APPENDIX A

T&B FIELD MONITORING STUDY

1. MONITORING STRATEGY

The planning and execution of the monitoring program was designed to provide measurements of key emissions activities during periods of high PM_{10} levels, and have the flexibility to adjust sampling strategies as additional information was gathered and analyzed. Going into the monitoring program there were a number of unknowns, so the program was designed to provide for the ability to change how data were collected and analyzed. This section describes the goals and design of the sampling program and how the data collection efforts were planned and executed.

1.1 Sampling Goals

At the outset of the program there were specific goals established to help guide the data collection design and sampling efforts. These goals were provided in the form of specific tasks to help define the work to be performed, how it would be collected, and how it would be analyzed. These tasks can be summarized as follows:

Task 1 - Refine the Work Scope -- During the course of the study, refinements were proposed and made to the sampling program that responded to findings from the initial analyses of past data, to inputs received from the MAG project manager and stakeholders during the kick-off meeting, and initial sampling in the study area. This ability to refine the work plan allowed an appropriate response to the observed conditions so as to optimize the usefulness of the data collected fulfill the goals of the data analyses task.

Task 2 - Conduct Analyses of Meteorological Data During High PM Episodes – Prior data collected in the Salt River Basin for the period November 2005 through February 2006 were analyzed to better understand the contribution of potential transport to high PM loadings at key Maricopa County monitors and help identify conditions that led to the high PM values in the Salt River Basin. This analysis helped define the measurements, technologies, and locations that were most useful for the air monitoring work performed in measurements task (Task 3).

Task 3 - Perform Particulate Matter Source Attribution and Deposition Monitoring – This task provided the basis for all measurements made and was designed to address the following specific questions:

1. Where are the specific source areas and/or sources in the Salt River region that contribute to the PM loading at the Durango Complex and West 43rd monitoring sites?

2. To obtain useful results from models such as AERMOD, can the regional particle size distribution be characterized on an area basis, i.e., is there an area of uniformity that can be generalized?

3. What are the causes of the heavy PM loading during the morning hours at the Durango Complex and West 43rd? Are the diurnal variations of PM_{10} and peaks due to reentrainment of paved road dust, or due to other activities in the surrounding source areas that are coincident with traffic peaks?

1.2 Sampling Methodology

To address the sampling goals and answer the specific questions in Task 3, several types of monitoring platforms were required. The approach was to employ monitoring systems that can measure the spatial distribution of particulate matter in and around the Salt River basin with a focus on identifying the source areas that can contribute to the observed loading at the existing monitoring

sites. This source identification was performed using both particulate matter and meteorological measurement technologies, and by video documentation. Sampling efforts were coordinated with the State of Arizona and Maricopa County for particulate matter and meteorological measurements they provided to augment the study. Measurements made during the program included the following:

Particulate Matter – Measurements included the existing network instrumentation operated by Maricopa County, along with enhancements to that network which consisted of mobile measurements using two mobile vans, fixed site measurements at a site added for the study, and remotely sensed measurements made by Arizona State University (ASU), under contract to the State of Arizona.

Meteorological – Measurements included the existing network operated by Maricopa County, along with enhancements to that network consisting of mobile measurements made from one of the vans during periods of non-moving operations, wind measurements in the lowest 200 meters using a miniSodar provided by the State of Arizona at the West 43rd monitoring site, fixed site measurements at a site added for the study, and remotely sensed measurements made by ASU under contract to the State of Arizona.

More details on the specific measurements are provided in Section 3.

1.3 Data Collection Planning and Execution

Following the initial planning meeting, analyses were performed of the existing data during high PM_{10} episodes. Meteorological conditions were evaluated in an attempt to identify the most prominent wind flow patterns that produced the high values at the Durango Complex (DC) and West 43rd (WF) sites. As this initial analysis continued, it became clear that there were other potential local sources near the monitors that had not been accounted for in the existing inventory. No clear pattern of source areas emerged from the existing data set.

On the basis of the preliminary findings, and consistent with the goals of Tasks 1 and 2 of the work scope, the sampling program was refined to provide measurements in a two phased approach. The first phase focused on the identification of local sources near the DC and WF monitors, which may be contributing to the exceedances at the monitors. This phase consisted of primarily mobile measurements of PM_{10} and $PM_{2.5}$, as well as visual documentation of the sources around the monitors. The results from Phase 1 of the monitoring were then used to refine the measurements to be made in the Phase 2 effort. A monitoring period of one month during the period of mid-November through mid-December was selected for field measurement tasks based on the analysis of the historical exceedance periods. Deployment to the field occurred on November 13 with Phase 1 sampling performed from November 15 through November 19, 2006. The results from this sampling were analyzed during the week of November 20 and revisions made to the sampling strategies that then resumed in Phase 2 on November 30, and continued through December 14, 2006. Additionally, during the Phase 2 sampling, coincident measurements were planned and executed with the road emissions measurements made by CECERT during the week of December 4, and with lidar measurements by Arizona State University (ASU) who were under contract to the State of Arizona.

Throughout the data collection efforts, close coordination was maintained with the program management regarding the findings of each day's sampling results. Preliminary data plots were submitted daily that highlighted the sampling findings and provided timely information to both MAG

and Sierra on key findings, and immediate feedback on how that information could be used to plan subsequent sampling missions. A key finding during the Phase 1 sampling was that mobile sampling provided a primary data input and sampling platform for the identification of what were previously unidentified sources of PM_{10}, such as open burning and truck driving schools adjacent to the WF and DC monitoring sites. On the basis of the Phase 1 sampling results, a second sampling van was added to the measurement program for Phase 2. This sampling van included the continuous particulate matter measurements as well as adding an Aerodynamic Particle Sizer (APS) to help refine the size distribution of particulate matter from the various identified sources.

Phase 2 of the sampling effort used both sampling vans to identify and characterize source areas as well as adding a continuous optical PM_{10} monitoring station at a location half way between the West 43rd and Durango Complex stations. The Phase 2 operations also included a concerted quality assurance effort to audit the measurements made and help establish uncertainties in the collected data. This allowed a more complete understanding of the data collected.

2. FIELD MEASUREMENT INSTRUMENTATION

The types of instrumentation used in the sampling program evolved as more was learned about the types of sources of PM. Described below are the measurement platforms used and the procedures used to assure the quality of the data were understood.

2.1 MAG Network Enhancements

Through the initial analyses performed it became clear that higher time-resolved wind and particulate matter information could greatly enhance the understanding of the PM problem in the Salt River Basin. With only hourly data available, and the analysis showing that the highest concentrations occurred during a short period of four hours or less, increasing the time resolution could greatly enhance the understanding of the processes involved.. During this short time period, the reported winds were always very light and variable. Part of the reason for the very light reported winds was the vector averaging technique used.. With highly variable wind directions, the resulting vector average over the relatively long hour period would show very low reported wind speeds, and hence, suggest not much transport. To better understand the low wind speed conditions, the Maricopa County monitoring group added higher time resolution measurements with 5-minute averages. Additionally, scalar wind calculations were recorded, in addition to the standard vector winds. Modifications were also made to the PM_{10} measurements to record 5-minute averages from the TEOM samplers. A refined trajectory analysis based on the higher temporal resolution winds revealed a slow but definable movement of parcels around the Salt River Basin which allowed a greater understanding of the origin of the high concentrations. The modifications to the network were made to the Durango Complex, West 43rd, West Phoenix, Central Phoenix, South Phoenix and Greenwood stations.

2.2 West 43rd Site Monitoring Enhancements

The WF site, because of the history of exceedances and its central proximity in the Salt River Basin, was selected as the base for field operations. In addition to the enhancements of the recorded averaging intervals to include 5-minute data, additional measurements were made at the site, as described below.

Wind measurements using a miniSodar – The Arizona Department of Environmental Quality (ADEQ) provided an AeroVironment model 4000 miniSodar for measurement of winds and mixing in

the lowest 200 meters of the atmosphere. The system was installed by ADEQ at the outset of the program and the operation verified by T&B Systems' personnel prior to the start of the data collection effort. The system was programmed to collect and report 10-minute average winds and provide the facsimile display of the acoustic backscatter. This facsimile display was subsequently used to evaluate the mixed layer depth during the high PM10 concentration episodes. Figure 2-1 shows the miniSodar system.

Figure 2-1. MiniSodar at the West 43rd monitoring station.

An automated digital camera was installed at the site to document the environment around the WF site. The camera was originally installed facing east to document sources along Broadway. The pointing direction was changed on November 15 to face the northeast, in the direction looking across the Salt River toward the DC site. On December 6 the camera was turned to the southwest to document local sources adjacent to the WF site. Figure 2-2 shows the camera system. High temporal resolution pictures were taken at intervals from 3 seconds to 30 seconds, depending on the pointing direction of the camera. Each picture was in a 640x496 pixel resolution with the date and time stamp embedded into the picture. Over 400,000 pictures were taken over the course of the study from this camera. Example views are shown in Figure 2-3.

Figure 2-2. Camera mounted at the West 43rd monitoring site. The view shown had the camera aiming to the northeast.

Looking East

Looking Northeast

Looking Southwest

Figure 2-3. Example views from the West 43rd site camera.

During the last week of Phase 2 monitoring ASU installed the particle lidar at the WF site. The lidar performed horizontal and vertical scans of the atmosphere to provide relative concentrations of particulate matter around the site. Additionally, the system estimated the wind field through an analysis of the Doppler shifted signals from the lidar pulses. More details on the measurements are provided in a separate report of findings from ASU submitted to the ADEQ. Figure 2-4 shows the lidar system installed at the WF site.

Figure 2-4. ASU lidar installed at the West 43rd site.

2.3 Additional Fixed Site Monitoring at the 35th Site

Following the Phase 1 monitoring, a key issue that arose was whether the high PM_{10} concentrations observed at the WF and DC sites were due primarily to local sources immediately adjacent to the sites, or some distance away from the local sources, but still within the Basin. To help answer this question a monitoring site was established near the Salt River, east of 35th Avenue, and away from any immediately local sources. The monitoring station was comprised of a PM_{10} configured DustTrak, recording average optical PM_{10} concentrations at 5-minute and 60 minute intervals. The values collected were adjusted using a K-factor derived from the filter sampler to DustTrak measurements in the monitoring van, and the DustTrak to TEOM measurements made at both WF and DC. Wind measurements were also made using a RM Young Wind Monitor AQ wind speed and wind direction sensor. Data were polled via radio modem from a computer at the WF site every 5-minutes and uploaded to a web page for a near real-time display of the values. Figure 2-5 shows the location of the station relative to the WF and DC sites. Figure 2-6 shows the monitoring site with the view looking to the south, over the Salt River.

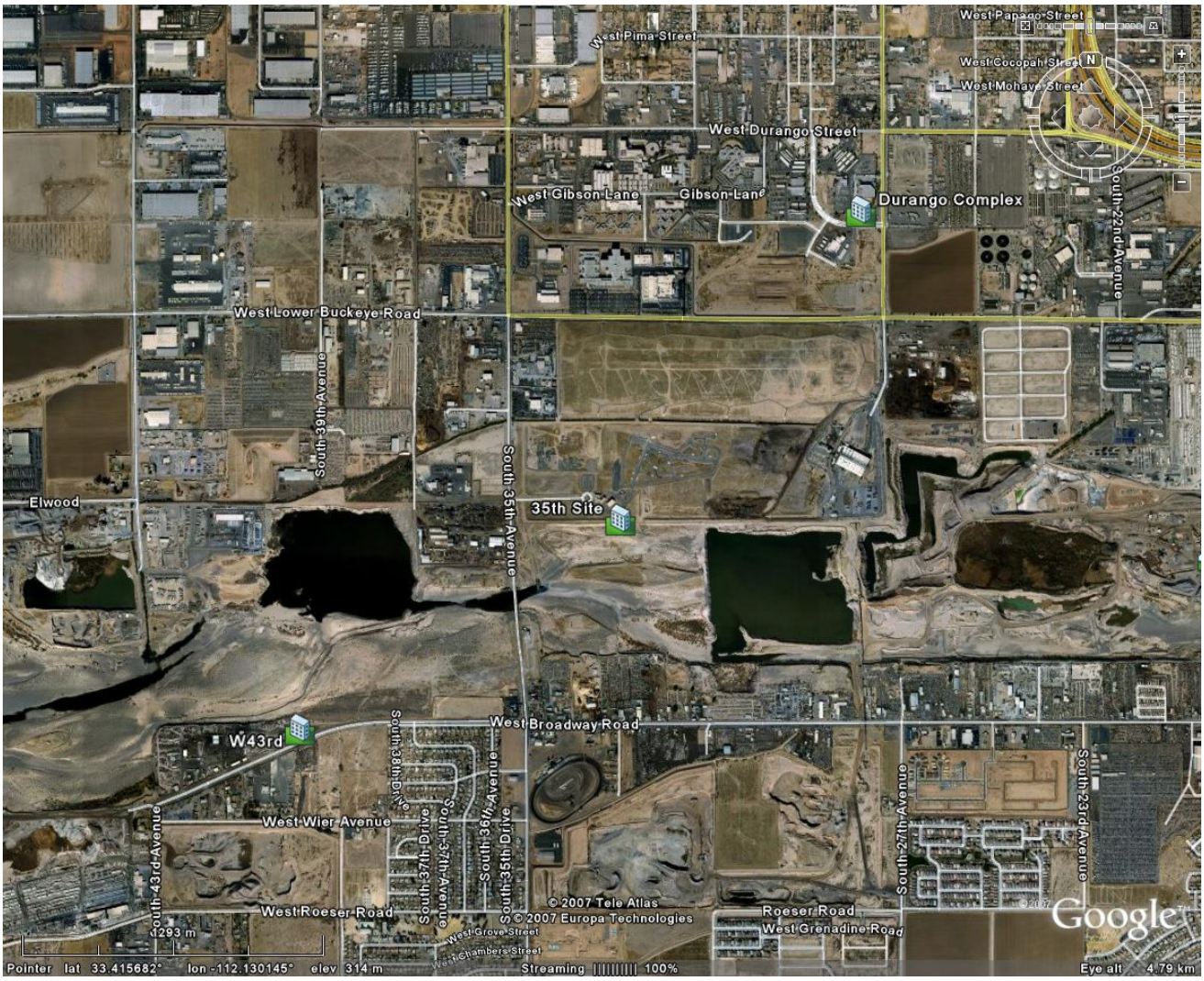

Figure 2-5. Location of the 35th site relative to the WF and DC sites.

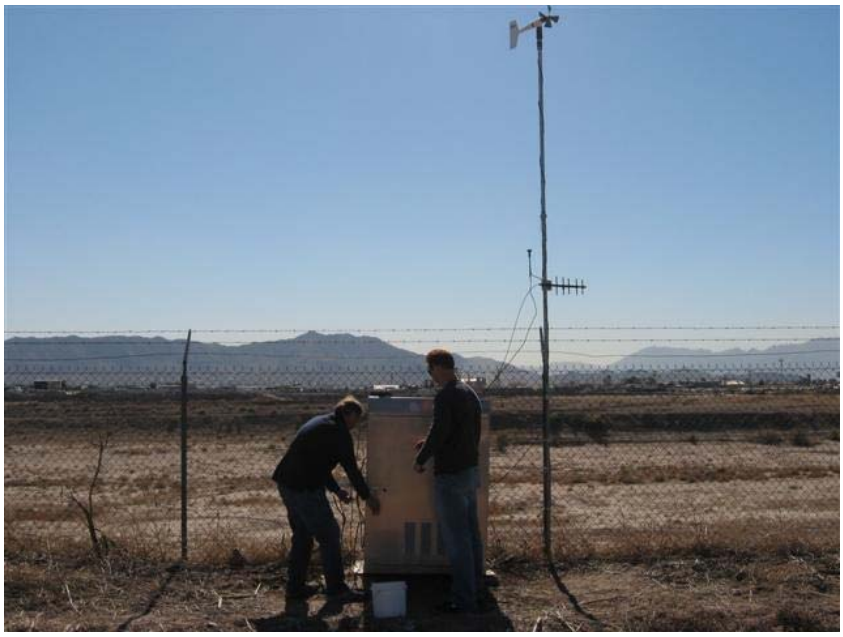

Figure 2-6. View of the 35th site.

2.4 Mobile Monitoring

Mobile monitoring was performed using two vehicles. The primary vehicle, referred to as Van 1, or the Pilot, performed measurements during both Phase 1 and Phase 2 of the sampling program. The second vehicle, referred to as Van 2, or the Kia, was added for sampling in Phase 2. The equipment used in each of the mobile vans is shown in Table 2-1. Figures 2-7 and 2-8 show the Pilot and Kia, respectively.

Table 2-1. Measurement equipment in the two 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 and direction)	X	
RTD temperature sensor (outside air temperature)	X	
RM Young Electronic Compass (van direction)	X	
Intellinet Network IP camera with recording laptop	X	

Vehicle with top mounted probes and wind and temperature sensors. The camera is dash mounted.

Instrumentation

Figure 2-7. Van 1 (Pilot).

Vehicle with top mounted probes

Instrumentation

Figure 2-8. Van 2 (Kia)

Measurements using the Pilot were made in both a mobile and fixed modes. The primary use was to map the region to obtain relative concentrations throughout the Salt River Basin and identify "hot spot" regions to be studied in more depth. The Kia was used to obtain the particle size distribution. Data were collected and stored in two-second intervals with all values stored in non-volatile memory within the data logger, and polled in real-time as well as on a backup local computers in each of the respective vans.

As the continuous optical method used in the TSI DustTraks for particulate matter concentration determination is not the same sampling principal as the filter based high volume method or the TEOM sampler, filter based measurements made with minivols were used to establish the "K" factor, or correction factor for the optical to filter based relationship. The filter samplers were allowed to run over multiple sampling periods to assure enough particulate matter had been collected to obtain an accurate weight difference between the initial and final weighings. Separate samplers were used to

collect samples for both PM_{10} and $PM_{2.5}$. Additionally, comparisons were made between the DustTraks and the real-time PM_{10} and $PM_{2.5}$ samplers at WF and DC. All of these data were used to establish the relationship of the DustTraks to the site monitors.

2.5 Quality Assurance and Quality Control

Integral to the data collection program was the quality assurance effort employed during the period of measurements. T&B Systems had an independent auditor visit the field sites and evaluate the measurements made during Phase 2 of the data collection program. A summary of the checks made and the findings is provided below.

In addition to the quality assurance procedures described, the data collection effort had quality control measures in place to internally monitor and establish data quality parameters that were used to verify data validity and provide support documentation used in the final processing of the data. Those measures are described following the quality assurance discussion.

Quality Assurance

Mobile Vans

The following performance checks were conducted:

- Flow checks of all samplers, including the APS, using a Gilibrator flow standard
- Zero checks of the DustTraks and APS
- Leak checks of the MiniVols
- Quasi-quantitative check of the APS by placing a PM_{10} inlet on the APS inlet
- Four-point check of the wind direction sensor on the Pilot, including orientation relative to the van
- Six-point check of the wind speed sensor using a constant speed motor
- A one-point ambient comparison of the temperature sensor

All checks were conducted using standards independent of those used for the monitoring effort. Figure 2-9 provides a picture of the audit.

Figure 2-9. The Pilot being audited for the accuracy of the instrumentation.

In addition, the auditor rode in each van to review operations, data collection equipment and procedures, and the representativeness of the collected data. Results of all performance checks were very good. The only recommendation from the systems review was to include recording of the MiniVol elapsed time meter readings as part of the daily checks in order to verify the actual sampling period for the collected samples.

To further investigate the representativeness of the collected PM data, the following special tests were conducted at the auditor's request. All tests were conducted near the T&B Systems 35th Avenue site under stable and relatively low PM_{10} conditions (less than 50 $\mu g/m^3$), which allowed for the identification of any interferents being investigated. In addition, wind conditions were steady but light (less than 2 m/s) and representative of typical sampling conditions during the study.

To investigate whether exhaust emissions from the van affected readings, the KIA was parked with the tailpipe upwind, and sampling conducted alternatively with the motor turned on and turned off. A total of seven 7-minute sampling intervals were measured, four with the motor off and three with the motor on. No difference in readings was noted, indicating that the van exhaust is not an interferent.

To investigate whether dust kicked up by the van influence readings while the van was moving, the KIA was driven down a dirt road at 15 MPH, representing a worst case scenario for possible interference. The test was also conducted on a paved, though lightly used, road at 25 MPH. Tests were repeated both heading into the wind and away from the wind. No changes from background ambient readings were noted, indicating that dust generated by the movement of the van does not significantly affect readings.

As an extension to the above test, measurements were monitored to see how the plume of dust generated by travel affected readings once the vehicle stopped. Even in the case of the very dusty plume generated on the dirt road, the affect of the plume was gone within 15 seconds after stopping.

35th Avenue Monitoring Site

A zero check was conducted on the DustTrak sampler at the site. Lowering the wind sensor at the site was considered undesirable in that it potentially affected measurement consistency. Thus, performance checks of the wind direction sensor were conducted by noting true bearing of the wind vane during steady conditions and comparing these readings with the simultaneous readings on the data logger. All such checks showed agreement to within 1°. Reported wind speeds were deemed to be in agreement with actual conditions.

Maricopa County Air Quality Department Monitoring

A systems review of the MCAQD monitoring effort was conducted at the Maricopa County office. The review concentrated on PM and meteorological measurements, and consisted of discussions with key personnel regarding monitoring QA/QC procedures and data validation. All personnel showed a high degree of concern for data quality, and no serious issues were noted. However, the following observations were made:

- The top range of the PM_{10} TEOM sampler was set at 1000 $\mu g/m^3$. Values higher than this were measured as 1000 $\mu g/m^3$. The data were flagged for two situations: exceeding a set upper limit and unstable readings (usually due excessive rates of PM loading on the filter to which the sampler cannot adjust for). It is the MCAQD's policy to invalidate any hour that has greater than 25% of the hour affected by these flags, consistent with the EPA 75% data recoverability criteria. The auditors initial concern was that hours of high PM_{10} concentrations were being invalidated because they exceeded the upper limit. However, they have set the upper limit criteria to 1200 $\mu g/m^3$, which can never physically be reached since it is beyond the set range. Thus, only electronic spikes were flagged. The period of time during which the sampler may have been over-ranging was therefore not recorded, and the extent of this is issue was therefore unknown. The second flag, regarding unstable readings, appeared to have affected data in the past. At both the Higley and Buckeye sites, some PM_{10} hourly concentrations were invalidated on both May 17 and May 22, 2006. The hours invalidated appeared to occur during very high PM concentrations, so high that the TEOM readings became unstable for more than 25% of the hour. This was a limitation with this method, and no further action was required other than to realize its potential affect on the data.
- Personnel were incorrectly calculating wind direction starting threshold torque. Due to confusion in interpreting the scale on newer RM Young torque meters, the calculated torque was only a tenth of the actual torque. In the case of both the West 43rd Avenue and Durango Complex sites' most recent calibrations, the torque was reported as 2.5 gm cm when it actually should have been reported as 25 gm cm. Relative to a torque criteria of 11 gm cm required for the RM Young wind sensors in order to have a starting threshold less than 0.5 m/s, these torque readings would have required changing of sensor bearings. Personnel were instructed on the correct method of measuring wind direction starting threshold torque. It is unlikely that the potentially higher starting thresholds of the sensors seriously affect the wind data.
- There were some inconsistencies in the delta temperature calibration at the West 43rd site. The top bath point showed the responses at the two levels differing by 0.2°F, though the actual delta temperature value reported by the data logger was only 0.04°F. Also, there was some confusion as to whether the criterion for the delta temperature check was 0.1 or 0.5°F. Different forms showed different criterion. The actual EPA criterion is 0.18°F. Thus, the 0.1° criterion is applicable, consistent with the MCAQD policy of having calibration criteria that are

tighter than the actual EPA-required monitoring objectives. Bottom line, the delta temperature sensor at West 43rd Avenue appeared to be calibrated correctly, despite these inconsistencies.

- As an additional check, the auditor checked the wind direction sensor alignment at both the West 43rd Avenue and Durango Complex sites. The sensor alignment at the West 43rd Avenue site was perfect. However, the Durango Complex sensor was oriented 4° low (aimed at 356° instead of 360°), relative to the EPA audit criteria of ±2°. Again, it is unlikely that this seriously affects the representativeness of the data collected at this site.

SCAMPER

A brief review of the CeCert SCAMPER monitoring was conducted through an informal discussion with Kurt Bumiller, the SCAMPER operator. Mr. Bumiller is very conscientious about data quality, and was addressing two issues at the time of the discussions. First, he was having trouble with high zero readings for one of the DustTraks, apparently related to sensitivity to light. He had solved this problem by the next day by wrapping the sampler in aluminum foil. Second, he was having trouble with both the device used to record sample flow rate for the PM_{10} sampler used to calculate K factors, as well as the flow standard used to check this device. At his request, he had the auditor check the flow using the audit standard in order to confirm flow rates for the day in question. The measured flow was 18.25 lpm with no filter installed versus his last measured flow rate of 17.5 lpm with a filter installed, showing good agreement.

Study Design Review

In general, the study design appeared to be appropriate in order to meet study goals. The auditor's one recommendation was to conduct longer north/south and east/west transects in order to better define the dimensions of the particulate matter plume. In this manner, transects would travel as far as necessary to demonstrate the edge of the high readings. Such transects were thought necessary in order to properly address the issue regarding the role that transport does or does not have on high concentrations in the Salt River area.

Quality Control

Separate from the quality assurance activities were procedures for the internal quality control of the measurements. Described below were the QC measures employed for each of the measurements made.

At the outset of the monitoring program, the four DustTraks provided by ADEQ were all run to verify proper operation. The test was performed at the WF site with all samplers operated on top of the shelter with the sample heads all in close proximity. The results showed all samplers to be reporting concentrations within ±3 $\mu g/m^3$ of each other in ambient concentrations up to 137 $\mu g/m^3$. Figure 2-10 shows the test setup. The mounting of the digital camera and the sodar antenna can also be seen in the picture.

Figure 2-10. Checkout of ADEQ provided DustTrak samplers.

To establish the link between the optical method for measuring PM10 (DustTrak) to the site method at the Maricopa County stations (TEOM) one DustTrak was allowed to operate for 45 hours with the DustTrak sampler inlet in close proximity to the TEOM inlet. The results of the comparison, shown in Figure 2-11, showed a "K-Factor" of about 1.7 that needed to be applied to the DustTrak measurements in order to provide "equivalent" measurements under the observed conditions. The results of the comparisons made from both the Pilot and Kia on December 1, 2006 at the DC and WF sites, respectively, showed K-Factors for PM_{10} of about 1.7 for the Pilot and 1.9 for the Kia. A comparison of the Pilot to DC $PM_{2.5}$ values showed a K-factor of 0.71. A further comparison was made using the minivol data collected during the Pilot measurements which incorporated moving sampling. The correction factor derived from these measurements showed a K-Factor of about 1.6 for the PM_{10} and 0.6 for the $PM_{2.5}$.

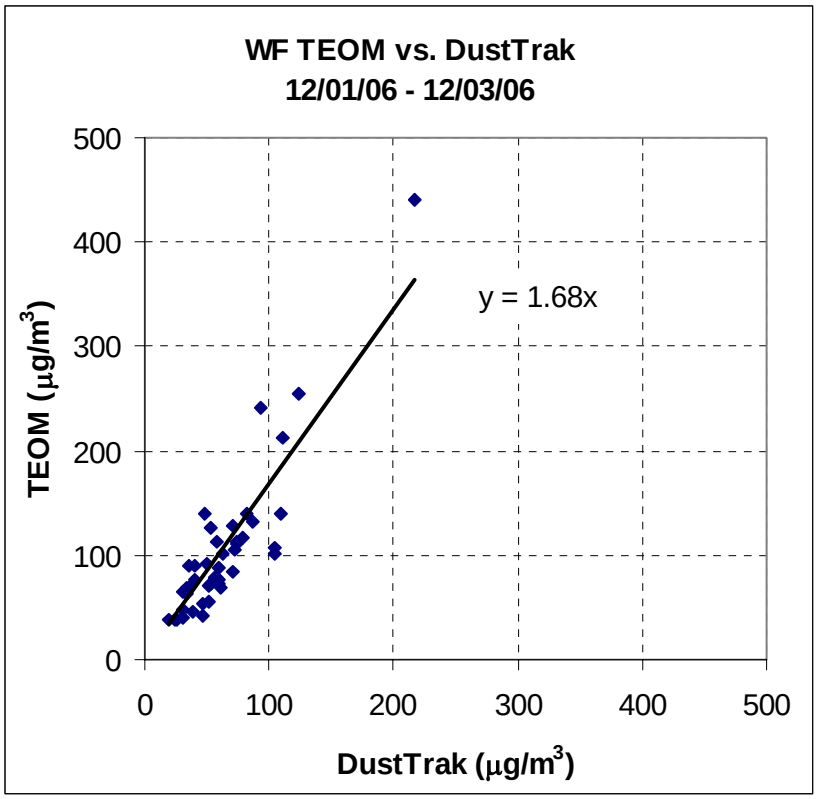

Figure 2-11. TEOM to DustTrak comparison at WF for a 45 hour comparison.

On the basis of all of the data collected, the K-factors selected for the DustTrak measurements are shown below. The reason for the slightly different Kia PM_{10} factor was the noticeable difference in response that may have been due to a slight anomaly in the sample inlet. This anomaly also resulted in an apparent speed dependency of the Kia PM_{10} data that defined the use of the data only when the Kia speeds were less than about 4 m/s.

Measurement	K Factor
Pilot PM_{10}	1.65
Pilot $PM_{2.5}$	0.70
Kia PM_{10}	1.90
Kia $PM_{2.5}$	0.70
35^{th} Site PM_{10}	1.65

Mobile Vans

Optical PM_{10} using the DustTrak – Flow rates were measured at the beginning and end of each sample day, adjusted as necessary in accordance with the manufacturer's instructions to obtain the 1.7 lpm flow rate, and documented in the respective van's log book. A zero filter was inserted in the sample line to obtain an instrument zero at the beginning and end of each sample day. Per the manufacturers instructions, adjustments were made to the zero if the resulting reading exceeded ±2 $\mu g/m^3$. Results of the checks were documented in the van log books.

Optical $PM_{2.5}$ using the DustTrak – Flow rates were measured at the beginning and end of each sample day, adjusted as necessary in accordance with the manufacturer's instructions to obtain the 1.7 lpm flow rate, and documented in the respective van's log book. A zero filter was inserted in the sample line to obtain an instrument zero at the beginning and end of each sample day. Per the manufacturers instructions, adjustments were made to the zero if the resulting reading exceeded ± 2 $\mu g/m^3$. The impactor plate was cleaned and regreased at approximately four-sample day intervals. Results of the checks were documented in the van log books.

Minivol PM_{10} and $PM_{2.5}$ – The indicated flows on the minivol samplers used in the Pilot were calibrated at the onset of the program using a Gilibrator 2 automated bubble flow meter. These flows were checked at the start of each sample day using the internal flow meter in the minivol. Included with the exposed filters that were analyzed by Airmetrics were five unexposed filters shipped as blanks to establish the analytical accuracy of the total process from the initial through the final weighings. These filters were randomly selected from the pre-weighted filters and returned with the normal shipment of exposed media for routine analysis.

Wind speed and direction – At the outset of the program, the response of the wind speed was verified using a RM Young selectable speed anemometer drive. The orientation of the wind direction sensor was oriented to true south when the vane was aimed in the forward direction of travel of the monitoring vehicle. This direction was corrected to 0° (true-north) in the data logger program and verified at the outset of the measurement program. Readings at 90° increments around the compass were also verified.

Ambient temperature – A multipoint calibration of the thermistor was performed prior to the deployment to the field, and the measurements reviewed for reasonableness following installation.

Electronic compass – The manufacturers recommendations for calibration of the flux gate compass (multiple slow 360° circles) were followed when the mounting array was installed on the top of the Pilot, and anytime that the array was moved or removed and reinstalled. Additionally, comparisons were made to the GPS vehicle heading during periods when the van was traveling in a constant direction. It should be noted that the data reported from the compass is in magnetic degrees.

GPS position – The GPS position was verified in transit using a real-time mapping program (Microsoft Streets and Trips) to plot the position of the van.

Digital camera pictures – The time of the computer on which images were stored was verified and set as necessary at the start of each sample day. This same computer time was used to date and time stamp the images from the Pilot (Van 1).

Aerodynamic Particle Sizer (APS) – The computer polling the APS was verified to have the proper time stamp that is synchronized with the balance of the measurements. The displays of the flow rates reviewed to assure no fault conditions existed.

35^{th} Site Measurements

Optical PM_{10} using the DustTrak – Measurements at this site were powered by high capacity solid gel batteries. The batteries were changed at approximately 5-day intervals. During the battery exchange the zero and flow was checked using the same procedures described for the mobile vans above. Battery voltage was monitored on the data logger as well as the temperature inside the monitoring shelter.

Wind speed and direction – Upon installation, the response of the wind speed was verified using a RM Young selectable speed anemometer drive. The orientation of the wind direction sensor was oriented to true south using the GPS walk-off method, and the response in the four cardinal directions verified.

West 43rd Site Measurements

Digital camera pictures – The time of the computer storing the images was verified at the outset of the program. As a real-time Internet connection was available through the CDMA modem, the clock for the time stamp on the images was set through the normal update process of the computer.

MiniSodar wind measurements – At the outset of the program the ADEQ miniSodar system was reviewed for the proper orientation and level, and the setup for the recording of the data was verified to be optimum for the program goals. Throughout the course of the study, ADEQ provided data as it was downloaded, and the data was reviewed for reasonableness with the the surface meteorological measurements made by the Maricopa County wind system at the site.

ASU Lidar – The lidar provided by ASU, under a separate contract with ADEQ, was installed at the WF site during the last week of the study. No QC checks by T&B Systems' personnel were possible during the study period.

2.6 Data Processing and Validation

All data collected were reviewed in the field for reasonableness and proper instrument operation. Any issues discovered were immediately corrected. Following the field data collection program, all data were validated and final calibrations applied to the collected values. Described below are the processing and validation steps performed for each measurement type to generate the validated data set.

Measurements from the Pilot (Van1)

Optical PM_{10} using the DustTrak – Zero and flow check records were reviewed for anomalies and any needed corrections were made. The selected K-factor of 1.65 was applied to all measurement values. It should be noted that there were periods when values from the DustTrak were over range. These values will show up in the data set as greater than 1630 $\mu g/m^3$ and, it should be noted, represent values of at least that concentration.

Optical $PM_{2.5}$ using the DustTrak – Zero and flow check records were reviewed for anomalies and any needed corrections were made. The selected K-factor of 0.7 was applied to all measurement values. It should be noted that there were periods when values from the DustTrak were over range. These values will show up in the data set as greater than 693 $\mu g/m^3$ and, it should be noted, represent values of at least that concentration.

Wind speed and direction – The values were reported with the caveat that corrections for vehicle speed will be needed to use the data in a moving mode. If fixed mode data is desired then a check should be performed to assure the vehicle is stopped for at least 30 seconds before the wind data is used. This allows the effect of vehicle wake to be removed from the reported values.

Ambient temperature – Data were reviewed for reasonableness and reported as recorded.

Electronic compass – Data were reviewed for reasonableness and reported as recorded.

GPS position – Data were reviewed for missing scans when the GPS lost lock and the position data filled in through interpolation. If more than four consecutive scans were missing then all data associated with the time of the missing scans were invalidated and removed from the data set. The resulting position data was plotted on a map of the region and the vehicle track was reviewed for reasonableness. Any obvious periods when the GPS reading appeared to wander off of roads were eliminated from the database. This included all associated data in the same time scans. There was only one period where this appeared to happen and the loss of data accounted for an interval of about 1 minute.

Digital camera pictures – Data were reviewed for reasonableness and reported as recorded.

Minivol PM_{10} – The filter before and after weighings were reviewed for reasonableness and internal consistency and compared with all filter values for filter-to-filter consistency. Average blank values were calculated and the average values subtracted from the net loading prior the calculation of concentration. The blank correction accounted for 1 to 9% of the filter loading (lightly loaded filters had a larger correction). The average correction for all PM_{10} filters was 4%.

Minivol $PM_{2.5}$ – As with the PM_{10} filters, the $PM_{2.5}$ filter before and after weighings were reviewed for reasonableness and internal consistency and compared with all filter values for filter-to-filter consistency. Average blank values were calculated and the average values subtracted from the net loading prior the calculation of concentration. The blank correction accounted for 4 to 27% of the filter loading (lightly loaded filters had a larger correction). The average correction for all $PM_{2.5}$ filters was 14%.

Measurements from the Kia (Van2)

Optical PM_{10} using the DustTrak – Zero and flow check records were reviewed for anomalies and any needed corrections were made. The selected K-factor of 1.9 was applied to all measurement values. It should be noted that there were periods when values from the DustTrak were over range. These values will show up in the data set as greater than 1880 $\mu g/m^3$ and represent values of at least that concentration.

Optical $PM_{2.5}$ using the DustTrak – Zero and flow check records were reviewed for anomalies and any needed corrections were made. The selected K-factor of 0.7 was applied to all measurement values. It should be noted that there were periods when values from the DustTrak were over range. These values will show up in the data set as greater than 693 $\mu g/m^3$ and represent values of at least that concentration.

GPS position – Data were reviewed for missing scans when the GPS lost lock and the position data filled in through interpolation. If more than four scans were missing then all data associated with the time of the missing scans were invalidated and removed from the data set. The resulting position data was plotted on a map of the region and the vehicle track was reviewed for reasonableness. Any obvious periods when the GPS readings appeared to wander off of roads were then eliminated from the database. This included all associated data in the same time scans.

TSI Aerodynamic Particle Sizer – Data collected from the APS were reported as-is. Periods when the vehicle was moving as well as when the vehicle was moving two minutes prior to the reported 1-

minute average were flagged in the database. Particle sizing in the moving environment was not valid because the sample inlet could not be made isokinetic over the speeds driven by the sampling van.

There were also special processing techniques used in the analysis of the data whereby average concentrations along a transect were calculated. The averages were formed by parsing the validated two-second values during an hour period into distance bins along the axis of the traverse. All values in the bins were averaged for the entire hour period thus forming hourly average data points along the traverse.

Measurements from the 35th Site

Optical PM10 using the DustTrak – Zero and flow check records were reviewed for anomalies and any needed corrections were made. The selected K-factor of 1.65 was applied to all measurement values.

Wind speed and wind direction – Data were reported as collected.

3. FIELD OBSERVATIONS

The measurements made during the two phases of the study are described below. The overall summary of intensive measurement periods is presented, along with evaluations and observations from key periods of sampling.

3.1 Summary of Intensive Measurement Periods

Phase 1 of the sampling program had data collection during Intensive Operational Periods (IOPs) from November 15 through November 19. A summary of each day's sampling activities and significant observations from the sampling is provided in Table 3-1. The Phase 2 sampling had IOPs from November 30 through December 14. A summary of the daily sampling activities and significant observations is provided in Table 3-2.

Table 3-1. Summary of Phase 1 sampling activities using the Pilot

Date	Sample Times	Sampling Goal	Significant Observations
11/15	0406 - 1031	Initial sample run to map the study area and obtain an initial assessment for where the "hot spots" were located and how they related to the WF and DC sites.	The sample run started east of the Salt River area with some elevated concentrations, but the observed values were greatest in the region bounded by Southern on the south, Buckeye on the north, and Central on the east and 67th Avenue on the west. The region in the vicinity of DC had significant concentrations that were not regional, but focused in the vicinity of the site, indicating a local source The regions along 35th Avenue and 19th Avenue had significantly higher concentrations from dust that was dragged out onto the road and reentrained by the traffic. Winds were light during the sampling period
11/16	0359 - 1054	Document area to the north as a potential source or region of PM that could be transported into the Salt River Basin.	Lots of regional haze observed in the Salt River area, even along roads that did not have much in the way of traffic. Moderate concentrations of PM were also observed on some of the roads with little traffic. When the transfer station along Lower Buckeye opened, there was visible dragout of dust from the facility. This was deposited on the roadway and stirred up by the traffic passing by. This type of occurrence was a common sight at any of the major facilities where trucks were exiting a facility that was either unpaved or was paved, but had a layer of dirt or dust on top of the pavement. Between 0700 and 0800 the Salt River area appeared stagnant with regional haze in all directions. Values along Van Buren appeared to mark a northern extent of the regional plume. Confirmation loops were made to verify measurements along the main streets were representative of the region. A final crossing down by the river verified higher concentrations in the region prior to the entire layer lifting and mixing out of the Salt River Basin region.
11/17	0401 - 1016	Document the area around Durango Complex	Noted the haze around the facilities along 19th as well as trucks exiting the transfer station along Lower Buckeye "dragging" a plume out to the street. Noted the truck yard across from the DC site as a potential source of dust. Regions along 27th were observed with values in excess of 1,600 $\mu g/m^3$. Significant dust was also along 35th Avenue. The region started clearing around 0850 with local flags showing air movement.

Table 3-1 (cont.)

Date	Sample Times	Sampling Goal	Significant Observations
11/18	0404 - 1011	Duplicate the run made on 11/17 to get a better feel where the sources are that affect the Durango Complex site.	From 0400 to 0445 the winds appeared to be light and from the northwest becoming calm around 0445. High values noted adjacent to the truck yard, across from the DC site. East winds were noted after 0500 with significant dust in the truck yard and increasing truck activity by 0546. At 0632 a distant look at the truck yard showed the dust reaching no higher than 100 feet. Overall traffic was much lighter, as this was a Saturday. By 0822 the overall region appeared to clear out with mixing and winds increasing. At 0915 values over 1600 were noted while passing the truck lot across from the DC site. There was significant movement of trucks in the yard with what appeared to be a truck school.
11/19	0400 - 0848	Document the levels around Durango Complex on a day with less traffic (Sunday).	Started with a loop by the facilities on 19th Avenue. No activity was noted, but the center median had a significant accumulation of dirt. The $PM_{2.5}$ fraction of the total PM_{10} appeared much higher on this day. By 0454 there was significant dust noted throughout the truck yard adjacent to DC, with the dust rising only about 50 feet above ground level. Because of the lack of activity in other areas, the plume from the truck yard was tracked and noted down on Lower Buckeye around 0515. By 656 it appeared that the general haze over the area surveyed seemed to be coming from the truck yard. A north/south traverse profile was performed which revealed temperature inversions. PM2.5 was higher north of the river and lower to the south. The plume from the truck yard adjacent to DC traced during an east wind within the 0800 hour along Lower Buckeye and to the west to 51st Avenue. This was a distance of about 1.5 miles. It appears that much of the PM was in the 2.5 size range by this distance. PM_{10} was several hundred $\mu g/m^3$ and $PM_{2.5}$, about 100 $\mu g/m^3$. Traveling back by WF the facility across from the site to the south was open with equipment operational and the site active.

Table 3-2. Summary of Phase 2 sampling activities using both the Pilot and the Kia.

Date	Sample Times	Sampling Goal	Significant Observations
11/30	Pilot 0432 – 0941 Kia 0421 – 1026	A sampling pattern was run with both of the vans to the east of the Salt River basin in an attempt to view PM that may be transported into the WF and DC regions from the east. The intent was to confirm or deny transport into the region within the drainage flow, which was thought to flow from the east to the west.	The primary traverses were north/south along 24th Street, 16th Street, 7th Street, Central Avenue, 7th Avenue, 19th Avenue and 35th Avenue. The streets were divided between both vans with both driving one common street for QC comparison purposes. The traverses performed in the eastern most regions did not show any appreciable transport of PM through the low terrain along the Salt River. Areas of highest concentration were along Southern Avenue in the vicinity of new roads where the shoulder was being used by commuters to obtain access to a more efficient right turns. There were a couple of hours during the commute time when the traffic backed up and commuters, out of frustration, used the unpaved shoulders for travel, creating the problem. A visit to the WF site revealed a wood burning smell combined with a diesel odor around 0700. Later that morning it was noted that a forklift was moving wooden utility poles around the yard to the west of the WF site and placing them in a large metal pit where they were burned. Elevated PM_{10} readings in excess of 400 $\mu g/m^3$ on the station TEOM were noted with light winds from the west. This wood burning pit was about 20 meters from the WF monitor and blowing right toward the site.
12/01	Pilot 0418 - 1256 Kia 0409 - 1314	This day was intended to obtain QC data by parking the Kia at WF and Pilot at DC and obtaining van data coincident with the respective monitoring stations.	
12/02	Pilot 0349 - 1022 Kia 0355 - 1100	Run a north/south traverse on 51st Avenue between Southern and Buckeye with the Pilot and east/west with the Kia going across 51st in the region Broadway and Williams. The goal was to observe any decrease in PM_{10} from 51st Avenue as the distance increased.	Both vehicles were able to perform about 12 passes each hour (6 in each direction). Observed values were elevated but no significant gradients were observed.

Table 3-2. (cont.)

Date	Sample Times	Sampling Goal	Significant Observations
12/04	Pilot 0347 - 1005 Kia 0359 - 1015	Perform the same test as 12/02, but now with the TSI Aerodynamic Particle Sizer (APS) installed in the Kia. Using the APS required sampling to be performed at fixed locations away from 51st Avenue. The Pilot followed the SCAMPER #1 route to obtain parallel data.	Conditions were quite clear with little regional haze, allowing a more isolated and successful evaluation of the gradient. A light easterly wind during period did show decreasing levels when moving away from 51st Avenue.
12/05	Pilot 0347 - 1041 Kia 0434 - 1055	Traverse Lower Buckeye between 27th Avenue and 51st Avenue with the Pilot and perform north/south gradient traverses with the Kia on 29th.	Regional haze was heavy and numerous local facilities added many local sources. This made any north/south gradients from Lower Buckeye disappear into the local sources. A pickup truck was observed stirring great quantities of dust in a private yard and the dust drifted across the roadway. The truck was moving less than 10 mph. Additionally, an agricultural field east of 51st Avenue was being plowed, with the activity starting before daybreak. This created large quantities of dust that drifted for long distances. This may have impacted the 35th site monitor as well as the WF monitor. Pictures were taken of the plowing. When returning to WF, significant black smoke from the yard to the west WF was noted with the plume rising about 75 to 100 feet and then fanning out. This plume was from the burning of old utility poles.
12/06	Pilot 0347 - 1012 Kia 0359 - 0957	Follow the SCAMPER on the #3 route with the Pilot. Use the Kia to map out key locations with the TSI APS.	Burning started in the yard adjacent to WF site and was seen during several of the passes of the Pilot along Broadway. The Kia mapped the location along Broadway and conducted sampling for particle size distribution at this location, and two additional downwind locations. The plume was followed out a little over 1km and was sensibly tagged by the smoke smell. Particle sizing was performed at about 0.15 km, 0.95 km and 1.1 km from the source location. Additional measurements were made with the APS at fixed sites around the loop. Particle sizing was performed downwind of agricultural operations (seeding or similar operation) to look at the signature of a rather “pure” dust plume, without much automobile exhaust. The region around DC was explored and the Kia then returned to the WF site. Upon return a significant black plume was noted in the adjacent yard. Pictures were taken and the on-site digital camera turned in the direction of the yard.

Table 3-2. (cont.)

Date	Sample Times	Sampling Goal	Significant Observations
12/07	Pilot 0345 - 1008 Kia 0404 - 1042	Follow the SCAMPER on the #4 route with the Pilot. Use the Kia to map the area around the truck yard adjacent to the DC site for particle size distribution	The activity at the truck yard was less than last observed. There were about 4 or 5 active trucks at a time, with fewer trucks in the yard than the last observation. It is estimated that there were about 100 to 150 trailers and maybe 25 to 35 tractors for pulling them. It appeared they were getting ready for a truck school. Levels throughout the region were high. The Pilot observed another agricultural field being worked with significant dust plumes picked up on the camera. Particle sizing was performed around the truck yard with noticeable differences observed between the areas along 27th and 22nd Avenues. Around 0645 the Kia parked for a short time at the DC site for parallel measurements. At the conclusion of the run the Kia parked for a time by the 35th site for parallel measurements. The MAG video crew was out taking pictures of the activities and observing the operations. Audits of the two vans were performed following the activities at the WF site. Overall levels were quite high with an apparent "carry over" from the prior day. This carry over likely contributed to the observed levels.
12/08	Pilot 0343 - 0922 Kia 0400 - 0914	The Pilot was parked outside the entrance to aggregate operations along 19th Avenue to measure the upwind or downwind contribution. The Kia was used to try and map the river areas for a tag of the plumes that may be moving through.	Overall, the day was reasonably clean. No drainage flow along the river established, but the flow was from the east. The flow was more synoptic than local drainage. For the sampling time, the Pilot was upwind of the aggregate plant with near background levels observed for most, if not all, of the sampling period. Measurements from the Kia were conducted downwind of another facility off of 7th Ave. During the time the plume moved back and forth across the sampler and particle sizing was conducted. A QA audit was conducted on the 35th site with no issues found. Tests were performed on the dirt road leading to the site to determine if the sampling drew in dust from the road while traveling. This was also repeated on the paved road. No issues were found. Only the dragging of the plume was seen when the vehicle initially stopped. It should be noted that there were extensive dust control activities in and around the aggregate facility on 19th Avenue, including street sweeping that clearly demonstrated that they have the ability to control the dust problem.

Table 3-2. (cont.)

Date	Sample Times	Sampling Goal	Significant Observations
12/12	Pilot 0343 - 1027 Kia 0406 - 1028	Document the north/south and east/west extent of the PM plume in the Salt River region.	The Pilot went north/south and Kia east/west. The highest PM_{10} concentrations were around Lower Buckeye and 51st with the east/west extent going out just past 99th Avenue on the west and to 7th Avene on the east. The highest 2.5/10 ratios were in the northwest, confirming the prior runs in the area. The north/south PM_{10} extent went from about Baseline in the south to just north of McDowell in the north, but with some sporadic values seen both in the extreme north and south from potential other local sources. Following the runs a survey was performed along the east side of 51st Avenue looking north at the one facility. Here there were several "drag-outs" documented and some bow wake observations. As a matter of interest, the 35th site did not show high concentrations. Conversely, the WF site did show them during the 6 – 8 AM time frame. A review of the site pictures aimed to the west showed a fire started before sunrise (in the dark), with smoke observed as the area became light. It is suspected the high values at the site were from the adjacent source.
12/13	Pilot 0356 - 0908 Kia 0359 - 0910	Document the area along 51st Ave where dirt shoulders pose a problem. Document the "drag-out" of dust to the roadway and the bow wake of large trucks	Data were collected using both vehicles along 51st Avenue near West Miami Street. This area has a narrow paved shoulder (about 1 to 2 feet) with very dusty shoulders on the east side. The west side is clean with the FedEx facility having extensive paving and landscaping that prevents dust generation. This stretch of road has both drag-out and bow wake effects from the trucks when they are moving at sufficient speed and/or are near the unpaved area. Vortices are formed that look like little dust tornadoes when the trucks pass. Both sampling vehicles were near the exit streets that were all unpaved. Just before sunrise a water truck did water both streets, but the one watering was obviously not enough to control the dust. Other areas were explored for dust concentrations (transfer station, DC, aggregate facilities), but no unusually high values or visible plumes were noted, so sampling was only performed along 51st Avenue. It appears from the morning observations that only the trucks and larger passenger vehicles were capable of generating bow wake, and the passenger vehicles needed to be within a couple feet of the dirt shoulder to do so. Not all trucks created the bow wake and it really depended on the frontal surface area and speed. Any kind of vehicle can generate drag-out. Once material is on the road then any vehicle can stir it up and keep it airborne. In addition to the dust, a smoke plume from one of the yards east of 51st was producing significant smoke from about 4:30 to 5:00. Winds after this time carried the plume away from the road.

Table 3-2. (cont.)

Date	Sample Times	Sampling Goal	Significant Observations
12/14	Pilot 0344 - 0913 Kia 0359 - 0922	Document the extent of the higher PM concentrations to the east, north and west of the Salt River region.	Documented to the north and east with the boundaries similar to the prior mapping. Profiled to the west including some sizing of the particulate matter around the regions of feedlots. During the peak periods the area outside of the aggregate facility along 19th Avenue, the adjacent metal recycling plant and the nearby cement facility were monitored with high readings observed. On this morning it was clear that the monitoring outside of the facilities was not expected, as there were a number of dust producing activities. Pictures were taken along Southern, west of 51st Avenue at some of the exit points from active areas. Trackout was observed and the influence of vehicles driving through and creating plumes was documented with pictures. The lack of paved shoulders was clearly a contributor to the reentrainment of dust.

4. RECOMMENDATIONS

On the basis of the measurements made and the observations of the activities and related impacts during the program, we have the following recommendations for follow up on the program:

- A number of observations were made during the field study and presented at workshops regarding specific issues in open burning, unpaved roads and trackout. It is recommended that a verification be performed on the actions taken with mobile measurements to confirm potential reductions. This may be related to the 5% plan to estimate the amount of reductions from specific source types.