# PM-10 Source Attribution and Deposition Study

**Maricopa Association of Governments**

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sierra research

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# 1. INTRODUCTION

Maricopa County has worked for over 20 years to identify the mix of control measures needed to attain the ambient air quality standard for particulate matter with an aerodynamic diameter of 10 micrometers or less (PM-10). Despite the completion of increasingly comprehensive planning cycles (i.e., inventory development, control measure evaluation, implementation of progressively more stringent controls, modeling of attainment, plan submission to EPA and approval), violations of the PM-10 standards have continued to occur. The result of the continued attainment shortfall has been a “bump up” in nonattainment classification severity and increasingly restrictive planning requirements. In late 2005 and early 2006, numerous exceedances were recorded and it became clear that the previously extended attainment date of December 31, 2006, could not be met. At that point, the nonattainment area became subject to section 189(d) of the Clean Air Act, which requires the preparation of a new State Implementation Plan (SIP) that shows reductions in PM-10 emissions of five percent per year until attainment is reached at all monitors. The new “Five Percent Plan” was due by the end of 2007, one year after the previously scheduled attainment date.

Recognizing the severity of the problem, the impact of the five percent per annum reduction requirement on the community, and the limitations of past planning efforts, the designated Air Quality Planning agency for the region—the Maricopa Association of Governments (MAG)—issued a procurement to (1) identify sources of emissions contributing to high PM-10 concentrations at monitors in the nonattainment area and (2) characterize the deposition of PM-10 particles emitted from those sources. Two respondents were selected to conduct these efforts: Sierra Research, Inc. (Sierra) and Technical and Business Systems, Inc. (T&B Systems). T&B Systems was responsible for ambient data collection efforts and Sierra was responsible for analysis, deposition characterization and air quality modeling. This report documents the results of those efforts.

## 1.1 Background

PM-10 in the nonattainment area is composed primarily of coarse particles (with an aerodynamic diameter ranging between 2.5 and 10 microns) that are typically crustal in nature. Key sources include windblown dust, resuspended road dust (from both paved and unpaved roads), unpaved parking lots, disturbed vacant land, mining operations, construction and agricultural activities (e.g., tilling, harvesting, travel on unpaved farm roads, etc.). While fugitive dust is the dominant source of emissions impacting monitors within the nonattainment area, other sources contributing to PM-10 concentrations include directly emitted PM-10 (e.g., Diesel soot, etc.) and secondary particulates (i.e., particles formed through atmospheric chemical reactions from precursor gases, primarily oxides of nitrogen, oxides of sulfur, and ammonia). Combustion-related particulates such as sulfates, nitrates, and organic and elemental carbons (OC and EC) are typically found in the fine fraction of particulates (i.e., aerodynamic diameter of less than or equal to 2.5 microns).

Previous analyses of PM-2.5 data in the Phoenix area have shown that mobile source exhaust, burning, and industrial sources are important constituents of PM-2.5. EPA designated Maricopa County as an attainment area for PM-2.5 in September 2005. Local monitoring by co-located PM-10 and PM-2.5 monitors confirms that PM-2.5 on high PM-10 days is a small fraction of the PM-10 concentrations. Therefore, the PM-10 problem in the Maricopa County nonattainment area is largely attributable to coarse particles, comprised primarily of geologic material.

High PM-10 concentrations generally occur during fall and winter months (i.e., September through March) on days with stagnant or near-stagnant conditions. Under these conditions, when winds are extremely light and variable, the contributions of local sources are significant. Past efforts to characterize the level of material emitted from these sources have relied largely upon the preparation of detailed emission inventories and the use of air quality modeling to assess the significance of individual sources to impacts recorded at modeling sites exceeding the ambient 24-hour PM-10 standard. Those efforts, however, reached varying conclusions about the significance of local sources versus the transport of material emitted outside of the modeling domain. Since these conclusions directly affect the control measures selected to demonstrate attainment and past efforts incorrectly modeled attainment, MAG determined that a field study was needed to collect measurements of ambient concentrations at locations throughout the area that routinely record the most frequent and highest PM-10 concentrations in the nonattainment area. These measurements could then be combined with meteorological, emissions, and monitoring data to perform air quality modeling and identify which sources impacted monitors under design day conditions. This information in turn could be used to support the selection of the control measures needed to demonstrate attainment.

Insight into which monitors consistently exceeded the 24-hour PM-10 standard is provided in Table 1-1. In 2005 and 2006, most of the PM-10 concentrations that exceeded the 24-hour federal standard occurred on fall and winter days (i.e., November through February) with stagnant or near-stagnant conditions. All but one of the exceedances in 2005 occurred in November and December during a regional drought (i.e., no measurable rain was recorded after October 18, 2005) and stagnant conditions. These monitors, Durango Complex and West 43$^{rd}$ Ave, are located in the Salt River area, a 29-square-mile area that has experienced the highest and most frequent violations of the ambient PM-10 standard. As a result of the history of these monitors and recent exceedances, MAG determined that the study should focus on the collection of measurement, activity, and monitoring data within the Salt River area.

**Table 1-1**
**Summary of PM-10 Measurements Collected at MCAQD[a] Monitoring Sites in 2005 & 2006 (24-hour NAAQS)**

| Site Name | 2005 | | | 2006 | | |
|---|---|---|---|---|---|---|
| | Max (µg/m$^3$) | Average 2$^{nd}$ High (µg/m$^3$) | # of Exceedances | Max (µg/m$^3$) | Average 2$^{nd}$ High (µg/m$^3$) | # of Exceedances |
| Bethune Elementary[b] | 198 | - | 1 | 140 | - | 0 |
| Buckeye[a] | 169 | 158 | 2 | 272 | 192 | 3 |
| Central Phoenix | 125 | 76 | 0 | - | - | - |
| Central Phoenix[c] | 116 | 104 | 0 | 134 | 99 | 0 |
| Chandler | 130 | 115 | 0 | - | - | - |
| Durango Complex[c] | 206 | 200 | 13 | 240[d] | 183 | 9 |
| Dysart | 76 | 68 | 0 | 67 | 55 | 0 |
| Glendale | 84 | 56 | 0 | 60 | 59 | 0 |
| Greenwood | 173 | 95 | 1 | 166 | 141 | 1 |
| Higley[c] | 142 | 121 | 0 | 170 | 166 | 2 |
| Mesa | 86 | 55 | 0 | 75 | 59 | 0 |
| North Phoenix | 81 | 72 | 0 | 79 | 62 | 0 |
| South Phoenix | 147 | 107 | 0 | 132 | 100 | 0 |
| South Scottsdale | 121 | 96 | 0 | 76 | 60 | 0 |
| West Chandler | 94 | 68 | 0 | 77 | 68 | 0 |
| West 43$^{rd}$ Ave[c] | 233 | 200 | 13 | 260[d] | 204 | 18 |
| West Phoenix | 155 | 103 | 1 | 147 | 122 | 0 |
| Total | - | - | 31 | - | - | 33 |

[a] Maricopa County Air Quality Department
[b] Bethune Elementary School is an ADEQ special-purpose monitor located within the Salt River Area.
[c] Indicates a continuous particulate monitor.
[d] Indicates a natural event.

The Durango Complex and West 43$^{rd}$ Ave. monitors were the subject of an extensive Arizona Department of Environmental Quality (ADEQ) report entitled "Revised PM-10 State Implementation Plan for the Salt River Area."[1] The technical documentation for that plan, referred to hereafter as the Salt River Area TSD (for Technical Support Document), described the conduct of an intensive air quality monitoring study in 2002, the development of a detailed emissions inventory, and an extensive modeling analysis of emission sources and control measure commitments that demonstrated attainment of the ambient PM-10 standard in 2006. While exceedances recorded in 2005 and 2006 mooted the need for EPA review and approval of the Salt River Area Plan,[2] the information

[1] Revised PM-10 State Implementation Plan for the Salt River Area, Technical Support Document, Air Quality Division, Arizona Department of Environmental Quality, June 2005
[2] While the ADEQ plan was not approved by EPA, the control measure commitments in the ADEQ Plan were approved by EPA in the Federal Register August 21, 2007.

assembled in the supporting TSD provide an excellent starting point for developing the Five Percent Plan and the modeling analysis of data collected in this study.

## 1.2 Study Goals

The principal goal of this project was to quantify the ambient contributions of significant sources to elevated PM-10 concentrations being measured at monitoring stations in the Salt River area during low wind conditions such as occurred during the fall and winter of 2005/06. During that time the jet stream so continuously followed a northerly track that it prevented storm fronts from passing through the Pacific Southwest and produced very stagnant air conditions in Maricopa County. During these low wind conditions, the atmospheric loading of PM-10 accumulated near significant sources, producing concentrations at nearby monitors that exceeded air quality standards at frequencies not seen in previous winters. The challenge was to determine which sources contributed to these elevated readings and to prepare the way for the implementation of control measures designed to prevent these exceedances from reoccurring.

A second goal of quantifying significant source impacts during high wind conditions was added to the project after commencement. During the late winter and early spring of 2006, exceedances of the federal 24-hour PM-10 standard were recorded on days when high wind conditions coincided with peak hourly ambient concentrations. Because of this relationship, and the fact that meteorological conditions on these days were significantly different from the stagnant conditions recorded on exceedance days earlier in the winter, identifying source contributions—especially those of windblown dust—on high wind days was deemed essential to attainment of the federal standard.

Another goal of the project was to investigate significant findings of the ADEQ's Salt River Area TSD. One of the key conclusions of that study was that a significant fraction of PM-10 measured in the Salt River Area came from sources located outside of the modeling domain. An early task of the project was to determine whether this hypothesis was correct. Correspondingly, questions arose as to whether morning drainage flows down the Salt River (i.e., from east to west) carried suspended particulate from upstream sources to the Salt River modeling domain. Evaluating this possibility was also an early goal of the project.

Another objective of the field study was to examine the causes of the ADEQ modeling shortfall on low wind days. Regression statistics showed very poor correlation between the modeled plus background values versus the monitored concentrations (the mean $R^2$ for all hours modeled was 0.27). This suggested potential problems with the modeling methodology. One issue was the method used to distribute area source emissions, such as those from paved roads and vacant lots, uniformly across 400 meter x 400 meter (0.25 mile x 0.25 mile) grid cells used to represent the modeling domain. It was suspected, due to the low release height of fugitive dust and the settling velocity of PM-10, that the sources producing significant impacts at the two Salt River monitors were sources located very close to the monitors, and that the distribution of emissions from road links spread evenly across grid cells would interfere with accurately quantifying the impacts of roads, unpaved work areas, and agricultural fields near the monitors. Thus, another goal was to determine whether the use of a more spatially accurate emission inventory would improve the correlation between modeled impacts and measured concentrations at each monitor.

Initial review of the hourly PM-10 data collected on low wind design days at both Durango Complex and West 43rd Avenue sites showed that peaks occurred during early morning and late evening periods. This dual peak profile was similar to diurnal traffic flow patterns in the area, suggesting that road travel was a significant source. The morning peaks were substantially higher than those of the evening, suggesting higher silt levels on roads in the morning than in the evening. The evaluation of diurnal silt levels on Salt River roads to determine why evening PM-10 peaks were lower than morning peaks became another goal of the project.

Because the project included an intensive field study phase during similar low wind conditions in the fall and winter of 2006/07 another goal was to use this field study to improve the accuracy of emission factors used in the emission inventory. Since the development of the ADEQ study in 2005, improved technologies for continuously sampling roadway emission rates have been developed. The University of California Riverside (UC Riverside) has employed a SCAMPER (System for Continuous Aerosol Measurement of Particulate Emissions from Roadways) to continuously measure vehicle paved road emission PM-10 emissions in several urban areas in the Pacific Southwest. Additionally, the improving ability of portable continuous particle counters with PM-10 sizing inlets to accurately measure ambient PM-10 concentrations offered new opportunities to isolate source plumes in ways that are impossible with fixed based continuous monitors. As a result it was determined these emerging technologies should be brought into play to add depth and accuracy to the emission inventories of the areas immediately surrounding the Salt River monitors.

A final goal of the project was to quantify the deposition rates of particulate matter at the Salt River monitors, based on the belief that a portion of the paved road silt levels resulted from deposition of fugitive dust emitted by industrial, commercial, and agricultural sources near these roads. The quantification of deposition would also provide a reality check on the deposition rates estimated by the dispersion models used to simulate PM transport from nearby sources to the PM-10 monitors.

Other initial goals included efforts to:

- Interview source operators and property owners for activity data on design days;
- Visually evaluate soil disturbance levels (from Google Earth);
- Collect traffic data;
- Obtain new measurements of roadway emissions via SCAMPER or manual collection method from targeted roads;
- Use results to prepare hourly link-specific emission estimates;

- Install/operate network of deposition monitors during field study period; and
- Contrast deposition gradients with T&B measurements and AERMOD estimates.

## 1.3 Approach

To assist in the planning of monitoring and modeling studies aimed at identifying the significant sources or source categories of PM-10 emissions, a literature search of relevant research documentation was conducted. Past studies of PM-10 emissions in the Salt River were reviewed to determine the extent of available data and conclusions relevant to this study. Similar studies of other fugitive dust areas such as Clark County, Nevada, and the San Joaquin Valley of California were reviewed to evaluate other research methodologies and results.

A field monitoring program was conducted from mid November through mid December of 2006 to respond to the questions raised about the relative contributions of PM-10 sources to high concentrations measured at Salt River area monitors. The monitoring program was conducted in two phases after a review of existing emission inventory and monitoring data. In the first phase, mobile monitoring and visual surveys were conducted within and beyond the boundaries of the proposed modeling domain. In the second phase, plume concentrations downwind of significant sources within the modeling domain were monitored to improve the accuracy of the emission inventory used for modeling.

The monitoring sites selected for analyses in the field study were the Durango Complex and West 43rd Avenue sites operated by the Maricopa County Air Quality Department. Initial modeling of source impacts using the ADEQ modeling files indicated that sources within approximately 2 miles of each monitor were responsible for the vast majority of concentrations recorded. This area generally conformed to the modeling domain selected by ADEQ for analyses published in the 2005 PM-10 SIP Technical Support Document. As a result, this modeling domain was selected as the area in which an intensive field monitoring study would be performed during November and December of 2006.

Described below is the instrumentation that was assembled and operated to collect ambient measurements of PM and meteorological activity. Appendix A provides a more detailed description of the field instrumentation, the procedures used to quality assure the equipment employed in the study, and a log of field observations made during both phases of the study.

Maricopa County Monitoring Network Enhancements – To better understand low wind speed conditions, the Maricopa County monitoring group added higher time resolution time measurements with 5-minute averages (instead of hourly average values). Modifications were also made to the PM-10 measurements to record 5-minute averages from the TEOM samplers. These modifications were made to the Durango Complex, West 43rd Avenue, West Phoenix, Central Phoenix, South Phoenix and Greenwood stations.

West 43rd Monitoring Site Enhancements – In addition to those described above, the ADEQ provided an AeroVironment model 4000 minSodar for measurement of winds and mixing in the lowest 200 meters of the atmosphere. The system was installed at the outset of the project and operation was verified by T&B Systems prior to the start of the data collection effort. The system was programmed to collect and report 10-minute average winds and a facsimile display of the acoustic backscatter. An automated digital camera was also installed at the site to document the environment surrounding the West 43rd Ave station. High temporal resolution pictures were taken at intervals of 3-30 seconds depending on the pointing direction of the camera. More than 400,000 pictures were taken over the course of the study.

During the last week of the second phase of the field study, Arizona State University installed a particle LIDAR unit at the West 43rd Avenue station. The LIDAR performed horizontal and vertical scans of the atmosphere to provide relative concentrations of particulate matter around the site. It also estimated the wind field through an analysis of Doppler shifted signals from LIDAR pulses.

Temporary Fixed Monitor at 35th Avenue – A key issue that arose after the first phase was whether the high PM-10 concentrations recorded at West 43rd Avenue and Durango Complex monitors were the result of local sources adjacent to the sites or sources located farther away, but within the Salt River area. To help answer this question, a monitoring site was established near the Salt River, east of 35th Avenue and away from any local sources. Figure 1-1 displays the location of this site as well as the location of the West 43rd Avenue, Durango Complex, and Bethune Elementary School monitors.

**Figure 1-1**
**Location of Fixed Monitoring Sites Within the Salt River Area**

The 35th Avenue monitoring site was equipped with a DustTrak configured to measure PM-10 concentrations at 5-minute and 60-minute intervals. Wind measurements were made with an RM Young Wind Monitor AQ wind speed and wind direction sensor. Meteorological measurements were averaged over 5-minute intervals.

Mobile Monitoring – Two vehicles were equipped to collect ambient measurements. The primary vehicle, referred to as Van 1 or the Pilot, performed measurements during both phases of the study. The second vehicle, referred to as Van 2 or the Kia, was added for sampling in the second phase. Table 1-2 provides a summary of the instrumentation installed in each of the vehicles. The Pilot collected data in both mobile (while driving) and fixed (at pre-selected sites) mode operation. The primary use was to map the region and to obtain relative concentrations throughout the Salt River area and identify "hot spot" areas to be studied in more depth. The Kia was used to obtain the particle size distribution measurements. Data were collected and stored in two-second intervals, with all values stored in the data logger and backup computers installed in each of the vans.

**Table 1-2**
**Summary of Measurement Equipment Installed in Sampling Vans**

| Measurement Equipment | Pilot (Van 1) | Kia (Van 2) |
|---|---|---|
| TSI 8520 DustTrak (PM-10) | X | X |
| TSI 8520 DustTrak (PM-2.5) | X | X |
| TSI 3321 Aerodynamic Particle Sizer | | X |
| Airmetrics minivol (PM-10) | X | |
| Airmetrics minivol (PM-2.5) | X | |
| Garmin GPS receiver (van 3-D position) | X | X |
| Campbell Scientific CR1000 (data logging) | X | X |
| RM Young Wind Monitor (wind speed & direction) | X | |
| RTD temperature sensor (outside air temperature) | X | |
| RTD Young Electronic Compass (van direction) | X | |
| Intellinet Network IP camera with recording laptop | X | |

Traffic Measurements – Under a separate procurement MAG had contracted with Field Data Services to collect traffic counts (some of the counters also provided information on vehicle size) on roads traversed by UC Riverside's SCAMPER vehicle. As part of this contract, MAG also tasked Field Data Services to collect traffic count data on a large number of road links within the Salt River modeling domain. These counts were also collected in December 2006.

Activity Measurements – Two Sierra subcontractors with offices in or near Phoenix − SOTA Environmental, Inc., and Applied Environmental Consultants, Inc. (AEC) –

conducted interviews of specific facilities, collected data on off-road vehicle activity, recorded opacity measurements of facility plumes, and obtained copies of permit files, among other tasks.

Particle Deposition – AEC staff constructed stands to support dust jars that were sited at four locations surrounding each of the Durango Complex and the West 43rd Avenue monitoring sites. Once approval for locating the stands was received from responsible agencies, dustfall jars were installed on these stands for a week at each location. AEC retrieved the jars and used distilled water to remove deposited dust from each dust jar at the two network locations. The samples were sent to Particle Measurement Technology Co. for measurement using an electro-optical particle analysis system.

Silt Measurements – Under a separate procurement, MAG had contracted with the University of California (UC) at Riverside to operate its mobile monitoring SCAMPER vehicle to measure PM-10 emissions from paved roads over a 100+ mile route that traversed the PM-10 nonattainment area. Separate traverses of this route were conducted in each of the seasons in 2006. Since only a small portion of the route fell within the boundaries of the Salt River modeling domain, a separate subcontract was established with UC Riverside to operate the SCAMPER vehicle multiple times over five pre-selected routes on roads located within the Salt River Area during a one-week period in December 2006.

Subsequent analysis of the SCAMPER measurements, which are based on contrasting PM-10 measurements at front and rear of the vehicle, determined that this measurement method was fundamentally different from the vacuuming method employed in past ADEQ Salt River road silt measurements. For this reason, AEC was tasked with collecting silt measurements on a representative sample of roads within the Salt River Area using the traditional vacuuming methodology.

As can be seen from the description above, a variety of ambient, meteorological, emission factor, activity, and visual measurements were collected by a mixture of contractors and agencies. The data were transmitted to Sierra where it was organized into appropriate databases for analysis. The data were analyzed using a variety of techniques. One of the analytical tools used to identify the locations of significant PM-10 sources impacting the two monitoring sites was non-parametric regression. This work was performed by Rincon Ranch Consulting (RRC), a statistical analysis subcontractor to Sierra. Preliminary results were forwarded to appropriate contractors and the Air Quality Planning Team for review and comment. Presentations were also made to MAG's Technical Advisory Committee and interested parties identified by MAG.

The next step was to use the results of the analysis to construct revised emission inventory estimates for sources located within the Salt River modeling domain. The results were contrasted with those prepared in ADEQ's Salt River Area TSD to assess the impacts of the revisions.

A review of available air quality models meeting EPA guidelines for dispersion modeling was conducted.  Two models were evaluated and configured to represent a subset of sources located within the Salt River modeling domain.  A review of the concentrations recorded during the field study and related meteorological conditions was performed and an episode representative of low wind conditions was selected for modeling.  The performance of the two models under these conditions was prepared and AERMOD, an EPA regulatory model, was selected to evaluate source-specific contributions to the Durango Complex and West 43rd Avenue monitoring sites.

## 1.4  Report Organization

Following this introduction, Chapter 2 provides a summary of the literature search of past research studies of PM-10 emissions in the Salt River, and other areas with fugitive dust problems such as Clark County, Nevada, and the San Joaquin Valley of California.  The results of the analyses of ambient measurements are presented in Chapter 3.  Similarly, a summary of the analysis of data collected to characterize individual source emissions is presented in Chapter 4.  Chapter 5 presents the results of the air quality modeling, including episode selection, inventory development, and model performance.  The study conclusions are presented in Chapter 6.  The appendices include a more detailed summary of the T&B field study, the air quality modeling comparison, silt measurements, and particle measurements.

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# 2. LITERATURE REVIEW

Numerous violations of the 24-hour PM-10 ambient air quality standard were recorded in the Salt River area of south central Phoenix during the fall and winter of 2005/06. From past studies, fugitive dust sources were the apparent dominant sources responsible for causing these violations. The area contains a mix of sand and gravel operations, agricultural lands, exposed dry river bed, industrial operations, trucking centers, residential and commercial construction sites, and landfills. Area roads are used by high fractions of heavy-duty trucks that access unpaved areas and transfer soils onto paved surfaces. Within the Salt River area, sources of disturbed soil particles are ubiquitous.

To assist in the planning of monitoring and modeling studies aimed at identifying the significant sources or source categories of PM-10 emissions, a literature search of relevant research documentation was conducted. Past studies of PM-10 emissions in the Salt River were reviewed to determine the extent of available data and conclusions relevant to this study. Similar studies of other fugitive dust areas such as Clark County, Nevada, and the San Joaquin Valley of California were reviewed to evaluate other research methodologies and results. Finally, research reports relating to alternative monitoring and modeling approaches not previously used in regional PM-10 monitoring and modeling efforts were reviewed to assess the feasibility and efficacy of applying new methods to solve the Salt River source-receptor relationship questions.

## 2.1 Attainment Demonstrations

Attainment demonstrations are the analyses required by the federal Clean Air Act to explain how air quality violations occur in each designated nonattainment area, and how proposed control programs will reduce emissions to levels that will assure attainment of ambient air quality standards. To identify promising methodologies for determining the significant sources causing PM-10 violations in the Salt River area, the attainment demonstrations of three serious PM-10 nonattainment areas were reviewed: Maricopa County, Arizona; Clark County, Nevada; and the San Joaquin Valley in California.

2005 ADEQ Study – In 1999, U.S. EPA required Arizona to submit an amended State Implementation Plan for the Salt River portion of metropolitan Phoenix demonstrating attainment of PM-10 ambient air quality standards by 2006. To assist in the analysis of PM-10 violations and design of appropriate control measures, the Arizona Department of Environmental Quality conducted an extensive study of Salt River sources and air quality. A final report, published in 2005, describes the analyses conducted and the conclusions reached.[1]

The 2005 Salt River PM-10 study consisted of three primary tasks:

- An ambient air quality study, including monitoring from April to December 2002;
- A complete emission inventory of the study area for calendar year 2002; and
- Air quality modeling of current and future year emissions.

A review of historical ambient air quality data in the Salt River area indicated that elevated concentrations occur during high wind conditions, typically during the spring, and during winter stagnant air conditions.[2] During the low wind speed design days, hourly PM-10 concentrations tended to be highest during the four hours after sunrise and during four hours after sunset. This diurnal trend closely matches traffic flow patterns in the Phoenix area and suggests that traffic flows may contribute significantly to measured PM-10 peaks.

In the modeling effort undertaken, emission rates for an extensive set of sources were estimated during each of the spring and winter of 2002, and one design day in each season was studied extensively to evaluate contributions from significant sources at nonattainment monitoring sites. Background PM-10 levels were estimated from concurrent data recorded at monitoring sites outside the Salt River modeling domain and added to the modeling results. The modeled results at two monitoring sites—Durango Complex and West 43d Avenue—were compared with continuous PM-10 monitoring data on an hour-by-hour basis to evaluate the accuracy of the modeling effort. For the high wind days, the correlation coefficient ($R^2$) between modeled and monitored concentrations was 0.58. On these days, the model predicted roughly 20% of the measured concentrations and the remaining 80% was estimated from upwind monitoring data to be urban background. Based on several parameters, the modeling of high wind days was judged to be a success.

On the low wind days, the $R^2$ correlation coefficient between modeled and measured PM-10 concentrations was 0.03, almost indicative of no relationship at all. This result suggests that either significant problems existed with the emission inventory or that the ISCST dispersion model failed to accurately represent air quality impacts during low wind speed conditions. On the low wind design day, background PM-10 concentrations were also estimated to be several times greater than modeled impacts at the two monitors. Unlike the high wind data, the variations in background were not at all in syncopation with the modeled impacts. The fact that the background was so variable on this design

[1] "Revised PM-10 State Implementation Plan for the Salt River Area, Technical Support Document," Arizona Department of Environmental Quality, Air Quality Division, September 2005.
[2] Because the current study focuses primarily on PM-10 exceedances that occurred during stagnant winter conditions in December 2005 through March 2006, the literature review likewise focuses primarily on low wind speed conditions.

day was unexpected and also raised significant questions about source-receptor relationship understandings.

Clark County PM-10 Nonattainment Plan – The Clark County, Nevada PM-10 nonattainment plan was approved by EPA on May 3, 2004. The nonattainment plan used an emission inventory rollback method to demonstrate attainment of the annual and 24-hour PM-10 standards. Only one monitoring site, at the J.D. Smith School, recorded an exceedance of the annual standard during the baseline period (1997–1999). This site and five others reported exceedances of the 24-hour standard. All of the exceedances of the 24-hour standard occurred on relatively high wind days. Clark County Department of Comprehensive Planning (CCDCP) concluded from analysis of monitoring data that PM-10 impacts at violating monitoring sites were driven by sources located within 2 kilometers of each monitoring site. CCDCP assumed that the non-background portion of measured PM-10 was proportional to the individual emission contributions of sources within the 2-kilometer microinventory area surrounding each nonattainment monitoring site. Background was assumed to be equal to the lowest PM-10 measurement recorded at any monitoring site on the design day or year plus an annual average aerosol contribution of 3.5 $\mu g/m^3$ as determined by Desert Research Institute through chemical mass balance modeling. The emissions reductions estimated for application of candidate control measures, as a fraction of the total emission inventory of each microinventory area, were applied to the design day and year PM-10 concentrations to demonstrate attainment. The absence of exceedances during low wind, stagnant winter conditions means that the conclusions drawn and the control measure proposed in the nonattainment plan were not of significant use in resolving winter exceedances in the Salt River area.

The assumption in the plan that significant fugitive PM-10 sources impacting monitors were located within a 2-kilometer radius of affected monitors was based on a dispersion modeling analysis. This analysis, conducted by Desert Research Institute for the Clark County Health District in 1997, concluded that sources more than 5 miles away from a monitor had minimal impact at the monitor site and that sources within 2 kilometers of a monitor drove measured concentrations.[1] Interestingly, this analysis also reported that modeled PM-10 concentrations at monitors exceeded measured values by factors of 2 to 4. This result was attributed to uncertainties in emissions and emission variability not captured by the model. The fact that modeled impacts exceeded monitored impacts in this study suggests that dispersion models do not invariably underpredict impacts as was the experience in the Salt River study, and thus should not be eliminated as analytical tools in identifying significant sources during the fall and winter of 2005/06 episode in the Salt River area.

San Joaquin Valley PM-10 Nonattainment Plan – PM-10 air quality in the San Joaquin Valley is driven by a combination of emissions and meteorological conditions. During the summer and early fall, fugitive dust sources dominate the emission inventory and PM-10 measurements. In the late fall and winter, substantial secondary aerosol is formed and regional emissions of fine particles, primarily composed of organic and elemental

[1] "Middle- and Neighborhood-Scale Variations of PM-10 Source Contributions in Las Vegas, Nevada," J. Chow et al, *Journal of the Air & Waste Management Association*, 49:641-564, June 1999.

carbon, tend to accumulate under conditions of low inversion heights and stagnant wind conditions.

Two areas in which fugitive dust emissions have contributed significantly to measured violations of the federal 24-hour PM-10 standard include Bakersfield and Corcoran.[1] Both of these sites were subjects of a series of studies in 1995 and 1999. In 1995, saturation monitoring of fine and coarse PM, and their constituents, was conducted in Corcoran, a small city surrounded by agricultural lands having high silt contents. Agricultural activities within the community, including a large cotton gin, and in the surrounding area caused Corcoran to register some of the highest PM-10 concentrations in the San Joaquin Valley. A saturation study in 1995 concluded that local sources within 1 km of the central community monitor dominated PM-10 readings during the fall, but that regional sources of fugitive dust also provided significant contributions.[2]

A second effort to determine local versus regional contributions to crustal PM-10 concentrations in Corcoran was conducted in the fall of 2000.[3] In this study, samples of ambient PM-10 and bulk soils in and about Corcoran were analyzed using scanning electron microscopy. Particle photographs were taken and the elemental composition of scanned particles was determined. The ambient particle and bulk soil elemental signatures were imported into a chemical mass balance model and evaluated to determine the soil source of ambient PM-10. The conclusions were that local and regional soils were equally dominant at the Corcoran site recording the highest PM-10 concentrations, but that regional soils were the dominant source at the other non-industrial monitoring sites in the community.

More recently, a plan for evaluating the relative contribution of local and regional fugitive dust sources to PM-10 concentrations measured in central Bakersfield was submitted to the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD).[4] This survey-level evaluation of 10 years of data from two monitors located in the metro-Bakersfield PM-10 area concluded that emissions from agricultural operations were the key source impacting regional PM-10 levels. Seasonal polygons, scaled to airport windroses, were constructed to represent 24-hour "airshed catchments" to define the average maximal area from which a PM-10 particle could be transported to impact each monitor. Analysis of activities from selected sources (not including unpaved roads or combustion emissions) within the polygons was used to assess source significance. The principal working hypothesis to be tested in Phase 2 was that conveyance of PM-10 emissions into the metro area from agricultural sources located

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[1] "2003 PM-10 Plan," San Joaquin Valley Unified Air Pollution Control District, December 2003, *http://www.valleyair.org/Air_Quality_Plans/2003%20PM-10%20Plan%20Amended.pdf*

[2] "California Regional PM-10/PM-2.5 Air Quality Study, 1995 Integrated Monitoring Study Data Analysis, Spatial Representativeness of Monitoring Sites and Zones of Influence of Emission Sources," prepared for the San Joaquin Valleywide Air Pollution Study Agency by Envair, July 1998.

[3] "Apportionment of Ambient PM-10 Crustal Component Using SEM Data – Corcoran Fall 2000 Study," prepared for California Air Resources Board by RJ Lee Group, March 2003.

[4] "Phase One Spatial Analysis of Metro-Bakersfield PM-10," Prepared by Hydro Bio Advanced Remote Sensing for Southern California Edison, Kern Council of Governments and San Joaquin Valley Air Pollution Control District, March 2005.

within the polygons increased summer to fall. This resulted in "enrichment" of particles in the metro area that could be readily entrained. Vehicles were thought to be the principal cause of entrainment.

This study has limited utility to the Salt River area. First, the analysis failed to assess the contribution of several potentially significant sources. Second, the methodology of assessing source significance (i.e., use of satellite data to quantify potential emissions from different land uses) is not directly applicable, particularly since the critical issue in the Salt River is establishing a link between source activity and localized diurnal emissions.

## 2.2 Fugitive Dust Monitoring Research

Several studies of fugitive PM-10 transport have been published in the past several years. This work has been motivated by the need to reconcile the contributions of fugitive dust sources to emission inventories and to speciated ambient PM-10 measurements. In several analyses, the portion of ambient PM-10 consisting of soil contributions has been found to be approximately 25% of the fractional contribution of fugitive dust sources to PM-10 emission inventories.[1]

A Desert Research Institute (DRI) study conducted at a southwest military base shows that surface roughness plays a significant role in the deposition and removal of fugitive dust during transport.[2] Over undulating dunes no greater than 0.3 meters in height, and in neutral stability atmospheric conditions, less than 9.5% of PM-10 was removed from plumes at 100 meters downwind of an unpaved road. The PM-10 deposition rate predicted by a Gaussian plume model, such as ISCST3, for the same transport distance is approximately 5% for the meteorological conditions existing during the field study.

In a comparison study by Veranth conducted over artificially created rough terrain and stable atmospheric conditions, 86% to 89% of PM-10 generated by unpaved road travel was removed within 95 meters of transport downwind from the source.[3] The rough terrain was created by placing 10 cargo containers, spaced 6.3 meters apart, in a row perpendicular to the roadway to simulate an urban housing environment. This caused particulate entrained in eddies downwind of each container to settle out of the air due to the stilling effect on air movement of the cavities between the containers. The deposition rate predicted by ISCST3 for these calmer conditions, and for a 95-meter transport distance, was approximately 30%. This type of plume model is not configured to account for roughness height (the height below which the horizontal wind velocity is essentially

[1] "Reconciling Urban Fugitive Dust Emissions Inventory and Ambient Source Contribution Estimates: Summary of Current Knowledge and Needed Research," prepared by for the U.S. Environmental Protection Agency by Desert Research Institute, May 2000.
[2] "Deposition and Removal of Fugitive Dust in the Arid Southwestern United States: Measurements and Model Results," Etyemezian, V. et al, *Journal of the Air & Waste Management Association*, Vol. 43: 1099-1111, September 2004.
[3] "Vehicle-Generated Fugitive Dust Transport: Analytic Models and Field Study," Veranth, J.M. et al, *Atmospheric Environment*, Vol. 37:2295-2303, 2003.

zero). These studies suggest that PM-10 removal in the field is greater than that predicted by ISCST3, and varies significantly with roughness height and atmospheric stability conditions. With respect to the transport of PM-10 in developed urban areas, the Veranth study indicates that regional transport of fugitive dust generated by sources within the developed area would not be transported any substantial distance due to impaction and deposition. This result suggests that transport of coarse fraction PM-10 across the developed portion of Maricopa County to the Salt River area is very improbable.

A literature review conducted by DRI to assess the differences between soil contributions to PM-10 emission inventories and ambient concentrations also supports limits on the transport distance of fugitive dust.[1] After identifying an insufficient accounting in the research literature for injection heights, deposition losses, and horizontal impaction losses in dispersion models, the authors suggest that a first approximation for transportable dust is an assumption that all particles within 2 meters above ground level do not travel more than a few kilometers from emission sources. Such particles will generally be produced by groundlevel fugitive dust sources during stable atmospheric conditions, such as those found in the Salt River area during last winter's series of exceedances.

## 2.3 Source-Receptor Modeling Approaches

The use of Gaussian dispersion models to assess fugitive dust impacts during low wind conditions is problematical at best, based on the lack of correlation with measured concentrations reported in the ADEQ Salt River study and the analyses of ambient air quality data in Corcoran, California. Chemical mass balance models are also severely limited in identifying separate fugitive dust source-receptor relationships due to the homogeneity of soil elemental signatures over the limited influence zones near monitoring sites. As a result, other analytical tools were reviewed in this literature review for usefulness in quantifying individual source impacts at monitoring sites.

Positive Matrix Factorization – Positive matrix factorization (PMF) is a statistical approach used to identify the elemental signatures of significant sources.[2] Because this method assumes that the elemental signatures of significant sources are sufficiently unique to be separately distinguishable, the use of this method has very limited applicability to PM-10 monitoring datasets dominated by fugitive dust source soil signatures of limited variability. Also, no PM-10 elemental data were collected during the episodes in the fall and winter of 2005/06 in the Salt River area and no comparable data were collected during the 2006/07 field study period. As a result, use of this analytical approach will not be useful in identifying significant fugitive PM-10 sources in the Salt River area at this time.

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[1] "Reconciling Urban Fugitive Dust Emissions Inventory and Ambient Source Contribution Estimates: Summary of Current Knowledge and Needed Research," prepared by for the U.S. Environmental Protection Agency by Desert Research Institute, May 2000.
[2] "Initial Exploration of Advanced Data Analysis Methods to Assist Air Quality Management," prepared by Philip K. Hopke for the California Air Resources Board, 2005.

Nonparametric Regression – Nonparametric regression is a form of regression analysis in which the predictor does not take a predetermined form but is constructed according to information derived from the data. In an initial study, nonparametric regression was used to identify the contribution of emissions from a large petrochemical facility to ambient cyclohexane concentrations measured in an industrial area.[1] In subsequent studies, the authors have evaluated contributions of large industrial and area sources on ambient concentrations of several non-reactive pollutants measured near large airports in Hong Kong and Los Angeles.[2] While this approach appears to offer promise in evaluating the impacts from nearby fugitive dust sources in the Salt River area, it is limited to the identification of sources lying less than one hour's distance by wind transport of a monitor as the approach cannot account for multi-hour wind trajectories from a source to a receptor.

A number of source-receptor studies of PM-10 were reviewed in this literature search. Many rely on chemical analyses to provide useful signatures of significant sources. These studies typically involve areas in which emission inventories are dominated by one or more large industrial sources. Such studies have limited applicability to the Salt River area, as emissions in this area are dominated by fugitive dust sources that cannot be distinguished from each other by chemical signature.

Trajectory Models – Trajectory models are used to describe the paths air parcels take, and have served to identify the potential locations of significant sources impacting monitoring sites. In many studies, these models have been run over domains of several hundred kilometers to identify regional or continental air quality influences. No study of neighborhood scale impacts being evaluated by trajectory model was found in the literature search. Also, most of the studies reviewed relied on three-dimensional wind field models to identify the vertical component of long distance transport. Such wind field data are not currently available for the design day period in the fall of 2005. The use of a simplified trajectory model using two-dimensional wind data from the Salt River monitoring sites may assist in identifying potentially significant sources of fugitive PM, as vertical mixing on the neighborhood scale and during winter inversion conditions is very limited.

## 2.4 Conclusions

The literature review produced mixed results with respect to the challenges posed by fugitive dust sources in the Salt River area. First, with respect to the domain over which significant emission sources affecting a particular monitoring site may be deployed, the literature suggests both that very localized PM-10 sources dominate nearby air quality on low wind days, but also that regional sources play a role in contributing to exceedances of

[1] "Locating Nearby Sources Of Air Pollution By Nonparametric Regression Of Atmospheric Concentrations On Wind Direction," R.C. Henry et al, *Atmospheric Environment*, Vol. 36 (2002) 2237-2244.

[2] "Identifying The Impact Of Large Urban Airports On Local Air Quality By Nonparametric Regression," K.N. Yu et al, *Atmospheric Environment*, Vol. 38 (2004) 4501-4507.

the federal 24-hour ambient air quality standard, especially under higher wind conditions. Second, no single analytical tool appears to have the power to correctly and separately identify the significant sources impacting a PM-10 monitor. As a result, several analytical approaches were employed in this study and the weight of evidence from these approaches was used to quantify PM-10 source-receptor relationships in the Salt River area.

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# 3. DATA ANALYSIS – AMBIENT MEASUREMENTS

As discussed in Chapter 1, the field study conducted in November/December 2006 was designed to collect data on meteorology, ambient concentrations, particle size distributions, particle deposition, and source-specific activity within the Salt River area. This required a coordinated effort from Sierra, T&B Systems, MAG, Maricopa County, and several subcontractors. The collected data were subjected to a variety of analytical techniques to gain insight into the causes and conditions producing elevated concentrations as well as the behavior of suspended particles during exceedance conditions. Presented below is a summary of the results of the analyses of ambient measurements. A summary of the results of analyses of data needed to characterize source specific activity and emissions is presented in Chapter 4.

## 3.1 Particle Size Distribution

To initially assess the contribution of secondary aerosol to peak PM-10 concentrations, the continuous PM-2.5 and PM-10 data collected by MCAQD in the Salt River area were reviewed. MCAQD monitored PM-2.5 continuously using TEOMs at the Durango Complex and West Phoenix sites in 2005 and 2006. Because of a calibration problem, PM-2.5 data collected prior to January 17, 2006, at the Durango Complex monitor were invalidated by MCAQD. Analysis of the remaining data at the Durango Complex site revealed ratios between PM-2.5 and PM-10 hourly concentrations that are shown in Figure 3-1.

This figure shows that PM-2.5 to PM-10 ratios decline as PM-10 concentrations rise, suggesting that secondary aerosol and combustion particulate do not constitute significant components of PM-10 on winter exceedance days.

To examine the same relationship just outside the Salt River modeling domain, similar data were compiled for the West Phoenix site. At this location, MCAQD collected valid hourly PM-2.5 and PM-10 data throughout the three months of stagnant weather that were the focus of this study—December 2005 through February 2006. The PM-2.5 to PM-10 relationships at this site are shown in Figure 3-2.

The data from the West Phoenix site show much lower contributions of PM-2.5 to PM-10 when PM-10 concentrations are high, and that PM-10 peaks occur less frequently than at the Durango Complex. A plot of PM-10 concentrations between January 17 and February 29, 2006, at the two sites is shown in Figure 3-3.

**Figure 3-1**
**Average Ratio of PM-2.5/ PM-10 for**
**Hourly PM-10 Concentrations Exceeding Threshold Value**
**Durango Complex – January 17, 2006 to February 28, 2006**

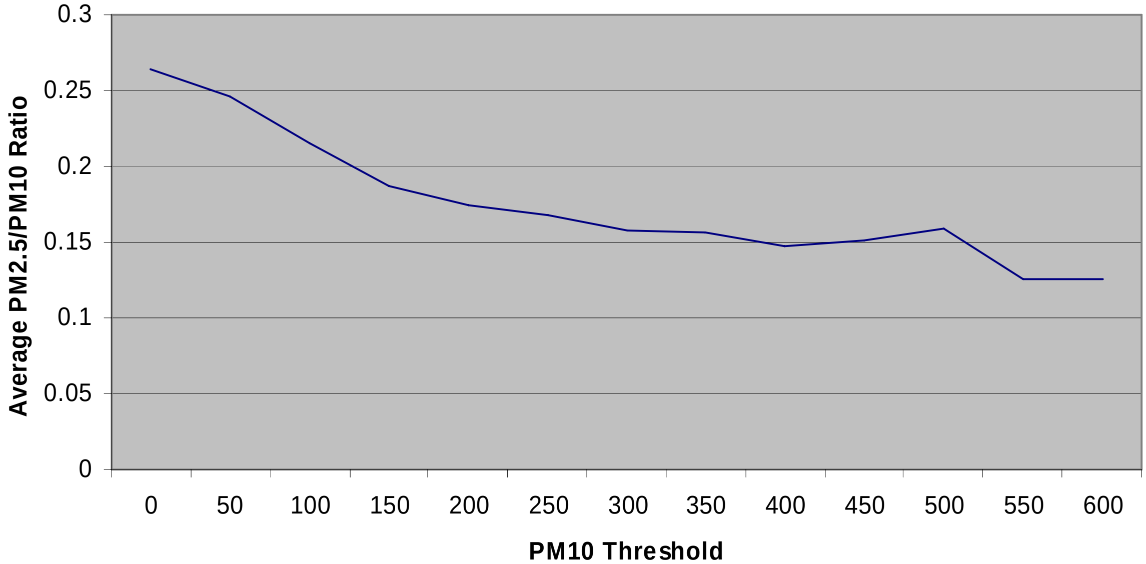



**Figure 3-2**
**Average Ratio of PM-2.5/ PM-10 for**
**Hourly PM-10 Concentrations Exceeding Threshold Value**
**West Phoenix – December 1, 2005 to February 28, 2006**

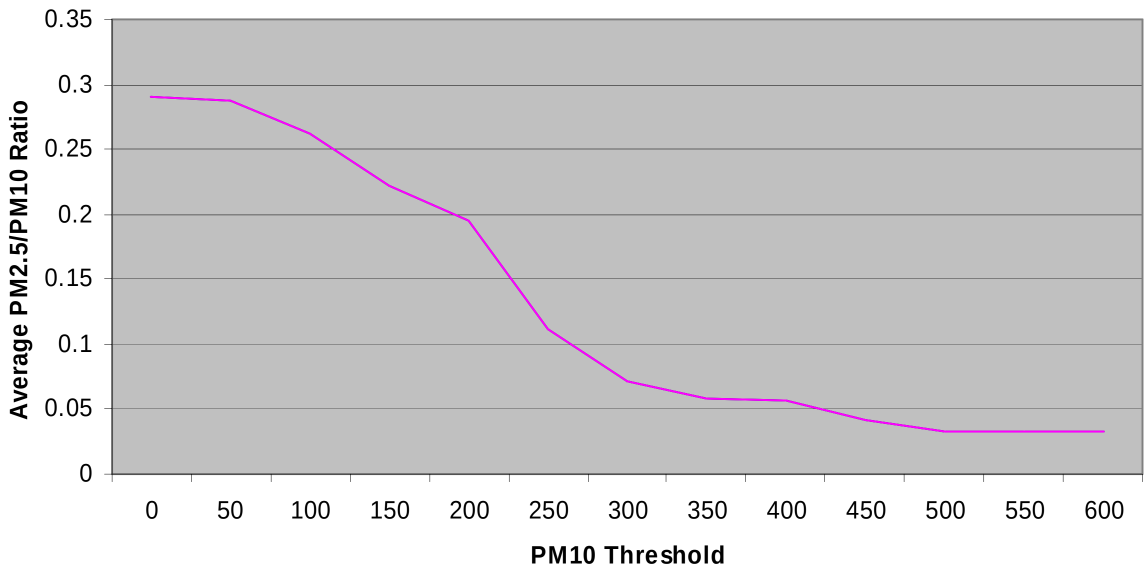
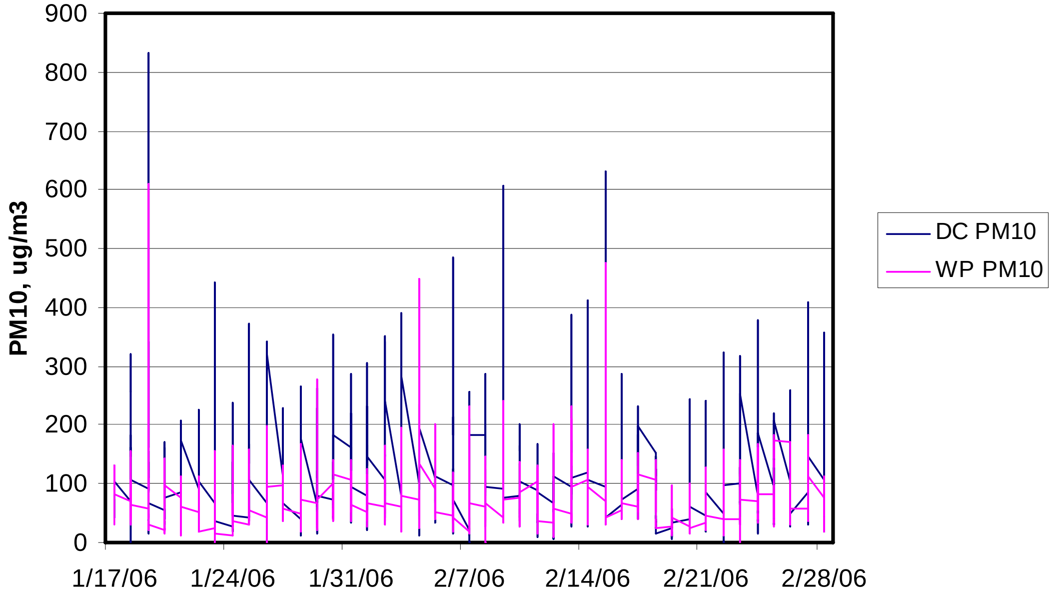
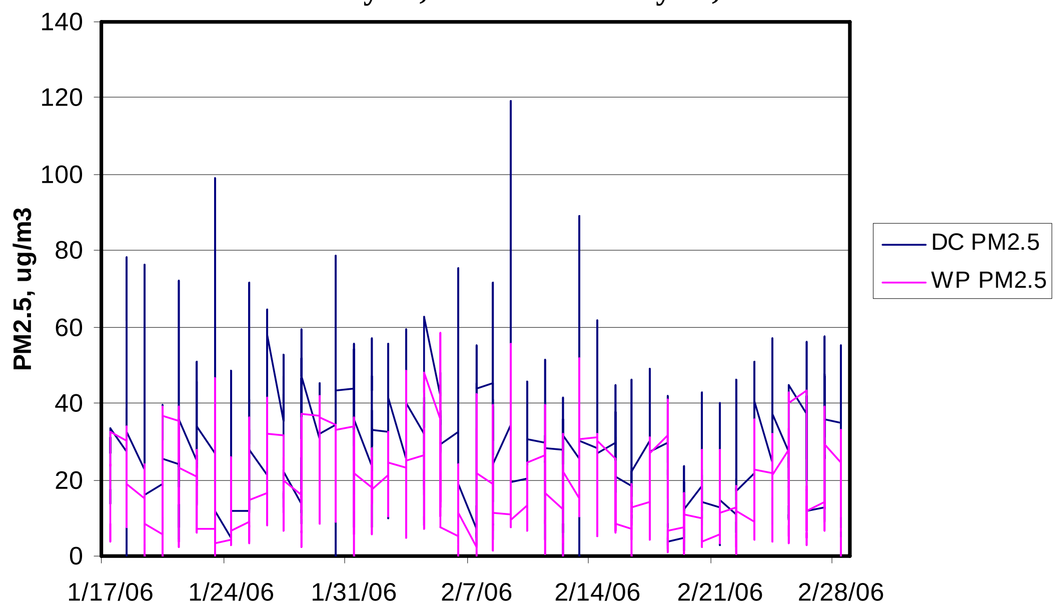


**Figure 3-3**
**Hourly PM-10 at Durango Complex and West Phoenix**
**January 17, 2006 to February 28, 2006**




Similarly, PM-2.5 concentrations at the West Phoenix site are lower than those recorded at Durango Complex during winter months. Plots of hourly PM-2.5 concentrations at the two sites for the January 17 – February 28, 2006 period when valid data were being recorded at both sites are presented in Figure 3-4.

**Figure 3-4**
**Hourly PM-2.5 at Durango Complex and West Phoenix**
**January 17, 2006 to February 28, 2006**



The monitoring data from this period suggest that PM-2.5 concentrations in the Salt River area are locally generated and are not the result of emission transport from outside the modeling domain. By virtue of the higher PM-10 concentrations at Durango Complex in relation to those at the West Phoenix, the same can be said of PM-10 transport from north of the modeling domain.

During the December 2006 portion of the intensive Salt River Area field study, T&B Systems used a multichannel particle counter to sample ambient particulate concentrations by particle size range in source plumes. The instrument used to conduct this monitoring, a TSI Aerodynamic Particle Size (APS) Counter, recorded particle counts in 52 diameter ranges extending from 0.5 to 20.0 microns. For this study, only the counts of particles less than or equal to 10 microns were analyzed.

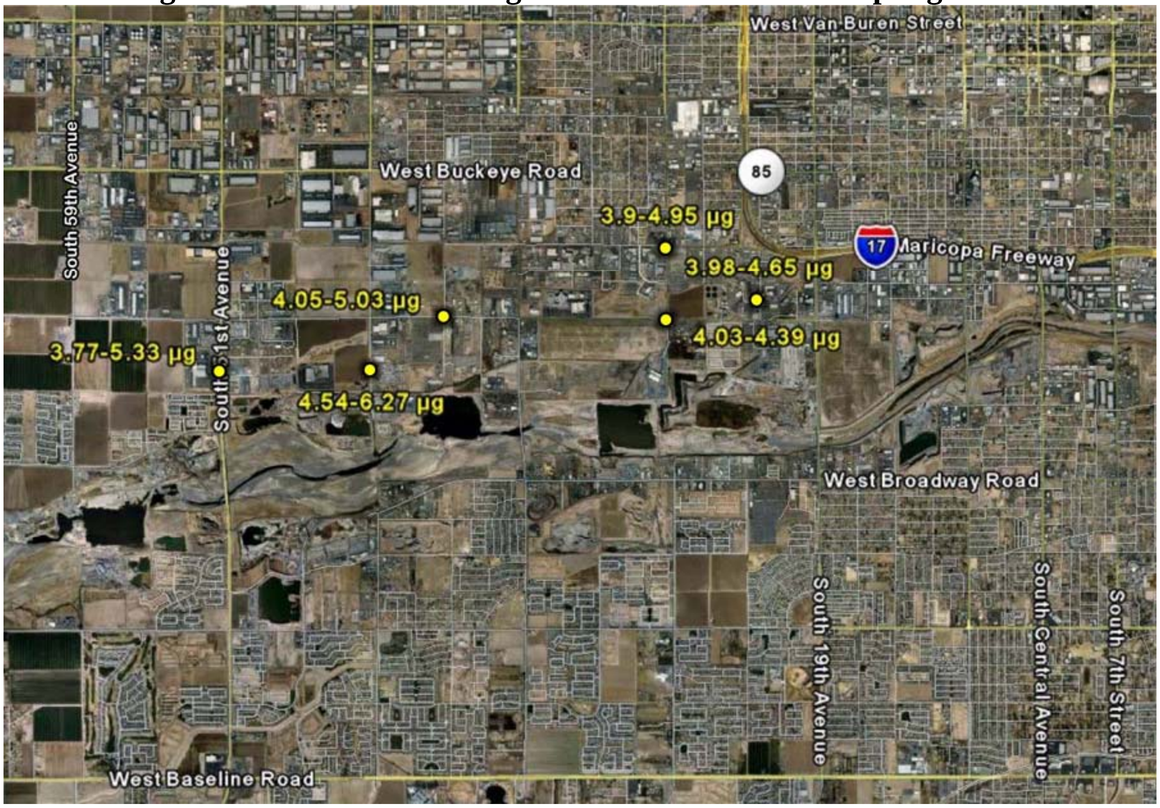
The APS particle counter does not operate well while in motion. As a result, particle counts were conducted only when the T&B vehicle carrying the instrument was stationary at discrete sampling locations. Particle size distributions were measured at the following locations in the Salt River Area:

- West and east of 51$^{st}$ Avenue near Lower Buckeye Road;
- Downwind of an agricultural tilling operation near 43$^{rd}$ Avenue and Elwood Street;
- North and south of Lower Buckeye Road at 38$^{th}$ Avenue;
- East and south of the Durango Complex monitoring site near 27$^{th}$ Avenue and Durango Street;
- North of Lower Buckeye at 27$^{th}$ Avenue; and
- West of 22$^{nd}$ Avenue near the City of Phoenix Fire Department Training Facility.

A map of these monitoring locations, showing the ranges in average particle diameters recorded at sites near each monitoring location, is shown in Figure 3-5.

The particle size distributions measured at these locations were strikingly similar to each other with one exception. One of three locations downwind of the agricultural tilling operation had a distribution weighted more toward larger particle sizes, probably because this one location—of all of the locations monitored—was directly in the downwind plume of a source producing substantial visible dust emissions. The average diameter of particles less than or equal to 10 microns, at locations other than in the agricultural tilling plume, varied between 3.8 and 5.0 microns. The average particle diameter in the tilling plume was 6.3 microns. These results suggest that particles above about 7 microns in diameter settle out of the air relatively quickly in the Salt River and that PM-10 ambient concentrations are dominated by particles from 3 to 7 microns in diameter.

**Figure 3-5**
**Average Particle Diameter Ranges at Salt River Area Sampling Locations**




As discussed in Section 3.3, particles in this size range are expected to remain aloft for 1 to 5 hours. Under stagnant conditions, when wind speeds are less than 1 mile per hour and wind directions are shifting, this suggests local sources are responsible for the majority of the impacts recorded at the Salt River monitoring sites.

## 3.2 Back Trajectory Analysis

To better determine the areas to be encompassed in the modeling domains for each of the Durango Complex and West 43rd Avenue monitors, back trajectory wind analyses were conducted to identify the areas traversed by winds blowing from contributing sources to the monitors. The datasets involved in these analyses were the five-minute average wind direction, wind speed, and continuous PM-10 data obtained from the MCAQD and the deposition times computed from empirical research.

During the November-December 2006 field study, MCAQD configured the data recorders at the two monitoring sites to store five-minute averages of meteorological parameters and continuous PM-10 measurements. These hourly PM-10 data were reviewed to select times of peak PM-10 concentrations on days with low wind speeds. The highest PM-10 concentrations recorded during the field study occurred during

December 5-7, 2006. The federal 24-hour PM-10 standard was exceeded on all three of these days at the West 43rd Avenue site, and on December 6 and 7 at the Durango Complex site. Because these days were also characterized by very low winds, they were selected as being most representative of the meteorological conditions that occurred during the December 11-13, 2005 design day period.

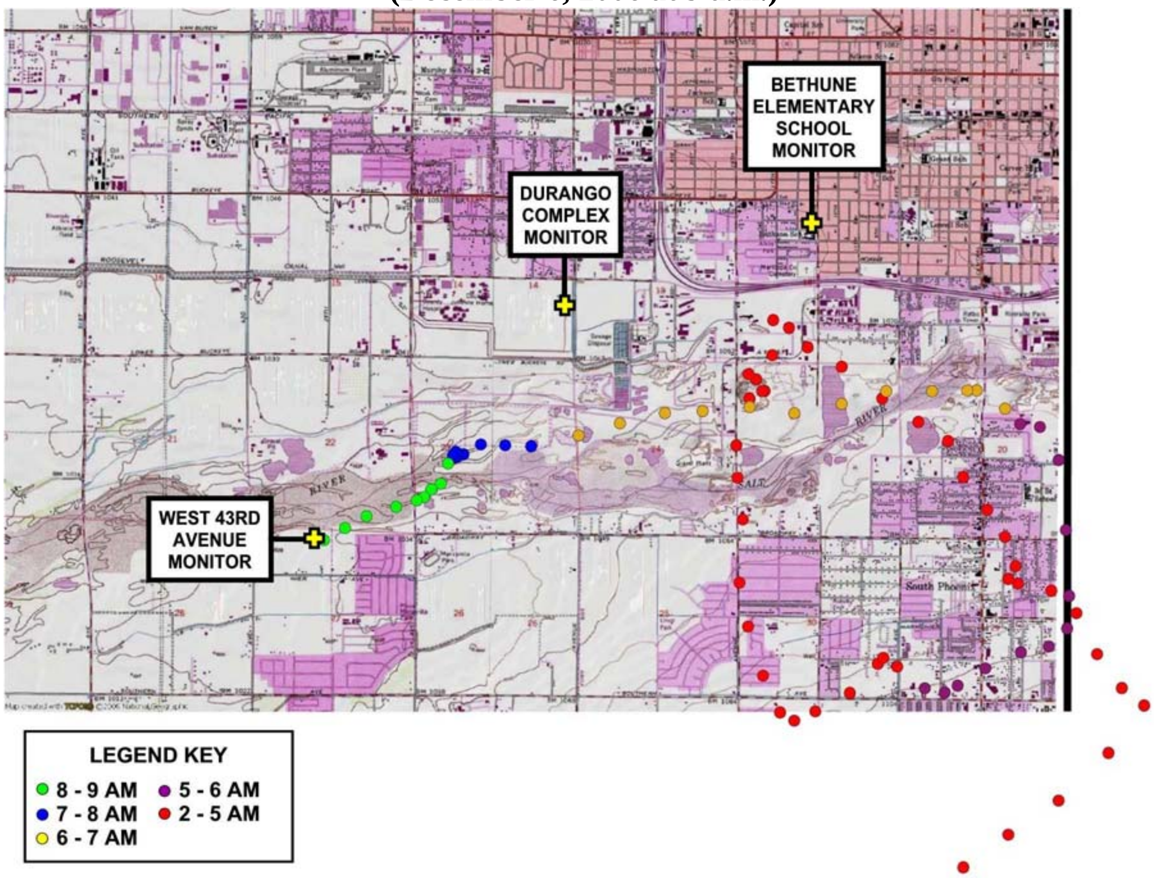
Particulate matter in the coarse fraction range, from 2.5 to 10 μm in aerodynamic diameter, is unique among air pollutants with respect to deposition properties. Because gravitational settling forces on particles in this size range are greater than the buoyant forces provided by air turbulence and Brownian motion, these particles settle out of the air within hours of being emitted and entrained into the ambient air. To estimate these settling times, a standard particle deposition velocity model was used to compute settling velocities of particles between 2.5 and 10 μm in diameter, and settling times given maximum entrainment heights above the ground were then computed. A description of the inputs used in the deposition velocity model, and the reported results, is presented in Chapter 3.5 below.

From these data, three hours were selected as the interval over which to evaluate back trajectories of particles arriving at the two monitors at times of high PM-10 readings. The back trajectories were computed by calculating the prior locations every five minutes for three hours of the air parcel that arrived at the monitor at the target time. For each monitoring site, the five-minute average wind speed and direction data measured at that site were used to compute the back trajectories, assuming a uniform wind field. An example plot of back trajectory analytical results for the West 43rd Avenue monitor is presented in Figure 3-6. This plot represents the trajectory every five minutes of an air parcel that arrived at the monitor at 9:00 am on December 6, 2006. This time represents the peak hourly PM-10 concentration recorded at the monitoring site on this day.

The analysis of three-hour back trajectories indicated that during low wind hours, air parcels were traveling no more than about 2 miles before arriving at either of the two monitors in the Salt River area. This result confirmed the view that the initial modeling domain of significant sources should extend out to two miles from each monitor, and this was therefore the radius in which emission inventory improvements and enhancements during the November-December 2006 field study were targeted.

Significant PM-10 emission sources within a 2-mile radius of each monitor included several riverbed quarries, sand and gravel processing facilities, unpaved truck parking lots, concrete casting facilities, agricultural fields, and paved arterial streets. The numbers and sizes of these facilities were sufficiently large to provide a rich emission inventory with respect to producing significant impacts at each monitor.

**Figure 3-6**
**Back Trajectory of Winds Impacting the West 43rd Avenue Monitor**
**(December 6, 2006 at 9 a.m.)**

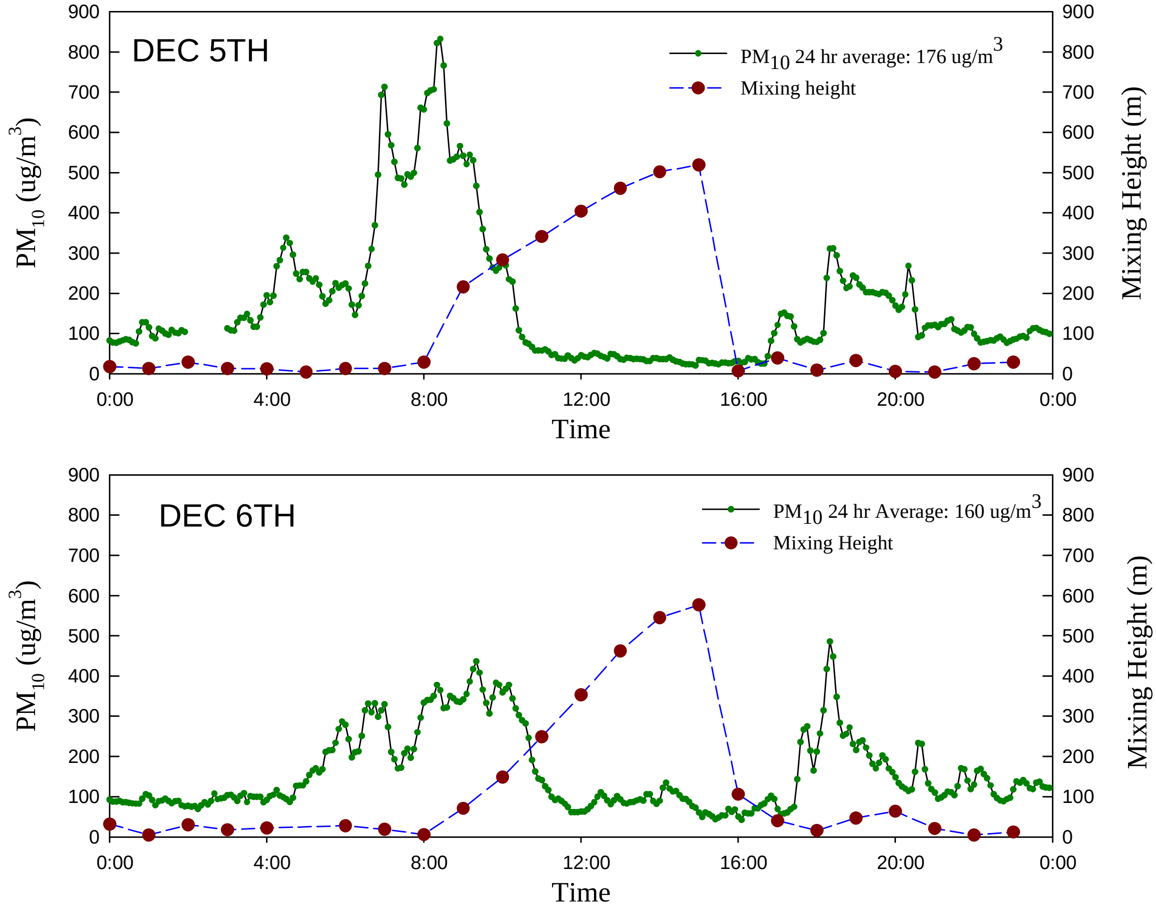



## 3.3 Particle Deposition Rate Modeling

To inform the analysis of back trajectories with respect to typical residence times of particles in the air between source and monitor, particle deposition velocities and rates were modeled under the meteorological conditions recorded on stagnant fall and winter days in the Salt River area.

Hourly surface meteorological data are collected at each Salt River monitoring site by MCAQD. Mixing height data are collected by the National Oceanographic and Atmospheric Administration (NOAA) in Tucson. Using these two datasets, mixing heights were computed for the Salt River area during the design period. These mixing heights, together with PM-10 concentrations, at the West 43rd Avenue monitor on December 5 and 6, 2006, are shown in Figure 3-7. The nocturnal mixing heights during this period were low, on the order of 30 meters above ground level. These conditions kept fugitive dust emitted in the Salt River region trapped in a layer of air near the ground and near the site of emission for several hours each day.

**Figure 3-7**
**Summary of Monitoring Conditions at West 43rd**
**(December 5-6, 2006)**




Coarse PM-10, with particle diameters greater than 2.5 µm and smaller than 10 µm, settles out from the atmosphere within a few hours, depending on release height above the ground. To estimate the maximum residence time of coarse PM during the design period, particle deposition velocities were computed as a function of particle diameter and release height. An online deposition velocity model was used to perform this calculation.[1] Inputs to the model include fluid density, fluid viscosity, particle diameter, and particle density. The density of air at a temperature of 53°F (the average daily temperature recorded at the two monitoring sites on December 5-6, 2006) and an elevation of 1,030 ft (the elevation of the two monitors as reported by the Google Earth website[2]) was found to be 0.0742 lb/ft$^3$ (1.189 kg/m$^3$), as computed by an online gas density calculator.[3] The viscosity of air at this temperature and elevation was computed

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[1] http://www.filtration-and-separation.com/settling/settling.htm, accessed on October 15, 2006.
[2] http://www.earth.google.com, accessed on October 15, 2006.
[3] http://www.denysschen.com/catalogue/density.asp, accessed on October 15. 2006.

on another online fluid dynamics calculator to be $1.80x10^{-5}$ kg/m-sec.[1] Particle release height was assumed to be the mixing height, which conservatively overestimated residence time since entrained particles are mixed throughout the mixing layer, not simply concentrated at the top of the layer. Particle density was assumed to be 2.65 gm/cc, the average soil particle density as reported in a soils science syllabus.[2] The calculated settling velocities and the residence times as functions of particle diameter and inversion height are presented in Table 3-1.

**Table 3-1**
**Particle Residence Times (hr)**

| Particle Diameter (µm microns) | Settling Velocity (m/hr) | Inversion/Release Height (m) | | |
|---|---|---|---|---|
| | | 20 | 30 | 40 |
| 10 | 28.9 | 0.69 | 1.04 | 1.39 |
| 8 | 18.5 | 1.08 | 1.35 | 1.89 |
| 6 | 10.4 | 1.92 | 2.41 | 3.37 |
| 4 | 4.6 | 4.33 | 5.41 | 7.58 |
| 2.5 | 1.8 | 11.08 | 13.85 | 19.40 |

Assuming a uniform distribution of particles within each particle size range between PM-2.5 and PM-10, the mass average particle diameter within this size range was computed to be 7.98 µm (= [(10^3 + 2.5^3)/2]^(1/3)). For this particle diameter, at a release height of 40 meters, the deposition time was calculated to be 1.89 hours. On the basis of this result, a two-hour deposition time was selected in computing the radius of the modeling domain around each monitor.

As Figure 3-7 indicates, PM-10 concentrations remained above 100 $µg/m^3$ at the West 43rd monitor after 4:00 pm on December 5 and 6 when the inversion height dropped. Because industrial activity and truck traffic levels were low and continued to decline after 4:00 pm, it was expected that PM-10 concentrations would also decline. However, as these plots show, PM-10 concentrations rose to 300 $µg/m^3$ (5-minute average) at about 6:00 pm and then slowly declined to about 100 $µg/m^3$ (5-minute average) at midnight.

After several possible sources of this elevated PM-10 were considered and discounted, it was hypothesized that particulate mixed into the deeper surface mixing layer during the day was settling out of the atmosphere in the evening after vertical mixing resulting from solar radiation ceased and the mixing height dropped. To evaluate the possibility of this phenomenon, particle trajectories were plotted at an elevation of 50 meters above the ground using SODAR measures of wind aloft measured at the West 43rd Avenue site.

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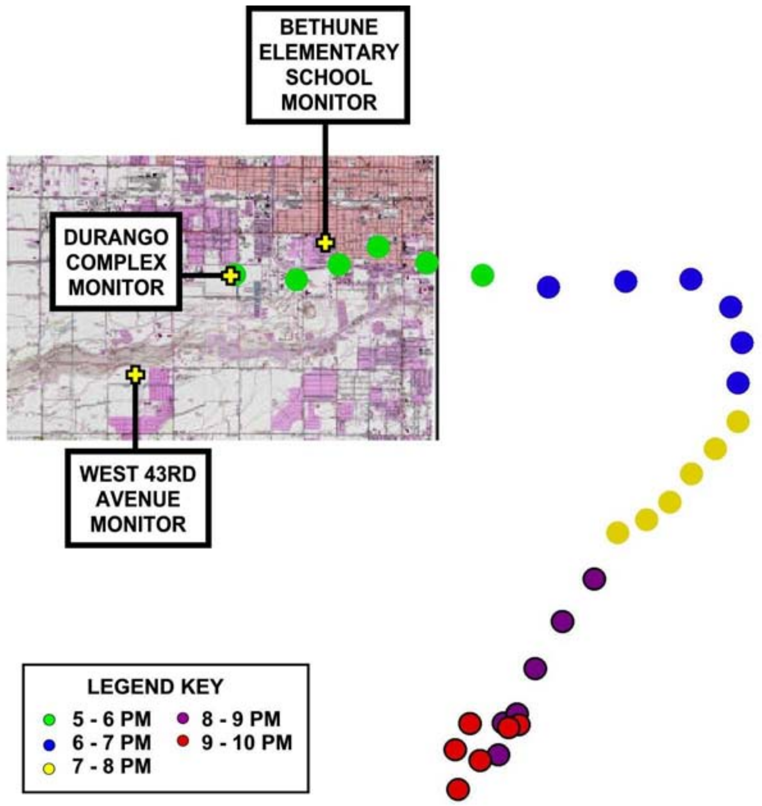
[1] http://www.lmnoeng.com/Flow/GasViscosity.htm, accessed on October 15, 2006.
[2] http://www.ju.edu.jo/ecourse/Lw%20Environment/Materials/lecture%2003.htm, accessed on October 15, 2006.

This analysis was not a back trajectory, but a forward trajectory as it documented where the air parcels move in the 8-hour period following the mixing height drop. The results of that analysis are displayed in Figure 3-8.

**Figure 3-8**
**Forward Trajectory of Winds Aloft Starting at the**
**West 43rd Avenue Monitor at 5:00 p.m., December 6, 2006**




This plot shows that winds just above the inversion height tend to transport particulate mixed aloft during the day quickly out of the modeling domain. Similar results were seen from forward trajectory analysis of radar data of higher altitude winds. Thus, this particulate does not deposit within the modeling domain and fails to contribute to elevated groundlevel concentrations during nocturnal hours. In truth, the analysis was unable to fully explain how nocturnal PM-10 levels were kept elevated during stagnant days.[1]

[1] The lack of transport combined with low mixing heights and wind speeds suggests sources operating nearby at night are most likely to be the cause of the elevated nocturnal PM-10 levels.

## 3.4 Particle Deposition Monitoring

To better understand particle deposition dynamics in the Salt River Area, MAG asked Sierra to study dust fallout near the Durango Complex and West 43rd Avenue monitors. To conduct this study, particulate matter deposition was monitored using dust fall jars over one-week periods at four locations surrounding each monitor by Applied Environmental Consultants (AEC), a subcontractor to Sierra Research. Generally, one jar was placed between the monitor and the nearest arterial road, one monitor was placed on the opposite side of the monitor, and two were placed at other locations of interest near the monitor.

The jars consisted of polyethylene tubs approximately 18 inches in diameter and 6 inches deep, mounted on top of portable wooden stands 6 feet in height. Jars were prewashed with deionized water and transported to and from the sampling locations with plastic covers to avoid contamination or loss of sample during transport. Upon return of each jar to AEC laboratories, the jar was rinsed with deionized water using a rubber policeman to remove particulate from the jar, and the aqueous solution was labeled and stored.

Since the mass of particulate in each solution was very small, the use of standard soil test methods for determining particle size was ineffective. After discussion with several Phoenix-area soils laboratories, Sierra learned of a particle counting method that offered the ability to quantify trace levels of particulate in aqueous solutions by particle diameter range. Particle Measurement Technology in Ventura, California, was retained to conduct particle counts using a laser counting technology. Only a portion of each solution was used in each count, allowing for the use of duplicate counts to quantify instrumental precision.

The particle counts were converted to particle mass using standard conversion methods. All particles were assumed to be spherical with an average density of 2.65 grams per cubic centimeter.[1] The results of the jar analyses are shown in Table 3-2.

The size distributions of particles collected by the dustfall jars were weighted more toward coarser particle diameters than the ambient samples analyzed by the T&B Systems APS counter. This could result from the jars being placed closer to significant emissions sources (e.g., arterial roads) than was the case for the APS sampling locations. Plots of the dustfall jar networks and the rates of PM-10 collected at each jar at the Durango Complex and West 43rd monitoring sites are shown in Figures 3-9 and 3-10, respectively.

[1] http://www.ju.edu.jo/ecourse/Lw%20Environment/Materials/lecture%2003.htm, accessed on October 15, 2006.

| Table 3-2<br>Size Fraction of Dustfall Collected Near<br>Durango Complex and West 43rd Avenue Monitors | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Size Range | Durango Complex | | | | West 43rd Avenue | | | |
| | #1 | #2 | #3 | #4 | #1 | #2 | #3 | #4 |
| 0-2.5 µm | 8.0% | 7.0% | 10.8% | 17.2% | 18.4% | 23.7% | 20.7% | 9.8% |
| 2.5-5.0 µm | 15.5% | 15.7% | 15.3% | 18.1% | 18.2% | 21.0% | 20.4% | 17.7% |
| 5.0-7.5 µm | 30.3% | 31.9% | 28.2% | 25.9% | 26.0% | 24.4% | 24.9% | 31.0% |
| 7.5-10.0 µm | 46.2% | 45.5% | 45.7% | 38.8% | 37.3% | 30.9% | 33.9% | 41.5% |
| Mean Dia. µm | 6.6 | 6.7 | 6.5 | 5.9 | 5.8 | 5.3 | 5.6 | 6.4 |

**Figure 3-9**
**Durango Complex Dustfall Jar Network**

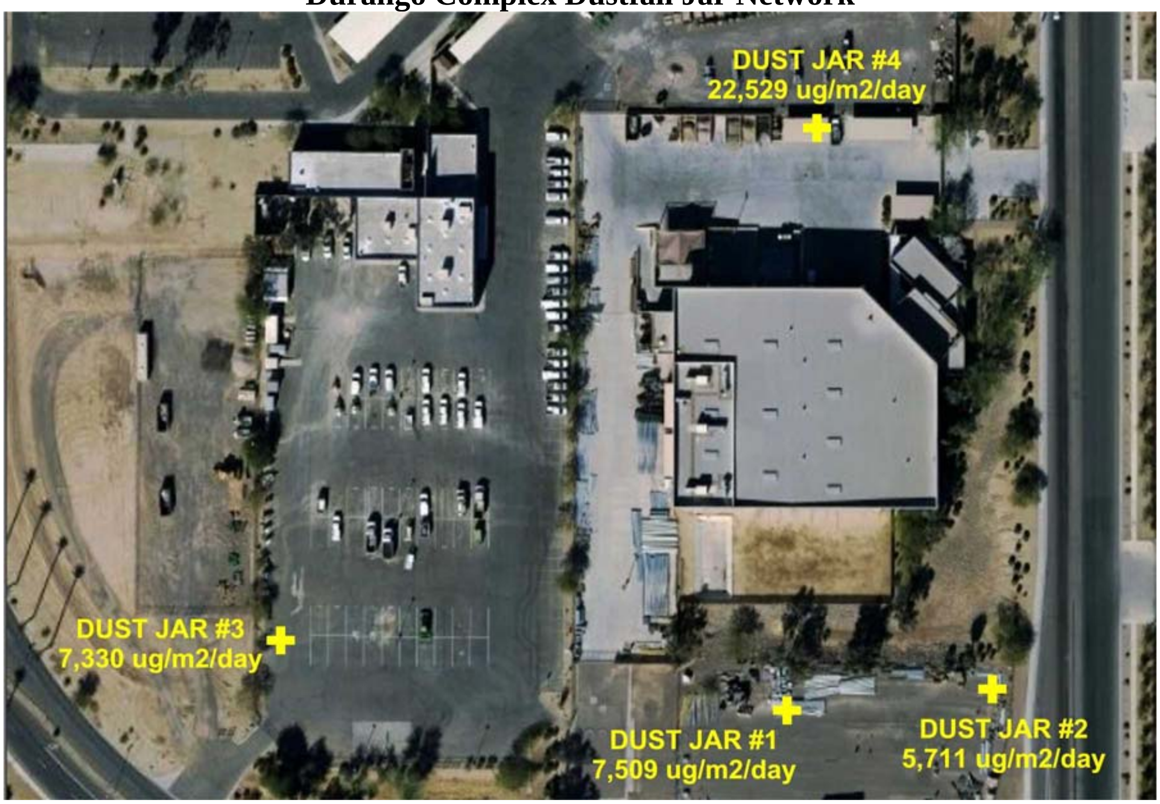


**Figure 3-10**
**West 43rd Avenue Dustfall Jar Network**


Review of the dustfall data from each of the Durango Complex and West 43rd Avenue monitoring sites shows significant gradients in particle deposition, but fails to provide useful information with respect to sources of emitted particles. At the Durango Complex site, for example, the highest deposition site is the northern-most jar, which collected almost three times as much PM-10 as the jar co-located with the MCAQD continuous monitors. This gradient suggests that a strong emission source lies to the north of the dustfall network, and yet no significant sources were found in this direction during site inspections. The results from jars #1 through #3 also suggest that particle deposition is greater at sites away from 27th Avenue than near it, which is somewhat counterintuitive. In the area surrounding the dustfall network, paved road emissions on 27th Avenue and unpaved road emissions from the truck yard to the east of 27th Avenue were found through emission analysis to be the most significant local sources of PM-10.

The dustfall data from the West 43rd Avenue dustfall network raise similar questions. The gradient shown by the dustfall mass at jars #1 and #2 suggests paved road emissions on Broadway Road to be the dominant source impacting these sites. The mass collected at jar #3, which is the same distance from the road as jar #2, however, shows lower dustfall levels than were measured at jars #1 or #2. The dustfall mass at jar #4, which is located closer to the Vulcan Materials quarry site—the most significant stationary source of PM-10 emissions near the West 43rd Avenue monitor—is lower than the mass collected at jar #2. Again, the dustfall mass data raise a number of questions that require additional monitoring to answer.

## 3.5 Transport Monitoring

To identify PM-10 gradients within the modeling domain, to assess the significance of pollutant transport into the modeling domain, and to identify the plumes of significant sources near the Salt River monitors, traverses across the modeling domain were conducted during the field study using vehicles equipped with continuous monitors. These mobile monitoring systems were constructed by T&B Systems to include DustTraks and MiniVols separately sampling PM-10 and PM-2.5; a GPS system to monitor vehicle position, speed, and altitude; a compass system for monitoring vehicle orientation; and a roof-mounted system for monitoring wind speed, direction, and temperature. This monitoring was conducted in two phases: an initial assessment of pollutant gradients using long longitudinal and latitudinal traverses, and a follow-up assessment of specific source impacts using close proximity upwind/downwind traverses.

During the first field study period, between November 13 and 19, 2006, T&B Systems operated one van-based mobile monitoring platform, collecting PM, meteorological, location, and photographic data in a series of traverses in the Salt River area. During this phase, the following initial monitoring objectives were pursued:

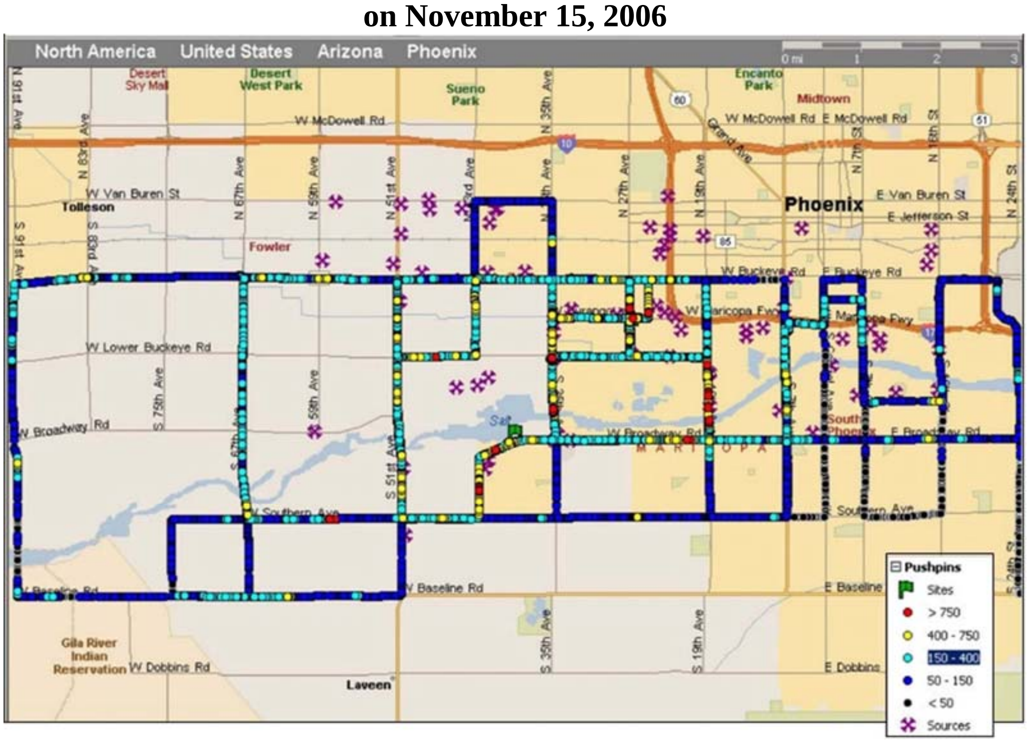
- Locating the van at each of the two Salt River monitors for a few hours to calibrate the DustTraks.
- Driving a circumferential route around the proposed modeling domain to assess boundary conditions, the modeling domain was bounded by Buckeye Road, 7$^{th}$ Avenue, Southern Avenue, and 51$^{st}$ Avenue.
- Driving north-south transects across the modeling domain (on 19$^{th}$ and 35$^{th}$ Avenues) to identify PM-10 gradients over distance and time.
- Driving east-west transects (along Lower Buckeye Road and West Broadway) to identify PM-10 gradients.
- Driving east-west in the area to the north of the modeling domain to assess gradients and evaluating the potential for transport into the Salt River area from the north.
- Driving north-south in the area to the east of the modeling domain to assess gradients and evaluating the potential of transport into Salt River from the east, especially during drainage flows in the early morning.

At the conclusion of the first phase, the collected data were analyzed by T&B Systems and Sierra Research for use in planning the second phase of the field study. Because the first phase of monitoring showed no evidence of significant PM-10 transport into the modeling domain from upwind areas, the second phase was designed to study the plumes of sources within the modeling domain. During the first phase, T&B Systems learned that the van-based platform was sufficiently automated as to enable its operation by a single vehicle occupant. Thus, a second van was instrumented and operated much like the first and the data collection activities were doubled during the second phase. A laser-based particle counter capable of characterizing particulate within 53 size ranges between 0.0 and 20 µm in diameter was added to one of the vans to further research particle size signatures of various sources.

The DustTraks were programmed to record ambient concentrations over 2-second averaging times. At an average speed of 30 miles per hour, this setting allowed for the recording of an ambient concentration every 88 feet along the traveled route. In this mode, the mobile DustTraks were used as a survey tool to map PM-10 and PM-2.5 gradients within and near the modeling domain. The DustTraks were calibrated by comparison to filter-based MiniVol PM-10 and PM-2.5 monitors operated in the van during the hours of travel. The MiniVols were also equipped with extended inlets located just below the DustTrak inlets. At the end of several testing periods, the MiniVol concentrations were compared to the average DustTrak concentrations, and the DustTrak 2-second averages were adjusted by the MiniVol:DustTrak ratio of average daily concentrations.

An example of the data collected in the first phase during an internal monitoring domain traverse series is presented in Figure 3-11. In this plot, the lowest PM-10 concentrations are represented by black dots. These concentrations appear in areas that were not close to significant sources and on roads that did not have elevated silt loadings. Elevated road

**Figure 3-11**
**Summary of PM-10 Mobile Monitoring Data**
**on November 15, 2006**

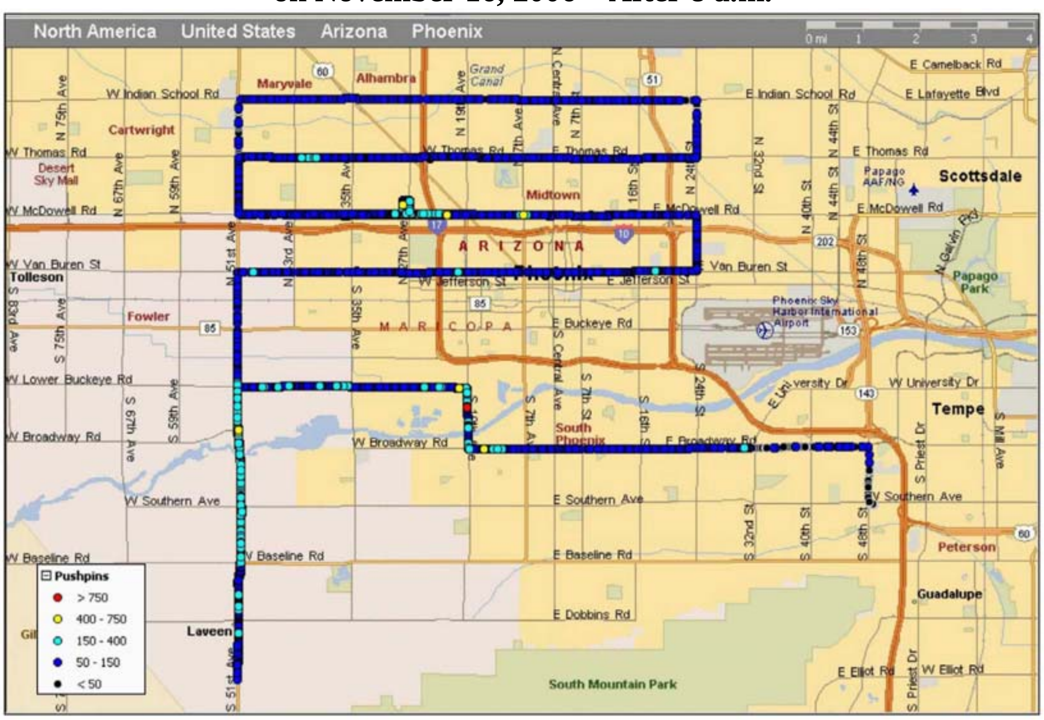


silt loadings in heavily trafficked areas are suspected of increasing the ambient concentrations recorded by the monitoring vans independent of stationary source plumes near roadways. These roadway background emissions resulted from traffic resuspending road silt in vehicle trailing vortex plumes that remained over roadways for minutes at a time during low wind conditions. The light blue dots, recording ambient concentrations between 150 and 400 ug/m$^3$, appear to represent roads with higher road silt and higher traffic levels due to their extent. The infrequent concentration peaks represented as yellow and red dots appear to represent the presence of stationary sources or very heavily soiled trackout areas where heavy-duty trucks enter arterial roads from unpaved areas.

An example of monitoring traverses conducted outside of the modeling domain in search of elevated PM-10 concentrations being transported into the modeling domain is presented in Figure 3-12. This plot shows that in the early morning, when inversion heights are very low prior to groundheating, ambient PM-10 concentrations north of the modeling domain are low and very uniform. These results suggest that on this particular day, PM-10 concentrations north of the modeling domain were generally lower than those within the modeling domain and, thus, no plumes of PM-10 being transported into the Salt River area from the north were observed.

A full set of domain-wide traverse plots recorded during the first phase of the field monitoring program is contained in Appendix B.

**Figure 3-12**
**Summary of PM-10 Monitoring Data**
**on November 16, 2006 – After 8 a.m.**



## 3.6 Non-Parametric Regression

Non-parametric regression, one of the analytical tools described in Chapter 2, was used to identify the locations of significant PM-10 sources impacting each of the two monitoring sites. This work was performed by Rincon Ranch Consulting (RRC), a statistical analysis subcontractor to Sierra.

The regression analyses developed by RRC used 5-minute average PM and meteorological measurements from the Durango Complex and West 43rd Avenue sites from the field study time period of November 15 through December 15, 2006. Data points missing any of the three values (PM-10 concentration, wind direction, wind speed) were omitted from the analyses. Data points with the wind speed below 1.0 mph were also omitted because the wind direction was poorly defined at such low speeds. The resulting data sets used in the analysis for each site included approximately 6,000 data points.

The distribution of PM-10 concentrations versus wind direction for the Durango Complex and West 43rd Avenue sites is presented in Figures 3-13 and 3-14. These plots suggest that winds are observed for all directions, but that the predominant wind directions are easterly and westerly.

The distribution of PM-10 concentration versus wind speed for Durango Complex and West 43rd Avenue monitors is shown in Figures 3-15 and 3-16, respectively. The Durango Complex plots show the effect of winds in excess of 6 mph in creating blowing dust by the absence of low PM-10 data points above this threshold velocity. This effect occurs at a higher wind speed of 14 mph at the West 43rd Avenue monitor.

The meteorological datasets were further combined to identify the sample size of combinations of wind speed and direction. This analysis was conducted to assess the distribution of wind speed versus direction and inform the subsequent analysis of PM-10 concentrations in relation to these meteorological parameters. The merging of wind speed and direction data was performed by compiling data counts within bins that spanned 5 degrees of wind direction and 2 mph of wind speed. The resulting plots of the samples sizes within these bins are shown in Figures 3-17 and 3-18 for the Durango Complex and West 43rd Avenue sites, respectively.

The highest sample size counts were in the vicinity of azimuth 70-110 degrees for Durango Complex and 270 degrees for West 43rd Avenue sites at wind speeds of 4 to 6 mph. These plots show that there were very few, if any, high wind conditions from the south and from the north. The upper boundaries of the contour plot were useful in gauging results of the non-parametric analysis because they show the directions in which there are no data under high-wind conditions.

**Figure 3-13**
**PM-10 Concentration versus Wind Direction**
**Durango Complex Monitor, 11/15 – 12/15/06**

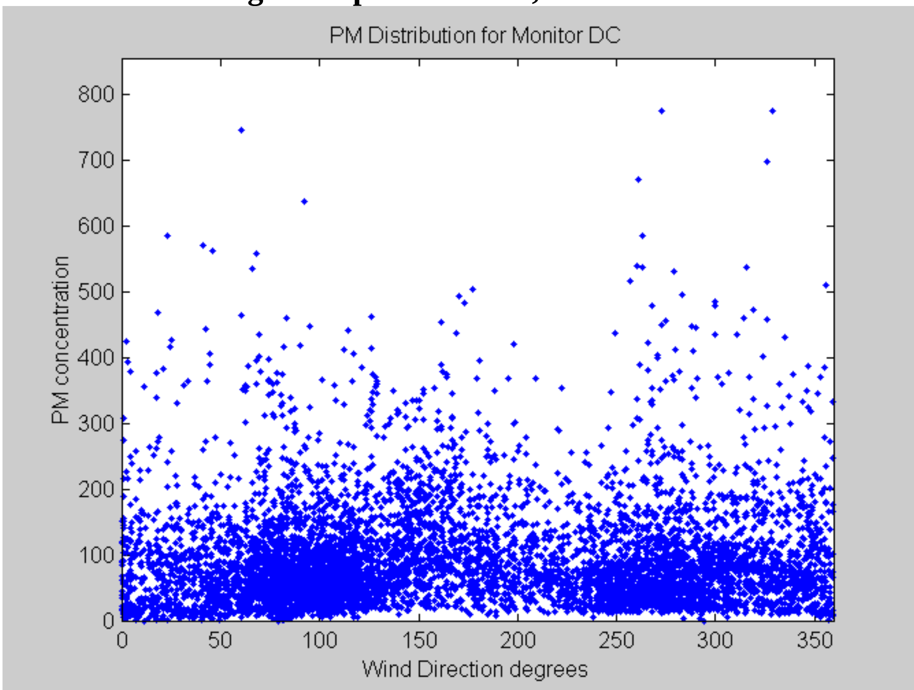



**Figure 3-14**
**PM-10 Concentration versus Wind Direction**
**West 43rd Avenue Monitor, 11/15 – 12/15/06**

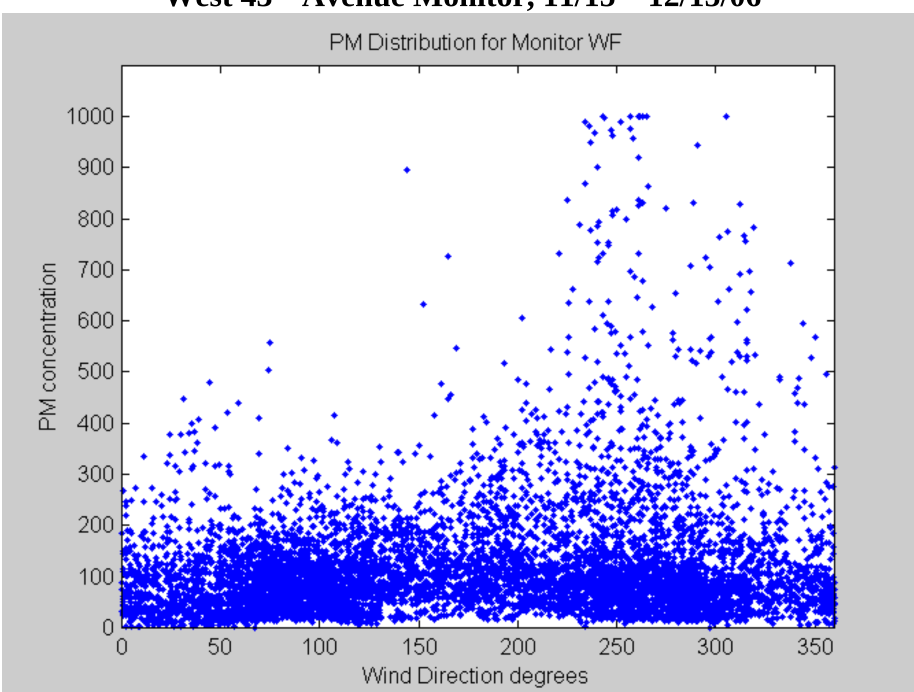


**Figure 3-15**
**PM-10 Concentration versus Wind Speed**
**Durango Complex Monitor, 11/15 – 12/15/06**

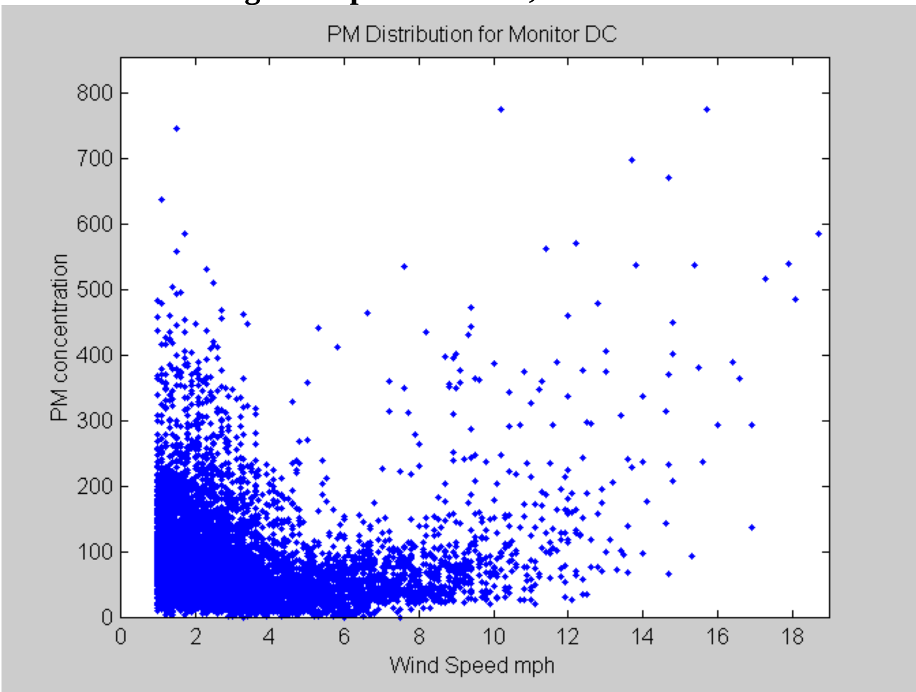



**Figure 3-16**
**PM-10 Concentration versus Wind Speed**
**West 43rd Avenue Monitor, 11/15 – 12/15/06**

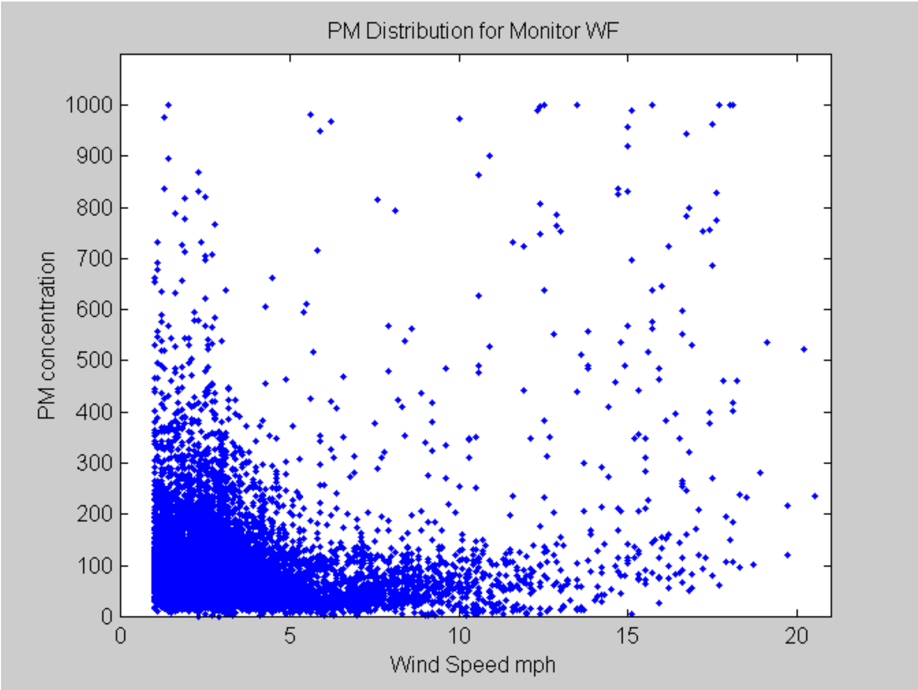


**Figure 3-17**
**Average PM-10 Concentration by Wind Speed and Direction**
**Durango Complex Monitor, 11/15 – 12/15/06**

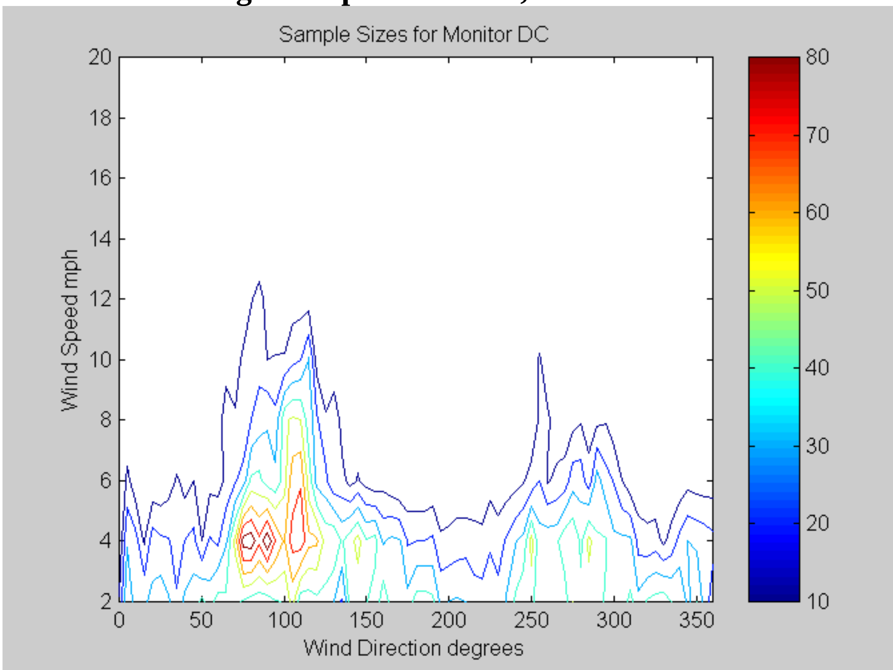
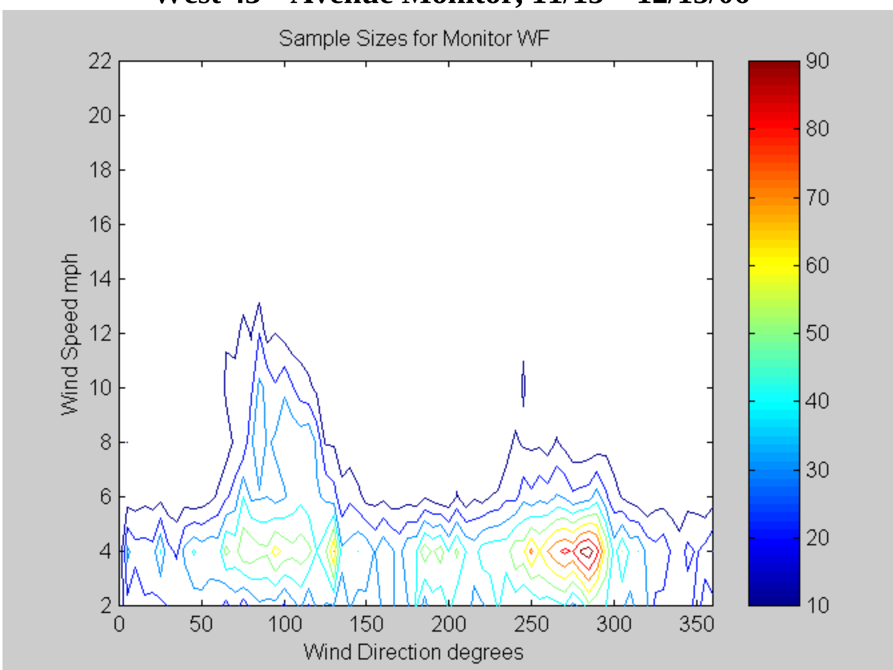



**Figure 3-18**
**Average PM-10 Concentration by Wind Speed and Direction**
**West 43rd Avenue Monitor, 11/15 – 12/15/06**



## 3.7 Non-Parametric Results for the One Dimensional Case

One dimensional non-parametric analysis was used with wind direction data to identify significant sources. In this type of analysis, data are smoothed using a filtering technique that weights PM-10 concentrations within a narrow band on each side of the wind direction being studied.

The results of this analysis for the Durango Complex and West 43rd Avenue sites are presented in Figures 3-19 and 3-20, respectively. In this analysis, only low wind conditions, defined as wind speeds less than or equal to 6 mph, were evaluated. The red line in each figure represents the average PM-10 concentration estimated by the non-parametric technique. The black lines are the upper and lower 95 percent confidence limits. The averages are based on a window of size ±7.5 deg in azimuth. Note that the averages over the one month period are never below about 75 μg/m$^3$ at Durango Complex and 55 μg/m$^3$ at West 43rd Avenue. All of the average values are statistically significant, showing that these monitors had elevated PM-10 readings no matter which direction the wind was blowing.

**Figure 3-19**
**One-Dimensional Non-Parametric Regression of PM-10 Concentrations and Wind Direction at Durango Complex Monitor, Nov. 15 – Dec. 15, 2006**

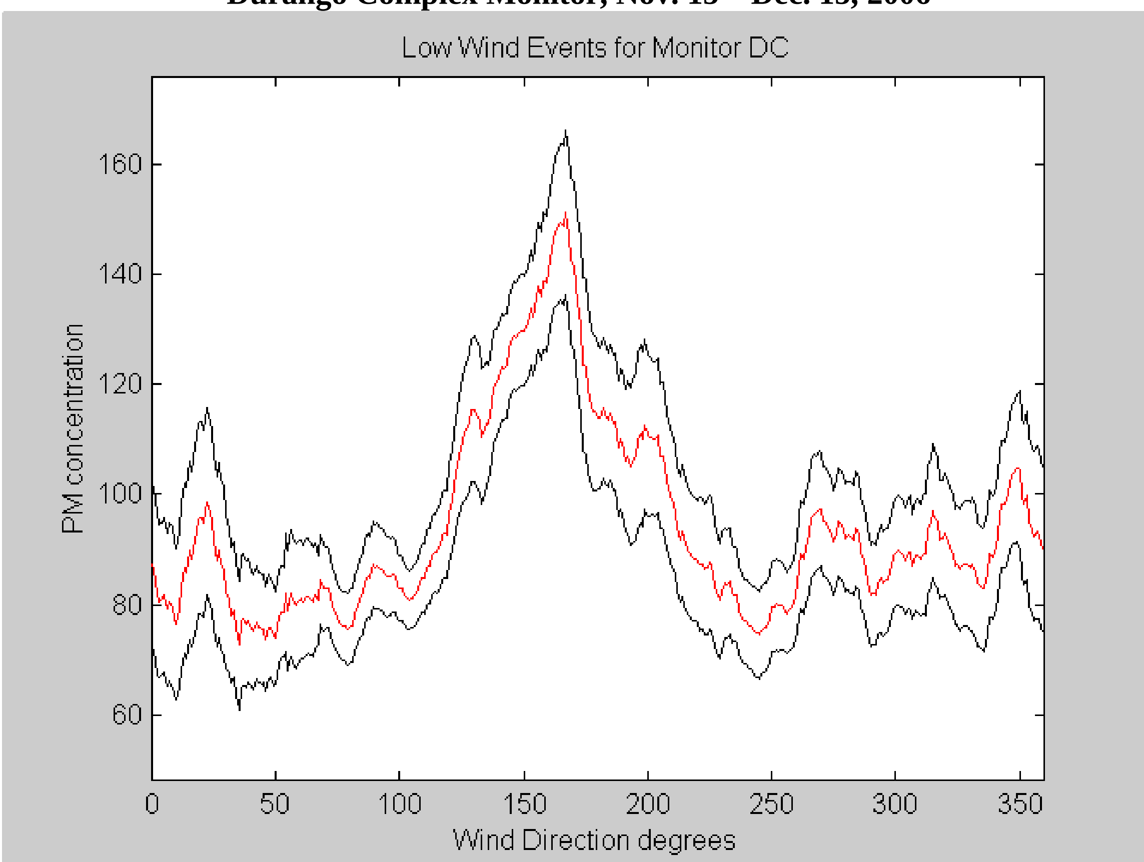
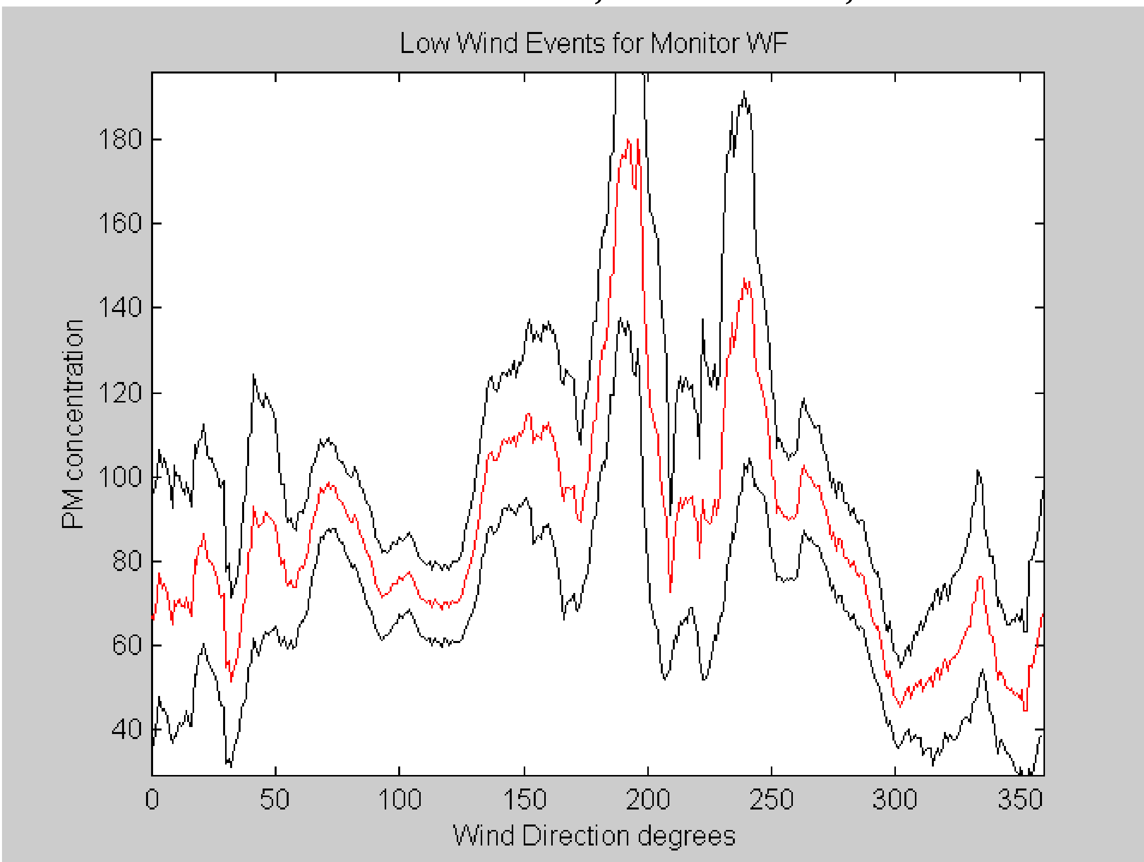


**Figure 3-20**
**One-Dimensional Non-Parametric Regression of**
**PM-10 Concentrations and Wind Direction at**
**West 43rd Avenue Monitor, Nov. 15 – Dec. 15, 2006**




Although the figures are optimally smoothed, there is still a fair amount of variability in the lines. To decide whether two adjacent peaks are likely to represent different sources, or are more likely from the same source, the 95% confidence limits must be examined. If the lower confidence limit of one peak approaches the upper confidence limit of the next peak (or vice versa), then the sources are likely distinct. In Figure 3-19, the first peak (at about azimuth 25) may or may not be distinct from the broad sequence of peaks from about azimuth 35 to 105. In fact, the azimuth range from 25 to 105 takes in essentially all of the truck yard to the east of the Durango Complex monitor, with azimuth 25 being the northwest corner of the lot at the intersection of 27th Avenue and Durango Street.

The peaks evident in Figure 3-19 and the potential sources near the Durango Complex monitor are listed in Table 3-3.

| Table 3-3<br>**Azimuth of Non-Regression Peaks at Durango Complex Monitor**<br>**November 15, 2006 – December 15, 2006** | | | |
|---|---|---|---|
| Source No. | Azimuth Range (degrees) | Peak Azimuth (degrees) | Comments |
| 1 | 12-31 | 22 | Probably part of source 2 |
| 2 | 32-105 | broad | Truck yard |
| 3 | 130-205 | 130, 167, 174, 199 | |
| 4 | 264-285 | broad | May be part of source 5 |
| 5 | 313-322 | 315 | |
| 6 | 341-358 | 344 | May be part of source 5 |

The corresponding peaks evident in Figure 3-20 and the potential sources near the West 43rd Avenue monitor are listed in Table 3-4.

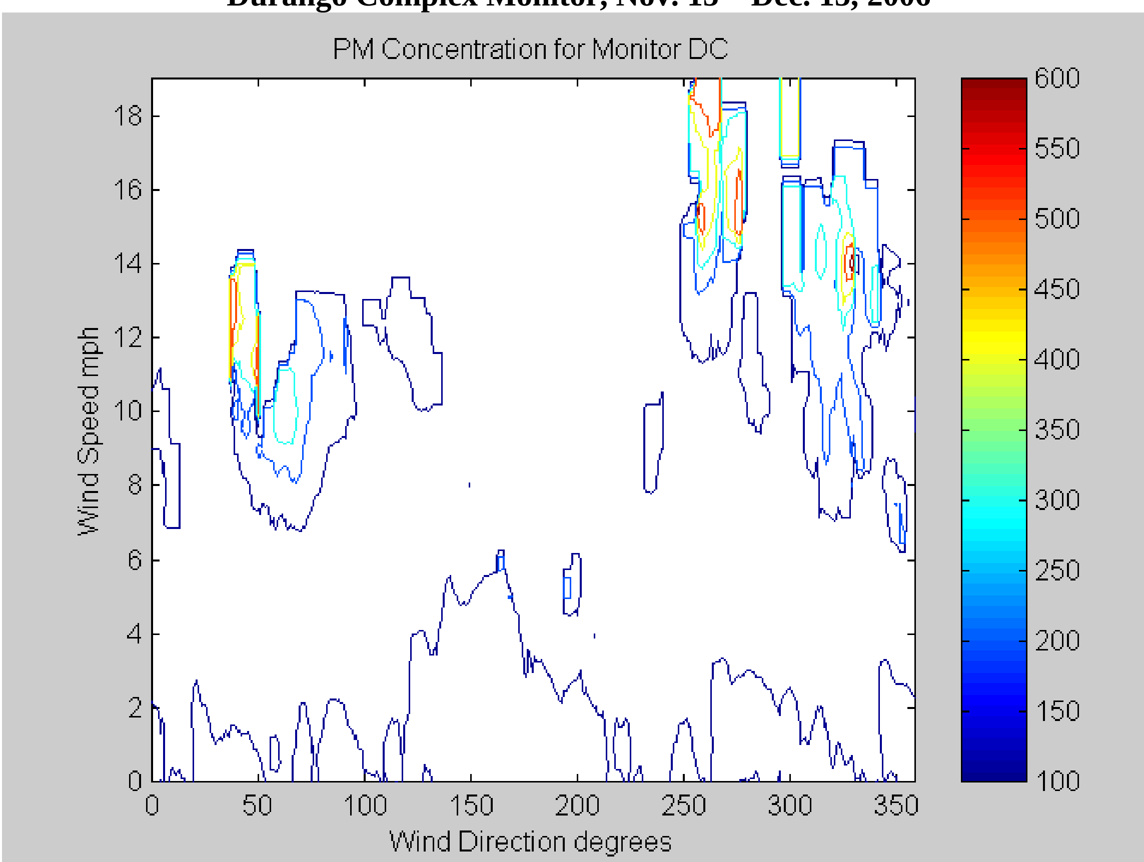
| **Table 3-4**<br>**Azimuth of Non-Regression Peaks at West 43rd Avenue Monitor**<br>**November 15, 2006 – December 15, 2006** | | | |
|---|---|---|---|
| Source No. | Azimuth Range (degrees) | Peak Azimuth (degrees) | Comments |
| 1 | 354 - 29 | 21 | Broadly elevated.<br>Peak = 87 ug/m3 |
| 2 | 29 – 56 | 41 | Peak = 93 ug/m3 |
| 3 | 59 – 89 | 71 | Peak = 99 ug/m3 |
| 4 | 90 – 126 | 104 | Broadly elevated.<br>Peak = 70-75 ug/m3 |
| 5 | 128 – 172 | 136-164 | Broadly elevated.<br>Peak = 105-115 ug/m3 |
| 6 | 174 – 209 | 190-196 | Peak = 170-180 ug/m3 |
| 7 | 211 – 228 | 213 – 218 | Peak = 90-95 ug/m3<br>May be shoulder between larger peaks, not new source |
| 8 | 229 – 251 | 239-241 | Peak = 145 ug/m3 |
| 9 | 261 – 270 | 263 | Peak = 102 ug/m3 |
| 10 | 271 – 300 | --- | PM levels are elevated, but tail off<br>Probably shoulder for sources in SW-W |
| 11 | 304 – 347 | 334-335 | Peak = 76 ug/m3 |

While the one-dimensional regression method is useful as a screening tool, the method does not well isolate contributions from nearby sources in a manner that allows for the sources to be accurately identified. This probably reflects the fact that there are a number of potential sources surrounding both the Durango Complex and West 43rd Avenue sites.

## 3.8 Non-Parametric Results for the Two-Dimensional Case

In subsequent analyses, a two-dimensional non-parametric method was used to improve on the results found in the one-dimensional approach. In these analyses, PM-10 concentrations were grouped by wind speed and direction, and then filtered within narrow bands to allow for the concentrations found in adjacent bands of wind speed and direction to be weighted and contribute to the band being analyzed. Figure 3-21 shows a contour plot for the average PM-10 concentration versus wind direction and speed at the Durango Complex monitor. These averages are outputs of the two-dimensional non-parametric regression using smoothing windows of ±5 deg in azimuth and ±1 mph in

**Figure 3-21**
**Two-Dimensional Non-Parametric Regression of PM-10 Concentrations, Wind Direction, and Wind Speed at Durango Complex Monitor, Nov. 15 – Dec. 15, 2006**



wind speed.[1] Only average values that exceed their standard deviations by enough to achieve 95% statistical confidence of being non-zero have been plotted. The empty areas below the dark blue contour line are largely areas where there are no (or nearly no) data.

The highest concentrations in this plot (above 400 $\mu g/m^3$) are at high wind speeds in the following directions:

- Azimuth 40-50 degrees;
- Azimuth 250-280 degrees; and
- Azimuth 340 degrees.

The first azimuth points directly to the center of the truck yard to the east of the Durango Complex monitor. This hot spot suggests that the highest emissions from the truck yard are generated by windblown dust and not by truck movement during low wind conditions. Azimuth 250-280 appears to point toward agricultural fields to the west 2.0 to 2.5 miles away, and azimuth 340 appears to point in a direction that has a number of plots of bare land. Because the hot spots at these azimuths occur at relatively high wind speeds, these sources may have greater surface roughnesses, which would raise the threshold wind speed for dust entrainment, than that of the truck yard. The lesser peak at azimuth 70 points toward the bend in I-17.

The highest concentrations at the West 43rd Avenue monitor in Figure 3-22 (above 400 $\mu g/m^3$) are at high wind speeds in the following directions:

- Azimuth 220-260 degrees; and
- Azimuth 290-300 degrees.

There is also have one spot above 400 $\mu g/m^3$ near azimuth 190 at wind speeds of about 6 mph. There are no other extreme PM areas at low wind speeds.

The first azimuth points to the Vulcan Materials quarry, the Coreslab Structures concrete casting facility, and the Vulcan Materials processing facility southwest of the monitor. The second azimuth points toward the Salt River channel and the Arizona Materials quarry to the northwest of the monitor.

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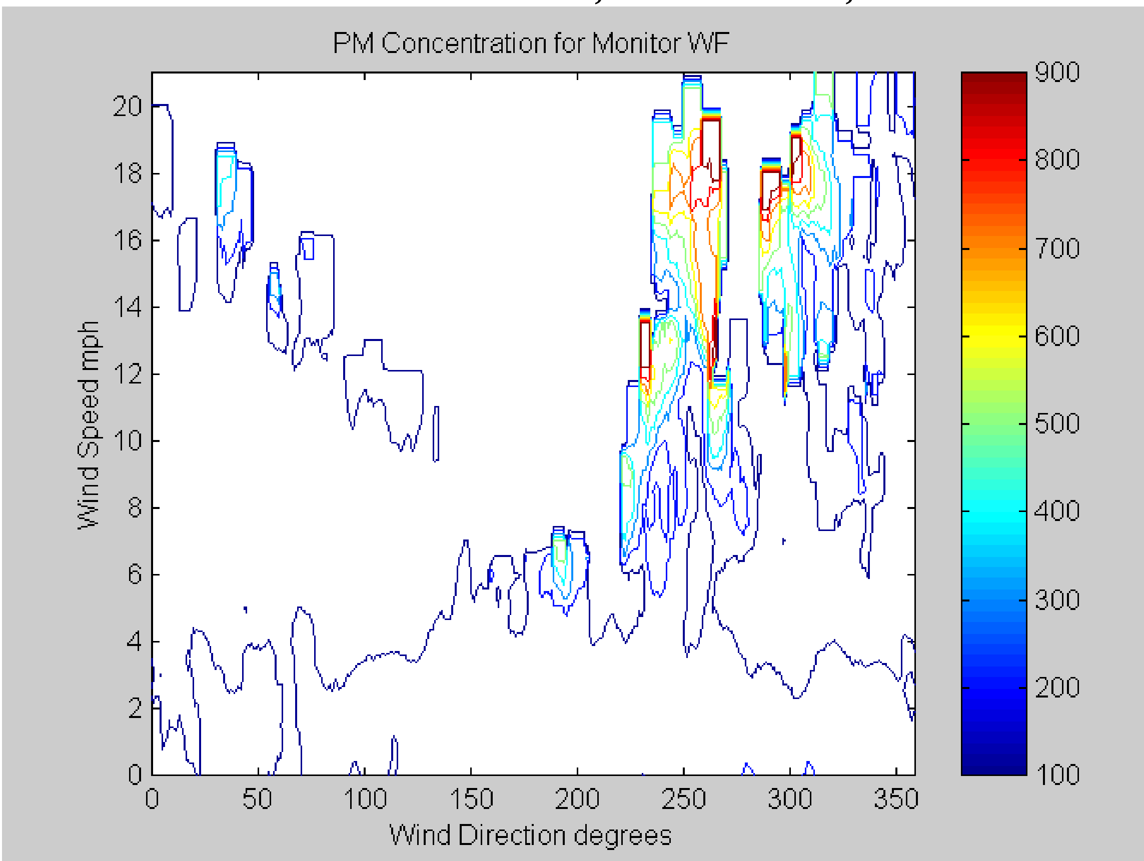
[1] These smoothing parameters were determined to be optimal by the cross-validation algorithm discussed in the two published papers referenced in Chapter 2.

**Figure 3-22**
**Two-Dimensional Non-Parametric Regression of**
**PM-10 Concentrations, Wind Direction, and Wind Speed at**
**West 43rd Avenue Monitor, Nov. 15 – Dec. 15, 2006**




Note two points, however, with respect to this method:

- The method does not provide information in every azimuth, because high winds occurred only in some directions during the period of the data. The preceding list is likely to miss many sources.

- It is easy to generate possible explanations, because disturbed undeveloped lands extend in almost every direction from the monitor. In this case, correlation does not prove causation.

From these results, it appears that the non-parametric technique may be more precise in identifying the directions to strong sources under high wind conditions than at low wind conditions. This is because the wind direction will be well-defined and an air cell will be blown to the monitor relatively quickly, even from greater distances, before settling and dispersal can have much effect.

A further comment about wind speed is warranted. This parameter is a useful second axis in the analysis, but one that is not easy to interpret. Hot spots at high wind speeds should not be interpreted as a rough measure of distance to source. Distance may be part of its interpretation, but only in the sense of setting an outer envelope within which sources can be observed; this envelop is larger (more distant) with higher winds, and smaller (more localized) with light winds because the air parcels would disperse or settle before reaching the monitor.

Overall, the use of non-parametric regression to identify the locations of significant sources is limited when sources surround the monitor at varying distances.

## 3.9 Field Observations

During the November-December 2006 field study, the source strengths of potentially significant sources were visually recorded using still photography and video. Some images were recorded before dawn as the data collection effort of T&B Systems was conducted during the period between 4:00 am and noon each day during the study period. This period was selected because peak hourly PM-10 concentrations recorded during the design day interval of December 11-13, 2005, were recorded during these hours. Most photographed sources were episodic in duration, as continuous sources with significant emissions generally would have been cited by MCAQD inspectors and fined.

Examples of significant episodic sources observed during the field study included agricultural plowing, trackout reentrainment, dragout plumes, and open burning, among others. During the field study, cotton fields were being plowed under to prevent pink bollworm attack, and field preparation activities were being conducted almost around the clock. A photograph of the plume generated by one plowdown operation is shown in Figure 3-23.

The reentrainment of soil tracked out onto paved roads from unpaved surfaces was readily visible during the field study at heavily loaded intersections. A view of one of these intersections—at the unpaved entrance to a construction site near Southern Avenue at 27$^{th}$ Avenue—is shown in Figure 3-24.

When large trucks exit from unpaved areas onto paved roads without stopping for traffic, the plume entrained in the trailing vortices of the truck is drawn onto the paved road. When this happens, the entrained particulate in the plume deposits onto the roadway where it is ground into smaller particles and reentrained into the air by passing traffic. A photo of truck "dragout" appears in Figure 3-25.

Truck movement on paved roads with unpaved shoulders also entrains particulate matter from the shoulder surface by action of the truck's bow wake. The strong vortices created near the front of a moving truck entrain loose surface particles on that portion of the unpaved shoulder near the paved lane and deposit some of that particulate onto the road

**Figure 3-23**
**Agricultural Field Plowing in the Salt River Area**
**December 5, 2006**

**Figure 3-24**
**Reentrainment of Paved Road Trackout in the Salt River Area**
**December 12, 2006**

**Figure 3-25**
**Entrained Particulate in a Truck Plume Being Dragged Onto a Paved Road in the Salt River Area - December 14, 2006**

surface, where it also is ground into smaller particles and reentrained by passing traffic. A photograph of a truck bow wake plume is shown in Figure 3-26.

Vehicle travel over unpaved shoulders is also an episodic source of PM-10 emissions. These emissions can be seen in the photograph in Figure 3-27, which was taken just across 27$^{th}$ Avenue from the Durango Complex monitor.

The open burning of scrap wooden poles may have influenced PM-10 concentrations recorded by the West 43$^{rd}$ Avenue monitoring site. A photograph of this activity, taken from the platform on which the monitor is located, is shown in Figure 3-28. AEC noted that unique black particles were captured in the dustfall jar located on the southeast corner of the intersection of Broadway Road and West 43$^{rd}$ Avenue, across Broadway Road from the site of the open burning.

All of these sources are episodic, with the exception of the open burning shown in Figure 3-28, which means that emissions are difficult to quantify because of the short duration. Because the frequencies of emissions from these sources are high in the Salt River area, however, the emissions contribute to background air quality and to concentrations measured at monitoring sites.

**Figure 3-26**
**Truck Bow Wake Plume in the Salt River Area**
**December 12, 2006**

**Figure 3-27**
**Unpaved Shoulder Travel Plume in the Salt River Area**
**December 12, 2006**

**Figure 3-28**
**Open Burning of Scrap Wooden Poles Near Broadway Road at West 43rd Avenue**
**December 6, 2006**

###

# 4. DATA ANALYSIS – SOURCE CHARACTERISTICS

## 4.1 Travel

Because the hourly PM-10 concentrations during the December 11-13, 2005 design period showed daily maximum levels occur in mid-morning, preceded by a steady ramp-up starting at about 4:00 am, Sierra initially concluded that morning traffic over primary roads within 2 miles of each monitor was a significant source impacting the two monitors. As a result, Sierra recommended that traffic counts be conducted on primary roads in the Salt River area during the field study period. MAG tasked Field Data Services (FDS) to conduct these counts during the period of December 4-8, 2006.

Traffic counts were conducted on 57 road sections simultaneously during this period. Many of the traffic counters were capable of differentiating between three axle-class groupings (2 axles, 3 to 4 axles, and 5 and more axles). Some counters only counted total traffic. The two different types of counters were designated as class counters and traffic counters, respectively. A map of the counter locations is shown in Figure 4-1.

The instruments summed counts every 15 minutes for the five days of operation. Counts were recorded separately for each direction of travel. For the Sierra analysis, the 15-minute traffic counts were summed into hourly counts, and the hourly counts in each direction were summed to determine total hourly counts per counting location.

An example of the class count results is presented in Figure 4-2. This plot illustrates the average hourly counts on the portion of 27$^{th}$ Avenue between Durango Road and Lower Buckeye Road on December 5 through 7, 2006. Each hourly bar is divided into counts for light-duty vehicles (LDV), medium-duty trucks (MDT), and heavy-duty trucks (HDT). These vehicle class terms are used to identify the three ranges of axle classes measured in the traffic counts.

The diurnal distribution of travel on the monitored arterials reflected the rush hour peaks and profile shown in Figure 4-2. Sharp increases in traffic occurred between 4:00 am and 7:00 am, when mixing heights were low, corresponding to similar increases in PM-10 recorded at the two monitors. This relationship reinforced the hypothesis that paved road traffic was a primary source of reentrained PM-10 on stagnant winter days when exceedances were recorded.

**Figure 4-1**
**Traffic Counter Locations in the Salt River Area**
**December 4-8, 2006**

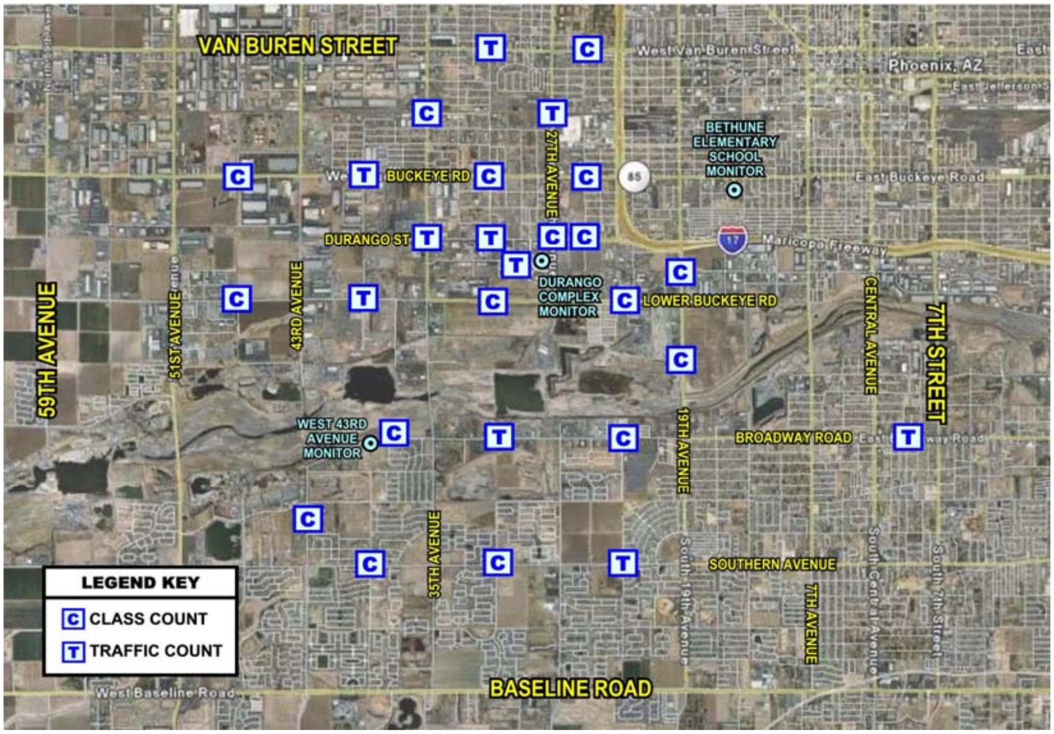
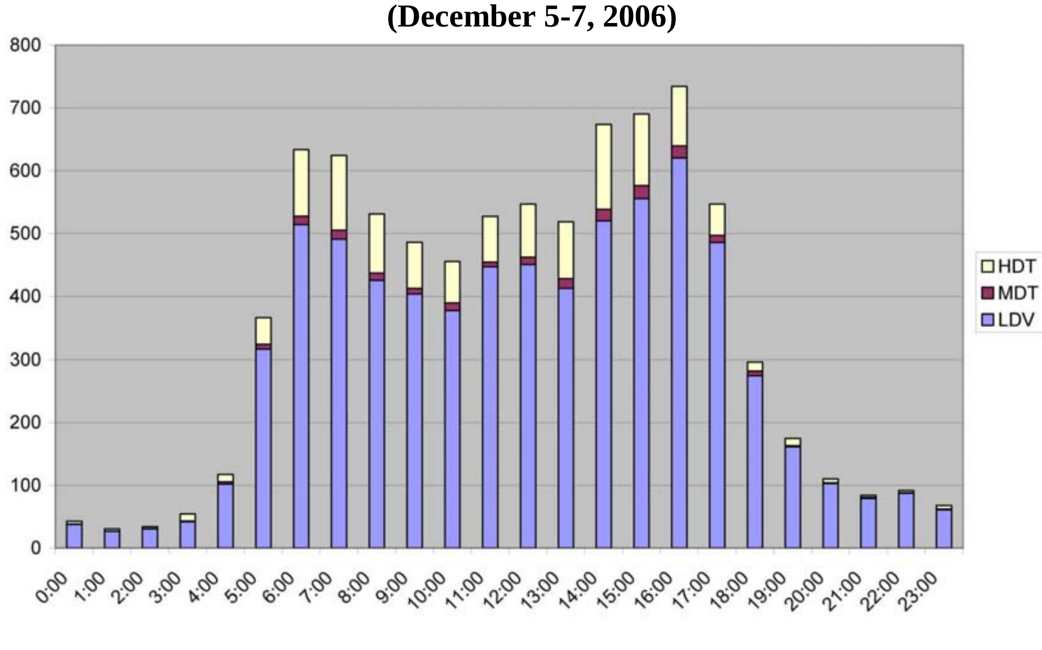



**Figure 4-2**
**Average Hourly Traffic on 27th Avenue**
**Between Durango and Lower Buckeye**
**(December 5-7, 2006)**



The axle-class traffic distribution also confirmed video observations recorded during the field study by T&B Systems. Heavy duty truck trips increased dramatically after 6:00 am on winter days. Many of these trips began at industrial sites and truck yards with unpaved surfaces, resulting in the trackout of soil onto paved roads. This trackout material was then rapidly reentrained by passing traffic and suspended into the limited mixing layer, adding to the increasing concentrations of PM-10 contributed by industrial stationary sources and unpaved yard and road travel before the solar groundheating caused the inversion to break.

The collection of traffic in three axle classes was also important in the estimation of paved road travel emissions for modeling purposes. Vehicle weight is a key determinant of fugitive dust emissions on paved roads as it is raised to the 1.5 power in the AP-42 equation; paved road travel PM-10 emissions from one 80,000 truck and trailer combination are equal to those of almost ninety 2-ton light-duty vehicles.

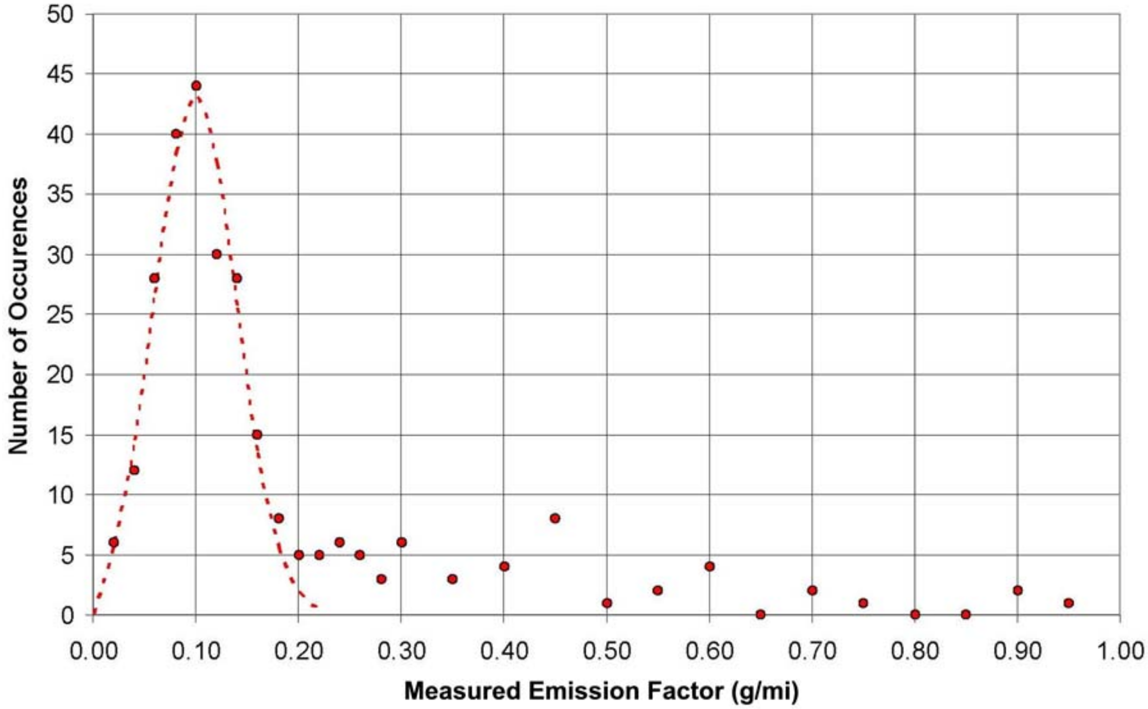
## 4.2 Silt Loadings

To better characterize the emissions of individual vehicles traveling over Salt River arterial roads during the field study period, Sierra Research subcontracted with the University of California Riverside (UCR) to collect paved road dust emission data using a trailer-based mobile sampler. The mobile sampler, known as the System for Continuous Aerosol Monitoring of Particulate Emissions from Roadways (SCAMPER), consists of a pair of DustTraks mounted on a van-trailer platform to monitor ambient PM-10 ahead of and behind the van in motion. The use of DustTraks allows for continuous monitoring of PM-10 while traversing a roadway circuit. This system is especially useful in quickly surveying variations in roadway emission rates over significant lengths of roadway. These roadway emission rates correlate to silt loadings on the roads being traversed through use of the AP-42 emission factor equation for paved road travel. To evaluate seasonal changes in roadway emissions, MAG contracted with UCR to conduct urban-wide street traverses during March, June, September, and December of 2006.[1] For the second phase of the field study (December 4-8, 2006), the SCAMPER was used to map the variability of roadway emission rates in traverses across the modeling domain and on single road links within the domain from hour to hour.

The emission measurements collected in the urban traverses for MAG and within the modeling domain for Sierra were reported by UCR in units of milligrams of PM-10 per meter of roadway travel (mg/m) and were converted by Sierra to g/mi. The data from all of the routes were summarized in the form of a histogram recording the number of roadway segments on which average emission factors for each segment/month were reported. These data, showing the overall distribution for the full calendar year, are presented in Figure 1.

[1] U.C. Riverside, MAG Silt Loading Study, February 2007.

**Figure 4-3**
**Distribution of SCAMPER Emission Factors for 2006**




Past silt measurement studies conducted in the Salt River area typically focused on representing roads with trackout (i.e., visible trackout). Thus, there are few data to profile roads that do not have visible trackout. Despite the lack of information, the expectation is that roads with visible trackout occur much less frequently than roads with no visible trackout. The SCAMPER data are consistent with this expectation.

As seen in the Figure 4-3, there are a large number of roadway segments with emission factors between 0.00 and 0.20 g/mi, while a relatively smaller number of roadways have factors that extend up to 5 times as high (1 g/mi). From these data it is reasonable to infer that the more numerous roadways at the lower end of the emission factor distribution correspond to lightly silted roads with no visible trackout, while roadways with substantially higher emission factors correspond to heavily silted roads.

A quantitative cutpoint between the two roadway groups was estimated by fitting a normal distribution to the peak at the lower end of the emission factor distribution. The roadways with no trackout can be summarized as a population of 216 segments with a mean emission factor of 0.10 g/mi and a standard deviation of 0.04 g/mi (the dotted line in the figure). The counts of roadway segments begin to consistently exceed the population distribution for lightly silted roadways with no visible trackout at 0.20 g/mi and above. Thus, a SCAMPER emission factor of 0.20 g/mi was chosen as the cutpoint to distinguish between roads with and without visible trackout.

The SCAMPER emission factors were converted to equivalent roadway silt levels using the AP-42 paved road emission factor equation. For the SCAMPER vehicle weighing 2.6 tons, this emission factor translates to a baseline silt loading of 0.011 $g/m^2$, which is significantly below any loading measured by the AP-42-recommended sweep sampling method in the Salt River area. In a recent study conducted in Las Vegas, the SCAMPER was found to underestimate road silt levels in comparison to those measured by swept sample analysis.[1] As a result, Sierra used the SCAMPER road section emission factors in a relative sense to compute true road section emission factors. To do this, a baseline road silt level of 0.3 $g/m^2$ on roads without visible trackout was assumed, based on road sweeping analyses reported in the ADEQ Salt River TSD. This baseline silt level produced an emission factor of 1.72 g/mi for a 2.6 ton vehicle using the AP-42 paved road emission equation, when the SCAMPER measured a PM-10 emission factor of 0.2 g/mi on roads without visible trackout. As a result, Sierra multiplied the SCAMPER road section emission factors by the ratio of 1.72 to 0.2 to convert SCAMPER factors to AP-42-equivalent factors.

The road segment-average emission factors measured by the SCAMPER system ranged from 0.044 to 0.728 g/mi. For those road segments with an average emission factor of 0.20 g/mi or less, Sierra used the adjusted SCAMPER emission factors to characterize baseline emissions. On these road segments, it was assumed that no trackout occurred. For the road segments with SCAMPER average emission factors greater than 0.20 g/mi, it was assumed that the increase in emission factor above 0.20 g/mi was due to trackout, and a baseline SCAMPER emission factor of 0.20 g/mi was assigned to these segments. For these segments, the excess emission factor was assigned to the trackout emission category, which is discussed in a separate section. As described above, the SCAMPER baseline emission factor of 0.2 g/mi was assumed to be measured on roads with the baseline silt loading of 0.3 $g/m^2$.

A map of the road sections traversed by the SCAMPER system within the Salt River area is shown in Figure 4-4. The road links shown in yellow are those surveyed every three months under a contract with MAG. The road links shown in blue are those surveyed during the week of December 4-8, 2006, under a subcontract to Sierra Research.

To confirm the validity of using the SCAMPER-derived silt loadings in a relative sense, instead of using these data directly in refining the Salt River area modeling inventory, Sierra contracted with Applied Environmental Consultants (AEC) to collect vacuum samples from several Salt River arterials that were sampled by the SCAMPER. Because of the time interval between road sampling by the SCAMPER and the delivery of verified data from testing to Sierra, the vacuum sampling was not performed until several months later in August 2007. The season of this vacuum sampling, however, coincided with that

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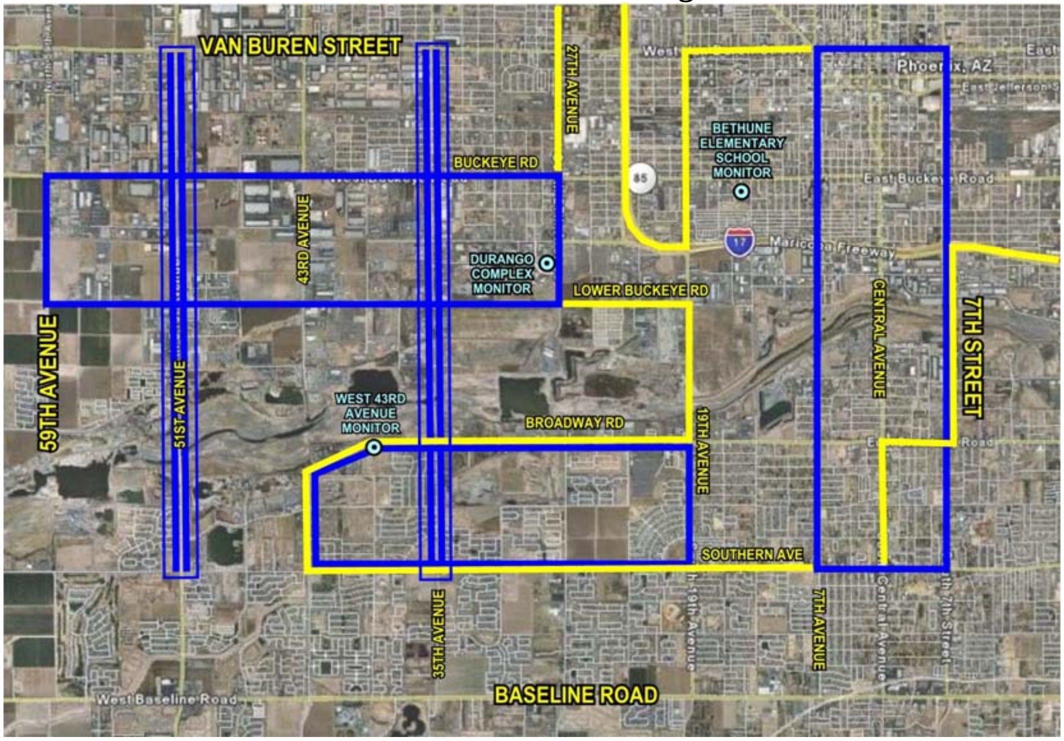
[1] The Preferred Alternative Method for Measuring Paved Road Emissions for Emissions Inventories: Mobile Technologies vs. the Traditional AP-42 Methodologies, Langston et al, 16th Annual International Emission Inventory Conference, Raleigh, NC, May 2007, *http://www.epa.gov/ttn/chief/conference/ei16/session11/langston.pdf*, accessed on October 27, 2007.

**Figure 4-4**
**SCAMPER Mobile Monitoring Routes**




of the most recent previous vacuum sampling prior to the field study, which was conducted by ADEQ in September 2003. The ADEQ sampling, however, was performed on a Salt River arterial that was not traversed by the SCAMPER.

MAG used the results of the SCAMPER measurements to select road segments for AEC to collect silt samples. A total of 10 segments were selected for sampling—5 with SCAMPER emission rates consistently above 0.2 g/mi (i.e., higher rates) and 5 with SCAMPER emission rates equal to or lower than 0.2 g/mi (i.e., lower rates). To ensure consistency between the sampling strata, traffic volume was also considered in the selection of segments included in each strata. The results, however, as presented in Table 4-1, show that the higher silt loadings occur in the segments selected to represent lower emission rates. The correlation between the two data sets is poor. Differences in seasons when the data were collected, however, may account for part of the inconsistency as the SCAMPER data were collected in each season of 2006 and the silt samples were collected in August 2007. Another contributing factor is that silt measurements are heavily influenced by daily changes in deposition from trackout, carryout, etc. Thus, differences between the measurements may simply be the result of the luck of the draw.

| Table 4-1<br>Silt Sampling Results Organized by SCAMPER Emission Rates<br>($g/m^2$) | | |
|---|---|---|
| **Location** | **Traffic Group** | **Silt Loading** |
| **SCAMPER Segments with Higher PM-10 Emission Rates** | | |
| Broadway between 35th Ave & 43rd Ave | l | 0.08 |
| 27th Ave between Lower Buckeye & Durango | l | 0.16 |
| Ray Rdbetween Santan Village Pkw & Higley Rd | l | 0.30 |
| Higley Rd between Ray Rd & Williams Field Rd | ll | 0.90 |
| 19th Ave between Broadway & Lower Buckeye | lll | 0.23 |
| **SCAMPER Segments with Lower PM-10 Emission Rates** | | |
| Roosevelt St between 7th St & 16th St | l | 0.17 |
| 39th Ave between Thomas Rd & Osborne Rd | l | 0.31 |
| 27th Ave between Van Buren & McDowell | ll | 0.12 |
| Santan Village Pkw between Williams Field Rd & Ray Rd | ll | 3.50 |
| Central Ave between Broadway & Southern | lll | 1.10 |

Five of the locations that AEC sampled were determined to be within (or directly adjacent to) the borders of the Salt River modeling domain. A comparison of the measurements obtained for those locations is contrasted with the 2003 measurements in Table 4-2. As can be seen, both studies collected measurements at 5 locations and both studies determined one of those locations to be representative of trackout. The criterion used to distinguish between "clean streets" and trackout in 2003 was whether silt levels were "visual." This resulted in an average clean street silt loading of 0.3 $g/m^2$ and an average assigned trackout silt loading of 1.5 $g/m^2$.

Information on whether trackout was visible was not included in the AEC report. Follow-up discussions with AEC indicated that while trackout was not generally visible, notes on visibility were not recorded for individual sampling locations.[1] Lacking this information, the 2003 study findings were used to assess whether a location had trackout. Given the uniformly low silt values recorded in 2007, the only measurement considered to be the result of trackout was Central Avenue (as it was clearly an outlier relative to the rest of the Salt River measurements). Since the 1.10 $g/m^2$ value is much more likely to fall within the distribution of values producing the average trackout value of 1.5 $g/m^2$ than the distribution of values producing the average clean street value of 0.3 $g/m^2$, Central Avenue was determined to represent a location with trackout. The remaining Salt River silt measurements produce an average value of 0.15 $g/m^2$, which represents a reduction of 50% from the values recorded in 2003.

[1] AEC collected measurements at three locations within each of the road links selected for sampling.

| Table 4-2<br>Comparison Between Salt River Silt Measurements<br>Collected in 2003 and 2007 | | |
|---|---|---|
| **Location** | **Silt Loading ($g/m^2$)** | **Trackout** |
| **2003 ADEQ Measurements** | | |
| 19th Ave S Lower Buckeye | 0.38 | - |
| 19th Ave river N Broadway | 0.57 | - |
| W. Broadway 38th Drive | 0.24 | - |
| 51st Ave S of bridge | 0.12 | - |
| Lower Buckeye W 35th Ave | 2.10 | X |
| Non Trackout Mean | 0.33 | |
| **2007 MAG Measurements** | | |
| 27th Ave between Van Buren & McDowell | 0.12 | - |
| 27the Ave between Lower Buckeye & Durango | 0.16 | - |
| Broadway Rd between 35th Ave & 43rd Ave | 0.08 | - |
| 19th Ave between Broadway & Lower Buckeye | 0.23 | - |
| Central Ave between Broadway & Southern | 1.10 | X |
| Non Trackout Mean | 0.15 | |

The importance of silt measurement cannot be overstated given its influence on emission inventory estimates and its value as a marker in tracking the progress of control programs towards attainment. With the benefit of hindsight, the sample sizes of silt measurements used to make important judgments about changes over time and the contribution of control programs are too limited and larger sample sizes are needed to improve confidence in these estimates.

## 4.3 Industrial

After identifying an episode in December 2006 for analysis (see Chapter 5 for a description of the days selected), requests for day-specific activity data were submitted to the larger aggregate operators located within the Salt River modeling domain. To assist in the preparation of diurnal profiles, a spreadsheet was prepared that provided space for an operator to mark the hours of operation for the following categories of operation:

- Quarrying;
- Aggregate processing;

- Aggregate loadout;
- Ready-mix concrete;
- Asphalt concrete; and
- Other.

Space was also provided for contact information, comments on other processes, etc. A copy of the spreadsheet was submitted to individual operators in some cases and to the Arizona Rock Products Association for distribution to member companies. Follow-up telephone conversations with the respondents found that most operators maintained computerized records of their operating hours so that they could track progress towards permitted emission levels. Through these discussions it was also determined that the operating hours of these companies were demand driven and as a result were highly variable. This finding reinforced the view that use of typical daily profiles or annual average hours of activity could significantly bias emission estimates and disadvantage air quality analysis of source-specific contributions to exceedances. Through discussions with operators it was found that activity levels in 2006 were generally lower than those that occurred in 2005 when construction activity was at a peak.

The results of the survey were used to configure the emission estimates for each of the respondents (roughly 10 companies provided responses). The approach used was to quantify the average annual hourly emission rate for each process using facility-specific emission estimates for 2005 obtained from the Maricopa County Air Quality Department (MCAQD). Those values were then applied uniformly to the hours of operation obtained in the surveys. The approach used to configure the remaining sources was to assume that facility-specific annual hourly emission rate obtained from Maricopa County for calendar year 2005 were uniformly distributed over the hours between 7:00 am to 5:00 pm.[1]

## 4.4 Light Industrial (Vacant and Unpaved Parking Lots)

During an early assessment of potential sources impacting the Durango Complex and West 43rd Avenue monitoring sites, Sierra identified several light industrial sites with unpaved yards that were within 100 meters of each monitor. Because vehicle travel on these unpaved yards could produce measurable impacts at a monitor, a monitoring subcontractor—AEC—was tasked with visually monitoring vehicle movements within approximately ten designated light industrial facilities over three hour periods. During the surveillance periods, which were generally scheduled between 5:00 and 8:00 am during peak PM-10 levels on winter stagnant days, AEC staff parked outside these facilities and counted vehicle trips within facility boundaries. For each trip on unpaved surfaces, data on vehicle type, travel distance, and vehicle speed were recorded. Vehicle speed could only be estimated by the observers, and vehicle weights were later estimated by Sierra staff on the basis of the vehicle descriptions recorded by AEC staff.

[1] This approach overestimates the contribution of these facilities to the extent that industrial operations declined in 2006 relative to 2005.

The collected data were used to estimate PM-10 emissions for each trip. Trip-specific emission factors were computed using the AP-42 equation for unpaved road travel at industrial sites.[1] Emissions per trip were calculated by multiplying the emission factor by the observed trip distance in units of miles. The emissions from all trips observed during the surveillance period were summed and divided by the number of hours of surveillance to compute average hourly PM-10 emissions from each site. Daily operating hours for each facility were obtained by AEC staff through telephone interview of facility operators.

## 4.5 Construction

Because the locations of construction activities and emissions shift within the modeling domain from year to year, separate estimates of construction emissions were prepared for December 2005 (low wind design days), February 2006 (high wind design days), and December 2006 (the modeling episode selected for analysis in this report). A description of the process used to prepare these estimates is presented in the TSD for the Five Percent Plan.[2] Using a combination of assumptions employed in the MCAQD inventory regarding the duration of construction activity and a listing of earth moving permits provided by Maricopa County for projects located within the Salt River modeling domain, a logic was constructed to determine which sites were active in each of the episodes analyzed. A summary of the results of that analysis is presented in Table 4-3. It shows that the use of different location assumptions significantly impacted the number of permits and acres disturbed for each of the episodes of interest.

**Table 4-3**
**Impact of Location Assumption**
**on Permits and Acreage Included in the Construction Emissions Inventory**

| Date | Location Criteria | Permits | Acreage |
|---|---|---|---|
| December, 2005 | 2 miles | 36 | 684.6 |
| December, 2005 | Salt River Area | 57 | 905.8 |
| February, 2006 | 2 miles | 51 | 966.3 |
| February, 2006 | Salt River Area | 72 | 1,226.6 |
| December, 2006 | 2 miles | 42 | 661.3 |

## 4.6 Agriculture

As discussed in the TSD for the Five Percent Plan, the key issue in calculating agricultural emissions is to estimate the level of activity that occurred on the design day. One end of the spectrum spreads all of the tilling (e.g., rip, disc, etc.) required to produce

[1] Compilation of Air Pollutant Emission Factors, AP-42, 5th Edition, January 1995, U.S. Environmental Protection Agency, Section 13.2.2 Unpaved Roads
[2] MAG, Five Percent Plan for PM-10 for the Maricopa County Nonattainment Area, December 2007.

a crop across all of the days included in a crop's lifespan. The result is an estimate of activity that significantly underestimates the level of activity on days when activity occurs (i.e., because there is no activity on many days of a crop's lifecycle). On the other end of the spectrum, there are days when farmers are operating almost continuously to comply with regulatory dates when operations have been delayed because of severe weather, etc.

Discussions with the Arizona Farm Bureau confirmed that during the December 2006 episode, farmers in the Salt River modeling domain were in the process of converting fields from cotton to wheat and operating continuously (i.e., 24-hours/day with different crews). Using this information, along with related estimates of tractor speed and acres located within the modeling domain, it was possible to determine the hours per day that tractors operated on each field.

## 4.7 Local Truck Yard

During the initial field survey of sources located near the two Salt River monitors, T&B Systems identified a truck yard with unusually high activity levels operating near the Durango Complex. Mobile measurements and video records showed that significant levels of PM-10 were being emitted from vehicles operating at the facility. Sierra contacted the operator and determined that the facility was being used as a school to train truck drivers. The operator did not maintain records of daily operation, but was able to provide information on the level of activity that typically occurred when the school was in operation, the days of the week the school operated, holidays observed, and the impact of holidays on weekly enrollment and activity occurring in the yard.

###

# 5. AIR QUALITY MODELING

Air quality modeling analyses are frequently hobbled because day-specific activity information is not available to support the development of source-specific emissions for the day(s) being modeled. Methods used to overcome this limitation typically involve the use of annual average activity levels, seasonal profiles, etc. The problem with these approaches is that the unique activity conditions of the day are not reflected in the emission estimates (e.g., unusual congestion caused by accidents, construction, etc., peaks in agricultural and industrial production, etc.) and the accuracy of the resulting inventory and estimated concentrations can be severely under- or overestimated. The collection of source specific activity on days when exceedances of the ambient PM-10 standard were recorded during December 2006 provided an opportunity to eliminate this layer of uncertainty in emission estimates and evaluate its impact on the ability of air quality modeling to represent concentrations recorded on those days. Thus, while the design days selected for the Five Percent Plan occurred in December 2005 and February 2006 (for low and high wind conditions, respectively), an initial air quality analysis was conducted for selected days in December 2006 when exceedances of the PM-10 standard were recorded. The goal of the analysis was to take advantage of the improved accuracy of the emission inventory estimates to assess relative source contributions, the significance of transport, and the ability of air quality modeling to represent concentrations recorded under exceedance conditions.

Since many of the air quality modeling steps have already been detailed in the TSD for the Five Percent Plan, those discussions will not be repeated here. Instead, the discussion will focus on differences in the following:

- Design day selection;
- Emission inventory development;
- Meteorological data;
- Background estimates; and
- Model performance

Since the Air Quality Modeling Team and MAG determined that grid-based dispersion modeling represented the best option for evaluating source-specific contributions impacting the Salt River monitors, the model choices were limited. Based on a review of EPA guidelines, AERMOD was determined to be the most suitable dispersion model for evaluating hourly source contributions to PM-10 exceedances recorded at the Salt River monitors (i.e., Durango Complex and West 43rd Ave.). Despite AERMOD's advantages, there was concern about how well a steady-state Gaussian plume dispersion model could represent low wind, stagnant conditions.  Therefore, before focusing exclusively on AERMOD, a puff model was evaluated because of its advantage over plume models in representing dispersion under low wind conditions.  Appendix C provides a summary of a comparison between AERMOD and CALPUFF in representing selected sources in the Salt River.  The results showed no discernable difference in the results between the two models.  They also showed that considerable effort would be required to properly configure CALPUFF to represent the Salt River modeling domain.  For these reasons, a decision was made to use AERMOD for the air quality modeling analysis.

## 5.1 Episode Selection

The episode was selected on the basis on 24-hour average PM-10 concentrations recorded at the Durango Complex and West 43rd Avenue monitors during the intensive field study. The field study commenced on November 15, 2006, and was completed on December 15, 2006.  Intensive field study data collection was not conducted on every day during this interval.  Table 5-1 tabulates the 24-hour average PM-10 concentrations during this period, and the days of intensive data collection are shown in shaded blocks.

**Table 5-1**
**24-Hour Average PM-10 Concentrations and Wind Speeds During Field Study**

| Date | PM-10, µg/m$^3$ | | Wind Speed, mph | |
|---|---|---|---|---|
| | Durango Complex | West 43rd Avenue | Durango Complex | West 43rd Avenue |
| 11/15/2006 | 104 | 129 | 1.8 | 4.2 |
| 11/16/2006 | 139 | 164 | 1.2 | 2.5 |
| 11/17/2006 | 123 | 175 | 1.1 | 2.5 |
| 11/18/2006 | 97 | 118 | 1.8 | 3.3 |
| 11/19/2006 | 84 | 72 | 2.2 | 2.5 |
| 11/20/2006 | 123 | 120 | 3.6 | 5.7 |
| 11/21/2006 | 100 | 93 | 3.7 | 2.4 |
| 11/22/2006 | 134 | 151 | 1.6 | 3.3 |
| 11/23/2006 | 75 | 108 | 1.6 | 3.3 |
| 11/24/2006 | 88 | 94 | 1.8 | 2.8 |
| 11/25/2006 | 71 | 74 | 1.3 | 4.1 |
| 11/26/2006 | 52 | 54 | 1.6 | 3.4 |
| 11/27/2006 | 95 | 164 | 2.5 | 4.0 |
| 11/28/2006 | 44 | 98 | 3.4 | 3.5 |
| 11/29/2006 | 100 | 138 | 7.7 | 8.9 |
| 11/30/2006 | 58 | 88 | 1.6 | 4.0 |
| 12/1/2006 | 117 | 115 | 1.4 | 2.3 |
| 12/2/2006 | 84 | 127 | 1.7 | 4.4 |
| 12/3/2006 | 40 | 51 | 3.0 | 10.4 |

**Table 5-1**
**24-Hour Average PM-10 Concentrations and Wind Speeds During Field Study**

| Date | PM-10, µg/m³ | | Wind Speed, mph | |
|---|---|---|---|---|
| | Durango Complex | West 43rd Avenue | Durango Complex | West 43rd Avenue |
| 12/4/2006 | 84 | 93 | 4.0 | 2.6 |
| 12/5/2006 | 114 | 174 | 1.8 | 1.6 |
| 12/6/2006 | 167 | 160 | 1.3 | 2.2 |
| 12/7/2006 | 175 | 160 | 4.6 | 5.4 |
| 12/8/2006 | 72 | 80 | 5.3 | 5.4 |
| 12/9/2006 | 50 | 52 | 3.5 | 3.3 |
| 12/10/2006 | 90 | 127 | 4.8 | 5.3 |
| 12/11/2006 | 103 | 105 | 1.9 | 3.3 |
| 12/12/2006 | 108 | 138 | 1.8 | 2.9 |
| 12/13/2006 | 136 | 138 | 1.8 | 3.1 |
| 12/14/2006 | 148 | 164 | 1.2 | 3.2 |
| 12/15/2006 | 139 | 178 | 1.5 | 3.1 |

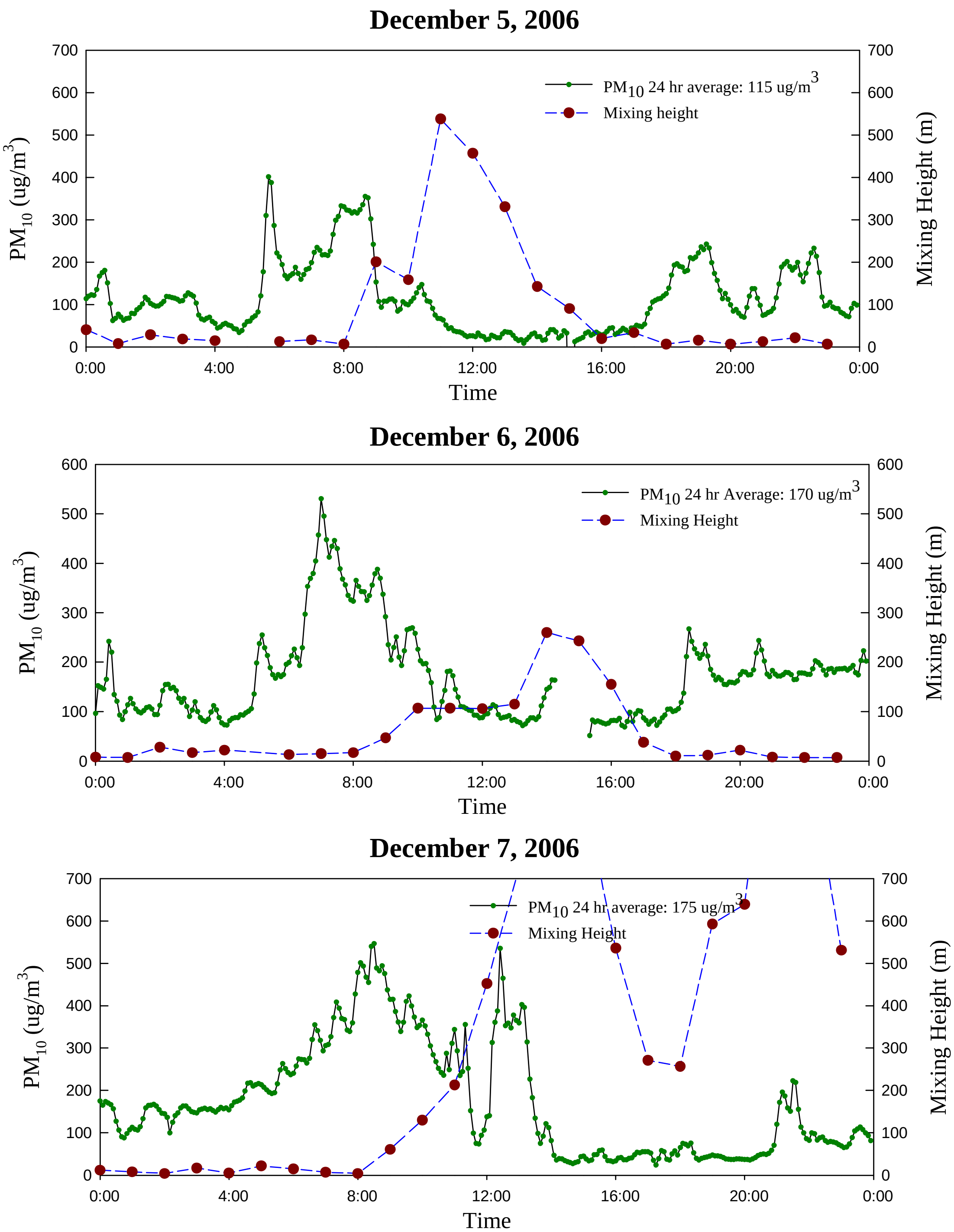
Note: Shaded blocks denote days of intensive data collection.

During the first intensive field study work, between November 15 and November 19, 2006, T&B Systems traversed the modeling domain with a single mobile monitoring platform and measured PM-10 profiles looking for hotspots. Daily PM-10 averages exceeded the federal 24-hour standard on November 16 and 17 at the West 43rd Avenue site during this period, but no exceedances were recorded at the Durango Complex monitor. These data suggested that localized sources were impacting the West 43rd Avenue, but that the remainder of the Salt River area was being sufficiently ventilated to avoid exceedances.

During the second intensive data collection period, between November 30 and December 8, 2006, a stagnation event occurred that caused simultaneous exceedances to be recorded at both monitoring sites. This period of low wind conditions commenced at about 2:00 a.m. on December 5, and extended through about 1:00 p.m. on December 7. The stagnation conditions caused locally emitted PM-10 to be trapped in the area of origin and to accumulate under low inversion ceilings. This stagnation event occurred coincidentally during the week of peak data collection activity in the field study program. As a result, the days when PM-10 exceedances were recorded at both the Durango Complex (December 6-7) and West 43rd Avenue (December 5-7) monitors was selected as the design day period for intensive emission inventory refinement and dispersion modeling.

The analysis of design day conditions began with an examination of 5-minute average PM-10 concentrations and hourly average meteorological conditions that were recorded during the three day period. Plots of these data are presented in Figures 5-1 through 5-3.

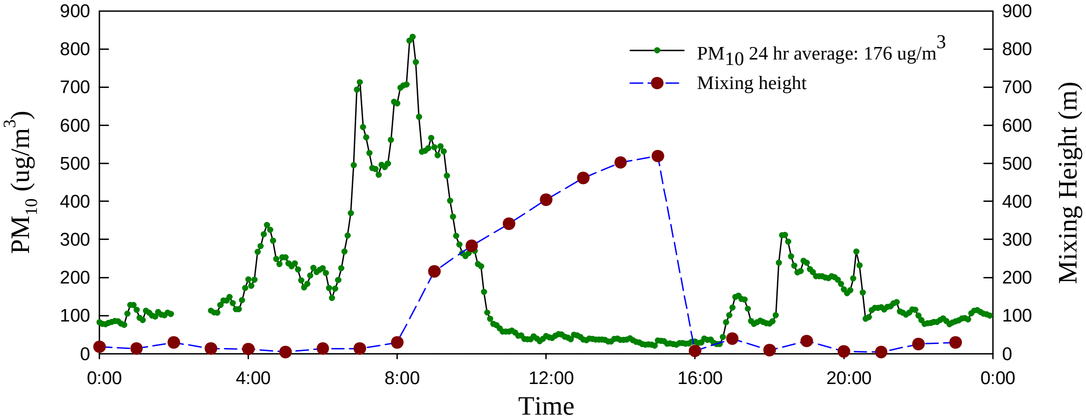
## Figure 5-1
## Summary of Monitoring Conditions at Durango Complex
## During December Episode



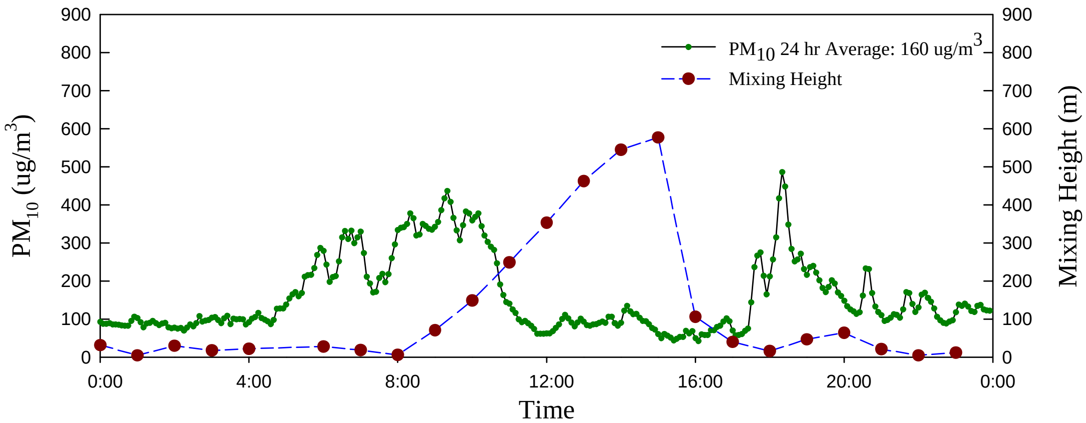

Note: In some cases the 24-hour values reported above are different from those displayed in Table 5-1. This is because the values displayed above are based on averages of 5-minute values, whereas those reported in Table 5-1 are based on an hourly average values.

**Figure 5-2**
**Summary of Monitoring Conditions at West 43rd Ave.**
**During December Episode**

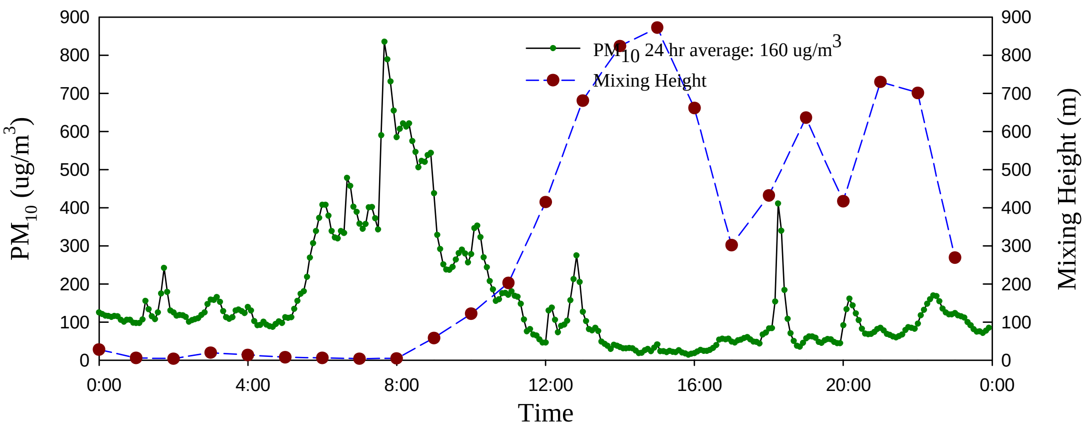
**December 5, 2006**




**December 6, 2006**



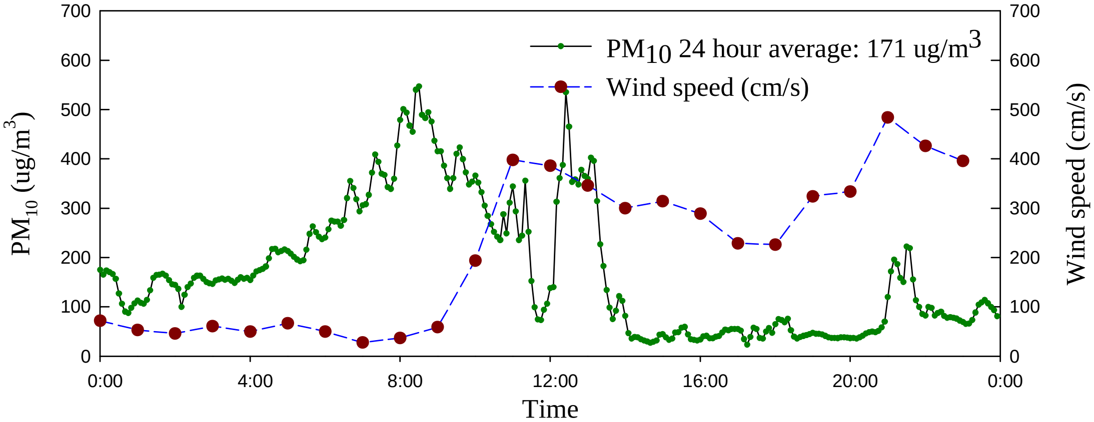

**December 7, 2006**



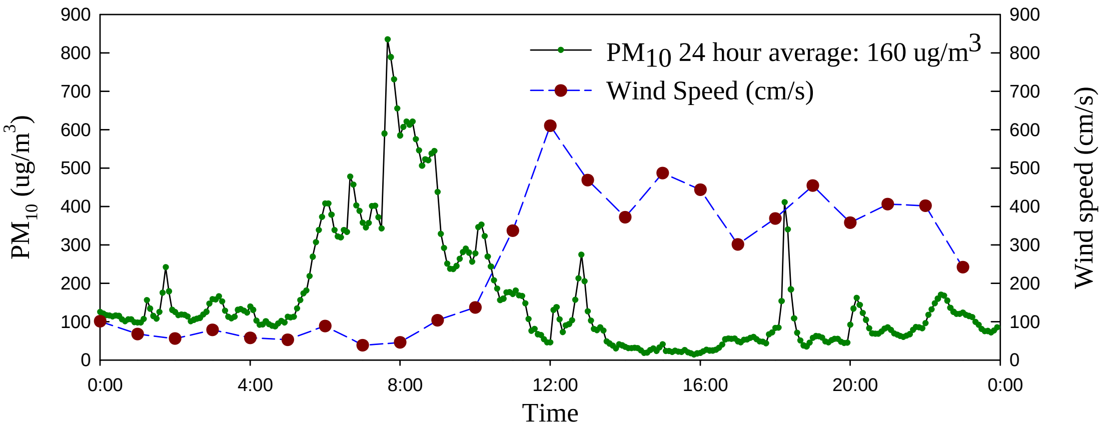

Note: In some cases the 24-hour values reported above are different from those displayed in Table 5-1. This is because the values displayed above are based on averages of 5-minute values, whereas those reported in Table 5-1 are based on an hourly average values.

**Figure 5-3**
**Summary of Monitoring Conditions at**
**Durango Complex and West 43rd Ave. on High Wind Day**
**During December Episode**

**Durango Complex – December 7, 2006**




**West 43rd Ave. – December 7, 2006**




Note: In some cases the 24-hour values reported above are different from those displayed in Table 5-1. This is because the values displayed above are based on averages of 5-minute values, whereas those reported in Table 5-1 are based on an hourly average values.

Figure 5-1 shows PM-10 concentrations at the Durango Complex monitor together with local mixing heights as computed by the AERMET program for 24-hour periods on December 5 through 7, 2006. In a validation test using mixing heights recorded at the West 43rd Avenue monitoring site by a miniSODAR system, as reported in the TSD for the Five Percent Plan, the AERMET program demonstrated close agreement with physical data. The plots for each day show very low mixing heights during nighttime hours with gradual rises with groundheating in the mornings and sharp declines in the evenings after sunset. The exception to the evening decline in mixing height occurred on

December 7 when elevated wind speeds produced significant mixing for the remainder of the day after 11 a.m.

On all three days shown, PM-10 concentrations rose in the early morning and then dropped substantially after the inversion lifted. The early morning ramp-up appeared to be due to the onset of industrial activity and heavy duty truck traffic after about 4:00 am. The morning decline in PM-10 also appeared to result from the rise in inversion height and mixing of groundlevel concentrations into the expanding mixing zone. After sunset, the inversion height was seen to drop dramatically, and PM-10 concentrations were seen to rise. In the absence of any significant sources that could be identified, however, it is unclear why PM-10 concentrations remained high during the nights of December 5/6 and 6/7.[1]

In Figure 5-2, the same morning rise and decline of PM-10 concentrations can be seen at the West 43rd Avenue monitoring site. As shown by these plots, these peaks were sufficiently high and broad as to cause the 24-hour average concentrations to exceed the federal PM-10 standard. At the West 43rd Avenue site, nighttime PM-10 concentrations were seen to steadily decline on December 5/6 and 6/7, suggesting that the initial rises caused by the rapid drop in inversion height were not sustained by continuing local emissions.

Figure 5-3 shows a comparison of PM-10 concentrations to wind speeds at each monitoring site on December 7. This day began under stagnant conditions, but a passing front caused a rise in wind speed that was sustained over the second half of the day. Afternoon and evening winds at both sites appeared to produce sufficient ventilation to keep PM-10 concentrations below 100 $\mu g/m^3$ over most of this period at both sites.

## 5.2 Emission Inventory Development

This section provides a review of differences in the modeling domain, source representation within the modeling domain and inventory development. Because several studies have been prepared to evaluate source contributions within the Salt River, key differences are noted between assumptions and methods employed in the following recent efforts:

- ADEQ's Salt River TSD;
- MAG's TSD for the Five Percent Plan; and
- MAG's 2006 Modeling Analysis (the analysis documented in this report)

[1] This suggests the concentrations were the result of an unknown source activity. Sierra checked accident statistics, night-time construction activity (e.g., road construction that forced vehicles to operate on shoulders, etc.) and notices of violation (NOVs) issued by the County on the dates of interest. No activity explaining these conditions could be identified.

A summary of the source specific emission estimates for the 2006 Modeling Analysis is presented at the end of the section.

Model Domain – As noted in the Introduction to this section, the domain used to represent the Salt River area is essentially the same for all three studies.[1] As shown in Figure 5-4, the domain is bounded by Van Buren Street to the north, Baseline Road to the South, 59th Ave to the west and 7th Street to the east. ADEQ selected this domain in the TSD for the 2005 Attainment Plan and identified the location and borders of all significant sources (e.g., vacant lots, agricultural land, industrial facilities, etc.) located within these boundaries. The information developed in that effort represented an excellent starting point for inventory development in the subsequent MAG analyses.

**Figure 5-4**
**Salt River Area Modeling Domain**


The Salt River TSD divided the modeling domain into 400 x 400 meter grid cells. Both area and on-road source emissions were distributed evenly throughout each grid cell in

[1] A review of the Salt River TSD shows that the boundaries of the modeling domain extended slightly beyond those displayed in Figure 5-4 (roughly one grid cell to the east and one grid cell to the north). This increment accounts for the 3.3 square mile difference between the 38.9 square mile size of the Salt River TSD and the 35.6 square mile size of the area displayed in Figure 5-4.

which sources were located. As noted earlier, Sierra suspected that this approach would eliminate any opportunity to accurately quantify the relative impacts of sources located near the monitors because the size of the area within which pollutants were emitted was enlarged and the emission density was diminished. For example, the geographical distribution of street sources disappears when distributed within grid cells, despite the fact that emissions from significant streets within the grid cell containing a monitor can impact modeled concentrations at the monitor independent of the wind direction. In light of this concern, the MAG studies (both the Five Percent Plan and the modeling analysis presented in this report) identified the boundaries of each source and distributed the emissions within those boundaries as uniform volume sources. Thus, emissions for each road link were distributed as series of volume sources located within the borders of the road (i.e., the pavement edge plus 3 meters on each side). Similarly, for construction, the boundaries of individual sites, which could range between 1 to over 100 acres, were identified and the emissions were uniformly distributed as volume sources located within those boundaries. Similar approaches were employed to represent other area sources, including unpaved parking lots, agricultural fields, etc.

Presented below is a review of differences in the approaches used to characterize sources in the three recent Salt River Area studies.

On-Road Emissions – Paved road fugitive dust is the largest source of PM-10 emissions in the Salt River modeling domain. A summary of differences among the three Salt River studies in preparing on-road emission estimates is presented in Table 5-2. It shows that in each study separate methods were used to characterize emissions from freeways, arterial and local roads. One significant difference is that while the Salt River TSD and the Five Percent Plan TSD prepared emission estimates for all paved roads located within the modeling domain, the 2006 Analysis prepared emission estimates for only a subset of the arterials and local roads (i.e., the higher volume arterials and the local roads located adjacent to the Durango Complex and West 43rd Ave. monitors, are highlighted in Figure 5-5). It should be noted that publicly accessible unpaved roads were not represented in any of the studies. That is because emissions from these roads were found to be negligible and emissions from unpaved haul roads on private lands were included in the industrial emission estimates.

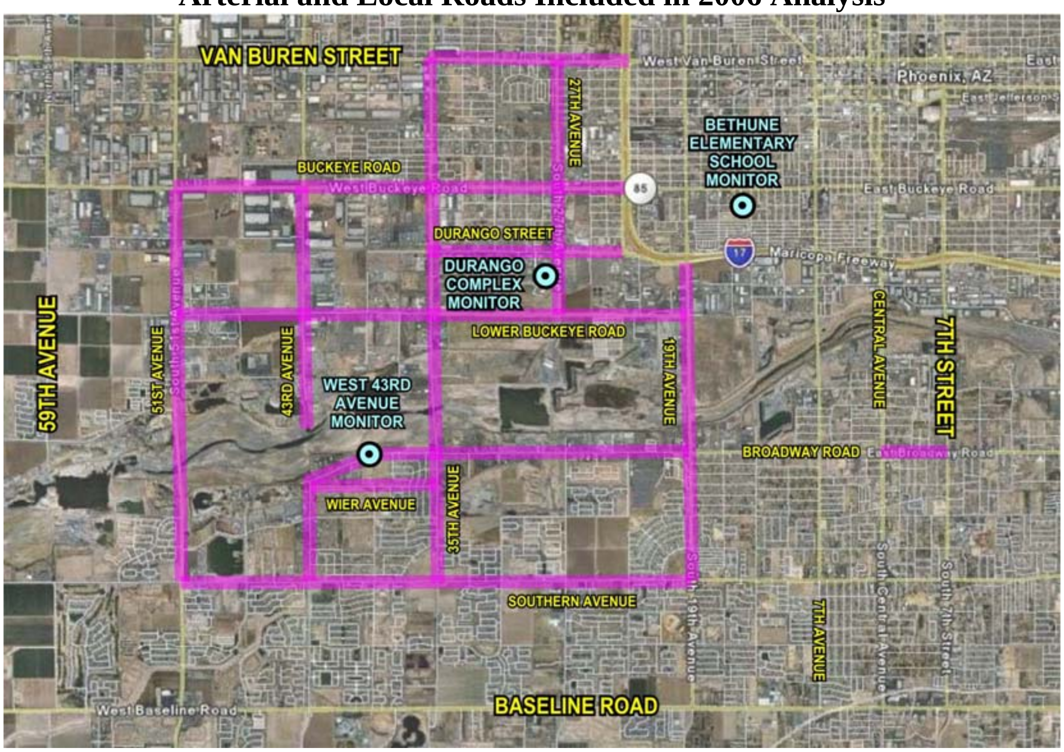
**Table 5-2**
**Differences in Road Network Emission Calculations Between Salt River Studies**

| Study | Roads | VMT | Diurnal Profile | Silt | Vehicle Weight | Emission Configuration |
|---|---|---|---|---|---|---|
| **ADEQ Salt River TSD** | Freeway | ADOT Counts | ADOT Counts | $0.3\ g/m^2$ | 3 tons | Distributed Across Grid-Cells |
| | Arterial | City of Phoenix Counts | Unclear | | | |
| | Local | 10% of Counts | Unclear | | | |

**Table 5-2**
**Differences in Road Network Emission Calculations**
**Between Salt River Studies**

| **Study** | **Roads** | **VMT** | **Diurnal Profile** | **Silt** | **Vehicle Weight** | **Emission Configuration** |
|---|---|---|---|---|---|---|
| **MAG Five Percent Plan TSD** | Freeway | MAG Model | MAG Contractor Hourly Counts | 0.3 g/m$^2$ | 4.1 tons | Volume Sources |
| | Arterial | | | | | Volume Sources |
| | Local | | | | | Distributed Across Grid Cells |
| **MAG 2006 Analysis** | Freeway | - | - | - | - | - |
| | Arterial | MAG Contractor Counts for Selected Roads | MAG Contractor Hourly Counts | 0.3 g/m$^2$ | Light-duty ( 3 tons) Medium-duty (13.8 tons) Heavy-duty (27.5 tons) | Volume Sources |
| | Local | Counts for Roads Adjacent to Monitors | MAG Contractor Hourly Counts | 0.3 g/m$^2$ | Light-duty ( 3 tons) Medium-duty (13.8 tons) Heavy-duty (27.5 tons) | Volume Sources |

**Figure 5-5**
**Arterial and Local Roads Included in 2006 Analysis**



The approaches used to estimate travel and diurnally distribute emissions also differed in that the Salt River TSD and the 2006 Analysis relied upon vehicle counts (i.e., counts multiplied by the length of the link in which the counts were collected provide an estimate of vehicle miles traveled, or VMT), whereas the Five Percent Plan TSD used estimates of VMT from MAG's model. MAG's model provides estimates of travel for multiple time periods of the day (i.e., am, pm, mid-day, and off-peak). These estimates were disaggregated to hourly traffic levels based on hourly profiles represented for each time period, which were derived from the traffic count data. While the silt levels used to compute the baseline (i.e., non-trackout) estimate of fugitive dust emissions were consistent across the studies, the assumptions about vehicle weight were not. The Salt River TSD relied upon a "national average" weight of 3 tons; the 2006 analysis prepared separate estimates for each vehicle class and estimated representative class average weights. When preparing to model paved road emissions for the 2005 TSD, it was determined that insufficient data was available to quantify average weight by vehicle class in the modeling domain. As discussed in the Five Percent Plan TSD, a review of the available data indicated that average vehicle weight was higher than 3 tons; therefore an EPA-referenced value of 4.1 tons was used for the Salt River area.

Arguably the most significant difference among the studies was the method used to represent road emissions within the modeling domain. As noted earlier, the Salt River TSD distributed emissions for roads located within each grid cell throughout the grid cell. Since this diminished the density of the emissions and the signature of the source, both the Five Percent Plan and the 2006 Analysis employed a method that provided a more representative source location. This was accomplished by representing each road link as a set of volume sources in dispersion modeling analysis. The volume source release heights and vertical dispersion parameters ($\sigma_z$) were taken from the CALINE-4 manual[1] formula 5-12 ($\sigma_z$ = 4.0/2.15 =1.86). The lateral dispersion parameter ($\sigma_y$) was set to L/2.15 meters, where L = (n*12+20)*0.3048 meters (length of volume source used to represent a piece of the freeway segment or the distance between separated volume sources used to represent the freeway segment, where n is the number of lanes on the segment of the road). The UTM coordinates for relevant freeways and freeway segments were identified and combined with the other dispersion parameters to prepare the AERMOD input files. The emissions of traffic (and, as will subsequently be discussed, the trackout) from each road segment were uniformly distributed among the total number of volume sources in that segment.

<u>Trackout Emissions</u> – While trackout emissions are produced by the same activity that produces paved road emissions, the controls applied to reduce the silt levels causing these emissions are different from those used to reduce baseline paved road emissions. For this reason, trackout emissions were estimated separately. Table 5-3 summarizes the differences in the methodologies used to estimate trackout emissions. As can be seen, the data and assumptions used to estimate and diurnally distribute the traffic are identical to

[1] CALINE4 – A Dispersion Model for Predicting Air Pollutant Concentrations Near Road Ways, California Department of Transportation, June 1989 Update.

| Table 5-3<br>Differences in Trackout Emission Calculations<br>Between Salt River Studies | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Study** | **Roads** | **VMT** | **Diurnal Profile** | **Silt Range** | **Silt Measurement Method** | **Vehicle Weight** | **Emission Configuration** |
| ADEQ Salt River TSD | Freeway | ADOT Counts | ADOT Counts | 0.75 – 3.06 g/m$^2$ | Limited sample collection + Visual Observation | 3 tons | Distributed Across Grid Cells |
| | Arterial | City of Phoenix Counts | Unclear | | | | |
| | Local | 10% of Counts | Unclear | | | | |
| MAG Five Percent Plan TSD | Freeway | MAG Model | | | Adjusted SCAMPER Data | 4.1 tons | Volume Sources |
| | Arterial | | MAG Contractor Hourly Counts | 0.00 - 1.34 g/m$^2$ | | | Volume Sources |
| | Local | | | | | | Distributed Across Grid Cells |
| MAG 2006 Analysis | Freeway | - | - | - | - | - | - |
| | Arterial | MAG Contractor Counts for Selected Roads | MAG Contractor Hourly Counts | 0.00 - 1.34 g/m$^2$ | Adjusted SCAMPER Data | Light-duty ( 3 tons) Medium-duty (13.8 tons) Heavy-duty (27.5 tons) | Volume Sources |
| | Local | Counts for Roads Adjacent to Monitors | | | | | |

those used to estimate paved road emissions. Similarly, the assumptions about vehicle weight and the source representation methods are also the same. Significant differences, however, can be seen in the ranges of silt values and the measurement methods used to estimate those silt values.

The Salt River TSD relied upon data collected using the EPA silt measurement methodology, which requires traffic to be blocked on the road to be measured and a pre-defined sampling area to be vacuumed from the edge of the road to the center of the road and then back to the edge of the road. The sample is collected on a pre-weighed vacuum bag, which is then extracted and weighed. A sieve analysis is then used to determine the silt content of the sample. Samples were collected from eight separate roads; analysis of the data determined that the silt loading on the road section with no visible trackout was 0.3 g/m$^2$. Silt loadings from areas with different amounts of trackout were found to range from a high of 11.2 g/m$^2$ to a low of 0.4 g/m$^2$.

In contrast to the Salt River TSD, which relied upon measurements collected in 2003, the 2006 Analysis obtained two separate measurements of silt loadings on Salt River roads.

As described in Section 4, the first measurements were collected with a trailer-based mobile sampler known as SCAMPER. The second used the EPA-approved vacuum procedure to collect measurements from 10 separate roads in the Salt River area in 2007.

The SCAMPER measurements were recorded in units of grams of PM-10 per mile and statistical analysis of the results revealed that the minimum emission factor was 0.20 grams per mile, suggesting that this was the baseline without trackout. As explained in the Five Percent Plan TSD, this SCAMPER emission factor was equated to the minimum silt loading of 0.3 $gm/m^2$ reported by ADEQ. Any road segment measured by the SCAMPER to have an emission factor greater than 0.2 gm/mi was assumed to have trackout, and the excess emissions above 0.2 gm/mi were attributed to trackout contributions. The trackout silt level was backcalculated from the SCAMPER trackout emission factor using the AP-42 equation and the 0.3 $gm/m^2$ to 0.2 gm/mi relationship discussed above.

A description of the procedures used to collect the vacuum measurements of silt loadings from Salt River roads in 2007 is presented in Appendix D. Those values were used to determine the effectiveness of trackout control measures implemented since the 2005/2006 winter.

<u>Industrial Emissions</u> – A summary of data and methods used to estimate industrial emissions is presented separately for point and area sources for the each of the three Salt River studies in Table 5-4. It shows the definitions used to distinguish between point and area sources differed between the Salt River TSD and the two MAG studies. The Salt River TSD selected 36 sources to be modeled separately as point sources based on ranking and distance from the air quality monitors. The remaining 45 sources were modeled as area sources. The MCAQD 2005 inventory, which was used to quantify emissions from industrial sources in both MAG studies, defined point sources on the basis of the level of pollutants emitted:

- 25 short tons of carbon monoxide (CO); or
- 10 tons of volatile organic compounds (VOC), oxides of nitrogen (NOx) or sulfur oxides (SOx); or
- 5 tons of PM-10 or ammonia compounds (NHx).

Using these criteria, 38 sources were identified and modeled as point sources in the 2006 Analysis and 27 were modeled as area sources.

The treatment of stationary and area source emissions at industrial facilities also differed among the three studies. In the ADEQ TSD, emission and stack data were derived from the MCAQD inventory and modeling files representative of the 2002 emission inventory year. Area sources emissions at 36 larger facilities were uniformly distributed within facility boundaries, and area source emissions within 45 smaller facilities were uniformly distributed within the grid cells in which the facilities were located.

**Table 5-4**
**Differences in Industrial Emission Calculations Between Salt River Studies**

| Study | Source Category | Definition | Location | Emission Rate | Diurnal Profile | Emission Configuration |
|---|---|---|---|---|---|---|
| ADEQ Salt River TSD | Point | Largest & Closest to Monitors | MCAQD Permit Records and GIS Analysis | MCAQD 2002 Permit Records | Operating hours by day of week | Stack Coordinates & Facility Boundaries |
| | Area | Remaining Industry Sources | | | 7 am – 5 pm | Distributed Across Grid Cells |
| MAG Five Percent Plan TSD | Point | MCAQD pollutant specific tons per year definition | MCAQD Address, Coordinates & Google Earth Inspection | MCAQD 2005 Inventory | Day-Specific for Largest 7 am – 5 pm for Remaining | Stack Coordinates & Facility Boundaries |
| | Area | Remaining Sources That Do Not Qualify As Point Sources | | | 7 am – 5 pm | Distributed Within Facility Boundaries |
| MAG 2006 Analysis | Point | MCAQD pollutant specific tons per year definition | MCAQD Address, Coordinates & Google Earth Inspection | MCAQD 2005 Inventory | Day-Specific for Largest 7 am – 5 pm for Remaining | Stack Coordinates & Facility Boundaries |
| | Area | Remaining Sources That Do Not Qualify As Point Sources | | | 7 am – 5 pm | Distributed Across Grid Cells |

In this study, Sierra used the same stack data and updated the emission data from 2006 MCAQD permit records. For stack sources not included in the ADEQ modeling files, stack parameters were derived from process descriptions in the MCAQD permit records. Area source emissions at 33 larger facilities were uniformly distributed within the actively disturbed portions of each facility as determined through Google Earth aerial photographs. Emissions from extended haul roads at two mineral processing facilities were represented as series of juxtaposed volume sources. Area source emissions at 44 smaller facilities were uniformly distributed within the grid cells in which the facilities were located. Temporal variability in emissions at 7 of the facilities with highest PM-10 emissions were based on design day-specific operating information gathered through telephone and email surveys of facility operators.

In the MAG Five Percent Plan TSD, this work was further refined to increase areal accuracy. The ADEQ TSD treated emissions from non-stack stationary sources, such as crushing and screening operations at mineral processing facilities, as area sources. In the Five Percent Plan, emissions from these sources were assigned quasi-stack parameters based on physical proximity, estimated emission release heights, and a default stack velocity of 0.1 meters per second representative of unventilated sources. In this manner, significant PM-10 emissions from mineral processing were more appropriately located with respect to areas of emission release and release heights. To facilitate model run times with the increased number of sources, however, sources reported to have annual PM-10 emissions of less than 0.5 tons in the 2006 MCAQD emission inventory were deleted from the model input files.

Construction Emissions – As shown in Table 5-5, the Salt River TSD used a variety of methods to identify construction sites located within the modeling domain. In contrast, the MAG studies relied upon information in the earthmoving permits issued by the Maricopa County Air Quality Department in 2005 and 2006 to determine which sites were active on the episode days being modeled. As discussed in Section 4, the number of active construction sites modeled in the Five Percent Plan TSD and the 2006 Analysis varied because of differences in the number of permits issued each year. These MAG studies also screened out sites that were smaller than an acre (equivalent to 8.8 lbs of PM-10/day). The 2006 Analysis also screened out sites that were located more than 2 miles from the Durango Complex and West 43rd Avenue monitors. All studies used similar methods to quantify emissions and identical assumptions for diurnal profiles (discussions with the construction industry confirmed the representativeness of this assumption). One significant difference between the studies is that the Salt River TSD distributed emissions

**Table 5-5**
**Differences in Construction Emission Calculations**
**Between Salt River Studies**

| Study | Location | Emission Rate | Activity Factor | Diurnal Profile | Emission Configuration |
|---|---|---|---|---|---|
| ADEQ Salt River TSD | Satellite Image Analysis<br>MCAQD Records<br>Site Visits & Aerial Photos | AP-42 Emission Factors | South Coast AQMD | 7 am – 5 pm | Distributed Across Grid Cells |
| MAG Five Percent Plan TSD | Maricopa County Earthmoving Permit Records For Sites ≥ 1Acre Located Within Salt River Area | MCAQD 2005 Inventory | MCAQD 2005 Inventory | 7 am – 5 pm | Distributed Within Site Boundary |
| MAG 2006 Analysis | Permits for Sites ≥1 Acre Located Within 2 Miles of Monitors | MCAQD 2005 Inventory | MCAQD 2005 Inventory | 7 am – 5 pm | Distributed Within Site Boundary |

within the grid cells in which the sites were located. The MAG studies used the information in the permit records to identify the location of the site and Google Earth to determine the coordinates of the boundaries of the actively disturbed areas. Emissions for each site were then distributed within these boundaries.

Agricultural Emissions – Unlike the previous source categories where there is a steady trend of increasing source representation accuracy from the Salt River TSD, to the Analysis to the Five Percent Plan (i.e., the sequence in which the studies were actually conducted), this trend did not continue in the calculation of agricultural emissions. That is because the primary insight needed to improve the representation accuracy of the emissions estimate, the hours of operation for the days of interest, were unavailable for the design days addressed in the Five Percent Plan; see Table 5-6 for a summary of the data and assumptions used in preparing the agricultural emission estimates. Without this information it was not possible to prepare a more accurate estimate of emissions and the diurnal profile. As discussed in Section 4, the Arizona Farm Bureau provided invaluable insight into the activity levels that occurred on fields in December 2006. Without the activity insight for the December 2005 and February 2006 design days the options for improving representation of the inventory were limited to merging the CARB emission rates and the boundaries identified for selected fields in the 2006 Analysis[1] with the emission estimates from the Salt River TSD. This was not a simple task because the emission values available from the Salt River TSD were distributed across the 400 x 400 meter grid cells and no information was available on the acreage within grid cell in which

**Table 5-6**
**Differences in Agriculture Emission Calculations**
**Between Salt River Studies**

| Study | Location | Emission Rate | Activity Factor | Diurnal Profile | Emission Configuration |
|---|---|---|---|---|---|
| ADEQ Salt River TSD | Satellite Image Analysis | Ag. BMP Report | Fraction of Annual Tillage Occurring on Design Day | Daylight Hours 8-Hours/day | Distributed Across Grid Cells |
| MAG Five Percent Plan TSD | ADEQ Selection | CARB Methodology | Fraction of Annual Tillage Occurring on Design Day | Daylight Hours 8-Hours/day | Distributed Across Grid Cells |
| MAG 2006 Analysis | ADEQ Update With Google Earth | CARB Methodology | Time Required to Till a Grid Cell with Ag Land | Day-Specific From Arizona Farm Bureau | Mixture of Field Boundaries and Grid Cells |

[1] A survey of Google Earth images of the modeling domain identified five agricultural fields located in the northeast corner of the modeling domain, beneath the I-17 which were not included in the Salt River TSD (i.e., grid cells in that area had no agricultural emissions).

agricultural operations were occurring. For this reason, the Five Percent Plan TSD adopted the Salt River TSD agriculture modeling parameters, including area size and operating hours from 2002 TSD modeling files. The emission rates from 2002 were reduced by the 4.6% annualized attrition rate detailed in the Five Percent Plan TSD to produce the 2005 inventory.

Vacant Lots – This source category typically encompasses only undeveloped lots that are periodically disturbed by vehicle trespass. Limited PM-10 emissions are generated when vehicle trespass occurs in low wind conditions, and more significant emissions are produced during high wind conditions when disturbed surface soils are entrained into the air. Because trespass rates are low on vacant lots in the Salt River area, due primarily to the high visibility of such trespass activities in this urbanized area, the ADEQ Salt River TSD did not include vacant lots as an emission source category in attainment demonstration modeling under low wind conditions. In the two MAG studies, however, the definition of vacant lot was expanded to include more emission-generating activities, and activity data were collected to support emission estimates in this category.

During initial surveys of emissions sources near the West 43rd Avenue monitoring site, Sierra noted vehicle activity on unpaved surfaces within several storage, recycling, and light industrial yards very close to the monitor. Investigation of the Salt River TSD showed that no emissions had been attributed to these properties. As a result, activity levels were monitored and emissions calculated for these vehicle operations and included in the modeling inventory for both MAG studies as vacant lot emissions in lieu of including them in any other category.

Activity levels on these yards were monitored by AEC, a subcontractor to Sierra, on the mornings of two consecutive days in April and May, 2007, by visual observation. Vehicle type, vehicle speed, and trip length of both intra-yard and inter-yard trips were recorded over two hour periods. The soil silt level was assumed to be the default of Salt River area soils used in the Five Percent Plan TSD. Daily activity hours were determined through telephone interviews of facility managers. PM-10 emissions were calculated using the AP-42 equation for unpaved road travel. For modeling purposes, emissions were uniformly distributed over areas of disturbance as visually mapped using the Google Earth aerial photographs. A comparison of vacant lot emission protocols among the three studies is presented in Table 5-7.

Unpaved Parking Lots – With limited exception, the same methodology was used to model unpaved parking lot emissions in each of the ADEQ Salt River TSD and the two MAG studies. ADEQ identified the area devoted to unpaved parking within each modeling grid cell, calculated emissions on the basis of estimated activity rates, and uniformly distributed these emission over the grid cells in which unpaved parking lots were located. Sierra used the ADEQ modeling files for this source category without change except where unpaved parking lot emission were found to significantly impact a PM-10 monitor.

| Table 5-7<br>Differences in Vacant Lot Source Data Collection and Analysis Methods<br>for the Salt River Area | | | | |
|---|---|---|---|---|
| **Study** | **Boundary Determination** | **Activity Hours** | **Activity Rates** | **Emission Factor** |
| ADEQ Salt River TSD | -- | -- | -- | -- |
| MAG Five Percent Plan TSD | Google Earth Plotting | Property Owner Interview | Visual Observation | AP-42 Emission Equation |
| MAG 2006 Analysis | | | | |

The major exception to the use of ADEQ files was the characterization of emissions from an unpaved truck yard directly east and across 27th Avenue from the Durango Complex monitor. Initial observations of this yard suggested that significant intra-yard travel by heavy duty Diesel truck and trailer combinations was occurring. T&B Systems filmed a video of these activities on November 18, 2006. Upon further investigation, Sierra learned that this unpaved parking lot was being used by a truck driving school, and that novice drivers started their training program by learning to drive continuously over this lot at engine idle speed (i.e., about 2 miles per hour). At any one time, up to twelve tractor-trailer rigs were traversing the lot simultaneously for several hours per day. Initial emission and modeling analyses revealed that emissions from this lot produced significant impacts at the Durango Complex monitor when winds were from the east. As a result, design day-specific information on hours of operation and the numbers of trucks engaged in intra-yard and inter-yard driving were collected through telephone interview of the yard manager. The boundaries of the disturbed areas were identified from Google Earth aerial photographs, and emissions were calculated using the AP-42 unpaved road emission factor equation using the default soil silt level used in the Five Percent Plan TSD. Plume intensity was verified by comparing modeled concentrations over 27th Avenue with PM-10 concentrations recorded by T&B Systems during their driving passes on this portion of the road.

The methodologies used to quantify activity rates and emissions from unpaved parking lots in the three studies is summarized in Table 5-8.

<u>Windblown Soil Sources</u> – Emission inventory estimates presented in the ADEQ Salt River TSD indicated that windblown soil sources dominated modeling domain emissions on high wind days. As a result, Sierra chose to improve the emissions estimates and source configurations for this source in the two MAG studies in order to increase the accuracy of impact estimates for this source category.

The ADEQ Salt River TSD uniformly distributed windblown soil emissions over individual grid cells. Emissions within each grid cell were calculated on the basis of the land area disturbed, as determined from visual inspection of aerial photographs of the

**Table 5-8**
**Differences in Unpaved Parking Lot Source Data Collection and Analysis Methods for the Salt River Area**

| Source | Study | Boundary Determination | Activity Hours | Activity Rates | Emission Factor |
|---|---|---|---|---|---|
| All other lots | ADEQ Salt River TSD | Aerial photograph | Assumed to be 7am to 5 pm | Assumed 20% turnover per hour | AP-42, unpaved road travel (1988) |
| | MAG Five Percent Plan TSD | | | | |
| | MAG 2006 Analysis | | | | |
| Truck yard at Durango Road & W. 27th Avenue | MAG Five Percent Plan TSD | Google Earth plotting | Property owner interview | Property owner interview | AP-42, unpaved road travel (2006) |
| | MAG 2006 Analysis | | | | |

modeling domain, and the use of an emission equation for windblown soil emissions at construction sites as reported in a study of Maricopa area soils conducted by Nickling and Gillies.[1] ADEQ computed emissions rates for a 15 mph wind speed and applied this rate to all disturbed areas for every hour during which the hourly average wind speed was greater than or equal to 15 mph.

Because Nickling and Gillies tested and reported on emission factors for disturbed soils on a variety of land uses in the Maricopa area, Sierra chose to use the different land use-specific equations reported in this study. Also, because the Nickling and Gillies emission equations used the wind speed raised to powers between 1.46 and 6.92, Sierra concluded that hourly average emission rates would be significantly influenced by peak wind gust velocities, and conducted a statistical analysis using 5-minute wind speed averages recorded at the two Salt River area monitors on high wind days to compute an adjustment factor for the Nickling and Gillies equations. This adjustment factor turned out to be about a 10% increase in effective wind speed for the construction soil equation that contained a wind speed exponent of 4.355.

Emitting areas were also treated differently in the MAG studies than in the ADEQ Salt River TSD. Instead of uniformly distributing emissions across grid cells in which disturbed areas were located, Sierra mapped the boundaries of each disturbed area using Google Earth aerial photographs. Near the two monitoring sites, Sierra included unpaved

[1] Evaluation of Aerosol Production Potential of Type Surfaces in Arizona, prepared for Engineering-Science by W.G. Nickling and J.A. Gillies, 1986.

road shoulders among the mapped sources. In the Salt River TSD, ADEQ concluded that unpaved shoulders would be insignificant sources due to their occupying only 0.2% of the land area within the modeling domain.

A summary of the differences between emission and modeling methodologies among the three studies is presented in Table 5-9**.**

In summary, it should be evident from the above discussion that there was a steady progression in improving the representation of source-specific emissions between the three Salt River studies. Where day-specific activity data were available, emission estimates were configured to specific days. In other cases, activity estimates were available to characterize emissions for the time of year (e.g., construction). In still other cases, the emission estimates were the same for all of the days addressed under both low and high wind conditions (e.g., travel related). A summary of the resulting source specific PM-10 emission estimates is presented in Table 5-10. As can be seen the dominant sources are related to travel (both traffic and trackout), industry and agricultural operations. Lacking access to the day specific activity data the latter would typically be an order of magnitude lower. This illustrates the potential loss of insight that comes from using annualized operating profiles instead of day specific activity data.

The day-specific inventories developed for the 2006 Analysis were designed to include only those sources thought to be capable of impacting the Durango Complex and West 43rd Ave. monitors. As a result, many of the sources located within the Salt River modeling domain (e.g., roads, construction sites, etc.) were not included. Thus, the emission estimates in this inventory are not directly comparable with either the Salt River TSD or the Five Percent Plan TSD.

<table>
<tr><th colspan="4">Table 5-9<br>Differences in Windblown Soil Source Data Collection and Analysis Methods<br>for the Salt River Area</th></tr>
<tr><th>Study</th><th>Boundary Selection</th><th>Land Use Emission Factor Equation Used</th><th>Wind Speed Used in Emission Factor Equation</th></tr>
<tr><td>ADEQ Salt River TSD</td><td>Grid cell boundaries</td><td>Construction</td><td>15 mph during hours when hourly average speeds were $\geq$ 15 mph</td></tr>
<tr><td>MAG Five Percent Plan TSD</td><td rowspan="2">Disturbed area boundaries from Google Earth aerial photographs</td><td rowspan="2">Construction, agriculture, alluvial, and all site average</td><td rowspan="2">Actual recorded hourly average wind speed as adjusted for gust speed contributions</td></tr>
<tr><td>MAG 2006 Analysis</td></tr>
</table>

| Table 5-10<br>Summary of Source Specific PM-10 Emissions for<br>Salt River Area Modeling Domain And Design Day Conditions<br>(tons/day) | | | |
|---|---|---|---|
| Source Category | 12/5/2006 | 12/6/2006 | 12/7/2006 |
| Traffic | 4.64 | 4.72 | 4.68 |
| Trackout | 1.42 | 1.43 | 1.35 |
| Industrial Area Sources | 2.29 | 2.29 | 2.29 |
| Industrial Point Sources | 0.75 | 0.75 | 0.75 |
| Vacant Lots | 0.13 | 0.13 | 0.13 |
| Unpaved Parking Lots | 0.04 | 0.04 | 0.04 |
| Agricultural Operations | 4.09 | 4.09 | 4.09 |
| Construction Activities | 2.01 | 2.01 | 2.01 |
| Local Truck Yard | 0.04 | 0.04 | 0.04 |
| Total | 15.36 | 15.45 | 15.33 |

## 5.3 Meteorological Data

AERMET, a preprocessor that converts raw meteorological data into an AERMOD-ready format, was used to prepare meteorological input files for the Durango Complex and West 43rd monitoring sites for selected design days in December, 2006. Outlined below are the data sources that were used to configure AERMET to produce these files.

- The on-site met data came from West 43rd and Durango met data, with parameters of wind direction, wind speed, and temperature. A wind speed threshold of 0.0 meters/second was specified.

- Upper air met data were derived from Tucson 1996-2006 twice-daily sounding data.

- National Weather Service (NWS) met data (specifically, cloud cover data) came from the Phoenix NWS met station at Sky Harbor Airport.

AERMET also requires information on three site-specific land use parameters: the Bowen ratio (a measure of moisture available for evaporation), Albedo (portion of sunlight that is reflected), and surface roughness length. The same values for these three site-specific parameters are used in Salt River TSD study and 2006 Analysis. AERMET output parameters used as meteorological inputs to AERMOD include wind speed, wind direction, temperature, Convective Boundary Height (m), Mechanical Boundary Height (m), and Monin-Obukhov Length (m). A summary of the values[1] produced for December 5-7 for each monitoring site is presented in Tables 5-11 and 5-12.

**Table 5-11**
**Meteorological Data File Used for December 2006 Modeling at Durango Complex**

| Date/Hour* | Wind Direction (Degrees) | Wind Speed (m/sec) | Temperature (K) | Convective Boundary Layer Height (m) | Mechanical Boundary Layer Height (m) | Monin-Obukhov Length (m) |
|---|---|---|---|---|---|---|
| 06120501 | 141 | 1.4 | 281 | -999 | 44 | 7.2 |
| 06120502 | 252 | 0.61 | 280.2 | -999 | 21 | 5.2 |
| 06120503 | 317 | 0.77 | 279.4 | -999 | 29 | 6.5 |
| 06120504 | 329 | 0.58 | 278.8 | -999 | 19 | 4.9 |
| 06120505 | 335 | 0.51 | 278.1 | -999 | 16 | 4.3 |
| 06120506 | 41 | 0.28 | 277.6 | -999 | 7 | 2.4 |
| 06120507 | 333 | 0.47 | 277.5 | -999 | 14 | 3.9 |
| 06120508 | 358 | 0.56 | 279.6 | -999 | 18 | 4.7 |
| 06120509 | 34 | 0.28 | 287 | -999 | 7 | 4.8 |
| 06120510 | 85 | 1.04 | 291.3 | 234 | 213 | -15.3 |
| 06120511 | 71 | 1.29 | 292.4 | 286 | 296 | -14.9 |
| 06120512 | 108 | 3.25 | 294.5 | 345 | 544 | -40.1 |
| 06120513 | 94 | 2.8 | 295.9 | 410 | 462 | -27.2 |
| 06120514 | 73 | 1.46 | 296.8 | 469 | 346 | -16.8 |
| 06120515 | 56 | 0.83 | 297.6 | 512 | 192 | -6.9 |
| 06120516 | 286 | 0.76 | 297.5 | 529 | 147 | -10.2 |
| 06120517 | 259 | 0.56 | 296.4 | -999 | 37 | 6.4 |
| 06120518 | 277 | 0.89 | 291.5 | -999 | 37 | 7.8 |
| 06120519 | 276 | 0.35 | 288.3 | -999 | 9 | 3 |
| 06120520 | 181 | 0.76 | 286.5 | -999 | 18 | 4 |
| 06120521 | 231 | 0.31 | 285 | -999 | 8 | 2.6 |
| 06120522 | 298 | 0.56 | 283.9 | -999 | 18 | 4.8 |
| 06120523 | 144 | 0.99 | 283.1 | -999 | 26 | 5.1 |
| 06120524 | 197 | 0.67 | 281.9 | -999 | 15 | 3.5 |
| 06120601 | 205 | 0.93 | 280.9 | -999 | 24 | 4.8 |
| 06120602 | 67 | 0.92 | 280.3 | -999 | 38 | 7.8 |
| 06120603 | 153 | 1.29 | 279.7 | -999 | 39 | 6.6 |
| 06120604 | 272 | 0.71 | 278.6 | -999 | 26 | 6 |
| 06120605 | 7 | 0.71 | 278.1 | -999 | 26 | 6 |
| 06120606 | 90 | 0.55 | 278 | -999 | -999 | -99999 |
| 06120607 | 312 | 0.75 | 277.9 | -999 | 28 | 6.5 |
| 06120608 | 290 | 0.5 | 279 | -999 | 15 | 4.3 |

[1] The Date/Hour format includes two digits each for year, month, day and hour – YYMMDDHH. -999 indicates missing data. For the convective boundary height is mainly driven by solar energy and that is why it is missing during night time and early morning. -99999 also indicates missing data for Monin-Obukhov Length.

**Table 5-11**
**Meteorological Data File Used for December 2006 Modeling at Durango Complex**

| Date/Hour* | Wind Direction (Degrees) | Wind Speed (m/sec) | Temperature (K) | Convective Boundary Layer Height (m) | Mechanical Boundary Layer Height (m) | Monin-Obukhov Length (m) |
|---|---|---|---|---|---|---|
| 06120609 | 348 | 0.58 | 283.6 | -999 | 19 | 16.8 |
| 06120610 | 140 | 0.45 | 289.6 | 74 | 66 | -1.3 |
| 06120611 | 170 | 0.78 | 292.3 | 156 | 123 | -2.3 |
| 06120612 | 254 | 0.61 | 294.2 | 260 | 155 | -3 |
| 06120613 | 321 | 0.47 | 294.9 | 366 | 122 | -1.9 |
| 06120614 | 238 | 0.65 | 296.4 | 480 | 161 | -3.7 |
| 06120615 | 250 | 1.21 | 297.2 | 564 | 271 | -14.4 |
| 06120616 | 266 | 1.29 | 296.8 | 596 | 251 | -30.6 |
| 06120617 | 304 | 1.53 | 296 | -999 | 158 | 58.9 |
| 06120618 | 293 | 0.61 | 291.3 | -999 | 40 | 5.4 |
| 06120619 | 226 | 0.49 | 288.6 | -999 | 15 | 4.2 |
| 06120620 | 114 | 0.62 | 287 | -999 | 13 | 3.2 |
| 06120621 | 132 | 0.96 | 286.1 | -999 | 25 | 5 |
| 06120622 | 88 | 0.38 | 284.9 | -999 | 10 | 3.2 |
| 06120623 | 61 | 0.4 | 283.5 | -999 | 11 | 3.4 |
| 06120624 | 306 | 0.8 | 282.3 | -999 | 31 | 6.8 |
| 06120701 | 171 | 0.72 | 281 | -999 | 16 | 3.7 |
| 06120702 | 27 | 0.53 | 280.9 | -999 | 17 | 4.5 |
| 06120703 | 193 | 0.46 | 280.3 | -999 | 8 | 2.4 |
| 06120704 | 81 | 0.61 | 279.8 | -999 | 21 | 5.1 |
| 06120705 | 163 | 0.5 | 279.5 | -999 | 9 | 2.6 |
| 06120706 | 353 | 0.67 | 279.5 | -999 | 24 | 5.7 |
| 06120707 | 16 | 0.5 | 279.4 | -999 | 15 | 4.2 |
| 06120708 | 344 | 0.28 | 280.6 | -999 | 7 | 2.4 |
| 06120709 | 185 | 0.37 | 286.9 | -999 | 6 | 3.6 |
| 06120710 | 283 | 0.59 | 292.3 | 61 | 123 | -5.2 |
| 06120711 | 76 | 1.94 | 295.6 | 130 | 452 | -34.4 |
| 06120712 | 71 | 3.98 | 298.6 | 213 | 1085 | -156.9 |
| 06120713 | 70 | 3.86 | 299.6 | 452 | 1049 | -137.8 |
| 06120714 | 74 | 3.46 | 300.2 | 723 | 909 | -113.5 |
| 06120715 | 83 | 3 | 300.6 | 854 | 743 | -102.9 |
| 06120716 | 68 | 3.14 | 300 | 902 | 737 | -241.7 |
| 06120717 | 66 | 2.89 | 298.9 | -999 | 545 | 225.3 |
| 06120718 | 70 | 2.29 | 296 | -999 | 276 | 46.5 |
| 06120719 | 77 | 2.26 | 293.8 | -999 | 250 | 43 |
| 06120720 | 88 | 3.24 | 293.5 | -999 | 600 | 138.6 |
| 06120721 | 84 | 3.34 | 292.8 | -999 | 636 | 149.4 |
| 06120722 | 82 | 4.84 | 293.3 | -999 | 1231 | 404.3 |
| 06120723 | 80 | 4.26 | 292.3 | -999 | 993 | 267 |
| 06120724 | 91 | 3.96 | 291.8 | -999 | 537 | 108.4 |

| Table 5-12<br>Meteorological Data File used for December, 2006 Modeling at West 43rd | | | | | | |
|---|---|---|---|---|---|---|
| Date/Hour* | Wind Direction (Degrees) | Wind Speed (m/sec) | Temperature (K) | Convective Boundary Layer Height (m) | Mechanical Boundary Layer Height (m) | Monin-Obukhov Length (m) |
| 06120501 | 151 | 0.68 | 279.1 | -999 | 20 | 4.7 |
| 06120502 | 282 | 0.78 | 278.9 | -999 | 18 | 4 |
| 06120503 | -999 | -999 | 278 | -999 | -999 | -99999 |
| 06120504 | 304 | 0.66 | 277.7 | -999 | 14 | 3.4 |
| 06120505 | 243 | 0.58 | 276.7 | -999 | 12 | 3 |
| 06120506 | 245 | 0.28 | 276.3 | -999 | 4 | 1.4 |
| 06120507 | 316 | 0.64 | 277 | -999 | 14 | 3.3 |
| 06120508 | 338 | 0.63 | 278.3 | -999 | 13 | 3.2 |
| 06120509 | 304 | 1.12 | 282.2 | -999 | 32 | 10.7 |
| 06120510 | 295 | 0.58 | 286.8 | 216 | 80 | -2.3 |
| 06120511 | 93 | 2.13 | 290 | 283 | 421 | -30.6 |
| 06120512 | 101 | 3.14 | 291.9 | 341 | 673 | -62.5 |
| 06120513 | 97 | 2.98 | 293.1 | 404 | 638 | -52.8 |
| 06120514 | 92 | 2.09 | 293.9 | 461 | 428 | -25.7 |
| 06120515 | 85 | 1.12 | 294.6 | 502 | 179 | -5.4 |
| 06120516 | 79 | 0.61 | 295 | 519 | 80 | -3.1 |
| 06120517 | 212 | 0.64 | 294.5 | -999 | 17 | 4.4 |
| 06120518 | 263 | 1.39 | 291.6 | -999 | 44 | 7.5 |
| 06120519 | 219 | 0.68 | 288.2 | -999 | 15 | 3.6 |
| 06120520 | 185 | 1.18 | 285.7 | -999 | 34 | 6.1 |
| 06120521 | 109 | 0.67 | 284.1 | -999 | 20 | 4.7 |
| 06120522 | 280 | 0.48 | 282.6 | -999 | 9 | 2.5 |
| 06120523 | 163 | 0.85 | 281.3 | -999 | 28 | 5.9 |
| 06120524 | 226 | 1.11 | 280.6 | -999 | 31 | 5.7 |
| 06120601 | 203 | 1.36 | 279.5 | -999 | 42 | 7 |
| 06120602 | 182 | 1.44 | 278.3 | -999 | 46 | 7.4 |
| 06120603 | 173 | 1.34 | 277.9 | -999 | 55 | 9.2 |
| 06120604 | 239 | 1.1 | 277.1 | -999 | 31 | 5.6 |
| 06120605 | 9 | 1.13 | 276.5 | -999 | 32 | 5.8 |
| 06120606 | 114 | 0.92 | 276.7 | -999 | -999 | -99999 |
| 06120607 | 240 | 1.32 | 276.1 | -999 | 40 | 6.9 |
| 06120608 | 280 | 0.85 | 275.9 | -999 | 21 | 4.5 |
| 06120609 | 302 | 0.41 | 279.2 | -999 | 7 | 6.2 |
| 06120610 | 183 | 0.51 | 283.9 | 71 | 73 | -1.6 |
| 06120611 | 192 | 0.89 | 287.1 | 149 | 138 | -3 |
| 06120612 | 3 | 0.74 | 289.8 | 249 | 121 | -1.9 |
| 06120613 | 109 | 0.63 | 291.6 | 353 | 134 | -2.4 |
| 06120614 | 284 | 0.55 | 293.7 | 462 | 91 | -1.2 |
| 06120615 | 253 | 1.51 | 295.4 | 545 | 223 | -9.9 |
| 06120616 | 255 | 1.28 | 295.4 | 577 | 163 | -13.3 |

| Table 5-12<br>Meteorological Data File used for December, 2006 Modeling at West 43rd | | | | | | |
|---|---|---|---|---|---|---|
| Date/Hour* | Wind Direction (Degrees) | Wind Speed (m/sec) | Temperature (K) | Convective Boundary Layer Height (m) | Mechanical Boundary Layer Height (m) | Monin-Obukhov Length (m) |
| 06120617 | 297 | 1.78 | 294.6 | -999 | 114 | 36.5 |
| 06120618 | 271 | 1.31 | 291.6 | -999 | 41 | 7 |
| 06120619 | 145 | 0.85 | 288 | -999 | 28 | 5.9 |
| 06120620 | 95 | 1.27 | 285.8 | -999 | 51 | 8.8 |
| 06120621 | 107 | 1.76 | 284.8 | -999 | 83 | 12.2 |
| 06120622 | 77 | 1.09 | 283.3 | -999 | 31 | 5.6 |
| 06120623 | 145 | 0.81 | 282 | -999 | 26 | 5.6 |
| 06120624 | 212 | 0.85 | 280.8 | -999 | 21 | 4.4 |
| 06120701 | 178 | 1.01 | 279.8 | -999 | 36 | 7 |
| 06120702 | 50 | 0.68 | 279.3 | -999 | 15 | 3.5 |
| 06120703 | 194 | 0.56 | 278.3 | -999 | 11 | 2.9 |
| 06120704 | 100 | 0.79 | 278 | -999 | 25 | 5.4 |
| 06120705 | 169 | 0.58 | 277.4 | -999 | 16 | 4 |
| 06120706 | 8 | 0.53 | 277.4 | -999 | 10 | 2.7 |
| 06120707 | 78 | 0.89 | 277.5 | -999 | 22 | 4.6 |
| 06120708 | 211 | 0.39 | 278.4 | -999 | 7 | 2 |
| 06120709 | 248 | 0.46 | 280.9 | -999 | 8 | 4.1 |
| 06120710 | 274 | 1.04 | 285.7 | 58 | 138 | -7.2 |
| 06120711 | 269 | 1.37 | 289.8 | 122 | 206 | -7.5 |
| 06120712 | 65 | 3.37 | 295.1 | 203 | 566 | -43.9 |
| 06120713 | 72 | 6.1 | 297.5 | 415 | 1210 | -186.8 |
| 06120714 | 80 | 4.69 | 298.1 | 681 | 868 | -102 |
| 06120715 | 75 | 3.72 | 298.4 | 824 | 627 | -74.1 |
| 06120716 | 60 | 4.87 | 298.5 | 872 | 841 | -328.1 |
| 06120717 | 62 | 4.44 | 297.7 | -999 | 663 | 286.6 |
| 06120718 | 71 | 3.01 | 294.4 | -999 | 306 | 50.2 |
| 06120719 | 74 | 3.69 | 291.9 | -999 | 437 | 90.3 |
| 06120720 | 83 | 4.54 | 291.6 | -999 | 644 | 151.4 |
| 06120721 | 87 | 3.58 | 291 | -999 | 418 | 82.9 |
| 06120722 | 93 | 4.06 | 290.7 | -999 | 727 | 177.2 |
| 06120723 | 90 | 4.02 | 290.6 | -999 | 714 | 173 |
| 06120724 | 115 | 2.42 | 289.6 | -999 | 281 | 36.5 |

Wind speed, wind direction, and temperature all play important roles in air dispersion. Additional parameters produced by AERMET that also influence dispersion include convective boundary height and mechanical boundary height, which are used to determine planetary boundary layer (PBL) height. PBL height is a term to describe the elevation level up to which vertical mixing of ground-based emissions takes place. A low PBL height indicates weak dispersion and the potential for pollutant concentrations to remain high. AERMET estimates the height of the PBL during convective conditions as the maximum of the estimated (or measured if available) convective boundary layer height *($z_{ic}$)* and the estimated (or measured if available) mechanical mixing height *($z_{im}$)*.

In early morning hours, or overnight when the atmosphere is stable, there is little or no convective mixing, and so the height of the PBL would be determined mainly by mechanical mixing. Therefore, AERMET sets the height of the boundary layer to the mechanical mixing height. In the daytime convection tends to take over, and so the height of the PBL is determined primarily by convective mixing. Therefore, AERMET assumes the height of the boundary layer is the greater of the mechanical and convective mixing heights. The Monin-Obukhov length (L) is used as the stability parameter, and is computed by the AERMET meteorological preprocessor. It is negative during the day when surface heating results in an unstable atmosphere and positive at night when the surface cools (stable atmosphere). Values near zero during the day time (negative) indicate very stable conditions while values near zero during the night time (positive) indicate very unstable conditions.

It should be noted that hour “06120606” data at both sites and hour “06120503” data at West 43$^{rd}$ are missing in the AERMET data. The model simulated impacts for these hours by averaging the preceding and subsequent hour estimates.

Similar to December 2005 design days, low wind speeds with significant inversion are evident in December 5, 6, and the first half of December 7, 2006. The inversions recorded on the December 2005 design days, however, were more severe than those in 2006.

## 5.4 Model Performance

AERMOD was configured with the meteorological inputs and emission inventories described above and used to estimate each source’s contribution to hourly concentrations on each of the episode days for each of the monitoring sites. It should be noted that no estimates of background were included in this analysis. Subsequent to the completion of this study, background values were estimated using monitoring data available in December 2006 (because earlier data was determined to be invalid). Those values were included in the air quality modeling prepared for the Five Percent Plan TSD.

The hourly source specific concentrations were contrasted with the hourly and daily concentrations recorded at the Durango Complex and West 43$^{rd}$ Avenue monitors to assess model performance. Figures 5-6 through 5-11 provide a summary of how well model predictions compare with measured concentrations on an hourly basis. The figures display each source category’s contribution to the hourly predicted concentration. Listed below are a brief set of comments on each of the figures. Note the scale is not uniform across all of the figures.

**Figure 5-6**
**Comparison of Diurnal Distribution of Measured Concentrations and AERMOD Predicted Source Concentrations for Durango Complex (December 5, 2006)**

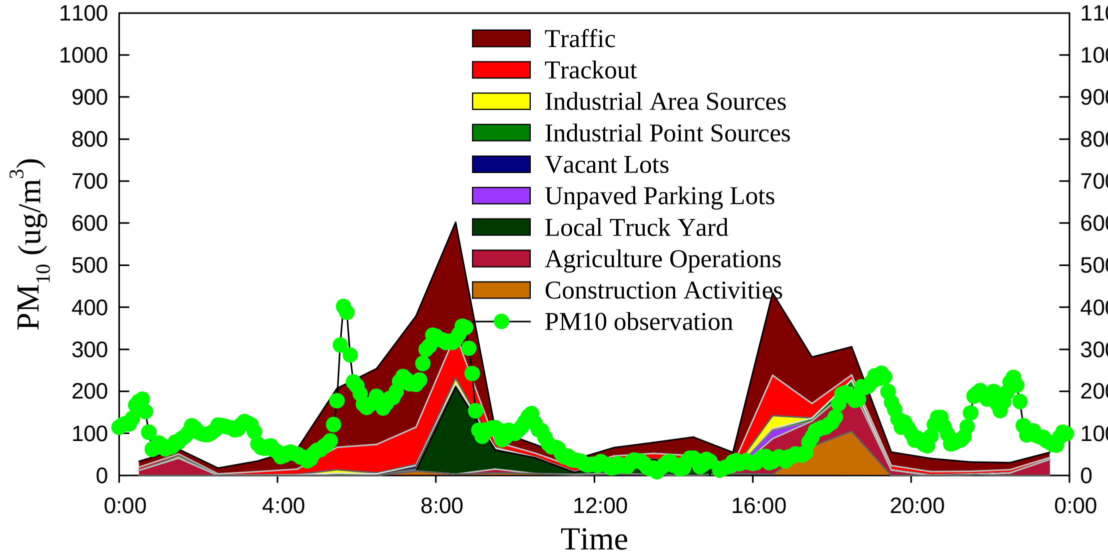



**Figure 5-7**
**Comparison of Diurnal Distribution of Measured Concentrations and AERMOD Predicted Source Concentrations for West 43rd Avenue (December 5, 2006)**

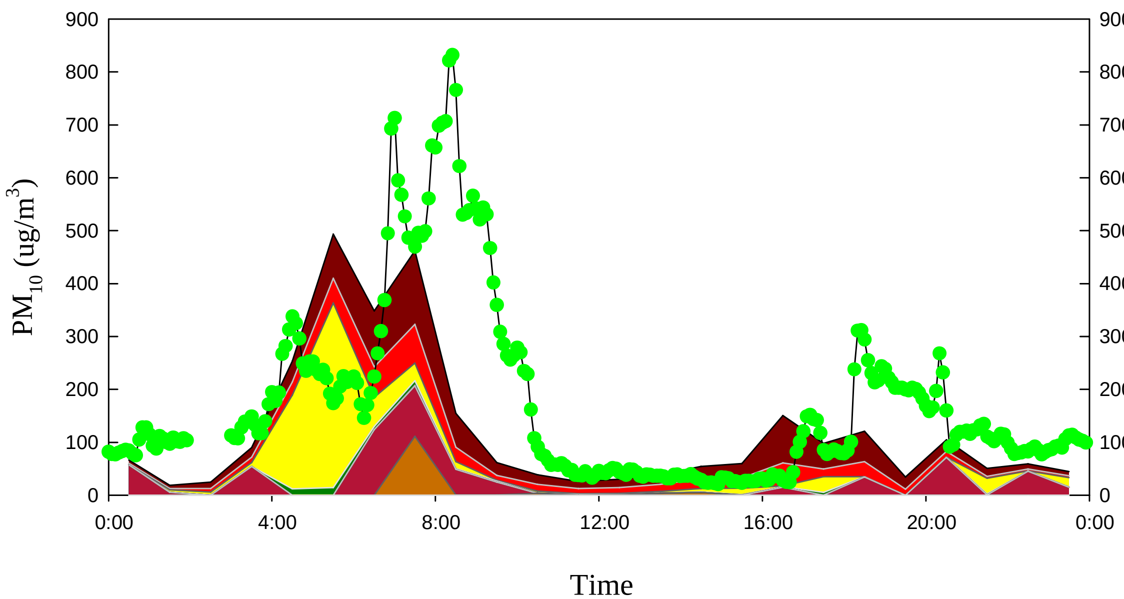


**Figure 5-8**
**Comparison of Diurnal Distribution of Measured Concentrations and AERMOD Predicted Source Concentrations for Durango Complex (December 6, 2006)**

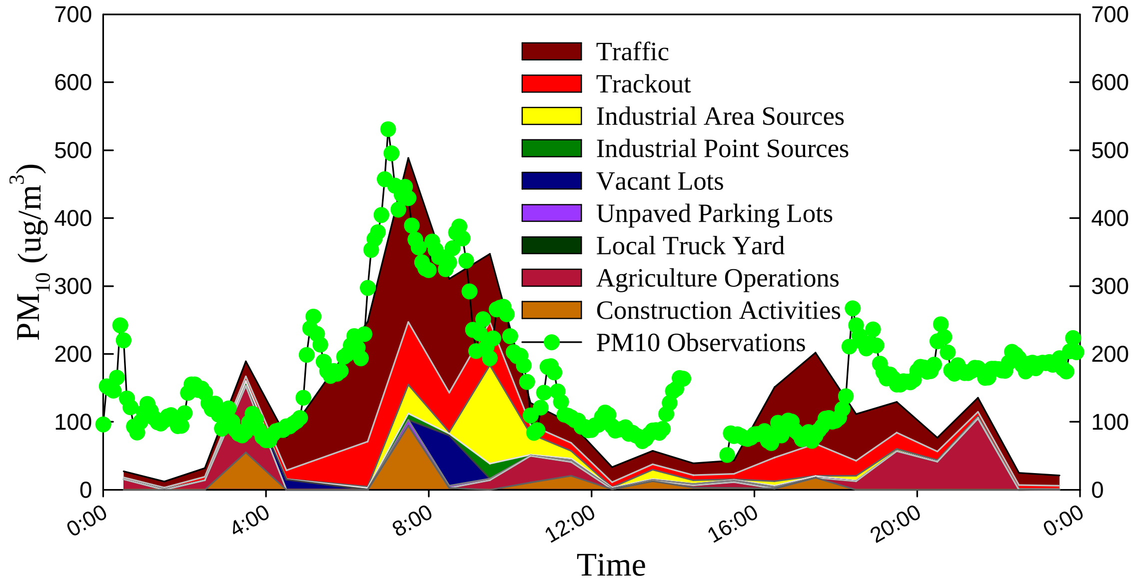



**Figure 5-9**
**Comparison of Diurnal Distribution of Measured Concentrations and AERMOD Predicted Source Concentrations for West 43rd Avenue (December 6, 2006)**

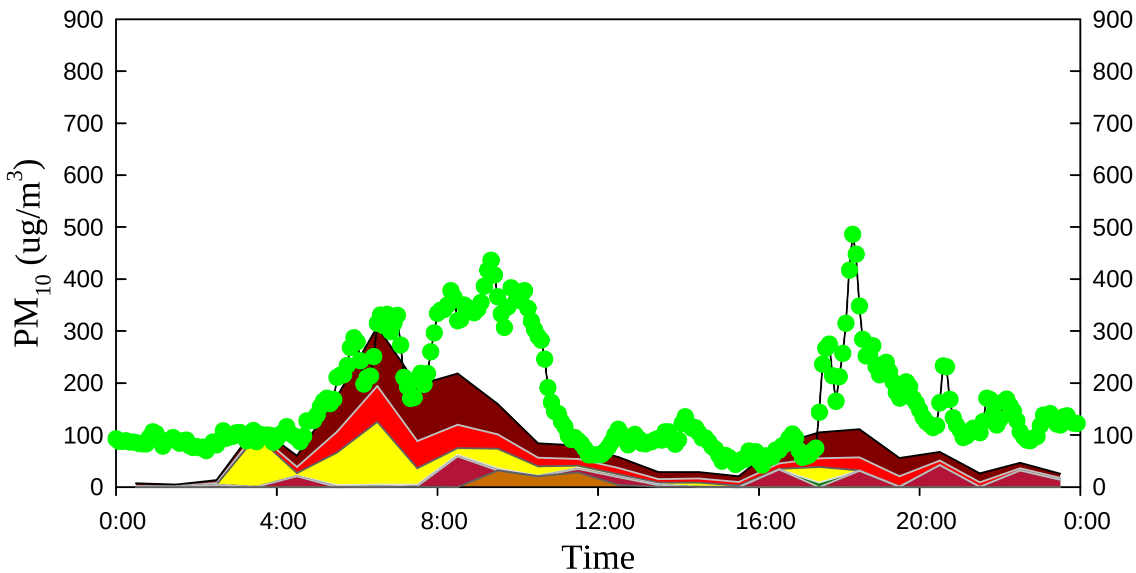


**Figure 5-10**
**Comparison of Diurnal Distribution of Measured Concentrations and AERMOD Predicted Source Concentrations for Durango Complex (December 7, 2006)**

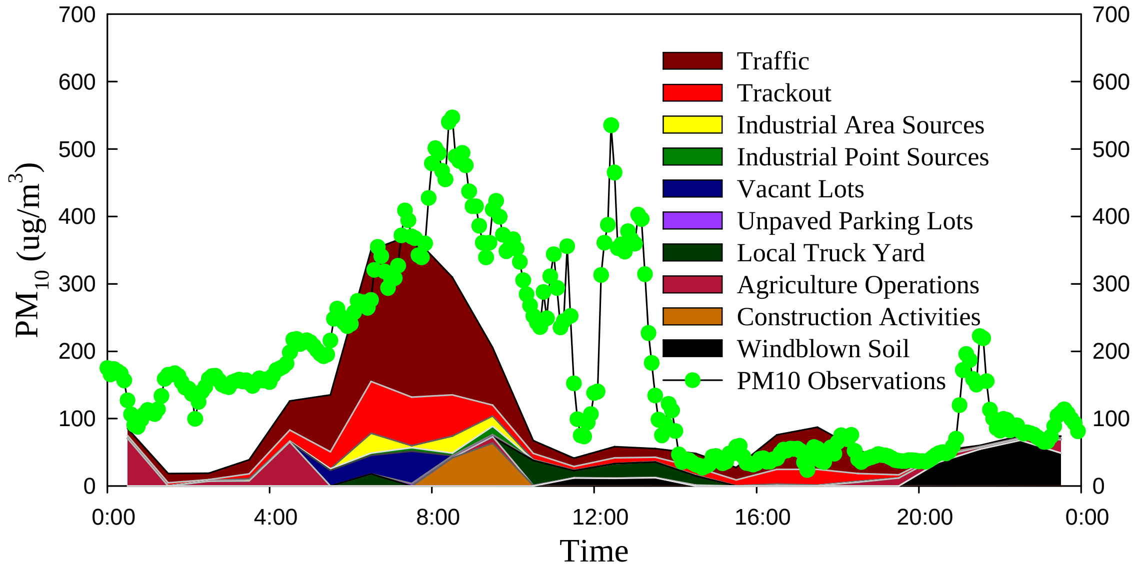
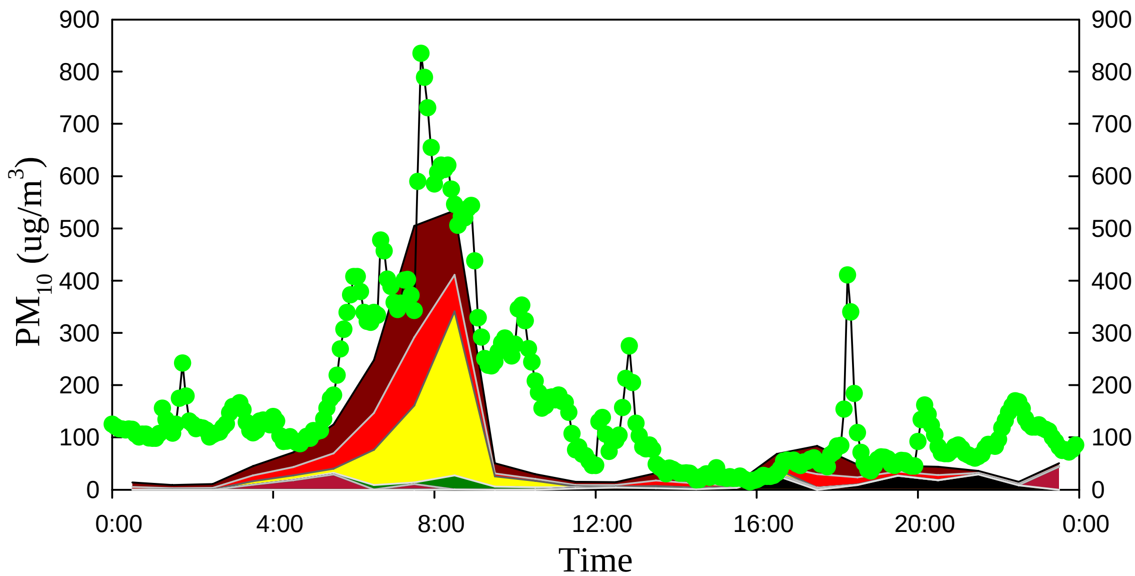



**Figure 5-11**
**Comparison of Diurnal Distribution of Measured Concentrations and AERMOD Predicted Source Concentrations for West 43rd Avenue (December 7, 2006)**



- *Durango Complex (December 5, 2006)* – Figure 5-6 shows that while predicted values exceeded the morning and evening peaks, they tracked the diurnal profile of the day. Predicted concentrations from road sources alone (i.e., traffic and trackout) exceed the early portion of the morning peak. As the wind shifts to the northeast and brings in emissions from the truck yard at 9 am, the three sources (traffic, trackout and truck yard) produce a significant overprediction of the measured concentration suggesting an over estimate of the emissions from one or more of those sources. The overprediction of the evening concentrations is more difficult to diagnose since the predicted concentrations reflect the rise in anthropogenic activity that starts about 4 pm when a larger number of sources is shown to be impacting the monitor. The measured concentrations, however, do not reflect the increased activity until later in the evening. This is surprising since the mixing height data, displayed in Figure 5-1, have dropped significantly by 4 pm and wind speeds after 2 pm remain are uniformly low (i.e., below a meter/second). One other point of note is that industrial sources are not shown to have any significant impact on this day.

- *West 43rd Avenue (December 5, 2006)* – Again, Figure 5-7 shows that the predicted values generally tracked the diurnal profile of the day. However, unlike the Durango Complex, industrial area source emissions are shown to be a significant contributor, particularly during the early morning hours. Since these estimates are based on activity profiles obtained from the large operators for this date, there is confidence that this finding is correct even though the impact is overpredicted. The predicted drop in traffic and trackout related emissions after 8 am, which is based on actual count data, however, does not match the elevated concentrations observed in the monitoring data. As shown in Figure 5-2 the decline in the morning concentrations lags the increase in the ceiling and the cause of this relationship is not clear.

- *Durango Complex (December 6, 2006)* – Figure 5-8 shows a strong correlation between predicted and measured concentrations particularly during the morning hours. These results suggest that insights from the field study incorporated into the inventory development and modeling analysis provide a significant gain in insight into the causes of exceedances recorded in the Salt River.

- *West 43rd Avenue (December 6, 2006)* – In contrast to Figure 5-8, Figure 5-9 shows that the improved representation of source specific activities seen at the Durango Complex was not replicated at the West 43rd Avenue monitor on the same date. While the predictions track the early morning increase in concentrations, the subsequent decline in anthropogenic activity shown in the predicted concentrations significantly underestimates the measured concentrations after 8 am. Figure 5-2 shows that despite a steady rise in the mixing height after 8 am and increase in dispersion potential the concentrations still continue to rise before falling in later hours. The mixture of sources represented in the evening and nighttime hours significantly underestimate the concentrations recorded.

- *Durango Complex (December 7, 2006)* – A familiar pattern of underpredicting early and late morning concentrations (i.e., after 8 am) despite a rise in mixing height is apparent in Figure 5-10. Also, the predicted values completely miss the elevated concentrations caused by the onset of higher winds starting at noon (i.e., roughly 4 m/sec or 9 mph). Clearly, the estimate of windblown emissions fails to account for the impacts recorded at the monitor. This finding indicates that the method used to represent these sources needs to be reexamined.

- *West 43rd Avenue (December 7, 2006)* – Figure 5-11 shows reasonable agreement between predicted and measured concentrations during the morning hours. Unlike the source distribution for the Durango Complex, industrial impacts are more evident at the West 43rd Ave. monitor during the morning hours. Unlike the Durango Complex, the increase in midday concentrations associated with elevated winds at West 43rd Ave is relatively modest despite the influence of higher winds (i.e., those exceeding 13 mph). The result is relatively good agreement between predicted and measured concentrations for the remainder of the day. It should be noted that the elevated winds recorded at mid day came from the northeast and the mix of sources impacting the monitors during these hours is significantly different from those the southwest that impacted both monitors under the high wind design day addressed in the Five Percent Plan.

In addition to the day-specific descriptions provided above, a comparison between predicted and measured concentrations is presented below in Table 5-13. When reviewing these comparisons, it is important to remember that background values have not been included. As can be seen the predicted values account for between 58 to 91 percent of the measured values. While the inclusion of background would lead to an overprediction of the December 5th concentration, it would substantially diminish the margin between the predicted and measured concentrations on December 6th and 7th.

Another metric that provides insight into how well the predicted values track the measured values comes from a correlation coefficient (i.e., $R^2$) of the hourly relation between predicted and measured concentrations. The results show values ranging between 0.27 and 0.66.

**Table 5-13**
**Comparison of Predicted and Monitored Concentrations**
**(averaged for both sites)**

| | December 5, 2006 | | December 6, 2006 | | December 7, 2006 | |
|---|---|---|---|---|---|---|
| | μg/m$^3$ | % of Monitored | μg/m$^3$ | % of Monitored | μg/m$^3$ | % of Monitored |
| Predicted | 132.6 | 91.3 | 110.9 | 67.6 | 97.7 | 58.3 |
| Monitored | 145.3 | - | 164.0 | - | 167.5 | - |

These findings represent a significant improvement relative to the Salt River TSD where predicted concentrations on low wind days only accounted for 14 percent of the measured concentrations and the $R^2$ was 0.03.

## 5.5 Modeled Impacts of Nearby Sources

To better evaluate the modeled impacts of nearby sources at each monitoring site, a set of modeling outputs were prepared showing impacts from sources within 0.5 and 1.0 mile from both the Durango Complex and West 43rd Avenue monitoring sites (essentially replicating portions of the runs displayed in Figures 5-6 through 5-11). Comparisons between these results and the figures in the report are cumbersome as the source category contributions are not as distinct in the subsequent runs as in the initial runs. Therefore, a tabular summary of the hourly and overall daily comparisons is presented below for each monitor in Tables 5-14 and 5-15.

Table 5-14 provides a summary of the comparisons for the Durango Complex monitor. It shows that overall sources located within a half mile of the monitor accounted for more than 50% of the predicted concentrations on two of the three days modeled. Sources located within a mile of the monitor accounted for 70+% on two of the three days modeled. Clearly these results support the conclusion that nearby sources dominate the monitored concentrations. The results, however, are far from consistent as the share of predicted concentrations on December 6, 2006, from sources located within a half mile were 42% and exceeded 50% only when the distance from the monitor was increased to a mile. A review of the hourly values across all of the days shows they are highly variable and obviously sensitive to the direction of the wind, the location of individual sources, and the emissions density (i.e., g/sec-$m^2$) of those sources. One of the reasons it is difficult to see a pattern in the hourly values is that the Durango Complex is surrounded by a dense network of anthropogenic activity to the east, west, and north. The only area where the density of emission sources diminishes is to the south, southwest (e.g., where there is a relatively undisturbed vacant lot, traffic on Lower Buckeye, and the landfill). Thus, when winds come from the southwest the share of the predicted concentrations from nearby sources falls off.

The picture that emerges for the West 43rd Avenue monitoring site is somewhat different as the local share of predicted concentrations is lower. Table 5-15 shows that sources located within a half mile of the monitor accounted for between 37% - 41% of the predicted concentrations from all sources across all of the days modeled. When the distance from the monitor is increased to a mile, the local share increased to between 47% - 59%. While these statistics are not as compelling as those from the Durango Complex, they still indicate that a dominant share of predicted concentrations comes from nearby sources. A review of a satellite image for the area surrounding the West 43rd Avenue monitor shows the distribution of anthropogenic activity is markedly different and less dense than the area surrounding the Durango Complex. The river bed is located directly to the north and east and again comes into play roughly a third of a mile to the west. Anthropogenic activity within the river bed has been severely restricted through the implementation of control measures. Thus, on low wind days, air must travel a longer distance before the effects of large sources can impact the monitor.

**Table 5-14**
**Share of Predicted Concentrations from Sources Located Within Selected Distances from the Durango Complex Monitor**

| Hour | December 5, 2006 | | December 6, 2006 | | December 7, 2006 | |
|---|---|---|---|---|---|---|
| | 0.5 mile | 1.0 mile | 0.5 mile | 1.0 mile | 0.5 mile | 1.0 mile |
| 1 | 78.7% | 83.8% | 20.6% | 27.8% | 10.1% | 12.8% |
| 2 | 10.8% | 15.6% | 62.0% | 76.6% | 60.1% | 81.5% |
| 3 | 47.4% | 70.5% | 42.8% | 48.2% | 35.6% | 45.3% |
| 4 | 59.8% | 80.5% | 8.9% | 39.9% | 54.3% | 75.3% |
| 5 | 56.3% | 78.0% | 37.3% | 60.9% | 37.6% | 42.1% |
| 6 | 64.2% | 77.0% | 56.3% | 72.3% | 43.7% | 63.9% |
| 7 | 60.8% | 76.8% | 62.2% | 75.9% | 59.0% | 69.9% |
| 8 | 43.5% | 67.4% | 44.9% | 63.9% | 45.6% | 66.2% |
| 9 | 79.7% | 87.5% | 45.5% | 58.6% | 53.0% | 62.9% |
| 10 | 75.7% | 80.5% | 20.7% | 28.1% | 36.8% | 37.1% |
| 11 | 88.2% | 89.8% | 23.4% | 45.3% | 95.1% | 96.4% |
| 12 | 85.5% | 88.8% | 14.6% | 21.5% | 96.3% | 97.4% |
| 13 | 85.2% | 88.1% | 44.3% | 59.5% | 97.6% | 98.3% |
| 14 | 94.0% | 95.1% | 31.5% | 36.8% | 97.2% | 98.1% |
| 15 | 93.7% | 95.2% | 43.7% | 50.1% | 94.3% | 96.2% |
| 16 | 55.4% | 69.7% | 55.2% | 56.0% | 97.1% | 98.9% |
| 17 | 39.1% | 47.0% | 53.9% | 63.6% | 78.6% | 85.8% |
| 18 | 26.5% | 59.4% | 45.3% | 66.2% | 68.4% | 79.5% |
| 19 | 8.7% | 50.8% | 35.4% | 48.7% | 56.2% | 73.5% |
| 20 | 43.9% | 52.7% | 73.2% | 79.7% | 41.1% | 67.2% |
| 21 | 42.9% | 61.2% | 71.5% | 76.9% | 64.8% | 78.5% |
| 22 | 43.5% | 60.5% | 10.8% | 48.1% | 80.9% | 87.8% |
| 23 | 67.7% | 75.8% | 46.7% | 65.7% | 82.3% | 88.5% |
| 24 | 18.7% | 22.3% | 50.2% | 64.6% | 48.6% | 70.1% |
| Total | 57.1% | 69.8% | 41.7% | 55.6% | 63.9% | 73.9% |

**Table 5-15**
**Share of Predicted Concentrations from Sources Located Within Selected Distances from the West 43rd Avenue Monitor**

| Hour | December 5, 2006 | | December 6, 2006 | | December 7, 2006 | |
|---|---|---|---|---|---|---|
| | 0.5 mile | 1.0 mile | 0.5 mile | 1.0 mile | 0.5 mile | 1.0 mile |
| 1 | 6.1% | 7.1% | 52.8% | 70.3% | 75.5% | 83.7% |
| 2 | 23.9% | 26.3% | 46.1% | 68.0% | 41.0% | 60.8% |
| 3 | 51.8% | 66.1% | 44.6% | 53.9% | 51.2% | 67.0% |
| 4 | 23.8% | 31.2% | 15.9% | 39.4% | 51.9% | 68.9% |
| 5 | 20.9% | 34.0% | 19.1% | 39.1% | 49.3% | 63.2% |
| 6 | 20.9% | 39.7% | 48.0% | 63.4% | 37.0% | 53.6% |
| 7 | 26.7% | 44.8% | 50.3% | 64.0% | 47.8% | 61.8% |
| 8 | 27.4% | 34.0% | 54.1% | 67.6% | 78.4% | 89.5% |
| 9 | 29.1% | 40.4% | 37.2% | 51.5% | 28.8% | 45.3% |
| 10 | 26.3% | 30.5% | 48.8% | 61.4% | 23.1% | 28.5% |
| 11 | 64.2% | 80.3% | 60.7% | 66.9% | 25.5% | 33.3% |
| 12 | 79.3% | 88.4% | 21.9% | 31.9% | 32.3% | 51.4% |
| 13 | 76.3% | 88.8% | 42.9% | 52.5% | 38.4% | 61.1% |
| 14 | 61.2% | 78.3% | 45.9% | 57.3% | 62.0% | 84.2% |
| 15 | 52.9% | 69.2% | 67.6% | 82.6% | 62.9% | 84.0% |
| 16 | 50.1% | 59.9% | 76.5% | 80.5% | 23.6% | 48.6% |
| 17 | 42.8% | 60.8% | 17.5% | 28.5% | 10.7% | 34.5% |
| 18 | 27.3% | 35.0% | 28.0% | 40.7% | 27.4% | 77.7% |
| 19 | 42.4% | 54.4% | 45.7% | 57.2% | 25.7% | 68.1% |
| 20 | 69.5% | 78.5% | 60.6% | 83.7% | 21.6% | 56.8% |
| 21 | 20.1% | 23.6% | 25.0% | 32.1% | 31.3% | 69.8% |
| 22 | 16.4% | 19.7% | 45.6% | 80.3% | 7.7% | 54.1% |
| 23 | 12.2% | 14.3% | 15.6% | 21.9% | 20.8% | 61.6% |
| 24 | 18.7% | 21.1% | 23.5% | 35.1% | 7.1% | 10.2% |
| Total | 37.1% | 46.9% | 41.4% | 55.4% | 36.7% | 59.1% |

## 5.6 Transport Considerations

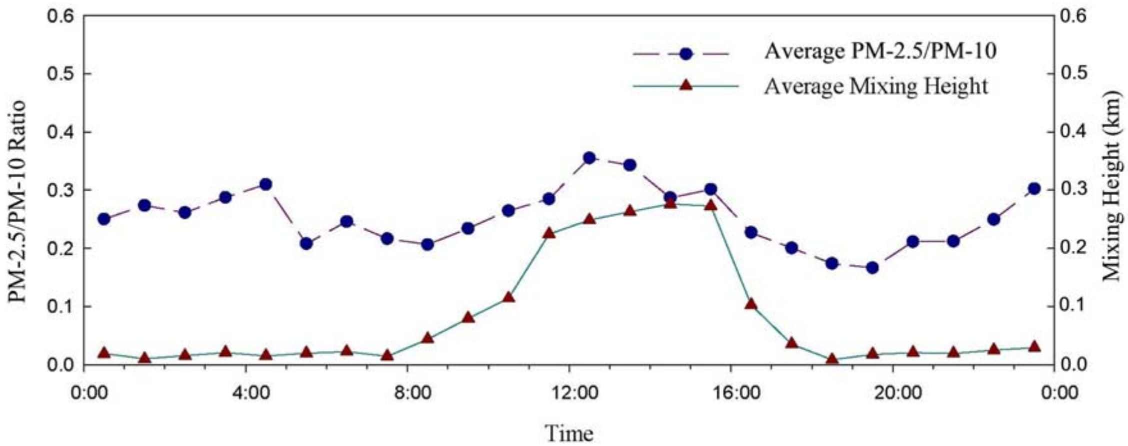
Several lines of investigation were used to assess the contribution of PM-10 transport into the Salt River area during the field study period. One of these investigations included the use of a mobile monitoring platform to measure ambient PM-10 concentrations along transects that were parallel to and outside the modeling domain boundaries. Other investigations included surface level and upper air back trajectory analyses, deposition analyses, LIDAR measurements and interstation hourly PM-10 comparisons.

Back trajectory analyses using surface-level meteorological data revealed that air parcels meander within the modeling domain during stagnant wind regimes when the highest PM-10 concentrations were measured in the Salt River area in December 2006. Figure 3-6 shows a typical 7-hour meander pattern of the air parcel that arrived at the West 43rd Avenue monitoring site at 9:00 a.m. on December 6, 2006, when the hourly PM-10 concentration was recorded as 371.5 µg/$m^3$. During the nocturnal hours represented by this back trajectory, the average mixing height was computed by AERMET to be 35 meters. The settling time of 6.6 micron diameter particles (the average size of particles collected in dustfall jars at the W. 43rd Avenue site) from a release height of 35 meters was calculated to be 2.8 hours, using the deposition velocity estimation methodology described in Chapter 3.3. This means that the vast majority of particles contributing to the 9:00 a.m. concentration at the monitor were entrained into the air from sources within the modeling domain.

With regard to upper air parcels, SODAR measurements showed that at 50 meters above the ground winds quickly transported material mixed aloft during the day out of the modeling domain. Similar results were seen from forward trajectory analysis of radar data measuring higher altitude winds. Thus, locally emitted particulate mixed into the deeper surface layer during the day cannot be a significant source of deposition within the modeling domain. Additional insight into this issue could be provided by the LIDAR measurements. The results of that effort, however, have not become available for review.

Another source of insight into transport was gained from a review of hourly measurements of PM-2.5 to PM-10 on days with stagnant conditions. Figure 5-12 provides a plot of the diurnal distribution of that ratio and changes in mixing height from data collected at the Durango Complex monitor. It shows the ratio remains relatively stable throughout the day. Given the changes in anthropogenic activity throughout the day, this is somewhat of a surprise but consistent with the results of the APS measurements which showed little variation in particle size distribution throughout the modeling domain. The ratio does, however, exhibit an upward rise in the late morning and again late at night. The cause of the midday rise is the result of many offsetting factors, including a rise in mixing height, residence time in the atmosphere, secondary formation, deposition rate, etc. It is difficult to see a pattern of transport among these factors. The cause of elevated nighttime patterns is a little more straightforward. Anthropogenic activity was extremely low relative to the rest of the day, so the amount of new particulate being emitted was limited. The mixing height remained relatively stable so its impact on deposition was also limited. Monitoring data (both displayed and not displayed in Figure 5-12) show that nighttime concentrations remained very stable despite the absence of anthropogenic activity and suggest an undefined source of particulate which could be other unidentified local sources and transport. Another insight is that the ratio of PM-2.5/PM-10 continued to rise, which could be the result of increased deposition of heavier particles as the night continued or a combination of that phenomenon and transport of lighter particles into the modeling domain (which is likely since they will remain aloft for longer periods of time to survive the longer transport distances indicated by the upper air data). Additional measurement and analysis would be required to confirm these effects.

**Figure 5-12**
**Average PM-2.5/PM-10 Ratio at Durango Complex[a]**




a. Average PM-2.5/PM-10 ratio was calculated at Durango Complex during two low wind speed, high PM-10 episodes with total of 5 days: Dec. 5th, 2006 (PM-10 24 hour average: 115 μg/m$^3$); Dec. 6th, 2006 (PM-10 24 hour average: 170 μg/m$^3$); Dec. 13th, 2006 (PM-10 24 hour average: 136 μg/m$^3$); Dec. 14th, 2006 (PM-10 24 hour average: 148 μg/m$^3$); Dec. 15th, 2006 (PM-10 24 hour average: 139 μg/m$^3$).

Finally, transport of material from outside of the modeling domain was addressed in the in the Five Percent Plan documentation. Separate background estimates were prepared and incorporated into the analysis of both low and high wind events.[1] A summary of the background share of total predicted normalized concentrations (Tables V-5-17 through V-5-19 from the Five Percent Plan TSD) is presented below in Table 5-16. It shows that the share of background ranged between 18% - 36% for low wind days and 43% - 55% on high wind days. While these estimates are significantly lower than those included in the 2005 ADEQ analysis, which ranged between 72% - 77%, they show that transport accounts for a significant, but not dominant, share of the concentrations impacting the Salt River monitors.

Transport is a significant factor on high wind days. Although the Five Percent Plan documentation did analyze this contribution for the high wind day of February 15, 2006, no similar high wind event occurred during the November-December 2006 field study. The modeling of high wind events is also problematical. As shown in Figures 5-8 and 5-9 of the Five Percent Plan documentation, AERMOD consistently underpredicted the sharp rise in afternoon concentrations caused by the onset of high winds. The reason for

[1] Estimates of background were prepared based on an analysis of concentrations recorded at monitors located outside of the modeling domain, transit time to Salt River monitors, and settling velocity rates. Since this calculation captures the contribution of transport and not carryover from one hour to the next, the term background may be misleading.

| Table 5-16<br>Share of Predicted Design Day Contributions From Transport<br>For Salt River Monitors | | | |
|---|---|---|---|
| **Date** | **Durango Complex** | **West 43$^{rd}$ Avenue** | **Bethune Elementary School** |
| Low Wind Days | | | |
| 12/12/05 | 20% | 18% | 21% |
| 12/13/05 | 25% | 36% | 24% |
| High Wind Day | | | |
| 02/15/06 | 55% | 43% | - |

the shortfall is thought to be "the failure of the wind-dependent emission factor algorithm in AERMOD to duplicate the initial hour spike in windblown emissions and the depletion of surface particles available for entrainment in subsequent hours even when average hourly wind velocities increase." While the same problem is thought to be one cause of a failure of AERMOD to duplicate the somewhat elevated concentrations recorded at the W. 43$^{rd}$ Avenue monitor at 6:00 p.m. on December 7, 2006, a contributing factor is that wind speeds on that date were considerably lower and less consistent than those typically associated with windblown dust generation. Because the wind speeds on that date were also inconsistent between the two monitoring sites, different phenomena are thought to be responsible for the underprediction of concentrations recorded on that date.

The highest winds on December 7, 2006, were recorded at the West 43$^{rd}$ Avenue monitor. Table 5-17 presents a comparison of the winds and concentrations recorded at that monitor during the February 15, 2006 high wind design day and December 7, 2006. To simplify the comparison only the highest wind hours are presented. As can be seen, the winds recorded on December 7$^{th}$ were lighter and more variable than those recorded on the high wind design day, which had sustained speeds above 14 mph for a four-hour period starting at 4:00 p.m. Similarly, the concentrations recorded on December 7$^{th}$ were considerably lower than on February 15$^{th}$. Clearly, the higher wind speeds on December 7$^{th}$ were not the cause of the exceedance of the ambient PM-10 standard; the high concentrations recorded under stagnation conditions in the morning were the cause of the exceedance. The underprediction of the peaks recorded at 1:00 p.m. and 7:00 p.m. are the result of lowered anthropogenic activity and relatively low and variable "high" wind speeds that did not produce significant windblown dust emission estimates.

The wind speeds recorded on December 7, 2006 at the Durango Complex monitor were considerably lower than at the West 43$^{rd}$ Avenue monitor. The 8.9 mph and 8.6 mph wind speeds recorded at noon and 1:00 p.m. on December 7$^{th}$ cannot be responsible for the sharp rise in concentrations (i.e., on the order of 500 $\mu g/m^3$) recorded during subsequent hours at the Durango Complex. The height of the peak also contradicts the

**Table 5-17**
**Comparison of Afternoon Wind Speeds and Concentrations Recorded During High Wind Events at the West 43rd Avenue Monitor on February 15, 2006 and December 7, 2006**

| Hour | February 15, 2006 | | December 7, 2006 | |
|---|---|---|---|---|
| | mph | $\mu g/m^3$ | Mph | $\mu g/m^3$ |
| Noon | 3.2 | 51.5 | 7.5 | 111.2 |
| 1 pm | 2.0 | 46.6 | 13.6 | 135.9 |
| 2 pm | 3.5 | 66.5 | 10.5 | 66.0 |
| 3 pm | 9.6 | 225.8 | 8.3 | 28.1 |
| 4 pm | 15.5 | 829.4 | 10.9 | 23.0 |
| 5 pm | 14.6 | 591.0 | 9.9 | 36.7 |
| 6 pm | 15.1 | 274.3 | 6.7 | 54.7 |
| 7 pm | 14.4 | 346.2 | 8.3 | 134.0 |
| 8 pm | 11.0 | 97.5 | 10.2 | 53.1 |

"event." Sierra contacted MCAQD to determine whether any Rule 316 violations were recorded on this date. A review of the violations recorded in the Salt River area found none were issued on this date. The lack of violation on this date, however, does not mean that an emissions event did not occur—it just means that one was not recorded.

This result is consistent with the observation that top-down inventories cannot be relied upon to assess source-specific emissions on design days. Access to day-specific activity data is critical to understanding source-specific emissions. Since regularly collected activity data may not always capture information on the critical emissions source(s), investigations of unusual activity (e.g., accidents, construction, violations, etc.) should be undertaken immediately after an exceedance is recorded (i.e., while insight is still fresh in people's minds even if the activity data were not recorded). Insights gained from this effort will aid in tracking progress towards attainment and in subsequent modeling investigations.

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# 6. CONCLUSIONS

Improving the understanding of PM-10 source-receptor relationships in the Salt River area, which is dominated by fugitive dust sources, has been a challenge. When the vast majority of particulates are produced by sources of fugitive dust, the tools (e.g., chemical and elemental speciation approaches) that can be applied to this problem are significantly limited. In light of these limitations, this study has treated ambient PM-10 as a gaseous pollutant and has focused on development of an accurate emissions inventory and dispersion modeling to identify the sources of PM-10 emissions.

At each step in the investigation and analyses, new insights were assimilated into the design of the subsequent analytical task. The success of this effort is demonstrated by the improved model performance relative to the Salt River TSD, where predicted concentrations for low wind days represented 14 percent of the monitored values and the $R^2$ was 0.03. In this study predicted concentrations accounted for 58 to 91 percent of the monitored value and the $R^2$ ranged between 0.27 and 0.66 depending on the day examined.

Presented below is a summary of the insights gained in this process.

<u>Source Strength</u>

- Paved road emissions, especially in areas of heavy soil silt loadings, are the largest contributor to ambient PM-10 in the Salt River area.

- Day-specific analysis of source emissions is critical to understanding the relationship of source contributions to monitored concentrations and determining the effectiveness of control measures in demonstrating attainment.

<u>Low Wind, Stagnant Days</u>

- Highest PM-10 impacts occur during early morning after emissions-generating activities commence operation and before inversion heights rise as a result of solar groundheating.

- Emissions from nearby sources (i.e., within 1 mile) dominate PM-10 concentrations recorded at the monitor.

- The site-specific location of emission sources—especially area sources such as paved roads, unpaved parking lots, etc.—is critical to the correlation of modeled PM-10 impacts to monitored impacts and, thus, the determination of source-receptor relationships in areas dominated by fugitive dust sources.

- Modeled estimates consistently underpredicted measured concentrations during late night and early morning hours when anthropogenic activity was low and after the morning peak in anthropogenic activity when the mixing height was increasing and emission levels were dropping. While the causes of this shortfall are not well understood, they are thought to include underestimates of emissions associated with "events" (e.g., accidents that divert traffic flows, localized construction activity, failure of emission control systems, etc.) particularly during nighttime hours.

Higher Wind Conditions

- Elevated wind speeds (those above stagnant conditions but below the threshold required for windblown emissions) generally disperse and reduce concentrations carrying over from stagnant wind periods. This effect is seen in the late afternoon and nighttime concentrations recorded on December 7, 2006, at both monitors.

The above findings were used to model the attainment of the 24-hour PM-10 standard in the Five Percent Plan. The study findings also provided valuable insights that aided selection of measures in the Plan that will reduce PM-10 emissions during stagnant and windy conditions. The implementation of the committed control measures in the Plan is expected to achieve attainment of the federal standard in the Salt River area, and throughout the PM-10 nonattainment area, by December 31, 2010.

## 6.1 Recommendations for Future Studies

In light of the above findings, it is recommended that both meteorological and concentration measurements in the Salt River area be recorded over shorter time intervals (e.g. 5-minute averages). This information is critical to assessing air movement, dispersion and source significance under the low wind stagnant conditions that occur in late November and early December. In addition, it recommended that the following studies be considered:

- Conduct a saturation monitoring study under low wind stagnant conditions. Data is needed on concentrations and particle size distribution recorded at multiple locations within the Salt River for extended periods of time to support a better understanding of dispersion and source significance.

- Evaluate the ability of "puff" models (e.g., CALPUFF) to better represent dispersion within the Salt River. Puff models have the ability to account for carryover (i.e., previous hour's contributions) and the effects of meandering wind currents.

- Identify and collect data on the activity of critical emission sources during periods of high PM-10 concentrations. Attention should be focused on records used to prepare emission inventories (e.g., travel activity, operating hours, permits, etc.), as well as records of unusual activity that provide insight into unexpected source significance (e.g., accidents, notices of violation, interviews, etc.). This information should be assembled and used to assess source significance for each day the standard is exceeded.

- Collect additional silt measurements in the Salt River area during periods of high PM-10 concentrations. Data are needed for roads with and without visible trackout. The data should be combined with previous measurements to improve confidence in estimates of control program benefits and to track progress towards attainment.

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