendix E of the project QAPP.
3. The QC check procedures for determining the accuracy and precision of the Lumex Mercury Analyzer can be found in Section 4.4.2, and Appendix F of the project QAPP.

4.2.1 DQI Check for UV-DOAS PAC Measurements

Three ultraviolet differential absorption spectroscopy measurement (UV DOAS) instruments, manufactured by OPSIS AB, Furulund, Sweden, were employed to capture elemental Hg^0 vapor concentrations in the VRPM plane. Before arriving at the site, EPA inspected and tested the instruments at the ORD laboratory in Research Triangle Park, North Carolina. The components included three UV DOAS opto-analyzers (model AR500), three emitter telescopes utilizing xenon arc lamps, three receiver telescopes, and an optical calibration bench. Each receiver telescope was connected to an AR500 opto-analyzer, located in the mobile lab, by a uv-transparent fiber optic cable.

An OPSIS calibration bench, located in the mobile lab, was used to calibrate the analyzers and to conduct periodic calibration checks. The optical bench consisted of a xenon arc lamp and paired emitter and receiver parabolic mirrors of similar optical

design as the telescopes. During calibration, the fiber optic cables were disconnected from the receiver telescopes and then reconnected to the receiver end of the optical bench. Using the same fiber optic cable ensured that measurement bias that may be caused by damaged fibers would be apparent during calibration checks.

Before challenging the analyzers with known concentrations of Hg^0 as described below, detector and signal processing functions were tested by conducting a System Check and Wave Precision Check, and by observing the spectral evaluation in Scan Signals to ensure the hardware was operating normally and that adequate signal was being transmitted to the analyzer from the receiver telescope. During calibration, closed UV-transparent cells containing liquid Hg^0 and vapor were placed in the optical bench light path to challenge the analyzers. The Hg^0 vapor concentrations were determined by measuring the cell temperature using a laboratory-grade digital thermometer and a headspace temperature-concentration curve provided by the manufacturer. Cells of differing lengths were used for multi-point span calibrations and periodic calibration checks. The linear range of calibration was approximately 0 to 14,000 ng/m^3 during the first month of measurements, and was reduced during the second month after it was concluded that 14,000 ng/m^3 was much higher than the recorded ambient concentrations. The linear calibration range was greater than the ambient concentrations measured during the project, and the accuracy and precision was within the acceptable range of ±15%.

The schedule of calibration checks is summarized in Tables 4-3, 4-4, and 4-5.

Table 4-3. Low Path (Analyzer Ser. No. E-202)

Date (2006)	Calibration Type	Range (ng/m^3)	Analyzer Response (%)	Notes
9-14	Reference, span, offset	0 – 13,528	1 to 2	Pre-measurement calibration.
9-21	Span, offset check	0 – 8,373	-9 to 7	
9-22	Reference, span, offset	0 – 11,094	-6 to 14	New calibration after replacing receiver fiber.
10-17	Span, offset check	0 – 7,434	-8 to 0	
11-13	Span, offset check	0 – 9419	-12 to 5	Post-measurement calibration check.

Table 4-4. Middle Path (Analyzer Ser. No. E-700)

Date (2006)	Calibration Type	Range (ng/m^3)	Analyzer Response (%)	Notes
9-15	Reference, span, offset	0 – 12,581	-1 to 8	Pre-measurement calibration.
9-19	Span offset check	0 – 12,446	-8 to 10	
9-23	Reference, span, offset	0 – 5,291	-15 to 5	Recalibration following hardware adjustments.
10-17	Span, offset check	0 – 8,411	-9 to 13	
11-13	Span, offset check	0 – 6,665	-9 to -11	Post-measurement calibration check.

Table 4-5. High Path (Analyzer Ser. No. E-466)

Date (2006)	Calibration Type	Range (ng/m^3)	Analyzer Response (%)	Notes
9-07	Span, offset	0 – 8772	3 to 8	Pre-measurement calibration.
9-21	Span, offset check	0 – 14,053	-7 to 10	
10-18	Span, offset check	0 – 6,268	-6 to 0	
11-14	Span, offset check	0 – 7,092	-3 to -5	Post-measurement calibration check.

The primary DQI is the standard deviation of the Hg^0 concentration measurement. A concentration measurement is valid when the ratio of the concentration to deviation (C:D) is greater than or equal to 10:1. The lowest C:D observed during calibration was 15:1 and the majority of the measurement points were in excess of 50:1, therefore the calibration data indicated that the analyzers performed normally during the project.

A secondary DQI is the signal strength, represented by the analyzer software as percent light, with 100% light being the saturation point of the detector. The minimum light level for valid measurements is determined by observing the point at which the measurement standard deviation increases sharply as a function of declining signal strength. Light levels below the minimum, or 10% to 15% light, occurred during periods of fog and heavy rain. However, there was adequate signal during all times when the wind direction and wind speed were within the VRPM acceptance parameters. Data capture during such periods was 100%.

The estimated minimum detection limit of the OPSIS analyzers is 49.6 ng/m³.

4.2.1.1 Problems Encountered

There were no problems encountered that affected the data.

4.2.2 DQI Checks for Lumex Measurements

A quality control check was performed on the Lumex Mercury Analyzer at the EPA facility prior to deployment to the field. The check was done using a Tekran 3310 instrument to generate a known concentration of mercury. The effluent from the Tekran 3310 was attached to the sample port of the Lumex Mercury Analyzer. A Thermo 80i monitor was used to measure the mercury concentration from the Tekran

3310 effluent line. The Lumex Mercury Analyzer collected ten consecutive mercury concentration measurements. The results were then compared to the mercury concentration measured with the Thermo 80i monitor (10.43 µg/m³). The average mercury concentration measured by the Lumex Mercury Analyzer was 12.20 µg/m³, or a 17% difference from the Thermo80i mercury concentration. The %RSD of the Lumex Mercury Analyzer measurements was 0.09. Based on the DQI criterion set forth for precision and accuracy (25%), the results of this QC check indicated that the Lumex Mercury Analyzer was operating within acceptable limits at the time of deployment.

Additional DQI checks were conducted in the field by performing a Serviceability Test described in the Lumex Mercury Analyzer User's Manual (Appendix F of the project QAPP). The test is done by performing measurements using a test cell, containing gas from the calibration standard. The cell is built into the instrument, and is accessed by setting the instrument to the "test" mode, and collecting measurements. According to the instrument User's Manual, if all measured relative deviation values (R%) are less than 25%, the instrument is operating adequately, and measurements may be collected. This check was conducted during the first week of deployment and during the calibration and maintenance visit by ARCADIS personnel.

During the Serviceability Test performed on 26 September 2006, all R% values were less than 25% (4, 6, 4, 5, 5, 6, 5, 5, 6. 6. 4, 5, 7, 5, 7, 7, 7, 6, 8, 6, 11, 7, 7, 7, and 7).

During the Serviceability Test performed on 18 October 2006, all R% values were also less than 25% (5, 5, 5, 5, 5, 6, 5, 6, 5, 5, 5, 4, 6, 6, 6, 6, 6, 7, 7, 7, 7, 7, 6, 8, 6, 7, 6, 7, 6, 8, 8, 8, 8, 8, 8, 6, 6, 7, 9, 6, 6, 6).

The results of the two tests indicated that the instrument was operating in an acceptable manner.

4.2.3 DQI Checks for Ambient Wind Speed and Wind Direction Measurements

The meteorological head DQIs are checked annually as part of the routine calibration procedure. The Climatronics Model 101990-G1 Meteorological Head used during the first four weeks of this field campaign (September 21, 2006 through October 18, 2006) was calibrated by the EPA's APPCD Metrology Laboratory on June 7, 2006. Validation of wind data collected were performed initially at the time of deployment. Upon deployment, the Field Team Leader performed a visual inspection of the wind vane, and compared the compass heading of the vane to the data displayed from the

instrumentation. The data was also validated as part of the weekday telemetry and data check procedures to ensure that data was being collected, and there were no communication problems with the instrumentation. While data collection was occurring (and ARCADIS and EPA staff were present at the site), the measured wind direction was compared to the forecasted and observed wind direction for that particular day.

Although the Climatronics monitor had been calibrated prior to field deployment, and had passed the QC checks in the field, some questionable wind direction readings were noted during the initial weeks of the measurement campaign. At times, the recorded wind direction did not agree with the actual wind direction observed by project personnel. Because of concerns for the reliability of the data being produced by this instrument, it was replaced with the R.M. Young monitor on 19 October 2006. The wind speed measurement collected with the R.M. Young head was calibrated by the EPA's APPCD Metrology Laboratory on June 7, 2006. The wind direction measurement was calibrated by the EPA's APPCD Metrology Laboratory on July 14, 2006.

In order to assess the reliability of the wind direction data collected with the Climatronics instrument during the first four weeks of the project, the wind direction data collected with the instrument were compared with National Weather Service data obtained from the Automated Surface Observation System (ASOS) located at the - Northwest Alabama Regional Airport, located approximately two miles from the project site. Based on two minutes wind averages, there were four days in which the directional trends matched, but where the wind direction data was offset by a consistent factor. Figures 4-1, 4-2, 4-3, and 4-4 present a time series comparison of wind direction data collected with the Climatronics head, and wind direction data from the National Weather Service ASOS for 21 September, 22 September, 30 September, and 8 October, respectively. The wind direction correction factors obtained from these comparisons are presented in Table 3-3 of this document.

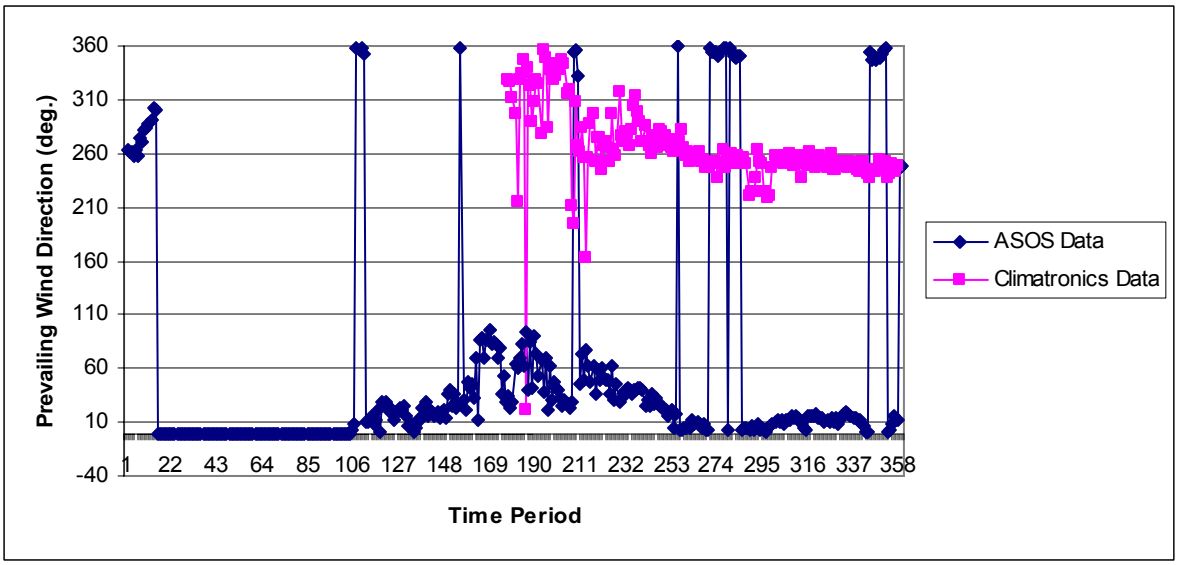

Figure 4-1. Comparison of prevailing wind directions from September 21, 2006 measured with the Climatronics meteorological head and the National Weather Service Automated Surface Observation System located at Northwest Alabama Regional Airport.

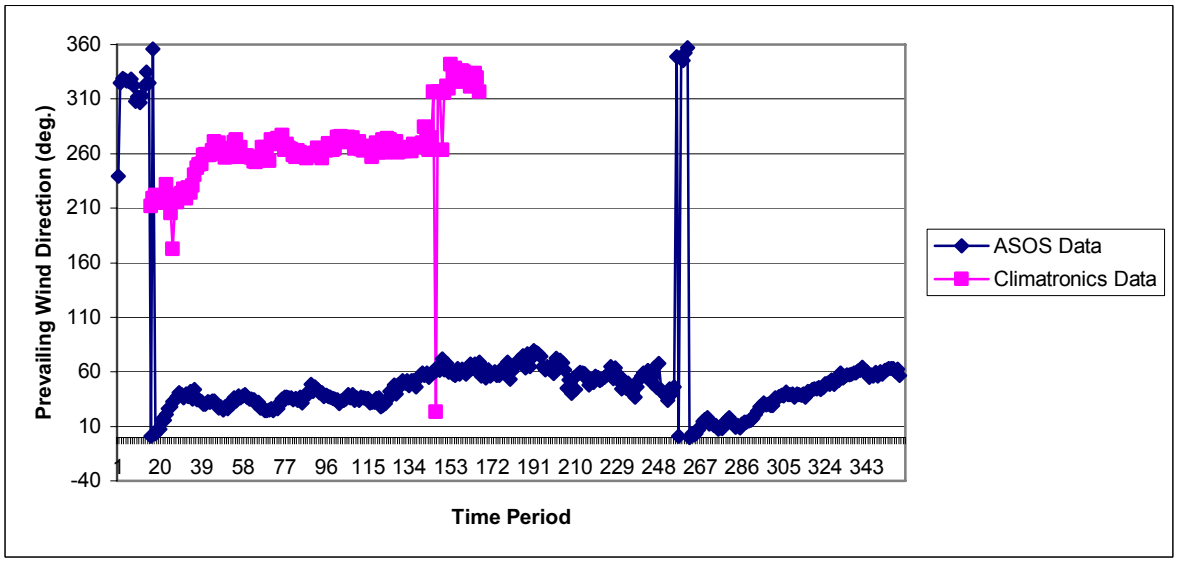

Figure 4-2. Comparison of prevailing wind directions from September 22, 2006 measured with the Climatronics meteorological head and the National Weather Service Automated Surface Observation System located at Northwest Alabama Regional Airport.

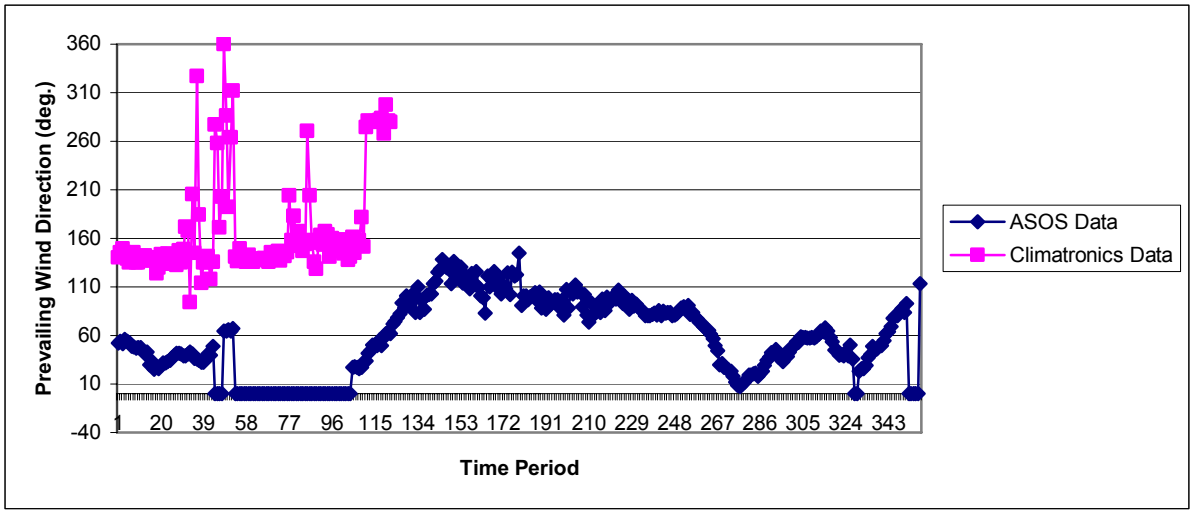

Figure 4-3. **Comparison of prevailing wind directions from September 30, 2006 measured with the Climatronics meteorological head and the National Weather Service Automated Surface Observation System located at Northwest Alabama Regional Airport.**

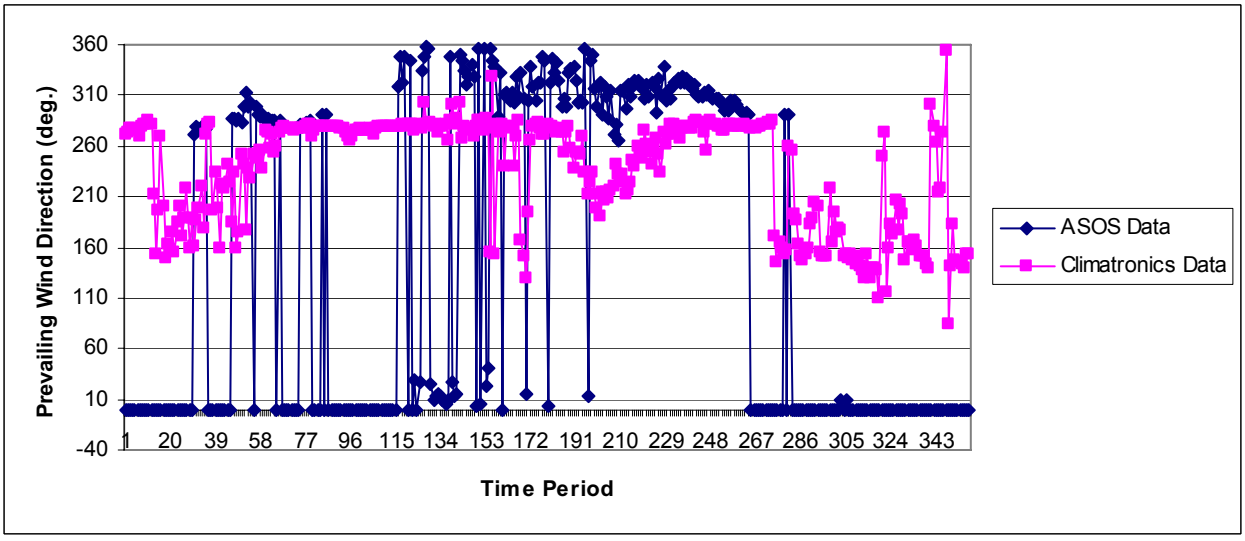

Figure 4-4. **Comparison of prevailing wind directions from October 8, 2006 measured with the Climatronics meteorological head and the National Weather Service Automated Surface Observation System located at Northwest Alabama Regional Airport.**

Figure 4-1 shows that wind direction data was collected with the Climatronics instrument from approximately time period 180 to 345. During this period, the Climatronics instrument was generally recording wind directions ranging from approximately 260° to 360°. However, the instrument recorded a baseline reading of approximately 260° for a long period of time. During this same period, the ASOS instrument recorded a baseline wind direction of approximately 10°. Based on this, a wind direction correction factor of 110° was applied to all wind direction data collected with the Climatronics instrument on September 21, 2006. It is additionally noted that the wind direction was visually verified by onsite personal during this day and found to be similar to the ASOS data. The Climatronics met head was aligned properly with the onsite wind sock but the collected data was displaying improper values. A malfunction with the auto north feature of the instrument was suspected.

Figure 4-2 shows that wind direction data was collected with the Climatronics instrument from approximately time period 20 to 150. During this period, the Climatronics instrument recorded a baseline wind direction of approximately 280°. During this same period, the ASOS instrument recorded a baseline wind direction of approximately 30°. Based on this, a wind direction correction factor of 110° was applied to all wind direction data collected with the Climatronics instrument on September 22, 2006. It is additionally noted that the wind direction was visually verified by onsite personal for during this day agreeing with ASOS data. Malfunctions in the Climatronics auto north alignment feature was suspected and were addressed at this point but intermittent operation of the unit continued

Figure 4-3 shows that wind direction data was collected with the Climatronics instrument from approximately time period 1 to 130. During this period, the Climatronics instrument recorded a baseline wind direction of approximately 140°. During this same period, the ASOS instrument recorded wind direction values ranging from 0° to 60°. Since the 0° values represent times when the wind conditions were calm, the actual baseline wind direction recorded with the ASOS instrument was approximately 40°. Based on this, a wind direction correction factor of 100° was applied to all wind direction data collected with the Climatronics instrument on September 30, 2006.

Figure 4-4 shows that wind direction data was collected with the Climatronics instrument for the entire day. Although there are instances of variable wind directions, the baseline wind direction recorded with the Climatronics instrument was approximately 270°. During this same period, the ASOS instrument recorded a baseline wind direction of approximately 330°. Based on this, a wind direction

correction factor of 60° was applied to all wind direction data collected with the Climatronics instrument on October 8, 2006.

The same analysis was performed on all other wind direction data produced by the Climatronics monitor during the project. The results of this analysis found that wind direction data collected with the Climatronics monitor on all other days were acceptable. Figures 4-5, 4-6, 4-7, and 4-8 present a time series comparison of wind direction data collected with the Climatronics head, and wind direction data from the National Weather Service ASOS for October 11, October 14, October 17, and October 18, respectively.

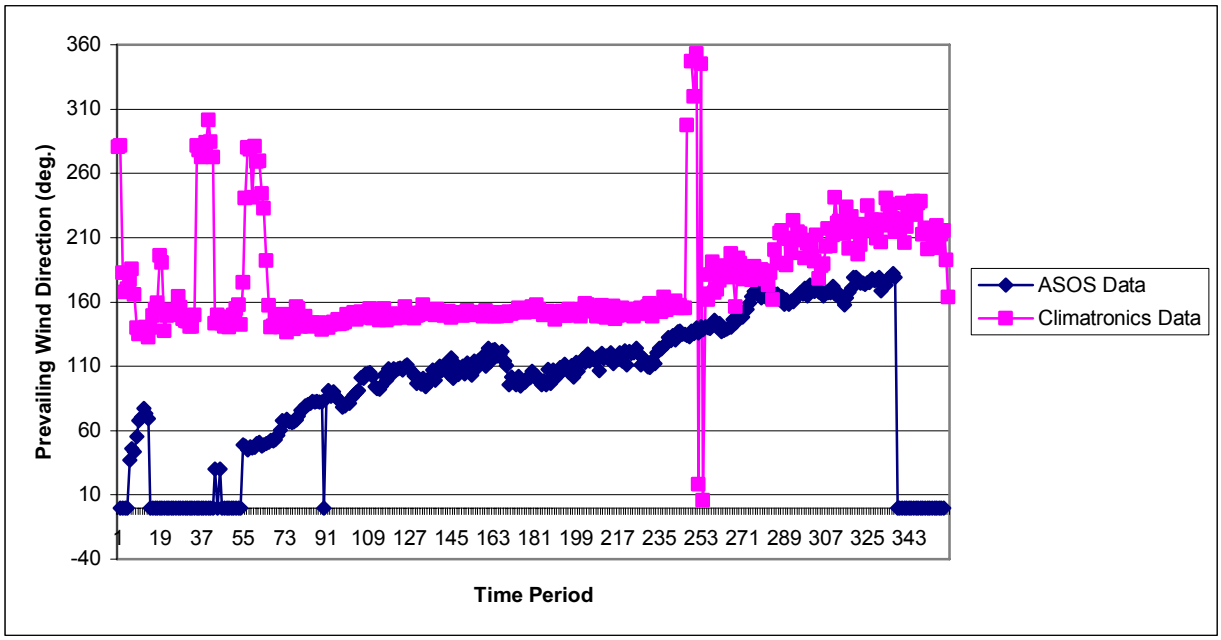

Figure 4-5. Comparison of prevailing wind directions from October 11, 2006 measured with the Climatronics meteorological head and the National Weather Service Automated Surface Observation System located at Northwest Alabama Regional Airport.

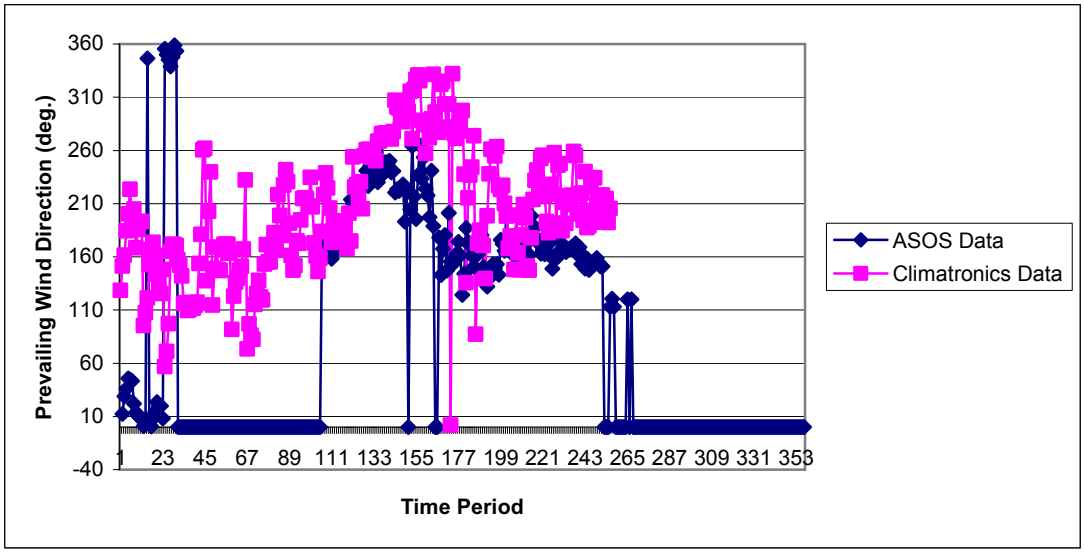

Figure 4-6. Comparison of prevailing wind directions from October 14, 2006 measured with the Climatronics meteorological head and the National Weather Service Automated Surface Observation System located at Northwest Alabama Regional Airport.

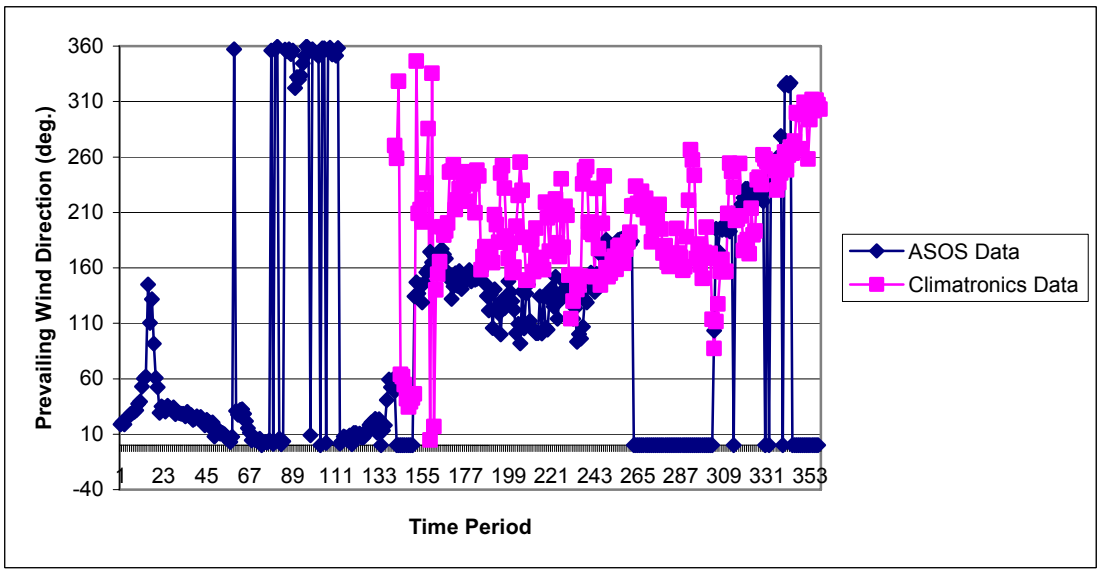

Figure 4-7. Comparison of prevailing wind directions from October 17, 2006 measured with the Climatronics meteorological head and the National Weather Service Automated Surface Observation System located at Northwest Alabama Regional Airport.

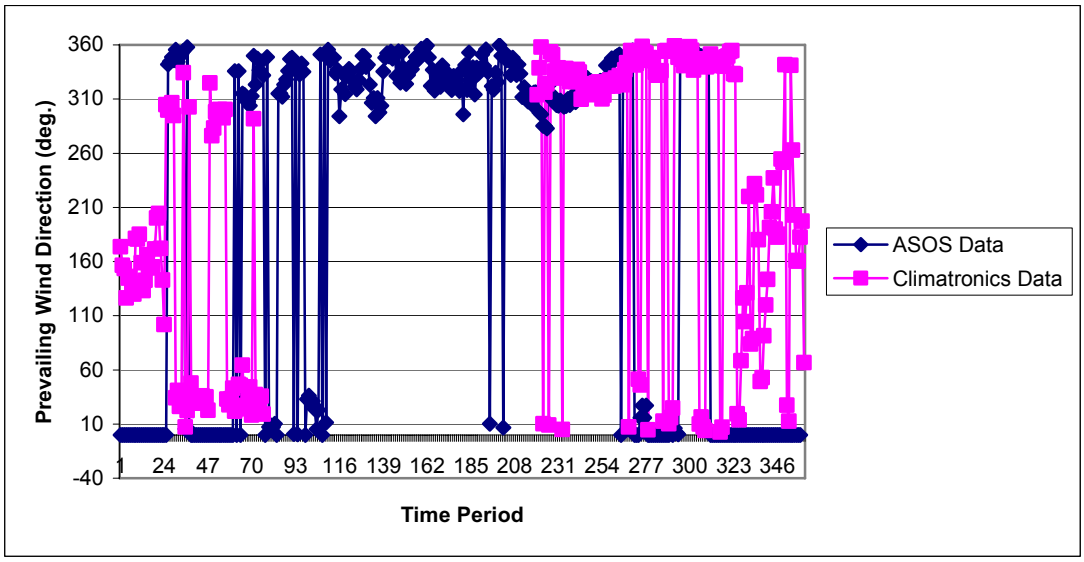

Figure 4-8. Comparison of prevailing wind directions from October 18, 2006 measured with the Climatronics meteorological head and the National Weather Service Automated Surface Observation System located at Northwest Alabama Regional Airport.

4.2.4 DQI Checks for the Topcon Theodolite

QC checks are not performed before each field campaign; however, the calibration date of the instrument was verified by referencing the calibration sticker. Before field deployment, the battery packs were charged. The following additional QC checks were made on April 19, 2006. The QC check of distance measurement was done at the EPA facility using a tape measure. The actual distance was 30.58 meters, and the measured distances were 30.61 and 30.59 meters. The results indicate accuracy and precision fall well within the DQI goals of ±1m. The QC check of angle measurement was also performed. The actual angle was 360°, and the measured angled were 359°37'53" and 360°27'27". The results indicate accuracy and precision fall well within the DQI goals of ±0.1°.

Additionally, there are several internal checks in the theodolite software that prevent data collection from occurring if the instrument is not properly aligned on the object

being measured, or if the instrument has not been balanced correctly. When this occurs, it is necessary to re-initialize the instrument to collect data.

4.2.5 Daily Telemetry Check Assessment

Each weekday of the six-week measurement campaign, the ARCADIS field team leader performed a telemetry check, downloaded and archived all data since the last check, and verified that continuous, acceptable data (according to UV-DOAS and Lumex Mercury Analyzer QC criteria) were collected. The data was downloaded following the procedures described in Appendix J of the project QAPP: *Project-Specific Operating Procedures for Data Downloading and Validation Via Telemetry.* Section 6.1 of this document details the data naming scheme that was used for the project. Data included path-averaged concentration (PAC) data from the three UV-DOAS instruments, mercury concentrations from the Lumex Mercury Analyzer, and wind data from both meteorological heads. All of this data were considered critical, as it was needed to meet project objectives.

4.2.6 Problems Encountered

During the six-week measurement campaign, the project encountered some problems with instrumentation and data telemetry. The issues encountered with the Climatronics meteorological head are discussed at length in Section 4.2.3 of this document.

The project team encountered some problems with the remote telemetry system used to download the data remotely. These problems primarily occurred during the first couple of weeks, and were expected. The problems included issues with the phone line which was installed to the field trailer, and problems with the interface between the data collection computer and the remote telemetry software. These issues were resolved by contacting Occidental Chemical personnel on site, who were able to assist in correcting the problems. During a subsequent site visit by ARCADIS and EPA ORD personnel, the settings on the data collection computer and remote communication software were adjusted, which resolved many of the problems, and improved the performance of the remote telemetry system for the duration of the project.

The project team encountered another minor problem in obtaining the distances and angles of the OPSIS sources mounted on the water tower, with respect to the location of the OPSIS receivers. Since it was not possible to deploy a retro reflecting mirror at the location of the sources mounted on the tower, it was necessary to use a Bushnell Field Rangefinder and Suunto Climometer to obtain the distances and angles of the

location of the OPSIS sources, respectively. The manufacturer states that the Bushnell Field Rangefinder has an accuracy of ±1 meter at a range of 100 meters.

4.3 EPA and ARCADIS Audits and Corrective Actions

Because this project has been designated QA Category II, an EPA internal technical systems audit (TSA) was performed at the site on October 19, 2006 by the EPA QA officer. In general, the auditors found that the EPA and ARCADIS project staff were doing a good job of measuring the mercury path-integrated concentrations at the plant, and the measurements were being implemented as stated in the project QAPP. The auditors did not find any issues that required corrective actions. A copy of the TSA report and responses to findings can be found in Appendix B of this document.

In addition to the EPA audit, the ARCADIS QA officer performed internal assessments. An internal on-site technical systems audit performed by the ARCADIS QA officer could not be scheduled for this project due to funding and time conflicts. To ensure field operations were conducted according to this QAPP, the ARCADIS QA officer prepared an internal technical systems audit checklist. Completion of the checklist was not considered an internal technical systems audit, but served as documentation that implementation of QAPP elements were reviewed at the site.

5. References

EPA quality assurance project plan entitled, *Measurement of Total Site Mercury Emissions from a Chlor-alkali Plant Using Open-Path UV-DOAS* (rev. 0.3 September, 2006).

Hashmonay, R.A., D.F. Natschke, K.Wagoner, D.B. Harris, E.L.Thompson, and M.G. Yost, Field evaluation of a method for estimating gaseous fluxes from area sources using open-path Fourier transform infrared, *Environ. Sci. Technol.*, 35, 2309-2313, 2001.

U.S. Environmental Protection Agency, *ECPB Optical Remote Sensing Facility Manual,* U.S. EPA National Risk Management Research Laboratory, Air Pollution Prevention and Control Division, Emissions Characterization and Prevention Branch, Contract No. EP-C-04-023, Work Assignment 0-33, April 2004.

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APPENDIX A

OAQPS Project Plan:
Study of Gaseous Mercury Fugitive Emissions from Cell Rooms and Other Sources at Mercury Cell Chlor-Alkali Plants
(dated September 8, 2005)

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PROJECT PLAN
STUDY OF GASEOUS MERCURY FUGITIVE EMISSIONS FROM CELL ROOMS AND OTHER SOURCES AT MERCURY CELL CHLOR-ALKALI PLANTS

Prepared for:

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September 8, 2005
Revision No. 2

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1.0 INTRODUCTION AND BACKGROUND

Mercury cell chlor-alkali plants produce chlorine and caustic soda (sodium hydroxide) or caustic potash (potassium hydroxide) in an electrolytic reaction. This process results in releases of mercury to the air from point and fugitive sources. Quantifying the level of emissions from fugitive sources has proven to be difficult. Since mercury cell chlor-alkali plants are unable to totally account for all the mercury entering and leaving their plants, this uncertainty in the amount of mercury that is emitted from fugitive emission sources has caused considerable debate. Currently, this discrepancy is at the center of litigation on the recently promulgated maximum achievable control technology (MACT) regulation for mercury emissions from mercury cell chlor-alkali plants. As part of the reconsideration of this regulation in response to this litigation, EPA is conducting a project to determine if the fugitive emissions from mercury cell chlor-alkali are better characterized by the historical assumptions or by the amount of mercury that is unaccounted for each year. This document describes this project.

The remainder of this section provides background on the industry, the air emissions and other releases, the fate of mercury, and the regulatory history. Section 2 provides the definition of the problem to be addressed in this project. Section 3 introduces the elements of the project, and Sections 4 and 5 provide more detail on the two elements. Section 6 discusses how the information received will be analyzed and potentially used in the reconsideration of the MACT regulation.

1.1 Description of Mercury Cell Chlor-Alkali Process

At a chlor-alkali plant, two chemicals (chlorine and an alkaline base (NaOH or KOH}) are simultaneously produced as a result of the electrolysis of saltwater. Most commonly the alkali is sodium hydroxide (caustic soda), which is produced from sodium chloride and water. Potassium hydroxide can also be produced from potassium chloride. This process also produces hydrogen as a by-product. The basic chlor-alkali reaction is shown in Equation 1:

$$2NaCl + 2H_2O \rightarrow 2NaOH + Cl_2 + H_2 \qquad \textbf{Equation (1)}$$

There are three types of electrolytic chlor-alkali processes: the diaphragm cell process, the mercury cell process, and the membrane cell process. Membrane cells are the state-of-the-art technology, and all new chlor-alkali plants that are built today use membrane cells. While mercury cells once made up the majority of the chlor-alkali industry, no new mercury cell plants have been constructed since the 1960s. In 1984, there were 24 mercury cell plants operating in the United States. When the NESHAP for Mercury Emissions from Mercury Cell Chlor-Alkali Plants (40 CFR 63, subpart IIIII) was proposed in 2002 (68 FR 44672, July 3, 2002), the number of operating mercury cell plants had decreased to 12. Currently, there are 9 mercury cell plants operating in the United States. Mercury cell plants are the only type of chlor-alkali plants that use and emit mercury.

A mercury cell plant typically has scores of individual cells (around 60 feet long and 9 feet wide) housed in one or more cell buildings. Mercury cells are electrically connected together in series in circuits of 30 or more cells. In the mercury cell process, each cell involves two distinct operations. The electrolytic cell produces chlorine gas, and a separate decomposer produces hydrogen gas and caustic soda/potash solution. There is one decomposer associated with each cell. The cell and the decomposer are linked at the two ends by an inlet endbox and an outlet endbox.

A stream of liquid mercury flows in a continuous loop between the electrolytic cell and the decomposer. The mercury enters the cell at the inlet endbox and flows down a slight grade to the outlet endbox. At the outlet endbox, the mercury flows out of the cell and falls down to the decomposer. After being processed in the decomposer, the mercury is pumped back up to the inlet endbox of the electrolytic cell.

Saturated salt brine (using either sodium chloride or potassium chloride) is fed to the electrolytic cell at the inlet endbox and flows toward the outlet endbox on top of the mercury stream. The brine and mercury flow under a dimensionally stable metal anode made of a titanium substrate with a metal catalyst. The mercury forms the cathode of the cell. An electric current is applied between the anode and the mercury cathode. The electric current causes a reaction producing chlorine gas at the anode and a mercury:sodium (HgNa) or mercury:potassium (HgK) amalgam at the cathode. Chlorine is collected at the top of the cell. The amalgam ultimately exits at the outlet endbox, falling into the decomposer. Depleted brine also exits the cell at the outlet endbox. This brine is generally piped to a tank for resaturation and reuse.

The decomposer is a packed bed reactor where the mercury amalgam is contacted with deionized water in the presence of a catalyst. The amalgam reacts with the water, regenerating elemental mercury and producing caustic soda/potash (NaOH or KOH) and hydrogen. The caustic soda/potash and mercury are separated in a trap at the end of the decomposer. The caustic soda/potash and hydrogen are transferred to auxiliary processes for purification, and the mercury is recycled back to the cell.

Chlorine is collected from the tops of the mercury cells by a common header system which runs through the cell building. Hydrogen is collected from the amalgam decomposers in a common header system. The hydrogen stream contains a small amount of mercury vapor from the liquid mercury processed in the decomposer. To remove the mercury vapor, the hydrogen stream is typically cooled, passed through a mist eliminator, and usually sent to a finishing device such as a carbon adsorber. The hydrogen may then be discharged to the atmosphere, used on-site, or sold for use off-site.

In a mercury cell process, a 50 percent caustic solution is obtained directly from the amalgam decomposers. Thus, the mercury cell caustic requires little further processing to yield a commercial product.

1.2 Mercury Releases From Mercury Cell Chlor-Alkali Plants

At a mercury cell chlor-alkali plant, mercury is emitted from point sources (i.e., stacks) and fugitive sources. Mercury also leaves the plant in wastewater and solid wastes. Table 1 summarizes the 2002 mercury releases from the nine mercury cell chlor-alkali plants currently operating in the United States.

There are three primary point sources at mercury cell plants: the end-box ventilation system vent, the by-product hydrogen system vent, and mercury thermal recovery unit vents. While every mercury cell plant has a hydrogen by-product stream and an end-box ventilation system, only five of the nine plants have thermal mercury recovery units. As shown in Table 1, the total mercury emissions reported in 2002 from point sources are 1,077 pounds, which averages around 120 pounds per plant.

Table 1. Summary of 2002 Mercury Releases from Mercury Cell Chlor-Alkali Plants in the Toxics Release Inventory[1]

	2002 Mercury Releases (lbs/yr) in TRI				
Plant	**Fugitive Air**	**Point Source Air**	**Total Air**	**Surface Water**	**Other On-Site and Off-Site**
ASHTA - Ohio	1,046	349	1,395	0	173
Occidental Chemical - Alabama	1,067	20	1,087	10	664
Occidental Chemical - Delaware	1,046	28	1,074	21	1,144
Olin - Georgia	585	154	739	7	282
Olin - Tennessee	1,045	85	1,130	14	1,368
Pioneer - Louisiana	862	48	910	13	261
PPG - Louisiana	1,045	177	1,222	7	231
PPG - West Virginia	1,045	188	1,233	34	900
Vulcan - Wisconsin	1,054	28	1,082	2	377
Total	8,795	1,077	9,872	108	5,400
Total Overall	15,380				

[1] Toxics Release Inventory Program. United States Environmental Protection Agency. http://www.epa.gov/tri/

Subpart IIIII or "The Mercury Cell MACT," contains numerical emission limits for each of these point sources. It also requires that the plants either install continuous mercury emission monitors or that they test each vent at least once per week. While the compliance date for the Mercury Cell NESHAP is not until December 6, 2006, most mercury cell plants have relatively recent test or monitoring data for these point sources. This is because these plants have been (and still are, until the new NESHAP takes effect on December 6, 2006) subject to 40 CFR 61, subpart E (the "Old Part 61 Mercury NESHAP"), which contains a numerical emission limit for point sources.

In addition, there are mercury fugitive emissions. The majority of fugitive mercury emissions occur from sources in the cell room such as leaks from cells, decomposers, hydrogen piping, and other equipment. Fugitive mercury emissions also occur during maintenance activities such as cell or decomposer openings, mercury pump change-outs, end-box seal replacements, etc. All of this equipment and activities occur in the cell room, so these fugitive mercury emissions would be emitted via the cell room ventilation system.

There are fugitive emission sources outside of the cell room, but these have generally been assumed to be insignificant in comparison to those from the cell room. Potential outside sources include leaks of mercury-contaminated brine in the brine treatment area, the wastewater system, and the handling and storage of mercury contaminated wastes.

The Old Part 61 Mercury NESHAP effectively contains a mercury emission limit of 1,300 grams per day for fugitive emissions from the cell room. However, mercury cell plants are allowed to demonstrate compliance by following a series of design, maintenance, and housekeeping procedures. All mercury cell plants have complied via these procedures rather than testing and complying directly with the 1,300 grams per day limit. The Mercury Cell MACT does not include a numerical emission limit for fugitive emissions from the cell room. Rather, it contains a set of work practice standards determined to represent the best practices from the industry, which are considerably more stringent than the Old Part 61 Mercury NESHAP procedures. It also contains an alternative program that involves continuous mercury concentration monitoring and problem correction when an action level is exceeded.

The difficulty in measuring fugitive mercury emissions from mercury cell chlor-alkali plants, and the fact that no regulation has required the quantification of these emissions, has resulted in a very limited data set on fugitive mercury emissions at mercury cell chlor-alkali plants. Specifically, we are aware of only five published studies in the last 30+ years that have measured fugitive emissions from mercury cell chlor-alkali plant cell rooms. These studies are summarized in Table 2. Because of this lack of data, mercury cell chlor-alkali plants have historically just used the 1,300 grams per day assumption (which is 1,045 pounds per year assuming continuous operation) from the Old Part 61 Mercury NESHAP in reporting fugitive emissions. This is reflected in the fugitive emission estimates shown in Table 1. The 1,300 grams per day level was based on the 1971 and 1972 studies shown in Table 2, and the estimate for Olin in Georgia is based on the 2000 study at their plant. Pioneer in Louisiana also

reported fugitive emissions less than the 1,300 grams per day, but this level of emissions is based on estimates of reductions expected from a series of process improvements they have made, rather than on a comprehensive test or monitoring study that quantified fugitive mercury emissions.

Table 2. Summary of Previous Studies to Measure Mercury Fugitive Emissions From Mercury Cell Chlor-Alkali Plant Cell Rooms

Year of Test	Location	Duration	Average Fugitive Emissions Level (grams/day)
1971	Bellingham, WA[2]	90 minutes	990
1972	Calvert City, KY[3]	180 minutes	1,518
1989	Sweden[4]	1 week	720
1992	Italy[5]	3 days	930
2000	Augusta, GA[6]	9 days	518

[2] Cadwallader, T.E., Cowan, B.W., November 1971. Test Report: Georgia-Pacific chlor-alkali plant, Bellingham, Washington. Roy F. Weston, Inc., West Chester, PA.

[3] Marks, Peter J., Davison, J.W., May 1972. Test Report: B.F. Goodrich Chemical Company chlor-alkali plant, Calvert City, Kentucky (EPA Test No. 72-PC-04). Roy F. Weston, Inc., West Chester, PA.

[4] Edner, H., Faris, G.W., Sunesson, A., Svanberg, S., 1989. Atmospheric atomic mercury monitoring using differential lidar techniques. Applied Optics 28, 921-930.

[5] Ferrara, R., Maserti, B.E., Edner, H., Ragnarson, P., Svanberg, S., Wallinder, E., 1992. Mercury emissions into the atmosphere from a chlor-alkali complex measured with the lidar technique. Atmospheric Environment 26A, 1253-1258.

[6] Kinsey, J.S., 2002. Characterization of mercury emissions at a chlor-alkali plant, vols. I and II. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Research Triangle Park, NC, EPA-600/R-02-007a and EPA-600/R-02-007b.

1.3 Overall Fate of Mercury

As the mercury in the cells diminishes, additional mercury is added to the cells to maintain the desired level for optimum process efficiency. Many assume that the amount of mercury added to the process to replace "lost" mercury leaves the plant in wastes or wastewater, in products, or via air emissions. However, mercury cell plants have not been able to account for all the lost mercury. The issue of unaccounted for mercury has been the subject of intense scrutiny from groups within EPA and the industry. As part of the Great Lakes Binational Toxics Strategy, mercury cell chlorine producers annually report the total mercury consumption for the industry.[7] For the years 1990-1995, the industry reported an average of 160 tons/yr of mercury used. They have achieved significant reductions in this amount since that time, down to 79 tons/yr in 2000, 30 tons/yr in 2001, 36 tons/yr in 2002, and 38 tons/yr in 2003. Even with this decrease in usage, significant mercury remains unaccounted for by the industry. In 2000, the 12 operating mercury cell plants reported total mercury releases of around 14 tons, meaning that there were approximately 65 tons of mercury unaccounted for in that year. As shown in Table 1, the 2002 releases reported total just under 8 tons, meaning that there were around 28 tons of mercury unaccounted for in 2002. These amounts equate to an average of between 3 and 5½ tons of unaccounted for mercury per mercury cell chlor-alkali plant.

There are two basic theories regarding the fate of this unaccounted for mercury. The first is it is emitted to the air. This would substantially increase the emissions from the levels reported and the levels measured in the previous studies. Since the point source emissions are relatively well studied, the assumption is that these emissions are fugitive in nature and originate from the cell room and/or other areas of the plant. The second is that mercury condenses and accumulates in pipes, tanks, and other plant equipment. Since this equipment is not routinely opened and the mercury removed and recovered, a substantial amount could build up that would not be accounted for in a shorter time period.

1.4 EPA's Reconsideration of the Mercury Cell MACT

On December 19, 2003 (68 FR 70904), the EPA promulgated the Mercury Cell MACT. On February 17, 2004, the National Resource Defense Council (NRDC) filed petitions on the final rule in DC District Court. The foundation behind many of the issues raised in the petitions was the uncertainty associated with the fugitive emission estimates used by the EPA in the rulemaking. In particular, the NRDC has concerns over the inability of mercury cell plants to account for all the mercury added to their processes to replace mercury that leaves in products or wastes or leaves via air emissions. The NRDC (along with a number of other concerned partiies) maintains that the majority of this missing mercury must be lost through fugitive emissions. They also contend that recognition of this fact would cause EPA would change many of the decisions that were made in developing and promulgating the Mercury Cell MACT.

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[7] Binational Toxics Strategy Mercury Workgroup - Reducing Mercury in the Great Lakes Region. Chlor-Alkali Industry. http://www.epa.gov/region5/air/mercury/reducing.html

On April 8, 2004, Jeffrey Holmstead, EPA Assistant Administrator for Air and Radiation, notified the NRDC that the EPA granted their petition and would reconsider aspects of the rulemaking. As part of this reconsideration, the EPA has agreed to conduct a project to address the uncertainty of the mercury fugitive emissions from this industry. Currently, NRDC has agreed to a stay of litigation while the Agency is conducting this study.

2.0 PROBLEM DEFINITION

The problem that this project will address is whether the fugitive emissions from a mercury cell chlor-alkali plant are on the order of magnitude of the historical assumption of 1,300 grams per day (0.5 tons/yr) or on the order of magnitude of the unaccounted for mercury (3-5 tons/yr).

3.0 PROJECT ORGANIZATION

Sources of fugitive mercury emissions at a mercury cell chlor-alkali plant can be classified in two major categories: (1) sources inside the cell room and (2) sources outside the cell room. This project contains two primary elements corresponding to these two categories. Table 3 shows these elements, along with an explanation of the data to be received related to each and the responsibilities for collecting these data. Table 3 also provides the date when data are expected from each element. Section 4 discusses sources inside the cell room and Section 5 discusses sources outside the cell room.

Data collected will be received and analyzed by EC/R Incorporated (ECR), under contract to EPA's Office of Air Quality Planning and Standards (OAQPS), Emissions Standards Division (ESD). Data will be collected by three basic organizations: ARCADIS, under contract to the National Risk Management Research Laboratory (NRMRL) of EPA's Office of Research and Development (ORD); MACTEC, under contract to the Emissions and Measurement Analysis Division (EMAD) of OAQPS, and mercury cell chlor-alkali companies.

Table 3. Summary of Project Elements and Specific Data/Information Expected

Project Element	Data/Information to Be Received[a]	Organization Responsible for Collection of the Data	Approximate Date When Data/ Information Are Expected
Fugitive Emissions From Inside the Cell Room	Validation of continuous mercury monitoring system installed in the cell room at Occidental Chemical in Delaware City, Delaware	MACTEC/ EMAD	9/05
	Cell-room mercury emissions data from Occidental Chemical's Delaware City, Delaware Plant	Occidental Chemical	12/05
	Process and cell-room maintenance activity data corresponding to time period of emissions data for Occidental Chemical's Delaware City, Delaware Plant	Occidental Chemical	12/05
	Validation of continuous mercury monitoring system installed in the cell room at Occidental Chemical in Muscle Shoals, Alabama	MACTEC/ EMAD	9/05
	Cell-room mercury emissions data from Occidental Chemical's Muscle Shoals, Alabama plant	Occidental Chemical	12/05
	Process and cell-room maintenance activity data corresponding to time period of emissions data for Occidental Chemical's Muscle Shoals, Alabama plant	Occidental Chemical	12/05
Fugitive Emissions From Outside the Cell Room	Mercury flux data from non cell-room emission sources at Occidental Chemical's Muscle Shoals, Alabama plant	ARCADIS/ NRMRL	2/06
	Non cell-room process and maintenance activity data corresponding to time period of flux measurement emissions data for Occidental Chemical's Muscle Shoals, Alabama plant	Occidental Chemical	2/06

[a] Note: These are the data items or other information identified as of the date of the current version of this project plan. It is expected that additional sources of data will be identified and incorporated into the project.

4.0 SOURCES INSIDE THE CELL ROOM

The objective of this element is to obtain emission estimates of the fugitive mercury emissions that occur inside the cell room of a mercury cell chlor-alkali plant. These estimates will represent emissions that occur during a wide range of maintenance and other activities in the cell room.

In mid-2004, EPA began scoping out a basic testing plan concept with the intention of conducting EPA-sponsored tests at two or more mercury cell chlor-alkali plants. After initial information gathering efforts to identify candidate mercury cell chlor-alkali plants for testing, EPA visited five plant sites as the first step in developing site-specific test plans. These efforts confirmed that there are significant technical, logistical, and/or safety issues associated with the measurement of fugitive emissions from mercury cell rooms. These issues are particularly monumental when contemplating a short-term (four to six week) testing effort. EPA has consulted industry representatives and testing experts inside and outside of the EPA, and is currently attempting to design a comprehensive short-term testing program.

In the meantime, the mercury cell chlor-alkali industry has been working toward long-term mercury measurement efforts. Two Occidental Chemical mercury cell plants (Delaware City, Delaware and Muscle Shoals, Alabama) have already installed continuous mercury monitoring systems in their cell rooms, which they are using to identify and correct mercury emission episodes in accordance with the alternative cell room monitoring program in the Mercury Cell MACT standard. In addition, they are also monitoring parameters to allow the continuous estimation of the mass of mercury emissions from the cell room. The more permanent nature of these systems has allowed these plants to overcome some of the obstacles that have been encountered for the short-term effort testing effort. As a result of the success of this program, other mercury cell plants are investigating similar systems.

Given the difficulties encountered in designing a short-term testing program to measure mercury fugitive emissions from cell rooms, and the fact that plants have already installed continuous mercury monitoring equipment, the focus has shifted from EPA conducting or sponsoring a short-term test to EPA receiving data collected by these systems.* Therefore, the primary source of data for this element (fugitive emissions from inside cell rooms) will be data collected by the industry from continuous mercury monitoring systems. However, since these data will be collected by the industry rather than EPA or their contractors, EPA requires that a quality control regime is in place to determine the quality of the data. Specifically, EPA will conduct studies to validate each cell-room mercury monitoring system prior to receiving data that will be used in this project. The following section includes brief descriptions of the cell room monitoring systems that will be included in the study and section 4.2 discusses the validation of these systems.

*Note: EPA has not abandoned the concept of conducting or sponsoring a short-term test at one or more mercury cell chlor-alkali plants. Rather, EPA is focusing current efforts on obtaining data already being collected by the industry.

4.1 Cell Room Continuous Monitoring Systems

At this time, data will be collected from the cell room mercury monitoring systems at two mercury cell chlor-alkali plants for approximately a six-week period during the time periods shown:

- Occidental Chemical in Delaware City, Delaware (August 2006 - November 2006)
- Occidental Chemical in Muscle Shoals, Alabama (August 2006 - November 2006)

Emissions data from these systems will be collected by the companies and provided to ECR/ESD as described in Attachment 1. Following are brief descriptions of the systems at these plants:

Occidental Chemical, Delaware City, Delaware

The cell room at the Delaware City Plant is a rectangular building measuring 352 feet by 140 feet. The cell room consists of two independent circuits, and each circuit is broken into two sections, resulting in four quadrants. The air flow in the cell room is via natural convection; there are no fans to provided either induced or forced draft air flow. During the summer months, approximately 40 percent of the sides on the lengthwise span are removed to improve ventilation. There are two rows of roof ventilators. Each ventilator is in two discrete sections for a total of four sections (corresponding to the four quadrants of the cell room).

The mercury concentration monitoring system is a Mercury Monitoring System Model MMS-16 analyzer manufacturing by Mercury Instruments GmbH Analytical Instruments in Germany. It collects samples from 16 points and analyzes them for elemental mercury using a Model VM-3000 ultraviolet absorption analyzer. The system takes one sample per minute, meaning that a sample is taken from each point once every 16 minutes. The sampling sequence is established so that a sample is taken from each quadrant once every four minutes. The flow rate for the building is estimated using a convective air flow model. The inputs to this model are atmospheric and ridge vent temperatures (which are continuously monitored), intake and discharge areas, and stack height.

Occidental Chemical, Muscle Shoals, Alabama

The cell room at the Muscle Shoals plant is a rectangular building measuring 260 feet by 357 feet. The cell room consists of two rows of cells broken into four-quarter sections. The cell room takes up half of a larger building, with a wall separating the cell room from the large open half that is used for equipment storage. The peak of the roof is over the center of the larger building (meaning that it is over the wall separating the cell room from the other side of the building). The ventilation for the cell room consists of both induced and forced draft. There are 43 forced draft fans positioned on the sidewall of the building pushing air towards the cent of the building. There are two rows of induced draft fans on the roof of the cell building. One row,

containing 33 fans, is directly over the center of the two rows of cells. The other row, which contains 32 fans, is over the wall separating the cell room from the other side of the building.

The mercury concentration monitoring system is a Mercury Monitoring System Model MMS-16 analyzer manufacturing by Mercury Instruments GmbH Analytical Instruments in Germany. It collects samples from 65 points (at the inlet to each induced draft fan) and combines them in groups of three or four to provide a representative profile of the cell room in a 20 point sample array. The elemental mercury concentration will be measured using a Model VM-3000 ultraviolet absorption analyzer. The system takes one sample per minute, meaning that a sample is taken from each point once every 20 minutes. Occidental tested each fan to determine the flow rate at standard conditions and is correcting to actual flow rate based on continuous monitoring of temperature, pressure, and humidity.

4.2 Validation of Systems

Each system described above will be validated to assess the quality of the data that will be received from the continuous cell room mercury monitoring system. This validation will consist of a review of the data collection, calculation, and archiving system; an assessment of the data quality provided by the mercury analyzer; and an assessment of the data quality provided by the air flow estimation technique. Attachment 2 contains the Validation Plan for the Occidental Chemical plant in Delaware City, Delaware and Attachment 3 contains the draft Validation Plan for the Occidental Chemical plant in Muscle Shoals, Alabama. Data will be collected for these validation studies in accordance with the plans in Attachment 2 and 3 by MACTEC/EMAD, and reports will be prepared. These reports and data will be provided to ECR/ESD.

4.3 Monitoring of Process and Maintenance Activities

For the period represented by the emissions data that will be provided by the plants, operational information will also be provided regarding production, process, and cell-room maintenance activity. Specifically, this information will include chlorine production (or a surrogate parameter such as electrical load); the number of cells online/offline; maintenance activities such as cell openings, decomposer openings, etc.; and housekeeping activities. Records of any major malfunctions or other circumstances that resulted in large mercury emission episodes will also be maintained. These activity data will be collected by the companies and provided to ECR/ESD.

5.0 SOURCES OUTSIDE THE CELL ROOM

The objective of this element is to determine if the fugitive emissions from outside the cell room are significant with respect to the emissions from inside the cell room. If it is determined that these "outside" fugitive emissions are significant, emission estimates from this activity will used in the addressing the overall problem. These estimates will represent emissions that occur during a wide range of maintenance and other activities outside the cell room.

5.1 Emissions Data Collection

The emission rate of fugitive mercury emissions from outside the cell room will be measured using Optical Remote Sensing/Vertical Radial Plume Mapping (ORS/VRPM). At this time, data will be collected at the following mercury cell chlor-alkali plants for approximately a six-week period during the time periods shown:

- Occidental Chemical in Muscle Shoals, Alabama (October 2005 - December 2005)

These data will be collected by ARCADIS/NRMRL in accordance with the site-specific Quality Assurance Project Plan (QAPP) provided in Attachment 4 and provided to ECR/ESD.

5.2 Monitoring of Process and Maintenance Activities

For the period represented by the outside fugitive emissions data that will be collected (see section 5.1), information will also be provided regarding process and maintenance activity that occurs outside the cell room. Specifically, this information will include waste-handling activities, thermal mercury recovery activity, maintenance activities, and housekeeping activities. Records of any major malfunctions or other circumstances that resulted in large mercury emission episodes will also be maintained. These activity data will be collected by the company and provided to ECR/ESD.

6.0 RECEIPT AND ANALYSIS OF DATA

6.1 Data to Be Received

ECR/ESD will receive the following data and information:

- *From MACTEC/EMAD* - Validation reports and associated data for the cell room continuous mercury emissions system at Occidental Chemical in Delaware City, Delaware.
- *From Occidental Chemical* - Mercury emissions data from sources inside the cell room at Occidental Chemical in Delaware City, Delaware.
- *From Occidental Chemical* - Operational information at Occidental Chemical in Delaware City, Delaware.
- *From MACTEC/EMAD* - Validation reports and associated data for the cell room continuous mercury emissions system at Occidental Chemical in Muscle Shoals, Alabama, Delaware.
- *From Occidental Chemical* - Mercury emissions data from sources inside the cell room at Occidental Chemical in Muscle Shoals, Alabama.
- *From Occidental Chemical* - Operational information at Occidental Chemical in Muscle Shoals, Alabama.

- *From ARCADIS/NRMRL* - Mercury emissions data from fugitive emission sources outside the cell room at Occidental Chemical in Muscle Shoals, Alabama if such sources are found to be significant with respect to the emissions from inside the cell room.
- *From Occidental Chemical* - Process and maintenance activity for activities outside of the cell room at at Occidental Chemical in Muscle Shoals, Alabama.

6.2 Analyses to be Performed

Following receipt of this data and information, ECR/ESD will, at a minimum, conduct the following analyses:

- Determine whether the fugitive mercury emissions from the cell room at Occidental Chemical in Delaware City, Delaware are on the order of magnitude of the historical assumption of 1,300 grams per day (0.5 tons/yr) or on the order of magnitude of the unaccounted for mercury (3-5 tons/yr).

- Determine whether the fugitive mercury emissions from the cell room at Occidental Chemical in Muscle Shoals, Alabama are on the order of magnitude of the historical assumption of 1,300 grams per day (0.5 tons/yr) or on the order of magnitude of the unaccounted for mercury (3-5 tons/yr).

- Determine whether the combined fugitive mercury emissions from inside and outside the cell room at Occidental Chemical in Muscle Shoals, Alabama are on the order of magnitude of the historical assumption of 1,300 grams per day (0.5 tons/yr) or on the order of magnitude of the unaccounted for mercury (3-5 tons/yr).

- Determine the process, maintenance, and other operational activities that most significantly impact fugitive mercury emissions.

- Evaluate whether a relationship exists between the fugitive mercury emissions and any activity factor (e.g., chlorine production, number of mercury cells, amount of mercury in cells, etc) that could be used to develop an emissions factor that could be applied industry-wide.

6.3 How this Project Will Impact the MACT Reconsideration

During the rulemaking for the Mercury Cell MACT, the baseline fugitive mercury emission levels were assumed to be 1,300 grams/day per plant. Based on this assumption, the current level of fugitive mercury emissions from mercury cell chlor-alkali plants in the United States would be around 4.7 tons/yr. However, if this project concludes that the fugitive mercury emissions are on the order of magnitude of the unaccounted for mercury (3-5 tons/yr/plant), the total fugitive mercury emission from mercury cell chlor-alkali plants in the United States could be as high as 45 tons/yr. This level would approximately be equivalent to the current mercury emissions from utilities, and would be three times higher than the mercury emissions expected

from utilities after implementation of the Clean Air Mercury Rule.[8] This obviously could impact all aspects of EPA's reconsideration of the Mercury Cell MACT.

In its February 17, 2004 petition, the NRDC cited five specific issues. The results of this project could directly impact the reconsideration of the following NRDC issue.

- EPA failed to consider non-mercury technology as above-the-floor MACT for existing sources. As NRDC has argued, eliminating the mercury cell process would eradicate mercury emissions altogether, and would be cost-effective.

If EPA does consider non-mercury technology as above-the-floor MACT for existing sources, a criterion considered in this decision will be the cost effectiveness of this option. Since the emission reduction is the denominator of cost effectiveness, an increase in the level of fugitive emissions from mercury cell chlor-alkali plants (and thus, an increase in the emissions reduction resulting from an option to eliminate mercury cell technology) would result in a lower cost effectiveness for this option.

This project would also inform another one of NRDC's major issues.

- EPA refused to establish a numeric emission standard for the cell room, opting instead to develop a set of work practices designed to minimize emissions. Work practices may be substituted for emission limits only upon a finding that "it is not feasible... to prescribe or enforce an emission standard." EPA argued that measurement technologies could not be used to enforce a standard.

While the finding regarding the magnitude of fugitive mercury emissions may not impact this issue, EPA will have a much better understanding of the feasibility of measuring fugitive mercury emissions at mercury cell chlor-alkali plants after this project. This will provide information to help in their consideration whether to prescribe a numerical emission standard.

[8] U.S. EPA. The Clean Air Mercury Rule - Basic Information. http://www.epa.gov/air/mercuryrule/basic.htm

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APPENDIX B

EPA Memorandum and Response:
Findings from the Technical Systems Audit of Measurements of Total Site Mercury Emissions from a Chlor-Alkali Plant using Ultraviolet Differential Optical Absorption Spectroscopy

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Air Pollution Prevention and Control Division

Research Triangle Park, NC 27711

October 27, 2006

MEMORANDUM

SUBJECT: Preliminary Findings from Technical Systems Audit of Measurements of Total Site Mercury Emissions from a Chlor-alkali Plant using Ultraviolet Differential Optical Absorption Spectroscopy

FROM: Robert S. Wright, Technical Services Branch

TO: Eben Thoma, Emissions Characterization and Prevention Branch

EPA conducted an internal technical systems audit (TSA) on October 19, 2006 of measurements of total site mercury emissions from a chlor-alkali plant in Muscle Shoals, Alabama using ultraviolet differential optical absorption spectroscopy (UV-DOAS). I was accompanied by Mark Bahner, a technical expert auditor from RTI International. This TSA was conducted according to auditing procedures described in *Guidance on Technical Audits and Related Assessments for Environmental Data Operations (EPA QA/G-7)*. ARCADIS' approved quality assurance project plan (QAPP), its appendices, and EPA's quality requirements provided the technical bases for the TSA. The checklist for the TSA was sent to EPA and ARCADIS project staff on October 16, 2006 and was distributed to the project staff prior to the audit. The following are preliminary findings of the audit.

1. The TSA addresses only the field measurements campaign during which path-integrated concentrations (PICs) for mercury were measured. It does not address the subsequent vertical radial plume mapping (VRPM)

calculations by ARCADIS which will convert the measured PICs and meteorological data into mercury emission flux estimates.

2. In general, the auditors observed that the EPA and ARCADIS project staff are doing a good job of measuring mercury PICs at the plant. The project staff are well qualified to perform the work and they conduct themselves in a professional manner. They cooperated with the auditors and took time out from their busy duties to explain what was happening. They helped to ensure the successful completion of the TSA.

3. In general, the measurements are being implemented as stated in the QAPP for the project. There are no findings that require corrective actions.

4. There were significant disruptions of the 10-meter meteorological measurements due to the failure of multiple Climatronics meteorological heads since the beginning of the project. This problem was solved on October 19 with the installation of an R.M. Young meteorological head and it appeared that valid measurements would be collected for the remainder of the project. For the earlier periods during which no valid meteorological data were collected at the chlor-alkali plant, the project staff will attempt to use hourly 10-meter meteorological data from the Automated Surface Observing System (ASOS) at the Northwest Alabama Regional Airport in the calculation of the mercury emission flux estimates. The airport is located approximately 1-3/4 miles south-southeast from that plant and meteorological data collected there should be representative of winds at the plant. EPA may be able to obtain 5-minute data for the airport. For those periods in which valid data are collected at both the plant and the airport, the auditors recommend that statistical analysis of these data be performed to assess representativeness of the airport data on a quantitative basis. If they are found to be representative, the airport data can be used for calculating mercury emission flux estimates.

5. Mercury PICs are calculated using a multipoint calibration whose values are based on a graph of the mercury saturation vapor pressure versus temperature. This graph was provided by OPSIS, the manufacturer of the UV-DOAS instrument. There is no information available about how the pressure values on the graph were obtained, the uncertainty of these values or the traceability of these values to national standards. Recently, Friend *et al.* of the National Institute of Standards and Technology (NIST) reviewed the available measurements of the vapor pressure of mercury and developed an equation predicting the vapor pressure over a wide

range of temperatures. The auditors recommend that the values from the OPSIS graph be compared to the NIST equation to determine whether these values reflect the current state of knowledge regarding mercury vapor pressure. If significant differences are detected, EPA should consider using the NIST equation, rather than the OPSIS values, in the multipoint calibration.

6. Near-ground mercury concentration measurements were obtained using three 25-meter-long, 1/4-inch ID sampling lines that were joined at the inlet of a Lumex mercury analyzer. The auditors recommend that the sample flow rates through these lines be measured at the conclusion of the project to allow calculation of the sample residence time and to demonstrate that the flow rates are equal in the three sampling lines.

A draft findings report for this TSA will be completed in the coming month. It is possible that it may contain additional findings that arise from closer consideration of the audit results, but I do not expect any new findings will address significant problems relating to the project.

Please contact me if you have any questions about the TSA or about this memorandum.

Response to "Preliminary Findings from Technical Systems Audit of Measurements of Total Site Mercury Emissions from a Chlor-alkali Plant using Ultraviolet Differential Optical Absorption Spectroscopy"

The following is a response to the internal technical systems audit (TSA) performed on October 19, 2006 of measurements of total site mercury emissions from a chlor-alkali plant in Muscle Shoals, Alabama using ultraviolet differential optical absorption spectroscopy (UV-DOAS).

Finding 1. The TSA addresses only the field measurements campaign during which path-integrated concentrations (PICs) for mercury were measured. It does not address the subsequent vertical radial plume mapping (VRPM) calculations by ARCADIS which will convert the measured PICs and meteorological data into mercury emission flux estimates.

Response 1. The final report outlines the VRPM calculations in section 1.3.1.

Finding 2. In general, the auditors observed that the EPA and ARCADIS project staff are doing a good job of measuring mercury PICs at the plant. The project staff are well qualified to perform the work and they conduct themselves in a professional manner. They cooperated with the auditors and took time out from their busy duties to explain what was happening. They helped to ensure the successful completion of the TSA.

Response 2. No response required.

Finding 3. In general, the measurements are being implemented as stated in the QAPP for the project. There are no findings that require corrective actions.

Response 3. No response required.

Finding 4. There were significant disruptions of the 10-meter meteorological measurements due to the failure of multiple Climatronics meteorological heads since the beginning of the project. This problem was solved on October 19 with the installation of an R.M. Young meteorological head and it appeared that valid measurements would be collected for the remainder of the project. For the earlier periods during which no valid meteorological data were collected at the chlor-alkali plant, the project staff will attempt to use hourly 10-meter meteorological data from the Automated Surface Observing System (ASOS) at the Northwest Alabama Regional Airport in the calculation of the mercury emission flux estimates. The airport is located approximately 1-3/4 miles south-

southeast from that plant and meteorological data collected there should be representative of winds at the plant. EPA may be able to obtain 5-minute data for the airport. For those periods in which valid data are collected at both the plant and the airport, the auditors recommend that statistical analysis of these data be performed to assess representativeness of the airport data on a quantitative basis. If they are found to be representative, the airport data can be used for calculating mercury emission flux estimates.

Response 4. In order to assess the reliability of the Climatronics wind speed and wind direction data, the data were compared with National Weather Service data obtained from the Automated Surface Observation System (ASOS) at the Northwest Alabama Regional Airport, located approximately two miles from the project site. Based on two minutes wind averages, there were four days in which the directional trends matched, but where the wind direction data was offset by a consistent factor. Those days and the correction factors applied are shown in Table 2-3 and described in Section 3.2.3 of the final report.

Finding 5. Mercury PICs are calculated using a multipoint calibration whose values are based on a graph of the mercury saturation vapor pressure versus temperature. This graph was provided by OPSIS, the manufacturer of the UV-DOAS instrument. There is no information available about how the pressure values on the graph were obtained, the uncertainty of these values or the traceability of these values to national standards. Recently, Friend et al. of the National Institute of Standards and Technology (NIST) reviewed the available measurements of the vapor pressure of mercury and developed an equation predicting the vapor pressure over a wide range of temperatures. The auditors recommend that the values from the OPSIS graph be compared to the NIST equation to determine whether these values reflect the current state of knowledge regarding mercury vapor pressure. If significant differences are detected, EPA should consider using the NIST equation, rather than the OPSIS values, in the multipoint calibration.

Response 5. This comparison was performed and a graph is attached. The NIST data was generated from "The Vapor Pressure of Mercury", D.G. Friend, M.L. Huber, and A. Laesecke, Physical and Chemical Properties Division, National Institute of Standards and Technology, Boulder, CO 80305 USA, prepared for Western Research Institute under Purchase Order No. 053003, July 2005. The OPSIS data was taken from the hard-print readouts used in this study. The differences in NIST and OPISIS saturated mercury values were deemed to be not significant in the context of this work.

<u>Finding 6.</u> Near-ground mercury concentration measurements were obtained using three 25-meter-long, 1/4-inch ID sampling lines that were joined at the inlet of a Lumex mercury analyzer. The auditors recommend that the sample flow rates through these lines be measured at the conclusion of the project to allow calculation of the sample residence time and to demonstrate that the flow rates are equal in the three sampling lines.

<u>Response 6</u>. The sample floe rates were measured as recommended, reference the attached calibration report (Met Lab ID 03140, 11/16/2006). The flow rates in the three lines were shown to be approximately equal (9.0 $\pm$ 0.25 SLPM). The volume of the 25 m , 0.635 cm dia. tube was 0.792 L indicating an approximate sample residence time of approximately 5 seconds. This residence time was deemed to be not significant in context of this work.