APPENDIX B
Volume 1

Emissions Inventory

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FINAL REPORT

Pinal County PM_{10} Nonattainment Area 2008 Base Year Emissions for Selected Design Days and Modeling Domains

prepared for:

Arizona Dept. of Environmental Quality

November 2013

prepared by:

Sierra Research, Inc.
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1. INTRODUCTION

1.1 Background

To guide the preparation of a PM_{10} State Implementation Plan (SIP) for Pinal County, the Arizona Department of Environmental Quality (ADEQ) commissioned an analysis of the 2008 base year monitoring data, the selection of design days, the identification of emission inventory calculation procedures for key source categories, and quality assurance/quality control (QA/QC) procedures for emission inventory development. The results of this effort were documented in an Inventory Preparation Plan (IPP).[1] It showed that two separate meteorological scenarios produced concentrations in excess of the 24-hour PM_{10} National Ambient Air Quality Standard (NAAQS) of 150µg/m^3: high wind and stagnation conditions. The emission sources responsible for the elevated concentrations are fundamentally different under these two scenarios.

During high wind conditions, disturbed soil surfaces typically dominate PM_{10} emissions, because of the tendency of wind trajectories to remain somewhat constant during these periods, sources within a narrow band along the upwind trajectory tend to contribute significantly to recorded PM_{10} concentrations. Conversely, during stagnation periods, when wind speeds are typically below 3 mph, wind entrainment of loose soil particles is virtually nonexistent and mechanical sources that lift particles into the air through combustion, vehicle movement, and other anthropogenic activities are primarily responsible for recorded concentrations. To the extent observed emissions are dominated by the coarse fraction of PM_{10}, only those sources within a mile in any direction of a monitor significantly contribute to high hourly concentrations during stagnation conditions. Because of these differences in source mix and the need to demonstrate attainment under the range of meteorological conditions found at Pinal County monitors, the ADEQ and Pinal County Air Quality Control District advisory committee providing technical guidance for SIP development recommended that each violating nonattainment monitor selected for emission inventory and attainment demonstration development include at least one stagnation and one high wind design day.

The analysis of PM_{10} exceedances on stagnation days[2] resulted in the selection of October 29, 2008, as being representative of meteorological conditions (i.e., wind speed and mixing height) leading to elevated concentrations. Three monitors exceeded the

[1] "Pinal County PM Inventory Preparation Plan," Report No. SR2013-01-01, prepared by Sierra Research for the Arizona Department of Environmental Quality, February 2013.

[2] The basis for distinguishing between low and high wind hours, and days, is the 12 mph aerodynamic entrainment threshold (i.e., five-minute average) established in MCAQD's 2008 PM10 Periodic Emissions Inventory.

24-hour PM_{10} NAAQS on that date: Cowtown,[3] Pinal County Housing, and Stanfield. Because no PM_{10} exceedances occurred on stagnation days at the Maricopa, Casa Grande, or Combs School monitoring sites, they were not included in the list of low wind speed attainment demonstrations to be addressed in the SIP. To guide the preparation of the modeling inventories, rectangular low wind domains were defined based on the maximum hourly distance traversed by wind parcels from the monitor to the source on the basis of wind speed and direction. Separate domains were defined for each monitor. The IPP also provided guidance on the activity data and methodology to be used in quantifying emissions for key source categories.

The analysis of PM_{10} exceedances on high wind days selected four monitors determined to be representative of conditions throughout the year, at the sites and dates listed below.

- Cowtown – April 27, 2008
- Pinal County Housing – January 1, 2008
- Stanfield – November 21, 2008
- Maricopa – October 27, 2008

The low wind domains were selected using the methodology described above; a more complex approach was used to define domains for high wind days. The domain for the high wind hours followed the methodology the Maricopa Association of Governments (MAG) used in the 2012 Five Percent Plan,[4] which plotted a back trajectory based on the average wind speed and direction recorded for each high wind hour. Each of these trajectories included land within a mile perpendicular to the trajectory on both sides; the result was therefore a 2-mile-wide parcel following the back trajectory for a distance equal to the average wind speed. To simplify the MAG methodology and limit repetitive calculations, all high wind hours were assembled into a single domain, which was easy to implement because there is little variation in wind direction during the high wind hours. The horizontal boundaries were defined by including land within a mile perpendicular to the bounding wind trajectories (i.e., all trajectories and land between them were included and the outside boundaries were extended by a mile). More discussion of the domain selection is presented in Section 2.

1.2 Approach

Since the completion of the IPP, substantial effort has been devoted to assembling the activity data and related insights needed to calculate emission inventories for each of the

[3] In 2008, 139 out of 147 low wind exceedances were recorded at the Cowtown monitor. While meteorological conditions—both wind speed and mixing height—on the Cowtown design day were found to be more severe (i.e., lower) than seasonal average exceedance values, peak nighttime concentrations were lower than average seasonal peaks. Since the concentration profile for the rest of the design day matched or exceeded the seasonal exceedance values, a decision was made in concert with EPA to continue to use the selected design day for Cowtown.

[4] "MAG 2012 Five Percent Plan for PM10 for Maricopa County Nonattainment Area," Maricopa Association of Governments, May 2012.

specified modeling domains and design days. A variety of data collection activities have been undertaken to better characterize local activity and conditions, including those listed below.

- Traffic Research and Analysis was hired to collect hourly counts of vehicles operating on 20 separate unpaved road links within the selected modeling domains.

- The Arizona Department of Transportation (ADOT) provided modeled estimates of VMT, speed, and vehicle mix operating on paved roads.

- ADOT also provided information on road shoulders (paved, graveled, etc.), which was supplemented with observations from Pinal County Air Quality Control District (PCAQCD).

- ADEQ and PCAQCD collected soil samples from a representative sample of unpaved roads (public and agricultural) and farm land.

- JBR analyzed the collected samples and measured silt and moisture levels.

- Cotton Research and Protection Council (CRPC) provided GIS shapefiles documenting crops under cultivation within selected modeling domains in 2008.

- The Arizona Beef Council provided information on the number of cattle located within specific stockyards on design days in 2008 and diurnal profiles of activity.

- Farmers provided information on hours of operation when harvesting and related traffic levels on agricultural roads.

- PCAQCD summarized disturbance levels observed by land use type within the nonattainment area.

- ADEQ prepared estimates of PM emission factor adjustments to account for saltation, reservoir depletion, etc., during high wind conditions.

- PCAQCD provided copies of permits for stationary sources operating within the selected modeling domains.

- PCAQCD provided information on construction permits issued in 2008.

- Rail activity levels were obtained from reviews of local planning (e.g., National Environmental Policy Act [NEPA]) documents.

- Meteorological data were obtained from the nonattainment monitors and from other stations located within the nonattainment area.

- ADEQ, with support from PCAQCD, provided GIS shapefiles that define land use for each parcel located within the PM_{10} nonattainment area.

- Numerous studies and emission inventory development methods employed in related PM_{10} SIPs (e.g., MAG's Five Percent Plan) were investigated.

Collectively, this information and other sources of data were combined to prepare hourly parcel-specific estimates of PM_{10} emitted for each land use category on the selected design days within the selected modeling domains. Stagnation and related low wind hour emissions are calculated from source-specific activity levels. High wind day and related high wind hour emissions are calculated from wind speed, surface area, and disturbance observations (and crop type for agricultural emissions). Discussions of the results and findings were presented in weekly and sometimes biweekly discussions with ADEQ and PCAQCD staff as well as monthly meetings with stakeholders. Preliminary summaries of the methods and data used to compute emissions were circulated to ADEQ, PCAQCD, and stakeholders for review and comment. This document addresses comments received.

1.3 Report Organization

Following this introduction, Section 2 discusses the need to address inconsistencies between the spatial extent of available activity data (particularly information on crops under cultivation) and modeling domains specified in the IPP. Section 3 documents the data and methods used to compute PM_{10} emissions for each of the selected source categories. Section 4 presents tabular summaries of hourly PM_{10} emissions by source category for the design days and monitors to be used in preparing attainment demonstrations. Section 5 summarizes the annual emissions inventory. A series of appendices provides more detailed information as aspects of the analysis.

###

2. MODELING DOMAIN REVISIONS

As noted in the introduction, separate modeling domains were defined for both high wind and stagnant day conditions. For high wind days, separate domains were defined for high wind hours (i.e., those exceeding 12 mph) and low wind hours (i.e., those with speeds of 12 mph or less). The largest domains were defined for the high wind hours, because they extended 12+ miles upwind from the monitor. The next largest domains were defined for the low wind hours on high wind days, because the wind speeds, while less than 12 mph, were generally higher than those found under stagnation conditions (3 mph or less). Domains for stagnation conditions were the smallest because they had the lowest wind speeds. In the course of assembling the collected activity data, it was found that one of the key land use information sources—the Cotton Research and Protection Council (CRPC)—was able to provide data on crops under cultivation in 2008 only within a 6 km radius of each of the selected monitors for lands not included in Indian Reservations. Thus, while the GIS shapefiles from ADEQ/PCAQCD provide land use information for the entire nonattainment area, no information on crops under cultivation is available for agricultural lands located outside of the 6 km radius supplied by CRPC. This is a significant issue because agriculture is the dominant land use within the nonattainment area and agricultural emissions (both low and high wind) are strongly affected by the crop under cultivation. Two options are available to address this limitation: (1) assume the distribution of crops outside of the 6 km CRPC area is proportional to the crop distribution within the CRPC area or (2) restrict the size of the domain to relevant boundaries within the 6 km CRPC area. The question is really which approach limits the uncertainty in the emissions calculations. Presented below is a brief review of issues considered, the approach adopted, and figures displaying differences in the IPP and revised domains.

Each of the domains selected presents information on land use from both CRPC and from ADEQ/PCAQCD shapefiles. CRPC provided information on the crops being cultivated in 2008 and each parcel is color coded to identify the crop listed in the legend on the right of the figures. ADEQ/PCAQCD provided information on the land uses[5] listed in Table 2-1 below.

[5] A detailed description of the procedures used to identify the land uses and a description of each land use category is presented in "Twelve Pinal County Land Use Descriptions, 9/17/2013" from ADEQ.

Table 2-1 ADEQ/PCAQCD Land Use Categories
Developed Urban Lands
Developed Rural Lands (low density residential)
Paved Roads
Unpaved Roads
Cleared Areas
Residential Construction
CAFOs and Dairies
Desert Shrubland
Agricultural Croplands
Commercial Construction
Other
Site Development

2.1 High Wind Domains

High Wind Hours – The results of the source-weighting analysis[6] presented in Appendix B of the 2012 MAG Five Percent Plan were used to examine the impact of excluding sources beyond the 6 km CRPC upwind boundary. It found that "Without question, receptors close to an upwind source will be much more dramatically impacted by emissions from that source—emission rates being equal—than by similar sources at increasing distances upwind of receptors." Based on the results of AERMOD modeling for sources located at different upwind distances, a weighting factor of 1/distance was recommended to adjust windblown dust emission impacts with increasing downwind distance in any modified rollback analysis in the Salt River area. Using this relationship, it was determined that 80% of the impacts, assuming equivalent source strength, would come from sources located within 4 miles of a 12 mile upwind trajectory (i.e., 12 mph high wind threshold). Based on this information, it was determined that little insight would be gained from characterizing sources beyond the 6 km (3.7 miles) boundary and that uncertainty of assuming crop distributions in upwind areas was unwarranted. A multistep process was then followed to select the appropriate domains for high wind hours on high wind days for each of the selected monitors. The process is described below, followed by a series of figures displaying (a) the original IPP domain, (b) the impact of the 6 km CRPC boundary, and (c) the boundaries of the final domain selected for modeling. They are displayed sequentially for each monitor, starting with Cowtown.

- *Figure 2-1a* displays the domain that encompasses the 7 high wind hours recorded at the Cowtown monitor on April 27, 2008. It shows each of the hourly back trajectories as well as the 1-mile area perpendicular to the bounding (outermost) trajectories.

[6] "MAG 2012 Five Percent Plan for PM10 for Maricopa County Nonattainment Area," Maricopa Association of Governments, May 2012.

- *Figure 2-1b* displays the effect of limiting the upwind domain to the 6 km radius of the CRPC boundary. Two legends are displayed: one shows crop type and has different colors[7] for each; the other delineates land use and crops under cultivation on non-Indian lands[8] within the 6-km CRPC boundary and land use outside of the 6-km domain. The orange area outside of the 6-km boundary predominantly to the northwest delineates Gila River Indian Community (GRIC) lands. Also displayed is a triangular domain extending along the high wind trajectory hours from the monitor. This domain is bounded by the 6-km arc and the area of dispersion impacting the monitor from each of the bounding high wind hours. AERMOD identifies sources that impact a monitor as being limited to 15° on either side of the upwind trajectory. Thus, for a one-hour period, a "V" shaped domain is defined by the area of dispersion impacting the monitor. Since multiple hours are included in the domain, the 15° area of influence is added to the outside of each bounding wind trajectory. The hypotenuse of the triangle is a straight line just inside of the 6-km CRPC boundary. To simplify calculations, emissions are computed for the domain inside of the triangle, not the slightly larger domain with the 6 km arc.

- *Figure 2-1c* provides higher resolution view of the sources located within the selected modeling domain. It shows that vacant land and alfalfa are nearest to the monitor and desert shrubland is located farthest upwind from the monitor.

Similar plots are presented in Figures 2-2 and 2-3 for Maricopa and for Pinal County Housing. Unlike Cowtown or Pinal County Housing, the Maricopa domain is shown to be predominantly composed of urban developed land, with much less land devoted to agriculture.

[7] Unfortunately, the color scheme employed by ARCGIS cannot be held constant; it changes as the number of land use categories shift. Thus, the colors in Figure 1b will not be consistent with Figure 1c or succeeding domain displays.

[8] ADEQ and PCAQCD provided land use information for Indian lands within the 6-km CRPC domain, as determined through aerial photography.

Figure 2-1a
High Wind Hours Modeling Domain Proposed in IPP for Cowtown

Figure 2-1b
Land Use for High Wind Hours Modeling Domain at Cowtown

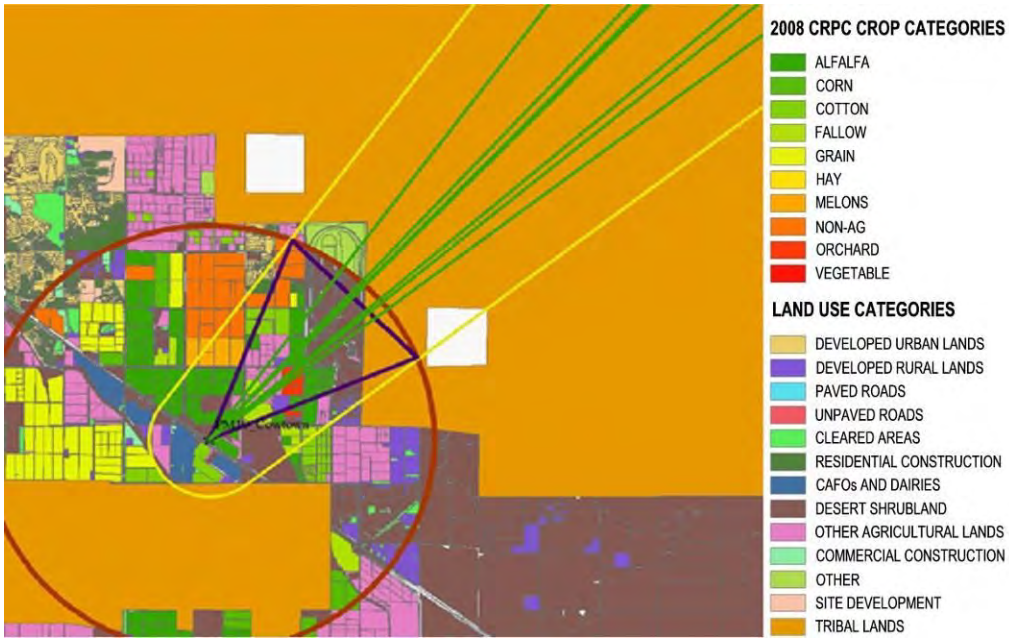


Figure 2-1c
High Wind Hours Modeling Domain Selected for Cowtown

Figure 2-2a
High Wind Hours Modeling Domain Proposed in IPP for Maricopa

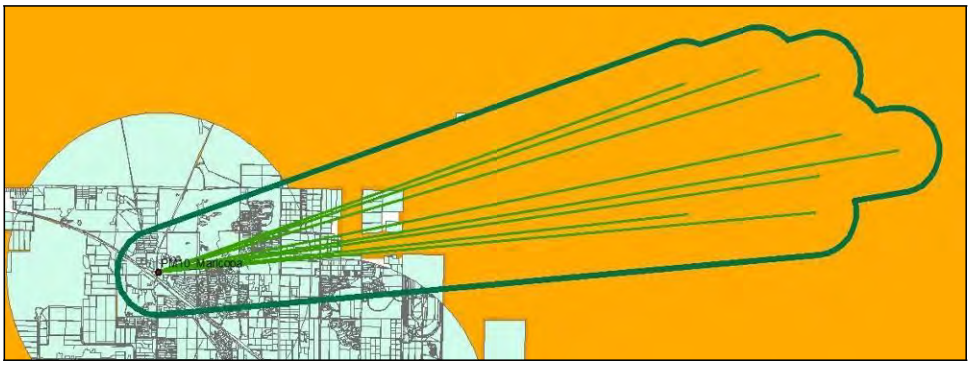


Figure 2-2b
Land Use for High Winds Hour Modeling Domain at Maricopa

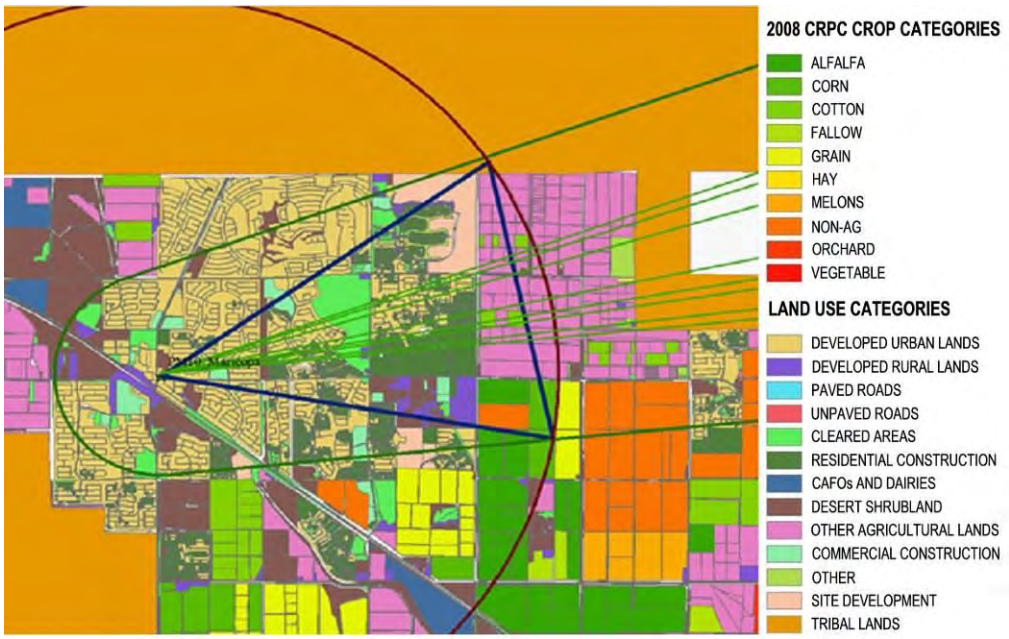


Figure 2-2c
High Wind Hours Modeling Domain Selected for Maricopa

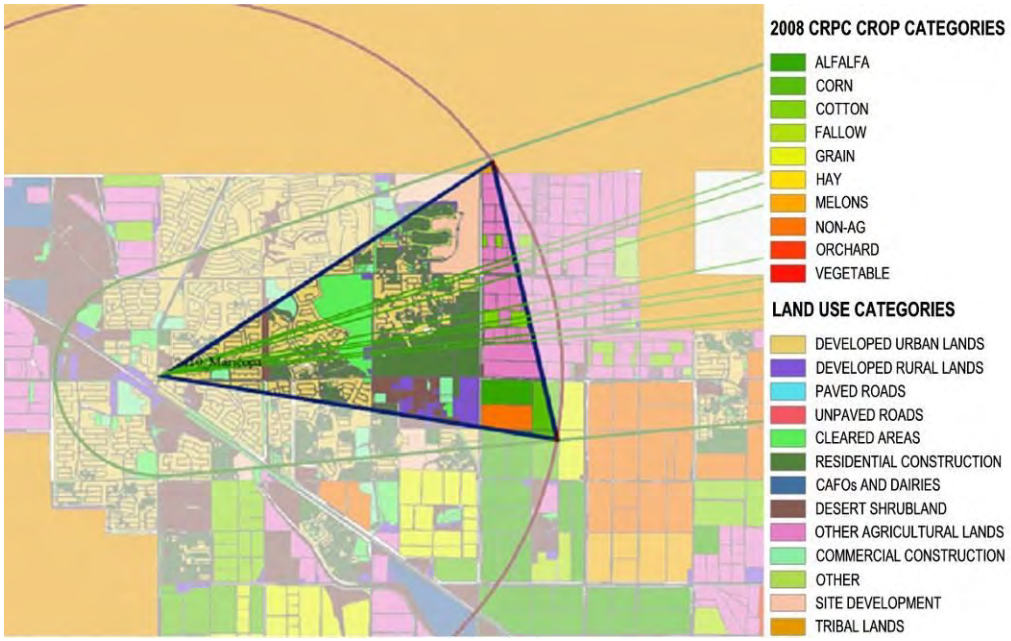


Figure 2-3a
High Wind Hours Modeling Domain Proposed in IPP for Pinal County Housing

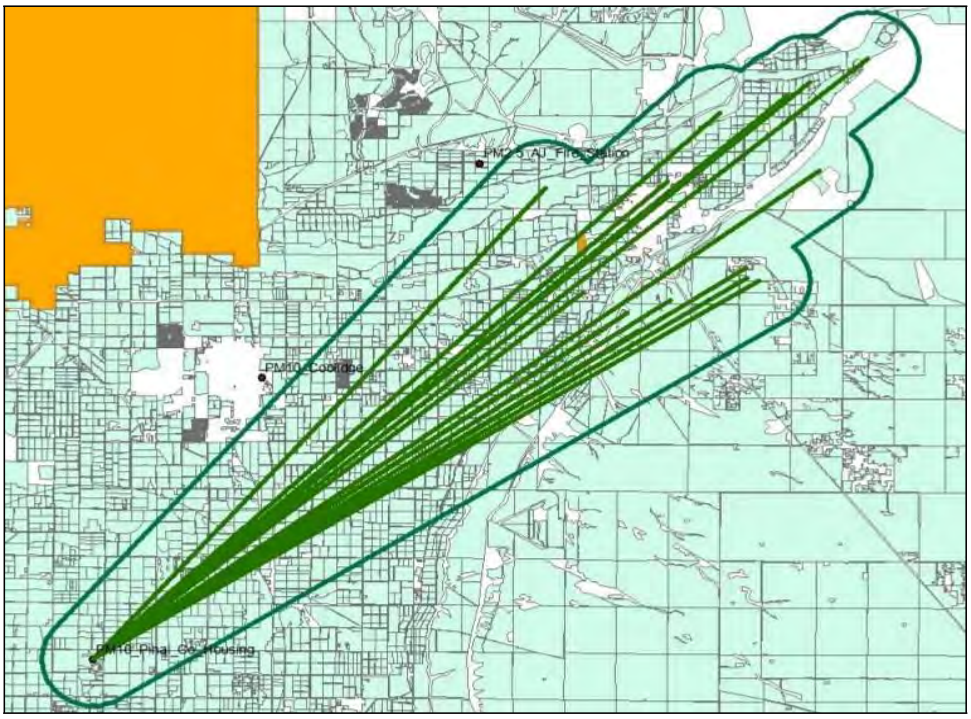


Figure 2-3b
Land Use for High Wind Hours Modeling Domain at Pinal County Housing

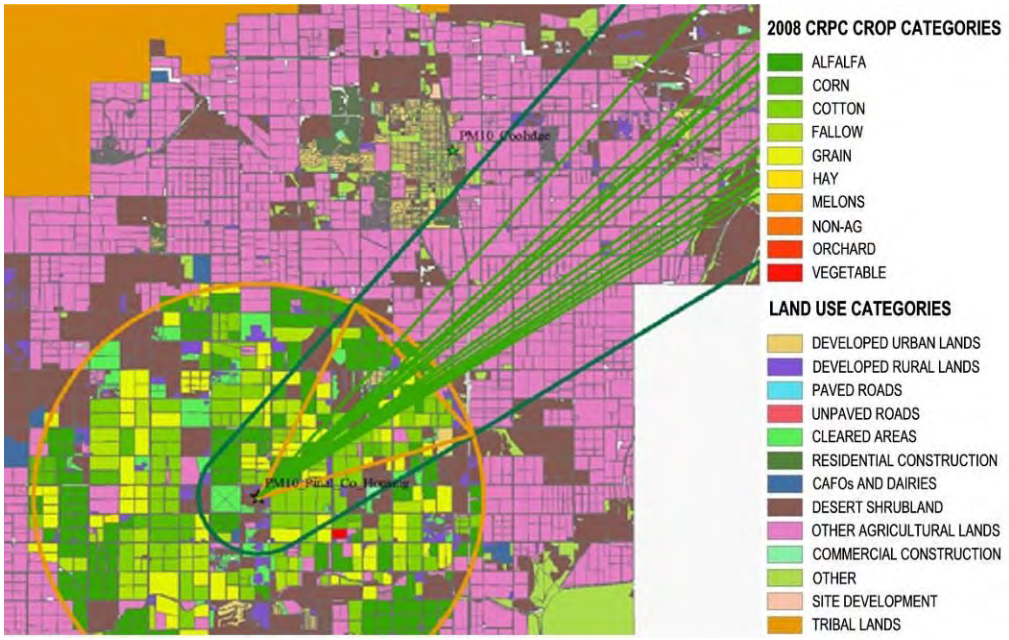
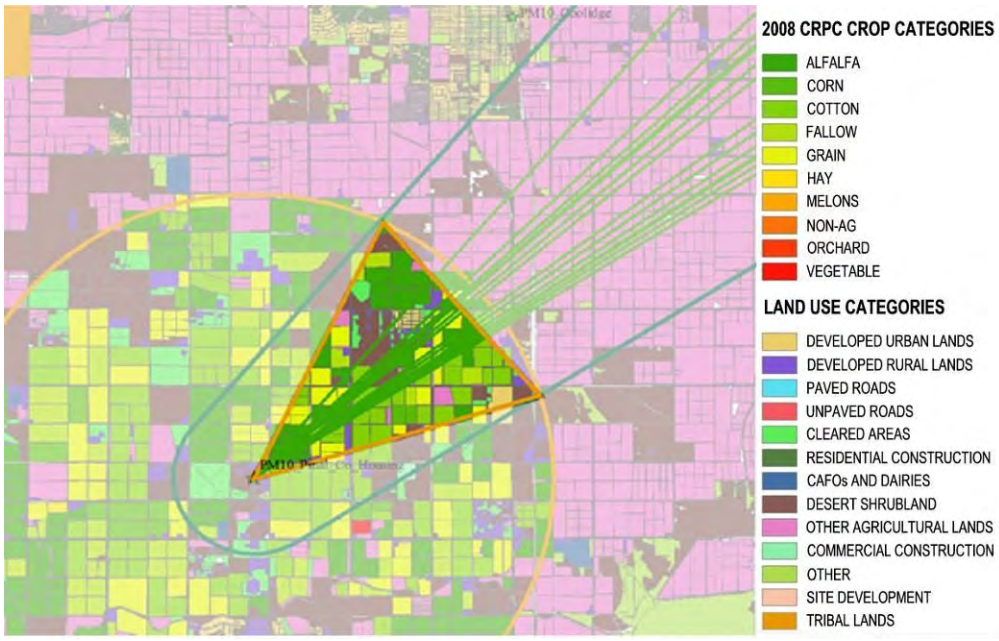


Figure 2-3c
High Wind Hours Modeling Domain Selected for Pinal County Housing



The remaining high wind domain is displayed in Figure 2-4 for Stanfield. The original IPP domain, shown in Figure 2-4a, was based on 15-minute meteorological measurements available for that site, whereas only hourly data were available for the remaining monitors. It shows that the calculated back trajectories do not follow a straight line but shift in response to the incremental values. To both standardize and simplify the inventory calculations, average hourly trajectories were computed from the 15-minute data and are plotted in Figure 2-4b. A review of the differences in land use from the two domains found that agriculture dropped from 83% in the 15-minute based domain to 73% in the average hourly domain and that desert shrubland increased from 11% to 18% with little change in the other categories. However, those values are for differences between the entire 1-hour domains—the change within the 6-km upwind domain was much less modest. Therefore, the straight-line hourly domain was employed. Figures 2-4c and 2-4d illustrate the effect of limiting the size of the upwind domain to the 6-km CRPC data and the arcs of dispersion influence. As shown, the selected domain is largely composed of active farmland.

Figure 2-4a
High Wind Hours Modeling Domain Proposed in IPP for Stanfield (15-minute data)

Figure 2-4b
High Wind Hours Modeling Domain for Stanfield (hourly data)

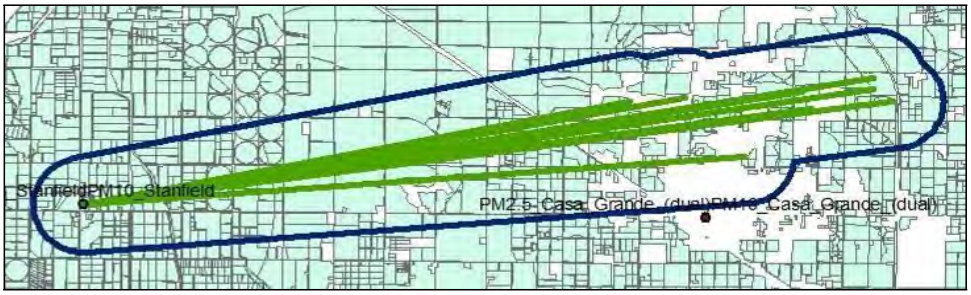


Figure 2-4c
Land Use for High Wind Hours Modeling Domain at Stanfield

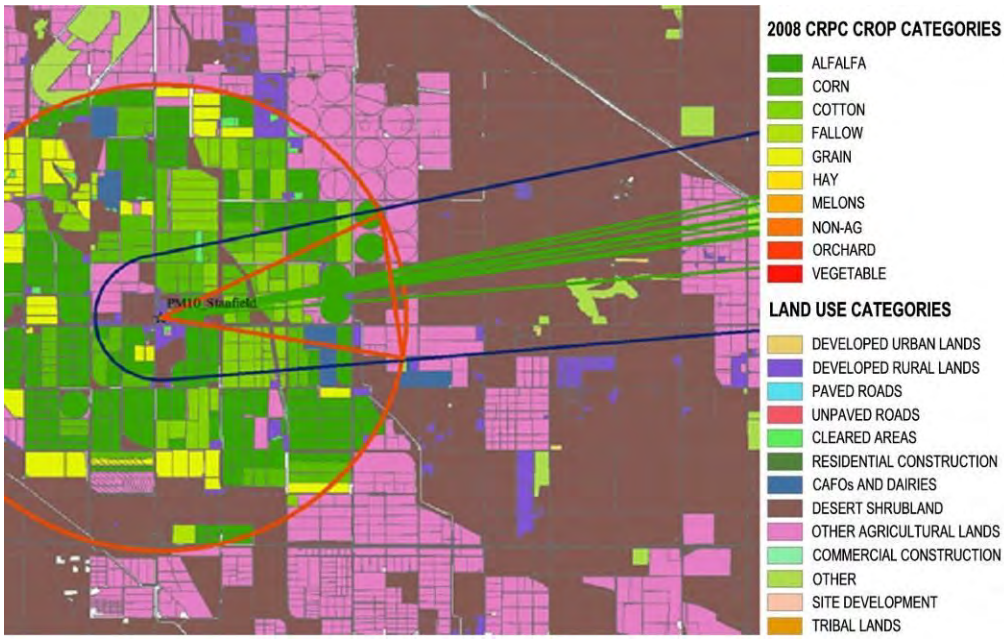
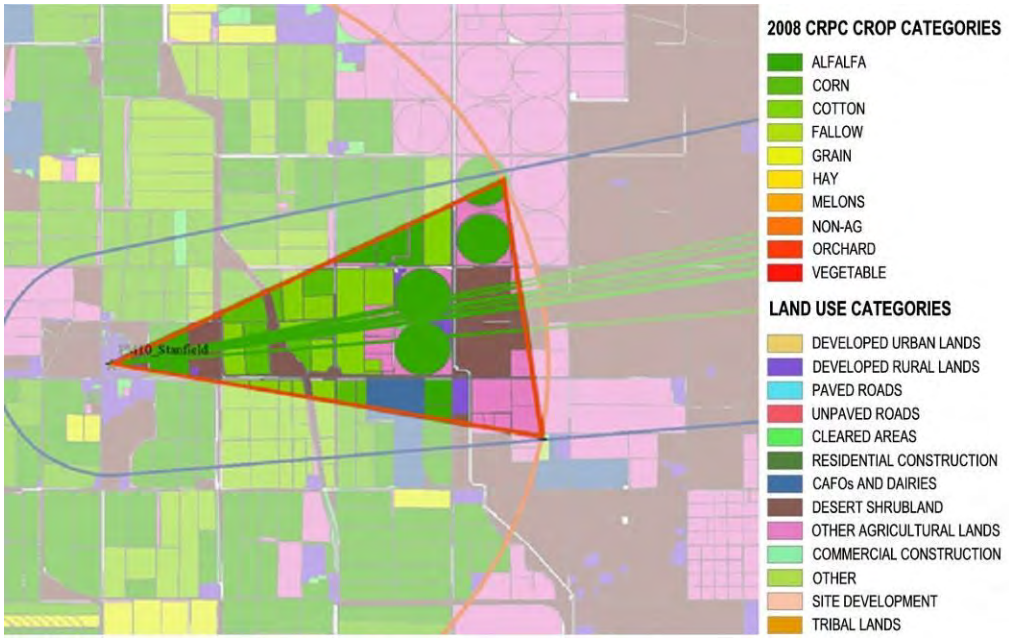


Figure 2-4d
High Wind Hours Modeling Domain Selected for Stanfield



Low Wind Hours – Following the pattern used to display the development of the high wind domains. Figures 2-5a, 2-5b, and 2-5c are displayed for the low wind hour domains associated with each high wind monitor: (a) the original IPP domain, (b) the impact of the 6-km CRPC boundary, and (c) the boundaries of the final domain selected for modeling. They are displayed sequentially for each monitor, starting with Cowtown.

Figure 2-5a
Low Wind Hours Modeling Domain Proposed in IPP for Cowtown

Figure 2-5b
Land Use for Low Wind Hours Modeling Domain at Cowtown

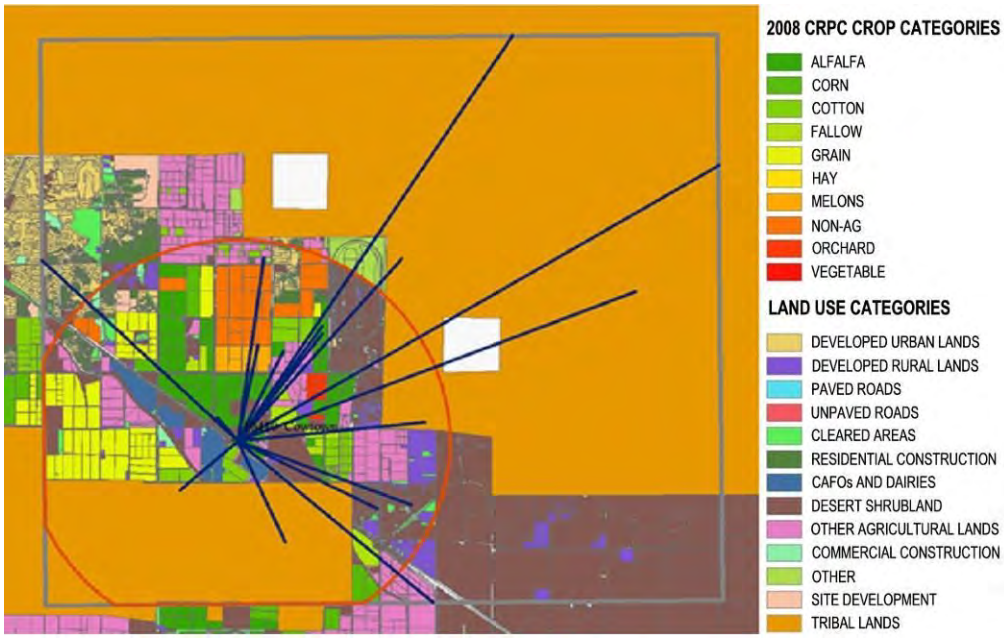
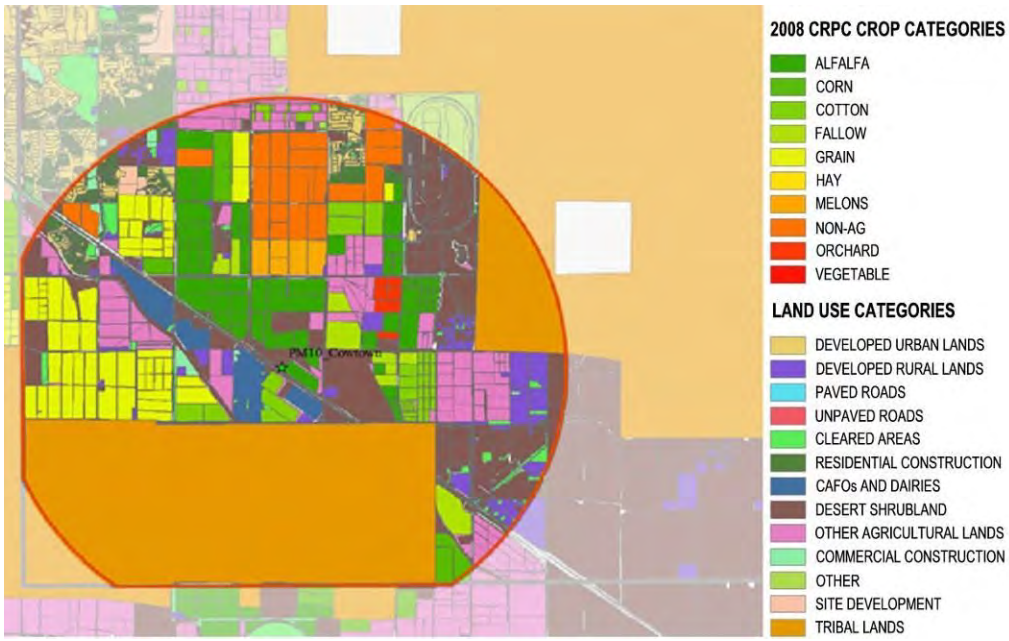


Figure 2-5c
Low Wind Hours Modeling Domain Selected for Cowtown



- *Figure 2-5a* displays the domain that encompasses the 17 low wind hours recorded at the Cowtown monitor on April 27, 2008. Unlike the high wind domains where wind direction and emissions are consistently from a single quadrant, wind and emissions impacting the monitor come from all directions. The rectangle for the domain is defined by the maximum hourly wind directions and speeds. It shows the domain is considerably larger than the 6 km radius of crop data provided by CRPC. It also shows that portions of GRIC lands are encompassed both within the overall low wind domain and within the CRPC domain. While the land use of GRIC parcels within the CRPC boundary is defined, the crops under cultivation are unknown. Thus, assumptions are required for activities within the GRIC lands included within the selected modeling domain(s).

- *Figure 2-5b* has two legends: one shows crop type and has different colors for each; the other delineates land use for non-agricultural lands within the 6-km CRPC boundary and agricultural and non-agricultural land use outside of the 6-km domain. The orange area outside of the 6-km boundary predominantly to the northeast delineates GRIC lands. The Ak-Chin lands lie to the south/southwest of the monitor and are identified as having active and fallow crop land (almond and light blue colors). Similar to the GRIC, no information about crop type is available from the CRPC data for the Ak-Chin lands.

- *Figure 2-5c* shows that, given the lower wind speeds, the five hours with trajectories extending beyond the 6-km CRPC domain have little influence on the

Cowtown monitor, based on the MAG weighting calculation. For this reason, a decision was made to truncate the low wind boundary to the intersection of the CRPC data and the overall domain (hence the flat boundary at the bottom of the CRPC domain).

Similar plots are presented in Figures 2-6, 2-7, and 2-8 for Maricopa, Pinal County Housing, and Stanfield.

Figure 2-6a
Low Wind Hours Modeling Domain Proposed in IPP for Maricopa

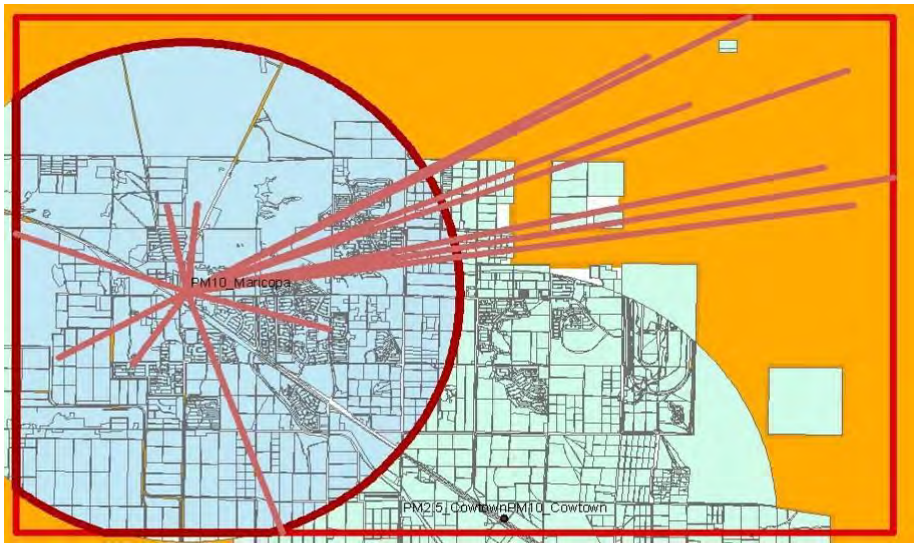


Figure 2-6b
Land Use for Low Wind Hours Modeling Domain at Maricopa

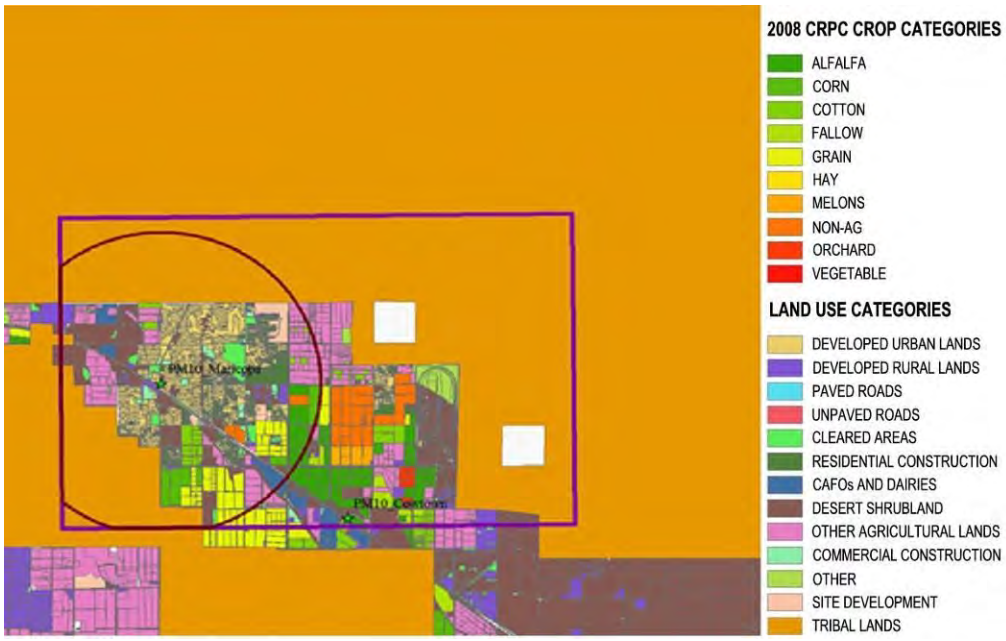


Figure 2-6c
Low Wind Hours Modeling Domain Selected for Maricopa

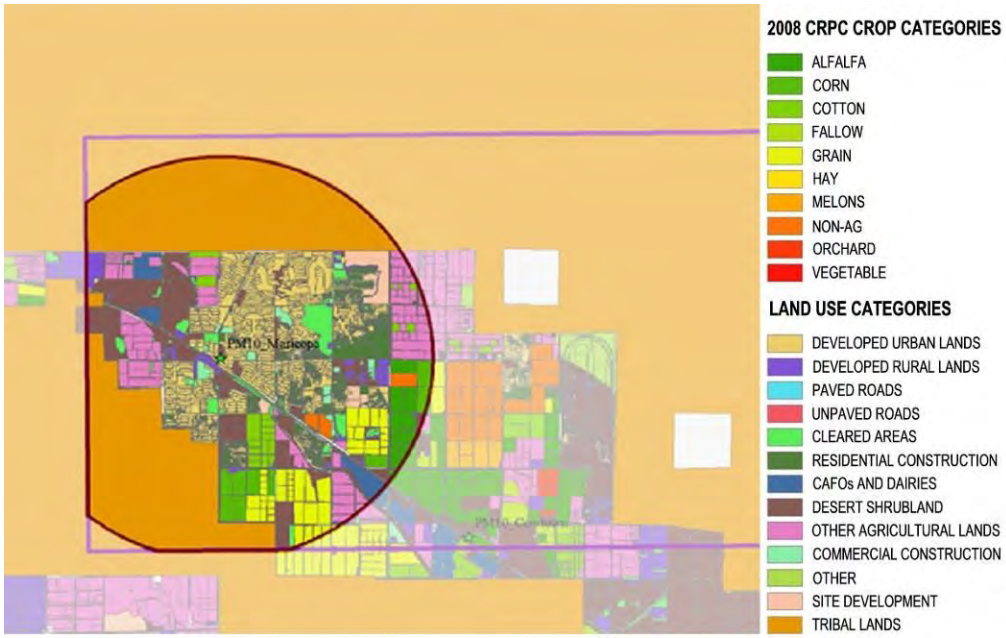


Figure 2-7a
Low Wind Hours Modeling Domain Proposed in IPP for Pinal County Housing

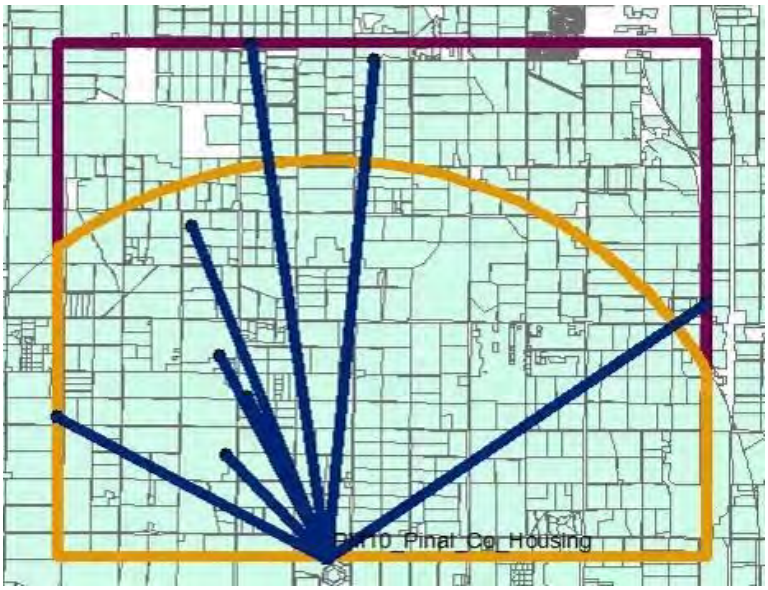


Figure 2-7b
Land Use for Low Wind Hours Modeling Domain at Pinal County Housing

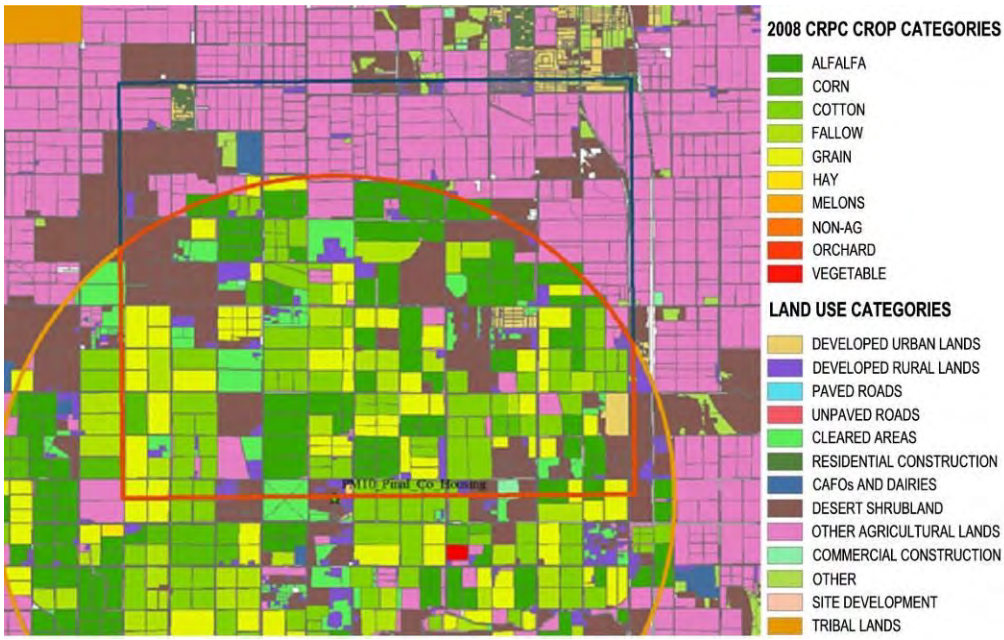


Figure 2-7c
Low Wind Hours Modeling Domain Selected for Pinal County Housing

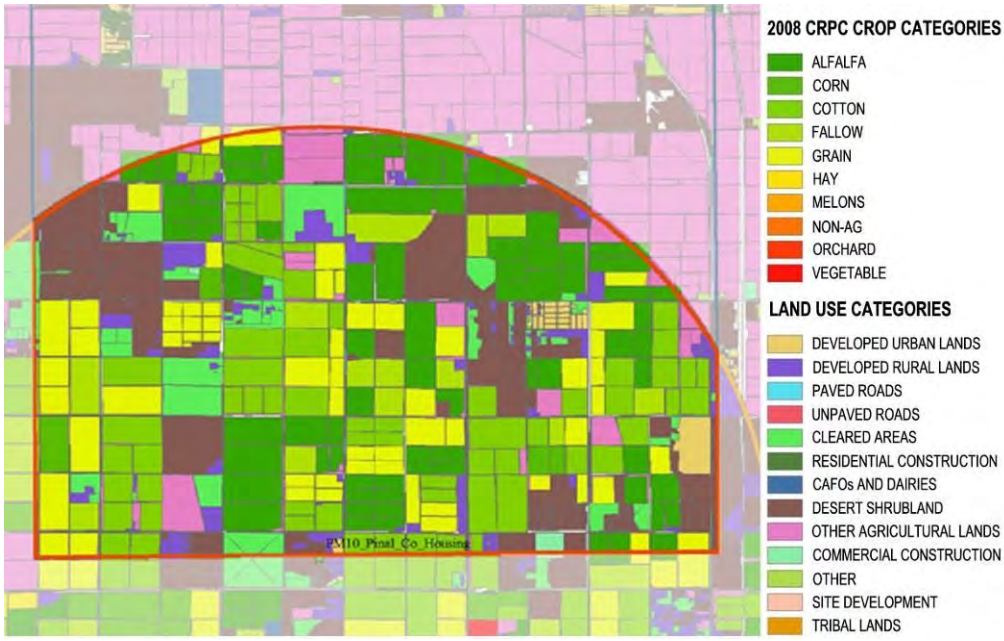


Figure 2-8a
Low Wind Hours Modeling Domain Proposed in IPP for Stanfield

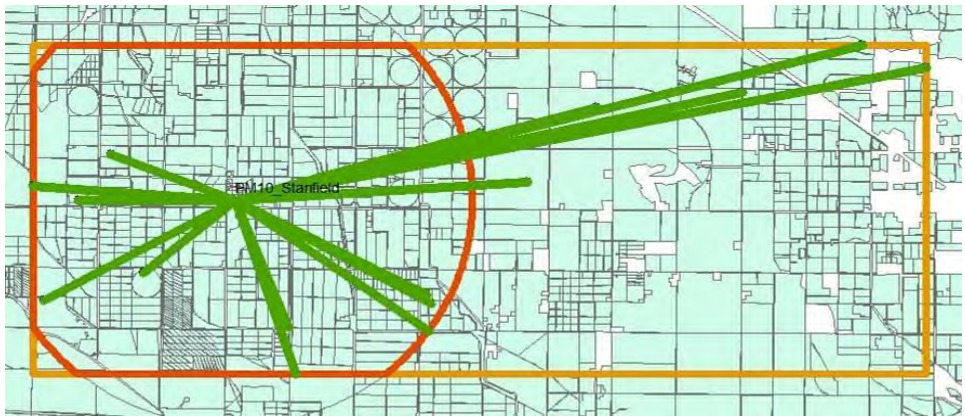


Figure 2-8b
Land Use for Low Wind Hours Modeling Domain at Stanfield

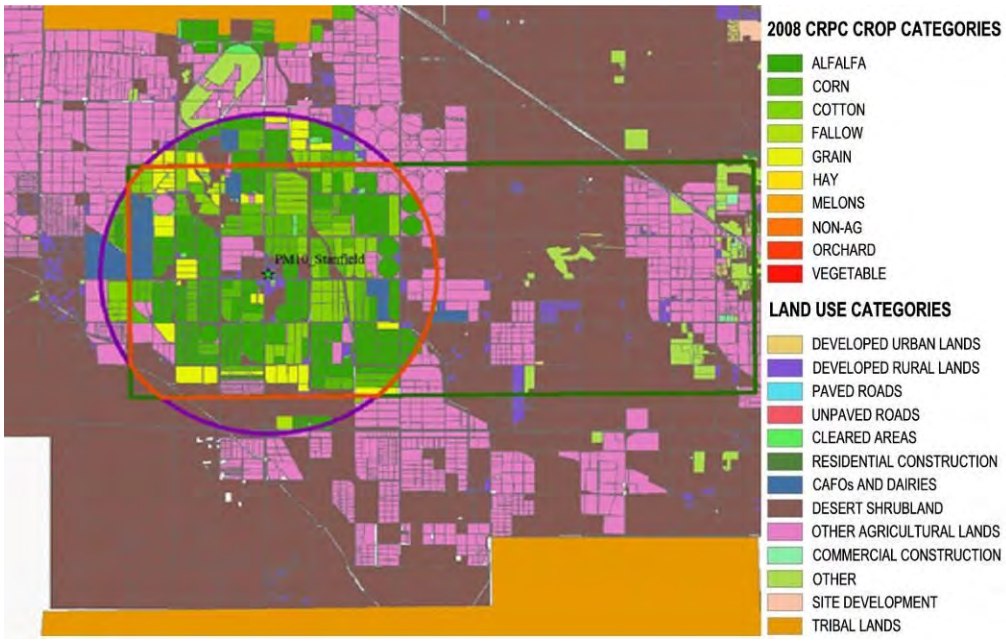
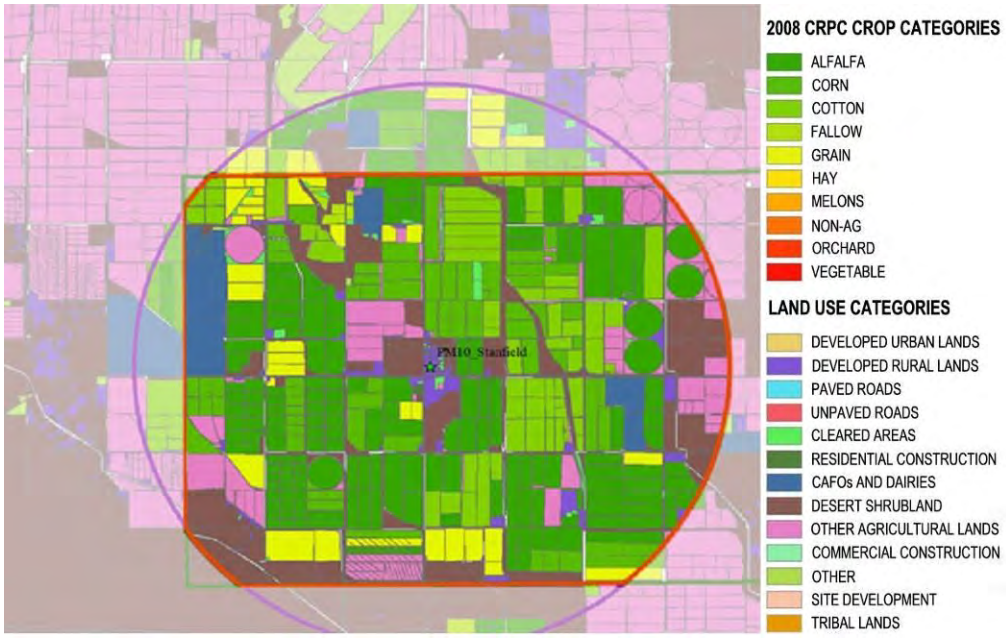


Figure 2-8c
Low Wind Hours Modeling Domain Selected for Stanfield



2.2 Low Wind Domains

As noted earlier, three monitors exceeded the 150 $\mu g/m^3$ standard under stagnation conditions: Cowtown, Pinal County Housing, and Stanfield. Since the wind speeds on the October 29, 2008 design day were extremely low (some fell below the measurement threshold of the monitor), the domains generally fell within the 6 km boundary of the data provided by the CRPC. Figures 2-9, 2-10, and 2-11 display the relationship between the IPP boundaries and the CRPC boundaries.

Figure 2-9 shows that the Cowtown domain is slightly larger than the CRPC domain and that assumptions will be needed for addressing crops under cultivation on both GRIC and Ak-Chin lands. Figure 2-10 shows that the low wind domain for Pinal County Housing falls entirely within the CRPC domain, so no additional assumptions about crop activity will be required. Figure 2-11 shows that small portions of the Stanfield modeling domain fall outside of the CRPC boundary so that assumptions about crop activity on agricultural lands outside the boundary are needed (no Indian lands fall within this domain). These assumptions, which are described in Section 3.1.11, parallel the approach adopted to characterize crops cultivated on Indian Lands.

Figure 2-9
Stagnation Modeling Domain Selected for Cowtown

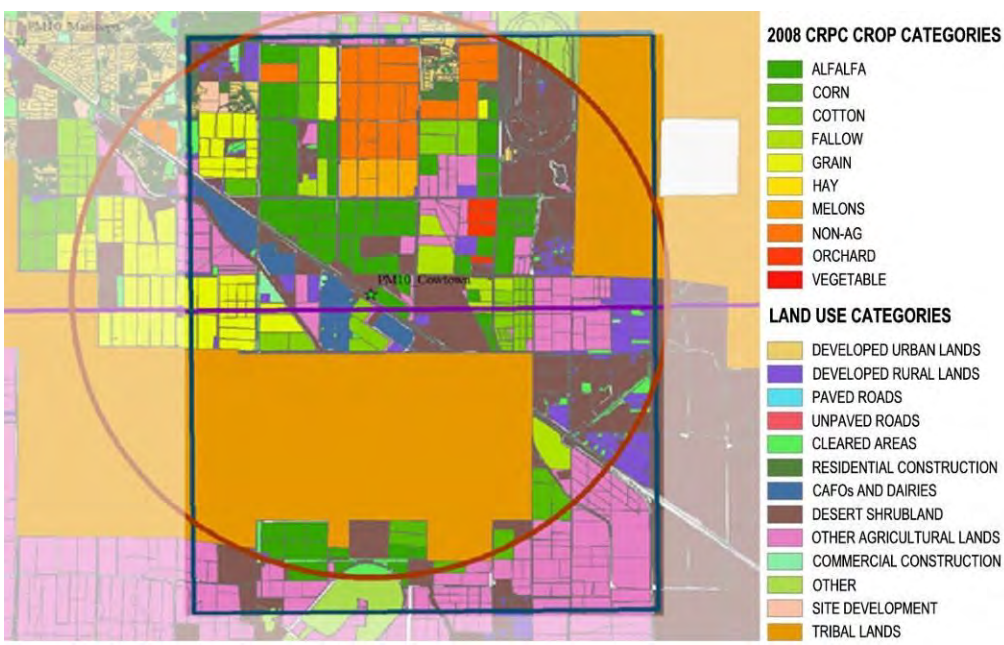


Figure 2-10
Stagnation Modeling Domain Selected for Pinal County Housing

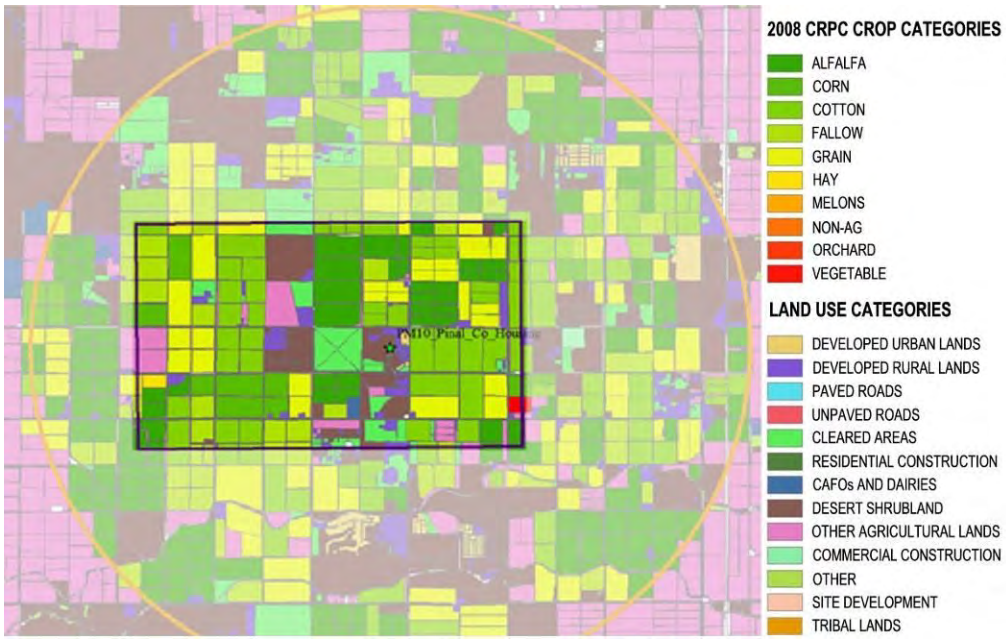
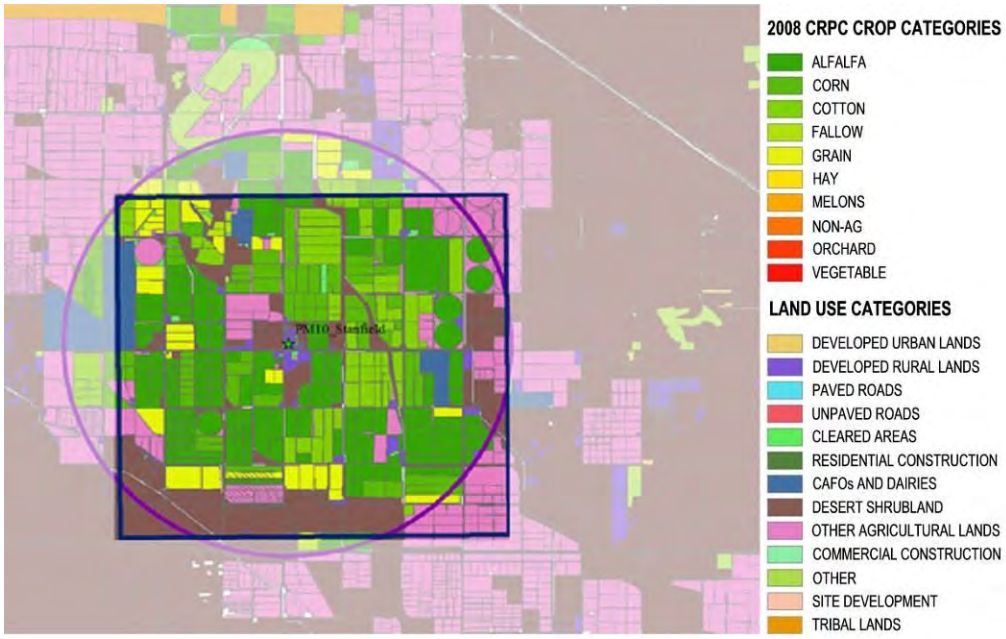


Figure 2-11
Stagnation Modeling Domain Selected for Stanfield



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3. EMISSION METHODS

As noted in the Introduction, considerable effort has been devoted to collecting, assembling, and assessing the activity data and related insights needed to calculate emission inventories. Presented are separate discussions of methods for calculating low wind emissions and high wind emissions.

3.1 Low Wind

A review of the data and methods employed to quantify emissions for each of the key low wind source categories is provided below.

3.1.1 Agriculture Methodology

Several methods are available to estimate fugitive dust emissions from agricultural operations; these include the Technical Support Document (TSD)[9] developed for Agricultural Best Management Practices (BMP) in Arizona, the Western Regional Air Partnership (WRAP) Fugitive Dust Handbook,[10,11] and the California Air Resources Board (CARB) paper titled "Computing Agricultural PM_{10} Fugitive Dust Emissions Using Process Specific Emission Rates and GIS."[12] Maricopa County in both the 2008 Periodic Emissions Inventory[13] and the MAG 2007 Five Percent Plan modeling[14] used the tillage methodology from the TSD, and estimated harvest emissions using crop-specific emission factors from CARB. Since these methods are designed to produce annual emission estimates associated with these activities, the challenges when modeling a specific design day include not only how to allocate the annual estimates to a daily value, but also how to spatially apportion the emissions to specific parcels. Several methods have been developed to address the allocation challenge, because without information on how operations occurring in the fields are impacting violating monitors on the design day, it is not possible to have certainty about the fugitive dust produced by agricultural operations on a day-to-day basis.

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[9] *http://www.azdeq.gov/environ/air/plan/download/tsd.pdf*.
[10] *http://www.wrapair.org/forums/dejf/fdh/content/Ch2-Agricultural_Tilling_Rev06.pdf*
[11] *http://www.wrapair.org/forums/dejf/fdh/content/Ch10-Harvesting_Rev06.pdf*
[12] *http://www.epa.gov/ttnchie1/conference/ei12/fugdust/yu.pdf*
[13] *http://www.maricopa.gov/aq/divisions/planning_analysis/docs/2008_PM10/08_PM10_PEI_Entire.pdf*
[14] "Air Quality Modeling for the Salt River Area in Support of the Five Percent Plan for PM-10," Sierra Research, November 2007

Presented below is a summary of the methods used to quantify annual emissions and to assess their potential impacts on selected design days. It is important to note that the number of operations required to cultivate and harvest a crop varies and therefore emissions vary considerably by crop type. Given the predominance of agricultural land use within the nonattainment area and most of the selected modeling domains, considerable effort was devoted to researching information about the crops being cultivated on individual land parcels. More information about the approaches adopted to research and apply information provided by the CRPC on crops under cultivation in 2008 is presented in Section 2.

Tilling – Tillage emissions were estimated using the emission factor equation employed in the TSD, combined with tillage activity estimates. The tillage emission factor equation is shown below.

$$EF_{tillage} = k\,(4.8)\,s^{0.6}$$

where:

$EF_{tillage}$ = Agricultural emission tillage factor (lbs PM_{10}/acre-pass)
k = Particle size multiplier (this value is 0.15 for PM_{10})[9]
s = Percent silt content of soil (12.1% for Pinal County)[15]

Given that the silt content of the soil in Pinal County is 12.1%, as listed above, the tillage emission factor for Pinal County is calculated as follows:

$$EF = 0.15 \times 4.8 \times (12.1)^{0.6} = 3.21 \text{ lbs } PM_{10}\text{/acre-pass}$$

This emission factor is used to calculate the annual crop-specific PM_{10} emissions associated with agricultural tillage using the following equation[9]:

$$\text{Tillage}_{crop} = EF \times AP_{crop} \times A_{crop}$$

where:

$Tillage_{crop}$ = Annual PM_{10} emissions from tilling each crop type (lbs)
EF = Tillage emission factor (lbs PM_{10}/acre-pass)
AP_{crop} = Number of tillage passes per crop (passes)
A_{crop}= Number of tilled acres for each crop type parcel (acres)

One option to estimate daily crop-specific tilling emissions is to divide the annual emissions by the estimated days per year of tillage operation for each crop (shown below in Table 3-1), which are based on the assumption that tillage activities occur seven days

[15] Calculated from "Summary of Silt and Moisture Analyses of Soil Samples from Pinal County, Arizona, Collected on May 8th, 2013," JBR Environmental Consultants, June 26, 2013

Table 3-1 Tillage Operation Assumptions		
Crop	Number of Tillage Passes Per Year	Tillage Operations (days/yr)
Alfalfa	5.1	91
Corn	7.3	152
Cotton	8.8	364
Grain	3.1	243
Vegetable	14	182
Hay	5.1	91
Melon	14	182
Orchard	5	91

per week during the months of tillage operations. This approach spreads the annual emissions uniformly over the period of time when they can occur. The reality, however, is much different—tillage occurs during a limited number of days and the number of acres impacted is a function of the equipment available to individual farms (either directly owned or leased or through contracted operations) and the power requirements of the operation. The TSD addressed this issue by dividing the year into tilling periods (e.g., March-May) and assuming that tilling was normally distributed throughout the period. This resulted in an estimate of a 1% chance of activity on a particular day, roughly paralleling the approach of distributing annual emissions over the period in which they can occur.

Since tillage operations are unlikely to occur more than once per day on the same acre of land, an alternate approach would be to estimate the number of acres that could be actively tilled in a day on an average farm. Assuming an average tilling rate of 36 acres/day (3 acres per hour over a 12-hour day) and 2 tractors/farm,[16] roughly 72 acres can be actively tilled in a day. According to the 2007 Census of Agriculture,[17] the average farm size in Pinal County is 1,334 acres; thus, it would take 19 days to complete one operation over the entire farm. Since multiple operations are required, roughly 100 days per year would be required to complete the tillage operations specified in Table 3-1 for most crops. A review of the time allotted to tilling operations in the Pinal County Crop Calendar[18] indicates that the time allotted to tillage operations is considerably smaller than the values cited in Table 3-1, and discussions with Pinal County farmers has indicated that values in Table 3-1 are overstated. Presented below is a comparison of

[16] These assumptions, which are recognized as rough, given variations in farm size, tillage practices, soil organic content, etc., were confirmed in a discussion with the Pinal County Extension Agent Rick Gibson, 7/16/13.

[17] *http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/County_Profiles/Arizona/cp04021.pdf*

[18] Email from Kate Edwards, Pinal County Air Quality Control District, 2008 Crop Calendar Corrected, 4/04/13. The Crop Calendar was derived from information presented in the Arizona Agricultural Statistics Bulletin.

alfalfa emission estimates associated with distributing emissions over the available tillage days (Method 1) and a bottom-up estimate of the number of acres per farm that can be tilled on a typical day (Method 2) for an average farm in Pinal County.

Method 1: (3.21 lbs/acre pass x 5.1 acre passes x 1,334 acres)/91 days = 240 lbs/day

Method 2: 3.21 lbs/acre pass x 72 acres/day = 224 lbs/day

Given the uncertainty in the assumptions, the difference in the emission estimates is minimal for alfalfa; the more significant difference is that the Method 1 value would be spread out over 1,334 acres and the Method 2 value would be spread out over 72 acres or 5.4% of an average farm (72/1,334) per day. The differences between the methods will vary among crops, depending on the number of operations and number of days available for tillage. The most extreme example is cotton, where Method 1 would produce an emission estimate that is less than half the Method 2 value (104 lbs/day versus 224 lbs/day). Given the potential difference in emissions between the methods and the dominance of cotton cultivation, Method 2 estimates have been chosen for use in estimating design day emissions.

Several alternatives were considered in determining where field activities occur within the modeling domain.

Since field operations do not occur on all fields within the modeling domain at the same time, a decision was required regarding where to allocate the activity. After considering alternatives (e.g., allocating activity to parcels closest to the monitor, allocating activity farthest from the monitor, etc.), a decision was made to spread activity across each parcel in the domain. Thus, emissions were calculated for 5.4% of each crop parcel with tilling activity.

Initial discussions with farmers indicated that tilling and harvesting activity was limited to daylight hours. More recent discussions with farmers, however, found that 50% of cotton farmers were performing tilling at night in 2008 and this practice continues to today. This information was used to prepare crop-specific diurnal activity profiles. Two values are presented for cotton—the first is for tilling and second is for harvesting. These values, presented in Table 3-2, can be used to distribute daily emission estimates by crop to hourly values. As can be seen, with the exception of cotton, all crop-specific activity is evenly distributed over the 12 daytime hours (i.e., 6:00 am to 6:00 pm) on the design days.

Table 3-2 Percent of Daily Activity Conducted During Each Clock Hour								
Hour	Alfalfa	Corn	Cotton	Grain	Vegetable	Hay	Melon	Orchard
1	0	0	2.8/0	0	0	0	0	0
2	0	0	2.8/0	0	0	0	0	0
3	0	0	2.8/0	0	0	0	0	0
4	0	0	2.8/0	0	0	0	0	0
5	0	0	2.8/0	0	0	0	0	0
6	0	0	2.8/0	0	0	0	0	0
7	8.3	8.3	5.6/8.3	8.3	8.3	8.3	8.3	8.3
8	8.3	8.3	5.6/8.3	8.3	8.3	8.3	8.3	8.3
9	8.3	8.3	5.6/8.3	8.3	8.3	8.3	8.3	8.3
10	8.3	8.3	5.6/8.3	8.3	8.3	8.3	8.3	8.3
11	8.3	8.3	5.6/8.3	8.3	8.3	8.3	8.3	8.3
12	8.3	8.3	5.6/8.3	8.3	8.3	8.3	8.3	8.3
13	8.3	8.3	5.6/8.3	8.3	8.3	8.3	8.3	8.3
14	8.3	8.3	5.6/8.3	8.3	8.3	8.3	8.3	8.3
15	8.3	8.3	5.6/8.3	8.3	8.3	8.3	8.3	8.3
16	8.3	8.3	5.6/8.3	8.3	8.3	8.3	8.3	8.3
17	8.3	8.3	5.6/8.3	8.3	8.3	8.3	8.3	8.3
18	8.3	8.3	5.6/8.3	8.3	8.3	8.3	8.3	8.3
19	0	0	2.8/0	0	0	0	0	0
20	0	0	2.8/0	0	0	0	0	0
21	0	0	2.8/0	0	0	0	0	0
22	0	0	2.8/0	0	0	0	0	0
23	0	0	2.8/0	0	0	0	0	0
24	0	0	2.8/0	0	0	0	0	0

Harvesting – Annual PM_{10} emissions associated with harvesting activities are estimated using the following equation, which utilizes crop-specific emission factors:[19]

$$Harvest_{Crop} = EF_{Crop} \times A_{Crop} \times (1 \text{ ton}/2{,}000 \text{ lbs})$$

where:

$Harvest_{crop}$ = harvest emissions for each crop type (tons PM_{10}/yr)
EF_{crop} = harvest emission factor (lbs PM_{10}/acre)
A_{crop} = number of harvested acres for each crop specific parcel per year

[19] Area-wide Source Methodologies, Section 7.5 Agricultural Harvest Operations, revised January 2003. California Air Resources Board, 2003. *http://www.arb.ca.gov/ei/areasrc/index7.htm*

The issue of how to allocate annual harvest emissions to a specific day parallels the tilling allocation challenge. In the case of harvest emissions, however, fewer assumptions are needed because meetings with Pinal County farmers indicated that they could only harvest 80–100 acres of cotton/day. Choosing the upper limit of 100 acres/day, it was determined that only 100 acres/1,334-acre farm—or 7.5% of an average farm—could be harvested per day. Stated another way, it could be assumed that on any given day, at most 7.5% of the cotton parcels identified in the selected modeling domains could be actively harvested (because farms typically cultivate more than one crop).

Thus, for an average farm, harvest emissions for cotton would be calculated as follows:

$$\begin{aligned} \text{Harvest emissions}_{\text{cotton}} &= 3.4 \text{ lbs/acre} \times 100 \text{ acres/day} \\ &= 340 \text{ lbs/day} \end{aligned}$$

Distributing these emissions must still be addressed—either they can be spread across all the 1,334 acres of an average farm (which is not identified in any of the available parcel data), they can be distributed proportionately to each parcel by crop, or they can be allocated closer and farther from the monitor through bounding scenarios. The approach adopted to address this issue for tilling will be used for addressing the allocation of harvest activity.

Hourly crop-specific tilling emissions can be calculated using the assumptions discussed above under the tillage discussion; activity is evenly distributed over the 12 daytime hours (i.e., 6:00 am to 6:00 pm) on the design days. Therefore, the diurnal variation for harvesting operations during the design days is identical to that shown in Table 3-3.

Table 3-3
Harvest Operation Assumptions

Crop	Emission Factor (lbs/acre-yr)[a]	Harvesting Operations (days/yr)[b]
Alfalfa	0	294
Corn	1.68	91
Cotton	3.4	143
Grain	5.8	60
Vegetable	0.08	116
Hay	1.68	294
Melon	0.08	116
Orchard	0.08	188

a. The EF (lbs/acre-yr) is extracted from the CARB, 2003 study.
b. Crop operation schedule is extracted from the MAG 2012 5% Plan.

Design Day Calculations – As noted earlier, October 29, 2008, was selected to represent stagnation conditions at Cowtown, Pinal County Housing, and Stanfield. A review of the Crop Calendar found that no planting activity occurs at this time of year. Instead, most crops are either being harvested, or have already been harvested. Discussions and correspondence with Pinal County farmers found harvest activity on this date is primarily limited to alfalfa, cotton, and hay. Using this information, crop distributions were quantified for each of the modeling domains. The distributions, presented in Table 3-4, show land use shares for each of the three harvested crops, the remaining CRPC crops not being harvested, fallow land, and Other Agricultural Land.[20]

Table 3-4
Crop Distribution for Stagnation Design Day Modeling Domains
(%)

Crop Category	Cowtown	Pinal County Housing	Stanfield
Alfalfa	20.5	22.3	42.7
Cotton	5.1	33.6	15.9
Hay	0.0	0.5	0.0
Remaining Crops	21.6	29.7	27.7
Fallow	5.8	10.3	0.5
Other Ag Lands	47.0	3.6	13.2

Separate emission estimates were calculated for each agricultural land parcel in each modeling domain for the three actively harvested crops shown in Table 3-4. No activity or emissions were assumed to occur for the remaining crops, fallow land, or for Other Agricultural Lands.

3.1.2 Concentrated Animal Feeding Operations (CAFO)

Literature Search – The identification of an appropriate PM_{10} emission factor for use in assessing design day and future emission levels from feedlot operations near the Cowtown monitor began with a limited literature search of feedlot emission monitoring studies. The search identified seven peer-reviewed studies of feedlot PM_{10} emissions published between 1994 and 2012. Emission factors reported in these studies ranged

[20] A review of the information presented in the shapefiles provided by ADEQ/PCAQCD and CRPC found CRPC did not identify crops for all agricultural parcels within its 6 km domain (i.e., within the overlap of the two shapefiles for each modeling domain). In addition, there are agricultural parcels located within the stagnant modeling domains that are outside of the CRPC 6 km domain that have no crop information. The overall portion of these Other Agricultural Lands varies by monitor

from 0.0092[21] to 0.063 lb[22] PM_{10}/head-day. Most of the studies reported emission factors on an annual-average-day basis only, intended for use in compilation of annual emission inventories. Understanding that feedlot emissions vary significantly from hour to hour based on specific activities such as animal feeding schedules, the use of an annual-average-day value was deemed to be too limiting in attempting to characterize the contributions of feedlots to hourly air quality impacts for a 24-hour attainment demonstration at the Cowtown site.

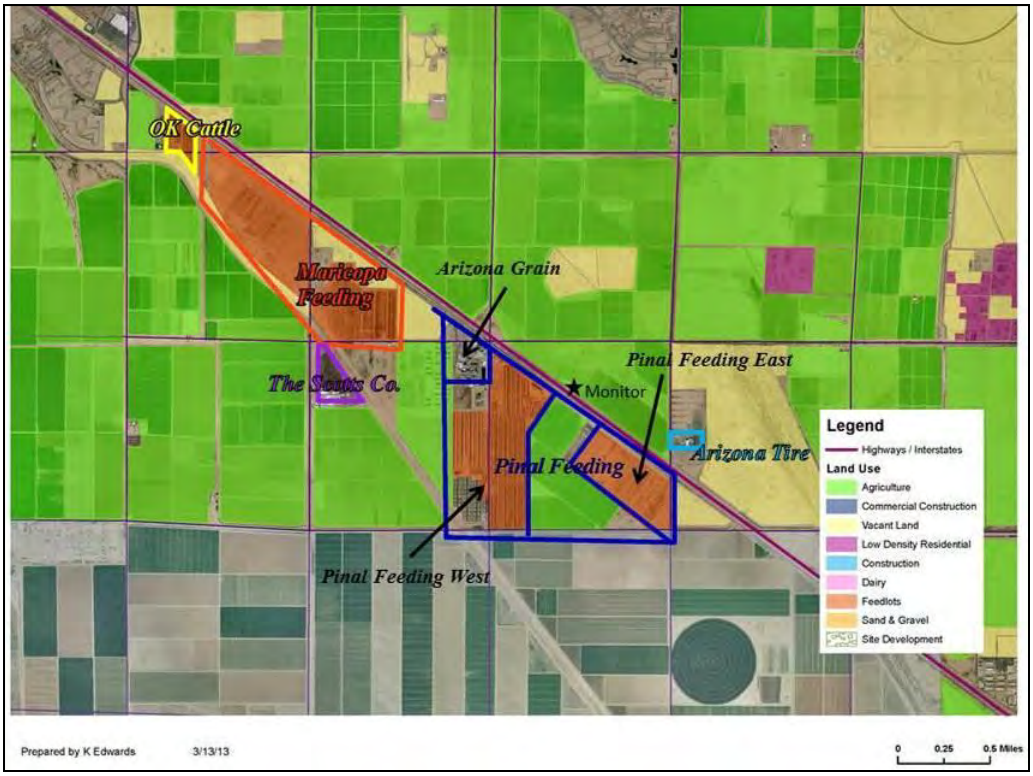
The most robust study gleaned from the literature search, one that included seasonal and diurnal profiles of emissions from two feedlots over a two-year period, was a study conducted in Kansas by Bonifacio et al.[23] Because feedlot pen emissions were demonstrated in the study to be proportional to ambient temperatures and resulting evapotranspiration (ET) rates, and because temperatures and ET rates are higher in Pinal County than in Kansas, the representativeness of these factors to Cowtown feedlots was questionable. Because the Cowtown feedlots were located 0.17 to 2.44 miles from the Cowtown monitoring station, and because the monitoring station has been in operation since 2001 recording hourly PM_{10} and meteorological data, an analysis of these data using the reverse dispersion modeling methodology described in the Bonifacio study was undertaken to produce potentially more representative emission factors for these facilities.

Feedlot Emission Isolation – In 2008, the Cowtown source complex consisted of seven feedlot pen areas, a grain mill, a tire recycling facility, a composting facility, and an ethanol plant. A map of these facilities and the monitoring station is presented in Figure 3-1. The feedlot pens closest to the monitoring station are operated by Pinal Feeding Company. In the 2008 baseline year, the company operated a feedlot 0.28 miles from the monitor in a south to southeasterly direction. This pen area, known as Pinal Feeding East (PFE), lay along one of the axes of prevailing low velocity nocturnal winds impacting the monitor and thus was identified as potentially significantly influencing PM_{10} concentrations at the monitor. Additionally, wind trajectories passing over the PFE pens to the monitoring station did not transport emissions from any of the other feedlot pens or other industrial facilities to the Cowtown monitor. These qualities suggested that the PFE pens represented the best feedlot source to analyze using reverse dispersion modeling techniques.

Although this approach did succeed in isolating the PFE emissions from those of other Cowtown industrial facilities, including other feedlots, non-industrial sources of PM_{10} near to and upwind of the PFE pens were recognized as also impacting the monitor and causing increased cumulative impacts when wind velocities were high enough to produce

[21] Parnell, S.E., B.J. Lesikar, J.M. Sweeten and R.E. Lacey. 1994. "Determination of the Emission Factor for Cattle Feedyards by Applied Dispersion Modeling," presented at the June 19-22, 1994 International Summer Meeting, Paper No. 944042 (revised). ASAE, 2950 Niles Road, St. Joseph, MI 49085
[22] Bonifacio, H.F, R.G. Maghirang, B.W. Auvermann, E.B. Razote, J.P. Murphy, and J.P. Harner III, "Particulate matter emission rates from beef cattle feedlots in Kansas – Reverse dispersion modeling," JAW&MA 62(3)350-361, 2012.
[23] Ibid.

Figure 3-1
Cowtown Monitor, Feedlots, and Other Industrial Sources



windblown PM_{10} emissions from disturbed soil surfaces. To eliminate this interference, the analysis of 2008 impacts was limited to hours in which wind speeds were below the threshold for soil entrainment, which was estimated to be 12 mph on an hourly average basis. During low wind hours, however, such sources as paved and unpaved road travel, locomotive exhaust, and agricultural operations were assumed to cumulatively add to PFE emission impacts as measured at the Cowtown monitor. During preliminary discussions with staff of the Pinal County Air Quality Control District (PCAQCD) on approaches to quantify the impacts of these other sources, Sierra Research learned that the PFE pens had been closed and demolished in the spring of 2010.[24] Since the monitoring record at Cowtown included hourly monitoring data for 2011 and 2012—years in which these other sources continued to operate in the absence of the PFE pens—the demolition of the PFE pens provided an opportunity to separately quantify the impacts of these other sources. The differences between the 2008 and the 2011/2012 impacts at the monitor represented the sole contributions from the PFE pens during 2008. This added benefit of selecting the PFE pens for feedlot emission analysis was believed to further reduce the confounding impact of other sources.

[24] Conference telecon with Sierra Research staff and contractor, Pinal County Air Quality Control District staff, and Arizona Department of Environmental Quality staff, June 13, 2013.

Basic Analytical Approach – In a reverse dispersion modeling analysis, air quality monitoring data are used to compute the emission rate of an upwind source in a process that is the reverse of typical source impact analysis. In source impact analysis, emissions from a source are estimated, and these emissions—together with stack information and meteorological data—are entered into a run file for a plume dispersion computer model. The source file is run by the model, resulting in estimates of pollutant concentrations occurring at specified downwind receptor sites. If, instead, an existing air quality monitor is designated as a downwind receptor site, and the pollutant concentrations measured at the monitor are assumed under appropriate wind directions to be due solely to emissions from an existing upwind source, the dispersion model can be used to back-calculate the emission strength of the source. The source emission rate in initial modeling is typically fixed over time at a unit value—such as 1 gm/sec—and the model is run to determine, hour by hour, the pollutant concentrations occurring at the monitor/receptor. The meteorological dataset used in this type of modeling is derived from locally collected hourly data covering one or more years. The dataset is filtered to include only those hours during which the wind direction requirements are satisfied. The resultant hourly pollutant concentrations forecasted by the model to occur at the monitor/receptor are then compared to the actual pollutant concentrations measured at the monitoring site, and the ratio of monitored concentration to modeled concentration is then multiplied by the unit emission rate assigned to the source to compute the estimated emission rate of the source. The basic equation that is used to perform this final step is shown below.

$$E' = E_0 \cdot (\xi'/\xi_0)$$

where:

E' = Back-calculated emission rate of source, g/sec
E_0 = Initial emission rate of source, g/sec
ξ' = Monitored pollutant concentration, $\mu g/m^3$
ξ_0 = Modeled pollutant concentration from source at initial emission rate, $\mu g/m^3$

Base Year Modeling – The modeling of PFE PM_{10} emission impacts at the Cowtown monitor was conducted using AERMOD, an EPA-approved model recommended for use with point and area industrial sources.[25] Meteorological files used by AERMOD were constructed using 2008 surface meteorological data collected at the Cowtown station and the Maricopa AZMET station,[26] and upper air data collected at Tucson, the closest site of measured upper air data that is approximately 80 miles to the southeast of Cowtown. The coordinates of the PFE pen perimeter and the Cowtown monitoring station were identified from the online Google Earth program. From these coordinates, the total pen

[25] Environmental Protection Agency, 2005, 40 CFR 51 Vol. 70, No. 216, pg. 68218, *http://www.epa.gov/scram001/guidance/guide/appw_05.pdf*

[26] The Cowtown meteorological data were not continuous through 2008. Data collected at the Maricopa AZMET station were used to fill in gaps in the Cowtown record for the periods of February 19 through April 25, 2008, and May 15 through September. 5, 2008. (Email from Scott DiBiase, PCAQCD, to Bob Dulla, Sierra Research, July 8, 2013.)

area of the PFE facility was calculated to be 292,667 m^2. A unit PM_{10} emission rate of 1.0 g/sec was assigned to the PFE facility, which converted to a unit-area emission rate of 3.417 $\mu g/m^2$-sec, and these emissions were assumed to be distributed uniformly across the facility and constant for every hour of 2008. From the Bonifacio study, the release height of PM_{10} emissions from livestock movement and on-site unpaved road travel was assumed to be 2.3 meters. Estimated hourly average PM_{10} concentrations at the Cowtown monitor were calculated by AERMOD for each hour of 2008 from this single area source. These data, together with the hourly meteorological PM_{10} data recorded at the monitor in 2008, were imported into a spreadsheet and merged into a single dataset by date and time stamp for analysis.

Initial Emission Factor Analysis – PM_{10} emissions from PFE pen activities significantly impact the Cowtown monitor when wind speeds are low and when wind directions carry these emissions directly from the pens to the monitor. Previous analysis of the relationships between PM_{10} concentrations and wind speeds at the monitoring stations designated for attainment demonstrations in the Inventory Preparation Plan indicated that wind entrainment of dust commenced in 2008 at a wind speed of approximately 12 mph (5.4 m/sec). To avoid the confounding impacts of windblown dust from upwind arrays of disturbed soil surfaces, an upper limit wind speed of 3.0 m/sec was selected for use in identifying hourly meteorological and PM_{10} monitoring data during which mechanically generated emission impacts, such as those generated by operation of the PFE facility, dominate PM_{10} concentrations measured at the Cowtown monitor.

Cowtown monitoring data collected in 2008 were further screened for hourly average wind directions associated with PFE emission impacts. Measurements taken from a Google Earth aerial photograph indicated that the boundaries of the PFE facility subtended a compass arc, as measured from the Cowtown monitor, ranging from 135 to 180 degrees. The dataset of 2008 monitoring data and modeled impacts was further filtered to include only this range of wind directions, and hours with missing data were removed. The remaining dataset was found to contain 1,802 hours that satisfied the specified meteorological conditions. During a series of sensitivity analyses, this dataset was further disaggregated into five different subsets based on various wind direction arcs. A map of the PFE facility and the five different wind arcs is shown in Figure 3-2.

The Bonifacio paper and information received from Pinal Feeding Company representatives revealed that PM_{10} emission rates from feedlots varied dramatically from hour to hour on a diurnal basis. Maximum PM_{10} emissions rates are associated with peaks in cattle movement, which typically occurs within a few hours of feeding times. At the PFE facility, cattle were fed between 6:00 am and 3:00 pm, and significant in-pen movement occurred between 4:00 and 8:00 pm as cattle responded to digested feed energy release and the desire to find relief from peak daily temperatures.[27] Because of these significant fluctuations in hourly emissions, and the need to develop diurnal emission profiles for the 24-hour PM_{10} standard attainment demonstration, the filtered

[27] Conference call with Bas Aja/Arizona Cattle Feeders Association and staff of the Arizona Department of Environmental Quality and Pinal County Air Quality Control District, May 13, 2013.

Figure 3-2
Cowtown Monitor, PFE Facility, and Wind Arcs

Legend (colors refer to lines perpendicular to wind directions):
Base Wind Arc Blue, 135-180 degrees (Table 3-5)
Narrow Wind Arc Red, 142.5-172.5 degrees (Table 3-6)
West Wind Arc Orange, 157.5-180 degrees (Table 3-7)
East Wind Arc Lt. Green, 135-157.5 degrees (Table 3-8)
East+ Dk. Green, 135-162.5 degrees (Table 3-9)

monitoring and modeling data were analyzed on an hour-of-day basis. The Bonifacio paper reported that hourly feedlot emissions rates over an annual period were not normally (i.e., bell curve) distributed, and that average values were best calculated using median instead of mean values. On the basis of the Bonifacio report, the analyses of the Cowtown monitoring and PFE modeling data used median values in the development of statistical relationships.

The results of the initial comparison between monitored and modeled PM_{10} concentrations in 2008 at the Cowtown monitor are displayed in Table 3-5. The tables show that modeled PM_{10} concentrations are less, with one exception, than monitored PM_{10} concentrations. This indicates that the actual PM_{10} emission rate of the PFE facility is greater than the 1.0 g/sec default rate used in the modeling analysis. The grouping of higher PM_{10} values at night in both the monitored and modeled data confirm the influence of low mixing heights during nocturnal hours. The higher values shown in the monitoring data for the hours of 1900 to 2200 compared to values shown for the hours of 2300 through 0700 suggests that PFE emissions are substantially higher during this period than during the other hours of the night. This ratio is especially in contrast to

Table 3-5
Hour of the Day Percentiles of 2008 Monitored and Modeled PM_{10} at Cowtown Monitor When Wind Speed is Less Than 3.0 m/sec and Wind Direction is between 135 and 180 Degrees (Base Arc) ($\mu g/m^3$)

Hour of the Day Percentiles of 2008 Cowtown Monitored PM10 When Wind Speed is Less than 3.0 m/sec and Wind Direction is Between 135 and 180 Degrees

%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	21	22	21	23	32	37	21	26	37	28	19	15	14	15	8	16	12	12	29	38	37	23	20	21
20%	32	36	42	51	58	71	67	43	47	36	25	21	23	19	13	23	15	22	39	95	62	44	40	40
30%	53	72	70	83	89	111	111	88	68	48	27	24	28	22	18	27	24	31	68	120	101	70	75	64
40%	85	125	91	104	116	152	135	165	93	62	36	31	30	25	22	30	37	39	107	247	183	99	105	115
50%	136	179	154	128	146	183	202	195	122	81	42	42	34	31	26	32	51	60	112	567	251	144	161	182
60%	195	229	209	164	177	218	237	226	145	93	52	48	35	41	33	37	51	82	231	754	421	242	200	220
70%	241	268	244	205	210	288	271	274	172	100	74	55	42	54	39	41	52	85	399	1021	483	294	251	267
80%	320	326	306	292	253	355	333	304	216	154	97	79	54	62	46	44	54	88	1040	1524	943	360	302	324
90%	393	461	418	377	336	443	393	353	252	270	123	100	70	84	55	45	59	317	1924	1994	1882	625	454	387
100%	1414	864	838	810	889	740	710	621	559	860	139	134	81	175	63	47	63	547	2159	3853	5457	2128	1355	736

Hour of the Day Percentiles of Modeled PM10 Impacts in 2008 at the Cowtown Monitor from the PFE Pen Facility
At 1.0 g/sec Emission Rate When Wind Speed is Less than 3.0 m/sec and Wind Direction is Between 135 and 180 Degrees

%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	8	6	6	7	7	5	4	1	1	1	1	1	1	1	1	1	1	2	3	9	9	7	9	8
20%	12	11	10	10	10	8	6	2	2	2	1	1	1	1	1	2	1	2	9	12	17	14	15	13
30%	20	13	14	13	14	12	8	4	2	2	1	1	1	1	1	2	1	2	14	18	28	19	22	17
40%	26	18	18	19	19	14	11	4	2	3	2	2	1	1	1	2	1	2	19	35	46	33	31	23
50%	32	28	22	25	24	20	20	6	3	3	2	2	1	1	1	2	1	3	34	51	57	45	39	29
60%	49	39	30	31	31	28	34	8	4	3	3	2	1	2	1	3	2	4	101	61	68	59	51	37
70%	63	47	45	46	39	35	45	26	5	4	4	2	2	2	1	3	2	67	119	92	77	78	72	57
80%	86	69	59	76	77	59	62	58	9	6	5	3	2	2	2	4	2	130	119	153	109	95	100	75
90%	127	100	127	140	132	120	128	92	17	9	6	3	3	2	2	4	2	150	124	179	136	126	136	103
100%	179	197	205	237	241	236	189	212	141	20	11	6	3	2	2	5	2	169	145	222	214	174	197	288

Ratio of Modeled to Monitored PM10 Percentiles by Hour of the Day at the Cowtown Monitor in 2008
When Wind Speed is Less than 3.0 m/sec and Wind Direction is Between 135 and 180 Degrees

%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	38.9%	26.4%	28.5%	28.6%	23.1%	13.9%	16.8%	4.7%	3.0%	4.5%	4.4%	6.1%	5.5%	5.4%	7.3%	7.6%	9.5%	13.5%	8.9%	22.8%	24.5%	32.9%	42.9%	38.0%
20%	36.9%	29.2%	22.6%	18.7%	17.1%	11.6%	8.6%	5.3%	3.5%	5.1%	4.3%	5.5%	4.4%	4.7%	5.6%	7.3%	8.2%	8.4%	23.1%	12.5%	27.6%	31.6%	37.9%	31.8%
30%	38.6%	18.4%	19.4%	15.4%	15.8%	10.5%	6.9%	4.0%	3.1%	3.9%	4.7%	6.0%	4.0%	4.9%	4.7%	7.0%	5.6%	6.1%	20.9%	14.8%	27.9%	26.9%	29.1%	26.2%
40%	30.2%	14.6%	19.4%	17.8%	16.6%	9.5%	8.2%	2.7%	2.6%	4.3%	4.4%	5.1%	3.8%	5.4%	4.1%	6.6%	3.6%	4.8%	18.0%	14.1%	25.3%	33.3%	29.8%	20.1%
50%	23.3%	15.5%	14.2%	19.3%	16.7%	11.2%	10.0%	3.0%	2.4%	3.5%	5.4%	4.1%	4.1%	4.5%	3.7%	6.2%	2.7%	4.9%	30.2%	9.1%	22.6%	31.4%	24.4%	15.9%
60%	25.0%	17.2%	14.3%	18.9%	17.7%	13.0%	14.2%	3.4%	2.7%	3.4%	6.0%	4.1%	4.2%	3.8%	3.5%	7.3%	3.0%	4.9%	43.8%	8.1%	16.1%	24.3%	25.5%	16.9%
70%	26.0%	17.4%	18.6%	22.4%	18.7%	12.1%	16.8%	9.6%	3.2%	4.1%	5.0%	4.1%	4.4%	3.1%	3.4%	8.1%	3.4%	79.3%	29.8%	9.0%	15.9%	26.6%	28.9%	21.4%
80%	26.8%	21.2%	19.2%	26.2%	30.6%	16.5%	18.7%	19.2%	4.0%	3.6%	5.4%	3.6%	3.9%	2.7%	3.2%	8.8%	3.4%	149%	11.4%	10.0%	11.6%	26.5%	33.1%	23.3%
90%	32.4%	21.7%	30.4%	37.0%	39.2%	27.2%	32.6%	26.0%	6.8%	3.3%	5.1%	3.2%	3.9%	2.3%	3.1%	9.5%	3.2%	47.2%	6.5%	9.0%	7.2%	20.2%	30.0%	26.5%
100%	12.6%	22.8%	24.5%	29.3%	27.1%	31.9%	26.7%	34.1%	25.3%	2.3%	7.7%	4.8%	3.8%	1.3%	3.0%	10.2%	3.0%	30.9%	6.7%	5.8%	3.9%	8.2%	14.5%	39.1%
Count	154	155	155	139	131	143	108	92	72	46	28	23	18	12	5	5	5	6	9	29	74	120	126	147
	1802	Total																						

the ratio of nocturnal values for the same hourly periods shown in the modeled data table. The suggestion of elevated emissions from the PFE facility during the middle evening conforms to the feedlot activity information provided by Pinal Feeding Company representatives.

Wind Direction Arc Sensitivity Analysis – Initial comparisons of median PM_{10} monitored concentrations by hour of the day for the 2008 and 2011/2012 years indicated that emissions from sources other than the PFE facility were significant in 2008 and contributed to approximately 40% of PM_{10} recorded at the monitor. In an attempt to determine the relative location of these other contributing sources, and also to test the consistency of the results shown in Table 3-5 and the sensitivity of these results to the selection of other wind direction arcs, three other wind direction arcs were initially analyzed in the 2008 Cowtown dataset.

In the first sensitivity analysis, the wind direction arc was reduced from a spread of 45 degrees (i.e., 135 to 180 degrees) to a spread of 30 degrees (i.e., 142.5 to 172.5 degrees). This reduced—or "Narrow"—arc was designed to reduce the influence of sources that abutted the edges of the PFE facility with respect to wind direction. Such sources would produce plumes that would overlap that of the PFE facility given the roughly 15 degree spread of emission plumes when dispersing downwind. By reducing the PFE wind direction arc by 7.5 degrees on each side, the intent was to reduce the influence area sources adjacent to the PFE pens.

Table 3-6 presents the results of the comparison between monitored and modeled PM_{10} concentrations in 2008 at the Cowtown monitor using hourly data filtered to this narrower wind direction arc. The tabular values in Table 3-6 are generally very similar to those shown in Table 3-5, except that the values for percentiles between the 10th and 50th[28] in the modeled data are higher by factors ranging from a few to over 200 percent. This result is somewhat expected as the wind direction arcs that were removed from consideration are those that lie over the east and west corners of the PFE facility where the pen areas contributing emissions are small in comparison to the area bounded by the center 30 degree wind direction arc. The percentiles of PM_{10} impacts from the narrower but deeper (on average) emission area should be higher, over the range of wind directions modeled, than those of the wider but less deep (on average) emission area used in the baseline analysis. In the absence of results dramatically different from this general trend, we can assume that there were no significant area sources operating in the wind directions adjacent to those of the PFE facility used in the baseline analysis.

[28]Percentiles, as used in this analysis, represent the positions—in units of percent—of individual numbers in a series of numbers ranked from lowest to highest. The 10th percentile value of a set of numbers, for example, is the number that is larger than 10% of the numbers in the set and smaller than 90% of the numbers. The median, or 50th percentile, is the number that is larger than 50% of the numbers in a set and smaller than the other 50%. All percentiles were calculated using the Excel percentile.inc function.

Table 3-6
Hour of the Day Percentiles of 2008 Monitored and Modeled PM_{10} at Cowtown Monitor When Wind Speed is Less Than 3.0 m/sec and Wind Direction is between 142.5 and 172.5 Degrees (Narrow Arc) ($\mu g/m^3$)

Hour of the Day Percentiles of 2008 Cowtown Monitored PM10 When Wind Speed is Less than 3.0 m/sec and Wind Direction is Between 142.5 and 172.5 Degrees

%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	24	20	26	25	32	49	23	29	30	29	24	14	15	19	8	34	11	10	27	131	41	22	21	21
20%	38	33	45	66	57	81	62	72	40	39	27	18	22	25	12	35	14	18	37	247	85	43	43	41
30%	61	56	74	84	80	119	110	109	56	54	31	23	28	34	17	36	16	26	50	285	121	67	81	78
40%	115	125	91	104	112	160	135	170	86	76	36	32	31	39	22	38	24	32	93	627	187	99	129	173
50%	163	176	133	126	134	192	182	202	122	89	43	46	35	44	26	39	34	39	183	922	277	137	169	210
60%	203	221	175	163	168	216	218	252	130	96	54	49	41	53	34	41	44	56	307	1021	435	195	206	246
70%	250	260	229	186	209	279	269	288	190	113	78	55	44	60	41	42	52	73	467	1651	644	288	259	280
80%	332	311	279	272	251	340	321	308	219	173	93	94	56	62	48	44	56	83	1315	1854	1006	360	302	331
90%	400	417	410	368	341	431	408	365	246	259	108	103	75	72	56	45	60	85	1953	2457	1879	689	456	389
100%	1414	764	766	739	889	740	710	621	559	860	137	134	81	87	63	47	63	88	2159	3853	5457	2128	1355	736

Hour of the Day Percentiles of Modeled PM10 Impacts in 2008 at the Cowtown Monitor from the PFE Pen Facility
At 1.0 g/sec Emission Rate When Wind Speed is Less than 3.0 m/sec and Wind Direction is Between 142.5 and 172.5 Degrees

%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	11	12	9	10	9	7	4	2	2	2	1	1	1	1	1	4	1	2	3	17	13	13	13	13
20%	19	15	14	14	13	11	7	4	2	2	2	1	1	1	1	4	1	2	7	37	25	25	23	19
30%	25	22	17	18	17	14	9	4	2	2	2	1	1	1	1	4	1	2	15	55	48	36	31	26
40%	30	29	21	24	21	20	18	6	3	3	2	2	1	2	1	4	1	2	30	61	58	47	39	33
50%	41	39	26	30	28	25	30	7	4	3	3	2	1	2	1	4	2	2	76	79	69	61	51	45
60%	54	45	41	43	39	31	44	9	5	3	3	2	2	2	2	4	2	53	118	95	76	78	68	62
70%	67	62	55	56	67	45	58	47	6	4	4	2	2	2	2	4	2	105	119	151	98	86	92	75
80%	86	78	91	97	92	90	78	65	10	5	5	3	2	2	2	5	2	138	119	169	126	111	121	88
90%	130	131	143	146	138	139	137	122	22	8	6	4	3	2	2	5	2	153	127	182	150	133	148	147
100%	179	197	205	237	241	236	189	212	141	20	11	6	3	2	2	5	2	169	145	222	214	174	197	288

Ratio of Modeled to Monitored PM10 Percentiles by Hour of the Day at the Cowtown Monitor in 2008
When Wind Speed is Less than 3.0 m/sec and Wind Direction is Between 142.5 and 172.5 Degrees

%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	46.5%	59.6%	33.4%	39.4%	28.7%	14.7%	16.6%	8.3%	5.4%	6.4%	5.8%	6.2%	7.1%	6.5%	13.8%	11.2%	9.9%	15.8%	9.4%	13.2%	31.8%	60.1%	59.5%	62.1%
20%	51.3%	47.1%	30.0%	20.7%	23.0%	13.7%	11.0%	4.9%	5.3%	4.9%	6.0%	7.6%	5.2%	5.6%	9.3%	11.1%	8.8%	9.7%	18.7%	15.1%	29.9%	57.9%	53.2%	46.6%
30%	41.4%	39.8%	23.4%	20.9%	21.2%	11.5%	8.0%	3.9%	4.3%	4.6%	6.4%	6.6%	4.4%	4.2%	7.3%	10.9%	8.0%	7.3%	31.1%	19.5%	39.6%	54.0%	38.9%	32.9%
40%	26.3%	22.8%	22.7%	23.4%	19.1%	12.6%	13.1%	3.3%	3.3%	3.6%	6.5%	4.9%	4.3%	3.8%	6.1%	10.8%	6.0%	5.8%	32.0%	9.7%	30.9%	47.2%	30.5%	19.2%
50%	25.3%	22.4%	19.8%	24.0%	20.8%	12.8%	16.7%	3.3%	3.2%	3.2%	6.5%	4.2%	4.1%	3.8%	5.3%	10.7%	4.7%	4.8%	41.4%	8.6%	24.9%	44.3%	30.0%	21.4%
60%	26.6%	20.5%	23.7%	26.4%	23.4%	14.4%	20.3%	3.6%	3.8%	3.4%	6.0%	4.2%	4.3%	3.2%	4.5%	10.6%	3.9%	94.8%	38.5%	9.3%	17.4%	39.7%	33.2%	25.3%
70%	26.7%	23.9%	23.8%	30.2%	31.8%	16.0%	21.5%	16.1%	3.3%	3.5%	5.1%	4.1%	4.6%	2.9%	3.9%	10.5%	3.5%	143%	25.4%	9.1%	15.3%	30.0%	35.5%	26.9%
80%	26.0%	24.9%	32.7%	35.8%	36.6%	26.4%	24.4%	21.2%	4.7%	2.9%	5.3%	3.3%	4.2%	3.1%	3.5%	10.4%	3.3%	166%	9.1%	9.1%	12.5%	30.7%	39.9%	26.5%
90%	32.5%	31.5%	34.9%	39.6%	40.6%	32.2%	33.7%	33.2%	8.8%	3.0%	5.6%	3.6%	3.7%	2.8%	3.2%	10.3%	3.1%	180%	6.5%	7.4%	8.0%	19.2%	32.4%	37.9%
100%	12.6%	25.8%	26.8%	32.1%	27.1%	31.9%	26.7%	34.1%	25.3%	2.3%	7.8%	4.8%	3.8%	2.6%	3.0%	10.2%	3.0%	193%	6.7%	5.8%	3.9%	8.2%	14.5%	39.1%
Count	123	108	110	97	97	95	76	62	47	34	16	19	9	7	3	2	4	5	8	17	58	89	99	94
	1279	Total																						

In the second and third sensitivity analyses, the wind direction arc bounding the PFE facility was split in half and the two complementary arcs were analyzed separately. The analysis began by splitting the baseline wind direction arc of 135 to 180 degrees in half along an azimuth of 157.5 degrees. The western portion of the PFE pens was represented by a wind direction arc of 157.5 to 180 degrees, and the eastern portion of the pens was represented by a wind direction arc of 135 to 157.5 degrees.

The results of the western half percentile analysis are presented in Table 3-7. One difference between the tabular values in the "West" arc analysis compared to those of the "Base" arc highlights a problem that occurs when there are very few database values found within a bin, such as occurs in 1600 hour bin. Within the "West" arc, the 2008 monitoring data contained only one hour in the 1600 hour subset that satisfied the prescribed meteorological conditions. With only one value in the subset, the percentile values from 10th percentile to 100th percentile do not change—all percentiles in this case are equal to the single monitored or modeled value represented by that hour. Ignoring this singularity, the other percentiles in the modeled "West" table are generally lower than those in the modeled "Base" table in Table 3-5, suggesting that some portion of high PM_{10} concentrations were recorded at the monitor when the wind direction was within the "East" half of the PFE arc.

The results of the eastern half percentile analysis are presented in Table 3-8. Within this wind direction arc, the 2008 dataset contained no hours in the 1700 hour column that satisfied meteorological conditions used in this analysis. In this situation, the tabular data simply reports "N/A" for all percentile values in this column. Comparison of the modeled-to-monitored ratios in Table 3-8 to the corresponding values in Table 3-7 suggests differences in source emissions within the "East" and "West" wind direction arcs. The ratio values in the "East" arc are higher than those of the "West" arc during the hours from 2200 through 1600, suggesting that lower non-PFE emissions are generated within the "East" arc during these hours in comparison to PFE emissions than occur in the "West" arc. As an example, to illustrate this relationship, during the 0100 hour, at the 50th percentile PM_{10} concentration recorded at the monitor during low wind conditions, the estimated emission rate of the sources within the "East" arc—when attributed entirely to the PFE pens—were 3.13 g/sec (= 1.0 gm/sec x 1/31.9%). However, in the "West" arc at the same time, the estimated emission rate when attributed entirely to the PFE pens was 5.52 g/sec (= 1.0 gm/sec x 1/18.1%). If the emission rate is uniform across the PFE pens at this hour of the early morning, as is suggested from discussions with Pinal Feeding Company representatives, then emissions from sources within the "West" arc other than the PFE facility are producing greater emissions than are estimated for other sources in the "East" arc.

Table 3-7
Hour of the Day Percentiles of 2008 Monitored and Modeled PM_{10} at Cowtown Monitor When Wind Speed is Less Than 3.0 m/sec and Wind Direction is between 157.5 and 180 Degrees (West Arc) ($\mu g/m^3$)

Hour of the Day Percentiles of 2008 Cowtown Monitored PM10 When Wind Speed is Less than 3.0 m/sec and Wind Direction is Between 157.5 and 180 Degrees

%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	24	29	33	25	31	45	49	54	35	24	21	21	28	14	18	9	12	13	37	30	39	22	22	25
20%	36	51	60	64	68	80	99	96	47	33	32	22	31	17	20	9	15	24	41	111	57	47	49	46
30%	59	89	80	89	101	147	133	170	73	38	38	24	34	19	22	9	24	35	56	249	100	71	84	99
40%	118	133	98	104	117	180	174	207	96	42	43	25	38	21	24	9	37	48	81	513	185	95	131	163
50%	151	172	157	149	146	213	207	224	123	60	49	29	43	29	26	9	51	60	105	763	230	133	161	210
60%	193	195	198	166	168	243	257	261	138	91	61	39	53	38	34	9	51	73	108	929	305	224	188	255
70%	228	260	233	230	187	340	306	290	153	149	78	47	62	43	41	9	52	82	111	1049	695	312	232	295
80%	290	314	299	283	259	394	355	308	207	239	102	55	67	70	48	9	54	84	521	1299	1825	380	273	352
90%	394	404	373	339	331	486	429	361	234	273	137	90	74	113	56	9	59	86	1340	1792	2624	821	354	395
100%	1414	864	838	739	889	740	710	621	559	860	139	95	81	175	63	9	63	88	2159	2550	5457	2128	610	736

Hour of the Day Percentiles of Modeled PM10 Impacts in 2008 at the Cowtown Monitor from the PFE Pen Facility
At 1.0 g/sec Emission Rate When Wind Speed is Less than 3.0 m/sec and Wind Direction is Between 157.5 and 180 Degrees

%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	7	3	5	5	5	4	2	1	1	1	1	1	1	1	1	1	1	1	2	5	6	6	8	5
20%	11	5	7	7	8	5	4	1	1	1	1	1	1	1	1	1	1	2	3	9	10	13	14	10
30%	17	10	10	11	13	8	4	2	2	1	1	1	1	1	1	1	1	2	5	14	15	17	20	16
40%	23	14	15	14	16	13	7	2	2	2	1	1	1	1	1	1	1	2	10	19	23	27	27	25
50%	27	20	19	18	19	20	9	3	2	2	1	1	1	1	1	1	1	2	16	34	41	41	36	32
60%	34	28	21	23	24	24	21	5	3	3	1	2	1	1	1	1	2	2	57	44	50	56	49	38
70%	51	37	27	27	35	31	46	7	4	3	2	2	1	2	1	1	2	15	98	55	65	70	59	59
80%	64	45	39	52	48	43	60	31	7	3	3	2	1	2	1	1	2	53	119	65	76	81	84	72
90%	80	68	61	78	92	65	79	81	10	4	4	2	1	2	1	1	2	92	119	84	95	93	101	89
100%	142	114	161	175	151	173	130	167	47	19	11	3	1	2	1	1	2	130	119	100	135	122	152	151

Ratio of Modeled to Monitored PM10 Percentiles by Hour of the Day at the Cowtown Monitor in 2008
When Wind Speed is Less than 3.0 m/sec and Wind Direction is Between 157.5 and 180 Degrees

%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	28.9%	11.7%	15.3%	19.5%	16.1%	8.0%	4.3%	1.3%	1.8%	2.8%	3.5%	4.2%	2.5%	5.7%	3.1%	8.3%	9.5%	11.7%	6.5%	18.2%	16.5%	25.3%	37.3%	22.1%
20%	30.2%	10.9%	12.1%	10.5%	11.5%	6.6%	3.6%	0.9%	2.3%	2.5%	2.7%	4.0%	2.5%	5.1%	3.3%	8.3%	8.2%	6.9%	6.3%	7.8%	17.3%	27.3%	27.6%	22.0%
30%	28.8%	11.6%	12.2%	12.0%	13.0%	5.1%	3.0%	0.9%	2.1%	3.4%	2.5%	3.9%	2.3%	4.7%	3.5%	8.3%	5.6%	5.1%	9.4%	5.6%	14.7%	24.4%	24.0%	16.5%
40%	19.1%	10.4%	15.6%	13.2%	13.5%	7.0%	3.9%	1.1%	1.8%	4.2%	2.5%	4.8%	2.3%	4.6%	3.6%	8.3%	3.6%	3.9%	12.9%	3.7%	12.4%	28.4%	20.4%	15.4%
50%	18.1%	11.9%	12.1%	12.4%	13.3%	9.2%	4.4%	1.3%	1.8%	3.8%	2.6%	5.0%	2.3%	4.1%	3.7%	8.3%	2.7%	3.1%	14.8%	4.4%	17.9%	30.8%	22.3%	15.1%
60%	17.4%	14.6%	10.5%	13.8%	14.6%	9.7%	8.3%	1.7%	2.1%	2.9%	2.3%	4.0%	2.0%	3.8%	3.2%	8.3%	3.0%	2.6%	52.7%	4.8%	16.5%	25.2%	25.9%	15.0%
70%	22.5%	14.3%	11.6%	11.9%	18.8%	9.0%	15.0%	2.5%	2.9%	1.9%	2.6%	3.6%	1.8%	3.8%	2.8%	8.3%	3.4%	17.9%	88.8%	5.3%	9.3%	22.6%	25.5%	19.9%
80%	22.2%	14.3%	13.0%	18.5%	18.5%	11.0%	16.9%	10.2%	3.1%	1.2%	2.5%	3.4%	1.6%	2.4%	2.6%	8.3%	3.4%	63.3%	22.8%	5.0%	4.2%	21.2%	30.6%	20.4%
90%	20.2%	16.9%	16.3%	22.9%	27.7%	13.3%	18.5%	22.3%	4.4%	1.4%	2.8%	2.5%	1.5%	1.6%	2.4%	8.3%	3.2%	107%	8.9%	4.7%	3.6%	11.3%	28.6%	22.5%
100%	10.0%	13.2%	19.3%	23.7%	16.9%	23.3%	18.4%	26.8%	8.5%	2.2%	7.7%	3.2%	1.4%	1.1%	2.2%	8.3%	3.0%	149%	5.5%	3.9%	2.5%	5.7%	25.0%	20.5%
Count	79	76	70	65	63	68	49	38	37	16	15	12	7	8	3	1	5	4	5	15	38	67	70	76
	887	Total																						

Table 3-8
Hour of the Day Percentiles of 2008 Monitored and Modeled PM_{10} at Cowtown Monitor When Wind Speed is Less Than 3.0 m/sec and Wind Direction is between 135 and 157.5 Degrees (East Arc) ($\mu g/m^3$)

Hour of the Day Percentiles of 2008 Cowtown Monitored PM10 When Wind Speed is Less than 3.0 m/sec and Wind Direction is Between 135 and 157.5 Degrees

%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	20	20	18	21	38	27	21	20	38	31	20	14	10	24	7	28	N/A	75	87	61	54	32	20	21
20%	35	32	41	51	65	63	53	35	51	43	23	29	16	25	11	30	N/A	127	162	95	79	43	32	49
30%	48	63	67	76	89	95	106	70	73	57	25	42	21	26	15	32	N/A	180	236	110	135	73	63	63
40%	72	136	87	94	117	133	125	109	108	79	27	47	27	33	19	34	N/A	232	307	123	243	122	96	103
50%	130	196	159	118	160	170	153	168	127	83	28	51	30	43	23	38	N/A	285	376	219	405	171	175	139
60%	203	259	214	162	197	195	230	200	152	93	40	55	33	52	27	41	N/A	337	445	509	431	242	226	189
70%	253	285	253	188	223	269	269	262	194	100	61	71	35	59	31	44	N/A	390	628	790	469	283	302	234
80%	331	344	308	292	256	321	309	298	225	123	90	103	35	60	34	45	N/A	442	1040	1545	703	352	371	299
90%	392	483	432	380	339	402	366	335	313	239	108	111	44	62	38	46	N/A	494	1453	2185	1419	411	477	339
100%	1144	809	766	810	515	527	548	527	474	324	117	134	73	63	42	47	N/A	547	1865	3853	3206	1181	1355	699

Hour of the Day Percentiles of Modeled PM10 Impacts in 2008 at the Cowtown Monitor from the PFE Pen Facility
At 1.0 g/sec Emission Rate When Wind Speed is Less than 3.0 m/sec and Wind Direction is Between 135 and 157.5 Degrees

%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	10	11	9	9	8	9	6	3	2	2	2	1	1	1	1	2	N/A	21	19	11	22	11	9	9
20%	15	12	12	12	11	11	8	4	2	2	2	2	1	1	1	2	N/A	37	26	25	37	17	15	13
30%	25	17	15	18	15	13	9	5	2	2	3	2	1	1	1	2	N/A	53	32	45	53	31	25	17
40%	30	25	19	26	23	17	19	6	3	3	4	2	2	1	1	2	N/A	70	51	68	65	42	34	22
50%	41	39	28	33	27	23	26	7	3	3	4	2	2	2	1	3	N/A	86	76	122	71	46	42	26
60%	61	47	45	45	38	32	35	11	5	4	5	2	2	2	1	3	N/A	103	101	157	75	66	55	35
70%	85	66	56	57	55	40	44	41	5	5	5	3	2	2	2	4	N/A	119	121	172	124	106	104	55
80%	107	83	97	116	83	97	84	58	7	7	6	3	3	2	2	4	N/A	136	129	182	129	126	136	78
90%	140	154	148	156	151	139	146	84	17	9	7	3	3	2	2	4	N/A	152	137	193	154	145	162	132
100%	179	192	205	237	241	236	189	212	81	20	8	5	3	2	2	5	N/A	169	145	222	214	174	197	193

Ratio of Modeled to Monitored PM10 Percentiles by Hour of the Day at the Cowtown Monitor in 2008
When Wind Speed is Less than 3.0 m/sec and Wind Direction is Between 135 and 157.5 Degrees

%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	48.2%	55.5%	47.9%	41.1%	22.1%	32.1%	30.2%	16.6%	5.5%	6.0%	7.8%	10.3%	13.7%	5.4%	13.2%	6.9%	N/A	27.4%	22.3%	18.8%	40.0%	33.7%	45.8%	45.8%
20%	41.6%	37.9%	28.9%	23.2%	16.7%	17.6%	15.5%	11.5%	4.7%	4.4%	8.6%	5.6%	8.8%	5.4%	9.5%	6.6%	N/A	29.1%	15.8%	26.3%	46.8%	40.1%	47.2%	27.0%
30%	52.4%	26.5%	23.1%	24.0%	16.9%	13.6%	8.7%	6.7%	3.4%	4.1%	11.6%	4.4%	6.8%	5.3%	7.7%	6.3%	N/A	29.8%	13.4%	40.7%	38.9%	42.2%	39.5%	27.1%
40%	42.0%	18.1%	21.4%	28.1%	19.4%	13.1%	15.1%	5.3%	2.7%	3.6%	13.6%	4.4%	5.9%	4.4%	6.7%	6.8%	N/A	30.1%	16.5%	55.1%	27.0%	34.1%	35.7%	21.1%
50%	31.9%	20.0%	17.8%	28.0%	17.1%	13.6%	17.0%	4.1%	2.7%	3.8%	13.2%	4.3%	6.2%	3.6%	6.0%	7.5%	N/A	30.4%	20.2%	55.6%	17.4%	26.6%	24.2%	18.5%
60%	30.2%	18.0%	21.1%	27.7%	19.5%	16.5%	15.1%	5.7%	3.1%	4.4%	12.8%	4.2%	6.5%	3.1%	5.5%	8.1%	N/A	30.5%	22.8%	30.9%	17.4%	27.5%	24.1%	18.4%
70%	33.7%	23.2%	22.0%	30.5%	24.9%	14.7%	16.5%	15.6%	2.8%	5.1%	8.9%	3.8%	6.2%	2.9%	5.1%	8.6%	N/A	30.7%	19.3%	21.7%	26.5%	37.3%	34.5%	23.3%
80%	32.3%	24.2%	31.5%	39.7%	32.2%	30.3%	27.3%	19.6%	3.3%	5.5%	6.5%	3.1%	7.6%	3.1%	4.9%	9.2%	N/A	30.8%	12.4%	11.8%	18.4%	35.9%	36.8%	26.1%
90%	35.7%	31.8%	34.1%	41.0%	44.5%	34.5%	40.0%	24.9%	5.4%	3.9%	6.2%	3.1%	6.3%	3.3%	4.7%	9.7%	N/A	31%	9.4%	8.8%	10.9%	35.3%	34.0%	38.9%
100%	15.6%	23.8%	26.8%	29.3%	46.7%	44.8%	34.6%	40.1%	17.1%	6.2%	6.7%	4.1%	4.2%	3.5%	4.5%	10.2%	N/A	31%	7.8%	5.8%	6.7%	14.7%	14.5%	27.6%
Count	73	77	82	74	65	75	57	52	33	29	13	10	11	4	2	4	0	2	4	14	34	52	54	66
	887	Total																						

One of the implications of this finding relates to the question of what caused elevated PM_{10} concentrations during the early morning hours of October 29, 2008, the low wind design day for the Cowtown monitor. One theory is that PM_{10} suspended in the air to a height of a quarter mile by an emissions spike at the PFE facility during the period of highest livestock movement on the previous late afternoon/early evening, settled out of the air during these later hours (0100 to 0400 hours) to impact the Cowtown monitor at far higher PM_{10} concentrations than would result from the very low emissions rates estimated to be generated at feedlots and other nearby area sources at this time of day. If the elevated concentrations recorded during the 0100 to 0400 hours on the morning of October 29, 2008—and several other early mornings found in the monitoring record—were due to deposition of suspended PM_{10} entrained in a cloud above the Cowtown area, then the contributions from this other "source" to impacts from the "West" and "East" portions of the PFE facility should be roughly equal. Since there are substantial differences in the contributions of non-PFE sources when winds blow from the "West" arc versus the "East" arc during these early morning hours, the differences cannot be due to the somewhat uniform impacts of deposition from an area-wide cloud of PM_{10}.[29] The differences in source strength between the "West" and "East" halves of the PFE pens plus nearby area sources discounts the possibility that the deposition of suspended PM_{10} would be responsible for any significant portion of these non-PFE impacts during these hours.

The lower emissions impact estimated for the "East" half of the PFE facility suggests that within the wind direction arc spanning this area, the contributions of other area sources are lower than those within the other wind direction arcs analyzed. Therefore, the correlation between monitored PM_{10} and modeled PM_{10} within this wind direction arc is more representative of emissions from the PFE facility and is less influenced by emissions from other sources. On this basis, the wind direction arc subtended by the "East" half of the PFE facility was tentatively selected for use in estimating diurnal feedlot emissions factors.

The monitoring dataset for this preferred wind direction arc suffers, however, from an absence of data representing hour 1700 during the 2008 inventory year. Using a dataset with this type of deficiency to compute diurnal emissions factors is problematical. As a result, an analysis of the wind directions recorded during hour 1700 at Cowtown when meteorological bounds were satisfied was conducted. Hourly monitoring data meeting these requirements are shown in Table 3-9.

[29] Additional research is needed to confirm the extent of deposition.

Table 3-9 Monitoring Data for Cowtown Hours in 2008 When Wind Speed < 3.0 m/sec, Wind Direction is Between 135 and 180 degrees, and Hour of the Day = 1700							
				WSpd	WDir	PM_{10} Concentrations	
Year	Month	Day	Hour	(m/sec)	(degrees)	Monitored	Modeled
2008	1	23	1700	2.1	172	63.4	1.9
2008	8	16	1700	2.1	172	50.5	1.1
2008	9	31	1700	1.5	162	9.1	1.8
2008	9	7	1700	1.1	162	16.9	1.3
2008	10	17	1700	1.8	174	51.9	1.4

This tabulation reveals that two hours of data representing the 1700 hour of the day could be included in the preferred wind direction arc dataset if the arc is extended from 135 to 162.5 degrees. This selection was made and the resulting wind direction arc is referred to as the "East+" PFE facility arc.

A comparison of 2008 monitored versus modeled PM_{10} percentiles at the Cowtown monitor using the "East+" wind direction arc as a filter is shown in Table 3-10. The tabular values for this arc are very similar to those for the "East" arc shown in Table 3-8, with the exceptions that hour 1700 is populated with non-zero values and the percentile values between the 10th and 50th in hour 1800 are considerably higher than those found in the "East" arc. This latter difference may be due entirely to the fact that the "East" arc includes two hours from the hour 1800 column while the "East+" arc includes three hours in this column. In percentile analysis, large changes can occur when data subsets are small (i.e., $n << 10$) and the number of elements (n) is modified.

<u>Calculation of Feedlot Emission Rates Unadjusted for Other Source Emissions</u> – PM_{10} emissions from the PFE facility were calculated from the ratios of 50th percentile values derived from the monitored and modeled PM_{10} concentrations at the Cowtown monitor under the five wind direction arc scenarios discussed above. For each scenario, the ratios of 50th percentiles for each hour in the diurnal profile were inverted and multiplied by the unit emission factor used in the modeling analysis to compute gross hourly emissions factors. "Gross emissions factors" in this sense refers to emission factors attributed to feedlot sources but unadjusted for the emissions contributions from other area sources within the same wind direction arc. The adjustment to eliminate these contributions from other unknown sources will be discussed later in this section.

In each of the "ratio" tables in Tables 3-5 through 3-10, the percent values represent the fractions of *monitored* PM_{10} concentrations represented by the impacts of *modeled* PM_{10} emissions generated at a unit emission rate (i.e., 1.0 g/sec) by the PFE facility during the same hours and under the same meteorological conditions recorded at the monitoring station. For example, if the 50th percentile ratio at 1200 hours under the Base wind direction arc scenario is reported to be 4.1% (see Table 3-5), then the modeling results

are suggesting that the PFE facility produces 4.1% of the average PM_{10} concentration recorded at the Cowtown monitor during this time of day and under the range of meteorological conditions specified, when the facility is generating PM_{10} emissions at the constant rate of 1.0 g/sec. The unit emission rate can be multiplied by the inverse of the 50th percentile ratio, equal to 24.4 (= 1/0.041), to estimate the emission rate which the PFE facility would have to achieve in order to be responsible for 100% of the average PM_{10} concentration recorded at the monitor. This equivalent emission factor would be 24.4 g/sec (= 24.4 x 1.0 g/sec).

A table of the 50th percentile values of monitored PM_{10} in 2008 for each hour of the day under the meteorological conditions specified, the modeled PM_{10} impacts reported by the AERMOD model from the PFE facility operating at a unit emission rate, the ratios of these two sets of values, and the inverses of these ratios, are presented in Table 3-11 for each of the five wind direction arc scenarios analyzed.

The lowermost table in Table 3-11 reports unadjusted 50th percentile emission rates by hour of the day at the PFE facility in 2008 under the different scenarios analyzed. The highest emissions rates are attributed to the "West" half of the facility, and are considerably higher from 0100 to 2100 hours than either the "East" or "East+" portions of the facility. The "East+" portion is shown to have lower emissions rates than any other scenario with the exception of the "East" scenario, which has roughly equivalent emissions but continues to contain a data gap in hour 1700 for reasons discussed earlier. Because we are assuming that emissions across the PFE pens are roughly uniform, based on information received from company representatives, the lower rates shown for the "East+" portion suggest lower contributions at the Cowtown monitor from other sources lying within the same wind direction arc. For this reason, this wind direction arc is tentatively selected to represent unadjusted feedlot emission rates in the remainder of the analysis.

Other Source Emissions Analysis – Hourly meteorological and PM_{10} data collected at the Cowtown monitoring station in 2011 and 2012 were analyzed in the same manner as the 2008 data to determine the impacts of other sources within the 5 different wind direction arcs at a time when the PFE facility was closed and demolished. According to historical aerial photographs available through the Google Earth program, the PFE facility was torn down in the spring of 2010, so no feedlot emissions were being transported in 2011 and 2012 by winds blowing from azimuths between 135 to 180 degrees to the monitor.

PM_{10} concentration percentile values recorded at the Cowtown monitor in 2011 under the meteorological conditions specified for each wind direction arc scenario are displayed by hour of the day in Table 3-12. The patterns in each scenario are somewhat similar to each other and are also similar to the corresponding percentile tables for 2008, with the exception that the 2011 values are generally lower than those in the 2008 tables. The last table in Table 3-12 shows the 50th percentile PM_{10} concentrations by hour of the day for each of the 5 scenarios.

Table 3-10
Hour of the Day Percentiles of 2008 Monitored and Modeled PM_{10} at Cowtown Monitor When Wind Speed is Less Than 3.0 m/sec and Wind Direction is between 135 and 162.5 Degrees (East+ Arc) ($\mu g/m^3$)

Hour of the Day Percentiles of 2008 Cowtown Monitored PM10 When Wind Speed is Less than 3.0 m/sec and Wind Direction is Between 135 and 162.5 Degrees

%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	21	20	18	22	36	27	20	24	38	29	21	13	10	20	11	28	10	35	28	69	31	20	19	20
20%	32	34	34	47	67	64	38	34	48	43	24	15	16	23	19	30	11	48	43	99	63	42	34	36
30%	48	66	56	79	89	94	106	68	69	54	26	19	21	24	27	32	11	61	152	112	103	67	61	57
40%	71	152	75	96	118	135	131	100	92	79	27	30	27	26	34	34	12	74	261	160	207	102	90	102
50%	128	196	128	124	148	172	201	157	121	85	36	46	30	31	42	38	13	88	376	422	397	148	152	145
60%	194	259	197	156	183	207	228	190	146	95	46	49	33	38	46	41	14	179	490	717	430	220	218	208
70%	244	284	232	183	213	254	266	252	199	102	76	55	35	43	51	44	15	271	1178	999	470	271	267	253
80%	319	341	289	231	253	318	316	294	219	142	95	84	35	53	55	45	15	363	1865	1447	777	352	329	298
90%	388	470	403	370	337	393	368	332	273	256	113	107	44	60	59	46	16	455	2012	2044	1782	442	440	337
100%	1414	809	766	810	889	527	642	527	474	324	137	134	73	63	63	47	17	547	2159	3853	5457	1181	1355	699

Hour of the Day Percentiles of Modeled PM10 Impacts in 2008 at the Cowtown Monitor from the PFE Pen Facility
At 1.0 g/sec Emission Rate When Wind Speed is Less than 3.0 m/sec and Wind Direction is Between 135 and 162.5 Degrees

%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	11	11	9	9	9	9	6	3	2	2	1	2	1	1	1	2	1	29	24	12	20	11	9	10
20%	16	13	13	12	12	12	7	4	2	2	2	2	1	1	1	2	1	55	34	33	29	18	15	13
30%	25	18	17	18	16	14	9	4	3	3	2	2	1	1	1	2	1	80	76	49	51	33	25	19
40%	31	26	22	25	21	19	16	6	3	3	2	2	2	1	1	2	2	105	118	61	63	43	36	24
50%	47	36	27	30	27	24	25	7	4	3	3	2	2	2	1	3	2	130	119	87	71	52	46	30
60%	62	44	43	40	38	33	36	13	5	4	4	3	2	2	2	3	2	138	119	148	83	80	58	40
70%	79	62	55	52	60	45	46	50	6	5	5	3	2	2	2	4	2	146	119	165	122	101	102	57
80%	108	81	95	109	90	96	76	66	11	6	5	3	3	2	2	4	2	153	119	177	131	121	132	86
90%	139	145	145	151	147	145	138	119	22	9	6	5	3	2	2	4	2	161	132	192	154	141	152	142
100%	179	197	205	237	241	236	189	212	141	20	8	6	3	2	2	5	2	169	145	222	214	174	197	288

Ratio of Modeled to Monitored PM10 Percentiles by Hour of the Day at the Cowtown Monitor in 2008
When Wind Speed is Less than 3.0 m/sec and Wind Direction is Between 135 and 162.5 Degrees

%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	54.0%	55.1%	48.9%	40.2%	24.2%	33.9%	27.6%	12.8%	5.6%	6.4%	6.7%	11.4%	13.7%	6.1%	8.6%	6.9%	13.8%	82.8%	83.7%	17.0%	64.7%	54.9%	47.0%	47.5%
20%	51.1%	36.7%	39.4%	25.3%	17.5%	18.3%	18.8%	10.7%	5.0%	4.8%	6.6%	12.0%	8.8%	5.9%	5.6%	6.6%	13.3%	113%	77.8%	33.6%	45.1%	42.1%	44.8%	36.9%
30%	52.8%	27.9%	31.2%	23.0%	18.2%	14.8%	8.3%	6.5%	3.7%	4.9%	8.1%	10.7%	6.8%	5.9%	4.4%	6.3%	12.8%	130%	49.9%	43.4%	49.0%	49.2%	40.8%	33.4%
40%	43.6%	17.3%	28.6%	25.7%	18.1%	14.1%	11.9%	5.8%	3.2%	3.6%	8.8%	7.2%	5.9%	5.4%	3.8%	6.8%	12.4%	141%	45.2%	38.0%	30.2%	41.9%	40.1%	23.2%
50%	36.6%	18.4%	21.2%	24.5%	18.5%	14.1%	12.6%	4.7%	3.1%	3.8%	8.9%	5.0%	6.2%	4.9%	3.3%	7.5%	12.1%	149%	31.6%	20.6%	17.8%	35.5%	30.4%	20.8%
60%	32.2%	16.9%	21.7%	25.6%	21.0%	16.0%	15.6%	7.0%	3.4%	4.2%	8.1%	5.4%	6.5%	4.4%	3.2%	8.1%	11.8%	76.9%	24.3%	20.7%	19.4%	36.4%	26.4%	19.4%
70%	32.2%	21.8%	23.6%	28.7%	28.0%	17.7%	17.1%	19.8%	3.1%	4.9%	6.7%	5.6%	6.2%	3.9%	3.2%	8.6%	11.5%	53.7%	10.1%	16.5%	25.9%	37.4%	38.2%	22.7%
80%	33.8%	23.6%	32.9%	47.1%	35.5%	30.2%	23.9%	22.6%	4.9%	4.1%	5.7%	3.8%	7.6%	3.5%	3.1%	9.2%	11.2%	42.3%	6.4%	12.2%	16.9%	34.4%	40.2%	29.0%
90%	35.9%	30.9%	36.1%	40.8%	43.7%	36.9%	37.5%	35.9%	8.0%	3.5%	5.6%	4.7%	6.3%	3.4%	3.0%	9.7%	11.0%	35.4%	6.6%	9.4%	8.6%	31.9%	34.6%	42.3%
100%	12.6%	24.4%	26.8%	29.3%	27.1%	44.8%	29.5%	40.1%	29.8%	6.2%	5.7%	4.8%	4.2%	3.5%	3.0%	10.2%	10.8%	30.9%	6.7%	5.8%	3.9%	14.7%	14.5%	41.2%
Count	100	98	103	94	86	91	77	66	42	34	17	13	11	8	3	4	2	3	6	16	45	67	72	88
	1146	Total																						

Table 3-11
Unadjusted PFE Emission Factors by Hour of the Day Based on 50th Percentiles of 2008 Monitored and Modeled PM_{10} at Cowtown Monitor Under Five Different Wind Direction Arc Calculation Scenarios

	2008 50th Percentile Values of Monitored PM10 by Hour of the Day for Different Wind Arc Scenarios, ug/m3																							
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Base	136	179	154	128	146	183	202	195	122	81	42	42	34	31	26	32	51	60	112	567	251	144	161	182
Nrrw	163	176	133	126	134	192	182	202	122	89	43	46	35	44	26	39	34	39	183	922	277	137	169	210
West	151	172	157	149	146	213	207	224	123	60	49	29	43	29	26	9	51	60	105	763	230	133	161	210
East	127	189	146	118	143	170	144	157	119	82	28	48	30	43	23	38	N/A	285	376	219	340	160	152	119
East+	128	196	128	124	148	172	201	157	121	85	36	46	30	31	42	38	13	88	376	422	397	148	152	145

	2008 50th Percentile Values of Modeled PM10 at Unit Emissions Rates by Hour of the Day for Different Wind Arc Scenarios, ug/m3																							
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Base	32	28	22	25	24	20	20	6	3	3	2	2	1	1	1	2	1	3	34	51	57	45	39	29
Nrrw	41	39	26	30	28	25	30	7	4	3	3	2	1	2	1	4	2	2	76	79	69	61	51	45
West	27	20	19	18	19	20	9	3	2	2	1	1	1	1	1	1	1	2	16	34	41	41	36	32
East	41	39	28	33	27	23	26	7	3	3	4	2	2	2	1	3	N/A	86	76	122	71	46	42	26
East+	47	36	27	30	27	24	25	7	4	3	3	2	2	2	1	3	2	130	119	87	71	52	46	30

	Ratios of 2008 50th Percentile Modeled PM10 to Monitored PM10 by Hour of the Day for Different Wind Arc Scenarios																							
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Base	23%	15%	14%	19%	17%	11%	10%	3%	2%	3%	5%	4%	4%	4%	4%	6%	3%	5%	30%	9%	23%	31%	24%	16%
Nrrw	25%	22%	20%	24%	21%	13%	17%	3%	3%	3%	6%	4%	4%	4%	5%	11%	5%	5%	41%	9%	25%	44%	30%	21%
West	18%	12%	12%	12%	13%	9%	4%	1%	2%	4%	3%	5%	2%	4%	4%	8%	3%	3%	15%	4%	18%	31%	22%	15%
East	33%	21%	19%	28%	19%	14%	18%	4%	3%	4%	13%	4%	6%	4%	6%	8%	N/A	30%	20%	56%	21%	28%	28%	22%
East+	37%	18%	21%	24%	18%	14%	13%	5%	3%	4%	9%	5%	6%	5%	3%	8%	12%	149%	32%	21%	18%	35%	30%	21%

	Unadjusted PM10 Emissions Rates for PFE Facility by Hour of the Day for Different Wind Arc Scenarios, g/sec																							
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Base	4.3	6.5	7.1	5.2	6.0	9.0	10.0	33.2	41.6	28.8	18.5	24.2	24.4	22.5	26.8	16.0	36.7	20.5	3.3	11.0	4.4	3.2	4.1	6.3
Nrrw	4.0	4.5	5.1	4.2	4.8	7.8	6.0	30.1	31.0	30.8	15.4	23.8	24.6	26.5	18.7	9.3	21.4	20.8	2.4	11.7	4.0	2.3	3.3	4.7
West	5.5	8.4	8.3	8.0	7.5	10.9	22.5	75.3	54.7	26.6	38.6	19.9	44.2	24.2	26.8	12.0	36.7	32.3	6.8	22.6	5.6	3.2	4.5	6.6
East	3.1	4.8	5.2	3.6	5.2	7.4	5.5	22.6	34.4	26.1	7.6	22.2	16.2	27.9	16.7	13.3	N/A	3.3	4.9	1.8	4.8	3.5	3.6	4.6
East+	2.7	5.4	4.7	4.1	5.4	7.1	7.9	21.3	32.1	26.2	11.2	20.2	16.2	20.6	30.0	13.3	8.3	0.7	3.2	4.9	5.6	2.8	3.3	4.8

Table 3-12
Hour of the Day Percentiles of 2011 Monitored PM_{10} at Cowtown Monitor When Wind Speed is Less Than 3.0 m/sec and Wind Directions Are Defined by the Five Wind Direction Arc Scenarios (µg/m^3)

	2011 Base - Hour of the Day																							
%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	20	18	18	12	17	17	23	52	28	23	19	18	13	10	9	15	21	10	32	47	42	29	26	23
20%	30	27	28	21	22	28	40	63	48	37	23	20	20	16	18	18	25	20	60	76	59	46	42	38
30%	41	34	35	33	33	36	48	72	67	48	27	26	25	17	23	21	34	26	73	97	71	56	58	47
40%	49	44	41	37	40	45	60	86	82	59	35	34	30	18	25	22	48	38	117	116	93	70	73	57
50%	58	52	49	46	45	57	72	100	102	65	39	38	33	27	27	22	56	61	136	157	130	87	90	67
60%	66	61	55	54	53	68	91	114	118	78	45	42	34	32	34	31	65	92	156	189	159	107	103	84
70%	79	68	66	70	66	83	111	136	133	95	53	54	45	37	44	39	68	124	192	403	203	124	125	102
80%	93	83	83	92	83	110	150	159	162	107	72	67	59	49	50	48	91	154	222	916	258	185	158	132
90%	128	116	105	157	124	140	217	220	209	133	103	124	124	72	70	60	127	209	252	1325	478	259	212	169
100%	708	346	262	658	543	546	943	396	353	386	238	203	191	92	112	73	134	283	724	2393	1421	1075	589	825
Count	158	147	159	147	164	156	148	133	130	94	50	41	30	18	16	7	9	14	23	36	75	95	125	156
	2131	Total																						
	2011 Narrow - Hour of the Day																							
%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	19	17	18	17	17	21	22	52	35	25	20	20	13	11	11	19	20	6	24	47	44	27	24	31
20%	33	26	28	22	23	28	40	64	48	41	24	23	19	15	22	21	33	16	33	76	58	47	40	41
30%	40	32	36	33	35	36	46	77	62	51	27	33	21	16	25	22	47	21	60	85	70	56	57	47
40%	47	44	42	42	41	44	60	91	75	60	32	35	29	17	26	22	54	25	65	110	89	70	74	57
50%	55	53	49	49	47	56	70	103	94	72	38	38	32	25	27	29	62	31	93	122	105	85	93	65
60%	63	61	55	60	54	65	86	119	111	82	45	42	34	31	32	37	67	40	119	168	162	105	105	81
70%	76	68	69	73	66	81	108	138	129	96	51	52	38	33	41	44	69	70	130	189	202	123	123	96
80%	90	87	89	94	84	103	140	152	144	112	82	80	55	39	44	51	103	127	154	706	250	156	150	134
90%	122	122	126	152	114	128	206	200	182	134	104	137	124	49	50	62	128	159	248	1185	470	218	204	167
100%	369	346	201	345	543	546	706	281	353	386	238	203	191	74	70	73	134	283	259	2393	1298	1075	589	825
Count	99	104	111	102	126	101	94	90	94	62	35	30	20	10	12	6	8	10	16	21	51	74	96	113
	1485	Total																						
	2011 West - Hour of the Day																							
%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	27	24	26	16	16	21	19	58	50	23	17	12	14	15	9	21	22	15	76	66	47	29	27	34
20%	37	28	34	23	23	35	42	68	90	34	27	19	21	16	10	24	33	23	111	107	57	45	48	41
30%	46	41	41	32	38	44	48	77	108	53	33	28	27	17	18	28	43	30	144	130	65	54	66	47
40%	48	46	45	37	41	56	62	98	117	61	38	34	31	18	21	31	48	43	159	159	94	78	80	64
50%	56	53	63	51	54	68	76	115	123	74	52	38	34	24	34	34	51	74	174	185	145	98	97	86
60%	65	67	69	66	67	90	88	139	133	91	68	43	35	31	44	37	54	131	192	651	179	119	125	121
70%	102	74	84	88	75	108	100	163	144	100	74	50	48	31	44	41	57	158	208	1013	223	202	166	148
80%	126	87	94	113	124	136	119	230	189	112	91	66	58	37	70	44	61	191	220	1295	400	263	195	176
90%	199	178	101	178	201	195	159	246	245	134	101	103	144	46	70	47	64	239	274	1683	547	306	240	191
100%	708	268	191	345	543	546	599	326	353	237	238	203	191	92	112	51	67	283	724	2393	1421	1075	589	825
Count	39	39	33	52	41	35	33	50	53	44	23	23	21	11	11	2	4	9	10	20	42	35	49	51
	730	Total																						

Table 3-12 (cont.)
Hour of the Day Percentiles of 2011 Monitored PM_{10} at Cowtown Monitor When Wind Speed is Less Than 3.0 m/sec and Wind Directions Are Defined by the Five Wind Direction Arc Scenarios (µg/m^3)

	2011 East - Hour of the Day																							
%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	18	17	17	12	17	16	23	48	21	28	21	20	16	8	25	15	25	12	20	44	36	32	27	22
20%	30	26	25	21	22	28	40	62	41	40	23	21	18	13	25	19	26	19	32	59	67	46	40	38
30%	39	32	34	34	32	36	49	71	53	44	25	23	19	16	26	21	35	27	51	78	82	56	54	46
40%	50	43	40	39	40	42	59	83	66	55	28	33	22	25	26	22	52	37	64	85	92	67	72	56
50%	58	51	47	43	45	52	70	94	73	61	36	38	31	37	26	22	69	47	108	99	105	84	84	63
60%	66	60	52	52	52	65	95	107	91	70	40	41	32	45	27	28	91	67	126	122	133	101	98	76
70%	77	66	60	64	58	79	115	119	109	83	45	54	38	55	27	34	114	87	137	178	179	118	113	87
80%	89	82	76	71	73	103	157	140	136	103	49	100	51	67	32	44	127	102	201	282	232	146	134	116
90%	108	104	109	134	105	123	226	170	176	133	75	141	66	72	41	59	131	112	252	443	294	214	176	139
100%	369	346	262	658	223	407	943	396	248	386	222	175	67	74	50	73	134	122	259	706	1174	621	302	337
Count	119	108	126	96	123	121	116	84	77	50	27	18	9	7	5	5	5	5	13	16	33	60	76	105
	1404	Total																						
	2011 East+ - Hour of the Day																							
%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	19	17	18	12	16	18	23	50	27	20	22	20	13	11	18	15	25	14	22	46	39	27	27	22
20%	30	26	27	21	22	28	40	64	45	37	23	22	17	15	25	19	32	20	32	73	60	44	40	38
30%	38	33	34	34	33	36	47	71	57	44	27	27	19	16	25	21	50	24	59	83	71	56	56	46
40%	49	44	41	39	40	43	59	85	71	56	31	34	24	16	26	22	61	33	68	101	93	67	71	57
50%	57	52	47	45	45	58	71	97	84	64	38	38	32	27	26	22	67	41	93	119	115	84	83	64
60%	64	60	52	53	53	67	95	108	102	72	44	40	33	37	27	28	68	57	121	155	153	100	99	77
70%	77	66	61	67	63	81	115	120	123	85	49	59	39	41	31	34	80	92	136	174	184	119	115	92
80%	89	80	76	79	82	106	156	144	136	107	67	73	54	55	41	44	114	112	180	292	228	144	138	119
90%	108	103	112	137	124	134	224	172	176	133	105	145	65	71	47	59	129	170	251	571	308	210	189	148
100%	369	346	262	658	543	546	943	396	248	386	238	203	67	74	50	73	134	283	259	1185	1174	621	589	337
Count	128	120	134	116	141	129	126	94	92	58	32	26	12	10	7	5	7	8	14	20	49	66	96	117
	1607	Total																						
	2011 50th Percentile Values by Hour of the Day for Different Calculation Methodologies																							
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Base	58	52	49	46	45	57	72	100	102	65	39	38	33	27	27	22	56	61	136	157	130	87	90	67
Nrrw	55	53	49	49	47	56	70	103	94	72	38	38	32	25	27	29	62	31	93	122	105	85	93	65
West	56	53	63	51	54	68	76	115	123	74	52	38	34	24	34	34	51	74	174	185	145	98	97	86
East	58	51	47	43	45	52	70	94	73	61	36	38	31	37	26	22	69	47	108	99	105	84	84	63
East+	57	52	47	45	45	58	71	97	84	64	38	38	32	27	26	22	67	41	93	119	115	84	83	64

Table 3-13 contains parallel tables of PM_{10} percentile values for 2012 that were constructed under the same approach as those of 2011. The 2012 values are similar to those for 2011, as can be seen by comparing the 50th percentile tables in Tables 3-12 and 3-13. In hours 0800-0900 and 1700-2100, 50th percentile values are slightly higher in 2011 than in 2012 under each scenario, but in the remainder of hours the values are roughly equivalent.

The slightly higher values in 2011 over 2012, when compared with the 2008 values, show a declining trend in PM_{10} concentrations at the Cowtown monitor over this period of time for the meteorological conditions specified. In comparing each of these two latter years to 2008, it would appear that the 2011 values better represent emissions from sources other than the PFE facility in 2008 than would the monitoring values from the 2012 dataset.

The 50th percentile of PM_{10} concentrations monitored at the Cowtown station by hour of the day and by scenario for 2008, 2011, and 2012 are displayed in the top three tables in Table 3-14. The ratios of the values from each of the 2011 and 2012 tables to the values shown in the 2008 50th percentile table are computed and presented in the two bottom tables in Table 3-14. Inspection of the ratio tables shows periodic irregularities in both the diurnal trends reading horizontally and the scenario trend reading vertically. These irregularities are primarily caused by the presence of very few hours of data in one or more arc scenarios during the late afternoon hours (i.e., 1600 to 1900 hours) when the wind roses for the Cowtown monitor show very low frequencies of wind blowing in the wind direction arcs subtending the PFE facility.

The 50th percentile values of PM_{10} impacting the Cowtown monitor from the PFE facility in 2008, by hour of the day and by arc scenario, could have been computed by deducting the fractional contributions of emissions from other sources, as shown in the two bottom tables in Table 3-14, from the 2008 50th percentile values of PM_{10} recorded at the monitor under each scenario. To do so, hour by hour, however, would have resulted in negative 50th percentile values for each hour and scenario combination that reported a value greater than 100% in either of the two ratio tables at the bottom of Table 3-14. Values above 100% in these tables result from the post-PFE shutdown PM_{10} concentrations monitored at the Cowtown station in 2011 or 2012 being higher than the pre-shutdown values for the same hour and scenario in 2008. Again, this anomaly is due to having too few hours (i.e. datapoints) in an hour-of-the-day column to produce a meaningful and representative percentile distribution.

The presence of these irregularities was overcome by computing hour-of-the-day average 50th percentile PM_{10} concentration and intra-year ratios for use in adjusting the 2008 data. Because the irregularities were present in hour-of-the-day columns with few datapoints, computing an hour-of-the-day average as an average of the 50th percentile values for each hour would have allowed the inordinately high—and sometimes low—values in the columns with irregularities to skew the result. To reduce the impact of these anomalous values, the 50th percentile PM_{10} values and ratios were weighted by the numbers of datapoints (hours) within that hour of the day count. This makes sense as the objective is

Table 3-13
Hour of the Day Percentiles of 2012 Monitored PM_{10} at Cowtown Monitor When Wind Speed is Less Than 3.0 m/sec and Wind Directions Are Defined by the Five Wind Direction Arc Scenarios (µg/m^3)

	2012 Base - Hour of the Day																							
%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	28	20	18	20	19	23	26	27	28	24	13	9	9	7	2	7	9	16	23	32	37	30	26	25
20%	42	31	28	26	25	33	38	47	38	40	20	14	11	13	9	9	16	32	30	57	75	52	53	35
30%	51	39	37	34	38	42	51	59	51	46	25	20	13	14	10	15	23	33	36	77	106	70	72	51
40%	59	46	46	41	42	49	59	71	70	61	35	27	16	18	18	16	26	35	53	104	114	91	86	64
50%	68	52	56	45	49	56	69	80	81	66	47	37	18	20	22	18	27	39	78	135	145	108	93	73
60%	76	61	64	52	59	61	79	90	92	72	52	42	23	23	25	23	34	44	107	348	169	120	102	83
70%	86	72	79	61	65	72	89	112	107	82	64	52	38	27	28	29	37	48	131	433	196	140	114	99
80%	102	83	92	69	79	90	114	134	135	95	84	70	43	32	41	34	44	52	172	513	225	168	144	116
90%	147	107	124	91	124	139	158	207	184	114	112	84	49	63	80	36	53	136	367	617	343	230	169	176
100%	488	338	328	206	414	601	634	395	253	201	195	101	126	74	125	43	53	191	402	1087	1376	1099	303	385
Count	164	181	169	163	161	155	152	140	99	81	68	41	24	23	23	16	9	12	19	28	74	108	136	171
	2217	Total																						
	2012 Narrow - Hour of the Day																							
%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	28	20	18	21	19	22	21	27	27	34	11	10	9	12	1	11	8	14	21	37	45	40	30	21
20%	42	31	27	29	23	32	31	41	37	44	17	14	11	14	5	14	9	28	28	66	78	55	53	35
30%	49	43	37	39	35	41	49	57	55	55	23	23	12	15	9	15	12	32	34	86	104	77	67	54
40%	58	47	45	44	42	46	57	71	70	63	31	27	16	17	10	16	16	35	41	128	119	92	85	66
50%	68	54	55	48	49	55	65	81	84	68	45	35	21	19	12	16	21	39	75	185	145	107	95	76
60%	76	66	64	53	59	59	76	104	92	75	52	43	29	22	22	18	23	43	103	372	179	118	103	88
70%	84	73	80	61	65	71	89	119	107	85	61	51	42	26	24	22	26	47	128	491	195	136	116	100
80%	102	86	94	69	79	86	112	137	135	97	84	70	44	28	26	30	32	50	184	567	212	169	144	116
90%	154	142	124	93	119	127	148	214	185	112	101	84	56	64	28	35	43	66	371	680	360	231	169	162
100%	371	338	328	206	370	601	634	321	250	196	165	101	126	73	125	37	53	191	402	1087	1376	1099	303	314
Count	115	121	118	108	113	95	93	97	70	57	43	25	20	12	13	7	5	10	17	22	51	77	102	103
	1494	Total																						
	2012 West - Hour of the Day																							
%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	28	21	22	20	18	30	21	30	34	19	17	10	7	7	7	7	23	32	29	30	57	39	28	18
20%	37	27	32	33	22	34	33	47	40	26	24	15	10	13	9	9	25	33	35	53	81	53	45	26
30%	49	39	42	40	31	44	48	66	63	39	31	17	14	19	10	15	26	33	52	118	111	79	56	32
40%	52	45	51	48	38	52	60	74	86	48	36	22	16	20	18	21	29	38	76	238	133	108	76	42
50%	66	56	56	52	46	59	72	83	98	59	48	26	16	21	26	24	32	46	78	438	148	116	85	56
60%	75	71	67	55	64	67	82	99	107	66	51	33	26	23	28	28	34	48	88	485	171	136	101	67
70%	87	73	82	62	73	78	94	126	136	72	57	45	39	27	29	33	38	50	116	528	212	160	124	91
80%	103	82	123	76	79	102	114	174	184	85	64	60	43	31	54	34	43	52	158	585	289	214	153	123
90%	130	120	171	100	113	184	155	209	211	99	100	73	48	69	91	36	48	108	230	708	343	311	198	178
100%	217	226	224	173	249	304	533	395	250	196	192	101	126	74	125	37	53	191	363	1087	1376	888	303	385
Count	47	39	32	38	37	34	40	52	36	39	27	20	12	12	18	10	4	7	9	17	31	45	38	49
	693	Total																						

Table 3-13 (cont.)
Hour of the Day Percentiles of 2012 Monitored PM_{10} at Cowtown Monitor When Wind Speed is Less Than 3.0 m/sec and Wind Directions Are Defined by the Five Wind Direction Arc Scenarios (µg/m^3)

	2012 East - Hour of the Day																							
%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	29	21	17	20	19	22	27	27	27	42	14	9	11	9	2	8	8	13	23	51	25	24	25	30
20%	42	32	27	26	26	33	40	48	34	47	18	13	11	13	3	14	9	14	26	65	49	55	57	47
30%	54	40	35	32	38	41	51	59	49	61	24	30	14	14	7	15	13	19	32	67	100	70	77	60
40%	62	46	45	39	43	46	58	71	66	66	35	37	17	15	14	16	20	28	42	77	111	86	87	69
50%	68	52	55	44	49	55	69	78	73	71	46	39	21	16	21	16	26	37	79	81	124	98	93	78
60%	77	60	64	51	56	59	78	88	82	78	54	49	22	22	21	16	31	39	118	106	161	110	102	88
70%	86	71	78	60	63	71	88	107	94	87	67	58	33	27	21	18	36	40	136	134	191	126	113	100
80%	98	83	88	69	79	88	113	128	117	102	85	74	42	32	22	19	41	62	202	233	203	150	139	115
90%	160	107	113	85	122	137	158	183	146	125	129	84	48	40	23	31	47	103	386	341	283	171	167	162
100%	488	338	328	206	414	601	634	317	253	201	195	101	126	68	25	43	53	145	402	378	886	1099	250	314
Count	117	143	137	125	124	121	113	88	63	42	41	21	12	11	5	6	5	5	10	11	43	63	98	122
	1526	Total																						
	2012 East+ - Hour of the Day																							
%tile	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
10%	28	20	17	21	19	22	27	27	26	26	12	9	10	10	3	8	9	14	18	58	30	27	30	30
20%	42	32	27	26	25	32	40	47	34	44	18	11	11	14	5	14	10	18	25	67	56	57	57	47
30%	52	40	37	34	38	41	52	59	48	56	24	25	13	15	8	15	15	29	32	79	95	70	78	59
40%	62	47	46	41	43	46	58	70	66	64	34	34	18	17	14	16	21	35	45	106	111	87	86	67
50%	68	53	56	44	50	53	68	79	76	69	42	38	21	21	21	16	23	37	75	135	124	103	95	77
60%	78	62	63	51	58	59	77	92	91	76	52	44	29	23	21	16	26	39	115	233	154	115	103	87
70%	87	72	76	59	63	71	88	110	104	85	66	54	42	27	22	18	32	43	139	360	184	125	114	98
80%	104	83	88	69	78	89	111	132	120	101	84	72	49	30	23	19	38	50	280	392	201	159	143	113
90%	159	107	120	87	119	138	152	203	147	124	112	84	95	38	24	31	46	89	380	512	273	177	167	162
100%	488	338	328	206	414	601	634	317	253	201	195	101	126	68	25	43	53	145	402	580	886	1099	303	314
Count	128	156	152	144	139	137	127	105	79	55	48	23	15	14	7	6	6	7	13	16	47	74	114	133
	1745	Total																						
	2012 50th Percentile Values by Hour of the Day for Different Calculation Methodologies																							
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Base	68	52	56	45	49	56	69	80	81	66	47	37	18	20	22	18	27	39	78	135	145	108	93	73
Nrrw	68	54	55	48	49	55	65	81	84	68	45	35	21	19	12	16	21	39	75	185	145	107	95	76
West	66	56	56	52	46	59	72	83	98	59	48	26	16	21	26	24	32	46	78	438	148	116	85	56
East	68	52	55	44	49	55	69	78	73	71	46	39	21	16	21	16	26	37	79	81	124	98	93	78
East+	68	53	56	44	50	53	68	79	76	69	42	38	21	21	21	16	23	37	75	135	124	103	95	77

Table 3-14
50th Percentile PM_{10} Concentrations Monitored at the Cowtown Station by Hour of the Day and By Wind Direction Arc Scenario for 2008, 2011, and 2012 ($\mu g/m^3$)

	2008 50th Percentile Values of Monitored PM10 by Hour of the Day for Different Wind Arc Scenarios																							
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Base	136	179	154	128	146	183	202	195	122	81	42	42	34	31	26	32	51	60	112	567	251	144	161	182
Nrrw	163	176	133	126	134	192	182	202	122	89	43	46	35	44	26	39	34	39	183	922	277	137	169	210
West	151	172	157	149	146	213	207	224	123	60	49	29	43	29	26	9	51	60	105	763	230	133	161	210
East	127	189	146	118	143	170	144	157	119	82	28	48	30	43	23	38	N/A	285	376	219	340	160	152	119
East+	128	196	128	124	148	172	201	157	121	85	36	46	30	31	42	38	13	88	376	422	397	148	152	145

	2011 50th Percentile Values of Monitored PM10 by Hour of the Day for Different Wind Arc Scenarios																							
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Base	58	52	49	46	45	57	72	100	102	65	39	38	33	27	27	22	56	61	136	157	130	87	90	67
Nrrw	55	53	49	49	47	56	70	103	94	72	38	38	32	25	27	29	62	31	93	122	105	85	93	65
West	56	53	63	51	54	68	76	115	123	74	52	38	34	24	34	34	51	74	174	185	145	98	97	86
East	58	51	47	43	45	52	70	94	73	61	36	38	31	37	26	22	69	47	108	99	105	84	84	63
East+	57	52	47	45	45	58	71	97	84	64	38	38	32	27	26	22	67	41	93	119	115	84	83	64

	2012 50th Percentile Values of Monitored PM10 by Hour of the Day for Different Wind Arc Scenarios																							
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Base	68	52	56	45	49	56	69	80	81	66	47	37	18	20	22	18	27	39	78	135	145	108	93	73
Nrrw	68	54	55	48	49	55	65	81	84	68	45	35	21	19	12	16	21	39	75	185	145	107	95	76
West	66	56	56	52	46	59	72	83	98	59	48	26	16	21	26	24	32	46	78	438	148	116	85	56
East	68	52	55	44	49	55	69	78	73	71	46	39	21	16	21	16	26	37	79	81	124	98	93	78
East+	68	53	56	44	50	53	68	79	76	69	42	38	21	21	21	16	23	37	75	135	124	103	95	77

	Ratio of 2011 to 2008 50th Percentile Values of Monitored PM10 by Hour of the Day for Different Wind Arc Scenarios																							
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Base	43%	29%	32%	36%	31%	31%	35%	51%	83%	81%	92%	90%	97%	87%	102%	68%	112%	100%	121%	28%	52%	60%	56%	37%
Nrrw	34%	30%	37%	39%	35%	29%	38%	51%	77%	80%	89%	83%	89%	56%	102%	74%	183%	80%	51%	13%	38%	62%	55%	31%
West	37%	31%	40%	35%	37%	32%	36%	51%	100%	123%	107%	131%	79%	83%	130%	383%	102%	123%	165%	24%	63%	73%	60%	41%
East	46%	27%	32%	37%	31%	31%	49%	60%	61%	74%	127%	80%	102%	86%	116%	58%	N/A	17%	29%	45%	31%	52%	55%	53%
East+	45%	26%	37%	36%	30%	34%	35%	62%	70%	75%	106%	83%	104%	85%	62%	58%	515%	47%	25%	28%	29%	56%	55%	44%

	Ratio of 2012 to 2008 50th Percentile Values of Monitored PM10 by Hour of the Day for Different Wind Arc Scenarios																							
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Base	50%	29%	36%	35%	34%	30%	34%	41%	66%	82%	111%	87%	54%	65%	81%	57%	54%	65%	69%	24%	58%	75%	58%	40%
Nrrw	42%	31%	41%	38%	37%	28%	36%	40%	69%	76%	105%	76%	58%	44%	47%	42%	61%	100%	41%	20%	52%	78%	56%	36%
West	43%	33%	36%	35%	31%	27%	35%	37%	80%	98%	98%	89%	38%	73%	97%	272%	62%	75%	74%	57%	64%	87%	53%	27%
East	54%	27%	37%	37%	35%	32%	48%	50%	61%	86%	165%	82%	67%	39%	93%	42%	N/A	13%	21%	37%	37%	61%	61%	65%
East+	53%	27%	44%	36%	34%	31%	34%	51%	63%	82%	115%	83%	68%	68%	50%	42%	180%	43%	20%	32%	31%	69%	62%	53%

to compute the average change in PM_{10} concentration over all of the datapoints recorded, and not discount the contributions of large numbers of datapoints by virtue of their densities within the hours of the day recording high frequencies of winds blowing toward the monitor.

The hour-of-the-day average 50th percentile PM_{10} concentrations for each arc scenario in each of 2011 and 2012, using an unweighted average-of-hour-percentile method and an hourly count-weighted method for averaging, are displayed in Table 3-15.

Table 3-15
Hour of the Day Average 50th Percentile PM_{10} Concentration

Arc Scenario	Unweighted Avg. ($\mu g/m^3$)	Weighted Avg. ($\mu g/m^3$)	Fraction of Weighted 2008 Value
2008 Monitored PM_{10}			
Base	136	162	N/A
Narrow	155	162	N/A
West	146	172	N/A
East	142	149	N/A
East+	143	159	N/A
2011 Monitored PM_{10}			
Base	67	69	42%
Narrow	62	66	41%
West	77	82	48%
East	60	62	41%
East+	61	64	40%
2012 Monitored PM_{10}			
Base	62	67	41%
Narrow	63	69	43%
West	75	77	45%
East	58	65	44%
East+	60	66	41%

Focusing on the "East+" data, the contributions of non-PFE sources to PM_{10} concentrations recorded at the Cowtown monitor in 2008 under the specified meteorological conditions were computed to be 40% in 2011, the year in which sources emitting within the prescribed arc most resembled those impacting the monitor in 2008. Applying this reduction factor to the weighted average 50th percentile PM_{10} concentration of 159 $\mu g/m^3$ for the "East+" scenario produces an adjusted monitored 50th percentile PM_{10} concentration at the Cowtown monitor of 95.4 $\mu g/m^3$ resulting solely from PFE facility emissions in 2008 under the specified meteorological conditions.

For 24-hour attainment demonstration purposes, the hour-of-the-day PM_{10} emission rates for the PFE facility were calculated using this general approach. The 50th percentile PM_{10} concentrations monitored in 2008 at the Cowtown station and computed on an hour-of-the-day basis under the different arc scenarios were reduced by the weighted fractions shown in Table 3-15 for the 2011 monitored data. The weighted fractions were applied uniformly across all hours of the day, in the absence of accurate hour-specific reduction fractions, and the resulting adjusted 2008 monitoring data were compared to the 2008 modeling results for the PFE facility configured with a unit emission rate. The resulting ratios between modeled 50th percentiles and adjusted-monitored 50th percentiles were inverted and multiplied by the unit emission rate (1.0 gm/sec) to derive hour of the day 50th percentile emission rates for the PFE facility in 2008. The results of these calculations are presented in Table 3-16.

The first table in Table 3-16 shows the 50th percentile values of all 2008 monitored PM_{10} concentrations that remained after filtering for the specified meteorological conditions in each arc scenario. The second table shows the same data reduced by the weighted fractions of 2011 to 2008 monitored PM_{10} data by arc scenario shown in Table 3-15. The third table in Table 3-16 presents the 50th percentile PM_{10} concentrations reported by the modeling of PFE emissions when configured with a unit emission rate. The fourth table displays the ratios of the 50th percentiles of PFE modeled impacts to adjusted 2008 monitoring PM_{10} concentrations. Finally, the fifth table shows the unit emission rate multiplied by the inverse of the ratios contained in the fourth table. These data in the fifth table represent the 50th percentile PM_{10} emissions rates by hour of the day under each of the five wind arc scenarios for the PFE facility in 2008. A diurnal plot of the hourly PM_{10} emissions rates in different groupings of wind arc scenarios is shown in the upper half of Figure 3-3.

The 50th percentile PM_{10} emissions rates by hour of the day were converted to daily emissions factors by averaging the hourly values over the 24-hour diurnal period, converting the 24-hour average from units of g/sec to g/day, and then dividing the 24-hour emission rate by the number of cattle housed in the PFE facility in 2008. The number of cattle housed in 2008 was reported by Pinal Feeding Company representatives to have been 18,900 head. The resulting PFE PM_{10} emissions rates in units of pounds of PM_{10} emitted per head-day are tabulated in Table 3-17.

Given the close correspondence of the annual per-head-day emission rate calculated under the East and East+ scenarios in this analysis to that published by Bonifacio, use of either of these factors is recommended for attainment demonstration purposes in western Pinal County. Because of the apparent lower interference of non-PFE area sources in the East versus East+ scenario analyses, the East scenario factor of 0.064 lb/head-day was selected for use in modeling at the Cowtown monitor.

Table 3-16
Calculation of Adjusted PFE Facility PM_{10} Emissions Rates in 2008 by Hour of the Day and by Wind Direction Arc Scenario

	2008 50th Percentile Values of Monitored PM10 by Hour of the Day for Different Wind Arc Scenarios, ug/m3																							
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Base	136	179	154	128	146	183	202	195	122	81	42	42	34	31	26	32	51	60	112	567	251	144	161	182
Nrrw	163	176	133	126	134	192	182	202	122	89	43	46	35	44	26	39	34	39	183	922	277	137	169	210
West	151	172	157	149	146	213	207	224	123	60	49	29	43	29	26	9	51	60	105	763	230	133	161	210
East	127	189	146	118	143	170	144	157	119	82	28	48	30	43	23	38	N/A	285	376	219	340	160	152	119
East+	128	196	128	124	148	172	201	157	121	85	36	46	30	31	42	38	13	88	376	422	397	148	152	145

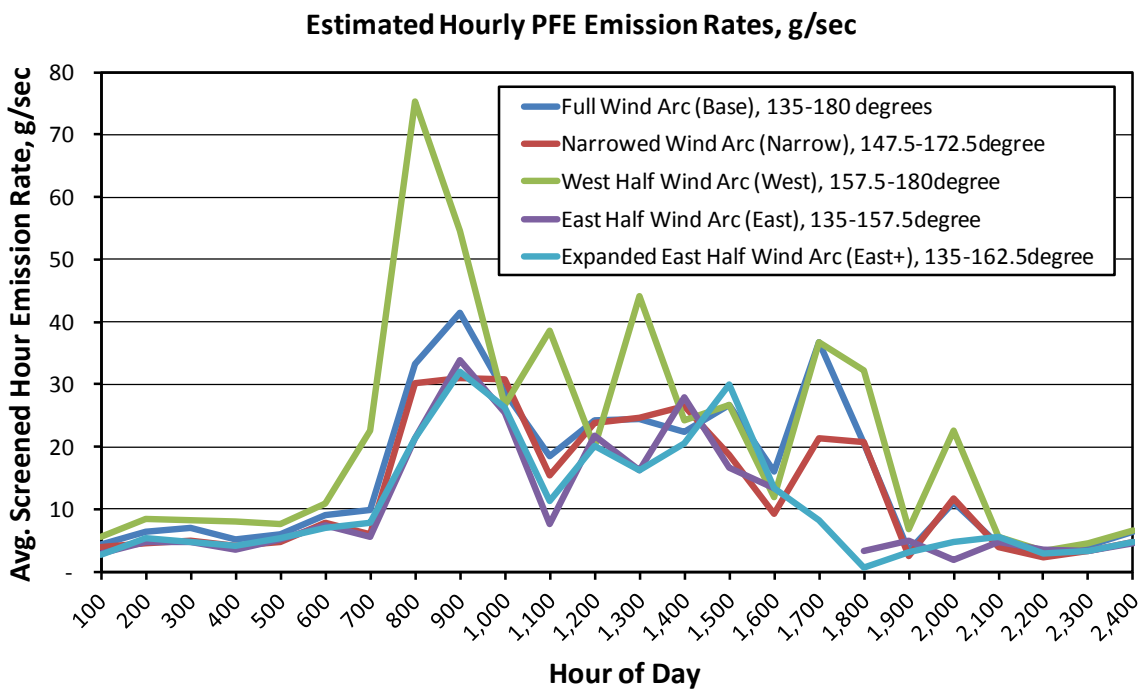
	2008 50th Percentile Values of Monitored PM10 by Hour of the Day Adjusted for Other Source Emissions Under Different Wind Arc Scenarios, ug/m3																							
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Base	78	103	89	74	84	105	116	112	71	47	24	24	19	18	15	19	29	35	65	327	144	83	93	105
Nrrw	96	104	78	74	79	113	107	120	72	53	25	27	21	26	16	23	20	23	108	544	163	81	100	124
West	79	89	82	78	76	111	108	117	64	31	25	15	22	15	14	5	26	32	55	398	120	69	84	109
East	74	111	86	69	84	99	84	92	70	48	16	28	18	25	13	22	N/A	167	220	128	199	94	89	70
East+	77	117	77	74	88	103	120	94	72	51	22	28	18	19	25	23	8	52	225	252	238	89	91	87

	2008 50th Percentile Values of Modeled PM10 at Unit Emissions Rates by Hour of the Day for Different Wind Arc Scenarios, ug/m3																							
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Base	32	28	22	25	24	20	20	6	3	3	2	2	1	1	1	2	1	3	34	51	57	45	39	29
Nrrw	41	39	26	30	28	25	30	7	4	3	3	2	1	2	1	4	2	2	76	79	69	61	51	45
West	27	20	19	18	19	20	9	3	2	2	1	1	1	1	1	1	1	2	16	34	41	41	36	32
East	41	39	28	33	27	23	26	7	3	3	4	2	2	2	1	3	N/A	86	76	122	71	46	42	26
East+	47	36	27	30	27	24	25	7	4	3	3	2	2	2	1	3	2	130	119	87	71	52	46	30

	Ratio of 2008 Modeled to Adjusted Monitored 50th Percentile PM10 Values by Hour of the Day for Different Wind Arc Scenarios																							
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Base	40%	27%	25%	34%	29%	19%	17%	5%	4%	6%	9%	7%	7%	8%	6%	11%	5%	8%	52%	16%	39%	54%	42%	28%
Nrrw	43%	38%	33%	41%	35%	22%	28%	6%	5%	5%	11%	7%	7%	6%	9%	18%	8%	8%	70%	15%	42%	75%	51%	36%
West	35%	23%	23%	24%	25%	18%	9%	3%	4%	7%	5%	10%	4%	8%	7%	16%	5%	6%	28%	8%	34%	59%	43%	29%
East	56%	35%	33%	48%	33%	23%	31%	8%	5%	7%	23%	8%	11%	6%	10%	13%	N/A	52%	35%	95%	35%	48%	48%	37%
East+	61%	31%	35%	41%	31%	24%	21%	8%	5%	6%	15%	8%	10%	8%	6%	13%	20%	249%	53%	34%	30%	59%	51%	35%

	Adjusted PM10 Emissions Rates for PFE Facility by Hour of the Day for Different Wind Arc Scenarios, g/sec																							
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Base	2.5	3.7	4.1	3.0	3.4	5.2	5.7	19.2	24.0	16.6	10.7	14.0	14.1	13.0	15.4	9.2	21.2	11.8	1.9	6.4	2.5	1.8	2.4	3.6
Nrrw	2.3	2.6	3.0	2.5	2.8	4.6	3.5	17.8	18.3	18.2	9.1	14.0	14.5	15.7	11.0	5.5	12.7	12.3	1.4	6.9	2.4	1.3	2.0	2.8
West	2.9	4.4	4.3	4.2	3.9	5.7	11.7	39.3	28.5	13.9	20.2	10.4	23.1	12.6	14.0	6.3	19.2	16.8	3.5	11.8	2.9	1.7	2.3	3.5
East	1.8	2.8	3.0	2.1	3.1	4.3	3.2	13.2	20.1	15.3	4.4	13.0	9.5	16.3	9.8	7.8	N/A	1.9	2.9	1.1	2.8	2.1	2.1	2.7
East+	1.6	3.3	2.8	2.4	3.2	4.2	4.7	12.7	19.2	15.7	6.7	12.1	9.7	12.3	17.9	8.0	4.9	0.4	1.9	2.9	3.4	1.7	2.0	2.9

Figure 3-3
Plots of Adjusted PFE Facility PM_{10} Emissions Rates in 2008 by Hour of the Day and by Diurnal Profile Method



Estimated Hourly PFE Emission Rates, g/sec
Best Wind Direction Arc Scenario and ACFA Activity-Based Estimates

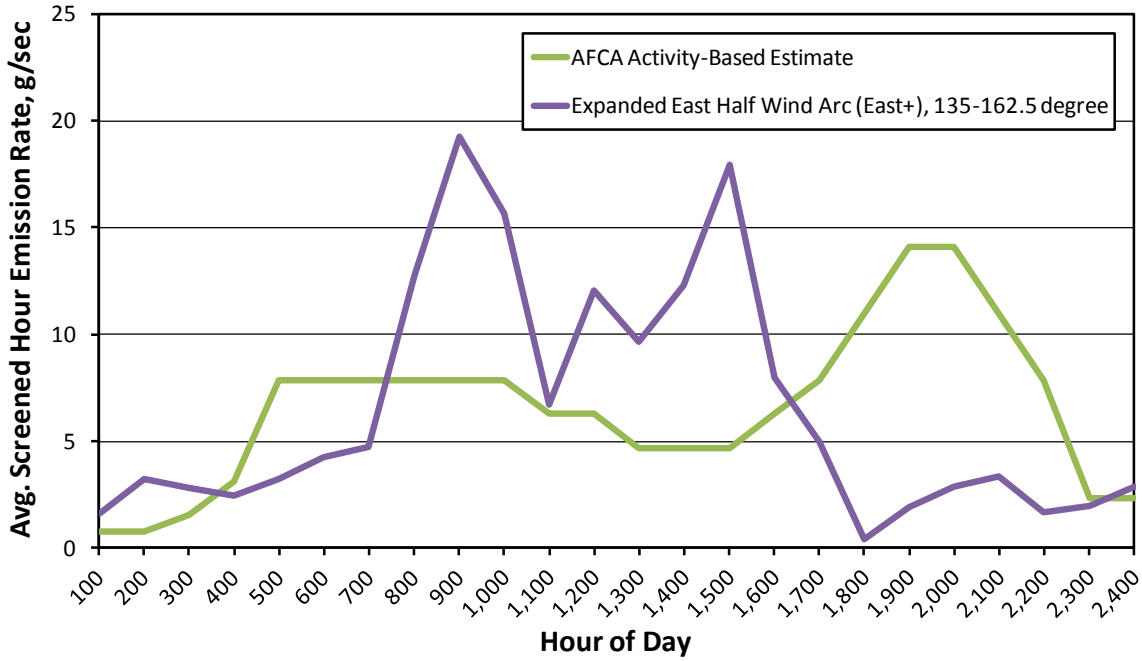


Table 3-17 2008 PFE PM_{10} Emissions Rates by Wind Arc Scenario				
Scenario	PM_{10} Emission Rate or Factor			Fraction of Bonifacio E.F.
	g/sec	lb/day	lb/head-day	
Base	9.0	1,708.8	0.090	144%
Narrow	7.8	1,486.0	0.079	125%
West	11.1	2,120.1	0.112	179%
East	6.3	1,204.4	0.064	101%
East+	6.5	1,243.5	0.066	105%

All of the wind direction arc scenarios evaluated produced somewhat anomalous median values of monitored and modeled data in the hour-of-the-day bins from 1500 through 1900 hours because of the paucity of days (e.g., n = 3 to 6) in 2008 during which the selected meteorological conditions were satisfied during these hours. As a result, concern was expressed by representatives of the Arizona Cattle Feeders Association (ACFA) with respect to the diurnal profile of hourly feedlot emission rates produced by this analysis.

In response to a request for an alternative profile recommended by the industry, the Association provided a diurnal profile that is shown in Table 3-18.[30] The ACFA profile is based on Pinal Feeding Company records of operations in 2008, visual observations by facility staff during 2008, and the technical judgment of ACFA staff. For comparison purposes, the profile produced by the East+ scenario is also shown in Table 3-18.

Because the diurnal profiles that were calculated from the Cowtown monitoring data analysis suffered from statistical uncertainty due to the small numbers of datapoints in the 1500 through 1900 hour bins, the activity-based diurnal profiles of feedlot PM_{10} emissions recommended by ACFA were used in the attainment demonstration modeling at the Cowtown monitor and at other monitors where feedlots were found in affiliated modeling domains. A comparison of the hourly emission rates for the PFE facility using the ACFA and the reverse dispersion modeling diurnal profiles appears in the lower half of Figure 3-3.

[30] "Estimate of Approximate Hourly Percentage Activity in Pinal County Feed Yards, Late October", Bas Aja, Arizona Cattle Feeders Association, August 27, 2013, as amended by Bas Aja in telecom on October 23, 2013.

Table 3-18 Diurnal Profiles of Feedlot PM_{10} Emissions (Percent of Daily Emissions)		
Hour	Initial ACFA Activity-Based Assessment	Cowtown Monitoring Data Assessment
0100	1.0%	1.0%
0200	1.0%	2.1%
0300	1.0%	1.8%
0400	2.0%	1.6%
0500	5.0%	2.1%
0600	5.0%	2.7%
0700	5.0%	3.0%
0800	5.0%	8.1%
0900	5.0%	12.3%
1000	5.0%	10.0%
1100	4.0%	4.3%
1200	4.0%	7.7%
1300	3.0%	6.2%
1400	3.0%	7.8%
1500	3.0%	11.4%
1600	4.0%	5.1%
1700	5.0%	3.2%
1800	7.0%	0.3%
1900	8.0%	1.2%
2000	8.0%	1.9%
2100	7.0%	2.1%
2200	5.0%	1.1%
2300	2.0%	1.3%
2400	2.0%	1.8%

The hourly emission rates for feedlots were also disaggregated into hourly rates for each of four contributory emission sources or activities deemed in the literature to constitute the vast majority of facility emissions. These contributory sources or activities are identified by the Governor's Agricultural Best Management Practices Committee (BMP Committee) as:

a) unpaved access connections;
b) unpaved roads or feed lanes;
c) animal waste handling and transportation; and
d) arenas, corrals, and pens.[31]

[31] Agricultural Best Management Practices for Livestock Operations, Governor's Agricultural Best Management Practices Committee, July 27, 2010.

This report also cites the San Joaquin Valley Air Pollution Control District (San Joaquin Valley) as the source of emission factors for these individual sources. The San Joaquin Valley report that is identified in the BMP Committee citation is the 2006 technical support document evaluating control measures for all agricultural and feedlot operations regulated by the Valley's Rule 4550 (Conservation Management Practices).[32] This report identified the four contributory emission sources or activities as:

a) unpaved areas;
b) unpaved roads;
c) overall management/feeding; and
d) pens/manure handling.

The San Joaquin Valley also estimated the fractional contributions of these sources to total facility emissions as follows: unpaved areas – 5%, unpaved roads – 15%, overall management/feeding – 5%, and pens/manure handling – 75%. These fractions were estimated from visual observations of feedlots operations and engineering judgment.

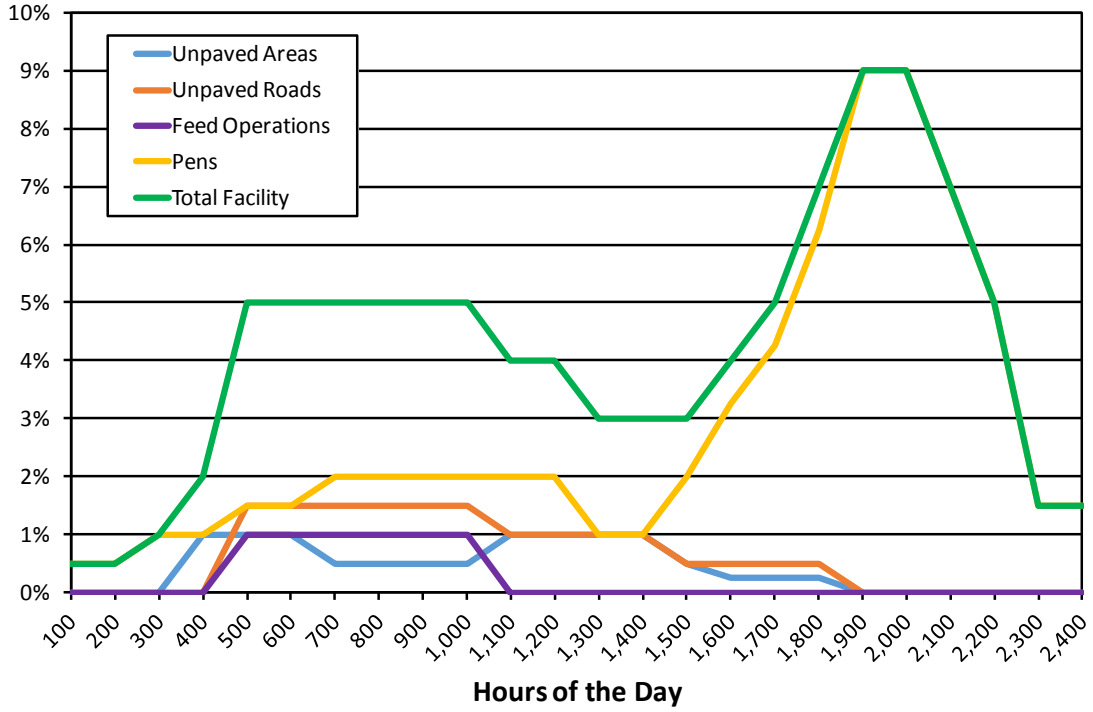
Information from the BMP Committee's report, the San Joaquin Valley report, and discussions with ACFA representatives was used to estimate hourly emission profiles for the four contributory sources. The emission profiles were initially designed to sum to the 24-hour total emission contribution fractions estimated in the San Joaquin Valley report, but the resulting hourly emission totals for the four sources—using the San Joaquin Valley source groups and underlying assumptions of activity—did not reconcile with the hourly activity-based emission profile for a whole facility as initially estimated by ACFA representatives. In a subsequent analysis, emission profiles for the four contributory sources were adjusted to reconcile with the ACFA whole facility profile without regard to the fractional contributions estimated by San Joaquin Valley. The results of this analysis were shared with an ACFA representative and, with minor adjustments, were accepted on behalf of ACFA as approximating the hourly profiles of the sources or activities contributing to total feedlot PM_{10} emissions on an average day in October, the month represented by the Cowtown stagnation design day. The adjustments suggested by ACFA reduced activity estimates in hours 0100, 0200, 2300, and 2400, and increased activity estimates in hours 1900 and 2000. A tabulation of the hourly fractional contributions of these sources to daily total feedlot emissions, together with the hourly profile of total feedlot emissions, recommended by ACFA is presented in Table 3-19. Note in the "Total" row at the bottom of Table 3-19 that the individual sources contribute the following fractions of 24-hour total facility emissions: unpaved areas – 10.25%, unpaved roads – 15.00%, feed operations – 6.00%, and pens – 68.75%. A plot of the diurnal profiles of the contributory source emission factors (in g/sec-head) and of the total facility emission factors is shown in Figure 3-4.

[32] Conservation Management Practices Program Report for 2005, San Joaquin Valley Air Pollution Control District, January 19, 2006.

Table 3-19
Diurnal Profiles of Contributory Sources and Total Feedlot PM_{10} Emissions
(Percent of Total Daily Facility Emissions)

Hour	Final ACFA Activity-Based Estimate				
	Unpaved Areas	Unpaved Roads	Feed Operations	Pens	Total
0100	0.00%	0.00%	0.00%	0.50%	0.50%
0200	0.00%	0.00%	0.00%	0.50%	0.50%
0300	0.00%	0.00%	0.00%	1.00%	1.00%
0400	1.00%	0.00%	0.00%	1.00%	2.00%
0500	1.00%	1.50%	1.00%	1.50%	5.00%
0600	1.00%	1.50%	1.00%	1.50%	5.00%
0700	0.50%	1.50%	1.00%	2.00%	5.00%
0800	0.50%	1.50%	1.00%	2.00%	5.00%
0900	0.50%	1.50%	1.00%	2.00%	5.00%
1000	0.50%	1.50%	1.00%	2.00%	5.00%
1100	1.00%	1.00%	0.00%	2.00%	4.00%
1200	1.00%	1.00%	0.00%	2.00%	4.00%
1300	1.00%	1.00%	0.00%	1.00%	3.00%
1400	1.00%	1.00%	0.00%	1.00%	3.00%
1500	0.50%	0.50%	0.00%	2.00%	3.00%
1600	0.25%	0.50%	0.00%	3.25%	4.00%
1700	0.25%	0.50%	0.00%	4.25%	5.00%
1800	0.25%	0.50%	0.00%	6.25%	7.00%
1900	0.00%	0.00%	0.00%	9.00%	9.00%
2000	0.00%	0.00%	0.00%	9.00%	9.00%
2100	0.00%	0.00%	0.00%	7.00%	7.00%
2200	0.00%	0.00%	0.00%	5.00%	5.00%
2300	0.00%	0.00%	0.00%	1.50%	1.50%
2400	0.00%	0.00%	0.00%	1.50%	1.50%
Total	10.25%	15.00%	6.00%	68.75%	100.00%

Figure 3-4
Feedlot Total and Contributory Source Hourly Fractions of Daily Emission Total (%)



3.1.3 On-Road Mobile Source Emissions Modeling for Paved Roads

As part of a larger emissions inventory effort for the Pinal County PM_{10} SIP modeling project, on-road mobile source emissions were modeled for five episode days in the year 2008. Episodic emissions are created from MOVES 2010b simulations in the emission rates mode using county-wide inputs configured with local data where available. The PM_{10} emission rates for exhaust, tire, and brake were then integrated into a lookup table in a spreadsheet containing link-specific Travel Demand Model (TM) outputs from the Arizona Travel Demand Model versions 2 (AZTDM2)[33] for Pinal County in 2008. Emissions due to fugitive dust and bow wake were also calculated for these links based on formulas used in the Maricopa Association of Government's 2007 and 2012 Five Percent Plans.[34,35] In addition to the exhaust, brake, and tire emissions, the paved-road vehicle emissions were distributed spatially to specific links within the different dispersion modeling domains. Configuration of the MOVES model for this work

[33] "Development of the Arizona Statewide Travel Demand Model: Phase 2 (AZTDM2)" by Parsons Brinckerhoff for Arizona Department of Transportation, September 19, 2011. Accessed from f*tp://ftp.azdot.gov/AZTDM2/AZTDM2 Model Documentation v8.pdf* on July 23, 2013.
[34] "Cost-Effectiveness of Selected PM_{10} Control Measures," prepared for Maricopa Association of Governments by Sierra Research, June 2006 p. 26.
[35] "MAG 2012 Five Percent Plan For PM-10 for the Maricopa County Nonattainment Area," Maricopa Association of Governments, March 2012, Appendix A, section 5.3, p. 117-119.

required formatting of the data to a MOVES compatible format and extrapolation of the available data sources. These operations are detailed in the following sections.

MOVES Configuration – Described below are the inputs used in configuring the MOVES model for the creation of episode-specific emission rates tables.

Average Speed Distribution – MOVES requires speed distribution information organized by vehicle types, road types, and hours. Speed must be translated into one of 16 speed bins in the process of creating this input field. Table 3-20[36] shows the relationship between the 16 speed bins and the average speed and speed ranges.

Table 3-20
MOVES Speed Bins

Speed Bin ID	Average Bin Speed	Speed Bin Range
1	2.5	speed < 2.5 mph
2	5	2.5 mph <= speed < 7.5 mph
3	10	7.5 mph <= speed < 12.5 mph
4	15	12.5 mph <= speed < 17.5 mph
5	20	17.5 mph <= speed < 22.5 mph
6	25	22.5 mph <= speed < 27.5 mph
7	30	27.5 mph <= speed < 32.5 mph
8	35	32.5 mph <= speed < 37.5 mph
9	40	37.5 mph <= speed < 42.5 mph
10	45	42.5 mph <= speed < 47.5 mph
11	50	47.5 mph <= speed < 52.5 mph
12	55	52.5 mph <= speed < 57.5 mph
13	60	57.5 mph <= speed < 62.5 mph
14	65	62.5 mph <= speed < 67.5 mph
15	70	67.5 mph <= speed < 72.5 mph
16	75+	72.5 <= speed

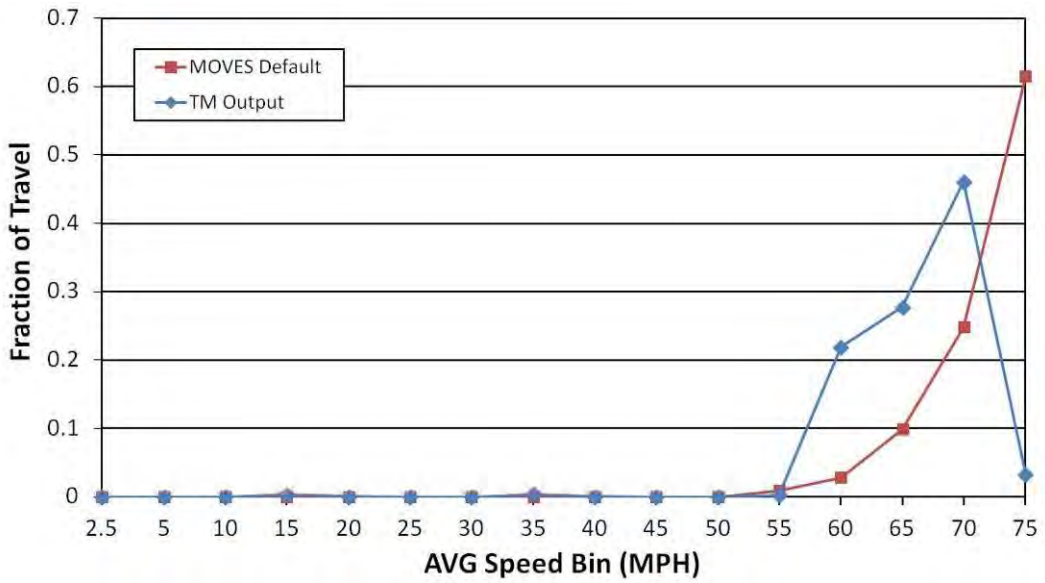
Outputs from the travel demand model were used to determine hourly, road-type specific speed distributions for Pinal County. ADOT provided a spreadsheet summarizing the speed fractions on four different road types between 2.5 and 65 mph for each hour

[36] This table was reproduced from the Technical Guidance on the Use of MOVES2010 for Emission Inventory Preparation in State Implementation Plans and Transportation Conformity, Transportation and Regional Programs Division Office of Transportation and Air Quality U.S. Environmental Protection Agency, EPA-420-B-09-042 December 2009, page 26, Table 3.6.

calculated on a VMT basis.[37] This sheet was modified to capture the speed data contained in the travel model out to 75 mph and to use VMT-based calculations for the speed fractions. For Pinal County, these same speed profiles were used across both weekends and weekdays for all vehicle source types.

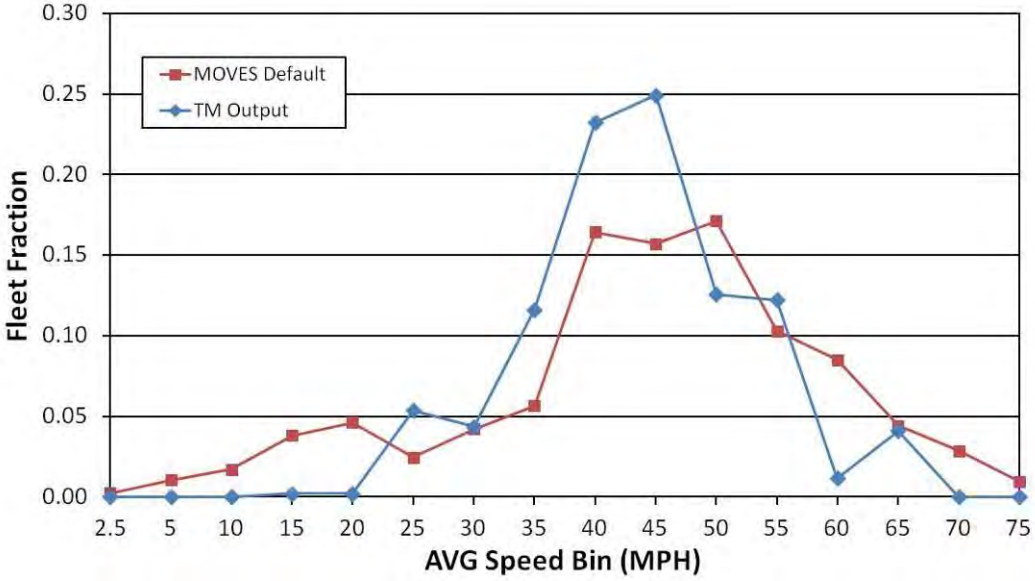
Comparisons were made among the travel model developed speed distribution fields and MOVES default values. The MOVES model contains default speed distributions that are representative of average national trends, but may fail to capture local conditions. Figures 3-5 and 3-6 plot the speed distributions for rural restricted (Figure 3-4) and rural unrestricted (Figure 3-5) peak PM traffic hours across all vehicle types.

Figure 3-5
Distribution of Speeds on Rural Restricted Roads for MOVES Default and TM Outputs for Pinal County



[37] Spreadsheet "ADOT Speed Calculator for Pinal.xlsx" was downloaded on March 6, 2013, from ftp://ftp.azdot.gov/MPDAirQuality/Sierra Research/ADOT MOVES Calculation for Pinal/.
A revised spreadsheet "ADOT Speed Calculator for Pinal_fixed.xlsx" was accessed on May 7, 2013.

Figure 3-6
Distribution of Speeds on Rural Unrestricted Roads for MOVES Default and TM Outputs for Pinal County



The TM output speed distribution for the restricted rural roads (interstates) appears to show slightly slower maximum speeds thanthe MOVES defaults during peak hours. However, the MOVES defaults and TM appear to generally show agreement for both of the rural restricted and unrestricted. Because the TM speed distribution outputs are link specific, they were ultimately favored over the MOVES defaults, which do not capture link-level activity. In order to best model the activity in the modeling domains, the link-level activity is necessary but it is unavailable from MOVES.

VMT Calculations – Total countywide Vehicle Miles Traveled (VMT) was supplied in a spreadsheet from ADOT that split out the VMT data into Functional Classes of roads. TM output VMT data was converted to Highway Performance Monitoring System (HPMS) Vehicle Type IDs using vehicle registration data.[38] As an example, the TM group "auto" contains both motorcycles and passenger cars. The total VMT for auto was split into HPMS Vehicle types 10 and 20 based on the population totals for motorcycles and passenger cars. The TM did not contain any VMT data for buses, meaning that HPMS vehicle type 40 is empty in the daily VMT splits from the TM. The AZTDM2 model accounts for travel generated within the county and outside of the county: intrastate, interstate, and international.[39]

[38] Spreadsheet "VMT_Summary_2008_with_FunctionalClass.xlsx" was attached in an e-mail correspondence from Ashim Garg (*AGarg@azdot.gov*) to Beverly Chenausky (*bchenausky@azdot.gov*) on February 14, 2013, and forwarded to Bryan Paris (*Paris.Bryan@azdeq.gov*) on February 15, 2013.
[39] "Development of the Arizona Statewide Travel Demand Model: Phase 2 (AZTDM2)" by Parsons Brinckerhoff for Arizona Department of Transportation, September 19, 2011, p 108. Accessed from *ftp://ftp.azdot.gov/AZTDM2/AZTDM2 Model Documentation v8.pdf* on July 23, 2013.

Table 3-21 shows the different stages of calculation used to develop the HPMS Vehicle Type annual VMT input for the MOVES model. The column titled "Daily VMT Splits" shows the final numbers for each of these vehicle types. The column titled "Daily VMT HPMS Normalized" shows the data from the TM that was normalized to the HPMS county VMT totals with one exception. The bus VMT was calculated to be a population-based fraction of the total HPMS VMT as presented in Table 7 of the *sourcetypepopulation* section. The total VMT was then normalized to the HPMS daily VMT. The VMT for each of the vehicle types was then normalized to the HPMS VMT total and multiplied by 365 to calculate the annual totals.

Table 3-21
VMT Input Calculations for MOVES
Daily VMT HPMS Normalized

HPMSVtypeID	Description	Daily VMT Splits (TM & Pop)	Daily VMT HPMS Normalized	Annual VMT
10	Motorcycle	371,732	352,027	128,489,979
20	Passenger Cars	6,907,913	6,541,738	2,387,734,442
30	Other 2 axle-4 tire Vehicles	276,466	261,811	95,561,076
40	Buses	0	25,141	9,176,297
50	Single Unit Trucks	339,733	321,725	117,429,583
60	Combination Trucks	226,480	214,475	78,283,250
Total		8,122,324	7,716,917	2,816,674,626

Hourly Fractions – Hourly VMT fractions were calculated using TM output data supplied by ADOT.[40] The temporal resolution of TM outputs is coarser than that required by MOVES. TM activity data are lumped in AM (morning peak), MD (midday off-peak), PM (afternoon peak), and NT (night and early morning off-peak) while MOVES requires hour specific data. VMT data for an hour group are translated into a MOVES hour ID using the default hourly VMT fractions in MOVES. As an example for a given hour in the AM group, the calculation would proceed as follows:

$$F_{hr} = \frac{VMT_{AM}}{VMT_{DAY}} * \frac{F(default)_{hr}}{\sum_{7}^{9} F(default)_{i}}$$

[40] Spreadsheet "ADOT Hourly VMT Calculator for Pinal.xlsx" was downloaded on March 6, 2013, from ftp://ftp.azdot.gov/MPDAirQuality/Sierra Research/ADOT MOVES Calculation for Pinal/.

where:

F_{hr} = hourly VMT fraction for an hour in the AM group
$F(default)_{hr}$ = default fractional hourly VMT at a given hour in MOVES
i = ranges from the start to end hour ID of an hour group containing hr
VMT_{AM} = VMT for the AM time group from the TM
VMT_{DAY} = VMT summed for the entire day from the TM

The mapping between the TM hour groups, MOVES hour ID, and actual time of day is shown in Table 3-22. For example, the first hour in the AM group is MOVES hour ID 7 which covers 6AM to 9AM in real time.

Table 3-22
Mapping of Travel Model Hour Groups to MOVES Hour ID

Travel Model Hour Groups	MOVES Hour ID	Time of Day
AM	7 – 9	6AM to 9AM
MD	10 – 15	9AM to 3PM
PM	16 – 18	3PM to 6PM
NT	19 – 24 ; 1 – 6	6PM to 12AM; 12AM to 6AM

In Table 3-23, the VMT fractions for each MOVES hour ID are shown along with the fractions that hour contributes to its given hour group from the TM. The hour group fractions show the hourly VMT fractions within one of the four TM hour groups. The hourVMTFraction column should sum to 1.0 for a given day while the Hour Group Fractions sum to 1.0 over each of the hour groups.

Table 3-23 Hourly VMT Fractions by TM Hour Groups			
hourID	hourVMTFraction	TM Hour Group	Hour Group Fractions
1	0.007866	NT	0.03373
2	0.007409	NT	0.031769
3	0.007318	NT	0.031376
4	0.008964	NT	0.038436
5	0.017014	NT	0.07295
6	0.055951	NT	0.239906
7	0.072766	AM	0.380673
8	0.064408	AM	0.336947
9	0.053977	AM	0.28238
10	0.052518	MD	0.147729
11	0.056603	MD	0.159219
12	0.059132	MD	0.166332
13	0.055533	MD	0.15621
14	0.058159	MD	0.163596
15	0.073559	MD	0.206914
16	0.089866	PM	0.408254
17	0.084430	PM	0.383559
18	0.045827	PM	0.208187
19	0.035582	NT	0.152568
20	0.028173	NT	0.120799
21	0.024148	NT	0.103542
22	0.017745	NT	0.076088
23	0.013172	NT	0.056478
24	0.009879	NT	0.042358

Road Type Distribution – A spreadsheet containing HPMS data broken down into functional class for Arizona and individual counties was used to calculate the road type distribution for Pinal County. Table 3-24 shows HPMS functional classes mapped to MOVES Road Type ID. The RoadTypeDistribution input values are determined by the sum of the VMT fractions the Functional Classes (FCs) that fall under a given RoadTypeID. For example the roadTypeVMTFraction of roadTypeID 5 (urban unrestricted access) would be the sum of FC14, FC16, FC17 and FC19 divided by the total VMT over all functional classes. These VMT fractions are reported across all sourceTypeIDs and so the roadtypeVMTfractions do not vary by vehicle types.

Table 3-24 Functional Class to Road Type Mapping			
Functional Class (FC)	FC Description	Road Type ID	Road Type Description
FC1	Rural Principal Arterial - Interstate	2	Rural Restricted Access
FC2	Rural Principal Arterial - Other	3	Rural Unrestricted Access
FC6	Rural Minor Arterial	3	Rural Unrestricted Access
FC7	Rural Major Collector	3	Rural Unrestricted Access
FC8	Rural Minor Collector	3	Rural Unrestricted Access
FC9	Rural Local	3	Rural Unrestricted Access
FC11	Urban Principal Arterial- Interstate	4	Urban Restricted Access
FC12	Urban Principal Arterial- Other Fwys & Expwys	4	Urban Restricted Access
FC14	Urban Principal Arterial - Other	5	Urban Unrestricted Access
FC16	Urban Minor Arterial	5	Urban Unrestricted Access
FC17	Urban Collector	5	Urban Unrestricted Access
FC19	Urban Local	5	Urban Unrestricted Access

Table 3-25 shows the final distributions of road types on a VMT basis.

Table 3-25 Road Type VMT Distributions		
roadTypeID	roadTypeVMTFraction	Road Type Description
1	0.0000	Off-network
2	0.3792	Rural Restricted
3	0.3457	Rural Unrestricted
4	0.0837	Urban Restricted
5	0.1913	Urban Unrestricted

Source Type Population – ADOT supplied vehicle registration information broken down by Source Type ID.[41] This information was used as is for the MOVES importer inputs. As shown in Table 3-26, the total population count for 2008 is 272,530.

[41] Spreadsheet "ADOT MVD_Registration Converter for Pinal.xlsx" was downloaded on March 6, 2013, from ftp://ftp.azdot.gov/MPDAirQuality/Sierra Research/ADOT MOVES Calculation for Pinal/.

Table 3-26 Vehicle Population for Pinal County 2008			
yearID	sourceTypeID	Source Description	sourceTypePopulation
2008	11	Motorcycle	8,243
2008	21	Passenger Car	153,180
2008	31	Passenger Truck	81,887
2008	32	Light Commercial Truck	26,447
2008	41	Intercity Bus	17
2008	42	Transit Bus	52
2008	43	School Bus	819
2008	51	Refuse Truck	28
2008	52	Single Unit Short-haul Truck	952
2008	53	Single Unit Long-haul Truck	72
2008	54	Motor Home	80
2008	61	Combination Short-haul Truck	430
2008	62	Combination Long-haul Truck	324
TOTAL			272,530

Source Type Age Distribution – Vehicle age distributions were supplied by ADOT from vehicle registration data for the year 2012 in Pinal County, broken out by specific vehicle classes.[42] These vehicle classes were mapped into MOVES source type IDs and the age distributions were calculated as fractions of registered vehicles for a given year divided by the sum total of vehicles in that class over all years. The years were translated into an equivalent ageID as dictated by the MOVES formatting requirements. The ageID is defined as the difference between the registration year and the year being modeled (2008 – registration year). The MOVES model requires age fractions for the age IDs between 0 and 30. It is assumed that the same source type age distribution will be maintained between the years 2008 and 2012.

Meteorology – The met conditions were imported as hourly temperature and relative humidity data from Casa Grande for each of the model episodes: January 1, April 27, October 27, October 29, and November 20.[43]

Monthly VMT Fractions – MOVES 2010b default values were used for this input field.

Fuel Supply – MOVES 2010b default values were used for this input field.

[42] Original spreadsheet "MOBILE6 REG DIST CALC 2008 for Pinal.xlsx" was downloaded on March 6, 2013, from ftp://ftp.azdot.gov/MPDAirQuality/Sierra Research/ADOT MOVES Calculation for Pinal/. An updated spreadsheet "August_2012.xls" was provided in an e-mail correspondence from Beverly Chenausky (*bchenausky@azdot.gov*) on May 28, 2013.
[43] These data were downloaded from ftp://ftp.ncdc.noaa.gov/pub/data/noaa/2008/ on July 3, 1013.

Fuel Formulation – MOVES 2010b default values were used for this input field.

I/M Programs – MOVES 2010b default values were used for this input field.

AVFT – MOVES 2010b default values were used for this input field.

Ramp Fractions – MOVES 2010b default values were used for this input field.

Emissions Calculations – The calculation of emissions due to exhaust, brake, tire, fugitive dust, and bow wake from paved road vehicle activity is explained below.

Onroad Exhaust, Brake, and Tire – Following the execution of the MOVES model for an episode day, the emission rate tables were extracted from the output database. The rate per distance (RPD) and rate per vehicle (RPV) tables were both exported from MySQL into Excel spreadsheets. The RPD table contains information on the vehicle emission rates in grams per mile for different pollutants by process, source type, speed, road type, and hour. These variables were converted via a pivot table to a lookup table for use with the travel model outputs. Travel model outputs contain VMT organized by link, hour-groups, speed, vehicle-type groups and facility type. Emission rates were selected from the lookup table based on a link's hour, speed and vehicle-type groups and then multiplied by the VMT of the vehicle-type group to give the emissions on that link for each vehicle-type group. The emissions were then summed over the vehicle-type groups to give the total emissions on a link due to exhaust, brake and tire.

The travel model uses four categories of vehicles—AUT, SUT, MUT, and TRK—as described in Table 3-27. With the exception of buses, the entire fleet is accounted for by the AUT, SUT, and MUT categories, and the TRK group is a combination of the SUT and MUT groups. The MOVES lookup tables have to be converted to these vehicle categories by taking population-weighted averages of the emissions rates across the MOVES vehicle types for a given travel model vehicle type. Table 3-27 shows Travel Model vehicle types mapped to the MOVES vehicle categories.

The emission rates for each TM vehicle category were then organized into a look-up table by hour, speed bin, and road type. Table 3-28 shows a sample segment of this final table over the first hour and first two speed bins and the four road types. The emission rates are given for PM_{10} summed over exhaust, brake and tire in grams per mile for the vehicle groups used by the TM. The emission rate for each vehicle group is then chosen based on the hour group, speed bin and road type, and multiplied by the VMT for that vehicle group. The total exhaust, brake, and tire PM_{10} is then summed across the three vehicle groups according to the following equation. Note that ER in the equation below stands for the emission rate of a given vehicle group.

Table 3-27 Travel Model Vehicle Groups Mapped to MOVES Vehicle Type IDs		
Travel Model Vehicle Types	MOVES Vehicle Type IDs	Description
AUT	11, 21	Motorcycles and Passenger cars
SUT	31, 32	Other two-axle, four-tire vehicles
MUT	51, 52, 53, 54, 61, 62	Single Unit, Combination Trucks
(N/A)	41, 42, 43	Buses

Table 3-28 MOVES Emission Rates Lookup Table					
Hour	avgSpeedBinID	roadTypeID	AUT PM_{10} (g/mi)	SUT PM_{10} (g/mi)	MUT PM_{10} (g/mi)
1	1	2	0.193563	0.539385	4.939788
1	1	3	0.200251	0.550764	4.599754
1	1	4	0.194939	0.537089	4.941009
1	1	5	0.198902	0.551916	4.603039
1	2	2	0.106547	0.29452	2.508547
1	2	3	0.111094	0.296764	2.394027
1	2	4	0.107235	0.293371	2.509163
1	2	5	0.110419	0.297341	2.395669

$$PM_{10} = VMT_{AUT} \times ER_{AUT} + VMT_{SUT} \times ER_{SUT} + VMT_{MUT} \times ER_{MUT}$$

Table 3-28 shows the MOVES emission rates organized by hour, speed bin, and road type, as well as total PM_{10} total for exhaust, brake and tire, summed by vehicle group. The table presented here is only a portion of the complete lookup table—only the first two speed bins on the first hour are presented below as a sample, whereas the full lookup table contains 24 hours and 16 speed bins. These rates were calculated using inputs for the entire county on the given episode days. The rates output table can be applied to any spatial domain desired given that speed bin, road type, and vehicle type VMT data is available.

Fugitive Dust – Paved-road vehicle emissions of fugitive dust were calculated using VMT and emission rates that vary by the silt loading of a given road. These rates are derived from an AP-42 equation shown below and described in detail in MAG's 2012 Five Percent Plan.[44]

[44] "MAG 2012 Five Percent Plan For PM-10 for the Maricopa County Nonattainment Area," Maricopa Association of Governments, March 2012 Appendix A, section 5.3, p. 117-119.

$$E = k \times sL^{0.91} \times W^{1.02} \times (1 - \frac{P}{4N})$$

where:

E = emission factor on an annual average basis

k = particle size allocation factor (1.0 for PM_{10} particles and 0.25 for $PM_{2.5}$)

sL= silt loading for road surface type (freeways are 0.02 g/m^2, high-traffic arterials are 0.067 g/m^2, low-traffic arterials are 0.23 g/m^2)

W = vehicle weight averaged over specific road ways (freeway vehicle averages are 3.53 tons and arterial vehicle averages are 2.65 tons)

P = number of days in a year with precipitation over 0.254 mm (0.01 in) and determined to be 31 days for 2008

N = the number of days in the year 2008 (366 days).

The values assigned to the variables described above were assigned to values used in MAG's Five Percent Plan in order to provide consistent and defensible assumptions for the Pinal County PM_{10} SIP modeling work.

Table 3-29 shows emission rates for a given road type ID and volume.

Table 3-29
PM_{10} Emission Rates for Paved Road Fugitive Dust

Road Type ID	Emission Rate	Road Description
2,4	0.1 (g/mi)	Freeways
3,5 (Low Traffic)	0.69 (g/mi)	Low Traffic Arterials (weekday counts < 10,000)
3,5 (High Traffic)	0.22 (g/mi)	High Traffic Arterials (weekday counts ≥ 10,000)

Values from the travel model were used to determine whether a specific link falls into the low or high traffic count category for arterials. The VMT values were summed over three of the four vehicle categories from the TM as the AUT, SUT, and MUT. Total link VMT for each hour group was multiplied by the emission rate for that link based on the road type and daily traffic count.

Bow Wake Emissions – PM_{10} generated from the bow wake of large trucks traveling on roads with unpaved shoulders was calculated from the following emissions rate formula:[45]

$$0.03 * (SPEED/55\ MPH)^2 = PM_{10}\ (lbs/VMT)$$

The variable SPEED is the link-specific speed from the travel model. Only the VMT from the large multi and single unit trucks (SUT category) was used in this calculation. To determine whether a particular road has paved or unpaved shoulders, a map was generated by ADOT that labeled some of the major roadways in the county with one of eight shoulder categories. Per the guidance of ADOT personnel, only shoulders labeled as gravel would be considered unpaved based on their maps.[46] Some of the shoulders that remained uncategorized were assigned to paved or unpaved based on guidance from Pinal County personnel.

Summary – Total PM_{10} emissions were summed across the exhaust, brake, tire, fugitive dust, and bow wake subtotals for a given link in a given hour group. Since the dispersion model requires an input of hourly emissions for the links, the PM_{10} emissions for an hour group are distributed to individual hours based on hourly VMT fractions. Table 3-23 above shows the hour group fractions used to allocate from each hour group to an individual hour. Emissions can then be pulled only from links in one of the modeling domains to be used as inputs for the dispersion modeling.

Supplemental Data – The full runspec and importer input files for these emission rate runs are provided in additional .mrs and .xml files, as listed below and available from Sierra Research upon request. These files can be opened in a text editor such as Notepad.

RunSpec_PINAL_2008_rates_v2_jan01.mrs
RunSpec_PINAL_2008_rates_v2_apr27.mrs
RunSpec_PINAL_2008_rates_v2_oct27.mrs
RunSpec_PINAL_2008_rates_v2_oct29.mrs
RunSpec_PINAL_2008_rates_v2_nov20.mrs

Pinal_importer_v2_jan01.xml
Pinal_importer_v2_apr27.xml
Pinal_importer_v2_oct27.xml
Pinal_importer_v2_oct29.xml
Pinal_importer_v2_nov20.xml

[45] "Cost-Effectiveness of Selected PM_{10} Control Measures," prepared for Maricopa Association of Governments by Sierra Research, June 2006, p. 26.
[46] PDF images—PinalCnty.pdf , PinalCnty_CasaGrande.pdf and PinalCnty_ApacheJunction.pdf—were provided in two separate e-mail correspondences from Beverly Chenausky (bchenausky@azdot.gov) on May 6, 2013.

Listed below are the spreadsheets used in calculating the MOVES 2010b inputs.

agedist_avft_calcs.xlsx
avgSpeedDist_ADOT_fixed_final.xlsx
roadtypedist_VMT_Summary_2008_with_FunctionalClass.xls
SourceTypePop_Jan08_final.xls
HPMS_TDM_CALCS.xlsx
ADOT_Hourly_frac_calculator_Pinal_final.xlsx

3.1.4 Unpaved Road Fugitive Dust Emissions

Fugitive dust emissions from unpaved roads were calculated by applying AP-42 emission factors to unpaved road VMT estimates. The unpaved road particulate emission factors were derived from the following AP-42 equation[47] for publicly accessible unpaved roads:

$$E = \left[\frac{k\left(\frac{s}{12}\right)^{1}\left(\frac{S}{30}\right)^{0.5}}{\left(\frac{M}{0.5}\right)^{0.2}} - C \right]\left(1 - \frac{P}{N}\right)$$

where:

E = annual average PM emission factor (lb/mile);

k = particle size multiplier for particle size range (1.8 lb/mile for PM_{10}) (AP-42 emission factors);

s = surface material silt content, which varies depending on the different types of roads, calculated based on a field study[48] (Appendix 2, Pinal County Field Sampling and Analysis for the Silt Characterization of Unpaved Road Dust and Agricultural Soil, conducted by ADEQ and PCAQCD, in May 2013) (values are listed in Table 3-30 below);

S = mean vehicle speed (varies depending on the type of roads, as listed in Table 3-30 below);

M = surface material moisture content, which varies depending on type of roads, calculated based on a field study (Appendix 2, Pinal County Field Sampling and Analysis for the Silt Characterization of Unpaved Road Dust and Agricultural Soil, conducted by ADEQ and PCAQCD, in May 2013) (values listed in Table 3-30 below);

[47] Emission Factors & AP 42, Compilation of Air Pollutant Emission Factors, Chapter 13.2.2. Unpaved Roads. *http://www.epa.gov/ttnchie1/ap42/ch13/final/c13s0202.pdf*

[48] The silt content values for AG road are calculated based on the average of both of the Ag roads samples collected in May 2013 and the Ag road samples collected in 2008, detailed in Appendix 2.

C = emission factor for 1980s vehicle fleet exhaust, brake wear, and tire wear (0.00047 lb/mile for PM_{10})[1];

P = annual number of "wet" days with at least 0.254 mm (0.01 in) of precipitation (31 days in 2008)[49]; and

N = annual number of days (366 days in 2008).

Among these variables, "s" (surface material silt content), "S" (mean vehicle speed), and "M" (surface material moisture content) vary depending the type of road surface and road activity. The collection and analysis of the data used to determine these variables is detailed in "Analysis of Unpaved Roads in the Pinal County PM_{10} Nonattainment Area" (Traffic Analysis Report), authored by Kate Edwards of the PCAQCD (see Appendix 1). Four different types of roads (public dirt, private dirt, agriculture, and trail) are used to characterize the roads in Pinal County in the analysis[50]. For the public dirt roads, five different classes (A, B, C, D, and E) are used to represent the different traffic volumes and vehicle speeds associated with each public dirt road. For the private dirt roads, traffic volumes and vehicle speeds are represented by two different classes (A and B). A discussion of information provided by local farmers on speeds and ADT levels is presented separately below. The values for these variables and the calculated emission factors (lbs/VMT) are summarized in Table 3-30.

Table 3-30
Measurements Used to Characterize Unpaved Road Emission Factors in the Pinal County PM_{10} Nonattainment Area

Road Types	Public Dirt					Private Dirt		Agriculture[a]	Trail
	A	B	C	D	E	A	B		
S = mean speed (mph)	20	25	30	35	40	25	15	see Table 3-31	15
s = surface material silt content (%)	7.1	7.1	7.1	7.1	7.1	14.4	14.4	14.9	14.4
M= surface material moisture content (%)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.8	0.3
E (lbs/VMT)	0.86	0.96	1.05	1.14	1.22	1.95	1.51	1.77 – 1.81	1.51

a Due to variations in maintenance and harvest activities, speeds vary by crop type. The range of emission factors represents the bounds of the speed estimates displayed in Table 3-31.

[49] Based on precipitation data for Pinal County from the AZMET netw.ork, *http://ag.arizona.edu/azmet/az-data.htm*.

[50] A fifth category, entitled "Neighborhood Roads," was added to address unpaved roads surrounding the Stanfield and PCH monitors. A review of the unpaved road networks provided in the ADEQ and PCAQCD shapefiles found they were not identified. However, due to their close proximity to the monitors, their emissions could not be ignored. Discussions with PCAQCD staff determined that ADT levels were limited to 2 vehicles per day at both sites. Emission factors were calculated using private road silt and moisture values.

Subsequent to the preparation of the Traffic Analysis Report, ADEQ held meetings with local farmers and they provided information on agricultural road activity for non-harvest and harvest operations. This information is summarized in a series of notes prepared by ADEQ staff and is presented in Appendix 9. It shows that non-harvest operations can be characterized by single average ADT levels and speeds. However, harvest operation ADT and speeds vary by crop type. Therefore, those values vary based on the crop distribution found within each modeling domain. A summary of the values calculated for each stagnation and high wind domain is presented below in Table 3-31.

Table 3-31
Average Daily Traffic (ADT) and Speeds Calculated for Unpaved Agricultural Roads in the Pinal County PM10 Nonattainment Area

Modeling Domain	Monitoring Site	ADT	MPH
Stagnation	Cowtown	13.6	27.4
	PCH	16.9	27.4
	Stanfield	15.1	27.2
High-Wind Day, Low-Wind Hours	Cowtown	11.3	28.2
	PCH	11.3	28.2
	Stanfield	11.3	28.2
	Maricopa	13.2	27.7

The emissions (lbs/hour) for each road are calculated by multiplying the VMT-specific emissions (E; lbs/VMT in Table 3-30) by the hourly estimated link-specific VMT in the modeling domain. The hourly VMT for each road link is calculated from the Average Daily Traffic (ADT) value, the road link length, and the related diurnal profile. The ADT values for the major roads in each modeling domain were obtained via a traffic map prepared by PCAQCD. For the rest of the roads, the ADT value is derived from the assumptions described in the Traffic Analysis Report (see Appendix 1). The average ADT value and the total miles of each roadway type in each of the modeling domains[51] are summarized in Table 3-32 and Table 3-33, respectively.

As noted, the diurnal variation data for different types of public and private roads were derived from the traffic data collected from 20 separate road segments in Pinal County. The values for agricultural roads and trails were limited to daylight hours and distributed uniformly within that period. Table 3-34 summarizes the diurnal variation associated with each road type in Pinal County as an hourly fraction of the daily total ADT.

[51] The selections of the modeling domains are detailed in Chapter 2, Modeling Domain Revisions.

Table 3-32
Average Daily Traffic (ADT) Values Used for Unpaved Roads Located in the Pinal County PM_{10} Nonattainment Area

Modeling Domain	Monitoring Site	Public Dirt					Private Dirt [a]		Trail
		A	B	C	D	E	A	B	
Stagnation	Cowtown	29	90	127	186	N/A	17	6	2
	PCH	N/A	90	127	186	N/A	17	3	2
	Stanfield	29	90	127	186	N/A	15	3	2
High-Wind Day, Low-Wind Hours	Cowtown	29	90	127	186	N/A	17	6	2
	PCH	29	90	127	186	N/A	19	4	2
	Stanfield	29	90	127	186	N/A	17	4	2
	Maricopa	29	90	127	N/A	N/A	13	6	2

a. The private dirt roads were separated in the Traffic Analysis Report (Appendix 1) into three categories—Non-Irrigation, Principal Canal, and Secondary Canal Roads—based on the ADT level and driving speed. The average driving speed for Non-Irrigation and for Principal Canal roads is estimated at 25 mph. Because the ADT levels for each road are provided by the County with maps (Appendix 4), there is no benefit in separating these roads in the emission estimates. Therefore, Private Dirt "A" Roads listed in the table here represent Non-Irrigation, Principal Canal roads; Private Dirt "B" Roads represent Secondary Canal roads.

Table 3-33
Total Length (miles) of Each Type of Unpaved Roads Used for Each Modeling Domain in the Unpaved Road Emission Calculation

Modeling Domain	Monitoring Site	Public Dirt					Private Dirt		Agriculture	Trail
		A	B	C	D	E	A	B		
Low-Wind Modeling Domain	Cowtown	1.6	1.0	8.0	5.7	N/A	38.5	31.1	162.2	9.3
	PCH	N/A	10.1	5.1	2.3	N/A	18.7	3.2	62.8	2.6
	Stanfield	3.0	10.5	2.1	6.7	N/A	27.8	4.7	297.8	10.0
High-Wind Day, Low-Wind Hour Modeling Domain	Cowtown	0.6	2.0	9.4	6.9	N/A	33.6	24.9	148.2	8.9
	PCH	0.0	7.6	10.3	2.5	N/A	19.1	4.4	110.2	11.3
	Stanfield	1.0	10.7	6.7	8.4	N/A	29.2	5.8	290.2	8.1
	Maricopa	0.5	1.1	3.8	N/A	N/A	17.9	4.3	83.2	4.0

Table 3-34 Diurnal Variation for Each Unpaved Road Type in the Pinal County PM_{10} Nonattainment Area									
Hour Number	Public Dirt					Private Dirt		Agriculture	Trail
	A	B	C	D	E	A	B		
Hour 1	0.003	0.004	0.005	0.005	0.007	0.003	0.003	0.000	0.000
Hour 2	0.013	0.007	0.001	0.008	0.007	0.013	0.013	0.000	0.000
Hour 3	0.006	0.003	0.006	0.005	0.003	0.006	0.006	0.000	0.000
Hour 4	0.000	0.005	0.004	0.005	0.005	0.000	0.000	0.000	0.000
Hour 5	0.008	0.013	0.011	0.007	0.012	0.008	0.008	0.000	0.000
Hour 6	0.026	0.020	0.029	0.016	0.032	0.026	0.026	0.000	0.000
Hour 7	0.053	0.043	0.047	0.049	0.042	0.053	0.053	0.083	0.083
Hour 8	0.033	0.063	0.074	0.067	0.067	0.033	0.033	0.083	0.083
Hour 9	0.044	0.069	0.063	0.057	0.063	0.044	0.044	0.083	0.083
Hour 10	0.083	0.068	0.081	0.058	0.057	0.083	0.083	0.083	0.083
Hour 11	0.055	0.068	0.070	0.052	0.062	0.055	0.055	0.083	0.083
Hour 12	0.085	0.073	0.085	0.062	0.070	0.085	0.085	0.083	0.083
Hour 13	0.061	0.065	0.071	0.057	0.086	0.061	0.061	0.083	0.083
Hour 14	0.098	0.069	0.080	0.066	0.079	0.098	0.098	0.083	0.083
Hour 15	0.078	0.074	0.085	0.077	0.079	0.078	0.078	0.083	0.083
Hour 16	0.083	0.074	0.082	0.090	0.080	0.083	0.083	0.083	0.083
Hour 17	0.060	0.085	0.065	0.086	0.066	0.060	0.060	0.083	0.083
Hour 18	0.050	0.068	0.058	0.078	0.056	0.050	0.050	0.083	0.083
Hour 19	0.053	0.039	0.030	0.045	0.044	0.053	0.053	0.000	0.000
Hour 20	0.040	0.024	0.013	0.028	0.022	0.040	0.040	0.000	0.000
Hour 21	0.045	0.027	0.012	0.030	0.022	0.045	0.045	0.000	0.000
Hour 22	0.013	0.019	0.011	0.027	0.020	0.013	0.013	0.000	0.000
Hour 23	0.011	0.011	0.009	0.017	0.011	0.011	0.011	0.000	0.000
Hour 24	0.004	0.010	0.008	0.010	0.007	0.004	0.004	0.000	0.000

3.1.5 Non-Road Vehicle Emissions

With the exception of the locomotive and aircraft categories, all non-road combustion emissions presented in this analysis were calculated using Pinal County specific emissions[52] from EPA's NONROAD model,[53] which were then allocated to the modeling domains based on the methodologies described below. The NONROAD model calculates emissions from a varied assortment of equipment that is generally categorized as follows:

- Recreational vehicles (e.g., all-terrain vehicles and off-road motorcycles);

[52] Input files are included in Appendix 8.
[53] U.S. EPA NONROAD Model, Version 2008a, released July 2009.

- Logging equipment (e.g., chain saws);
- Agricultural equipment (e.g., tractors);
- Commercial equipment (e.g., welders and compressors);
- Construction and mining equipment (e.g., graders and backhoes);
- Industrial equipment (e.g., forklifts and sweepers);
- Residential and commercial lawn and garden equipment (e.g., leaf and snow blowers);
- Recreational and commercial marine vessels (e.g., powerboats and oil tankers);[54]
- Locomotive equipment (e.g., train engines and support equipment); and
- Aircraft (e.g., aircraft and ground support equipment).

It is important to note that with the exception of aircraft, none of the non-road vehicles and equipment listed above were federally regulated until the mid-1990s.

EPA utilizes a "top down" approach, and has based NONROAD default equipment populations on national averages, which are then scaled down to represent smaller geographic areas (i.e., statewide and countywide) on the basis of human population; employment and construction statistics; acres of harvested cropland; and proximity to recreational, industrial, and commercial facilities within each area. In the absence of equipment populations and activity estimates specific to the Pinal County region, the default NONROAD estimates for equipment population, growth rates, and annual and seasonal activity rates (all of which incorporate some degree of regional adjustment) were used for this analysis.

Note that the growth factors (developed for NONROAD in calendar year 2002) that determine future equipment population totals appear to accurately account for the rapid pre-2008 growth rates, but do not reflect the results of the economic downturn that affected the U.S. beginning in the 2007-2008 timeframe. Specifically, NONROAD assumes the following annual growth rates for construction equipment:

- CY 2000-2005: 10.5%
- CY 2006-2010: 9.8%
- CY 2011-2015: 8.9%

These rates agree reasonably well with the 2000-2008 Pinal County human population[55] growth rate of 11.9%, and with the averaged annual growth rate for the number of residential building permits[56] issued in Pinal County over the same time period (i.e., 12%). Because of this overall agreement, and because this relatively small emission source does not justify the time-consuming commensurate adjustments to NONROAD activity rates that would be required if a more precise growth factor were to be

[54] The NONROAD model is not capable of modeling emissions from oil tankers or other comparably large vessels, train engines, or aircraft.
[55] See http://censtats.census.gov/
[56] See http://censtats.census.gov/cgi-bin/bldgprmt/bldgdisp.pl

developed, the default NONROAD growth rates for construction equipment were used for the 2008 baseline inventory.

NONROAD Calculation Methodology – EPA's NONROAD emissions model calculates emissions from each source according to the methodology shown below. Note that this calculation yields emission results in grams per year, which the model then converts to tons.

$$\text{Emissions} = EF \times DF \times P \times LF \times \text{Hours} \times \text{Units}$$

where:

EF = emission factor in g/hp-hr
DF = deterioration factor (dimensionless)
P = power in horsepower
LF = load factor (dimensionless)
Hours = annual operating hours for each unit
Units = total population of engines operating in a given year

Pinal County Inputs – Total emissions estimates for Pinal County were determined for four specific months (January, April, October, and November)[57] during CY 2008[58] using average ambient temperatures specific to each.[59] Calendar year 2008 wintertime fuel parameters for both Diesel and gasoline, shown below in Table 3-35, were obtained from the 2008 North American fuel surveys published by the Alliance of Automobile Manufacturers (AAM), and were verified by staff at the PCAQCD; it is assumed that the fuel mix used in Phoenix during the four months of interest is delivered to all areas of Pinal County as well, because the fuel requirements are the same in both areas during this period.[60] Gasoline and Diesel parameters are based on values reported in the Phoenix area, which are the same as those for Pinal County fuel during the four months of interest.

[57] These are the months during which the design days occur.
[58] Although this baseline analysis is focused on these four specific months, the annual emissions inventory will include CY 2008 total based on a NONROAD model run for CY 2008.
[59] See http://www.weatherforyou.com/
[60] Confirmed via telephone conversion with Scott Dibiase at the PCAQCD.

Table 3-35 NONROAD Modeling Fuel Parameters Pinal County – CY 2008		
Fuel Parameter	NONROAD Default	Pinal County (2008)
Fuel RVP for gas	8.0	8.8
Oxygen Weight (%)	2.44	3.5
Gas Sulfur (%)	0.0339	0.0015
Diesel Sulfur (%)	0.0351	0.0006
CNG/LPG Sulfur (%)	0.003	0.003
Stage II Control (%)	0	0[a]
EtOH Blend Market (%)	75.1	100
EtOH Volume (%)	9.3	10

a. Note that while Stage II controls are required at the highest-volume stations in Pinal County's "Area A," we assumed zero Stage II coverage because none of the modeling domains are located within Area A boundaries.

Equipment Categories – With the exception of equipment in the "Pleasure Craft" and "Railway Maintenance" equipment categories, all NONROAD equipment categories were included in the analysis. These equipment categories were excluded due to the absence of recreational areas and rail yards in the modeling domains that would accommodate their use. Note that the NONROAD model estimates that 12.5% of CY 2008 Pinal County PM emissions are due to the operation of recreational equipment during three of the four months of interest. Shown in Table 3-36 are the equipment types with a Pinal County population greater than zero that NONROAD includes in this category, as well as the activity rates (in units of hours per year) assumed for each.

Table 3-36 Pinal County NONROAD Recreational Equipment		
Equipment Category	Equipment Description	Activity Rate (hrs/yr)
Recreational Equipment	Motorcycles: Off-Road	1600
	All Terrain Vehicles	1608
	Golf Carts	1080
	Specialty Vehicle Carts	65

Nonroad Emission Allocation Methodology – Several different methods were used to allocate the county-wide emission estimates to the low wind modeling domains. A description of each method is presented below.[61]

- *Recreational Equipment* – A population- and geographically based allocation approach was used for this equipment category. County-specific census block data were obtained and were used to distribute the NONROAD emissions for this equipment over each modeling domain. Emissions associated with this category were further allocated within each domain based on the percentage of total miles of off-road equipment trails (used by off-road motorcycles and ATVs) located within each domain, vs. the total miles of trail within Pinal County.

- *Industrial and Commercial Equipment* – A population-based allocation approach was used for this equipment category; NONROAD equipment emissions were distributed over the modeling domain in proportion to its human population, compared to the county-wide population total. Within each domain, the emissions were then further allocated to specific developed rural and urban area parcels, in proportions equivalent to the size of each parcel.

- *Residential and Commercial Lawn and Garden Equipment* – NONROAD emissions associated with this equipment category were allocated to the modeling domains using the methodology described for industrial and commercial equipment, which considered both human population and acreage of developed land within each area.

- *Construction Equipment* – NONROAD emission results were allocated to the modeling domain (none of which include more than one county) based on information obtained from county-specific construction permits, which include total acres involved in the construction activity. Specifically, emissions were allocated according to the total acres of construction activity within each domain compared to the total acres of construction activity in Pinal County.

- *Agricultural Equipment* – Agricultural equipment emissions include combustion emissions from the NONROAD model, combined with fugitive dust emissions that were calculated using harvested and tilled acreage specific to each modeling domain, as described in the Agricultural Activities section. The NONROAD combustion emissions were allocated to each modeling domain based on the total acres of agricultural land in each modeling domain vs. the countywide total of agricultural land. The emissions associated with each domain were then further allocated to individual parcels based on the percentage of harvesting and/or tillage activities associated with each parcel, compared to the total harvesting and/or tillage activities for the domain.

[61] Please see Section 3.1.11 for a description of how emissions were allocated to Indian Reservations.

3.1.6 Trackout Methodology

Surface loadings of material on roadways have many sources, including wind transport, spillage of transported material; trackout from industrial and construction sites with unpaved roads; and trackout from unpaved parking lots, driveways, and staging areas. These actions replenish material that is re-suspended by vehicles traveling across road surfaces. Locations with elevated silt loadings are referred to as "hotspots"—these typically occur where unpaved roads meet paved roads and there is regular vehicle activity to transport loose material onto adjacent paved road surfaces. Control of trackout has been found to be an effective particulate control measure in many communities.

Early on in the development of the emissions inventory, a decision was made by the ADEQ/PCAQCD advisory committee to adopt silt loadings used in calculating paved road fugitive dust in MAG's 2012 Five Percent Plan due to a lack of locally available silt loading data. Listed below are the values used for Pinal County (see the on-road emissions methodology discussion in Section 3.1.3).

- Freeways – 0.02 g/m^2
- High traffic arterials (≥ 10,000 vehicles/weekday) – 0.067 g/m^2
- Low traffic arterials (< 10,000 vehicles/weekday) – 0.23 g/m^2

In the MAG analysis, trackout was associated with silt measurements of 0.3+ g/m^2. Measurements were obtained from samples collected manually on selected roadways and back calculated from emission measurements collected by an instrumented vehicle (i.e., SCAMPER[62]) operated over a network of Salt River roads. Measurements incorporated into the MAG 2007 Five Percent Plan[63] included silt values ranging from 0.3-1.34 g/m^2 as representative of trackout. Higher values (up to 11 g/m^2) were reported in the Salt River TSD.[64]

Lacking any recent measurements of silt loadings on paved roads in Pinal County, particularly hotspots, but recognizing the potential exists for trackout because of the large number of unpaved roads with high activity levels, a request was made to PCAQCD staff to identify potential hotspot locations where high volume unpaved roads intersect with paved roads. The reasoning was that these locations were likely to have elevated silt levels because of the regular transfer to dry (and wet after rainfall) material to adjacent paved road surfaces. PCAQCD staff responded and identified potential hotspot locations for Cowtown, Pinal County Housing, and Stanfield. Locations for each monitor/domain are presented in Figures 3-7, 3-8 and 3-9.

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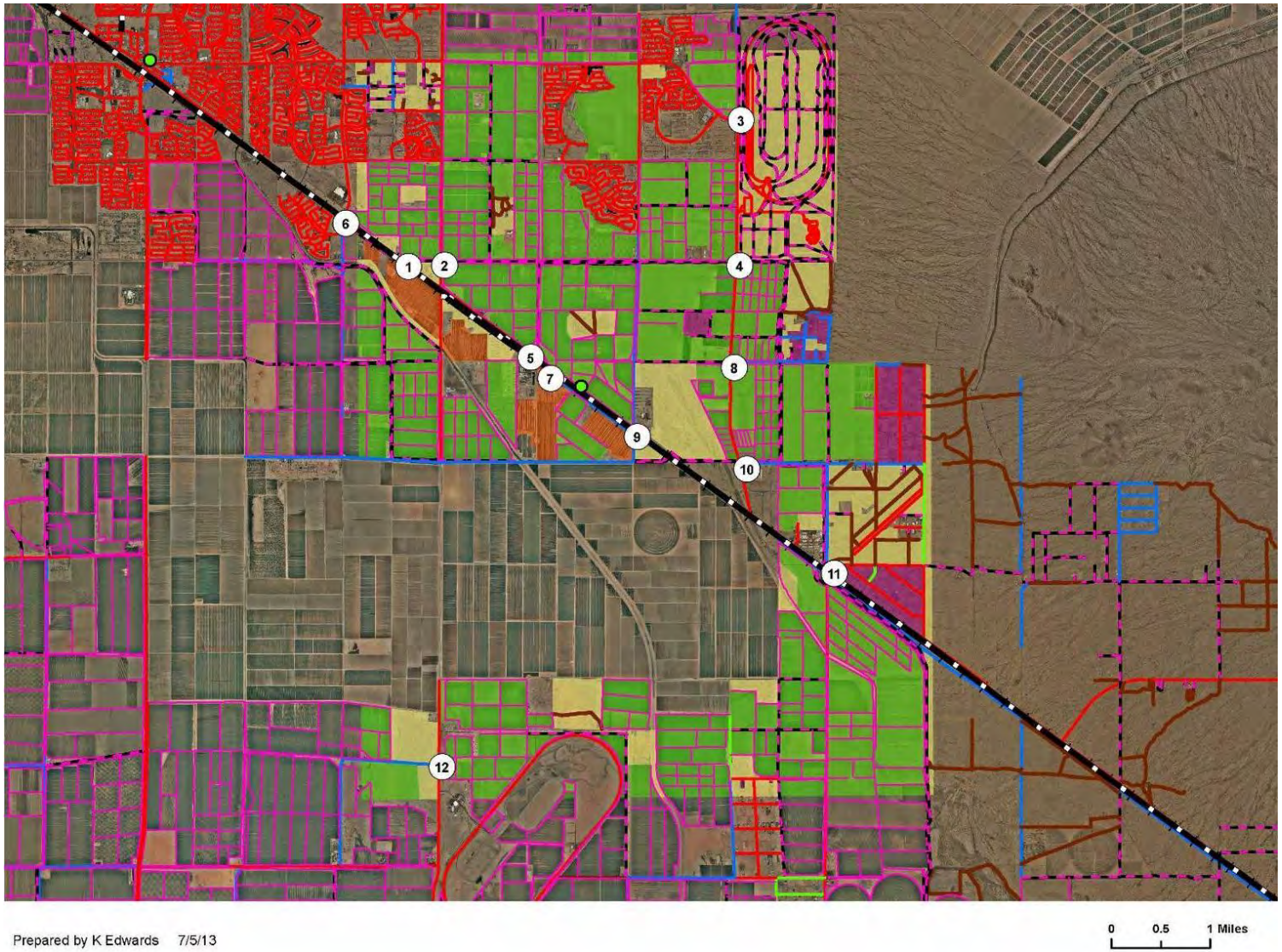
[62] System for Continuous Aerosol Monitoring of Particle Emissions from Roadways (SCAMPER)
[63] "PM-10 Source Attribution and Deposition Study," Report No. 2008-03-01 prepared by Sierra Research for Maricopa Association of Governments, March 2008
[64] "Revised PM10 State Implementation Plan for the Salt River Area, Technical Support Document," ADEQ Air Quality Division, September 2005

Figure 3-7
Cowtown Trackout Hot Spots



Prepared by K Edwards 7/5/13

Figure 3-8
Stanfield Low Wind Hot Spots

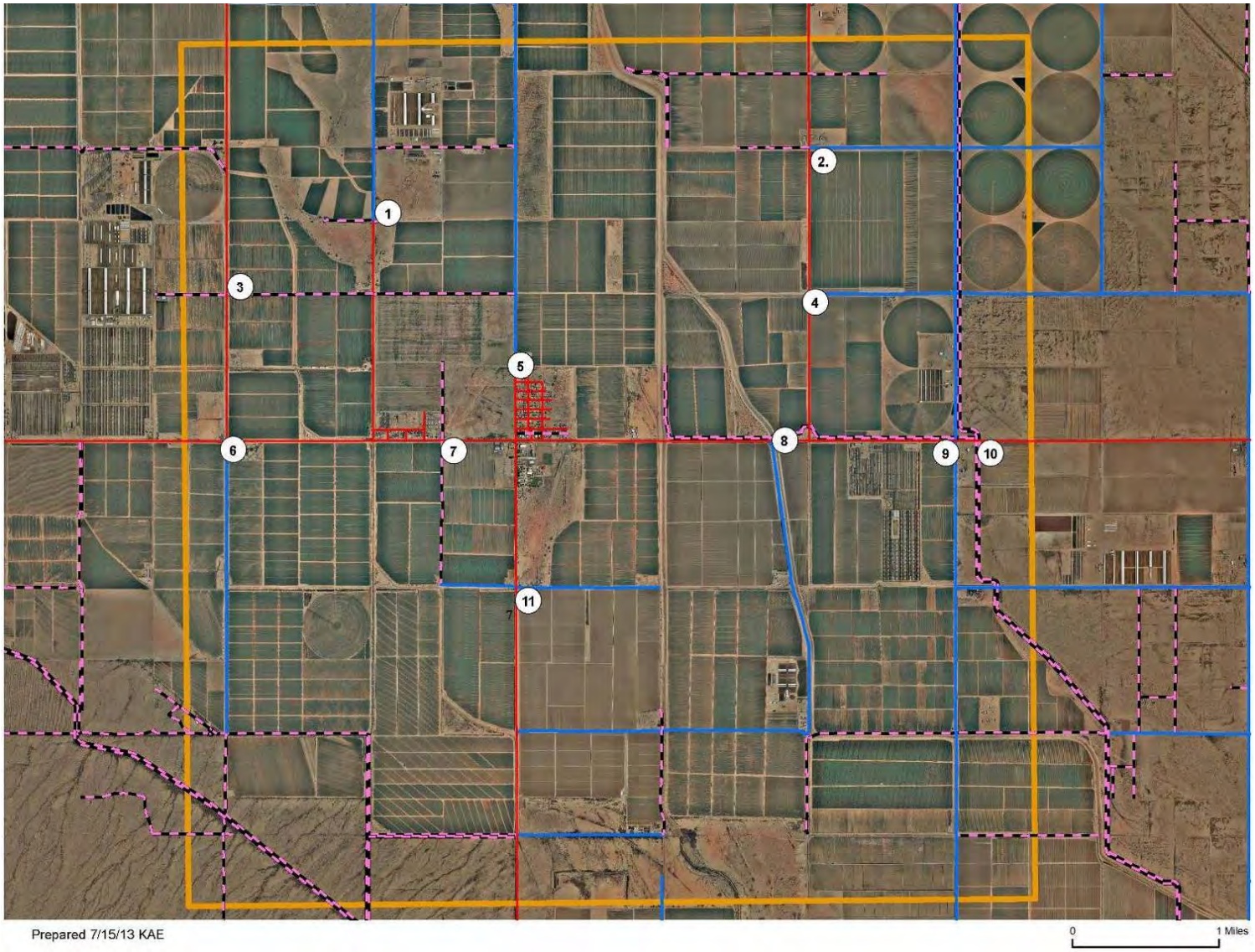
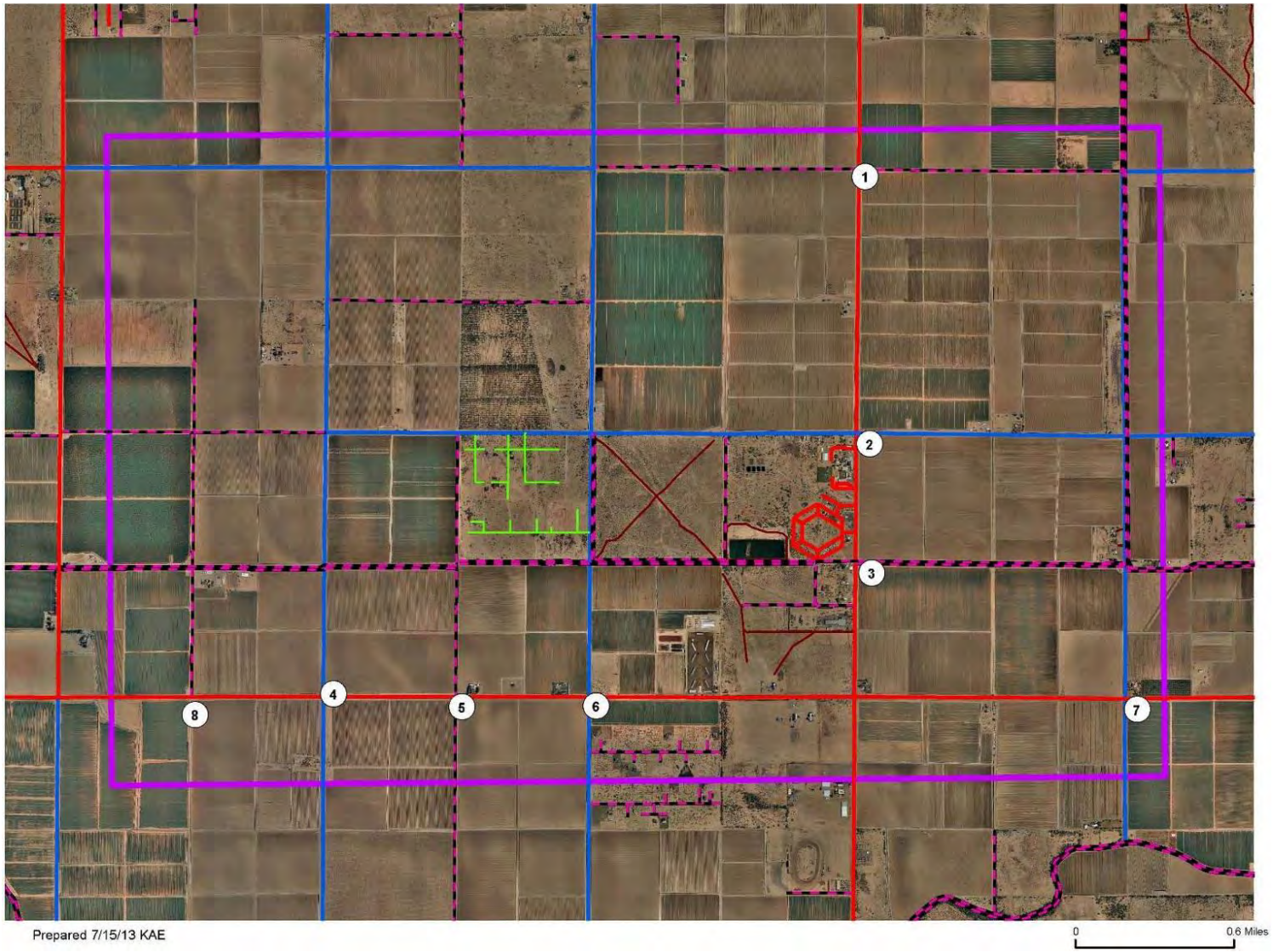


Figure 3-9
PCH Low Wind Hot Spots



The largest potential for impact is at the Cowtown monitor along the adjacent Maricopa-Casa Grande Hwy. Several hotspots are within a mile, with the closest being 0.1 miles. To evaluate the potential for emission impacts from these sites, silt loadings were increased from 0.23 g/m^2 to 1.0 g/m^2 between the end points marked by PCAQCD. The goal was to use a conservative increase to assess the potential impact. Similar silt loadings were used to quantify the impact of trackout at the other locations identified by PCAQCD staff in Figures 3-7, 3-8 and 3-9.

As discussed in Section 3.1.3, the default 0.23 g/m^2 silt loading produces an emission rate of 0.69 g/mi. Increasing the silt loading to 1.0 g/m^2 increases the emission rate to 2.63 g/mi. The impact of this increase depends on the level of travel (i.e., VMT) across roads with trackout, which is a function of road mileage with elevated silt loadings and average daily traffic (ADT). Since the extent of roadway with increased silt loadings is unknown, it was assumed that the increase would extend between endpoints of applicable road segments (i.e., to the next intersection). In the case of the Maricopa-Casa Grande Highway, the entire segment included within the Cowtown monitoring domain was assumed to have trackout, due to the number of hot spots identified by PCAQCD staff.

A review of the local roads surrounding each of the low wind monitoring sites found that no ADT levels were available from ADOT travel demand modeling.[65] For Cowtown, this was not a problem since ADOT estimates were available for the Maricopa-Casa Grande Highway and other relatively higher volume roads (e.g., John Wayne Highway, etc.). Most of the remaining roads are unpaved and, as discussed in Section 3.1.4, PCAQCD provided guidance on ADT for each of those roads.

For the Stanfield and Pinal County Housing modeling domains, a decision was made to combine household trip generation rates from the Institute of Transportation Engineers (ITE)[66] with information on the number of homes located on each of the adjacent roads obtained from Google Earth images.[67] A review of the Google Earth images, shown in Figures 3-10 and 3-11, also determined that each of the surrounding neighborhoods contained unpaved roads and alleys not included in the ADEQ/PCAQCD GIS files. Travel estimates on the paved and unpaved roads were derived by counting the number of homes on each street and multiplying that value by 10 trips per household, per the ITE trip generation guidance, and then using average values for all roads within each neighborhood (i.e., 70 trips/day). Discussions with PCAQCD staff responsible for maintaining each of the monitors provided further guidance on the level of travel to assume for the unpaved roads within each neighborhood. For the Stanfield site, it was assumed the unpaved alleys had 2 trips per day; for the Pinal County Housing site, it was

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[65] Because it is impractical to model travel on all roads, travel demand models breakup modeling domains into traffic analysis zones or TAZs and assess demand for travel on local roads (i.e., low ADT roads) within that zone through a "centroid connector" that aggregates travel for local roads. This approach ensures the model accounts for all travel activity, but it does not provide estimates of travel for individual local roads, which because of their proximity to individual monitors can be very important.

[66] "Informational Report, Trip Generation," by ITE Technical Council Committee 6A6. *http://www.ite.org/membersonly/itejournal/pdf/JJA76A42.pdf*

[67] MAG used this approach to quantify travel for homes located on unpaved roads. *https://www.azmag.gov/Documents/pdf/cms.resource/PM10_2007_Appendices_vol-3.pdf*

Figure 3-10
Local Roads Surrounding Stanfield Monitoring Site

Figure 3-11
Local Roads Surrounding Pinal County Housing Monitoring Site

also assumed that unpaved roads had 2 trips per day. The silt levels used for unpaved roads were based on guidance provided in Section 3.1.4. The emissions produced for each road were distributed diurnally based on the profiles employed for paved roads (Section 3.1.3) and unpaved roads (Section 3.1.4).

The overall increase in paved road emissions within each modeling domain is relatively large (ranging from 50.8-203.6%); the increase in unpaved road emissions is relatively small (ranging from 0.17-0.24 for unpaved roads). Those impacts, however, will increase because of their proximity to the monitors; they will be quantified in subsequent air quality modeling analysis.

3.1.7 Railroad Emission Methodology

PM_{10} emission rates for railroad operations within the Cowtown low wind attainment demonstration modeling domain were derived from EPA emissions studies and industry financial reports. This Cowtown domain is the only one evaluated in this plan that hosts an active rail line and locomotive emissions. A Union Pacific Railroad (UPRR) main line runs parallel and to the south of the West Maricopa-Casa Grande Highway (Arizona Route 238), adjacent to the feedlots on Cowtown Road and within 300 feet of the Cowtown monitoring station. The frequency of trains passing the monitor on an annual average day in 2008 has been difficult to quantify accurately as this information cannot be readily obtained from the carrier. Information provided by ADOT on a proposed project to construct a grade-separated crossing of this main line by Arizona Route 347 within the Maricopa city limits reports train frequencies in 2012 to be 40 to 60 per day.[68]

PM_{10} Emission Factor – EPA most recently summarized emissions factors for locomotives in a 2009 study.[69] The PM_{10} emission factor averaged over the line haul locomotive fleet in the United States is reported as 5.1 grams emitted per gallon of Diesel fuel consumed. This factor can be converted to activity units of engine brake-horsepower hours by dividing it by 20.8 bhp-hr/gallon of fuel consumed, producing a PM_{10} emission factor of 0.245 g/bhp-hr. No information could be found on the average speed of trains traversing the main line section between Maricopa and Casa Grande during October 2008. UPRR reported to the American Association of Railroads, however, that the average speed traveled by trains in its system in October 2008 was 24.0 mph.[70] A typical line haul locomotive is rated at 4400 bhp and operates at a fleetwide load factor of 27.5% on level ground at 24.0 mph.[71] Applying these factors to the emission factor above produces a PM_{10} emission rate of 296.5 g/hr-locomotive. Line haul trains typically operate with three locomotives, resulting in train emissions of 889.4 g/hr-train. At an

[68] State Route 347 at Union Pacific Railroad, Agency and Public Scoping Summary, ADOT, November 2012, http://www.azdot.gov/highways/Projects/SR347_Union_Pacific_RR/PDF/Agency-Public-Scoping-Summary-Report.pdf, accessed on July 15, 2013.
[69] Emission Factors for Locomotives, EPA-420-F-09-025, U.S. Environmental Protection, April 2009
[70] Performance Measures 2008, Union Pacific Railroad, AAR, http://www.up.com/investors/attachments/reports/dwell/2008.pdf, accessed on July 15, 2013
[71] "Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters Per Cylinder," EPA-420-R-08-001, U.S. Environmental Protection Agency, March 2008.

average speed of 24.0 mph, the PM_{10} emissions from each train passing the Cowtown monitor is 37.06 g/mi.

PM_{10} Emission Rate – The line haul trains are assumed to have passed the Cowtown monitor in 2008 at a maximum rate of 60 per day, based on the ADOT Maricopa grade-crossing project information. At this frequency, the PM_{10} emissions from each mile of track would be 2,233.4 g/mi-day, or 4.90 lb/mi-day. This emission rate was used in the Cowtown low wind design day attainment demonstration modeling analysis to represent PM_{10} emissions from locomotives passing near the monitor.

3.1.8 Construction

The location of construction activity and related fugitive dust emissions shifts from year to year. The best source of information for tracking activity within a specific domain and time period is dust control permits. PCAQCD staff[72] reviewed permits issued in late 2007 (4th quarter) and selected those that were most likely to continue into 2008; these were then combined with permits issued in 2008 to create a shape file of polygons identifying the location of each of the issued permits. A total of 2,874 sites were identified in the PM_{10} nonattainment area. The following information was provided for each site:

- Permit type;
- Site location coordinates; and
- Acreage.

Three types of permits were found in the file provided:

- 5 – Construction;
- 7 – Commercial Construction; and
- 8 – Site Development.

Discussions with PCAQCD staff confirmed that type 5 represented residential construction and type 7 represented commercial construction (as listed). Type 8 was assumed to represent commercial construction and accounted for 2% of the issued permits. Type 5 residential projects were assumed to represent a single home if the acreage was ≤ 5 acres; larger plots of land were assumed to represent multi-home subdivisions.

Since the duration of construction activity varies by project type, information on the starting date for each project is needed to assess whether it was active on specific design days. To address this limitation, random starting dates from 10/1/2007 through

[72] Email from Kate Edwards, Pinal County to Bob Dulla, Sierra Research, 2008 Construction Dust Permits, November 28, 2012.

12/31/2008 were assumed for each single home (i.e., type 5 with ≤ 5 acres) and for commercial development. The duration of single-family home house construction were estimated to be six months, according to EPA's Emission Inventory Improvement Program (EIIP) guidance.[73] The duration of nonresidential construction were estimated to be 11 months according to the WRAP Fugitive Dust Handbook.[74] The estimates of project duration were used to count backwards from the design date to determine if a permitted site could be active on the design day. Thus, for example, any commercial project started more than 11 months prior to the day to be modeled was excluded from the inventory of sources that impacted that date. No construction activity was assumed to occur on weekends. For residential projects larger than 5 acres, with more than one home under development, it was assumed that construction would occur at that site throughout the entire year.

The methodology used by Maricopa County to estimate the 2008 PEI[75] was used to estimate emissions for each project determined to be active on the design day. Emissions for each project were calculated by multiplying the number of acres times an emission factor that varies by project type (in units of tons/acre-month as shown in Table 3-37). The tons/month were converted to lbs/day by dividing its emission by the number of days per month (22 days per month) of construction duration assuming number of weeks per month for a construction schedule that is assumed to run 5 days per week. The daily emissions in lbs/day were converted to hourly emissions (lbs/hour) by dividing the emissions by the number of hours of operation per day (10 hours/day, from 7 am to 5 pm, were assumed as number of hours of operation per day for each source).

Table 3-37
Average Construction Project Duration and Emission Factor by Project Type

Project Type	Average Duration (Months)	Emission Factor (Tons PM_{10}/Acre-Month)
Residential Single Family	6	0.032
Commercial	11	0.19

Thus, for a 5-acre residential project, monthly emissions are calculated to be 0.16 tons of PM_{10} (0.032 x 5) or 320 lbs of PM_{10} (2000 x 0.16). The 320 lbs are spread across 22 days and amount to 14.5 lbs/day. Uniform hourly values of 1.45 lbs/hour are assumed to be emitted between 7 am and 5 pm on a design day on which construction occurs for this permit.

[73] See http://www.epa.gov/ttnchie1/eiip/techreport/volume09/residn3.pdf
[74] See http://www.wrapair.org/forums/dejf/fdh/content/Ch3-Construction_and_Demolition_Rev06.pdf
[75] 2008 PM10 Periodic Emissions Inventory for the Maricopa County, Arizona, Nonattainment Area, Maricopa County Air Quality Department

Table 3-38 summarizes the number of construction permits located within each modeling domain on both low wind days and high wind days with low wind hours. As can be seen, the Maricopa domain was estimated to have the highest level of construction activity.

Table 3-38
Active Construction Permits for Pinal County
PM_{10} Modeling Domains in 2008

Modeling Domain		# of Permits
Pinal County Housing	Low Wind Day	1
	Low-Wind Hours on High-Wind Design Days	0
Cowtown	Low Wind Day	111
	Low-Wind Hours on High-Wind Design Days	183
Stanfield	Low Wind Day	1
	Low-Wind Hours on High-Wind Design Days	3
Maricopa	Low-Wind Hours on High-Wind Design Days	525

In 2008, PCAQCD staff conducted a total of 416 dust permit inspections—374 were found to be in compliance, suggesting a compliance rate of 90%. Permitted sites are required to comply with construction dust rules[76] that address site preparation, bulk material handling, and carryout activity and emissions. While no local estimate of control efficiency is available, a review of the WRAP handbook[77] shows that applying water at various intervals results in a 61% PM_{10} control efficiency. When combined with the compliance rate of 90%, this produces an estimate of overall control effectiveness of 54%.

3.1.9 Permitted Source Emission Methodology

PM_{10} emissions rates for permitted industrial facilities were derived from the Pinal County Air Quality Control District (PCAQCD) permit files. PCAQCD permits provide estimates of PM_{10} emissions for stationary sources only—PM_{10} emissions from area sources such as unpaved road travel, livestock movement, and windblown dust were estimated separately and these separate methodologies are discussed elsewhere.

[76] Article 3, Construction Site Fugitive Dust, *http://pinalcountyaz.gov/Departments/AirQuality/Documents/Dust/Article%203%20Construction%20Dust.pdf*

[77] Table 3-7. Control Efficiencies for Control Measures for Construction/Demolition, Chapter 3 Construction and Demolition, *http://www.wrapair.org/forums/dejf/fdh/content/Ch3-Construction_and_Demolition_Rev06.pdf*

Cowtown Monitoring Station – For the Cowtown attainment demonstration modeling, several industrial facilities with permitted sources were found to be operating in the Cowtown low wind modeling domain in 2008. Hourly emission data for stationary source processes and stacks were extracted from the current permits provided by PCAQCD for the following facilities:

- Arizona Grain, Inc./Eagle Milling Company, Inc. – Maricopa;
- Pinal Feeding Company – Maricopa;
- Pinal Energy, LLC – Maricopa;
- Reliant Processing, Ltd. – Maricopa; and
- The Scotts Company – Maricopa.

Initial review of these data and the process descriptions indicated that PM_{10} emissions from the Pinal Energy and Reliant Processing facilities were less than significant in comparison to those of the other permitted facilities and the area sources included in the low wind design day modeling analysis. As a result, no further analysis of the PM_{10} emissions from these two facilities was conducted.

Review of the Arizona Grain/Eagle Milling permit indicated that two stationary sources at this facility emitted the majority of PM_{10}: the railcar unloading shed, and the airsweep systems that exhausted suspended PM_{10} from the railcar and truck unloading sheds. Permit conditions allow for lower-than-average capture and control efficiencies for systems installed to reduce PM_{10} emissions from these sources.[78] Using these permitted capture and control efficiencies, PM_{10} emissions were calculated to be higher than the estimates reported in the permit. As a result, PM_{10} emissions from minor sources at this facility that are not included in the modeling analysis are subsumed by the use of over-estimated emissions rates from the railcar unloading shed and the airsweep systems. These sources were assumed on a worst-case basis to operate continuously on the low wind design day because unloading a dedicated supply train requires more than 24 hours to complete.

The Pinal Feeding permit listed a number of material transfer points and emissions sources within the facility area dedicated to grain processing and storage. To expedite modeling of these emissions, the permitted emissions rates of all of these stationary sources were combined and assumed to be vented from a volume source that enclosed all of the source release points. Emissions were assumed to occur for up to 4 hours per day between 6:00 am and 4:00 pm based on information provided by representatives of the company. In a sensitivity modeling run, emissions were switched on during the hours ending at 11:00 am, 12:00 pm, 2:00 pm, and 3:00 pm, when measured winds blew from this facility to the monitor on the low wind design day of October 29, 2008.

The Scotts Company operates a bark and soil processing facility approximately 1.3 miles west of the monitoring station. The permit requires operation of a water spray system to

[78] The permit specified cyclone capture and control efficiencies of 50% and 80%—well below industry standards (e.g., where the capture efficiency is 99%).

control emissions from conveyors, crushers, vibrating screens, stockpiles, and shakers. Based on the allowed processing rates in the permit and emissions factors for these types of equipment that process low density and friable materials like bark and soil, the maximum PM_{10} emission rate for the facility—assuming that only one of the three processing lines operates at one time—was calculated to be significantly higher than that estimated in the permit. The modeling of emissions from this facility used the calculated worst-case PM_{10} emission rate (144 lb/hr) that was much higher than that contained in the permit (1.1 lb/hr). In the absence of operating hour information in the permit, the processing line responsible for producing this high emission rate was assumed to operate for only two hours per day based on the maximum processing capacity of this line and the annual production rate of this product as specified in the permit. In a sensitivity modeling run, worst-case impacts at the Cowtown monitor were assessed when this processing line was operating and the wind direction during the hour ending at 12:00 pm was pointed directly toward the monitor from the facility. The reported PM_{10} impact was very low, probably because of the separation distance between this facility and the monitor. On the basis of this information, the higher emission rate was used in the attainment demonstration modeling and the processing line was assumed to operate during the two hours on the low wind design day that winds blew generally from the facility to the monitor.

Stanfield Monitoring Station – Three facilities are located within the low wind modeling domain of the Stanfield monitoring station:

- Potters Field;
- Carranza Farm Airstrip; and
- Pinal Gin.

Since permits for these facilities were not available, data from the 2008 National Emission Inventory[79] (NEI) were reviewed. Potters Field and Carranza Farm Airstrip are coded as "Airports" in the NEI, with annual PM_{10} emissions of less than 0.02 tons per year each. Pinal Gin is coded as a cotton gin in the NEI, with annual PM_{10} emissions of less than 0.02 tons per year. In the absence of information on any industrial facility operating in 2008 with PM_{10} emissions greater than 10 tons per year, no stationary source process or stack emissions were included as point sources in the low wind design day attainment modeling analysis for this site.

Pinal County Housing Monitoring Station – One facility that is located within the low wind modeling domain for Pinal County Housing (PCH): the Eleven Mile Corner Farmers Gin. This facility was permitted by PCAQCD for annual PM_{10} emissions of 33 tons per year in 2008. The facility operates two cotton cleaning lines—a long staple gin and a short staple gin—that are assumed to operate 24 hours per day during the cotton harvesting season. PM_{10} emissions from each line are ducted to a bank of cyclones where fibers and larger particles in the exhaust stream are captured and the PM_{10} fraction is

[79] 2008 National Emissions Inventory Data, U.S. Environmental Protection Agency, *http://www.epa.gov/ttn/chief/net/2008inventory.html*, accessed on July 13, 2013

emitted to the air. The PCAQCD permit for the two gins allows hourly PM_{10} emissions of 33 lb/hr, and this emission rate was used in the PCH low wind design day attainment demonstration modeling analysis. Combined PM_{10} emissions from the two banks of cyclones were modeled as a single volume source that encompassed the gin building and the banks of cyclones on each side.

3.1.10 Dairy Emission Methodology

Although dairies are scattered throughout the PM_{10} nonattainment area, only two—Rio Bravo Dairy near Stanfield and Sidewinder Dairy near Pinal County Housing—are located within low wind modeling domains. PM_{10} emissions factors for dairy operations were derived from the Agricultural Best Management Practices for Livestock Operations guide published by the Governor's Agricultural BMP Committee.[80] Because of the substantial separation distances between the dairies and the PM_{10} monitoring stations, PM_{10} emissions factors for the following four different area source operations at dairies were combined into a single factor for use in computing average daily emissions from each facility:

- Unpaved access connections and equipment areas;
- Unpaved roads or feed lanes;
- Animal feeding, waste hauling and transporting, and
- Arenas, corrals and pens.

The combined factor of 5.21 lb./head-year was converted to 6.48 gm/head-day and multiplied by the reported livestock population at each facility in 2008 to produce a facility-wide daily emission rate. In the absence of specific activity data for dairies, emissions from unpaved road travel, feed lane travel, feed transfer, and animal corrals were assumed to be uniform between 6:00 am and 9:00 pm. For modeling purposes, PM_{10} emissions were assumed to be released from each facility at a height of 2.3 meters uniformly across a single area source covering all corrals and active unpaved roads.

3.1.11 Tribal Sources

Both the AK-Chin and Gila River Indian communities (GRIC) fall within portions of three modeling domains: the Low Wind Design Day at Cowtown, low wind hours of High Wind Design Day at Cowtown, and low wind hours of High Wind Design Day at Maricopa.

Contacts were established with the air quality staff at each community to request information on activities for key sources located within the design day modeling domains. Formal requests were submitted for the following:

[80] Agricultural Best Management Practices for Livestock Operations, As Adopted by the Governor's Agricultural Best Management Practices Committee on July 27, 2010.

- Unpaved Roads: Name, ADT, and speed for road links or categories of roads located within each of the modeling domains;

- Agriculture: GIS information on the size and location of each parcel, crops under cultivation in 2008, identification of fallow land, and insight into changes in crop distribution in subsequent years; and

- Point Sources: the coordinates, stack height and stack temperature, and emissions (and changes over time) for each source.

GRIC provided a copy of a 2007 emission inventory for the entire community[81] and traffic count data collected for 188 community roads in 2004.[82] Google Earth images[83] for Ak-Chin lands and unpaved roads and a map documenting the level of PM_{10} control on individual roads[84] were also received. While the GRIC emissions inventory provided source-specific emission estimates, it did not provide the detail needed to characterize activity and emissions on their lands within the design day modeling domains. A review of the traffic count data found that only three paved and three unpaved roads links fell within the design day modeling domains. For the unpaved roads, the counts were contrasted with estimates for similar road categories provided by PCAQCD. For paved roads, the counts were contrasted with travel model estimates provided by ADOT and discrepancies were noted. Given the limited sample size, a decision was made to use the ADOT and PCAQCD estimates, to provide consistency in the paved and unpaved road emission calculations. The Google Earth images and related road map for the Ak-Chin lands contained no information on vehicle activity or emissions. Therefore, other methods were needed to estimate emissions on their lands within the design day modeling domains.

Presented below is a description of the methods used to quantify emissions within each of the tribal domains.

- Unpaved Roads – Based on Google Earth, the coordinates of the end points of AK-Chin and GRIC unpaved roads within the Cowtown and Maricopa modeling domains were identified and input to ARCGIS Shape files. These shape files were sent back to the tribes for confirmation. A similar approach was used to identify end points for Ag roads (a total of 59 miles within the Cowtown modeling domains were identified). There is no information, however, on the ADT levels, the width of roads, the vehicle speeds on the roads, and traffic diurnal variation for these roads. To estimate the emissions for non-AG roads, the average ADT levels, the average width, the average vehicle speeds and the average diurnal variations of non-Ag unpaved County roads that fall into the rest

[81] 2007 Emissions Inventory Update for the Gila River Indian Community, submitted to EPA, Region 10, January 2009
[82] Memorandum from Sandra Shade to Patricia Mariella, re Traffic Counts, April 7, 2004
[83] Email from Bryan Paris to Steve Calderon and Bob Dulla, *Ak Chin EI data for Pinal County SIP*, 5/10/13
[84] Email from Bryan Paris to Bob Dulla and Steve Calderon, *Maps*, 5/15/2013

of corresponding domains were used to represent these roads. For unpaved AG roads, the values for County unpaved Ag roads within the corresponding domains were used. Estimates of travel activity on paved roads within the tribal domains were provided by ADOT. Emissions on these roads were calculated using the paved road methodology.

- Agriculture – As discussed in Chapter 3, most of the low wind modeling domains fell within 6 km radius of the CRPC data provided for each monitor. The land use information provided by ADEQ/PCAQCD identified land parcels within the tribal domains and provided general information on uses (e.g., agriculture, etc.), but did not provide information on crop type. Since CRPC data provided no information on crop type within the tribal domains, an average was computed for the crops included within the CRCP domains and the fractional share of each crop was applied to each land parcel in the tribal domain. Emissions on those parcels were calculated using the appropriate low wind methodology described in this section for agriculture.

- Nonroad – NONROAD estimates of Pinal County emissions were allocated to the tribal lands following methods described in the EPA NONROAD methodology in Section 3.1.5.

- Point Sources – A review of point source data determined that no GRIC sources were located within either Maricopa or Cowtown modeling domains. Ak-Chin lands were determined not to have sources within the Cowtown domains.

3.2 High Wind Fugitive Dust Methodology

Background – Two different methods for quantifying high wind emission factors were proposed in the Inventory Preparation Plan (IPP).

- The ADEQ method back-calculates emission factors for upwind areas by regression analysis of wind speed, PM_{10} concentration, and the pattern of land use along the back-trajectory path. The method uses a least-squares approach to compute emission rates by wind speed range and land use type within a "footprint," or bounded area, responsible for a high fraction of PM_{10} impacts at the monitoring station. This method is summarized in a report entitled "A Method for the Back-Calculation of Wind-Blown Emission Factors from Field Measured PM_{10} Emissions."[85]

- The MAG method, which was employed in quantifying high wind emissions rates for the Maricopa County 2008 Periodic Emission Inventory (PEI) for PM_{10} and MAG's 2012 Five Percent Plan for PM_{10} for the Maricopa County Area, computes emissions as a function of land use, disturbance level, and wind speed; agricultural emissions are calculated using a U.S. Department of Agriculture

[85] Ryan Templeton, Arizona Department of Environmental Quality, 7/02/2012

(USDA) equation for soil erodibility. A copy of this methodology is presented in Appendix 5.

Analysis – AERMOD, an EPA-approved dispersion model of general utility, was used to perform quality control assessments of the ability of each method to replicate emissions rates of area sources responsible for PM_{10} concentrations recorded during high wind hours. Initial efforts focused on the 14 high wind hours at the PCAQCD's Pinal County Housing (PCH) monitoring station on January 1, 2008. Land use information provided by ADEQ and PCAQCD was used to support the calculation of parcel-specific emission estimates for key land use categories (e.g., agriculture, developed rural, developed urban, cleared area, desert shrubland, unpaved roads, etc.).

The ADEQ method calculated emissions factors for each of the land use categories located within the domain determined by the footprint model to be impacting the monitor. In the PCH proof-of-concept test, the modeling domain specified by the footprint model was considerably smaller than the domains proposed in the IPP, which were designed to encompass the one-hour back trajectories of high wind hours on each high wind design day. For each land use category, the footprint model computed PM_{10} emission factors within each of several user-specified wind speed ranges.

The MAG method used portable wind tunnel test data collected on soil surfaces dedicated to specific disturbance activities to compute wind speed-dependent PM_{10} emissions factors for most local land uses. Analysis of the test data, collected by Nickling and Gillies in 1986 in central Arizona,[86] suggested that land use was not a factor in constructing an emission factor equation for windblown PM_{10}, with one exception—PM_{10} emissions rates of agricultural soils did not follow the same trend with respect to wind speed that was common to the emissions rates of soils disturbed by non-agricultural activities. As a result, separate methodologies were used by MAG to estimate windblown PM_{10} emissions rates for agricultural versus non-agricultural lands in the Maricopa County area. The data collected by Nickling and Gillies on all non-agricultural lands were combined and used to generate an emission factor equation using a derivative of wind speed as the dependent variable. For computational ease, the equation was used to compute emissions factors for specific wind speeds designed to represent wind speed ranges spanning 5 mph intervals. These factors were then employed in each hour that the average of wind speeds measured by a set of regional monitors exceeded the threshold velocity for generating windblown PM_{10}.

MAG used a soil erodibility formula developed by the USDA to compute windblown PM_{10} emissions factors on agricultural lands.[87] This formula calculates emissions as a function of soil erodibility, climate, surface roughness, uncovered field width and vegetative cover, but does not use wind speed as a variable; it thus cannot replicate the

[86] "Evaluation of Aerosol Production Potential of Type Surfaces in Arizona," W.G Nickling and J.A. Gillies, EPA Contract No. 68-02-380, 1986

[87] "Development of Emission Factors for Fugitive Dust Sources," EPA 450/3-74-037, U.S. EPA, Research Triangle Park, NC, June; updated in September 1988 in "Control of Open Fugitive Dust Sources," EPA-450/3-88-008.

relationship between PM_{10} concentration and wind speed that is strongly evident in Pinal County monitoring data on high wind days.

The MAG method also configured separate high wind modeling domains around the 1-hour back-trajectories of each high wind hour in the design day. The modeling of PM_{10} impacts from area sources along these back-trajectories revealed that emissions from area sources within a few miles of the monitor dominated the concentrations measured at the monitoring station. This understanding led to the IPP design of high wind modeling domains at the Pinal County attainment demonstration sites that were initially restricted to rectangular domains one mile long along the back-trajectory and two miles wide centered over the trajectory. The coordinates and land use designations of parcels within each domain were provided by ADEQ and PCAQCD. Parcel-specific information on crops under cultivation within a 6 km radius of each monitoring station was obtained from the Arizona Cotton Research and Protection Council (CRPC). The IPP proposed that emissions would be computed using the MAG non-agricultural emission factors and the USDA equation specific to the crops under cultivation within the restricted domain.

The ADEQ-derived emission factors were applied to the same domain and land use data employed in the development of the MAG-based high wind emissions inventory, with the thought that contrasting AERMOD-estimated hourly concentrations using the same meteorology and modeling domain with the different emission factors would be revealing.

A review of the initial results found several differences between the two methods, as outlined below.

- The ADEQ method did a better job of tracking changing hourly values, whereas the MAG method produced a more uniform result that was insensitive to speed or time of day.

- Both methods were found wanting in terms of their representation of agricultural emissions. The ADEQ method aggregated all agricultural land uses into a single factor, so there was no crop distinction. On the other hand, the USDA equation was found to produce windblown emission estimates that were orders of magnitude lower than the non-agricultural windblown emission estimates and therefore had little or no impact on the resulting hourly concentrations.

- The MAG method was found to be largely insensitive to wind speed because of the 5 mph speed bins, applied to the non-agricultural lands. A review of the wind speeds used shows that all of the high winds (at 10 meters) were addressed by two speed bins: 15-20 mph and 20-25 mph.

- The upwind area, defined by the ADEQ methodology, as impacting the PCH monitor was limited to a trajectory of roughly 400 yards, which was barely sufficient to reach nearby agricultural lands. This suggests little or no impact from sources outside of that very limited domain.

- The USDA equation has no term for wind speed. This means that modifications to other variables to more accurately represent Pinal County will show no diurnal variation, just more of a contribution to the total emission inventory.

After considering the advantages and disadvantages of both methods, the analysis evolved to consider several revisions/improvements in the MAG methodology to estimate high wind fugitive dust emissions in Pinal County, as described below.

- The MAG methodology for non-agricultural lands (disturbed and undisturbed) was revised to evaluate the effect of emission factors in 1 mph increments (using an interpolation scheme), the development of these emission factors is described in Appendix 6.

- Given that little difference was observed between agricultural lands and non-agricultural lands in the Nickling and Gillies report, MAG's method was revised to apply to agricultural lands with one modification—the vegetative cover factor was added to adjust emissions to account for crop-specific coverage effects (e.g., the factor for alfalfa is 0, whereas the factor for cotton is 0.7).

- The initial analysis of MAG's method applied uniform disturbance fractions to land use parcels in the upwind domain. Many of MAG's values, however, are not applicable to Pinal County because they were based on the results of field inspections. This led to a joint effort between PCAQCD and ADEQ to collect local observations and conduct a literature review of land disturbance levels used in other PM_{10} SIPS of similar climatology (e.g., Clark County, Imperial County, etc.). The literature review determined that in most cases, Pinal County has differentiated land use types to a greater resolution than the other SIPs analyzed. Thus, some judgment was applied, based on the available information, to prepare the summary of the resulting disturbance and stable land estimates presented in Table 3-39 for non-agricultural lands.

- ADEQ staff developed emission factor (EF) adjustment curves through an analysis of monitor-specific concentrations recorded during high wind hours (exceeding 12 mph) with steady wind direction. The EF adjustment curves account for Pinal County windblown emissions during sustained high winds and are assumed to account for saltation initialization periods, reservoir depletion, etc. Calculation of the EF adjustment curves is detailed in Appendix 7.

- A review of the current Guide to Agricultural PM_{10} Best Management Practices (BMPs) and the related 2001 Technical Support Document found that BMP emission reduction estimates for wind erosion control measures were based on the USDA equation. The TSD, however, recognized that wind tunnel test data were used to estimate windblown emission factors in the micro-inventory study conducted at West Chandler and Gilbert, and that it was not appropriate to compare the results of the two different methods because each was appropriate for its specific spatial resolution and intended purpose.

- The modeling domains impacting the high wind design day monitors are substantially larger than those defined by the ADEQ methodology; they are also larger than the initial 1 mile x 2 mile domain noted above. To address this limitation, the domains were extended farther along the high wind back trajectories. A description of the method derived to select the upwind domains is presented in Section 2.1.

Table 3-39
Disturbance Level for Non-Agricultural Land Used in Pinal High Wind Annual Emission Inventory

Land Use ID	Description	Disturbance	Stable
A	Developed Urban Lands[88]	2.5%	0.0%
B	Developed Rural Lands (low density residential)	5.0%	95.0%
C	Paved Roads[89]	0.0%	0.0%
D	Unpaved Roads (Private Dirt, Ag Road, and Trail)	100.0%	0.0%
D	Unpaved Roads (Public Dirt)	75.00%	25.00%
E	Cleared Areas	15.00%	85.00%
F	Residential Construction*	46.0%	54.0%
G	CAFOs and Dairies	50.0%	50.0%
H	Desert Shrubland	5.0%	95.0%
J	Commercial Construction*	46.0%	54.0%
K	Other	10.00%	90.00%
L	Site Development	28.0%	72.0%

* See discussion below on how these values were estimated.

To address the issues outlined above, separate methods were developed to calculate windblown emissions for agricultural lands, non-agricultural lands, and construction sites. A discussion of each follows.

Agricultural Windblown Emissions – Given the extent of agricultural land located within each modeling domain and the difficulty of developing observational estimates of disturbance levels by crop type, ADEQ determined that estimates of disturbance should be interpreted from an existing data set. The crop calendar was selected to provide insight on crop-specific disturbance levels. Presented below is a summary of the approach used to extract that insight.

[88] In contrast to other communities, this land use category did not include urban fringe areas, but only lands within the urban core. Given the extensive surface coverage observed on urban core lands in Pinal County, the disturbance levels are limited.
[89] Maintenance practices within the County ensure that paved roads have 0% disturbance and that there is no distinction between disturbed and stable.

A review of the information contained in the shapefiles provided by ADEQ/PCAQCD and by CRPC identified several different categories of agricultural land use within each modeling domain, including the following:

- CRPC crop lands – crop types CRPC identified for parcels under cultivation in 2008;
- Fallow lands – parcels CRPC identified as being fallow in 2008;
- Other Agricultural Lands – parcels not addressed by CRPC, but identified by ADEQ/PCAQCD as agricultural land.

The "Other" agricultural lands category includes (1) parcels identified by AZDEQ/PCAQCD, through aerial photography and land ownership records, as agricultural but for which CRPC did not provide crop data for (i.e., lands within the overlap of the two shapefiles), and (2) parcels ADEQ/PCAQCD identified as agricultural, through land ownership records, located outside of the 6 km radial boundary supplied by CRPC.

The distribution of crop lands, including fallow land and Other ag lands, was calculated for each monitor/modeling domain from the CRPC and ADEQ/PCAQCD shapefiles. A summary of those values is presented in Table 3-40. The results show many crops were not identified by CRPC within the modeling domains as being actively cultivated in 2008; these are listed as N/A. The crop categories actively under cultivation within the domains include cotton, alfalfa, corn, and, to a lesser extent, grain and orchards. Fallow land is shown to represent a small fraction of land for all domains (less than 10%), while the significance of Other Agricultural Land varies by monitor.

An understanding of the significance of agricultural lands within each modeling domain can be gained from a review of the agricultural land share presented at the bottom of Table 3-40. It shows agriculture has a dominant share of the modeling domains at PCH and Stanfield, a significant share of the Cowtown domain, and a more modest share of the Maricopa domain.

As discussed earlier, emissions are calculated separately for disturbed and stable land. The approach used to determine if CRPC crop lands were disturbed or stable was to review the crop calendar provided by PCAQCD (presented in Appendix 3) and ask farmers for insight on design day activities. The 10-day period in which the design day occurred (highlighted in Appendix 3) was reviewed to determine if any activity (i.e., harvesting, planting, etc.) occurred for each crop. The results, summarized in Table 3-41, show that design days for PCH, Stanfield, and Maricopa all occurred in periods when cotton was being harvested (scored with a "D" for disturbed), while the design day for Cowtown occurred in the spring, which had a mixture of activities depending on the crop type. Crops being planted were also scored "D," while those between harvest and planting were scored with an "S" for stable, as no activity was

Table 3-40 Distribution of Crop Categories for Agricultural Lands Located in High Wind Modeling Domains (%)				
Crop	PCH	Stanfield	Cowtown	Maricopa
Cotton	30.6	31.7	10.7	1.4
Alfalfa	39.5	30.6	38.1	17.6
Corn	N/A	14.4	N/A	12.8
Grain	19.0	N/A	N/A	N/A
Melons	N/A	N/A	0.3	N/A
Orchard	N/A	N/A	8.0	N/A
Wheat	N/A	N/A	N/A	N/A
Barley	N/A	N/A	N/A	N/A
Sorghum	N/A	N/A	N/A	N/A
Other Vegetables	N/A	N/A	N/A	N/A
Citrus	N/A	N/A	N/A	N/A
Fallow	6.2	0.0	9.0	0.0
Other Agriculture	4.7	23.3	34.0	68.1
Ag land share (%) of the domain	78.8	73.1	46.1	27.0

Note: NA denotes crops not identified within the modeling domains as being actively cultivated in 2008.

Table 3-41 Disturbance Assumptions for Agricultural Lands Identified in Cotton Research and Protection Council Shapefile for High Wind Modeling Domains					
Crop	VC	PCH	Stanfield	Cowtown	Maricopa
Cotton	0.7	D	D	D	D
Alfalfa	0.0	-	-	-	-
Corn	0.44	-	S	-	S
Grain	0.0	-	-	-	-
Melons	0.77	-	-	S	-
Orchard	0.77	-	-	S	-
Wheat	0.0	-	-	-	-
Barley	0.0	-	-	-	-
Sorghum	0.0	-	-	-	-
Other Vegetables	0.77	-	-	-	-
Citrus	0.77	-	-	-	-
Design Date		01/01/08	11/21/08	04/27/08	10/27/08
Previous Rainfall Date		12/11/07	09/10/08	02/16/08	09/10/08

D = 100% disturbed
S = 100% stable

assumed. As previously noted, insight gained from discussions with farmers about design day activities was used to modify crop calendar listings. For example, corn is shown to be actively harvested in October in the crop calendar, but farmers indicated that corn harvesting occurs earlier in the June/July/August time frame, so the disturbance assumption is listed as "S" instead of "D".

The next step was to identify the most recent date preceding the design day on which measurable rainfall (0.01") occurred to determine if soil moisture levels were sufficient to prevent particle entrainment. Three of the sites (Stanfield, Cowtown, and Maricopa) had a period of more than a month between rainfall and the design day. The shortest period was at PCH, which had 20 days between rainfall and design day—sufficient time for the soil to dry and not invalidate decisions about the land disturbance.

In addition to rainfall, a number of other factors can influence windblown dust emissions on agricultural lands, including crop canopy, post-harvest crop residue, etc. Since the influence of these factors is only partially addressed in the original Nickling and Gillies wind tunnel measurements and is also not readily available for Pinal County, the vegetative coverage (VC) factor employed in the USDA soil erodibility formula[90] was used to account for the collective effect of these factors on windblown dust production. The crop-specific values are displayed in Table 3-41. As can be seen, the dense vegetative cover produced by alfalfa eliminates windblown dust throughout the year, whereas cotton coverage reduces windblown emissions by 30%. To simplify the table, no information was extracted from the crop calendar for crops with a VC value of "0"or for crops not being actively cultivated as shown in Table 3-40. The disturbance values for those crops is represented by "-".

The equation used to calculate windblown dust emissions for disturbed agricultural land is shown as Equation 1 below.

$$Esj = F_{EFAdjusment} A \bullet EF_{Disturbed,bin} \bullet V' \qquad (1)$$

where:

Esj = suspended PM_{10} in gram/sec for hour j

$F_{EFAdjustment}$ = the Emission Adjustment factor for reservoir depletion

A = the area of each crop's land parcel, in m^2

$EF_{Disturbed,bin}$ = the windblown dust emission factor developed for disturbed soil for that wind speed bin, gram/m^2-sec for hour j (detailed in Appendix 7)

V' = vegetative cover for crop specific, presented above in Table 3-41

[90] MAG used the soil erodibility formula to quantify high wind emissions from active agricultural lands in the Five Percent Plan.

Equation 1 was used to quantify windblown dust emissions for disturbed land at PCH, Stanfield, and Maricopa during the harvesting season. For Cowtown, the vegetative coverage factor was not included in the disturbance calculation, because the crop coverage would be limited during the planting season.

The equation used to calculate windblown dust emissions from stable agricultural lands is presented below as Equation 2. (The same equation is used to calculate emissions for stable non-agricultural lands.) It assumes 100% stable land ($P_{Stable}=1$).

$$Esj = F_{EFAdjusment} A \bullet EF_{stable,bin} \bullet P_{stable} \tag{2}$$

where:

Esj = suspended PM_{10} in gram/sec for hour j

$F_{EFAdjustment}$ = the Emission Adjustment factor

A = the area of each parcel, in m^2

$EF_{Stable,bin}$ = the windblown dust emission factor developed for stable soil for that wind speed bin, gram/m^2-sec for hour j (detailed in Appendix 7)

P_{Stable} = the percentage of stable soil for agricultural land

For fallow lands and for Other Agricultural Lands, guidance from PCAQCD and ADEQ[91] staff was used to estimate the distribution of stable and disturbed land (90%/10%). Equation 2 was used to quantify windblown dust emissions for the stable portion of fallow and Other Agricultural Lands. Equation 1 without the crop coverage factor was used to quantify emissions from the disturbed portion of both land use categories.

Non-Agricultural Windblown Emissions – Information provided by PCAQCD staff on disturbance for non-agricultural lands, presented in Table 3-39, was used to quantify emissions for disturbed and stable lands. Equation 3 was used for computing windblown dust emissions for the disturbed portion of non-agricultural land:

$$Esj = F_{EFAdjusment} A \bullet EF_{Disturbed,bin} \bullet P_{Disturbed} \tag{3}$$

where:

Esj = suspended PM_{10} in gram/sec for hour j

$F_{EFAdjustment}$ = the Emission Adjustment factor for reservoir depletion

[91] Email from Ryan Templeton, ADEQ to Bob Dulla, Sierra Research, 10/30/13.

A = the area of each parcel, in m^2

$EF_{Disturbed,\ bin}$ = the windblown dust emission factor developed for disturbed soil for that wind speed bin, gram/m^2-sec for hour j (detailed in Appendix 7)

$P_{disturbed}$ = the disturbed level, in percentage for each category of non-agricultural land, specified in Table 3-38

Equation 4, which is essentially the same as Equation 2, was used to quantify emissions for stable non-agricultural lands:

$$Esj = F_{EFAdjusment} A \bullet EF_{stable,bin} \bullet P_{stable} \tag{4}$$

where:

Esj = suspended PM_{10} in gram/sec for hour j

$F_{EFAdjustment}$ = the Emission Adjustment factor

A = the area of each parcel, in m^2

$EF_{Stable,bin}$ = the windblown dust emission factor developed for stable soil for that wind speed bin, gram/m^2-sec for hour j (detailed in Appendix 7)

P_{Stable} = the percentage of stable soil for agricultural land for each different non-agriculture land, detailed in Table 3-39.

Construction – A review of the literature and discussions with industry representatives failed to provide insight into soil disturbance levels on construction sites. Lacking this information, the stagnant construction dust construction calculation assumes 100% of the permitted acreage is disturbed. The uncontrolled emission estimate computed for this acreage is then reduced to account for the combined effect of fugitive dust rule compliance and control measure efficiency. As discussed in Section 3.1.8, construction dust permit inspections found a 90% compliance rate with the rule requirements. Discussions with industry representatives determined that watering is the most common control measure employed in Pinal County and the 61% control efficiency for watering at 3.2-hour intervals at construction sites listed in the WRAP Fugitive Dust Handbook is representative of Pinal County applications. Collectively, these metrics indicate a 54% fugitive dust control effectiveness. Since this benefit should apply to both low and high wind hours, it is used to estimate the fraction of land that is stabilized on construction sites. The remaining 46% of permitted lands are assumed to be disturbed.

Low Wind Hours on High Wind Days – The emission estimates for the low wind hours during high wind days are calculated using the source-specific emission estimates outlined earlier in the low wind section of this chapter. A description of the methods used to select the low wind hour domains on high wind days is presented in Section 2.2.

Activity-Based Emissions – Activity-based emissions are quantified for stagnation conditions and are generally not addressed in inventory development during high wind hours, because of differences in magnitude. A review of the diurnal profiles presented in Section 4, however, found that activity-based estimates in low wind hours exceeded the fugitive-based estimates for many of the high wind hours. Similarly, low wind hour concentrations were found to exceed high wind hour concentrations for one or more hours at all of the violating high wind monitors. Recognizing that activity-based emissions in high wind hours can be significant led to a decision to include them in the inventory. The approach used was to quantify activity-based emissions within the low wind domains for each hour of the high wind days. Because the areal extent of these domains encompassed the high wind domains, activity (or mechanically) driven emissions for sources located within the high wind domains could be extracted for the high wind hours in the modeling analysis.

Table 3-42 summarizes activity-based emissions during low and high wind hours within the low wind domains for each of the high wind design days. It shows that in most cases the high wind hour activity emissions are substantially greater than the low wind hour values. That is because the high wind hours typically occur during the middle of the day when anthropogenic activity is highest. A detailed listing of diurnal estimates for windblown emissions, activity-based emissions, and total emissions by source category is presented in Appendix 10.

Table 3-42
Summary of Activity-Based PM_{10} Emitted Within Low Wind Domains During Low and High Wind Hours on High Wind Days
(Average lbs/day)

Model Domain	Units	Construction	Agriculture	CAFOs	Unpaved Roads				Total[a]
					Ag	Public	Private	Trail	
PCH	Low Wind	-	10.0	-	22.8	24.7	6.0	0.3	78.6
	High Wind	-	33.1	-	68.5	81.8	26.7	1.1	212.3
	Total	-	44.1	-	91.3	106.5	32.7	1.4	290.9
CWT	Low Wind	-	12.3	210.6	41.2	69.9	19.8	0.4	404.2
	High Wind	-	21.2	98.5	82.2	95.8	29.7	0.7	393.5
	Total	-	33.5	309.1	123.4	165.7	49.5	1.1	797.7
MAR	Low Wind	10.7	1.3	47.6	19.9	8.4	10.5	0.1	111.7
	High Wind	96.2	3.9	26.7	59.7	17.3	19.1	0.4	235.0
	Total	106.9	5.2	74.3	79.6	25.7	29.6	0.5	346.7
STF	Low Wind	0.1	6.2	70.6	78.8	62.5	15.1	0.2	234.2
	High Wind	0.4	18.5	41.5	236.3	87.6	21.4	0.8	406.6
	Total	0.5	24.7	112.1	315.1	150.1	36.5	1.0	640.8

a. Total includes values for all source categories not just those displayed in this table.

###

4. EMISSION SUMMARY

The methods and activity levels described in Section 3 were applied to the modeling domains and land uses detailed in Section 2 to estimate emissions for each parcel under stagnation/low wind and high wind conditions. A summary of the hourly emission estimates in units of lbs/hour for each source category is presented in Tables 4-1 through 4-3 for Cowtown, Stanfield, and Pinal County Housing stagnation design days and Tables 4-4 through 4-7 for the high wind Pinal County Housing, Cowtown, Maricopa, and Stanfield monitors.

To provide perspective on hourly changes by source, information on hourly wind speed (WSPD) in miles/hour, wind direction (WD) in degrees, and PM_{10} observations (µg/m3) is also provided. To gain insight into source apportionment, average daily emission estimates are presented along with their percentage contribution to the overall level of PM_{10} emitted. Air quality modeling—which combines information on emissions, location, and meteorology—will provide more detail on each source's contribution to concentrations recorded on the selected design days.

To aid review of the high wind day estimates, the high wind hours (WSPD $\geq$ 12 mph) are shaded to distinguish them from low wind hours. Estimates in the high wind tables show that loose particles entrained during high wind hours are substantially greater than those produced by mechanical activities and combustion during low wind hours.

Neighborhood roads, including paved with trackout and unpaved, are presented separately for the Stanfield and Pinal County Housing domains to provide insight into the magnitude of their emissions. Trackout for all other paved roads is included with the paved road estimates to simplify the summaries. Non-road emissions are not displayed because they account for very small portions of the stagnation emissions: 0.6% for Cowtown, 0.01% for Stanfield, and 0.0004% for Pinal County Housing.

Table 4-1
Emissions Inventory (lbs/hour) for the Stagnation Day Modeling Domain at Cowtown on 10/29/2008

Hour	WSPD (mph)	WD (degree)	PM_{10} Observation ($\mu g/m^3$)	RailRoad	Permitted Point Sources	Paved Road	Construction	CAFOs	Agriculture		Unpaved Road					Total
									County	Tribal Land	AG Road	Public Dirt	Private Dirt	Trail	Tribe road	
1	2.2	153.0	402.3	1.2	10.0	2.0	0.0	37.1	0.0	0.0	0.0	12.6	3.5	0.0	2.2	68.6
2	2.9	178.0	343.0	1.2	10.0	1.9	0.0	37.1	0.0	0.0	0.0	12.5	17.5	0.0	4.7	84.8
3	3.4	133.0	417.8	1.2	10.0	1.8	0.0	74.2	0.0	0.0	0.0	12.5	8.7	0.0	2.7	111.2
4	3.8	153.0	125.4	1.2	10.0	2.2	0.0	148.4	0.0	0.0	0.0	10.7	0.0	0.0	1.4	173.9
5	2.0	152.0	248.4	1.2	10.0	4.3	0.0	370.9	0.0	0.0	0.0	20.9	10.5	0.0	5.0	422.7
6	0.9	198.0	156.5	1.2	10.0	14.0	0.0	370.9	0.0	0.0	0.0	52.3	36.7	0.0	13.3	498.5
7	2.9	198.0	294.2	1.2	10.0	24.0	0.0	370.9	19.3	0.8	318.6	115.3	73.4	2.3	154.5	1090.4
8	2.9	182.0	171.8	1.2	10.0	21.2	194.4	370.9	19.3	0.8	318.6	165.2	45.5	2.3	156.7	1306.1
9	2.5	184.0	136.3	1.2	10.0	17.8	194.4	370.9	19.3	0.8	318.6	143.0	61.2	2.3	157.8	1297.3
10	0.9	252.0	219.5	1.2	10.0	13.6	194.4	370.9	19.3	0.8	318.6	164.6	115.4	2.3	167.6	1378.8
11	1.6	327.0	165.8	1.2	207.4	14.7	194.4	296.7	19.3	0.8	318.6	144.1	76.9	2.3	160.4	1436.8
12	2.5	348.0	103.2	1.2	207.4	15.4	194.4	296.7	19.3	0.8	318.6	173.7	118.9	2.3	170.1	1518.8
13	2.7	13.0	76.3	1.2	10.0	14.4	194.4	222.5	19.3	0.8	318.6	152.3	85.7	2.3	163.9	1185.5
14	4.0	326.0	61.7	1.2	63.4	15.1	194.4	222.5	19.3	0.8	318.6	173.8	136.4	2.3	173.3	1321.1
15	3.1	328.0	38.5	1.2	63.4	19.1	194.4	222.5	19.3	0.8	318.6	192.3	108.4	2.3	170.4	1312.7
16	2.5	336.0	41.5	1.2	10.0	32.3	194.4	296.7	19.3	0.8	318.6	204.7	115.4	2.3	172.4	1368.1
17	1.8	4.0	103.2	1.2	10.0	30.3	194.4	370.9	19.3	0.8	318.6	182.0	83.9	2.3	165.4	1379.2
18	3.4	327.0	60.6	1.2	10.0	16.5	0.0	519.2	19.3	0.8	318.6	164.2	69.9	2.3	160.0	1282.0
19	1.1	347.0	67.2	1.2	10.0	8.9	0.0	667.6	0.0	0.0	0.0	91.5	73.4	0.0	24.1	876.7
20	1.8	286.0	300.9	1.2	10.0	7.1	0.0	667.6	0.0	0.0	0.0	51.6	56.0	0.0	15.8	809.3
21	2.7	131.0	383.6	1.2	10.0	6.1	0.0	519.2	0.0	0.0	0.0	53.7	63.0	0.0	17.2	670.4
22	1.6	158.0	194.8	1.2	10.0	4.4	0.0	370.9	0.0	0.0	0.0	45.8	17.5	0.0	8.7	458.5
23	3.4	149.0	228.4	1.2	10.0	3.3	0.0	111.3	0.0	0.0	0.0	31.7	15.7	0.0	6.3	179.5
24	4.0	149.0	189.2	1.2	10.0	2.5	0.0	111.3	0.0	0.0	0.0	21.0	5.2	0.0	3.5	154.7
Average			188.7	1.2	30.9	12.2	81.0	309.1	9.7	0.4	159.3	99.7	58.3	1.2	86.6	849.4
Percentage Contribution				0.1%	3.6%	1.4%	9.5%	36.4%	1.1%	0.0%	18.8%	11.7%	6.9%	0.1%	10.2%	100.0%

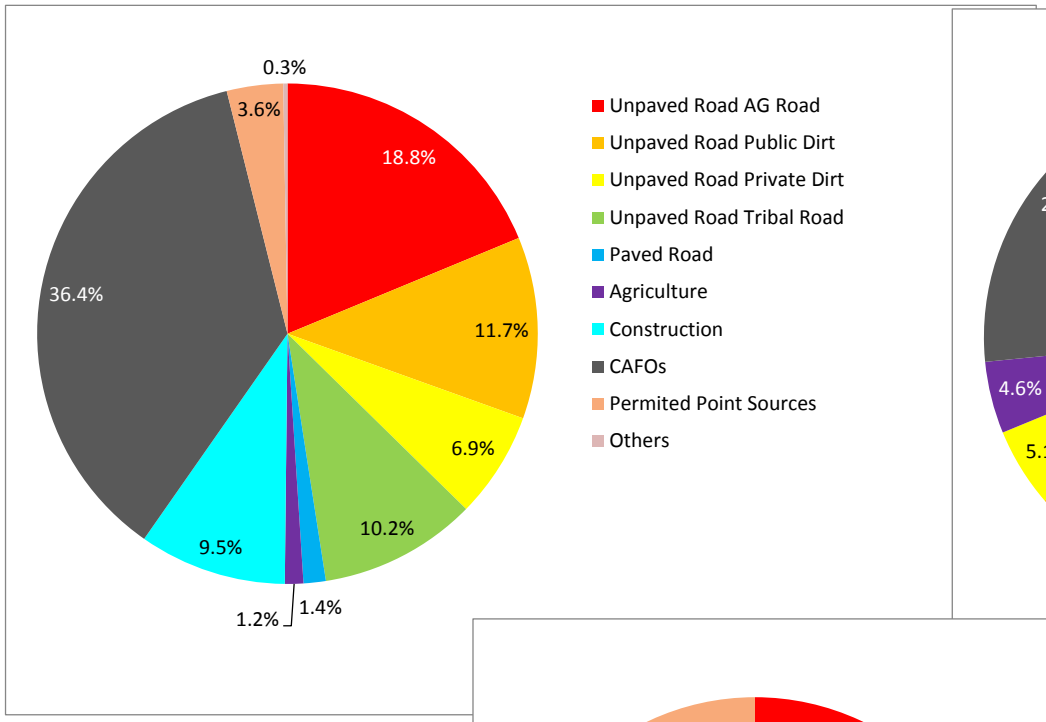
Table 4-2
Emissions Inventory (lbs/hour) for the Stagnation Day Modeling Domain at Stanfield on 10/29/2008

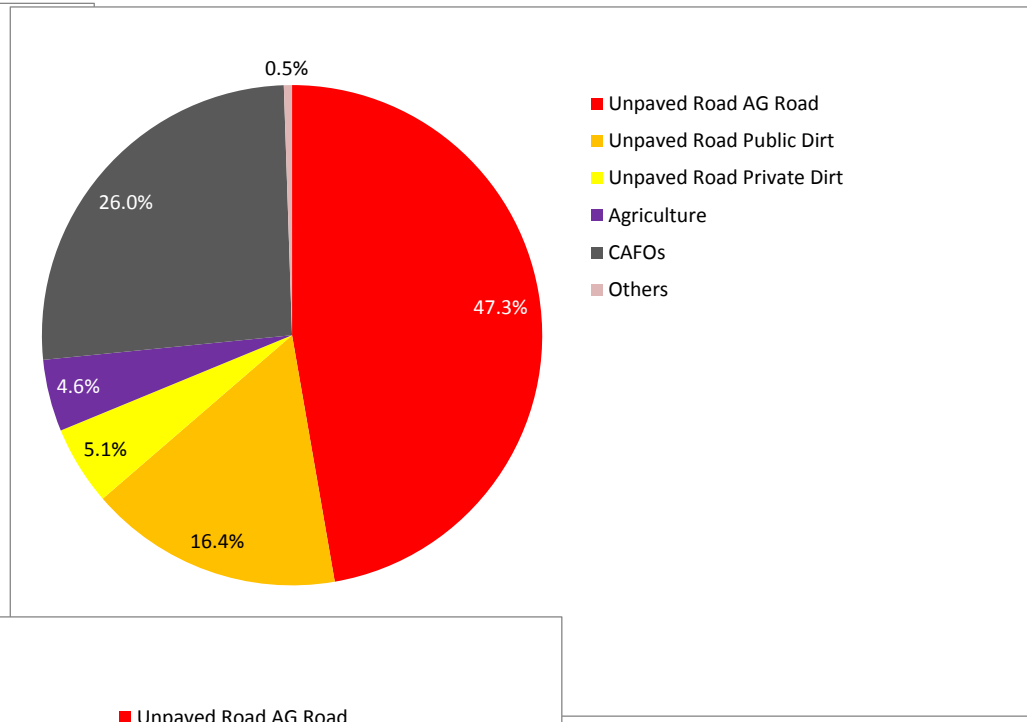
Hour	WSPD (mph)	WD (degree)	PM_{10} Observation ($\mu g/m^3$)	Paved Road	Neighbor-hood Paved Road	Neighbor-hood UnPaved Road	Construction	CAFOs	Agri-culture	Unpaved Road				Total
										AG Road	Public Dirt	Private Dirt	Trail	
1	2.1	251.9	46.0	0.3	0.0	0.0	0.0	21.4	0.0	0.0	19.2	10.5	0.0	51.4
2	2.3	159.9	79.0	0.2	0.0	0.0	0.0	21.4	0.0	0.0	11.8	5.2	0.0	38.7
3	3.5	139.5	76.8	0.2	0.0	0.0	0.0	42.8	0.0	0.0	12.4	0.0	0.0	55.4
4	2.8	155.2	63.0	0.3	0.0	0.0	0.0	85.5	0.0	0.0	24.9	6.3	0.0	117.0
5	2.8	99.4	144.0	0.5	0.0	0.0	0.0	213.8	0.0	0.0	50.3	22.0	0.0	286.7
6	1.9	108.0	183.5	1.8	0.0	0.1	0.0	213.8	0.0	0.0	126.1	44.1	2.5	388.4
7	1.8	179.6	187.7	3.1	0.1	0.2	0.0	213.8	63.5	646.7	174.8	27.3	2.5	1132.1
8	1.8	171.9	307.2	2.7	0.1	0.1	1.3	213.8	63.5	646.7	164.0	36.7	2.5	1131.5
9	1.5	183.8	226.0	2.3	0.1	0.2	1.3	213.8	63.5	646.7	172.1	69.3	2.5	1171.8
10	3.6	82.4	133.2	1.8	0.0	0.3	1.3	213.8	63.5	646.7	158.9	46.2	2.5	1135.1
11	3.2	121.4	126.2	1.9	0.0	0.2	1.3	171.1	63.5	646.7	183.4	71.4	2.5	1142.0
12	2.9	129.8	116.1	2.0	0.1	0.3	1.3	171.1	63.5	646.7	164.5	51.4	2.5	1103.4
13	3.0	165.8	101.7	1.9	0.0	0.2	1.3	128.3	63.5	646.7	185.4	81.9	2.5	1111.8
14	2.0	112.1	69.7	2.0	0.0	0.4	1.3	128.3	63.5	646.7	205.8	65.1	2.5	1115.6
15	2.2	67.2	65.5	2.5	0.1	0.3	1.3	128.3	63.5	646.7	223.8	69.3	2.5	1138.2
16	2.4	94.3	43.8	4.0	0.1	0.3	1.3	171.1	63.5	646.7	221.2	50.4	2.5	1161.1
17	2.8	59.4	43.8	3.8	0.1	0.2	1.3	213.8	63.5	646.7	192.8	42.0	2.5	1166.7
18	2.6	5.3	509.1	2.1	0.1	0.2	0.0	299.4	63.5	646.7	111.5	44.1	0.0	1167.5
19	2.5	297.8	341.7	1.1	0.0	0.2	0.0	384.9	0.0	0.0	68.6	33.6	0.0	488.5
20	1.8	296.4	628.5	0.9	0.0	0.2	0.0	384.9	0.0	0.0	74.1	37.8	0.0	497.9
21	2.9	260.5	124.8	0.8	0.0	0.2	0.0	299.4	0.0	0.0	58.7	10.5	0.0	369.6
22	2.2	253.8	72.7	0.6	0.0	0.0	0.0	213.8	0.0	0.0	38.0	9.4	0.0	261.9
23	2.9	169.3	93.1	0.4	0.0	0.0	0.0	64.1	0.0	0.0	25.3	3.1	0.0	93.1
24	3.5	163.9	106.6	0.3	0.0	0.0	0.0	64.1	0.0	0.0	25.9	3.2	0.0	93.6
Average			162.1	1.6	0.0	0.2	0.5	178.2	31.8	323.4	112.2	35.0	1.3	684.1
Percentage Contribution				0.2%	0.0%	0.0%	0.1%	26.0%	4.6%	47.3%	16.4%	5.1%	0.2%	100.0%

Table 4-3
Emissions Inventory (lbs/hour) for the Stagnation Day Modeling Domain at PCH on 10/29/2008

Hour	WSPD (mph)	WD (degree)	PM_{10} Observation ($\mu g/m^3$)	Paved Road	Neighbor-hood Paved Road	Neighbor-hood UnPaved Road	Permitted Point Sources	Construction	Dairies	Agriculture	Unpaved Road				Total
											AG Road	Public Dirt	Private Dirt	Trail	
1	2.1	100.2	91.4	0.2	0.0	0.0	33.0	0.0	0.2	0.0	0.0	9.7	1.6	0.0	44.8
2	1.3	122.1	86.1	0.2	0.0	0.0	33.0	0.0	0.2	0.0	0.0	10.7	8.1	0.0	52.2
3	1.1	73.5	72.5	0.2	0.0	0.0	33.0	0.0	0.4	0.0	0.0	8.8	4.0	0.0	46.5
4	1.1	144.0	67.8	0.2	0.0	0.0	33.0	0.0	0.8	0.0	0.0	9.4	0.0	0.0	43.4
5	1.1	246.0	76.6	0.5	0.0	0.0	33.0	0.0	2.0	0.0	0.0	21.9	4.9	0.0	62.2
6	1.1	142.8	60.1	1.5	0.0	0.0	33.0	0.0	2.0	0.0	0.0	44.3	17.0	0.0	97.9
7	1.1	189.5	145.8	2.4	0.0	0.0	33.0	0.0	2.0	35.7	152.4	93.8	34.0	0.7	353.9
8	1.1	276.0	287.0	2.2	0.0	0.0	33.0	0.2	2.0	35.7	152.4	137.3	21.0	0.7	384.4
9	1.6	133.5	179.2	1.8	0.0	0.0	33.0	0.2	2.0	35.7	152.4	130.7	28.3	0.7	384.7
10	1.1	300.9	455.2	1.5	0.0	0.0	33.0	0.2	2.0	35.7	152.4	141.9	53.4	0.7	420.7
11	1.4	18.9	234.8	1.6	0.0	0.0	33.0	0.2	1.6	35.7	152.4	131.7	35.6	0.7	392.5
12	1.6	259.9	85.6	1.7	0.0	0.0	33.0	0.2	1.6	35.7	152.4	150.7	55.0	0.7	430.9
13	1.4	308.7	71.4	1.6	0.0	0.0	33.0	0.2	1.2	35.7	152.4	132.3	39.7	0.7	396.6
14	2.6	263.9	62.7	1.7	0.0	0.0	33.0	0.2	1.2	35.7	152.4	145.8	63.1	0.7	433.7
15	2.2	292.9	65.6	2.1	0.0	0.0	33.0	0.2	1.2	35.7	152.4	159.1	50.2	0.7	434.5
16	1.5	244.0	54.5	3.3	0.0	0.0	33.0	0.2	1.6	35.7	152.4	163.9	53.4	0.7	444.2
17	1.5	294.0	40.8	3.1	0.0	0.0	33.0	0.2	2.0	35.7	152.4	159.6	38.9	0.7	425.5
18	1.1	300.1	368.4	1.7	0.0	0.0	33.0	0.0	2.8	35.7	152.4	136.6	32.4	0.7	395.2
19	1.1	53.0	588.4	1.0	0.0	0.0	33.0	0.0	3.6	0.0	0.0	76.2	34.0	0.0	147.7
20	1.1	57.4	453.5	0.8	0.0	0.0	33.0	0.0	3.6	0.0	0.0	43.9	25.9	0.0	107.2
21	1.1	91.7	281.6	0.7	0.0	0.0	33.0	0.0	2.8	0.0	0.0	46.7	29.1	0.0	112.3
22	1.1	82.1	199.3	0.5	0.0	0.0	33.0	0.0	2.0	0.0	0.0	36.8	8.1	0.0	80.4
23	1.1	128.4	128.6	0.4	0.0	0.0	33.0	0.0	0.6	0.0	0.0	24.4	7.3	0.0	65.6
24	1.1	187.8	114.4	0.3	0.0	0.0	33.0	0.0	0.6	0.0	0.0	18.8	2.4	0.0	55.1
Average			188.7	1.3	0.0	0.0	33.0	0.1	1.6	17.9	76.2	84.8	27.0	0.3	242.2
Percentage Contribution				0.5%	0.0%	0.0%	13.6%	0.0%	0.7%	7.4%	31.5%	35.0%	11.1%	0.1%	100.0%

Figure 4-1
Summary of Stagnation Design Day Source Distribution by Modeling Domain





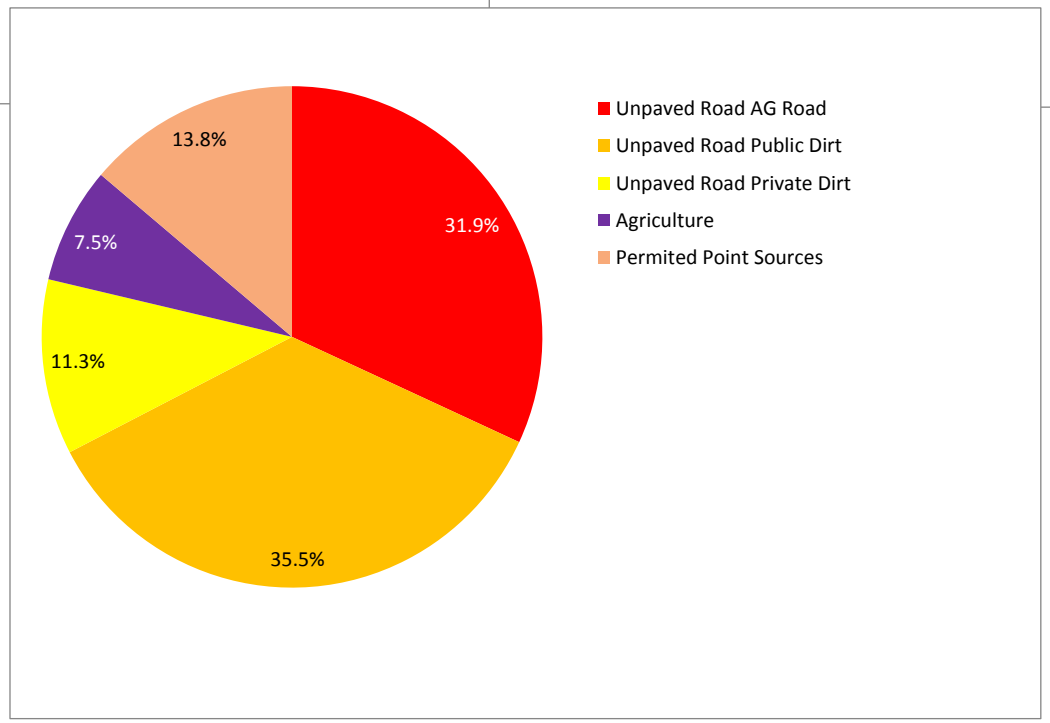


Table 4-4
Emissions Inventory (lbs/hour) for the High wind Day at PCH on 1/1/2008

Hour	WSPD (mph)	WD (degree)	PM^{10} Observation ($\mu g/m^3$)	Paved Road	Permitted Point Sources	Dairies	Cleared Area	Desert Shrubland	Developed Rural Lands	Developed Urban Lands	Agriculture	Unpaved Road				Total
												AG Road	Public Dirt	Private Dirt	Trail	
1	1.6	303.8	28.2	0.5	33.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	12.8	2.0	0.0	48.5
2	1.5	318.0	21.0	0.5	33.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	10.4	9.8	0.0	53.8
3	2.0	335.4	22.2	0.4	33.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	12.3	4.9	0.0	51.1
4	2.5	333.7	24.5	0.5	33.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	11.5	0.0	0.0	45.8
5	5.9	352.2	16.4	1.0	33.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	26.8	5.9	0.0	68.7
6	3.2	299.6	19.1	3.4	33.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	60.8	20.6	0.0	119.8
7	3.9	339.3	16.2	5.5	33.0	2.0	0.0	0.0	0.0	0.0	88.2	182.6	119.4	41.3	2.8	474.8
8	5.7	5.0	22.7	4.9	33.0	2.0	0.0	0.0	0.0	0.0	88.2	182.6	177.7	25.5	2.8	516.8
9	4.8	53.9	34.7	4.1	33.0	2.0	0.0	0.0	0.0	0.0	88.2	182.6	162.1	34.4	2.8	509.2
10	16.3	41.2	871.2	0.0	0.0	2.0	119.0	297.2	42.6	11.0	2521.4	352.2	230.0	107.5	15.6	3698.5
11	21.4	46.3	919.3	0.0	0.0	1.6	355.2	823.7	118.2	37.3	8165.9	755.1	315.6	187.1	45.9	10805.6
12	25.1	49.6	1136.1	0.0	0.0	1.6	641.0	1486.2	213.3	67.3	14663.9	1215.6	463.7	326.4	80.5	19159.6
13	23.6	48.5	790.7	0.0	0.0	1.2	275.3	638.4	91.6	28.9	6348.8	626.3	284.8	159.6	36.2	8491.2
14	22.9	48.3	946.1	0.0	0.0	1.2	135.1	313.3	45.0	14.2	3160.4	400.3	245.5	131.3	19.2	4465.5
15	19.2	47.6	320.0	0.0	0.0	1.2	65.5	163.5	23.5	6.1	1427.0	275.9	229.5	84.4	9.9	2286.4
16	22.3	53.6	397.9	0.0	0.0	1.6	87.6	203.2	29.2	9.2	2081.0	323.8	245.1	100.3	13.5	3094.4
17	19.9	53.6	281.9	0.0	0.0	2.0	80.0	199.8	28.7	7.4	1724.6	296.7	219.5	75.8	11.4	2645.9
18	15.0	50.6	65.8	0.0	0.0	2.8	20.5	53.3	7.7	1.8	480.7	209.6	172.7	46.1	4.9	1000.0
19	15.5	54.6	50.9	0.0	0.0	3.6	14.6	38.1	5.5	1.3	280.3	19.3	95.4	46.1	1.5	505.7
20	19.4	58.1	61.5	0.0	0.0	3.6	18.2	45.4	6.5	1.7	371.9	25.9	55.8	37.9	1.9	568.8
21	19.3	56.7	70.6	0.0	0.0	2.8	21.8	54.5	7.8	2.0	446.3	31.1	58.8	43.2	2.3	670.6
22	19.2	57.4	67.6	0.0	0.0	2.0	21.8	54.5	7.8	2.0	446.3	31.1	49.5	17.6	2.3	635.0
23	17.2	55.7	32.7	0.0	0.0	0.6	6.6	16.6	2.4	0.6	135.5	9.4	31.4	11.2	0.7	215.0
24	14.9	54.6	139.3	0.0	0.0	0.6	13.0	33.9	4.9	1.1	249.3	17.2	27.0	7.3	1.3	355.6
Average			264.9	0.9	12.4	1.6	78.1	184.2	26.4	8.0	1782.0	214.1	138.3	63.6	10.7	2520.3
Percentage Contribution				0.0%	0.5%	0.1%	3.1%	7.3%	1.0%	0.3%	70.7%	8.5%	5.5%	2.5%	0.4%	100.0%

Shaded Area = High Wind Hours

Table 4-5
Emissions Inventory (lbs/hour) for the High Wind Day Modeling Domain at Cowtown on 04/27/2008

Hour	WSPD (mph)	WD (degree)	PM_{10} Obser-vation ($\mu g/m^3$)	Rail Road	Permitted Point Sources	Paved Road	Construc-tion	Cleared Area	Desert Shrubland		Devel-oped Rural Lands	Devel-oped Urban Lands	Un-known	CAFOs	Agriculture		Unpaved Road					Total
									County	Tribal					County	Tribal Land	AG Road	Public Dirt	Private Dirt	Trail	Tribal road	
1	6.1	332.4	68.3	1.2	10.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	37.1	3.5	1.5	0.0	19.6	3.0	0.0	2.3	79.0
2	0.7	320.5	73.0	1.2	10.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	37.1	3.5	1.5	0.0	22.2	14.8	0.0	4.8	96.0
3	5.9	314.7	88.1	1.2	10.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	74.2	3.5	1.5	0.0	18.1	7.4	0.0	2.8	119.5
4	3.9	84.4	59.7	1.2	10.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	148.4	3.5	1.5	0.0	18.3	0.0	0.0	1.5	185.3
5	2.2	25.7	92.3	1.2	10.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	370.9	3.5	1.5	0.0	39.7	8.9	0.0	5.1	442.8
6	2.4	156.6	492.9	1.2	10.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	370.9	3.5	1.5	0.0	84.1	31.2	0.0	13.7	522.5
7	1.6	229.1	326.4	1.2	10.0	10.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	370.9	63.5	52.1	246.7	185.9	62.3	2.2	138.1	1143.4
8	2.1	11.6	222.0	1.2	10.0	9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	370.9	63.5	52.1	246.7	268.9	38.6	2.2	140.4	1203.6
9	10.9	33.2	372.4	1.2	10.0	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	370.9	63.5	52.1	246.7	249.1	51.9	2.2	141.5	1196.9
10	20.0	52.9	886.8	0.0	0.0	0.0	621.2	59.8	1156.3	451.0	101.0	3.5	0.2	370.9	2022.3	52.1	415.5	301.2	385.2	6.3	151.6	6098.2
11	17.6	44.4	107.7	0.0	0.0	0.0	164.7	15.8	306.5	119.5	26.8	0.9	0.1	296.7	582.7	52.1	291.4	256.7	141.5	3.3	144.2	2402.9
12	15.7	43.0	122.3	0.0	0.0	0.0	75.2	7.2	140.0	54.6	12.2	0.4	0.0	296.7	300.6	52.1	267.1	291.8	135.7	2.7	154.2	1790.8
13	17.7	37.0	72.0	0.0	0.0	0.0	153.7	14.8	286.0	111.5	25.0	0.9	0.1	222.5	548.0	52.1	288.5	261.6	143.8	3.3	147.8	2259.5
14	14.7	44.0	38.4	0.0	0.0	0.0	51.6	5.2	105.1	41.0	9.2	0.3	0.0	222.5	230.8	52.1	260.3	285.7	139.0	2.6	157.5	1562.9
15	16.1	49.6	36.4	0.0	0.0	0.0	76.2	7.3	141.8	55.3	12.4	0.4	0.0	222.5	303.7	52.1	267.4	315.6	127.3	2.7	154.4	1739.1
16	15.1	50.7	23.1	0.0	0.0	0.0	60.9	6.2	124.1	48.4	10.8	0.3	0.0	296.7	261.1	52.1	262.8	330.5	125.4	2.6	156.5	1738.5
17	12.1	59.4	69.7	0.0	0.0	0.0	11.6	1.2	23.7	9.2	2.1	0.1	0.0	370.9	101.2	52.1	249.8	314.0	76.5	2.3	149.3	1363.9
18	9.2	68.9	101.2	1.2	10.0	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	519.2	63.5	52.1	246.7	272.8	59.4	2.2	143.7	1378.2
19	5.2	40.9	230.1	1.2	10.0	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	667.6	3.5	1.5	0.0	152.8	62.3	0.0	24.8	927.8
20	4.0	8.0	72.9	1.2	10.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	667.6	3.5	1.5	0.0	88.7	47.5	0.0	16.3	839.6
21	2.9	37.2	79.7	1.2	10.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	519.2	3.5	1.5	0.0	94.2	53.4	0.0	17.8	703.6
22	3.0	35.3	42.6	1.2	10.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	370.9	3.5	1.5	0.0	76.2	14.8	0.0	9.0	489.2
23	3.8	111.6	232.5	1.2	10.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	111.3	3.5	1.5	0.0	50.7	13.4	0.0	6.5	199.5
24	4.7	9.3	127.5	1.2	10.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	111.3	3.5	1.5	0.0	36.6	4.5	0.0	3.6	173.3
Average			168.3	0.8	6.7	2.5	50.6	4.9	95.1	37.1	8.3	0.3	0.0	309.1	193.6	26.8	137.1	168.1	72.8	1.5	78.6	1194.0
Percentage Contribution				0.1%	0.6%	0.2%	4.2%	0.4%	8.0%	3.1%	0.7%	0.0%	0.0%	25.9%	16.2%	2.2%	11.5%	14.1%	6.1%	0.1%	6.6%	100.0%

Shaded Area = High Wind Hours

Table 4-6
Emissions Inventory (lbs/hour) for the High Wind Day Modeling Domain at Maricopa on 10/27/2008

Hour	WSPD (mph)	WD (degree)	PM_{10} Observa-tion ($\mu g/m^3$)	Rail Road	Paved Road	Construc-tion	CAFOs	Cleared Area	Desert Shrub-land	Devel-oped Rural Lands	Devel-oped Urban Lands	Un-known	Agriculture		Unpaved Road					Total
													County	Tribal Land	AG Road	Public Dirt	Private Dirt	Trail	Tribal road	
1	3.8	160.0	239.9	1.0	3.0	0.0	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	1.8	0.0	1.0	18.9
2	2.0	106.0	143.5	1.0	2.8	0.0	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	8.9	0.0	2.2	25.2
3	1.3	6.0	70.3	1.0	2.8	0.0	17.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	4.4	0.0	1.3	30.6
4	1.3	348.0	73.8	1.0	3.4	0.0	35.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.7	43.4
5	2.5	290.0	98.7	1.0	6.5	0.0	89.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	5.3	0.0	2.3	111.1
6	2.0	241.0	91.8	1.0	21.3	0.0	89.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.8	18.7	0.0	6.3	153.3
7	1.3	215.0	129.8	1.0	32.5	0.0	89.2	0.0	0.0	0.0	0.0	0.0	10.4	7.2	159.1	28.9	37.4	1.0	18.2	384.9
8	5.6	82.0	160.4	1.0	28.8	256.5	89.2	0.0	0.0	0.0	0.0	0.0	10.4	7.2	159.1	43.9	23.1	1.0	19.2	639.5
9	13.0	84.0	326.2	0.0	0.0	631.0	89.2	108.5	52.4	59.9	30.2	8.8	247.3	7.2	175.9	41.6	36.4	1.6	19.7	1509.8
10	16.1	85.0	852.9	0.0	0.0	2657.9	89.2	663.4	305.9	349.2	200.6	53.0	1428.2	7.2	270.5	63.4	94.0	5.0	24.3	6211.9
11	18.3	81.0	496.5	0.0	0.0	2401.5	71.3	592.5	273.3	311.9	179.2	47.3	1276.8	7.2	258.6	55.7	70.7	4.6	20.9	5571.4
12	16.3	82.0	293.2	0.0	0.0	1193.1	71.3	425.3	119.3	136.2	78.3	20.7	563.3	7.2	202.6	56.8	74.2	2.6	25.5	2976.4
13	17.0	79.0	176.0	0.0	0.0	1055.9	53.5	220.8	101.8	116.3	66.8	17.6	482.4	7.2	196.2	47.9	55.3	2.3	22.6	2446.6
14	16.8	74.0	141.9	0.0	0.0	878.3	53.5	171.8	79.2	90.4	51.9	13.7	377.5	7.2	188.0	52.1	78.5	2.0	27.0	2071.0
15	15.4	72.0	84.8	0.0	0.0	514.8	53.5	71.5	36.2	41.3	20.8	6.1	173.8	7.2	170.7	52.6	58.8	1.4	25.6	1234.4
16	13.6	71.0	76.6	0.0	0.0	350.1	71.3	27.1	13.1	15.0	7.6	2.2	69.6	7.2	163.3	50.3	60.0	1.2	26.6	864.7
17	13.0	72.0	68.6	0.0	0.0	318.9	89.2	18.1	8.7	10.0	5.0	1.5	49.9	7.2	161.9	42.3	43.6	1.1	23.3	780.6
18	8.7	62.0	60.4	1.0	23.1	0.0	124.8	0.0	0.0	0.0	0.0	0.0	10.4	7.2	159.1	36.7	35.6	1.0	20.7	419.7
19	7.2	61.0	56.2	1.0	13.5	0.0	160.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.6	37.4	0.0	11.3	243.3
20	7.4	68.0	45.1	1.0	10.7	0.0	160.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6	28.5	0.0	7.5	217.7
21	9.6	70.0	36.1	1.0	9.2	0.0	124.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.5	32.0	0.0	8.1	184.6
22	9.8	80.0	30.8	1.0	6.8	0.0	89.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.6	8.9	0.0	4.1	117.5
23	9.2	82.0	33.2	1.0	5.0	0.0	26.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	8.0	0.0	3.0	49.6
24	8.9	78.0	38.7	1.0	3.8	0.0	26.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	2.7	0.0	1.7	40.9
Average			159.4	0.6	7.2	427.4	74.3	95.8	41.2	47.1	26.7	7.1	195.8	3.6	94.4	27.6	34.3	1.0	13.5	1097.8
Percentage Contribution				0.1%	0.7%	38.9%	6.8%	8.7%	3.8%	4.3%	2.4%	0.6%	17.8%	0.3%	8.6%	2.5%	3.1%	0.1%	1.2%	100.0%

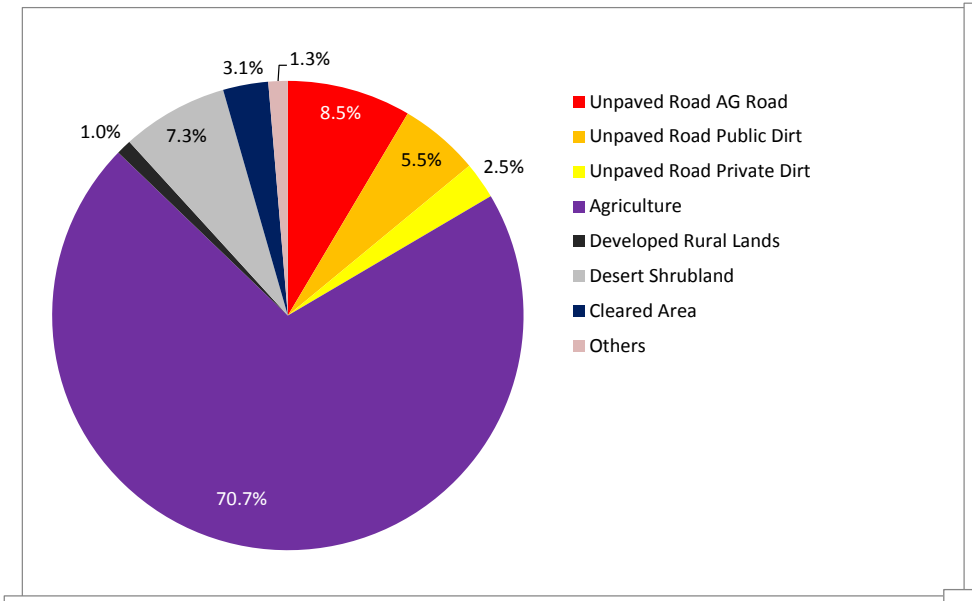
Shaded Area = High Wind Hours

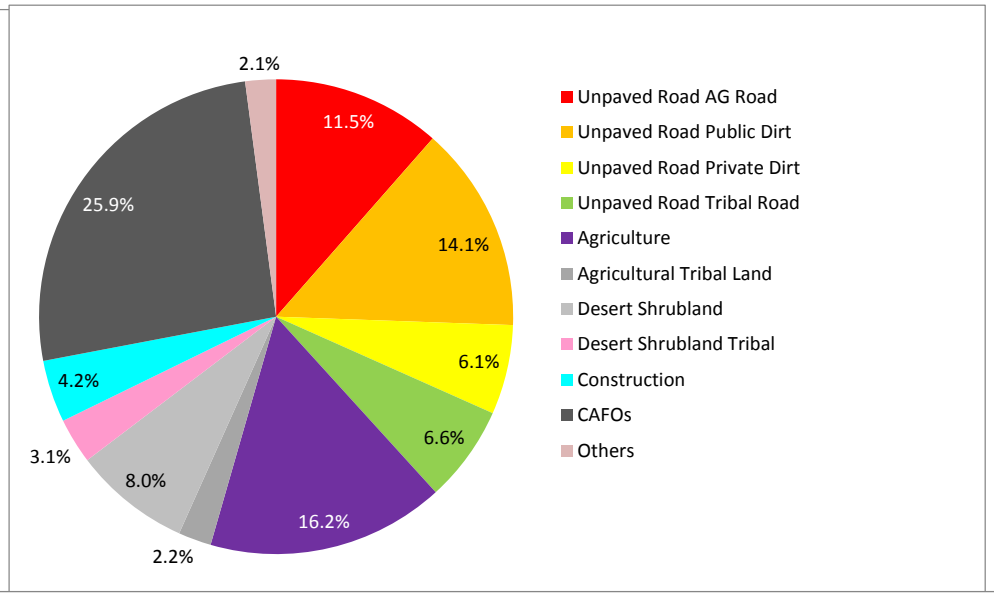
Table 4-7
Emissions Inventory (lbs/hour) for the High Wind Day Modeling Domain at STF on 11/21/2008

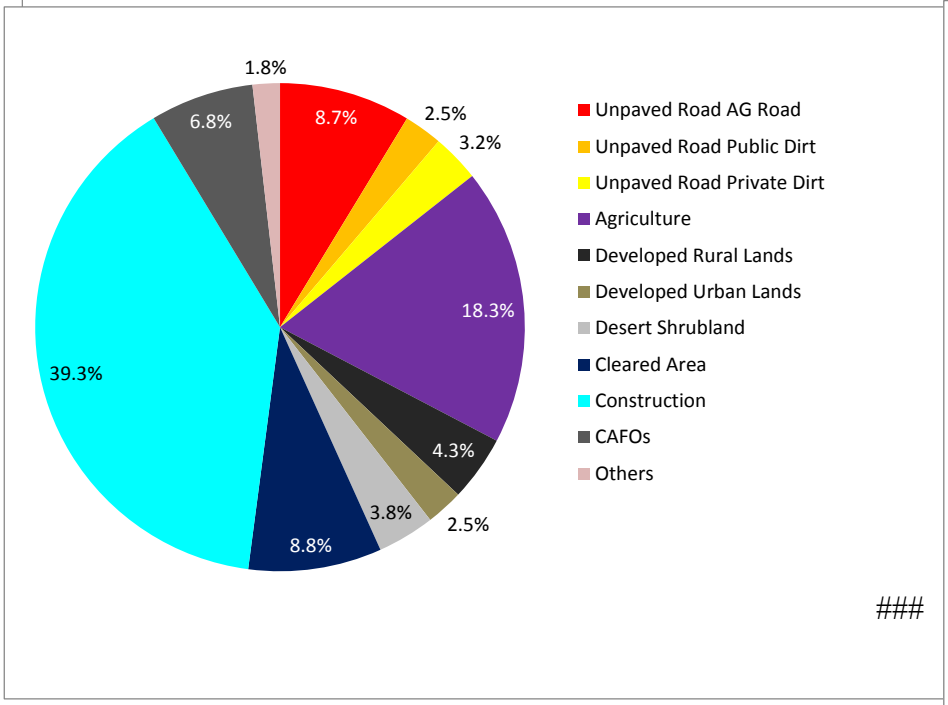
Hour	WSPD (mph)	WD (degree)	PM_{10} Observation ($\mu g/m^3$)	Paved Road	Construc -tion	CAFOs	Cleared Area	Desert Shrubland	Developed Rural Lands	Developed Urban Lands	Agri-culture	Unpaved Road				Total
												AG Road	Public Dirt	Private Dirt	Trail	
1	4.1	119.2	112.4	0.2	0.0	13.5	0.0	0.0	0.0	0.0	0.0	0.0	18.0	2.2	0.0	33.9
2	3.5	161.6	59.4	0.2	0.0	13.5	0.0	0.0	0.0	0.0	0.0	0.0	22.4	10.9	0.0	47.0
3	3.9	117.3	157.4	0.2	0.0	26.9	0.0	0.0	0.0	0.0	0.0	0.0	16.7	5.5	0.0	49.3
4	4.3	125.4	158.4	0.3	0.0	53.8	0.0	0.0	0.0	0.0	0.0	0.0	16.7	0.0	0.0	70.8
5	3.7	274.2	102.3	0.5	0.0	134.5	0.0	0.0	0.0	0.0	0.0	0.0	33.6	6.6	0.0	175.2
6	4.0	240.9	234.2	1.7	0.0	134.5	0.0	0.0	0.0	0.0	0.0	0.0	72.2	23.0	0.0	231.5
7	15.9	85.5	357.4	0.0	0.0	215.9	2.1	112.8	9.5	0.1	697.8	668.3	181.7	49.3	2.5	1939.9
8	18.3	81.9	326.6	0.0	1.3	267.8	3.4	185.0	15.5	0.2	1112.4	692.6	261.2	33.9	2.9	2576.2
9	20.4	82.2	584.6	0.0	1.3	720.1	14.8	812.6	68.2	0.8	4719.2	904.2	304.6	62.4	5.7	7613.9
10	19.9	81.1	429.2	0.0	1.3	351.8	5.5	301.5	25.3	0.3	1782.0	731.9	269.3	81.1	3.4	3553.4
11	20.0	80.2	334.3	0.0	1.3	255.4	3.7	205.0	17.2	0.2	1227.5	699.3	238.5	54.2	3.0	2705.4
12	18.2	80.4	186.1	0.0	1.3	175.8	1.7	94.5	7.9	0.1	592.7	662.1	262.9	77.2	2.5	1878.7
13	14.7	79.2	93.9	0.0	1.3	104.3	0.6	36.0	3.0	0.0	239.1	641.0	228.7	54.5	2.2	1310.8
14	13.4	78.5	65.1	0.0	1.3	90.7	0.3	15.2	1.3	0.0	129.7	634.8	254.4	85.7	2.1	1215.5
15	12.3	75.3	64.8	0.0	1.3	84.8	0.1	6.2	0.5	0.0	90.3	632.1	282.0	68.0	2.1	1167.4
16	9.9	77.2	65.2	3.9	1.3	107.6	0.0	0.0	0.0	0.0	49.4	630.2	302.0	72.2	2.0	1168.7
17	7.1	74.7	87.1	3.7	1.3	134.5	0.0	0.0	0.0	0.0	49.4	630.2	289.0	52.5	2.0	1162.7
18	4.7	73.8	104.6	2.0	0.0	188.4	0.0	0.0	0.0	0.0	49.4	630.2	254.2	43.8	2.0	1170.0
19	6.3	75.1	88.3	1.1	0.0	242.2	0.0	0.0	0.0	0.0	0.0	0.0	143.5	45.9	0.0	432.7
20	5.6	86.2	56.1	0.9	0.0	242.2	0.0	0.0	0.0	0.0	0.0	0.0	85.0	35.0	0.0	363.0
21	2.6	158.4	98.3	0.7	0.0	188.4	0.0	0.0	0.0	0.0	0.0	0.0	90.5	39.4	0.0	319.0
22	2.2	230.2	249.6	0.5	0.0	134.5	0.0	0.0	0.0	0.0	0.0	0.0	74.5	10.9	0.0	220.5
23	2.9	270.1	171.6	0.4	0.0	40.4	0.0	0.0	0.0	0.0	0.0	0.0	49.1	9.8	0.0	99.8
24	2.4	291.4	99.5	0.3	0.0	40.4	0.0	0.0	0.0	0.0	0.0	0.0	33.4	3.3	0.0	77.4
Average			178.6	0.7	0.5	165.1	1.3	73.7	6.2	0.1	447.5	339.9	157.7	38.6	1.4	1232.6
Percentage Contribution				0.1%	0.0%	13.4%	0.1%	6.0%	0.5%	0.0%	36.3%	27.6%	12.8%	3.1%	0.1%	100.0%

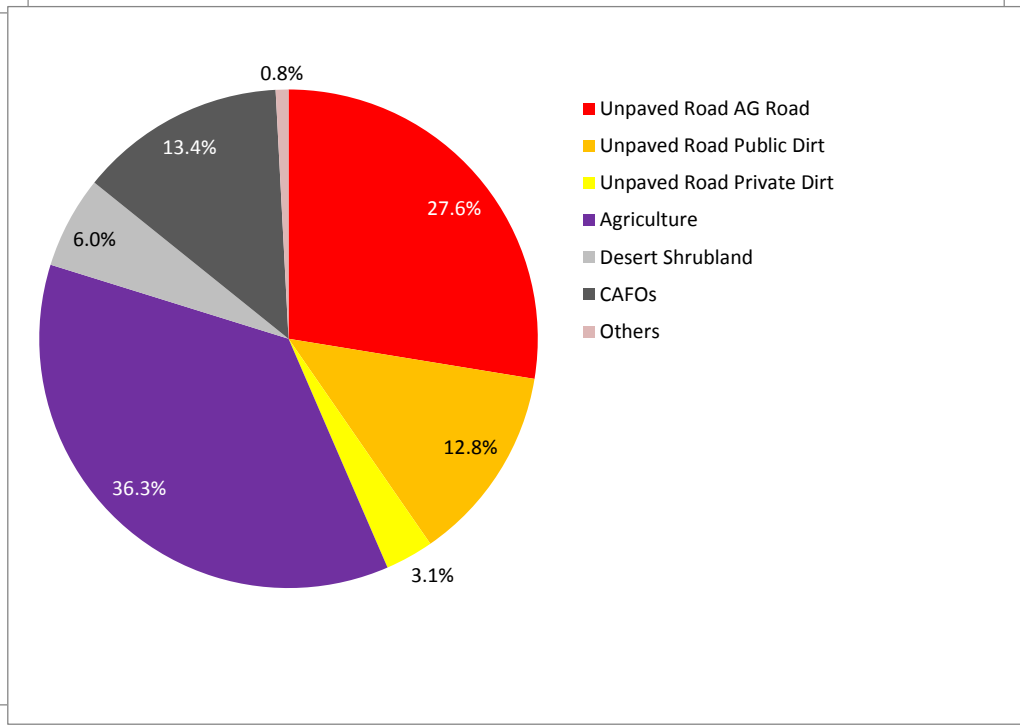
Shaded Area = High Wind Hours

Figure 4-2
Summary of High Wind Design Day Source Distribution by Modeling Domain









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5. ANNUAL EMISSIONS INVENTORY

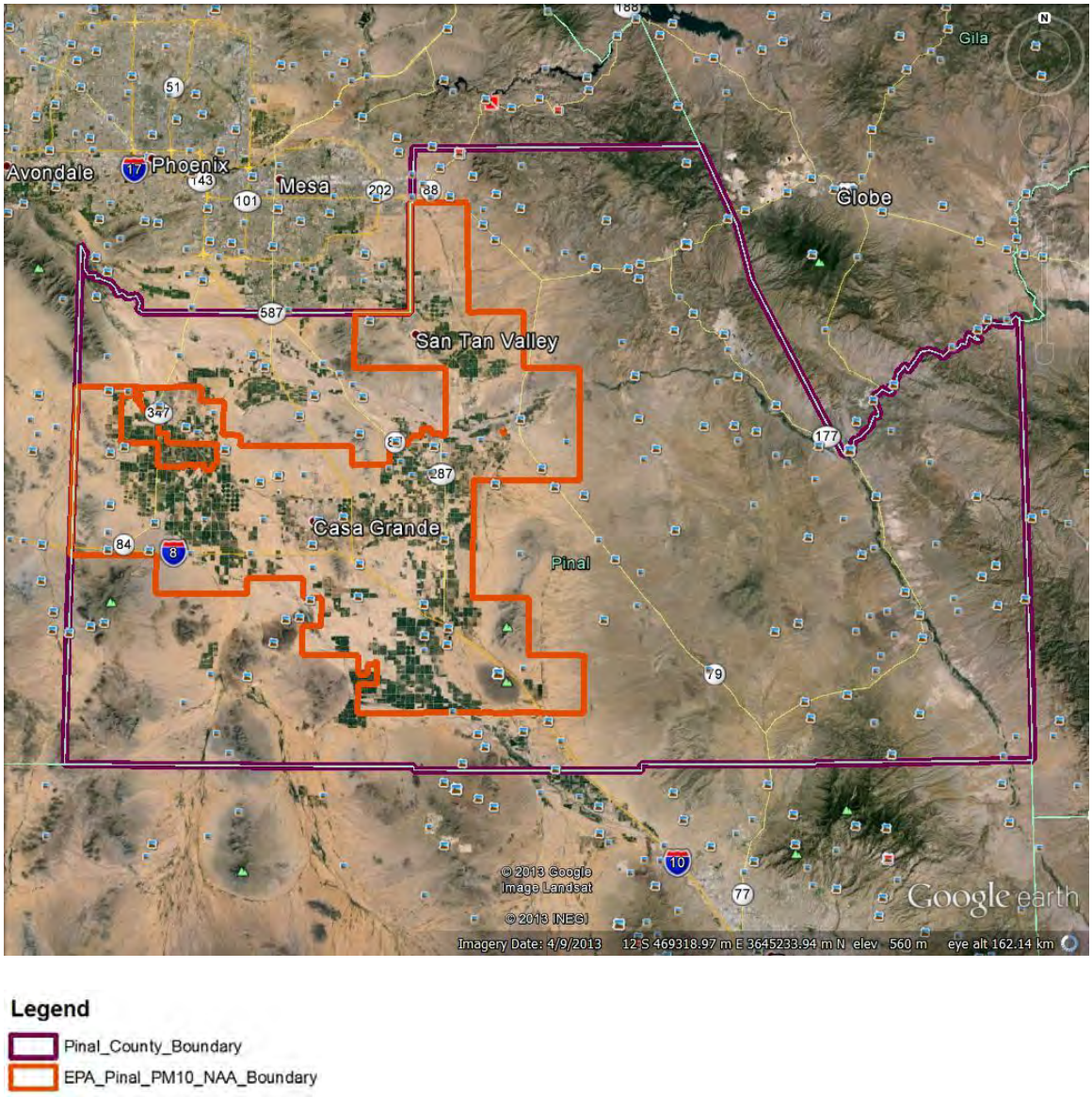
EPA designated the western portion of Pinal County, excluding tribal lands, as nonattainment for the 24-hour PM_{10} national ambient air quality standard (NAAQS) in 2012. Title I of the 1990 Clean Air Act Amendments requires the development of a baseline emission inventory and periodic revisions for areas that fail to meet the NAAQS. The earlier sections of this report addressed the requirement to develop baseline emission inventory estimates for the design days and related modeling domains selected to demonstrate attainment; this section addresses the requirement to develop an annual baseline emissions inventory for the entire PM_{10} nonattainment area. As noted in the Inventory Preparation Plan, also prepared earlier to guide compilation of these baseline inventories, an annual emissions inventory helps identify which sources and source categories predominate in the generation of PM_{10} emissions across the nonattainment area. This ranking of source significance provides the basis for analysis of long-term emission trends impacted by changes in source activity rates and implementation of regulatory control strategies.

A map of Pinal County and the PM_{10} nonattainment area is displayed in Figure 5-1. The County, as reported on its website,[92] covers an area of about 5,400 square miles and is comprised of two distinct geographic regions: an eastern portion characterized by mountains reaching 6,000 feet in elevation, and a western area consisting primarily of low desert valleys hosting irrigated agricultural land. As can be seen in Figure 5-1, the nonattainment area is an irregular shape that covers the western portion of the County with an area of 1325.2 square miles. It should also be noted that while Indian lands are located within the boundaries of the nonattainment area, and within the Maricopa and Cowtown monitoring station modeling domains, these lands are not designated nonattainment for the 24-hour PM_{10} NAAQS and, therefore, are not included in this annual emissions inventory.

The spatial distribution of estimated PM_{10} emissions within the nonattainment area was facilitated by GIS shapefiles provided by ADEQ and PCAQCD that provide information on land use, population, etc. For several source categories (e.g., nonroad vehicles and equipment), emissions in the nonattainment area were estimated from available county-wide values adjusted by the ratio of nonattainment area population to the county total. For other source categories (e.g., construction, confined animal feeding operations (CAFO), and railroads), estimates are based on activity rates of sources within the nonattainment area and emissions factors representative of these sources.

[92] *http://pinalcountyaz.gov/Departments/BudgetOffice/Documents/BB0607/countyoverview.pdf*

Figure 5-1
Comparison of Pinal County and Western Pinal County PM_{10} Nonattainment Boundaries



Following the approach described in Section 3, separate estimates of emissions were prepared for low and high wind conditions. Where appropriate, local precipitation event data were factored into the annual fugitive dust emissions calculations according to EPA guidance (e.g., such as reported for paved and unpaved road emissions in AP-42[93]). Since the Maricopa Association of Governments (MAG) is responsible for the development of transportation conformity budgets for the Western Pinal County PM_{10}

[93] Compilation of Air Pollutant Emissions Factors, AP-42, U.S. Environmental Protection Agency, *http://www.epa.gov/ttn/chief/ap42/index.html*, accessed on July 29, 2013.

nonattainment area, emissions data and assumptions derived from these budgets, as discussed in in Section 3, were used to prepare annual emission estimates for on-road sources in this section. Summaries of the methods and data sources used to estimate emissions for PM_{10} source categories that are significant in the nonattainment area are presented below.

5.1 Low Wind Emissions Inventory

Descriptions of the adjustments made to the Section 3.1 low wind methodologies to estimate annual emissions are presented in the subsections below. No estimates are provided for emissions on tribal lands because these areas are not included in the nonattainment designation; also, no estimates of trackout emissions from local paved roads are provided because insufficient information is available to characterize the locations and activity levels of such source areas within the nonattainment area. The remainder of the source discussions are presented in the order in which they occur in Section 3.1.

5.1.1 Agriculture Emissions

To compute annual emissions within the entire nonattainment area, the methods presented in Section 3.1.1 were adjusted to:

- Develop estimates of total areas within the nonattainment area devoted to cultivation of locally-prominent crops;
- Develop an estimate of the total acreage considered to be fallow; and
- Eliminate adjustments for diurnal variations, which are not germane to annual emission estimates.

While the Arizona Cotton Research and Protection Council (CRPC) provided detailed information on crops under cultivation within 6 kilometers of each high wind monitor, no similar information is available for portions of the nonattainment area outside these zones. A review of available data sources found that the 2007 Agricultural Census[94] contained county-specific information on farm operations in Arizona, including total acres harvested by crop. Recognizing that farmers respond to market conditions and that decisions on crops to plant/harvest change year to year, the county agricultural agent was contacted for information on crops under cultivation in 2008.[95] He provided information from the 2008 Arizona Agricultural Statistics Bulletin on acres in production in Pinal

[94] *http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/County_Profiles/Arizona/cp04021.pdf*

[95] Phone conversation with Rick Gibson, University of Arizona Cooperative Extension and Bob Dulla, August 23, 2013

County for a limited number of crops. A comparison of these values with those reported in the 2007 Agricultural Census found total cultivated acreages to be roughly equivalent (~ 12,000 acre difference = 6% of the county total) and the crop distributions to be similar. However, the Census provided more valuable detail on the crops under cultivation. For this reason, the 2007 Census values for Pinal County were used to characterize the crop distribution in the PM_{10} nonattainment area in 2008. Table 5-1 provides a summary of the acreage and percentage distribution by crop type found in the 2007 Census data.

Table 5-1
Acres of Crops Under Cultivation in 2007 Agricultural Census for Pinal County

Crop	Acres	Percent
Field Crops		
Barley for Grain	11,718	6.1%
Corn for Grain	1,101	0.6%
Cotton	73,718	38.3%
Sorghum for Grain	10,255	5.3%
Wheat for Grain	19,316	10.0%
Field Seeds, Hay, Forage, Silage		
Field and Grass Seed	2,836	1.5%
Forage - All Hay, Haylage, Sileage & Greenchop	63,811	33.2%
Vegetables – Total	9,611	5.0%
Total	192,366	100.0%

Since annual tilling emissions are based on the number of passes per year and harvesting emissions are based on lbs/acre-year, crop calendar information was not used to prepare the annual emission estimates. Total annual PM_{10} emissions and annual-average day emissions are presented in Table 5-2 for tillage operations and in Table 5-3 for harvest operations by crop type. The acreage values presented in the tables are derived from the GIS shapefiles provided by ADEQ and PCAQCD. The total number of agricultural acres in the nonattainment area was reduced by 7% to account for the average share of fallow land found within each of the modeling domains.

Table 5-2 2008 Crop Acreage, Annual PM_{10} Tillage Emissions, and Typical Daily Tillage Emissions in Pinal PM_{10} Nonattainment Area					
Crop	Acres	Tillage Passes (per year)	PM_{10} Annual Emissions (tons/year)	Tillage Operation (Days/year)	Typical Daily Emissions (lbs/day)
Alfalfa	74,007	5.1	606	91	13,329
Corn	1,277	7.3	15	152	197
Grain	47,943	3.1	239	243	1,966
Cotton	85,496	8.8	1,209	364	6,643
Hay	3,289	5.1	27	91	592
Vegetable	11,147	14.0	251	182	2,756
Total	223,159	N/A	2,347	N/A	25,482

Table 5-3 2008 Crop Acreage, Annual PM_{10} Harvesting Emissions, and Typical Daily Harvesting Emissions in Pinal PM_{10} Nonattainment Area					
Crop	Acres	PM_{10} Emission Factor (lbs/acre-yr)	PM_{10} Annual Emissions (tons/year)	Harvest (Days/year)	Typical Daily Emissions (lbs/day)
Alfalfa	74,007	0.00	0.0	294	0.0
Corn	1,277	1.70	1.1	91	23.9
Grain	47,943	5.80	139.0	60	4,634.5
Cotton	85,496	3.40	145.3	143	2,032.8
Hay	3,289	1.70	2.8	294	19.0
Vegetable	11,147	0.17	0.9	116	16.3
Total	223,159	N/A	289.2	N/A	6,726.5

5.1.2 Concentrated Animal Feeding Operations (CAFO)

Annual PM_{10} emissions generated by CAFOs within the nonattainment area in 2008 were computed using the average daily PM_{10} emission factor described in Section 3.1.2 and 2008 animal population averages for affected facilities provided by representatives of the Arizona Cattle Feeders Association. The daily PM_{10} emission factor for CAFOs, in units of pounds of PM_{10} per animal head-day, was computed from the medians of hourly emissions factors per the recommendation of Bonifacio et al.[96] in their assessment of PM_{10} emissions from two CAFOs in Kansas. Because the hourly emissions factors were calculated from a subset of the 2008 hourly PM_{10} and meteorological data collected at the

[96] "Particulate matter emission rates from beef cattle feedlots in Kansas – Reverse dispersion modeling," Bonifacio, H.F., R.G. Maghirang, B.W. Auvermann, E.B. Razote, J.P. Murphy, and J.P. Harner III; JAW&MA 62(3)350-361, 2012.

Cowtown monitoring station, these factors represent annual average values and not design-day-specific values. Thus, the daily emission factor computed in Section 3.1.2 represents an annual-average-day value that is appropriate for use in compiling an annual inventory for the nonattainment area.

Annual-average-day animal population values for each of the nine CAFOs located in the nonattainment area were provided by the Arizona Cattle Feeders Association.[97] These population values were multiplied by the average daily PM_{10} emission factor to derive daily PM_{10} emission rates for each CAFO, and these rates were further multiplied by 366 to determine annual PM_{10} emissions. The annual emissions rates for all of the CAFOs in the nonattainment area were summed to determine total annual PM_{10} emissions in 2008 for this source category. A summary of the facilities, the head counts, and related emissions is presented in Table 5-4.

Table 5-4
Summary of the 2008 Annual Emissions and Typical Daily Emissions for CAFOs in Western Pinal County PM_{10} Nonattainment Area

Facility	# Head	Emission Factors (lbs/head/day)	Annual Emissions (tons/yr)	Typical Daily Emissions (lbs/day)
Pinal East Pens	18,900	0.066	228	1,244
Pinal West (W of Fuqua)[a]	15,645	0.066	188	1,029
Pinal West (E of Fuqua)[a]	33,497	0.066	403	2,204
Owen Kelly Feed Yard	5,900	0.066	71	388
Maricopa Cattle Company	21,200	0.066	255	1,395
Maricopa Cattle Company	17,600	0.066	212	1,158
Red River Feed Yard	48,200	0.066	580	3,171
Benedict Feed Yard	16,800	0.066	202	1,105
Paradise Cattle	3,000	0.066	36	197
Total	180,742	N/A	2,176	11,892

a. Fuqua Road is at the mile mark between White & Parker Road and Hartman Road.

5.1.3 Fugitive Dust Emissions from Paved Roads

Fugitive PM_{10} emissions from paved roads were calculated using the guidance in section 13.2.1 of AP-42.[93] The new AP-42 equation published by EPA in January 2011 has been applied to estimate PM_{10} emissions from paved roads in the nonattainment area.

[97] Conference call with Bas Aja/Arizona Cattle Feeders Association and staff of the Arizona Department of Environmental Quality and Pinal County Air Quality Control District, May 13, 2013; and email correspondence from Bas Aja dated June 11, 2013.

In the AP-42 equation, paved road emissions are a function of silt loading values and the average weight of vehicles traveling on paved road surfaces. Paved roads have been classified as freeways, high-traffic arterials, and low-traffic arterials to reflect different silt loading assumptions. An arterial carrying a traffic volume of less than 10,000 vehicles per average weekday is classified as low-traffic; all other roads that are not freeways are classified as high-traffic arterials. The silt loading levels used in this inventory, in grams per square meter, are 0.02 for freeways, 0.067 for high-traffic arterials, and 0.23 for low-traffic arterials. The silt loadings and average vehicle weights were derived from the MAG 2012 Five Percent Plan for PM-10 in the Maricopa County nonattainment area. The fugitive dust emission factors for paved roads were calculated using the following AP-42 equation:

$$E = k \times sL^{0.91} \times W^{1.02} \times (1 - P/4N)$$

where:

E = annual average particulate emission factor (g/mile);

k = particle size multiplier for particle size range (1.0 g/mile for PM_{10} and 0.25 g/mile for $PM_{2.5}$);

sL = road surface silt loading (0.02 g/m^2 for freeways, 0.067 g/m^2 for high-traffic arterials, and 0.23 g/m^2 for low-traffic arterials);

W = average weight of the vehicles traveling on the roads (3.53 tons on freeways and 2.65 tons on arterials);

P = annual number of "wet" days with at least 0.254 mm (0.01 in) of precipitation (31 days in 2008); and

N = annual number of days (366 days in 2008).

The annual average PM_{10} and $PM_{2.5}$ emission factors for paved roads derived from the AP-42 equation are presented in Table 5-5.

Table 5-5
2008 Paved Road Emission Factors

Silt Loading Category	PM_{10} Emission Factor (g/mile)
Freeways	0.10
High Traffic Arterials	0.23
Low Traffic Arterials	0.69

The 2008 vehicle miles of travel (VMT) by silt loading category was used to estimate paved road fugitive PM_{10} emissions. Daily VMT by silt loading category is shown in Table 5-6. The 2008 VMT for the West Pinal PM_{10} nonattainment was obtained from ADOT. This VMT was multiplied by 0.92 to convert from average weekday to annual average daily traffic. The distribution by silt loading category within the West Pinal PM_{10} nonattainment area was derived from a MAG 2011 traffic assignment.

Table 5-6
2008 VMT by Silt Loading Category for Paved Roads

Silt Loading Category	PM_{10} Nonattainment Area Annual Average Daily VMT
Freeways	1,399,459
High Traffic Arterials	757,558
Low Traffic Arterials	3,625,871
Totals:	5,782,889

Applying the emission factors in Table 5-5 to the VMT values in Table 5-6 produces the 2008 particulate emissions from paved roads for the West Pinal PM_{10} nonattainment area, as shown in Table 5-7.

Table 5-7
2008 Paved Road Emissions for the West Pinal PM_{10} Nonattainment Area

Silt Loading Category	Typical Daily Emissions (lbs/day)	Annual Emissions (tons/yr)
Freeways	309	56
High Traffic Arterials	384	70
Low Traffic Arterials	5,516	1,009
Totals:	6,208	1,136

5.1.4 Fugitive Dust Emissions from Unpaved Roads

Fugitive PM_{10} emissions from unpaved roads were calculated using the guidance in Section 13.2.2 of AP-42. AP-42 emission factors were applied to unpaved road VMT values to estimate fugitive PM_{10} emissions. The unpaved road particulate emission factors were derived from the following AP-42 equation for publicly accessible unpaved roads.

$$E = \left[\frac{k\left(\frac{s}{12}\right)^{1}\left(\frac{S}{30}\right)^{0.5}}{\left(\frac{M}{0.5}\right)^{0.2}} - C \right]\left(1 - \frac{P}{N}\right)$$

where:

E = annual average particulate emission factor adjusted for natural mitigation (lb/mile);

k = particle size multiplier for particle size range (1.8 lb/mile for PM_{10} and 0.18 lb/mile for $PM_{2.5}$);

s = surface material silt content;

S = mean vehicle speed;

M = surface material moisture content;

C = emission factor for 1980s vehicle fleet exhaust, brake wear, and tire wear (0.00047 lb/mile for PM_{10});

P = annual number of "wet" days with at least 0.254 mm (0.01 in) of precipitation (31 days in 2008); and

N = annual number of days (366 days in 2008).

Four categories of unpaved roads have been identified in Pinal County: agricultural, public, private, and trails. The surface material silt and moisture contents for each category are shown in Table 5-8. The silt and moisture contents were obtained from a Pinal County field study conducted in June 2013.

Subcategories were developed for agricultural, public, and private unpaved roads to account for variations in average vehicle speeds and annual average daily traffic (ADT). The speed, ADT, and total mileage for each subcategory are identified in Table 5-8. The ADT and speed values for public and private roads and trails were obtained from the PCAQCD Traffic Analysis Report cited in Section 3.1.4. The ADT and speed values for agricultural roads were calculated from information provided by Pinal County farmers for non-harvest and harvest activities, also cited in the same section. ADT is multiplied by total mileage to calculate daily VMT. The PM_{10} emission factors were multiplied by the VMT in Table 5-9 to produce unpaved road emissions for the PM_{10} nonattainment area, which are summarized by category in Table 5-10.

Table 5-8 Pinal County Inputs to AP-42 Equation for Unpaved Roads			
Subcategory	Silt Content	Moisture Content	Speed
Agricultural			
Operations	14.9%	0.8%	28.2 mph
Inspection			28.2 mph
Harvest			22.8 mph
Public			
Class A	7.1%	0.3%	20 mph
Class B			25 mph
Class C			30 mph
Class D			35 mph
Class E			40 mph
Private			
Non-Irrigation	14.4%	0.3%	25 mph
Principal Canal			25 mph
Secondary Canal			15 mph
Trails			
	14.4%	0.3%	15 mph

Table 5-9 2008 Unpaved Road Emission Factors and Daily VMT		
Subcategory	PM_{10} Emission Factor (g/mi)	Daily VMT
Agricultural		
Operations	487.47	10,454
Inspection	770.87	32,071
Harvest	597.07	8,412
Public		
Class A	399.66	2,556
Class B	446.85	21,408
Class C	489.52	11,347
Class D	528.76	22,186
Class E	565.28	26,222
Private		
Non-Irrigation	906.50	22,330
Principal Canal	906.50	2,223
Secondary Canal	702.12	2,231
Trails		
	702.13	2,488

Table 5-10 2008 Unpaved Road Emissions for the West Pinal PM_{10} Nonattainment Area		
Unpaved Road Category	Typical Daily Emissions (lbs/day)	Annual Emissions (tons/yr)
Agricultural	90,477	16,557
Public	94,130	17,226
Private	52,522	9,612
Trails	3,851	705
Total	240,980	44,100

5.1.5 Nonroad Emissions

The same general nonroad exhaust emission calculation methodology used for preparing the modeling domain inventories (described in Section 3) was also used to calculate annual nonroad emissions for the nonattainment area. Pinal County-specific emissions[98] were determined using EPA's NONROAD model,[99] which included Pinal County-specific input values where available. As described below, in the absence of sector-specific information for the entire nonattainment area county-wide nonroad emissions were allocated to the nonattainment area using human population ratios.[100]

NONROAD Calculation Methodology – EPA's NONROAD emissions model calculates emissions from each source according to the methodology described below. Note that this calculation yields emission results in grams per year, which the model then converts to tons.

$$Emissions = EF \times DF \times P \times LF \times Hours \times Units$$

where:

EF = emission factor in g/hp-hr
DF = deterioration factor (dimensionless)
P = power in horsepower
LF = load factor (dimensionless)
Hours = annual operating hours for each unit
Units = total population of engines operating in a given year

[98] Input files are included in Appendix 8.
[99] U.S. EPA NONROAD Model, Version 2008a, released July 2009.
[100] The ratio (i.e., 280,006/ 375,770 = 74.5%) was determined using 2010 Pinal County population from U.S. Census data, (http://quickfacts.census.gov/qfd/states/04/04021.html), and 2010 PM_{10} nonattainment area census block data provided by ADEQ.

Pinal County Inputs – Total emissions estimates for Pinal County were determined for calendar year 2008 by determining totals for each of the 12 months, using average ambient temperatures specific to each.[101] Calendar year 2008 summertime and wintertime fuel parameters for both Diesel and gasoline, shown below in Table 5-11, were obtained from the 2008 North American fuel surveys published by the Alliance of Automobile Manufacturers (AAM), and were verified by staff at the PCAQCD. Gasoline and Diesel parameters are based on values reported in the Phoenix area; it is assumed that the fuel mix used in Phoenix during calendar year 2008 is delivered to the Pinal County nonattainment area as well because the fuel requirements are the same in both areas.[102]

Table 5-11
NONROAD Modeling Fuel Parameters Pinal County – CY 2008

Fuel Parameter	NONROAD Default	Pinal County (2008)	
		Winter	Summer[a]
Fuel RVP for gas	8.0	8.8	6.6
Oxygen Weight (%)	2.44	3.5	0.0
Gas Sulfur (%)	0.0339	0.0015	0.0039
Diesel Sulfur (%)	0.0351	0.0006	0.0006
CNG/LPG Sulfur (%)	0.003	0.003	0.003
Stage II Control (%)	0	0[b]	0[b]
EtOH Blend Market (%)	75.1	100	0
EtOH Volume (%)	9.3	10	0

a. A "Summer" fuel blend is required in virtually all parts of the nonattainment area during June-September/
b. Note that while Stage II controls are required at the highest volume stations in Pinal County's "Area A," we assumed zero Stage II coverage both to be conservative and to simplify the analysis.

Nonroad Emission Allocation Methodology – As noted above, the sector-specific information used to allocate county-wide nonroad emissions to the low wind modeling domains was not available for the nonattainment area. Therefore, for all equipment categories listed in Table 5-12 below, county-wide emissions were allocated to the nonattainment area using resident population data. As was the case with the nonroad analysis presented in Section 3, the "Pleasure Craft" and "Railway Maintenance" equipment categories were excluded due to the absence of recreational areas and rail yards in the nonattainment area that would accommodate their use.

[101] See http://www.weatherforyou.com/
[102] This was confirmed by Scott Dibiase at the PCAQCD.

Table 5-12 2008 NONROAD Emissions – Western Pinal County PM_{10} Nonattainment Area			
Equipment Category	Equipment Population	PM_{10} (tons/year)	PM_{10} (tons/day)
Agricultural	2,348	11.0	0.030
Airport Ground Support	0	0.0	0.000
Commercial	2,087	1.7	0.005
Construction and Mining	6,054	73.6	0.201
Industrial	390	2.8	0.008
Lawn and Garden	77,716	7.2	0.020
Logging	-	0.0	0.000
Recreational	20,909	10.7	0.029
Underground Mining	-	0.0	0.000
TOTAL	109,505	107	0.29

5.1.6 Railroad Emissions

The daily PM_{10} emission factor and emission rates for estimating railroad operations are described in Section 3.1.7. The same emission factors are used in calculating the annual railroad emissions by assuming 2 trains travelling through the nonattainment area each hour, 366 days per year. Table 5-13 summarizes the length of track and the annual and typical daily emissions in the nonattainment area.

Table 5-13 Summary of the 2008 Annual Emissions and Typical Daily Emissions for Railroads in Pinal County PM_{10} Nonattainment Area				
Track Length in PM_{10} Nonattainment Area (miles)	Emission Factors (g/mile/hour/train)	# of Trains (per hour)	Annual Emissions (tons/yr)	Typical Daily Emissions (lbs/day)
120	37	2	86	470

5.1.7 Construction Emissions

As discussed in Section 3.1.8, PCAQCD staff[103] reviewed building permits issued in late 2007 (4th quarter) and selected those that were most likely to continue into 2008. These

[103] Email from Kate Edwards, Pinal County to Bob Dulla, Sierra Research, 2008 Construction Dust Permits, November 28, 2012.

were combined with permits issued in 2008 to create a shape file of polygons identifying the location of each of the issued permits. A total of 2,668 construction sites were identified in the PM_{10} nonattainment area in 2008. The following information was provided by PCAQCD for each site:

- Permit type;
- Site location coordinates; and
- Acreage.

Three types of permits were found in the data provided:

- 5 – Construction;
- 7 – Commercial Construction; and
- 8 – Site Development.

Discussions with PCAQCD staff confirmed that Type 5 permits represented residential construction and Type 7 represented commercial construction (as listed); Type 8 was assumed to represent commercial construction and accounted for 2% of the issued permits. Type 5 residential projects were assumed to represent single homes if the acreage was ≤ 5 acres; larger plots of land were assumed to represent multi-home subdivisions.

The methodology used by Maricopa County to estimate the 2008 PEI[104] was used to estimate emissions for each project determined to be active on the design day. Annual emissions for each construction project were calculated by multiplying the number of acres by an emission factor that varies by project type (in units of tons/acre-month as shown in Table 5-14) by the average duration for a project type. The typical daily emissions were calculated by dividing the emissions by the number of days per month (22 days per month), and by the average duration of a project type.

In 2008, PCAQCD staff conducted a total of 416 dust permit inspections—374 were found to be in compliance, suggesting a compliance rate of 90%. Permitted sites are required to comply with construction dust rules[105] that address site preparation, bulk material handling, and carryout activity and emissions. While no local estimate of control efficiency is available, a review of the WRAP handbook[106] shows that applying water at various intervals results in a 61% PM_{10} control efficiency. When combined with the compliance rate of 90%, this would produce an estimate of overall control

[104] 2008 PM10 Periodic Emissions Inventory for the Maricopa County, Arizona, Nonattainment Area, Maricopa County Air Quality Department

[105] Article 3, Construction Site Fugitive Dust, *http://pinalcountyaz.gov/Departments/AirQuality/Documents/Dust/Article%203%20Construction%20Dust.pdf*

[106] Table 3-7. Control Efficiencies for Control Measures for Construction/Demolition, Chapter 3 Construction and Demolition, *http://www.wrapair.org/forums/dejf/fdh/content/Ch3-Construction_and_Demolition_Rev06.pdf*

effectiveness of 54%. The number of precipitation days in 2008 was also used to adjust the annual emissions by multiplying a factor of (1-P/N), where *P* = annual number of "wet" days with at least 0.254 mm (0.01 in) of precipitation (31 days[107] in 2008), and *N* = annual number of days (366 days in 2008).

Table 5-14 summarizes the number of construction sites located within the nonattainment area, the emission factors, the control efficiency, the annual emissions, and the annual-average-day construction PM_{10} emissions in the nonattainment area.

Table 5-14
Summary of 2008 Construction Project, Annual Emissions, and Annual-Average-Day Construction PM_{10} Emissions by Project Type

Project Type	Project Duration (Months)	Total Area (Acres)	Emission Factor (Tons PM_{10}/ Acre-Month)	Annual Emissions (Tons PM_{10}/ Year)	Number of Working Days[a] (Days/year)	Typical Daily Emissions (lbs/day)
Residential Single Family	6	4,728	0.032	382	264	2,896
Commercial	11	2,429	0.19	2,137	264	16,193
Site Development	11	3,454	0.19	3,039	264	23,026
Total	N/A	10,611	N/A	5,559	N/A	42,114

a. The total number of working days per year was assumed to be 22 days/month times 12 months/year (i.e., 264 days/year).

5.1.8 Emissions from Permitted Sources

PM_{10} annual emissions (tons/yr) for each permitted industrial facility in the nonattainment area were provided by the Pinal County Air Quality Control District (PCAQCD) from permit files. PCAQCD permits include estimates of PM_{10} emissions for stationary sources only. PM_{10} emissions from area sources such as unpaved road travel, livestock movement, and windblown dust were estimated separately and these separate methodologies are discussed in Section 3. Table 5-15 summarizes the annual emissions and annual-average-day emissions for these facilities assuming they are operating 366 days/yr.

[107] 2008 precipitation data was obtained from the AZMET station located in the City of Maricopa.

Table 5-15 Summary of the 2008 Annual Emissions and Annual-Average-Day PM_{10} Emissions for Permitted Sources in the Western Pinal County Nonattainment Area		
Total Permittted Facilities	Annual Emissions (tons/yr)	Typical Daily Emissions (lbs/day)
220	516	2,822

5.1.9 Dairy Emissions

Annual PM_{10} emissions for dairy operations in the nonattainment area in 2008 were derived from an emission factor published by the Arizona Governor's Agricultural BMP Committee[108] and estimates of average annual animal populations at affected dairies provided by United Dairymen of Arizona[109]. The published emission factor was reported to represent annual-average-day conditions and, thus, no adjustment was needed to use this factor in the computation of annual PM_{10} emissions from individual dairies. This factor, 5.21 lb./head-year, was multiplied by the average annual animal population at each dairy to calculate annual PM_{10} emissions at each affected facility, and the annual emissions of all affected facilities were summed to compute annual PM_{10} emissions from this source category on an annual basis for 2008. Table 5-16 summarizes the number of cows and their annual emissions.

Table 5-16 Summary of the 2008 Annual Emissions and Annual-Average-Day PM_{10} Emissions for Dairies in the Western Pinal County Nonattainment Area			
Total # Head in PM_{10} Nonattainment Area	Emission Factor (lbs/head/year)	Annual Emissions (tons/yr)	Typical Daily Emissions (lbs/day)
72,852	5.21	190	1,037

5.2 High Wind Emission Inventory

The methodology described in Section 3.2 was designed to quantify emissions for lands located within the high wind modeling domains during hours when hourly-average wind speeds exceeded 12 mph. To quantify emissions over the entire nonattainment domain,

[108] Agricultural Best Management Practices for Livestock Operations, As Adopted by the Governor's Agricultural Best Management Practices Committee on July 27, 2010.
[109] Mike Billotte, United Dairymen of Arizona, email to Lisa Tomczak ADEQ, June 11, 2013.

an alternative method needed to be developed to estimate the hourly wind speeds impacting each land parcel over calendar year 2008. The preferred method selected for this purpose assigned each parcel to an area surrounding one of the six PM_{10} monitoring sites at which, or near to which, hourly meteorological data is recorded[110] (i.e., Casa Grande, Combs School, Cowtown, Maricopa, Pinal County Housing, and Stanfield). The method used to assign a parcel to its nearest monitoring station involved computing the distance from the centroid of that parcel to each of the six monitors. Meteorological data collected at the monitor closest to the parcel was selected to represent meteorological conditions at the parcel in 2008.

The next step was to screen the hourly wind speeds throughout the year and select those hours in which the hourly-average speed exceeded 12 mph[111]. Unlike the high wind days, which were selected for having elevated winds during several consecutive hours, days with high wind episodes as short as one hour were found in the monitoring station records. The numbers of high wind hours, low wind hours, and total windspeed monitoring hours at each of the six stations in 2008 are presented in Table 5-17. This tabulation shows that the ratio of total high wind hours to total low hours varies from monitor to monitor and ranges from a low of 4.9% at Pinal County Housing to a high of 9.2% at Casa Grande.

Table 5-17
Summary of Low and High Wind Hours in 2008 for the Western Pinal County PM_{10} Monitors

Monitors	Number of High Wind Hours	Number of Low Wind Hours	Total Number of Hours[a]
Cowtown	539	6,720	7,259
PCH	349	6,810	7,159
Stanfield	411	6,913	7,324
Casa Grande	738	7,302	8,040
Maricopa	493	7,531	8,024
Combs School	480	7,560	8,040

a. Missing data vary by monitor and influence the totals.

As described in Section 3.2, hourly high wind emission factors during multi-hour high wind episodes were adjusted to account for the effects of delayed initialization of saltation and reservoir depletion. To be consistent, the same saltation initiation delay factors from Section 3.2 were applied to emission factors for single hour high wind

[110] For some monitors with missing data, values from other monitors were substituted (e.g., for Maricopa AZMET wind data was substituted for missing Cowtown data on 2/19/08-4/25/08 & 5/15/08-9/5/18).
[111] ADEQ adjusted the wind measurements at each monitor to a standard height of 10 meters using methods described in Section 3. In the process of preparing these values, days with moisture levels exceeding 0.01 inches of rainfall were excluded from hourly counts.

events.[112] Other adjustments outlined in Section 3.2 were also applied to the emission factors used to compute fugitive PM_{10} emitted from each land parcel in the nonattainment area during a high wind hour.

Agriculture – For agricultural windblown emissions, information was needed on the distribution of disturbance levels by crop type across the year. PCAQCD staff provided a spreadsheet for the 2008 crop calendar for Pinal County that breaks each month into three 10-day periods (0-10, 10-20 and 20-30). The calendar color codes each 10-day period for the following activities:

- Planting,
- Begin/end harvest,
- Most active harvest, and
- No activity.

Using the information in the calendar, each 10-day period was assumed to be 100% disturbed if it was coded for one of the first three activities noted above. 10-periods with no activity were coded 0% activity. The number of 10 day periods with 100% activity was summed for each crop, multiplied by 10 and the total was divided by 360 for each crop; the same calculation was prepared for the 10-periods with 0% activity. A summary of the results for the crops identified in the 2007 Agricultural Census, which provided % crop acreage distribution for land under cultivation within Pinal County, is presented below in Table 5-18.[113] Also presented in Table 5-18 is the crop distribution obtained from the 2007 Agricultural Census for Pinal County. It shows that cotton and forage account for 66% of the land under cultivation.

Estimates of the total agricultural acreage within the nonattainment area were obtained from the shapefiles supplied by ADEQ/PCAQD. The acreage under active cultivation was calculated after subtracting the share[114] of fallow land (7%) from the total. The crop distribution from the 2007 Agricultural Census, presented in Table 5-18 was used to determine the acreage for each of the crop categories. Emissions were then calculated for each crop type following Equation 1 (disturbed) and Equation 2 (stable) presented in Section 3-2. The crop-specific emission estimates were weighted in proportion to the disturbance/stable values presented in Table 5-18 to quantify annual windblown emissions for active crop lands within the nonattainment area. Emissions for fallow lands were calculated using Equations 1 and 2 (from Section 3-2). The emission estimates were weighted according to the 90%/10% undisturbed/disturbed estimate provided by PCAQCD staff. Total emissions were calculated by summing estimates from active agricultural crop lands and fallow lands.

[112] Application of this curve to subsequent low wind hours was considered, but not applied because of concern about overstating the effect during low wind hours.
[113] 7 percent of Fallow lands were considered in the calculation based on the Crop information we received from CRPC.
[114] The average calculated for the shapefiles provided CRPC.

Table 5-18 Annual Crop Distribution for Pinal County and Disturbance Levels Derived from 2007 Agricultural Census and 2008 Pinal County Crop Calendar			
Crop Type	Crop Distribution	Disturbed	Undisturbed/Stable
Barley for Grain	5.7%	41.7%	58.3%
Corn for Grain	0.5%	47.2%	52.8%
Cotton	35.6%	58.3%	41.7%
Sorghum for Grain	5.0%	47.2%	52.8%
Wheat for Grain	9.3%	41.7%	58.3%
Field and Grass Seed	1.4%	30.6%	69.4%
Forage[a] – All Hay, Haylage, Silage & Greenchop	30.8%	83.3%	16.7%
Vegetables – Total	4.6%	63.9%	36.1%

a. Includes alfalfa

Construction – The randomized process used to quantify high wind emissions presented in Section 3.2 for a specific day becomes quite complex for calculating annual emissions. Therefore simplifying, but conservative assumptions were employed. Each permit was assumed to have a period where the land was (1) cleared and (2) the land was under active construction. All residential permits were assumed to have a 6-month period of construction activity in 2008. All commercial and site development permits were assumed to have 11 months of construction activity in 2008. The residential construction estimate was modified to account for the average increase calculated for cleared emissions in Section 3.2. Commercial construction emissions were modified to include 1-month of cleared emissions to complete the year.

A summary of the total annual emissions estimated for each land use category during high wind hours in 2008 is presented in Table 5-19. It shows desert shrubland is estimated to account for more than half of the windblown dust emissions. Agriculture is estimated to account for almost 32% of the windblown dust emissions. These values reflect the dominance of these lands within the nonattainment area.

5.3 Summary of Annual Emissions

A summary of source specific contributions to the annual emissions inventory is presented below in Table 5-20. It shows that even though windblown hours occur less than 10% of the year, the emissions produced during that time is sufficient to account for almost 65% of the annual inventory. Emissions from unpaved roads are the next largest source accounting for 28% of the annual inventory. Collectively these two sources account for over 93% of annual emissions.

Table 5-19 Summary of the 2008 Annual High Wind Emissions in Western Pinal County			
Land Use ADEQ ID	Land Use Category	Emissions (Tons/year)	Percentage
A	Developed Urban Lands	253	0.2%
B	Developed Rural Lands (low density residential)	2,482	2.4%
D	Unpaved Roads	5,855	5.7%
E	Cleared Areas	475	0.5%
F	Residential Construction	1162	1.1%
G	CAFOs and Dairies	1,009	1.0%
H	Desert Shrubland	52,531	50.8%
I	Agricultural Croplands	32,357	31.3%
J	Commercial Construction	585	0.6%
K	Other	5,826	5.6%
L	Site Development	789	0.8%
Total Emissions		103,324	100%

Table 5-20 Summary of the 2008 Annual PM_{10} Emissions in the Western Pinal County Nonattainment Area			
Source Category		PM_{10} Emissions (tons/year)	% of Total
Agriculture	Harvesting	302	0.2%
	Tilling	2,452	1.5%
CAFOs		2,176	1.4%
Paved Road		1,136	0.7%
Unpaved Road		44,100	27.6%
Non-Road		107	0.1%
Railroad		86	0.1%
Construction		5,559	3.5%
Dairy		190	0.1%
Permitted Sources		516	0.3%
Sub-Total: Low Wind Emissions		56,624	35.4%
Windblown Emissions		103,324	64.6%
Total Emissions		159,948	100.0%

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