Appendix 3.1

Calculating Rule Effectiveness for Agricultural Activities

A. Most important factors (1 criteria with an assigned weight of 25% of total):

	Range		Midpt. value	Description	Value assigned to MCAQD	Weight	Score (= weight × value)
Compliance History	86%	100%	93%	Over 90% of facilities inspected in the source category are in compliance.	93%	25%	23%
	70%	85%	80%	Over 75% of facilities inspected in the source category are in compliance.			
		< 70%	35%	Over 60% of facilities inspected in the source category are in compliance.			

B. Other important factors (6 criteria, each assigned weighting of 10% of total):

Compliance Certification	86%	100%	93%	Source is subject to some type of compliance certification.			
	70%	85%	80%	Source is subject to some type of compliance certification.			
		< 70%	35%	Source is not subject to any type of compliance certification.	35%	10%	4%

Level of Inspection	86%	100%	93%	Inspections are thorough and detailed, and include close examination of control equipment, and a detailed records review.			
	70%	85%	80%	Inspections consist of a records review, and sometimes inspection of control equipment.			
		< 70%	35%	Inspections generally consist of a records review only.	35%	10%	4%

Unannounced Inspections	86%	100%	93%	Unannounced inspections are sometimes done.			
	70%	85%	80%	Unannounced inspections are done, but infrequently.	0.7	10%	7%
		< 70%	35%	Unannounced inspections are never done.			

Inspections Frequency	86%	100%	93%	Percent of facilities inspected in the sector in a given year is 25% or greater.			
	70%	85%	80%	Percent of facilities inspected in the sector in a given year is 15% or greater.			
		< 70%	35%	Percent of facilities inspected in the sector in a given year is less than 15%.	35%	10%	4%

	Range		Midpt. value	Description	Value assigned to MCAQD	Weight	Score (= weight × value)
Enforcement	86%	100%	93%	Agency takes prompt enforcement action, including monetary fines, against violators.			
	70%	85%	80%	Agency usually takes enforcement action, including monetary fines, against violators.			
		< 70%	35%	Agency usually does not take enforcement action against violators.	35%	10%	4%

Compliance Assistance Programs	86%	100%	93%	A compliance assistance program exists and is adequately staffed, and includes such things as workshops, mailings, web-based tutorials, etc.	0.93	10%	9%
	70%	85%	80%	A compliance assistance program exists, but is minimally staffed. The program occasionally makes workshops, mailings, web-based tutorials, etc.;available.			
		< 70%	35%	A compliance assistance program does not exist.			

C. Other factors (3 criteria, each assigned weighting of 5% of total):

Monitoring Requirements	86%	100%	93%	Monitoring requirements exist and must be reported to regulatory agency at least once a year.			
	70%	85%	80%	Monitoring requirements exist but records don't have to be filed with regulatory agency.			
		< 70%	35%	Monitoring requirements do not exist.	35%	5%	2%

Follow-up Inspections	86%	100%	93%	Follow-up inspections are done when violations are noted most (>75%) of the time.			
	70%	85%	80%	Follow-up inspections are done when violations are noted most (>75%) of the time.			
		< 70%	35%	Follow-up inspections are not routinely done.	35%	5%	2%

Media Publicity	86%	100%	93%	Media publicity of enforcement actions is routinely conducted.			
	70%	85%	80%	Media publicity of enforcement actions is sometimes done.			
		< 70%	35%	Media publicity of enforcement actions is rarely if ever done.	35%	5%	2%
							59%

Appendix 3.2

Development of a Fugitive Windblown PM_{10} Dust Emission Inventory for the Phoenix PM_{10} Nonattainment Area

Final Report

Development of a Fugitive Windblown PM10 Dust Emission Inventory for the Phoenix PM10 Nonattainment Area

Prepared for

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16 May 2007

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1. INTRODUCTION

The Maricopa County Air Quality Department (MCAQD) has contracted with ENVIRON to develop a windblown dust PM10 emissions inventory for the metro Phoenix PM10 non-attainment area (NAA). The draft inventory was developed for calendar year 2005 and the first quarter of calendar year 2006 for inclusion in a complete 2005 PM10 emissions inventory. As part of this development effort, the Windblown Dust emissions model, developed by the Western Regional Air Partnership Regional Modeling Center (WRAP RMC), was used in combination with local and regional data sets describing the land characteristics within the study area. The development of the windblown PM10 dust emission inventory is described in this report.

ENVIRON applied the WRAP RMC Windblown Dust Model to develop the necessary PM_{10} and $PM_{2.5}$ emissions inventory. The dust model was developed to generate hourly gridded estimates of PM dust emissions based on landuse, soils characteristics, hourly meteorological data and additional information related to agricultural practices. The accuracy and quality of the dust estimates is limited by the detail and resolution of available input data, particularly the characterization of land use and landcover. The existing databases used previously for the WRAP Regional Haze modeling efforts were augmented with additional local data for Maricopa County and surrounding areas. In addition to surface characteristics data, the model requires gridded, hourly wind speeds to estimate PM10 dust emissions from wind erosion. The Maricopa Association of Governments (MAG) has provided ENVIRON with observed wind data from meteorological monitoring sites within the Phoenix PM10 non-attainment area (NAA).

The emission inventory pollutants include both PM_{10} and $PM_{2.5}$ in order to facilitate the assessment of potential control measures. Emission estimates were apportioned to specific land use categories based upon GIS analysis and existing land use data bases. Emissions estimates were developed at a spatial resolution of 12-km on a modeling domain encompassing Maricopa County, the Phoenix PM_{10} Non-Attainment Area, and Pinal County. Figure 1-1 displays the 12-km windblown dust modeling domain used in the present study. The emission estimates were aggregated and provided separately for each of the regions from the gridded modeling results.

The draft dust emission inventory and project report (Mansell and Hoats, 2007) presented and discussed results for both calendar year 2005 and the first quarter of 2006. This report and the final windblown dust emissions inventory focuses only on the calendar year 2005 estimates.

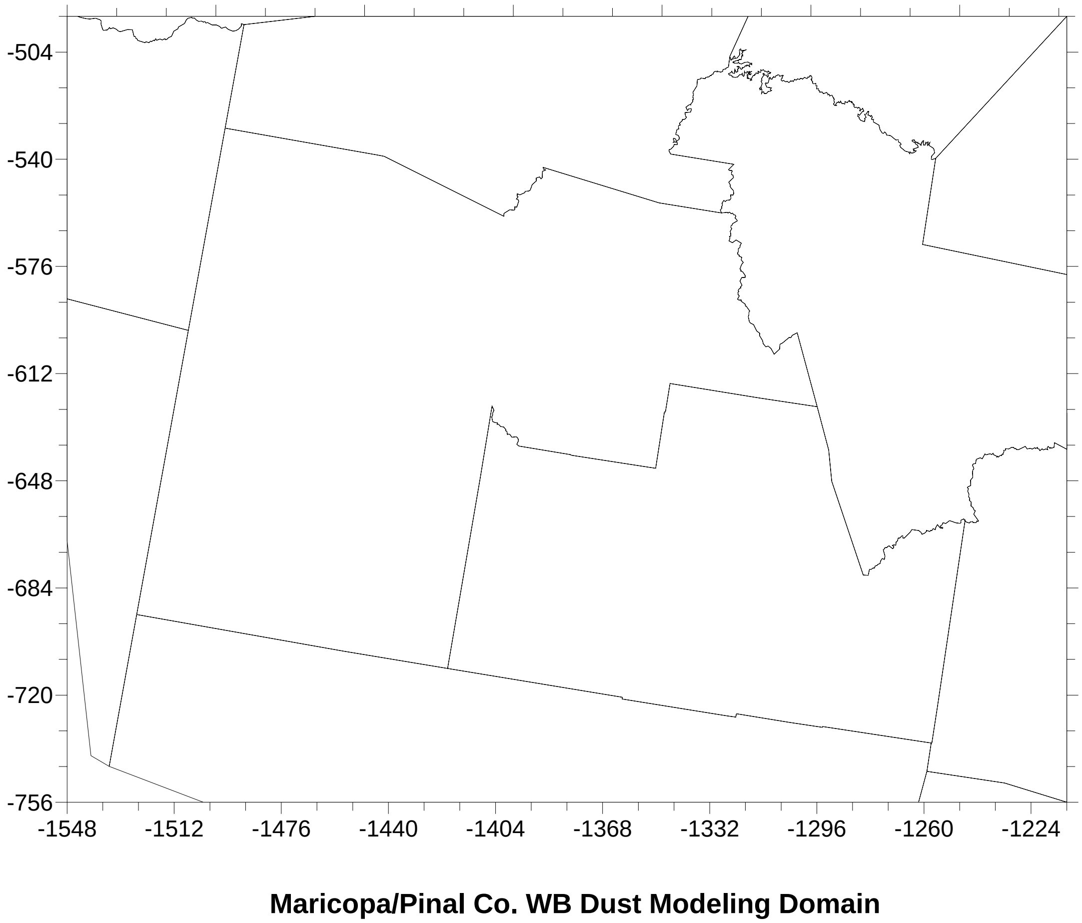


Figure 1-1. MCAQD 12-km windblown dust emissions modeling domain.

This report is organized as follows:

- Section 2 provides a summary of the WRAP RMC windblown dust emission estimation methodology used for the project.
- Section 3 presents and discusses the various data sources used for the emissions inventory development.
- The implementation of the dust model for Maricopa and Pinal Counties is described in Section 4.
- Section 5 documents the results of the windblown dust emissions modeling for calendar year 2005. Various sensitivity simulations performed during the course of the project are also discussed in this section.
- Section 6 provides an overall summary of the work performed as part of the project. Limitations of the model and results, as well as recommendations for future modeling efforts are also provided.
- Section 7 includes references for this report.

2. WINDBLOWN PM10 DUST EMISSION ESTIMATION METHODOLOGY

The WRAP Windblown Dust model was developed by the WRAP Regional Modeling Center (RMC) in two phases. The current application for Maricopa and Pinal Counties uses the most recent version developed during Phase II of the RMC's model development efforts. A brief description of the Phase I methodology is provided below, including a discussion of the various assumptions and associated limitations. A discussion of the Phase II estimation methodology used for this project is then presented.

Summary of Phase I Methodology

The development of the Phase I Wind Blown Dust model and implementation, including various assumptions incorporated in the estimation methodology, has been documented previously (ENVIRON, 2004; 2003a; 2003b; Mansell, 2003a; 2003b). In summary, the method relies on the characterization of vacant land types and soil conditions, and numerous assumptions regarding dust reservoir characteristics. Wind erosion is initiated in the model based on an arbitrary wind speed assignment, independent of surface conditions. Emission factors, or dust fluxes, were derived from very limited wind tunnel study results as a function of wind speed and soil texture. Adjustments were applied to the resulting emission rates based on vegetation density of vacant land parcels. Surface disturbance levels were based on land use types. In addition, adjustments were applied for agricultural lands based on non-climatic factors. Land use characterization was based on the Biogenic Emission Landuse Database (BELD3); soil texture was derived from the State Soil Geographic Database (STATSGO).

The relative lack of detail in the data sets used for characterizing the physical conditions of land parcels and soils required a number of assumptions to be employed in the methodology. These assumptions were presented and discussed in detail by Mansell, 2003b and Mansell et al., 2004. The primary assumptions affecting the model results can be summarized as follows:

- Threshold wind velocities: The threshold wind velocity is assumed to be 20 mph, independent of land use and soil texture.
- Vacant land stability: The methodology developed relies on the specification of stability of vacant land parcels. The stability characteristics of land parcels are based solely on the land use type.
- Dust Reservoirs: Reservoir properties are based on the stability characteristics of vacant land parcels and determine the duration of dust events. Limited reservoirs emit dust for a shorter duration of time than unlimited reservoirs. Assumptions are made concerning the amount of time a reservoir will emit wind blown dust. Also assumed are the reservoir recharge intervals.
- Rain, Snow and Freeze Events: Assumptions are included which determine time intervals after which land parcels will emit dust following precipitation, snow and freeze events. These assumptions greatly impact the number of wind events treated in the methodology as well as the total dust emissions generated.

- Vegetation Density: The percentage of vegetative, or canopy, cover is determined by the general land use category of vacant land parcels. These percentages are constant for a given land type. Estimated emission factors, or emission rates, are attenuated based on the assumed canopy cover percentage.

These various assumptions have a number of implications with respect to the estimation of fugitive dust from wind erosion. However, in many cases, the data necessary to address these issues on a regional scale domain are lacking. These issues and their implications were discussed in Mansell et al., 2004. The Phase II Windblown Dust methodology, described in the following section, seeks to address these assumptions and limitations and provide improvements to the overall estimation methodology and dust model implementation. It should be noted that previous windblown PM10 dust emission inventories for the State of Arizona have been developed using the Phase I estimation methodology (Pollack, et al., 2004)

WRAP RMC Phase II Methodology

The WRAP RMC developed the Phase II estimation methodology based a review of recent literature and windblown dust studies. A summary of the literature review can be found in Mansell, et al., 2004. Based on a review of wind tunnel studies it was noted that the two important components to characterize the dust emission process from an erodible surface are the threshold friction velocity that defines the inception of the emission process as a function of the wind speed and as influenced by the surface characteristics, and the strength of the emissions that follow the commencement of particle movement. The two critical factors affecting emission strength are the wind speed (wind friction velocity) that drives the saltation system, and the soil characteristics.

Friction Velocities

Surface friction velocities are determined from the aerodynamic surface roughness lengths and the 10-meter wind speeds. Friction velocity u_*, is related to the slope of the velocity versus the natural logarithm of height through the relationship:

$$\frac{u_z}{u_*} = \frac{1}{\kappa} \ln \frac{z}{z_o}$$

where u_z = wind velocity at height z (m s^{-1})
u_* = friction velocity (m s^{-1})
κ = von Karman's constant (0.4)
z_o = aerodynamic roughness height (m)

Threshold Friction Velocities

The methodology relies on the determination of threshold surface friction velocities, u_{*t}, as a function of aerodynamic surface roughness length, z_0. In addition to aerodynamic roughness, the degree of disturbance of the surface also plays a key role in the estimation of threshold friction velocities. Based on the work of Marticorena et al. (1997), relationships between u_{*t} and z_0

where identified and compared with wind tunnel data from Gillette et al. (1980, 1982), Gillette (1988) and Nickling and Gillies (1989). This comparison is presented in Figure 2-1.

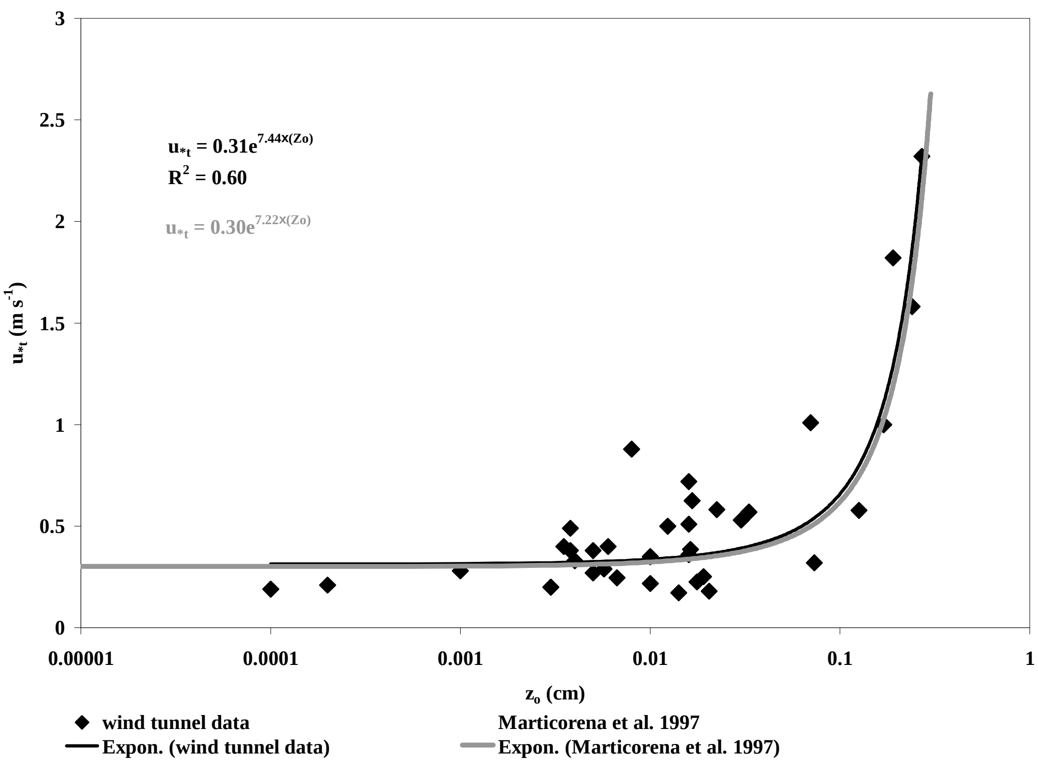


Figure 2-1. Comparison between the Marticorena *et al*. (1997) modeled relationship of threshold friction velocity and aerodynamic roughness length and wind tunnel data from Gillette *et al*. (1980, 1982), Gillette (1988) and Nickling and Gillies (1989).

Several general relationships can be described for threshold friction velocity data. Two major factors have the greatest influence on the threshold of wind erodible soils: the degree of disturbance and the aerodynamic roughness. For loose or disturbed soils the most important factor that controls the threshold friction velocity is aerodynamic roughness. The effect of surface disturbance on threshold friction velocity can be seen in Table 2-1 for data from Gillette et al. (1980, 1982), Gillette (1988), and Nickling and Gillies (1989) where surfaces are grouped by land type. For a given surface type, the effect of disturbance is to lower the threshold between ~90% to ~20% of the undisturbed value.

Table 2-1. Threshold friction velocities for typical surface types calculated from available data and as reported in the literature[1].

Site Type	Average u_{*t}(m s^{-1}) Undisturbed	Std. D. u_{*t} (m s^{-1}) Undisturbed	No. of Data Points	Average u_{*t} (m s^{-1}) Disturbed	Std. D. u_{*t} (m s^{-1}) Disturbed	No. of Data Points	% change [1-(dist./undist.)]
agricultural fields	1.29	0.74	41	0.55	0.25	37	0.57
alluvial fan	0.72	0.09	2	0.60	0.18	2	0.17
desert flat	0.75	0.06	4	0.51	0.19	4	0.32
desert pavement	2.17	0.67	4	0.59	0.10	5	0.73
fan surface	1.43	0.59	5	0.47	0.25	5	0.67
play, crusted	2.13	0.67	4	0.63	0.50	15	0.70
playa	1.46	0.98	12	0.58	0.56	25	0.60
prairie	2.90	n/a	1	0.24	0.03	3	0.92
sand dune	0.44	0.10	4	0.32	0.05	4	0.27

[1]Sources include: Gillette *et al*. (1980, 1982), Gillette (1988), and Nickling and Gillies (1989).

Surface Roughness Lengths

Surface friction velocities, including the threshold friction velocity, are a function of the aerodynamic surface roughness lengths. The surface roughness lengths are in turn dependent on surface characteristics, particularly land use/land cover. While these values can vary considerable for a given land type, published data are available which provide a range of surface roughness lengths for various land use types and vegetation cover. These data were presented in Table 2-1.

Application of the relationship shown in Figure 2-1 to assign a threshold friction velocity to a surface requires information on a surface's aerodynamic roughness length. This type of information is not generally available in land use databases, because they were not specifically developed to quantify aerodynamic properties of surfaces. Based on the designation of land use type, the aerodynamic roughness can be assigned based on previously reported values for similar surfaces. A list of surface types and reported aerodynamic roughness lengths is presented in Table 2-2. In the RMC Phase II model, as implemented in the current project, surface roughness lengths were assigned based on the land cover type, and are documented in Section 3.

A degree of uncertainty exists upon assigning an aerodynamic roughness length to a surface, as it will be complicated by the individual condition of the surface, which can change through time on several scales. For agricultural fields, aerodynamic roughness will change as a function of plant height and cover through a growing season and the tillage practices. These affects are considered for agricultural lands within the model, as described below. For natural surfaces, the aerodynamics can change through the season as well as annually through several years affecting dust production cycles. This is linked to plant growth in response to annual and long term climate variability, which will affect plant cover.

Table 2-2. Typical surface aerodynamic roughness lengths calculated from available data and as reported in the literature.

Site Type	Average z_o (cm)	Std. D. z_o (cm)	Number of Data Points	Estimated u_{*t} (m s^{-1})	Source
agricultural fields (bare)	0.031	0.039	9	0.38	Gillette et al. (1980, 1982), Gillette (1988) Nickling and Gillies (1989)
desert flat/pavement	0.133	0.180	8	0.79	Gillette et al. (1980, 1982), Gillette (1988) Nickling and Gillies (1989)
fan surface	0.088	0.148	5	0.57	Gillette et al. (1980, 1982), Gillette (1988) Nickling and Gillies (1989)
play, crusted	0.059	0.099	15	0.46	Gillette et al. (1980, 1982), Gillette (1988) Nickling and Gillies (1989)
playa	0.057	0.083	33	0.46	Gillette et al. (1980, 1982), Gillette (1988) Nickling and Gillies (1989)
prairie	0.049	0.088	4	0.43	Gillette et al. (1980, 1982), Gillette (1988) Nickling and Gillies (1989)
sand dune	0.007	0.006	4	0.32	Gillette et al. (1980, 1982), Gillette (1988) Nickling and Gillies (1989)
scrub desert	0.045	0.040	2	0.42	Nickling and Gillies (1989)
sparse veg. (0.04% cover)	0.370				Wolfe (1993)
sparse veg. (10.3% cover)	6.800				Wolfe (1993)
sparse veg. (13.5% cover)	7.200				Wolfe (1993)
sparse veg. (26% cover)	8.300				Wolfe (1993)
sparse veg. (8% cover)	5.400				Wolfe (1993)
thick grass	2.3				Sutton (1953)
thin grass	5				Sutton (1953)
sparse grass	0.12				Oke (1978)
agricultural crops	2-4				Oke (1978)
orchards	50-100				Oke (1978)
Decid. Forests	100-600				Oke (1978)
Conf. Forests	100-601				Oke (1978)
agricultural crops	15				Deursen et al. (1993)
urban	100				Deursen et al. (1993)
Decid. Forests (closed canopy)	121				Deursen et al. (1993)
Conif. Forests (closed canopy)	134				Deursen et al. (1993)

Emission Fluxes

Field and wind tunnel experiments suggest that dust emissions are proportional to wind friction speed and approximate theoretical model predictions, but the considerable scatter in the available data make it impossible to clearly define this dependence (Nickling and Gillies, 1993). Different surfaces appear to have different constants of proportionality for the flux versus wind friction velocity relationship, implying that the flux is predictable, but surface and soil properties affect the magnitude of the flux. A detailed discussion of wind tunnel studies, including various limitations and measured data, was provided in ENVIRON, 2003a; 2003b. The findings of the various wind tunnel studies are briefly summarized here.

Recently Alfaro, et al. (2003) re-analyzed the Nickling and Gillies (1989) data and found that the tendency of a surface to emit dust depends not primarily on its textural qualities, but on the size distribution of the loose soil aggregates available for saltation, and the aerodynamic roughness length that conditions the emission threshold. The re-analysis was based in part on the work of Chatenet, et al. (1996) in which they found that desert soils could be broadly divided into four populations based upon their soil aggregate populations. The differences between the four groups are based upon the estimated geometric mean diameter of the soil particles. The four size classes are 125 mm, 210 mm, 520 mm, and 690 mm, which are labeled FFS, FS, MS, and CS by Chatenet, et al. (1996).

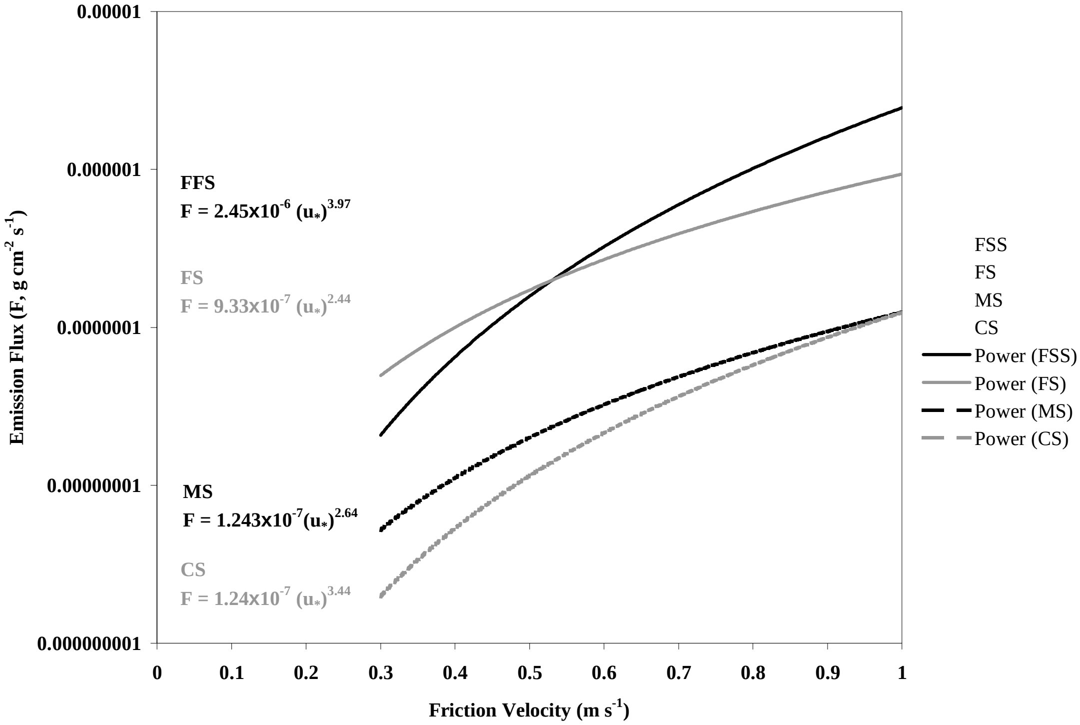


FIgure 2-2. The emission flux as a function of friction velocity predicted by the Alfaro and Gomes (2001) model constrained by the four soil geometric mean diameter classes of Alfaro et al. (2003).

Alfaro et al., (2003) grouped the Nickling and Gillies (1989) emission data based on these classes then tested how well the grouped data matched predicted output of a dust production model developed by Alfaro and Gomes (2001) that was constrained to use the four different geometric mean diameters. The modeled dust emission relationships for the four size classes are shown in Figure 2-2. As presented in Alfaro, et al. (2003) the emission data from Nickling and Gillies (1989), which fall into the FS class (10 out of 13) are well explained by the model (Figure 2-3).

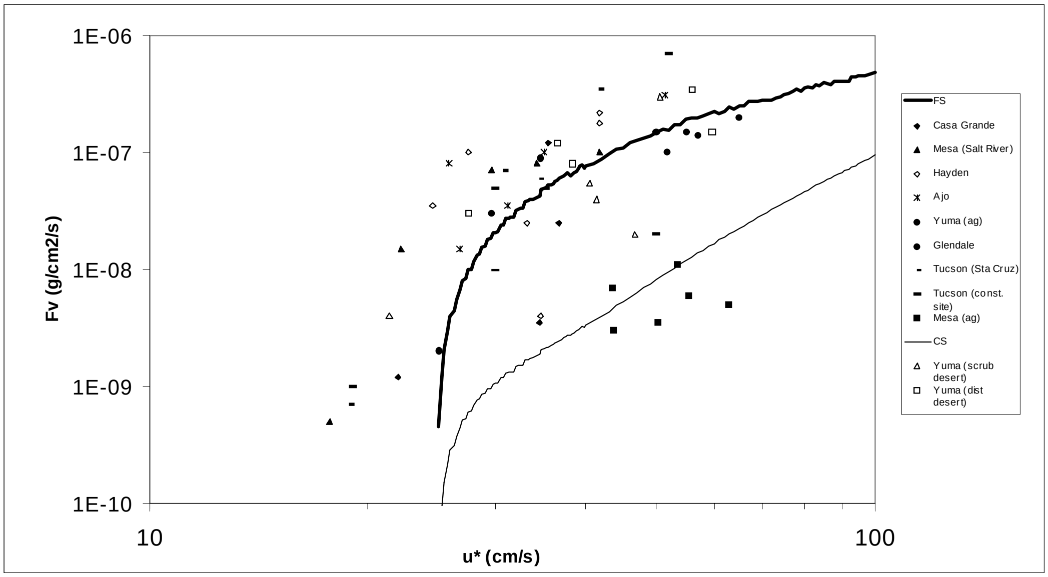


Figure 2-3. Comparison between the Alfaro et al. (2003) model relationship for FS and CS sizes and the wind tunnel flux data of Nickling and Gillies (1989). Ten (out of 13) sites have a dust production potential similar to the FS model and one site (Mesa agricultural) is closely aligned with the CS model (after Alfaro et al., 2003).

Using the Alfaro, et al. (2003) approach, emissions of dust for soils can be confined to four different emission factors, depending on the geometric mean grain size, as determined by the methods of Chatenet, et al. (1996). The model predictions were tested against the wind tunnel data set of Nickling and Gillies (1989) and found to fit the measured data satisfactorily. Of key importance is that Chatenet, et al. (1996) established relationships between the 12 soil types that are defined in the classical soil texture triangle and their four dry soil types (silt [FSS], sandy silt [FS], silty sand [MS], and sand [CS]). The soil texture categorization and the relationships among texture assignments and soil groupings are discussed below.

Reservoir Characteristics

Dust emissions from vacant lands are limited by the amount of erodible soil available for suspension into the atmosphere. In addition to the amount of soil present, the condition of the soils, including textural and stability, as well as climatological factors influence the total wind blown dust emission potential of a given parcel of vacant land. The amount of soil available for a given land parcel is referred to as the reservoir and can be classified as limited or unlimited. Classification of reservoirs as limited or unlimited has implications with respect to the duration of time over which the dust emissions are generated. In general, the reservoirs should be classified in terms of the type of soils, the depth of the soil layer, soil moisture content and meteorological parameters. Finally, the time required for a reservoir to recharge following a wind event is influenced by a number of factors including precipitation and snow events and freezing conditions of the soils.

Given that the soils database for use in the project does not provide information concerning the moisture content or the depth of the soil layer, certain assumption are made regarding the determination and classification of soil reservoirs. These assumptions are based primarily on the land use type and stability of the vacant land parcel. Reservoirs are classified as limited for stable land parcels and unlimited for unstable land parcels.

The duration and amount of precipitation and snow and freeze events will also affect the dust emissions from wind erosion. Barnard (2003) has compiled a set of conditions for treating these events based on seasons, soil characteristics and the amounts of rainfall and snow cover. These conditions were based on limited information found in the literature and additional assumptions. The results of the analysis of Barnard are summarized in Tables 2-3 and 2-4. .

Table 2-3. Number of days after precipitation event to re-initiate wind erosion for rainfall amounts (constant) exceeding 2 inches.

Soil type	Spring/Fall	Summer	Winter
Sand	3	2.1	4.2
Sandy Loam	3	2.1	4.2
Fine Sand Loam	3	2.1	4.2
Loam	4	2.9	3.8
Silt Loam	4	2.9	3.8
Sandy Clay Loam	4	2.9	3.8
Clay Loam	5	3.6	7.2
Silty Clay Loam	6	4.3	8.6
Clay	7	5	10

Table 2-4. Number of days after precipitation event to re-initiate wind erosion for rainfall amounts (constant) less than or equal to 2 inches.

Soil type	Spring/Fall	Summer	Winter
Sand	1	0.7	1.4
Sandy Loam	1	0.7	1.4
Fine Sand Loam	1	0.7	1.4
Loam	2	1.4	2.8
Silt Loam	2	1.4	2.8
Sandy Clay Loam	2	1.4	2.8
Clay Loam	3	2	4
Silty Clay Loam	4	2.8	5.6
Clay	5	3.6	7.2

Soil Disturbance

It has been noted that the level of disturbance of an erodible surface is an important parameter in the estimation of wind blown dust emissions. Disturbed surfaces tend to generate more dust than un-disturbed surfaces. In the application of the Phase I model, different emissions rates were applied for disturbed versus un-disturbed surfaces. The assumed disturbance level of the surface was to be determined by the land type and invariant in time and across the modeling domain. Thus, assumptions were required to assign surface disturbance based on land cover type. As noted previously, the disturbance level of a surface more appropriately has the effect of altering the threshold surface friction velocity; disturbed surfaces have lower thresholds while undisturbed surfaces exhibit higher threshold friction velocities.

The disturbance level of various surfaces across a regional scale modeling is difficult to determine given the lack of detail in both the LULC and soils data available for use in the model. Except for agricultural lands, which are treated separately in the model as described below, vacant land parcels are typically un-disturbed unless some activity is present such as to cause a disturbance, for example, off-road vehicle activity in desert lands, or animal grazing on rangelands.

For the RMC Phase II model implementation, all non-agricultural land types are considered un-disturbed, since there is no a priori information to indicate otherwise for the regional scale modeling domain to be considered. Additional information concerning disturbance levels for certain land types should be was investigated to determine whether an assumed percentage of specific land types can be considered disturbed versus un-disturbed. The windblown dust emission model application for the draft Phoenix NAA emission inventory considered various assumptions regarding the disturbance levels of barren lands and shrublands only, as documented in Mansell and Hoats, 2007. Revised assumptions regarding disturbance levels of various land types for the final inventory are presented and discussed in Section 4 of this report.

<u>Agricultural Land Adjustments</u>

Unlike other types of vacant land, windblown dust emissions from agricultural land are subject to a number of non-climatic influences, including irrigation and seasonal crop growth. As a result, several non-climatic correction or adjustment factors were developed for applicability to the agricultural wind erosion emissions. These factors included:

- Long-term effects of irrigation (i.e., soil “clodiness”);
- Crop canopy cover;
- Post-harvest vegetative cover (i.e., residue);
- Bare soil (i.e., barren areas within an agriculture field that do not develop crop canopy for various reasons, etc.); and
- Field borders (i.e., bare areas surrounding and adjacent to agricultural fields).

The methodology used to develop individual non-climatic correction factors for the Phase I study was described in detail in ENVIRON, 2004. Most of these methods were based upon previous similar work performed by the California Air Resources Board (CARB) in their development of California-specific adjustment factors for USDA’s Wind Erosion Equation (WEQ) (CARB, 1997). These correction factors were developed for specific soil textures, crop types, and geographic locations and then applied to the wind erosion estimates developed from the wind tunnel studies. Correction factors are developed only for the 17 field crops specifically identified in the BELD3.1 data set (i.e., alfalfa, barley, corn, cotton, grass, hay, oats, pasture, peanuts, potatoes, rice, rye, sorghum, soybeans, tobacco, wheat, and miscellaneous crops). Due to the insufficient characterization of the wind erosion emission processes for orchards and vineyards, correction factors for this type of agricultural land were not developed.

For the current windblown dust emission model application, these same non-climatic adjustments are applied. However, because the BELD3 database will not be used, these factors are related to the agricultural land types available in the LULC data used for the project. The existing county-level crop percentages from the BELD3 database are linked to the aggregated agricultural land parcels from the LULC data used. Specific updates to the agricultural information for Maricopa County are considered, as discussed in Section 5 of this report.

The agricultural correction factors are applied to the wind erosion emission rates for agricultural lands developed from wind tunnel studies. The data and methodology used for developing the correction factors is documented in ENVIRON, 2003b, and summarized below.

Long-Term Irrigation Effect Correction Factor

The correction factor for the long-term effects of irrigation is as follows:

$C_{il} = I_i/I_n$

Where: C_{il} = correction factor for long-term effects of irrigation;
I_I = irrigated soil erodibility (tons/acre/year); and
I_n = non-irrigated soil erodibility (tons/acre/year).

This correction factor is the ratio of irrigated and non-irrigated soil erodibilities ("I"). Non-irrigated soil erodibility values (I_n) can be assigned to each soil texture (U.S. EPA, 1974; U.S. EPA, 1977). Irrigated soil erodibilities (I_i) were assigned by staff of the USDA Agricultural Research Service (ARS) to corresponding non-irrigated soil erodibilities (I_n) as shown in Table 3 on Page 7.11-23 of the ARB windblown dust document (ARB, 1997). The long-term irrigation effect correction factors are developed for each soil texture and applied to all irrigated croplands, regardless of crop type. This correction factor has a value of 1.0 for all non-irrigated croplands. The correction factor is applied throughout the year with no seasonal variation.

Crop Canopy Correction Factor

The correction factor for crop canopy cover is as follows:

$C_{cc} = \exp(-0.201CC^{0.7366})$

Where: C_{cc} = correction factor for canopy cover;
exp = exponential function; and
CC = canopy cover (percent).

This correction factor is shown as Equation 7 on Page 7.11-26 of the ARB windblown dust document (ARB, 1997). Because the crop canopy cover correction factor equation contains an exponential function, the correction factor can change significantly with relatively small changes in percent crop cover. In the absence of canopy cover (i.e., CC = 0 percent), the correction factor is 1.000. With total canopy cover (i.e., CC = 100 percent), the correction factor is 0.0025 (i.e., effectively zero). More realistic canopy cover values of 10 and 20 percent give correction factors of 0.334 and 0.161, respectively. As a result, windblown emissions can vary significantly for a given crop depending upon the stage of canopy growth. For this reason, crop-specific canopy profiles should be developed; however, the ability to develop these profiles (i.e., growth curves) is dependent on the availability of data, and the resources and time to collect these data.

Post-Harvest Soil Cover Correction Factor

The correction factor for post-harvest soil cover is as follows:

C_{sc} = exp (-0.0438SC)

Where: C_{sc} = correction factor for post-harvest soil cover;
exp = exponential function; and
SC = post-harvest soil cover (percent).

This correction factor is shown as Equation 8 on Page 7.11-28 of the ARB windblown dust document (ARB, 1997). The post-harvest soil cover correction factor applies to the period of time between harvest and the next year's planting. Because the post-harvest soil cover correction factor equation contains an exponential function, the correction factor can change significantly with relatively small changes in percent post-harvest soil cover. Without any post-harvest soil cover (i.e., SC = 0 percent), the correction factor is 1.000. With total post-harvest soil cover (i.e., SC = 100 percent), the correction factor is 0.013 (i.e., effectively zero). More realistic post-harvest soil cover values of 10 and 20 percent give correction factors of 0.645 and 0.416, respectively.

Unlike canopy cover that varies throughout the growing season, the level of post-harvest soil cover is assumed constant during the post-harvest to pre-planting period. If disk-under operations are conducted for particular crops, then two levels of post-harvest soil cover will be used.

As with the crop canopy during the growing season, crop-specific post-harvest soil cover profiles will need to be developed for the non-growing season. All of the issues discussed regarding crop canopy (e.g., weekly average versus aggregated monthly, non-field crops, sub-state variability, etc.) are also applicable to developing correction factors for post-harvest soil cover.

As described above for the crop canopy correction factor, the planting and harvesting data for RUSLE2 is used to develop the post-harvest soil cover correction factor (ARS, 2003; Lightle, 2003). RUSLE2 provides crop-specific residue profiles for individual CMZs. However, residue levels are extremely dependent upon the equipment treatments conducted between harvest and planting.

Also, the Conservation Technology Information Center (CTIC) maintained by Purdue University provides information regarding the amount of residue left on a field after harvest (e.g., 0-15 percent, 15-30 percent, >30 percent), by crop and by county for the U.S. These data are collected from surveys and stored in CTIC's Crop Residue Management Program (CRM) database (Towery, 2003). State- and county-level data are available on-line for years 1989–1998, 2000, and 2002. Years 1989–1998 are for a suite of 8 crops; years 2000 and 2002 are for 8-crop and 22-crop suites.

Bare Soil Adjustment Correction Factor

The correction factor for bare soil accounts for the fraction of cultivated area that remains barren during the growing cycle. There are many possible reasons for this including uneven ground, uneven irrigation, soil salinity, pest damage, etc.

The bare soil adjustment correction factor is simply a small fraction applied to the total cultivated acreage. The ARB windblown dust document uses bare soil fractions of 0.5 percent for crop acreage and 0.05 percent for pasture (ARB, 1997). These fractions were estimated from limited visual observations by ARB staff. Although statistics quantifying bare soil fractions have not been identified, the USDA has indicated that 2-3 percent of planted cropland experiences “crop failure” (USDA, 1997b). The term “crop failure” appears to indicate that planting occurred, but that harvest did not. However, it may not be appropriate to assume that crop failure acreage is equivalent to bare soil acreage (i.e., some vegetation growth may have occurred, but for some reason the harvest did not). Therefore, ARB’s assumed bare soil fractions seem to be reasonable.

Although the bare soil adjustment correction factor is relatively small compared to overall agricultural acreage, the contribution from the bare soil area may be significant because many of the other non-climatic correction factors are not applicable (i.e., crop canopy cover, post-harvest vegetative cover, post-harvest planting, etc.).

The assumed ARB bare soil adjustment correction factors is applied throughout the year and does not vary by month or season.

Border Adjustment Correction Factor

The correction factor for border adjustment accounts for the fact the surrounding borders of most agricultural fields (excluding pastures) that are not covered in vegetation.

The border adjustment correction factor is simply a small fraction applied to the total cultivated acreage. The ARB windblown dust document uses fractions of 0.5 percent for crop acreage; pastures are assumed to have no borders (ARB, 1997). These fractions were estimated from limited visual observations by ARB staff.

Like the bare soil adjustment correction factor, the border adjustment correction factor is relatively small compared to overall agricultural acreage. However, the contribution from agricultural field borders may be significant. In fact, it may be more significant than the bare soil areas because the field borders are typically non-irrigated (i.e., long- and short-term irrigation adjustments are not applicable.

The assumed ARB border adjustment correction factor is applied throughout the year and does not vary by month or season.

3. INPUT DATA

The various data sets required for implementation of the windblown dust emission model are summarized in this section. These include:

- Landuse/landcover data;
- Soil characteristics data;
- Meteorological data, and;
- Agricultural data

Landuse/Landcover

Landuse and landcover data are required by the model to determine the susceptibility of the surfaces to wind erosion. As discussed previously, wind erosion is initiated when wind speeds exceed the threshold wind speed as determined by surface friction velocities. Surface friction velocities are dependent on the surface roughness lengths, which are assigned based on the landuse/landcover characteristics.

The current application of the model utilizes landuse data for Maricopa County obtained from the Maricopa Association of Governments (MAG). These data provide varying degrees of detail with respect to urban lands and natural landscapes within the modeling domain. Because these data cover only Maricopa County and the Phoenix NAA region of Pinal county, other landuse data were required. The Southwest GAP database was used for this purpose.

The purpose of the Gap Analysis Program (GAP) is to provide regional assessments of the conservation status of native vertebrate species and natural land cover types and to facilitate the application of this information to land management activities. The National GAP URL is http://www.gap.uidaho.edu/. The GAP is conducted as state-level projects and is coordinated by the USGS Biological Resources Division. Currently the program is developing land cover mappings for all U.S. States. The entire GAP process for a state requires four to six years. Although each state is being developed separately, detailed vegetation species covers are being developed based on predetermined classifications.

The National GAP data is available in an Albers Conical Equal Area projection coordinate system at a nominal spatial resolution of approximately 50 meters. Depending on the state, a minimum mapping unit of 2, 5, 40 or even 100 hectares (1 km^2) is used, although 0.09 hectares (30 m^2) is most common. The land cover classifications are based on the National Vegetation Classification System and are derived primarily from Landsat Thematic Mapper (TM) imagery. The base year for the TM scenes used by each state is supposed to be less than three years old at the start of the project. Ancillary input data from aerial photography and other maps is also used. The classification system provides for several hundred species designations, but includes broad categories stratified according to primary, secondary and tertiary coverages based on percent of land cover in each of several broad regions.

For model application of Maricopa and Pinal Counties, the MAG and SW GAP landuse data bases were merged to obtain a single coverage for the entire modeling domain. Table 3-1 presents the landuse classifications available within the final merged dataset. Also included in

Table 3-1 are the assignments of each LULC class to the corresponding dust code used in the model. Note that the assignments for each LULC category presented in Table 3-1 differ from those used in the development of the draft inventory. These revised assignments were based a review and assessment of the landuse categories specific to the Phoenix area conducted by staff at the MCAQD and MAG. The dust code is used to determine the surface roughness lengths as a function of landuse/landcover. These roughness lengths, in turn determine the threshold surface friction velocities, as discussed previously in Section 2. Table 3-2 presents the assigned surface roughness lengths as a function of landuse/landcover and dust codes. Note that for dust codes 1 (urban lands), 2 (forest) and 5 (orchards and vineyards), the assumed surface roughness lengths result in threshold surface friction velocities with magnitudes too high to be considered susceptible to wind erosion, and are therefore not included in the model. Figure 3-1 displays the complete, merged LULC data used for the project.

Table 3-1. Merged land Use/Land Cover classifications (codes < 1000 correspond to MAG LU database).

LU_MRG_Code	LU_Code	Description	Dust_Code
0	0	N/A	0
100	100	General Residential - Residential where no detail available	1
110	110	Rural Residential - <= 1/5 du per acre	1
120	120	Estate Residential - 1/5 du per acre to 1 du per acre	1
130	130	Large Lot Residential (SF) - 1 du per acre to 2 du per acre	1
140	140	Medium Lot Residential (SF) - 2-4 du per acre	1
150	150	Small Lot Residential (SF) - 4-6 du per acre	1
160	160	Very Small Lot Residential (SF) - >6 du per acre (includes mobile home parks)	1
161	161	Very Small Lot Res (SF-Mobile Homes) - Mobile home parks/RV Parks (>6 du per acre)	1
170	170	Medium Density Residential (MF) - 5-10 du per acre	1
180	180	High Density Residential (MF) - 10-15 du per acre	1
190	190	Very High Density Residential (MF) - > 15 du per acre	1
198	198	Parking structures serving Residential - Parking structures serving Residential	1
199	199	Parking lots serving Residential - Parking lots serving Residential	1
200	200	General Commercial - Commercial where no detail available	1
201	201	Very Low Density Commercial - Amusement facilities	1
202	202	Low Density Commercial - Movie Theatres, Skating Rinks	1
203	203	Greenhouse Commercial - Nurseries, Greenhouses	1
210	210	Specialty Commercial - <=50,000 square feet	1
220	220	Neighborhood Commercial - 50,000 to 100,000 square feet	1
230	230	Community Commercial - 100,000 to 500,000 square feet	1
240	240	Regional Commercial - 500,000 to 1,000,000 square feet	1
250	250	Super-Regional Commercial - >= 1,000,000 square feet	1
298	298	Parking structures serving Commercial - Parking structures serving Commercial	1
299	299	Parking lots serving Commercial - Parking lots serving Commercial	1
300	300	General Industrial - Industrial where no detail available	1
310	310	Warehouse/Distribution Centers -	1
320	320	Industrial -	1

ENVIRON

LU_MRG _Code	LU_Code	Description	Dust_Code
398	398	Parking structures serving Industrial - Parking structures serving Industrial	1
399	399	Parking lots serving Industrial - Parking lots serving Industrial	1
400	400	Office General - Office where no detail available	1
410	410	Office Low Rise - 1-4 stories	1
420	420	Office Mid Rise - 5-12 stories	1
430	430	Office High Rise - 13 stories or more	1
498	498	Parking structures serving Office - Parking structures serving Office	1
499	499	Parking lots serving Office - Parking lots serving Office	1
500	500	General Employment - Employment where no detail available	1
510	510	Tourist and Visitor Accommodations - Hotels, motels and resorts	1
511	511	Motels - Motels	1
512	512	Hotels - Hotels	1
513	513	Resorts - Resorts	1
520	520	Educational - Public schools, private schools, universities	1
521	521	Schools (K-12 grade) - Schools	1
522	522	Post High School Institutions - Including public and private colleges and technical training institutions	1
523	523	Arizona State University - ASU Main and Extended Campuses	1
524	524	Dormitories - Dormitories associated with educational institutions	1
525	525	Preschool/Daycare facilities - Preschool/Daycare facilities	1
530	530	Institutional - Includes hospitals, churches	1
531	531	Medical Institutions - Hospitals/Medical Centers	1
532	532	Religious Institutions - Churches/Religious Institutions	1
533	533	Nursing Homes - Nursing Homes (Group Quarter)	1
534	534	Assisted Care Facilities - Assisted Care Facilities	1
540	540	Cemeteries -	1
550	550	Public Facilities - Includes community centers, power sub-stations, libraries, city halls, police and fire stations and other government facilities	1
551	551	Public Offices - Includes city halls	1
552	552	Public Services - Includes community centers, libraries, police and fire stations, courts, prisons and other government services	1
553	553	Large Public Facilities - Includes power sub-stations, Work yards, Sewer and Water treatment plants	1
554	554	Military - Military Use	1
555	555	Limited Use Public Facilities - Very small difficult to access parcels	1
560	560	Special Events - Includes stadiums, sports complexes, and fairgrounds	1
570	570	Other Employment (low) - Proving grounds, land fills	1
571	571	Landfill - Landfill	7
572	572	Sand and Gravel - Sand and Gravel	7
573	573	Proving Grounds - Proving Grounds	7
574	574	Mining - Mining	7
580	580	Other Employment (medium) -	1

LU_MRG _Code	LU_Code	Description	Dust_Code
590	590	Other Employment (high) -	1
598	598	Parking structures serving Facilities/Emp - Parking structures serving Facilities/Employment	1
599	599	Parking lots serving Facilities/Employment - Parking lots serving Facilities/Employment	1
600	600	General Transportation - Transportation where no detail available	1
610	610	Transportation - Includes railroads, railyards, transit centers and freeways	1
611	611	Parking Lots - Parking Lots	1
612	612	Parking Structures - Parking Structures	1
613	613	Park and Ride lots - Park and Ride lots	1
614	614	Transit Center - Transit Center	1
620	620	Airports - Includes public use airports	1
621	621	Sky Harbor Airport - Sky Harbor Airport	1
699	699	Unassigned	1
700	700	General Open Space - Open Space where no detail available	7
710	710	Active Open Space - Includes parks	7
720	720	Golf courses -	4
730	730	Passive Open Space - Includes mountain preserves and washes	7
731	731	Restricted Open Space - Restricted Open Space (Including Firing Range)	7
740	740	Water -	7
750	750	Agriculture -	3
800	800	Multiple Use General - Multiple Use where no detail available	1
798	798	Parking structures serving Open Space - Parking structures serving Open Space	1
799	799	Parking lots serving Open Space - Parking lots serving Open Space	7
810	810	Business Park - Includes enclosed industrial, office or retail in a planned environment	1
820	820	Mixed Use - Jurisdiction defined	1
821	821	Mixed Use/Indian Community - Mixed Use/Indian Community	1
830	830	Planned Developments -	1
898	898	Parking structures serving Multiple Use - Parking structures serving Multiple Use	1
899	899	Parking lots serving Multiple Use - Parking lots serving Multiple Use	1
900	900	Vacant (existing land use database only) - Vacant	7
910	910	Developing Residential - Residential Under Construction	7
920	920	Developing Commercial - Commercial Under Construction	7
930	930	Developing Industrial - Industrial Under Construction	7
940	940	Developing Office - Office Under Construction	7
950	950	Developing Public/Other Employment - Employment Under Construction	7
960	960	Developing Transportation - Transportation Under Construction	7
970	970	Developing Open Space - Developing Open Space	7
980	980	Developing Multiple Use - Multiple Use Under Construction	7
999	999	Salvage/Unknown - Evaluate on an individual basis	1

LU_MRG _Code	LU_Code	Description	Dust_Code
1000	0	N/A	1
1001	1	North American Alpine Ice Field	1
1002	2	Rocky Mountain Alpine Bedrock and Scree	1
1003	3	Mediterranean California Alpine Bedrock and Scree	1
1004	4	Rocky Mountain Alpine Fell-Field	1
1005	5	Rocky Mountain Cliff and Canyon	1
1006	6	Sierra Nevada Cliff and Canyon	1
1007	7	Western Great Plains Cliff and Outcrop	1
1008	8	Inter-Mountain Basins Cliff and Canyon	1
1009	9	Colorado Plateau Mixed Bedrock Canyon and Tableland	1
1010	10	Inter-Mountain Basins Shale Badland	1
1011	11	Inter-Mountain Basins Active and Stabilized Dune	7
1012	12	Inter-Mountain Basins Volcanic Rock and Cinder Land	1
1013	13	Inter-Mountain Basins Wash	7
1014	14	Inter-Mountain Basins Playa	7
1015	15	North American Warm Desert Bedrock Cliff and Outcrop	1
1016	16	North American Warm Desert Badland	1
1017	17	North American Warm Desert Active and Stabilized Dune	7
1018	18	North American Warm Desert Volcanic Rockland	1
1019	19	North American Warm Desert Wash	7
1020	20	North American Warm Desert Pavement	1
1021	21	North American Warm Desert Playa	7
1022	22	Rocky Mountain Aspen Forest and Woodland	2
1023	23	Rocky Mountain Bigtooth Maple Ravine Woodland	2
1024	24	Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland	2
1025	25	Inter-Mountain Basins Subalpine Limber-Bristlecone Pine Woodland	2
1026	26	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	2
1027	27	Northern Pacific Mesic Subalpine Woodland	2
1028	28	Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	2
1029	29	Rocky Mountain Lodgepole Pine Forest	2
1030	30	Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland	2
1031	31	Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland	2
1032	32	Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland	2
1033	33	Madrean Pine-Oak Forest and Woodland	2
1034	34	Rocky Mountain Ponderosa Pine Woodland	2
1035	35	Southern Rocky Mountain Pinyon-Juniper Woodland	2
1036	36	Colorado Plateau Pinyon-Juniper Woodland	2
1037	37	Great Basin Pinyon-Juniper Woodland	2
1038	38	Inter-Mountain West Aspen-Mixed Conifer Forest and Woodland Complex	2
1039	39	Rocky Mountain Alpine Dwarf-Shrubland	6
1040	40	Inter-Mountain Basins Mat Saltbush Shrubland	6
1041	41	Rocky Mountain Gambel Oak-Mixed Montane Shrubland	6

LU_MRG _Code	LU_Code	Description	Dust_Code
1042	42	Rocky Mountain Lower Montane-Foothill Shrubland	6
1043	43	Western Great Plains Sandhill Shrubland	6
1044	44	Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland	6
1045	45	Madrean Encinal	6
1046	46	Colorado Plateau Pinyon-Juniper Shrubland	6
1047	47	Great Basin Semi-Desert Chaparral	6
1048	48	Inter-Mountain Basins Big Sagebrush Shrubland	6
1049	49	Great Basin Xeric Mixed Sagebrush Shrubland	6
1050	50	Colorado Plateau Mixed Low Sagebrush Shrubland	6
1051	51	Mogollon Chaparral	6
1052	52	Apacherian-Chihuahuan Mesquite Upland Scrub	6
1053	53	Colorado Plateau Blackbrush-Mormon-tea Shrubland	6
1054	54	Mojave Mid-Elevation Mixed Desert Scrub	6
1055	55	Chihuahuan Succulent Desert Scrub	6
1056	56	Chihuahuan Creosotebush Mixed Desert and Thorn Scrub	6
1057	57	Sonoran Paloverde-Mixed Cacti Desert Scrub	6
1058	58	Inter-Mountain Basins Mixed Salt Desert Scrub	6
1059	59	Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub	6
1060	60	Sonora-Mojave Creosotebush-White Bursage Desert Scrub	6
1061	61	Sonora-Mojave Mixed Salt Desert Scrub	6
1062	62	Inter-Mountain Basins Montane Sagebrush Steppe	4
1063	63	Southern Rocky Mountain Juniper Woodland and Savanna	4
1064	64	Inter-Mountain Basins Juniper Savanna	4
1065	65	Apacherian-Chihuahuan Piedmont Semi-Desert Grassland and Steppe	4
1066	66	Inter-Mountain Basins Big Sagebrush Steppe	6
1067	67	Inter-Mountain Basins Semi-Desert Shrub Steppe	6
1068	68	Chihuahuan Gypsophilous Grassland and Steppe	4
1069	69	Rocky Mountain Dry Tundra	1
1070	70	Rocky Mountain Subalpine Mesic Meadow	4
1071	71	Southern Rocky Mountain Montane-Subalpine Grassland	4
1072	72	Western Great Plains Foothill and Piedmont Grassland	4
1073	73	Central Mixedgrass Prairie	4
1074	74	Western Great Plains Shortgrass Prairie	4
1075	75	Western Great Plains Sandhill Prairie	4
1076	76	Inter-Mountain Basins Semi-Desert Grassland	4
1077	77	Rocky Mountain Subalpine-Montane Riparian Shrubland	6
1078	78	Rocky Mountain Subalpine-Montane Riparian Woodland	2
1079	79	Rocky Mountain Lower Montane Riparian Woodland and Shrubland	6
1080	80	North American Warm Desert Lower Montane Riparian Woodland and Shrubland	6
1081	81	Western Great Plains Riparian Woodland and Shrubland	6
1082	82	Inter-Mountain Basins Greasewood Flat	2
1083	83	North American Warm Desert Riparian Woodland and Shrubland	6
1084	84	North American Warm Desert Riparian Mesquite Bosque	2
1085	85	North American Arid West Emergent Marsh	1
1086	86	Rocky Mountain Alpine-Montane Wet Meadow	1

LU_MRG _Code	LU_Code	Description	Dust_Code
1087	87	Temperate Pacific Montane Wet Meadow	1
1088	88	Mediterranean California Subalpine-Montane Fen	1
1089	89	Western Great Plains Saline Depression Wetland	1
1090	90	Chihuahuan-Sonoran Desert Bottomland and Swale Grassland	4
1091	91	Madrean Upper Montane Conifer-Oak Forest and Woodland	2
1092	92	Madrean Pinyon-Juniper Woodland	2
1093	93	Chihuahuan Sandy Plains Semi-Desert Grassland	4
1094	94	Sonora-Mojave-Baja Semi-Desert Chaparral	6
1095	95	Madrean Juniper Savanna	4
1096	96	Chihuahuan Mixed Salt Desert Scrub	6
1097	97	Coahuilan Chaparral	6
1098	98	Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland	6
1099	99	Western Great Plains Floodplain Herbaceous Wetland	1
1100	100	Mediterranean California Red Fir Forest and Woodland	2
1101	101	Sierra Nevada Subalpine Lodgepole Pine Forest and Woodland	2
1102	102	Mediterranean California Ponderosa-Jeffrey Pine Forest and Woodland	2
1103	103	Rocky Mountain Foothill Limber Pine-Juniper Woodland	2
1104	104	Wyoming Basins Low Sagebrush Shrubland	6
1105	105	Sonoran Mid-Elevation Desert Scrub	6
1106	106	Western Great Plains Tallgrass Prairie	4
1107	107	North Pacific Montane Grassland	4
1108	108	Southern Colorado Plateau Sand Shrubland	6
1109	109	Western Great Plains Mesquite Woodland and Shrubland	7
1110	110	Open Water	1
1111	111	Developed Mixed Desert and Thorn Scrub	6
1112	112	Developed Medium - High Intensity	1
1113	113	Barren Lands Non-specific	7
1114	114	Agriculture	3
1115	115	Disturbed Non-specific	6
1116	116	Recently Burned	7
1117	117	Recently Mined or Quarried	7
1118	118	Invasive Southwest Riparian Woodland and Shrubland	6
1119	119	Invasive Perennial Grassland	4
1120	120	Invasive Perennial Forbland	4
1121	121	Invasive Annual Grassland	4
1122	122	Invasive Annual and Biennial Forbland	4
1123	123	Recently Logged Areas	7
1124	124	Recently Chained Pinyon-Juniper Areas	2
1125	125	Disturbed Oil Well	7
2200	22	Alfalfa	3
2300	23	Barley	3
2400	24	Corn	3
2500	25	Cotteon	3
2600	26	Grass	3
2700	27	Hay	3
2800	28	Misc. crops	3
2900	29	Oats	3

LU_MRG _Code	LU_Code	Description	Dust_Code
3000	30	Pasture	3
3100	31	Peanuts	3
3200	32	Potatoes	3
3300	33	Rice	3
3400	34	Rye	3
3500	35	Sorghum	3
3600	36	Soybeans	3
3700	37	Tobacco	3
3800	38	Wheat	3
3900	39	Forest (from FIA data)	2

Table 3-2. Surface roughness lengths by LULC and dust code.

Landuse Category	Dust Code	Surface Roughness Length (cm)
Agricultural (bare field)	3	0.015
Grasslands	4	0.1
Shrublands	6	0.05
Barren Lands	7	0.002

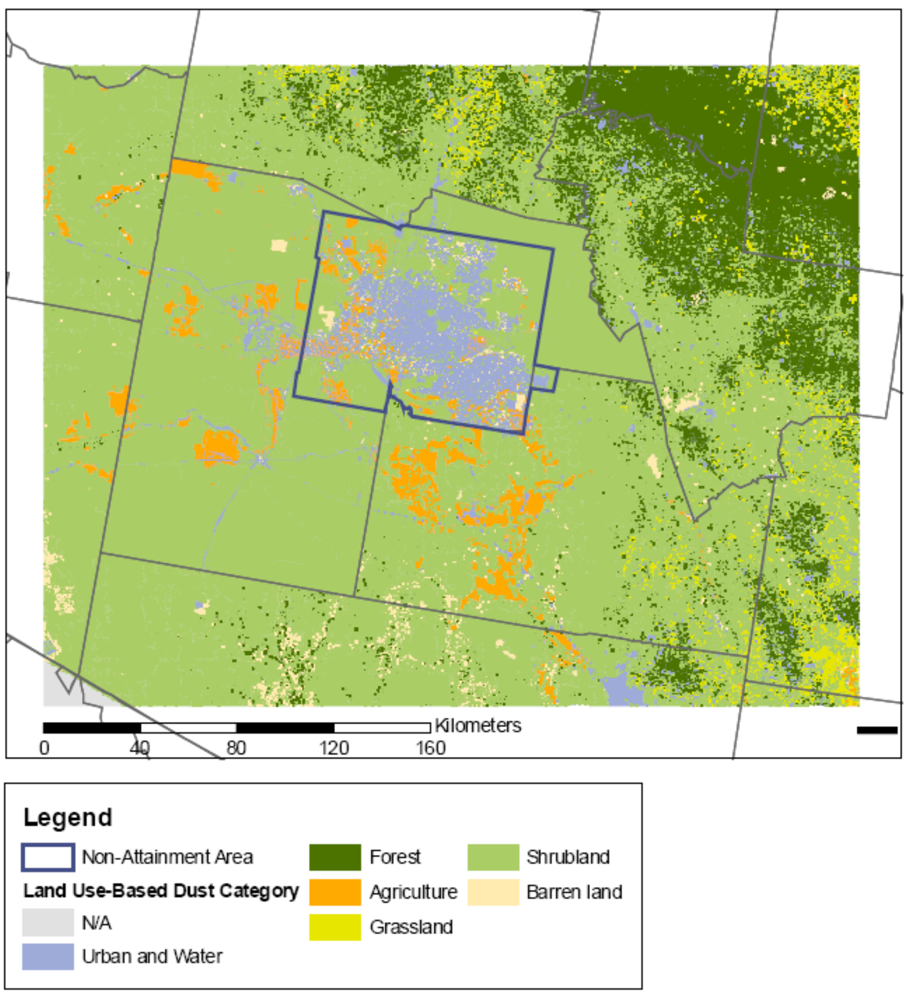


Figure 3-1. Merged LULC data for windblown dust model application.

Soil Characteristics

Soils characteristics data (soil texture) are used in the model to determine dust emissions rates as a function of wind speeds. Application of the emission factor relations described above requires the characterization of soil texture in terms of the 4 soil groups considered by the model. The characteristics, or type, of soil is one of the parameters of primary importance for the application of the emission estimation relations derived from wind tunnel study results.

The SSURGO1 soils geographic database developed by USDA Natural Resource Conservation Service was used as the primary soils database for this study. Because some of the survey areas within the modeling domain were missing from the SSURGO1 database, the State Soil Geographic Database (STATSGO) was used to fill in these regions. The SSURGO1 database was obtained from http://soildatamart.nrcs.usda.gov while the STATSGO databases were obtained from the Earth System Science Center (ESSC) at Penn State University (http://www.essc.psu.edu/soil_info/).

The classification of soil textures and soil group codes is based on the standard soil triangle that classifies soil texture in terms of percent sand, silt and clay. Combining the soil groups defined by the work of Alfaro, et al. (2003) and Chatenet, et al. (1996) and the standard soil triangle provides the mapping of the 12 soil textures to the 4 soil groups considered in their study. Combining the data from these two soil texture/soil group mappings results in the unique mapping of soil textures to the soil groups for which emission factor data can be applied. The results of combining these soil texture definitions allows the assignment of the loam soil group in terms of standard soil texture. The soil texture mappings are summarized in Table 3-3. Figures 3-2 and 3-3 display the merged soils data used for the project.

Table 3-3. Soil texture and soil group codes.

Soil Texture	Soil Texture Code	Soil Group	Soil Group Code
No Data	0	N/A	0
Sand	1	CS	4
Loamy Sand	2	CS	4
Sandy Loam	3	MS	3
Silt Loam	4	FS	1
Silt	5	FSS	2
Loam	6	MS	3
Sandy Clay Loam	7	MS	3
Silty Clay Loam	8	FSS	1
Clay Loam	9	MS	3
Sandy Clay	10	MS	3
Silty Clay	11	FSS	1
Clay	12	FS	2

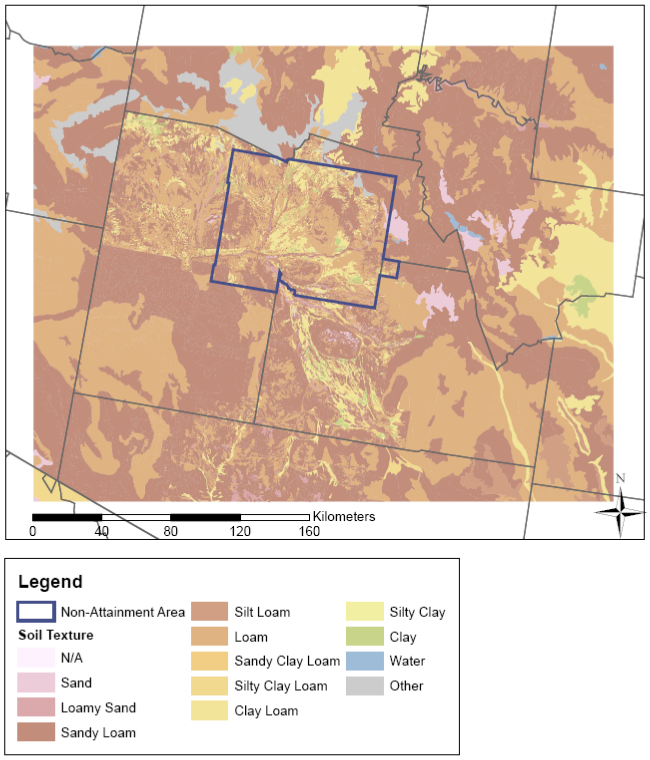


Figure 3-2. Merged soil texture data for windblown dust model application.

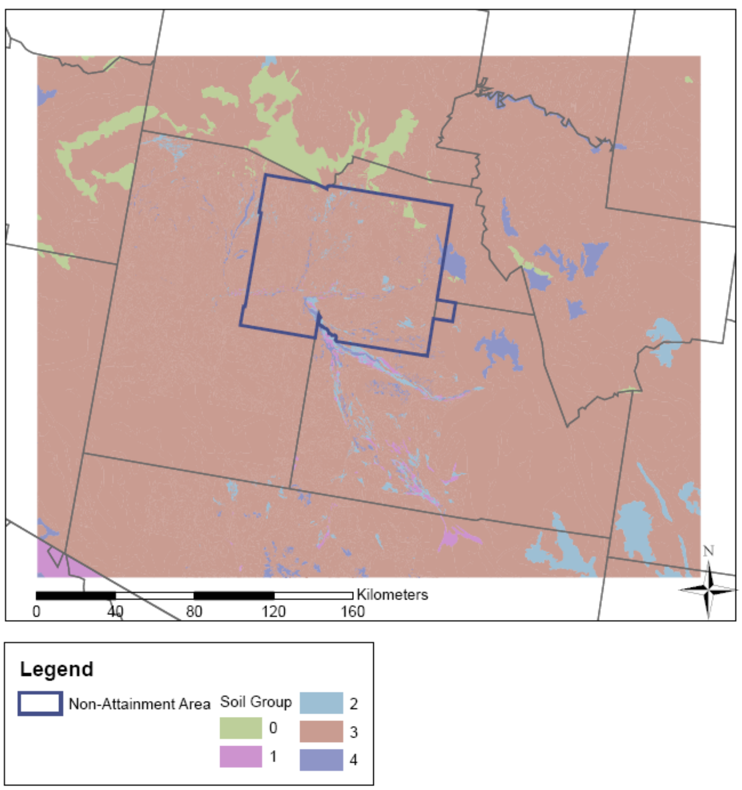


Figure 3-3. Merged soil group data for windblown dust model application.

Meteorology

The RMC windblown dust model, as used in the present application, was developed to generate hourly gridded estimates of PM dust emissions based on landuse, soils characteristics, hourly meteorological data and additional information related to agricultural practices. In previous regional applications, the necessary meteorological data have been derived from the results regional MM5 model simulations. Additionally, for local-scale applications, meteorological data has been developed from CALMET simulations using the regional MM5 simulation results as inputs to the CALMET model. For the current application to the Phoenix PM10 non-attainment area, hourly observational data was provided by MAG. These observational data were as the basis for interpolation to gridded, hourly-resolved wind speed fields. The data provided by MAG consists of comma-delimited ASCII files containing the meteorological fields shown in Table 3-4.

Table 3-4. Meteorological data provided by MAG.

Column	Description	Type
1	Julian date in dddhh.ff (ff: a fraction of minute to hour)	Real
2	Y-location (I dot-point location on coarse mesh)	Real
3	X-location (J dot-point location on coarse mesh)	Real
4	Vertical height from the ground (in meter)	Real
5	U wind (in m/sec)	Real
6	V wind (in m/sec)	Real
7	Temperature (in Kelvin)	Real
8	Water vapor mixing ratio (in kg/kg)	Real
9	Pstar (in cb) (99999. for the model in nonhydrostatic mode)	Real
10	Site ID	Char
11	Network Name	Char
12	Latitude	Real
13	Longitude	Real
14	Pressure	Real

The meteorological data tabulated above were provided for calendar year 2005 from the AZMET weather stations listed in Table 3-5. All measurements are taken at a height of 3 meters AGL.

Table 3-5. AZMET observation stations.

Site	Abbr.	Lat	Lon	UTM (Zone 12)		Elev. (m)	County
Buckeye	BCK1	33.400000	-112.683333	3696899	343454	304	Maricopa
Harquahala	HARQ	33.483333	-113.116667	3706876	303337	350	Maricopa
Paloma	PALO	32.926667	-112.895556	3644751	322765	219	Maricopa
Phx. Encanto	ENCA	33.479167	-112.096389	3704947	398135	335	Maricopa
Phx. Greenway	PGRN	33.621389	-112.108333	3720728	397193	401	Maricopa
Queen Creek	QUEE	33.258333	-111.641667	3680110	440233	430	Maricopa
Waddell	WADD	33.618056	-112.459722	3720763	364592	407	Maricopa
Coolidge	COOL	32.980000	-111.604722	3649232	443496	422	Pinal
Maricopa	MARI	33.068611	-111.971667	3659313	409299	361	Pinal
Aguila	AGUI	33.946667	-113.188889	3758401	297716	655	Maricopa

For the current windblown dust model application, these observational wind data were interpolated to the modeling grid (Figure 1-1) using a kriging algorithm. Figure 3-4 displays an example of the results of this approach for the windspeed observational data of noon on January 28, 2006. Also shown are the locations of the AZMET observational stations.

Monthly average wind speeds obtained through interpolation of the observational data are displayed in Figure 3-5 for the 12-km modeling domain used in the project.

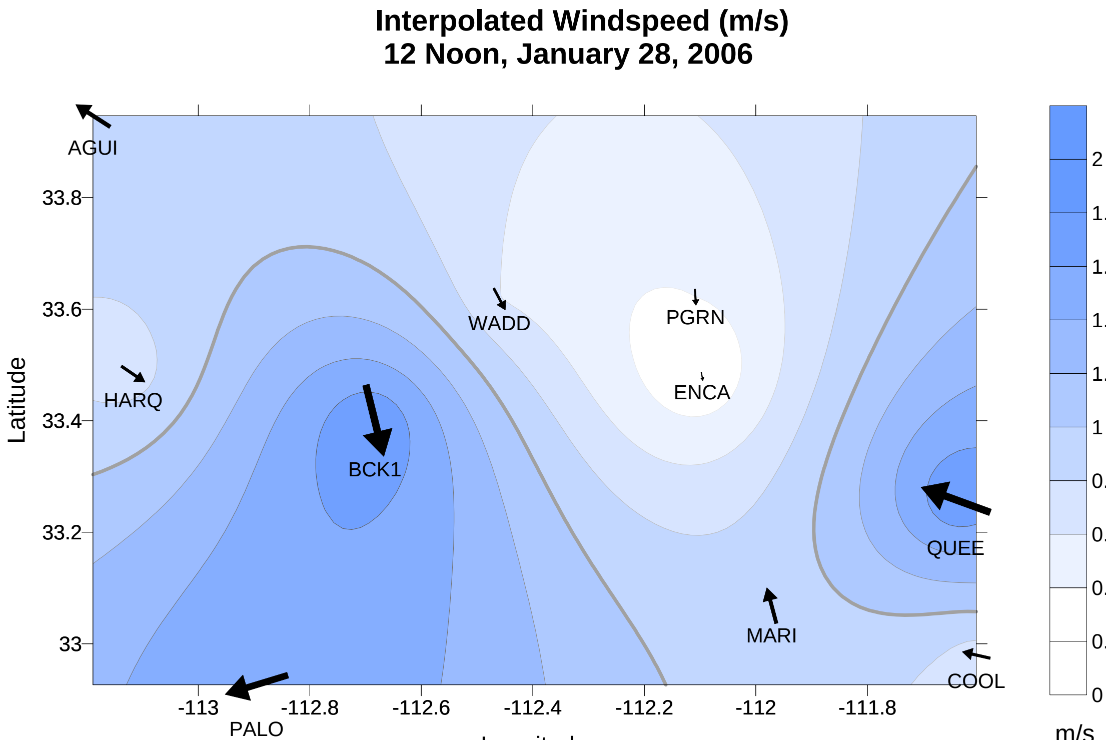


Figure 3-4. Example interpolated wind speeds for 12 Noon, January 28, 2006.

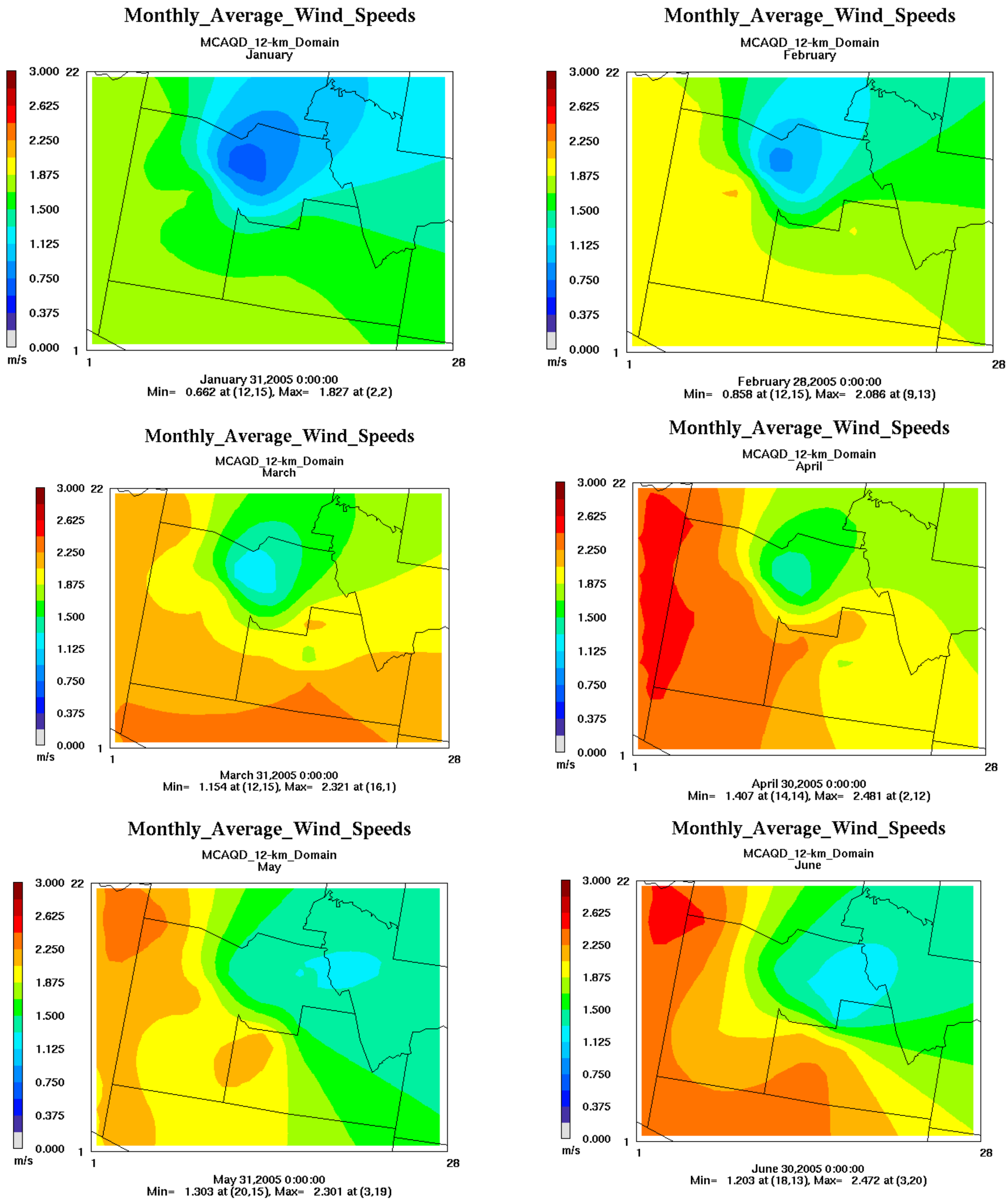


Figure 3-5. Monthly average wind speeds on the 12-km windblown dust modeling domain.

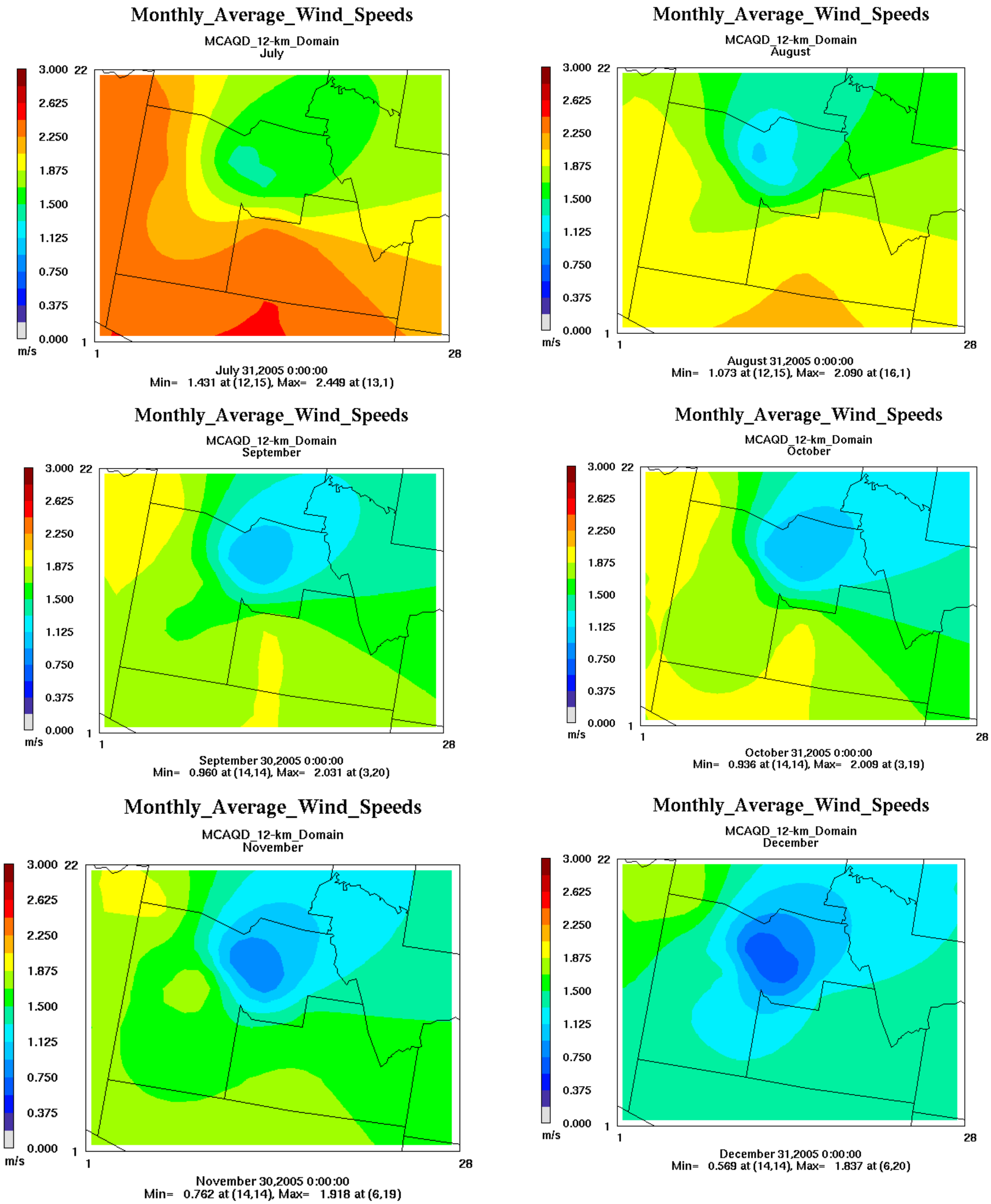


Figure 3-5. (concluded). Monthly average wind speeds on the 12-km windblown dust modeling domain

Hourly precipitation data used in the current application were based on data provided by the Maricopa County Flood Control District and consisted of a five average (2001-2005) of measured hourly rainfall rates. The locations of these monitoring stations are displayed in Figure 3-6. To generate gridded hourly rainfall for model application, a nearest neighbor interpolation scheme was utilized. Figure 3-7 displays the result of the interpolation in terms of monthly total rainfall, in inches, across the domain.

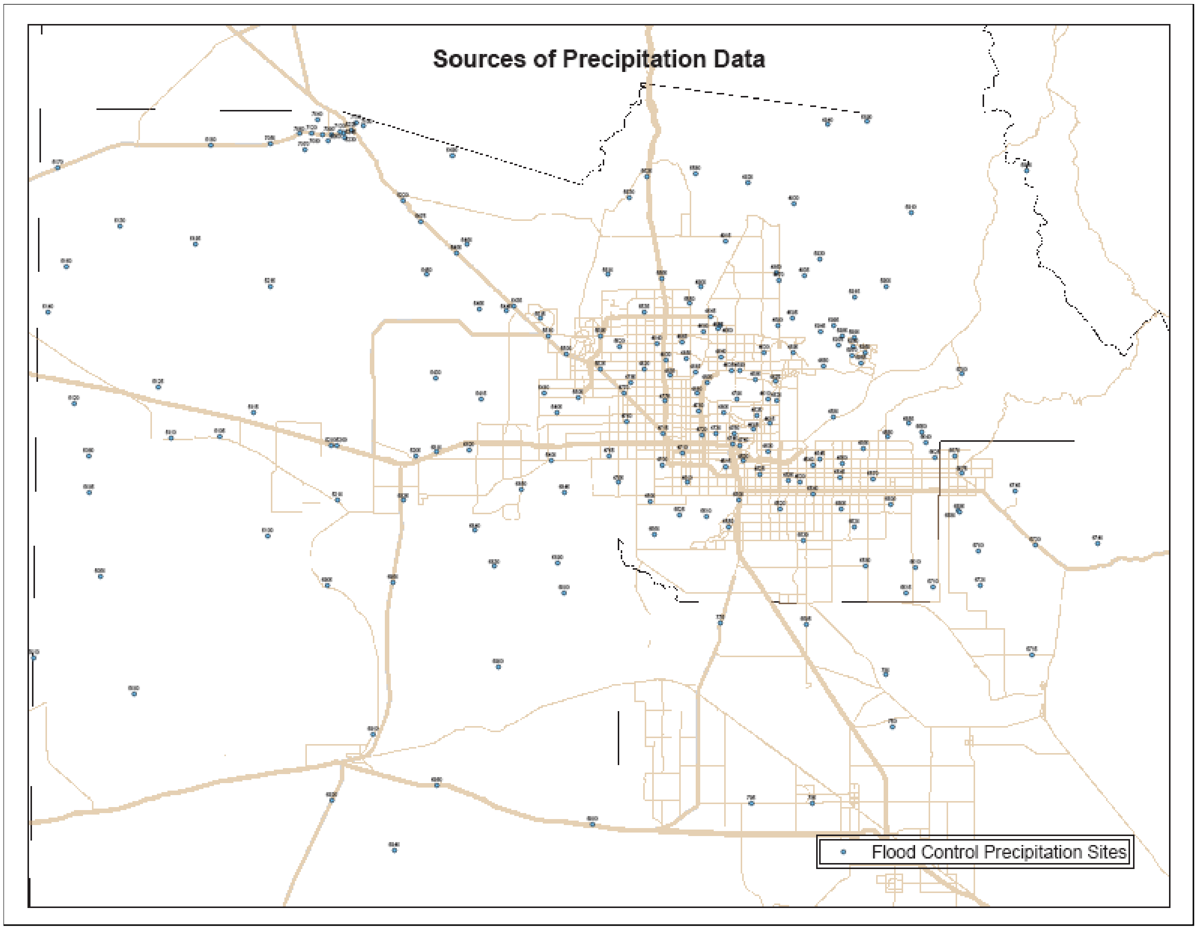
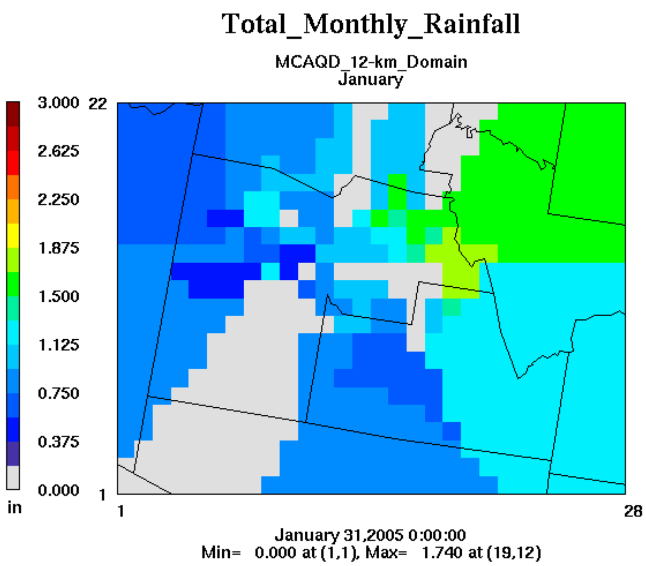
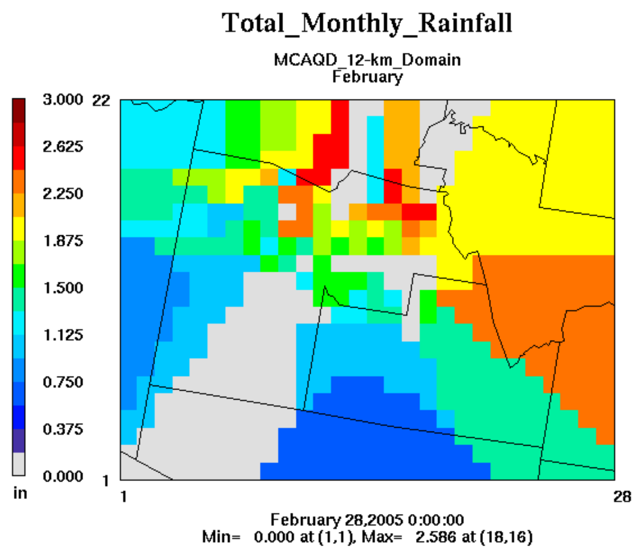
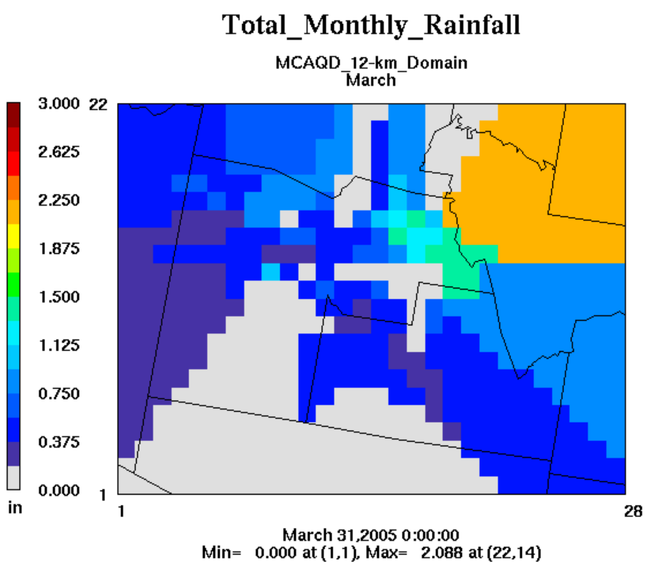
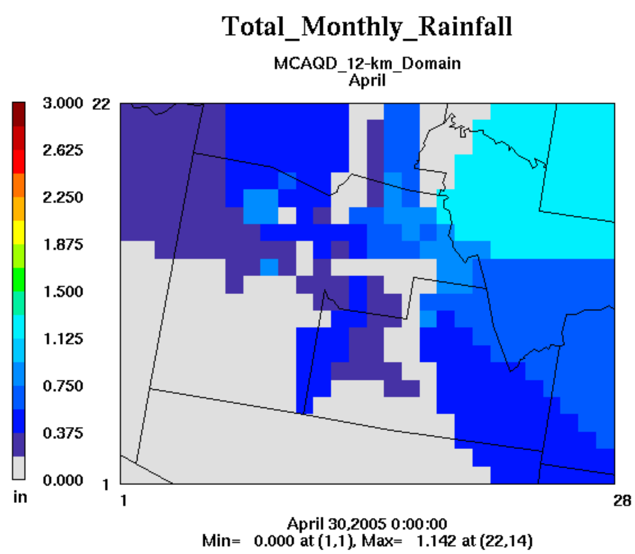


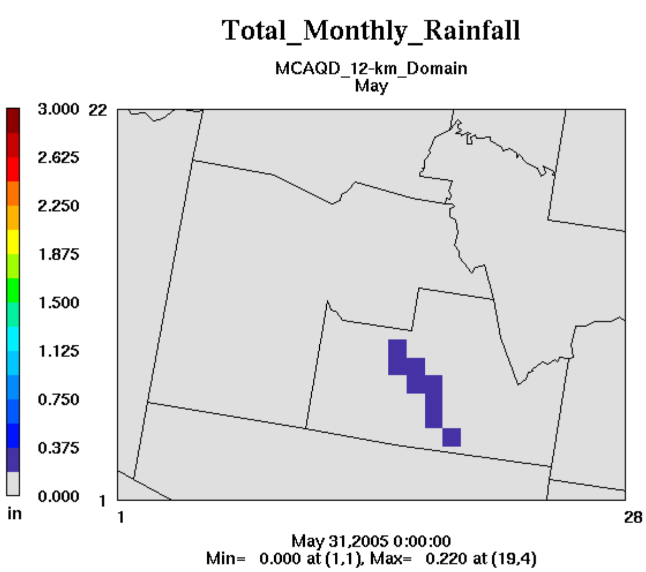
Figure 3-6. Flood Control Precipitation Sites.


Total_Monthly_Rainfall
MCAQD_12-km_Domain
January
3.000
2.625
2.250
1.875
1.500
1.125
0.750
0.375
0.000
in
22
1
1
28
January 31,2005 0:00:00
Min= 0.000 at (1,1), Max= 1.740 at (19,12)


Total_Monthly_Rainfall
MCAQD_12-km_Domain
February
3.000
2.625
2.250
1.875
1.500
1.125
0.750
0.375
0.000
in
22
1
1
28
February 28,2005 0:00:00
Min= 0.000 at (1,1), Max= 2.586 at (18,16)


Total_Monthly_Rainfall
MCAQD_12-km_Domain
March
3.000
2.625
2.250
1.875
1.500
1.125
0.750
0.375
0.000
in
22
1
1
28
March 31,2005 0:00:00
Min= 0.000 at (1,1), Max= 2.088 at (22,14)


Total_Monthly_Rainfall
MCAQD_12-km_Domain
April
3.000
2.625
2.250
1.875
1.500
1.125
0.750
0.375
0.000
in
22
1
1
28
April 30,2005 0:00:00
Min= 0.000 at (1,1), Max= 1.142 at (22,14)


Total_Monthly_Rainfall
MCAQD_12-km_Domain
May
3.000
2.625
2.250
1.875
1.500
1.125
0.750
0.375
0.000
in
22
1
1
28
May 31,2005 0:00:00
Min= 0.000 at (1,1), Max= 0.220 at (19,4)

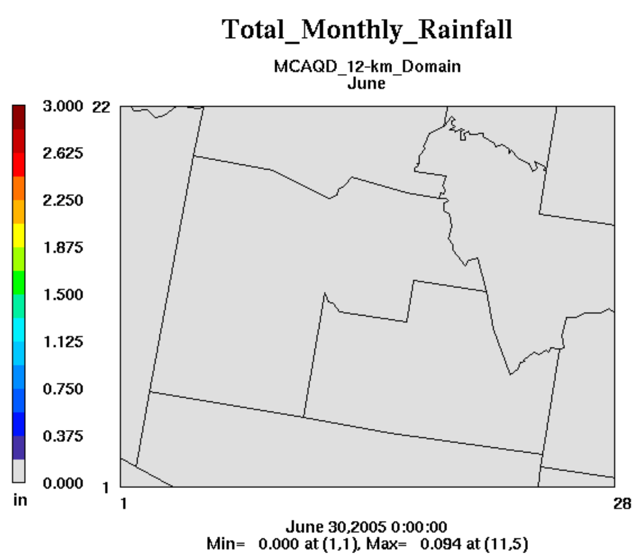

Total_Monthly_Rainfall
MCAQD_12-km_Domain
June
3.000
2.625
2.250
1.875
1.500
1.125
0.750
0.375
0.000
in
22
1
1
28
June 30,2005 0:00:00
Min= 0.000 at (1,1), Max= 0.094 at (11,5)

Figure 3-7. Monthly total rainfall in inches (2001-2005 data)

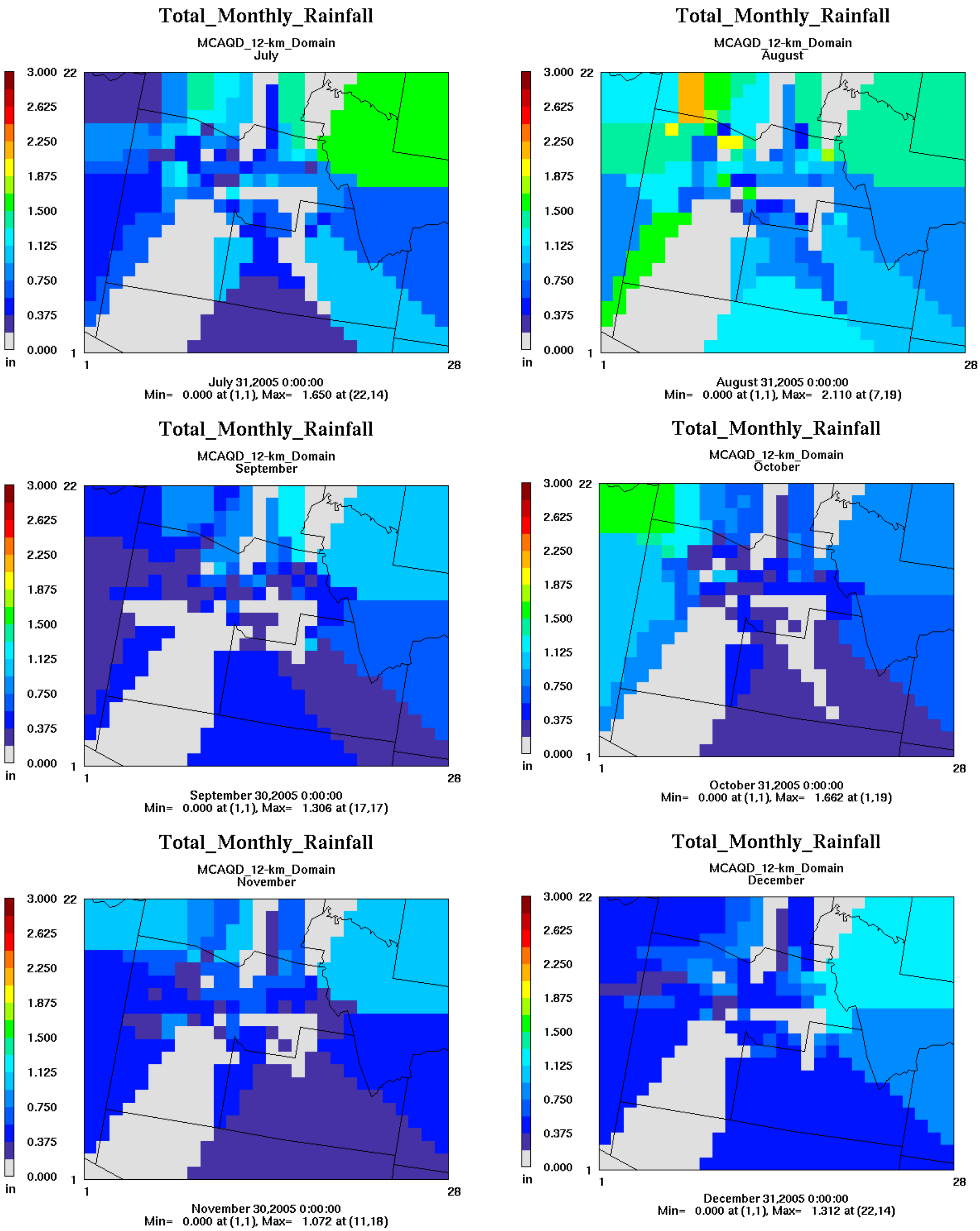


Figure 3-7. (concluded). Monthly total rainfall in inches (2001-2005 data)

Agricultural Data

Agricultural information is used in the model to adjust the estimated windblown dust emissions based on crop growth and agricultural management practices. The adjustments applied were described previously in Section 2. The primary adjustments for agricultural lands are based on the growth of crop canopy from planting to harvest. The RMC model is populated with default crop calendars derived from a variety of sources, as discussed in Section 2. The crops considered are those included in the BELD landuse database, which is based on USDA crop acreages by county.

For the current application, the crop acreages included in the BELD database were compared with the most recent USDA statistics for Maricopa and Pinal counties. This comparison is summarized in Table 3-6. Due to inconsistencies between the BELD data (based on 1997 USDA statistics) and the most recent data from the USDA, the default data sets for the windblown dust model were updated to reflect the more recent information using a combination of the 2004 and 2005 USDA data for Maricopa and Pinal counties.

Table 3-6. Agricultural crops in Maricopa and Pinal Counties.

		Maricopa			Pinal		
BELD Code	**Crop**	**BELD**	**USDA 05**	**USDA 04**	**BELD**	**USDA 05**	**USDA 04**
28	Misc	39%		13%	34%		3%
25	Cotton	38%	27%	26%	52%	57%	53%
27	Hay	13%	55%	43%	5%	28%	24%
38	Wheat	5%	9%	9%	4%	8%	12%
23	Barley	3%	8%	8%	2%	5%	7%
24	Corn	1%	1%	0%	0%	3%	1%
32	Potatoes	1%			0%		
35	Sorghum	1%			1%		
29	Oats	0%			0%		
26	Grass	0%			0%		

The current version of the RMC dust model includes default crop calendars based on crops defined in the BELD database. These data were reviewed for the study area and determined to be acceptable as is. Table 3-7 presents these data, as currently implemented in the model.

Table 3-7. Default agricultural crop calendar for Maricopa and Pinal Counties.

Plant/Harvest Dates by CMZ and BELD category (current data in WBD model "crop_plt_dates_US.txt")								
CMZ	**BELD3**	**Crop**	**Plant_Spr**	**Harv_Spr**	**Plant_Fall**	**Harv_Fall**	**Cano_Spr**	**Cano_Fall**
30	22	Alfalfa	Apr	Mar	-	-	ALF01	0
30	23	Barley	May	Aug	-	-	BAR01	0
30	24	Corn	May	Oct	-	-	COR01	0
30	25	Cotton	May	Nov	-	-	COT02	0
30	26	Grass	Apr	Apr	-	-	GRA01	0
30	27	Hay	Apr	Mar	-	-	HAY01	0
30	28	Misc	-	-	-	-	0	0
30	29	Oats	May	Aug	-	-	OAT01	0
30	32	Potatoes	May	Oct	-	-	POT01	0
30	35	Sorghum	May	Oct	-	-	SOR01	0
30	38	Wheat	-	-	Oct	Sep	0	WHE03
33	22	Alfalfa	Apr	Mar	-	-	ALF01	0
33	23	Barley	-	-	Dec	Jun	0	BAR03
33	24	Corn	Apr	Oct	-	-	COR01	0
33	25	Cotton	Apr	Oct	-	-	COT02	0
33	26	Grass	Apr	Apr	-	-	GRA01	0
33	27	Hay	Apr	Mar	-	-	HAY01	0
33	28	Misc	-	-	-	-	0	0
33	29	Oats	Mar	Sep	Dec	Aug	OAT01	OAT03
33	32	Potatoes	Jan	Jun	-	-	POT01	0
33	35	Sorghum	May	Nov	-	-	SOR01	0
33	38	Wheat	-	-	Dec	Jun	0	WHE03
Most of Maricopa and Pinal counties in CMZ 33; Only NE corner of each in CMZ 30								

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4. MODEL APPLICATION

The application of the WRAP RMC windblown fugitive dust emission model for the Phoenix PM10 non-attainment area and surrounding areas is described in this section.

Spatial Resolution and Modeling Domain

As noted previously, the RMC windblown dust model is designed to estimate fugitive windblown dust emissions for regional air quality modeling. The outputs of the model are gridded, hourly estimates of PM10 and PM2.5 dust emissions. For the current application to Marciopa and Pinal counties, the modeling domain was defined based on a 12-km grid encompassing the entirety of Maricopa and Pinal counties in Arizona. The modeling domain was displayed ion Figure 1-1 of this report.

Input datasets include soil characteristics, landuse/landcover data and gridded wind speed fields. Meteorological data were developed at a spatial resolution of 12-km, as described in the previous section. Although the winds are modeled at 12-km resolution, the modeling system is designed to allow higher resolution surface characteristics data. Soil characteristics, soil texture and soil groups, were processed at 4-km using the ArcINFO GIS software. In addition, LULC data were gridded at 4-km spatial resolution. However, higher spatial resolution of the LULC data is possible through the inclusion of the percentages of land, by LULC category, within each 4-klm model grid cell.

Temporal Period and Resolution

Windblown dust modeling for the Phoenix PM10 NAA, and all of Maricopa and Pinal counties was conducted for the entire calendar year 2005. The temporal duration of the modeling was determined by the availability of the meteorological data provided by project sponsors.

The model is run on an hourly temporal resolution and provides hourly outputs of coarse (PM10 – PM2.5) and fine (PM2.5) particulate matter dust emissions. The results are subsequently aggregated to annual emissions estimates for reporting purposes.

Model Outputs

As previously noted, the model provides hourly gridded estimates of windblown fugitive PM dust emissions. The output data files are formatted for input to regional air quality models, in particular, the CMAQ model. Using GIS tools, these gridded emission estimates are summarized on the county-level as well as at the non-attainment area level, for reporting. Model outputs were obtained with and without the application of fugitive dust transport fractions, described below.

Fugitive Dust Transport Fractions

The concept of fugitive dust transport fractions has been considered and refined in recent years. It has been recognized that, due to various mechanisms, dust particles are subject to near source removal. These mechanisms include gravitational settling, particle deposition to the ground and impaction and removal due to particle capture by the surrounding vegetation canopy and other physical structures. The EPA for many years had promoted the “divide by four” approach for reducing the emission from fugitive dust sources to account for these processes. The idea is that only a limited amount of the dust emitted by a particular source is transported significantly to affect the total available emissions in the atmosphere for air quality grid modeling.

Recent research has shown that the amount of fugitive dust captured in the surrounding canopy or on physical structures can be related to the physical characteristics of the land surface, i.e., land use/land cover. The EPA recently developed county-level transport fractions for use in emissions inventory development for air quality modeling (Pace, 2003; 2005). The county-level transport fractions were based on the percentage of land use in each county derived from the BELD3 LULC database. The transport fractions were calculated as a weighted sum of landuse-specific fractions for each landuse type.

Within the wind blown dust model, rather than applying county-level fractions, landuse-dependent transport fractions were calculated based on the gridded landuse data used in the estimation methodology. The fractions used for each of the relevant land use types are presented in Table 4-1. Note that the inclusion of the transport fractions should only be considered in situations where the results of the model are to be used in grid-based air quality modeling studies. For inventory reporting requirements and SIP development, the emissions should be developed and reported without the application of the transport fractions. For the current project, model outputs were developed without the application of transport fractions.

Table 4-1. Transport fractions as a function of landuse.

LULC	Original Transport Fractions	Revised Transport Fractions
Barren & Water	0.97	1.00
Agricultural	0.85	0.75
Grasses	0.70	0.75
Scrubland & Sparsely Wooded (Shrublands)	0.60	0.75
Urban	0.30	0.00
Forested	0.30	0.00

Specific Revisions for Maricopa and Pinal Counties

As noted previously, the amount disturbance of the vacant lands for which emissions from wind erosion are to be estimated will have a direct impact on the magnitude of those emissions. In the default configuration of the model, all lands are assumed to be undisturbed and have stable soil characteristics. The primary reason for this assumption was directly related to the lack of detailed information available in the regional-scale data sets used in previous applications. However, for small-scale applications and/or where more detailed data is available, this assumption can be relaxed.

In the case of Maricopa and Pinal counties, the disturbance levels of the vacant land parcels were revised to reflect a better understanding of the local landscapes, as well as to reflect various control measures (in the case of vacant lots and construction sites) and seasonal variations in disposition of agricultural lands (i.e., increased disturbance levels of agricultural lands prior to planting and post-harvest).

Based on consultation with the project sponsors, the percentage of disturbed acreage for each of the individual landuse types within the MAG database were revised. The percent of disturbed acreage for each LU type is presented in Table 4-2, which lists only those landuse categories available in the MAG database. Outside of the Phoenix PM10 nonattainment area where the Southwest GAP database is used, it was assumed that 30% of all barren lands were disturbed, while 8% of all shrublands were assumed disturbed. Table 4-2 also presents the assignment of each landuse category to the 8 general land categories for aggregation and reporting of modeling results. Note that the water landuse category has been re-assigned to dust code 7 (barren land) to reflect the fact that, within the MAG database, these regions are essentially alluvial fans along and dry riverbeds and washes.

The treatment of agricultural lands was further refined to reflect varying disturbance levels of the lands based on crop-specific tilling and harvesting schedules. The primary crops considered for this treatment include barley, corn, cotton and wheat. Based on the crop calendars for these crops, soil disturbance levels where assigned for each month. In general, during tilling activities, 100% of the crop-specific agricultural lands were assumed disturbed. The disturbance levels during harvesting varied by crop and month. During the growing season, the default undisturbed soil assumption is applied. Note that during the growing season, reductions to the estimated windblown dust emissions for agricultural lands are applied based on the growth of crop canopy. Table 4-3 presents the assumed soil disturbance percentages by crop and month.

Disturbed land surfaces have the effect of reducing the threshold surface friction velocities required to initiate wind erosion. Based on a review of studies found in the literature (see Tables 2-1 and 2-2) and from various sensitivity scenarios performed for the WRAP during model development, assumed percentage reductions in the threshold friction velocities were applied for disturbed vacant lands. In the present application, for disturbed shrublands, the threshold friction velocities were assumed to be 50% of the undisturbed values, while for disturbed barren lands the threshold friction velocities were assumed to be 27% of the undisturbed value.

Table 4-2. Revised disturbance assumptions for MAG Landuse/Landcover classifications.

LU_CODE	Model Output category	Description	Dust Code	Areal % Disturbance	Z0 (cm)
100	DEVELOPED	General Residential - Residential where no	1	0.00%	100
110	DEVELOPED	Rural Residential - <= 1/5 du per acre	1	0.00%	100
120	DEVELOPED	Estate Residential - 1/5 du per acre to 1	1	0.00%	100
130	DEVELOPED	Large Lot Residential (SF) - 1 du per acre	1	0.00%	100
140	DEVELOPED	Medium Lot Residential (SF) - 2-4 du per a	1	0.00%	100
150	DEVELOPED	Small Lot Residential (SF) - 4-6 du per ac	1	0.00%	100
160	DEVELOPED	Very Small Lot Residential (SF) - >6 du p	1	0.00%	100
161	DEVELOPED	Very Small Lot Res (SF-Mobile Homes) - Mob	1	0.00%	100
170	DEVELOPED	Medium Density Residential (MF) - 5-10 du	1	0.00%	100
180	DEVELOPED	High Density Residential (MF) - 10-15 du p	1	0.00%	100
190	DEVELOPED	Very High Density Residential (MF) - > 15	1	0.00%	100
198	DEVELOPED	Parking structures serving Residential - P	1	0.00%	100
199	DEVELOPED	Parking lots serving Residential - Parking	1	0.00%	100

LU_CODE	Model Output category	Description	Dust Code	Areal % Disturbance	Z0 (cm)
200	DEVELOPED	General Commercial - Commercial where no d	1	0.00%	100
201	DEVELOPED	Very Low Density Commercial - Amusement fa	1	0.00%	100
202	DEVELOPED	Low Density Commercial - Movie Theatres	1	0.00%	100
203	DEVELOPED	Greenhouse Commercial - Nurseries	1	0.00%	100
210	DEVELOPED	Specialty Commercial - <=50	1	0.00%	100
220	DEVELOPED	Neighborhood Commercial - 50	1	0.00%	100
230	DEVELOPED	Community Commercial - 100	1	0.00%	100
240	DEVELOPED	Regional Commercial - 500	1	0.00%	100
250	DEVELOPED	Super-Regional Commercial - >= 1	1	0.00%	100
298	DEVELOPED	Parking structures serving Commercial - Pa	1	0.00%	100
299	DEVELOPED	Parking lots serving Commercial - Parking	1	0.00%	100
300	DEVELOPED	General Industrial - Industrial where no d	1	0.00%	100
310	DEVELOPED	Warehouse/Distribution Centers -	1	0.00%	100
320	DEVELOPED	Industrial -	1	0.00%	100
398	DEVELOPED	Parking structures serving Industrial - Pa	1	0.00%	100
399	DEVELOPED	Parking lots serving Industrial - Parking	1	0.00%	100
400	DEVELOPED	Office General - Office where no detail av	1	0.00%	100
410	DEVELOPED	Office Low Rise - 1-4 stories	1	0.00%	100
420	DEVELOPED	Office Mid Rise - 5-12 stories	1	0.00%	100
430	DEVELOPED	Office High Rise - 13 stories or more	1	0.00%	100
498	DEVELOPED	Parking structures serving Office - Parkin	1	0.00%	100
499	DEVELOPED	Parking lots serving Office - Parking lots	1	0.00%	100
500	DEVELOPED	General Employment - Employment where no d	1	0.00%	100
510	DEVELOPED	Tourist and Visitor Accommodations - Hote	1	0.00%	100
511	DEVELOPED	Motels - Motels	1	0.00%	100
512	DEVELOPED	Hotels - Hotels	1	0.00%	100
513	DEVELOPED	Resorts - Resorts	1	0.00%	100
520	DEVELOPED	Educational - Public schools	1	0.00%	100
521	DEVELOPED	Schools (K-12 grade) - Schools	1	0.00%	100
522	DEVELOPED	Post High School Institutions - Including	1	0.00%	100
523	DEVELOPED	Arizona State University - ASU Main and Ex	1	0.00%	100
524	DEVELOPED	Dormitories - Dormitories associated with	1	0.00%	100
525	DEVELOPED	Preschool/Daycare facilities - Preschool/D	1	0.00%	100
530	DEVELOPED	Institutional - Includes hospitals	1	0.00%	100
531	DEVELOPED	Medical Institutions - Hospitals/Medical C	1	0.00%	100
532	DEVELOPED	Religious Institutions - Churches/Religiou	1	0.00%	100
533	DEVELOPED	Nursing Homes - Nursing Homes (Group Quart	1	0.00%	100
534	DEVELOPED	Assisted Care Facilities - Assisted Care F	1	0.00%	100
540	DEVELOPED	Cemeteries -	1	0.00%	100
550	DEVELOPED	Public Facilities - Includes community ce	1	0.00%	100
551	DEVELOPED	Public Offices - Includes city halls	1	0.00%	100
552	DEVELOPED	Public Services - Includes community cent	1	0.00%	100
553	DEVELOPED	Large Public Facilities - Includes power	1	0.00%	100
554	DEVELOPED	Military - Military Use	1	0.00%	100
555	DEVELOPED	Limited Use Public Facilities - Very small	1	0.00%	100
560	DEVELOPED	Special Events - Includes stadiums	1	0.00%	100
570	DEVELOPED	Other Employment (low) - Proving grounds	1	0.00%	100
571	OTHER	Landfill - Landfill	7	30.00%	0.002

LU_CODE	Model Output category	Description	Dust Code	Areal % Disturbance	Z0 (cm)
572	OTHER	Sand and Gravel - Sand and Gravel	7	30.00%	0.002
573	OTHER	Proving Grounds - Proving Grounds	7	30.00%	0.002
574	OTHER	Mining - Mining	7	30.00%	0.002
580	DEVELOPED	Other Employment (medium) -	1	0.00%	100
590	DEVELOPED	Other Employment (high) -	1	0.00%	100
598	DEVELOPED	Parking structures serving Facilities/Emp -	1	0.00%	100
599	DEVELOPED	Parking lots serving Facilities/Employment -	1	0.00%	100
600	DEVELOPED	General Transportation - Transportation wh	1	0.00%	100
610	DEVELOPED	Transportation - Includes railroads	1	0.00%	100
611	DEVELOPED	Parking Lots - Parking Lots	1	0.00%	100
612	DEVELOPED	Parking Structures - Parking Structures	1	0.00%	100
613	DEVELOPED	Park and Ride lots - Park and Ride lots	1	0.00%	100
614	DEVELOPED	Transit Center - Transit Center	1	0.00%	100
620	DEVELOPED	Airports - Includes public use airports	1	0.00%	100
621	DEVELOPED	Sky Harbor Airport - Sky Harbor Airport	1	0.00%	100
700	VACANT	General Open Space - Open Space where no d	7	30.00%	0.002
710	VACANT	Active Open Space - Includes parks	7	30.00%	0.002
720	VACANT	Golf courses -	4	0.00%	0.1
730	VACANT	Passive Open Space - Includes mountain pre	7	30.00%	0.002
731	VACANT	Restricted Open Space - Restricted Open Sp	7	30.00%	0.002
740	WATER	Water -	7	0.00%	0.002
750	AGRICULTURE	Agriculture -	3	70.00%	0.015
800	DEVELOPED	Multiple Use General - Multiple Use where	1	0.00%	100
798	DEVELOPED	Parking structures serving Open Space - Pa	1	0.00%	100
799	DEVELOPED	Parking lots serving Open Space - Parking	7	30.00%	0.002
810	DEVELOPED	Business Park - Includes enclosed industr	1	0.00%	100
820	DEVELOPED	Mixed Use - Jurisdiction defined	1	0.00%	100
821	DEVELOPED	Mixed Use/Indian Community - Mixed Use/Ind	1	0.00%	100
830	DEVELOPED	Planned Developments -	1	0.00%	100
898	DEVELOPED	Parking structures serving Multiple Use -	1	0.00%	100
899	DEVELOPED	Parking lots serving Multiple Use - Parkin	1	0.00%	100
900	VACANT	Vacant (existing land use database only) -	7	30.00%	0.002
910	RESIDENTIAL CONSTRUCTION	Developing Residential - Residential Under	7	75.00%	0.002
920	COMMERCIAL CONSTRUCTION	Developing Commercial - Commercial Under C	7	75.00%	0.002
930	COMMERCIAL CONSTRUCTION	Developing Industrial - Industrial Under C	7	75.00%	0.002
940	COMMERCIAL CONSTRUCTION	Developing Office - Office Under Construct	7	75.00%	0.002
950	COMMERCIAL CONSTRUCTION	Developing Public/Other Employment - Emplo	7	75.00%	0.002
960	TRANSPORTATION CONSTRUCTION	Developing Transportation - Transportation	7	75.00%	0.002
970	VACANT	Developing Open Space - Developing Open Sp	7	30.00%	0.002
980	COMMERCIAL CONSTRUCTION	Developing Multiple Use - Multiple Use Und	7	30.00%	0.002
999	DEVELOPED	Salvage/Unknown - Evaluate on an individua	1	0.00%	100

Table 4-3. Monthly, crop-specific soil disturbance percentages.

Month	Corn	Cotton	Barley	Wheat
January	100	100	-[1]	-
February	100	100	-	-
March	100	100	-	-
April	-	100	100	-
May	-	-	100	-
June	-	-	-	10
July	30	-	-	-
August	-	-	10	-
September	-	-	-	-
October	-	80	-	-
November	-	-	-	100
December	-	-	-	100

[1] (–) denotes no revisions to default disturbance levels

5. MODELING RESULTS

The results of the windblown PM10 dust emission modeling is presented in this section. The emission estimation methodology and required input data were described in Section 2 and Section 3 of this report. Specific revisions to the data and/or model implementation for the Phoenix PM10 Non-Attainment Area, as well as the entirety of Maricopa and Pinal counties, were discussed in Section 4.

Preliminary Model Simulations

A number of preliminary simulations were performed prior to finalizing the various inputs and assumptions associated with the development of emission estimates for windblown fugitive PM dust. These initial model simulations were performed with the assumed landuse specific soil disturbance percentages presented in Table 4-2. These results provide the base default estimates upon which the specific agricultural adjustments and revisions were built.

Preliminary default results of the windblown model for 2005 are presented in Tables 5-1 and 5-2. Table 5-1 presents the modeled monthly 2005 windblown PM10 dust emissions for the Phoenix PM10 Non-Attainment Area for each of the 8 aggregated landuse types defined in Table 4-2. Note that while nearly one third of Maricopa County is within the Phoenix PM10 NAA, only a very small portion of Pinal County is included in the NAA. Note also that the emission estimates presented in these tables do not include the application of the fugitive dust transport fraction, discussed in the previous section of this report. Thus, these estimates are appropriate for emission inventory reporting purposes and for SIP development efforts.

Monthly 2005 county-level PM10 emission estimates for Maricopa and Pinal Counties are presented in Table 5-2 for each landuse category defined in Table 4-2. As seen, the majority of the windblown dust emissions are from the vacant land and “other” category. Shrublands and grasslands are included within the “other” category, which comprises a significant portion of both Maricopa and Pinal Counties. A relatively small amount of windblown dust is estimated from the agricultural lands in each county. Based on the distribution of the landcover across the domain, and the reductions applied to agricultural lands due to crop canopy and agricultural management practices, these results appear reasonable in light of the various assumptions incorporated in the model.

Figure 5-1 provides a graphical representation of these results. As seen, the estimated dust emissions peak during the spring and summer months reflecting the impact of higher wind speeds and agricultural activity during these time periods. The corresponding results for the entire counties of Maricopa and Pinal are presented in Figure 5-2.

Table 5-1. Preliminary 2005 Monthly PM10 windblown dust emissions for the Phoenix NAA.

Preliminary 2005 PM10 Windblown Dust Emission (tons) -- Phoenix NAA													
Month	Total	Other Agricultural	Comm. Constr.	Res. Constr.	Trans. Constr.	Developed	Vacant	Water (Alluvial)	Other	Barley	Corn	Cotton	Wheat
Jan	**250.6**	1.5	4.3	27.0	0.3	0.0	176.6	17.8	23.1	0.00	0.00	0.00	0.00
Feb	**433.4**	1.4	7.4	45.4	0.5	0.0	310.5	41.7	26.5	0.00	0.00	0.00	0.00
Mar	**709.2**	3.4	11.6	69.5	0.7	0.0	503.2	65.5	55.4	0.00	0.00	0.01	0.00
Apr	**900.1**	6.5	13.9	84.4	0.8	0.0	642.3	84.5	67.5	0.00	0.00	0.02	0.00
May	**897.3**	5.8	13.6	83.8	0.8	0.0	638.4	91.0	64.0	0.00	0.00	0.01	0.00
Jun	**908.3**	2.5	14.3	87.8	0.8	0.0	659.8	101.6	41.4	0.00	0.00	0.00	0.00
Jul	**1,101.7**	4.9	17.0	100.5	1.1	0.0	786.3	114.1	77.7	0.00	0.00	0.02	0.00
Aug	**821.0**	4.4	12.9	75.2	0.9	0.0	586.2	80.0	61.4	0.00	0.00	0.02	0.00
Sep	**507.4**	2.2	7.8	49.0	0.5	0.0	363.5	51.2	33.1	0.00	0.00	0.01	0.00
Oct	**431.2**	2.4	6.6	42.7	0.4	0.0	309.9	44.1	25.1	0.00	0.00	0.01	0.00
Nov	**276.0**	1.3	4.3	30.4	0.3	0.0	201.3	22.3	16.1	0.00	0.00	0.00	0.00
Dec	**141.2**	0.0	2.3	18.3	0.1	0.0	110.0	6.8	3.7	0.00	0.00	0.00	0.00
Annual	**7,377.5**	**36.2**	**116.0**	**713.9**	**7.3**	**0.0**	**5,288.1**	**720.6**	**495.2**	**0.00**	**0.01**	**0.10**	**0.01**

Table 5-2. Preliminary 2005 Monthly PM10 windblown dust emissions for Maricopa and Pinal Counties.

Preliminary 2005 PM10 Windblown Dust Emission (tons) -- County Totals													
Month	Total	Other Agricultural	Comm. Constr.	Res. Constr.	Trans. Constr.	Developed	Vacant	Water (Alluvial)	Other	Barley	Corn	Cotton	Wheat
Jan	**2,917.2**	7.7	4.6	31.1	0.3	0.0	2,003.8	41.4	828.2	0.01	0.00	0.16	0.02
Feb	**3,663.6**	9.6	7.8	51.2	0.5	0.0	2,608.5	71.0	914.9	0.00	0.00	0.06	0.00
Mar	**5,104.0**	22.1	12.0	76.7	0.7	0.0	3,445.6	102.6	1,444.1	0.01	0.01	0.14	0.02
Apr	**6,360.6**	31.5	14.5	93.1	0.8	0.0	4,454.9	131.1	1,634.2	0.03	0.01	0.33	0.05
May	**6,214.0**	26.6	14.2	92.7	0.8	0.0	4,542.7	142.1	1,394.6	0.02	0.01	0.26	0.03
Jun	**6,739.9**	25.1	14.9	96.8	0.8	0.0	4,686.8	154.1	1,761.1	0.01	0.00	0.18	0.02
Jul	**7,938.7**	28.2	17.7	110.2	1.1	0.0	5,203.2	171.3	2,406.7	0.02	0.01	0.42	0.04
Aug	**5,859.8**	22.4	13.3	82.3	0.9	0.0	3,975.7	121.4	1,643.4	0.02	0.01	0.33	0.03
Sep	**4,147.2**	9.7	8.3	55.2	0.5	0.0	3,073.9	88.3	911.2	0.01	0.00	0.13	0.01
Oct	**3,758.5**	13.3	7.0	48.5	0.4	0.0	2,810.2	76.0	803.0	0.01	0.00	0.14	0.02
Nov	**2,625.4**	7.4	4.6	35.1	0.3	0.0	1,993.2	46.6	538.2	0.00	0.00	0.03	0.00
Dec	**1,895.4**	0.9	2.6	22.3	0.1	0.0	1,711.7	29.2	128.7	0.00	0.00	0.00	0.00
Annual	**57,224.3**	**204.5**	**121.3**	**795.0**	**7.3**	**0.0**	**40,510.1**	**1,175.1**	**14,408.4**	**0.13**	**0.05**	**2.18**	**0.26**

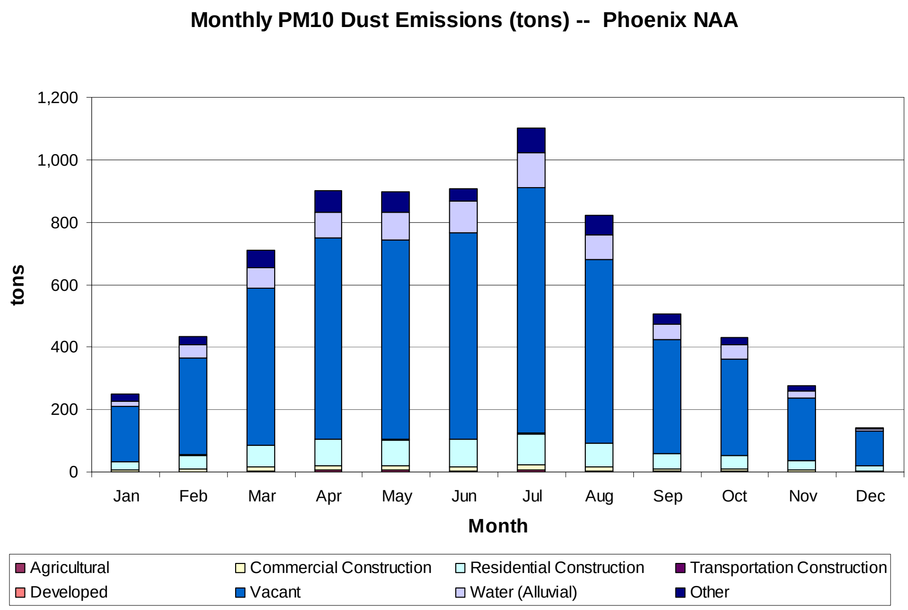

Figure 5-1. Monthly windblown PM10 dust emissions for the Phoenix Nonattainment area.

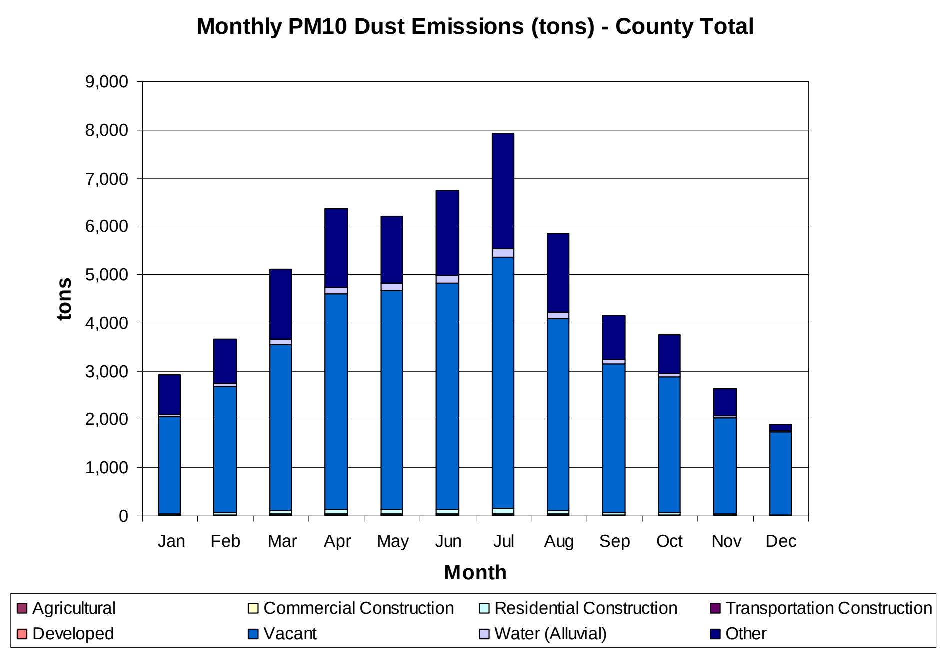

Figure 5-2. Monthly windblown PM10 dust emissions for Maricopa and Pinal Counties.

The spatial distribution of the estimated windblown dust PM emissions are presented in Figure 5-3. Figure 5-3 presents the monthly total PMC (=0.9*PM10) windblown dust emissions for calendar year 2005. Note that these displays do not reflect the monthly, crop-specific revisions to soil disturbance percentages incorporated into the final model simulations, presented below. The dependence on landuse can be seen as the spatial distribution of the estimated emissions corresponds to the distribution of the various landuse types across the domain.

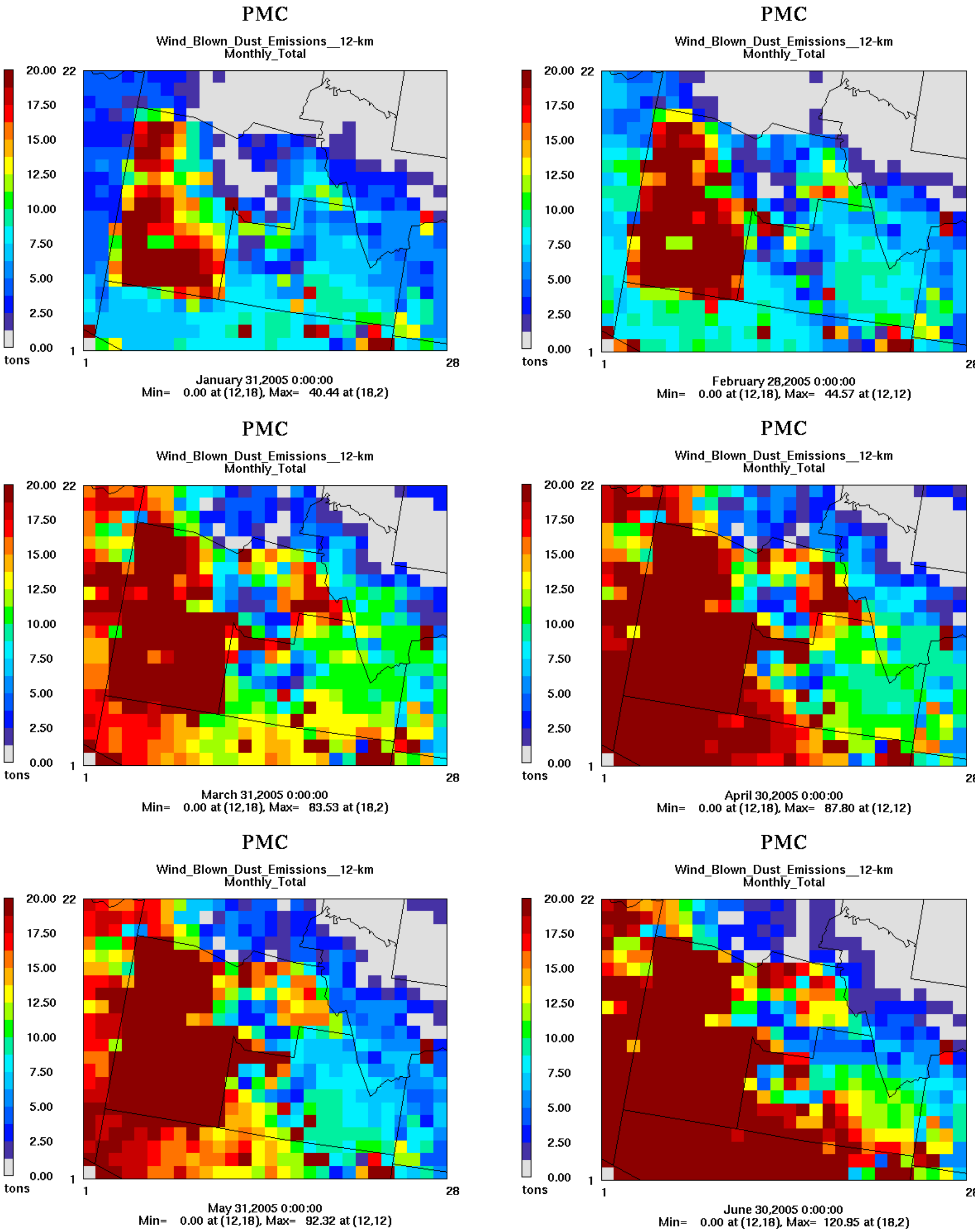

Figure 5-3. Spatial distribution of estimated PMC windblown dust emissions.

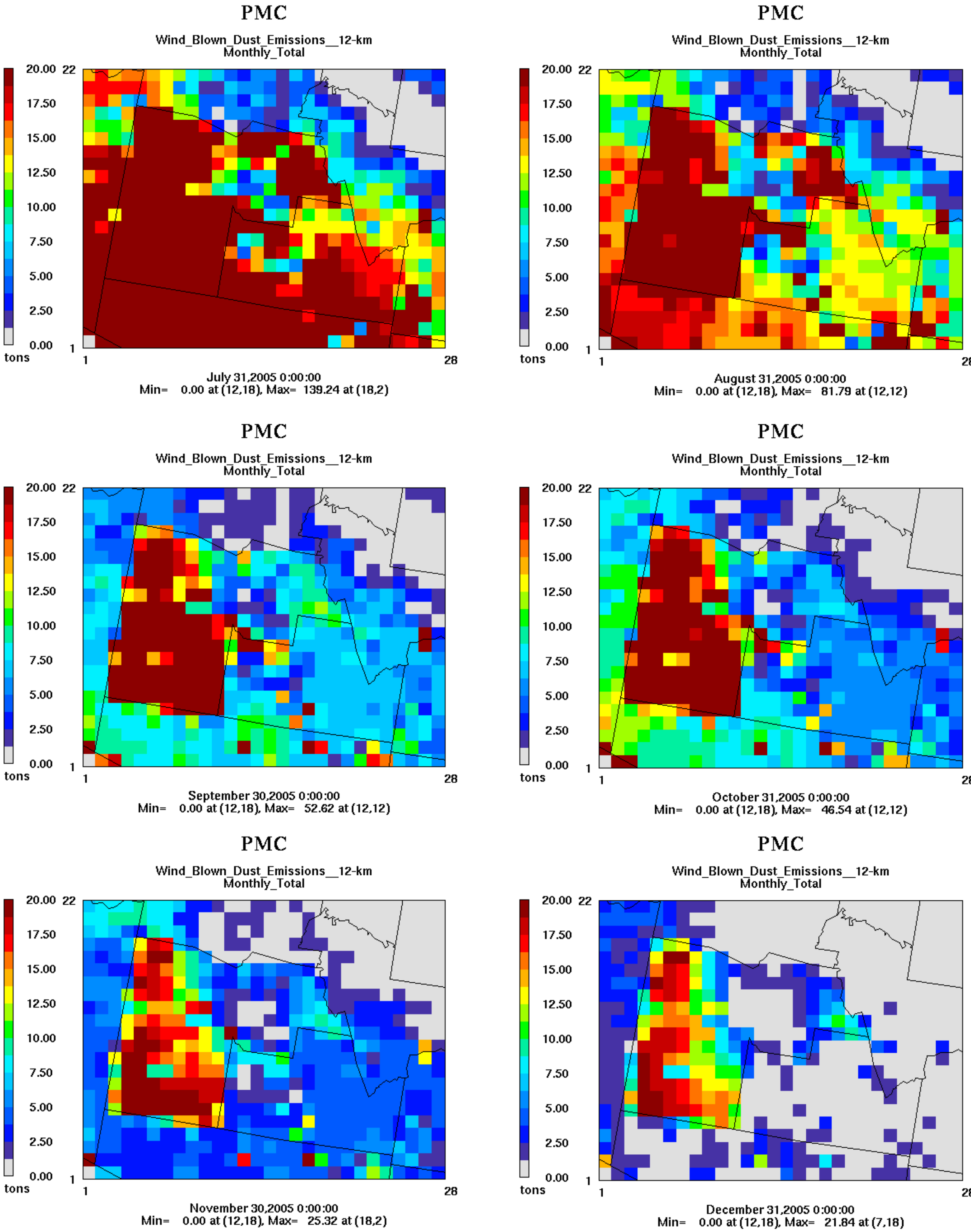

Figure 5-3 (concluded). Spatial distribution of estimated PMC windblown dust emissions.

Final Model Simulation Results

As discussed in Section 4, the final model simulations considered the monthly variation in soil disturbance levels due to agricultural activities through out the year. Table 4-3 presented the assumed monthly disturbance percentages of agricultural lands throughout the Phoenix Non-Attainment Area. These monthly variations were based on the crop calendars for 2005 for Maricopa County. The final windblown dust emission model runs incorporated these disturbance levels within the estimation methodology by reducing the threshold surface friction velocities. For those months were no assumed disturbances are listed in Table 4-3, the results of the preliminary model simulation were substituted. These results reflect the default assumptions of the estimation methodology, i.e., loose undisturbed soils. The results of the final windblown dust model simulation are presented below.

Table 5-3 presents the 2005 annual windblown PM10 dust emissions for the Phoenix Non-Attainment Area by county and landuse category. Table 5-4 presents the corresponding results for the entirety of Maricopa and Pinal Counties. As can be seen, the implementation of the monthly variation of disturbance for agricultural lands has only minor impacts on the estimated emissions. In the final model simulation only the four main crops were considered for variations in disturbance levels. The remaining croplands, approximately 10% ogf the total agricultural lands in the region, were treat4d as miscellaneous crops with the default disturbance treatment of the model. Additionally, only a very small portion of the total land area within the Phoenix NAA is categorized as cropland, thus the effects of these model revisions are minimal.

The corresponding monthly windblown PM10 dust emissions are summarized for the Phoenix NAA and Maricopa/Pinal Counties, by landuse category, in Tables 5-5 and 5-6, respectively. Figures 5-4 and 5-5 present these results graphically.

Table 5-3. 2005 Annual PM10 windblown dust emissions for the Phoenix NAA.

2005 Annual Windblown PM10 Dust Emission in Phoenix NAA (tons)													
County	Total	Other Agricultural	Comm. Constr.	Res. Constr.	Trans. Constr.	Developed	Vacant	Water (Alluvial)	Other	Barley	Corn	Cotton	Wheat
Maricopa	7,284.3	36.1	116.0	712.8	7.3	0.0	5,287.1	720.6	401.3	0.4	0.2	2.3	0.2
Pinal	96.2	0.1	0.0	1.1	0.0	0.0	1.0	0.0	93.8	0.0	0.0	0.0	0.0
Total	**7,380.4**	**36.2**	**116.0**	**713.9**	**7.3**	**0.0**	**5,288.1**	**720.6**	**495.2**	**0.4**	**0.2**	**2.3**	**0.2**

Table 5-4. 2005 Annual PM10 windblown dust emissions for Maricopa and Pinal Counties.

2005 Annual Windblown PM10 Dust Emisisons (tons) - County-wide													
County	Total	Other Agricultural	Comm. Constr.	Res. Constr.	Trans. Constr.	Developed	Vacant	Water (Alluvial)	Other	Barley	Corn	Cotton	Wheat
Maricopa	44,488.8	149.7	121.2	790.7	7.3	0.0	40,468.2	1,175.1	1,766.9	1.1	0.6	7.1	0.9
Pinal	12,769.5	54.7	0.1	4.4	0.0	0.0	41.9	0.0	12,641.4	1.1	0.7	23.9	1.2
Total	**57,258.3**	**204.5**	**121.3**	**795.0**	**7.3**	**0.0**	**40,510.1**	**1,175.1**	**14,408.4**	**2.2**	**1.3**	**31.0**	**2.1**

Table 5-5. 2005 Monthly PM10 windblown dust emissions for the Phoenix NAA.

2005 PM10 Windblown Dust Emission (tons) -- Phoenix NAA													
Month	Total	Other Agricultural	Comm. Constr.	Res. Constr.	Trans. Constr.	Developed	Vacant	Water (Alluvial)	Other	Barley	Corn	Cotton	Wheat
Jan	**250.8**	1.5	4.3	27.0	0.3	0.0	176.6	17.8	23.1	0.00	0.03	0.21	0.00
Feb	**433.9**	1.4	7.4	45.4	0.5	0.0	310.5	41.7	26.5	0.00	0.06	0.36	0.00
Mar	**709.8**	3.4	11.6	69.5	0.7	0.0	503.2	65.5	55.4	0.00	0.08	0.53	0.00
Apr	**900.9**	6.5	13.9	84.4	0.8	0.0	642.3	84.5	67.5	0.19	0.00	0.66	0.00
May	**897.5**	5.8	13.6	83.8	0.8	0.0	638.4	91.0	64.0	0.19	0.00	0.01	0.00
Jun	**908.3**	2.5	14.3	87.8	0.8	0.0	659.8	101.6	41.4	0.00	0.00	0.00	0.03
Jul	**1,101.7**	4.9	17.0	100.5	1.1	0.0	786.3	114.1	77.7	0.00	0.01	0.02	0.00
Aug	**821.0**	4.4	12.9	75.2	0.9	0.0	586.2	80.0	61.4	0.02	0.00	0.02	0.00
Sep	**507.4**	2.2	7.8	49.0	0.5	0.0	363.5	51.2	33.1	0.00	0.00	0.01	0.00
Oct	**431.5**	2.4	6.6	42.7	0.4	0.0	309.9	44.1	25.1	0.00	0.00	0.28	0.00
Nov	**276.3**	1.3	4.3	30.4	0.3	0.0	201.3	22.3	16.1	0.00	0.00	0.19	0.09
Dec	**141.3**	0.0	2.3	18.3	0.1	0.0	110.0	6.8	3.7	0.00	0.00	0.00	0.06
Annual	**7,380.4**	**36.2**	**116.0**	**713.9**	**7.3**	**0.0**	**5,288.1**	**720.6**	**495.2**	**0.40**	**0.18**	**2.29**	**0.19**

Table 5-6. 2005 Monthly PM10 windblown dust emissions for Maricopa and Pinal Counties.

2005 PM10 Windblown Dust Emission (tons) -- County Totals													
Month	Total	Other Agricultural	Comm. Constr.	Res. Constr.	Trans. Constr.	Developed	Vacant	Water (Alluvial)	Other	Barley	Corn	Cotton	Wheat
Jan	**2,921.1**	7.7	4.6	31.1	0.3	0.0	2,003.8	41.4	828.2	0.01	0.28	3.77	0.02
Feb	**3,668.7**	9.6	7.8	51.2	0.5	0.0	2,608.5	71.0	914.9	0.00	0.36	4.81	0.00
Mar	**5,110.7**	22.1	12.0	76.7	0.7	0.0	3,445.6	102.6	1,444.1	0.01	0.47	6.40	0.02
Apr	**6,368.5**	31.5	14.5	93.1	0.8	0.0	4,454.9	131.1	1,634.2	0.98	0.01	7.19	0.05
May	**6,215.0**	26.6	14.2	92.7	0.8	0.0	4,542.7	142.1	1,394.6	1.02	0.01	0.26	0.03
Jun	**6,740.1**	25.1	14.9	96.8	0.8	0.0	4,686.8	154.1	1,761.1	0.01	0.00	0.18	0.21
Jul	**7,938.9**	28.2	17.7	110.2	1.1	0.0	5,203.2	171.3	2,406.7	0.02	0.14	0.42	0.04
Aug	**5,859.9**	22.4	13.3	82.3	0.9	0.0	3,975.7	121.4	1,643.4	0.13	0.01	0.33	0.03
Sep	**4,147.2**	9.7	8.3	55.2	0.5	0.0	3,073.9	88.3	911.2	0.01	0.00	0.13	0.01
Oct	**3,762.3**	13.3	7.0	48.5	0.4	0.0	2,810.2	76.0	803.0	0.01	0.00	3.98	0.02
Nov	**2,629.8**	7.4	4.6	35.1	0.3	0.0	1,993.2	46.6	538.2	0.00	0.00	3.56	0.88
Dec	**1,896.2**	0.9	2.6	22.3	0.1	0.0	1,711.7	29.2	128.7	0.00	0.00	0.00	0.79
Annual	**57,258.3**	**204.5**	**121.3**	**795.0**	**7.3**	**0.0**	**40,510.1**	**1,175.1**	**14,408.4**	**2.21**	**1.29**	**31.03**	**2.11**

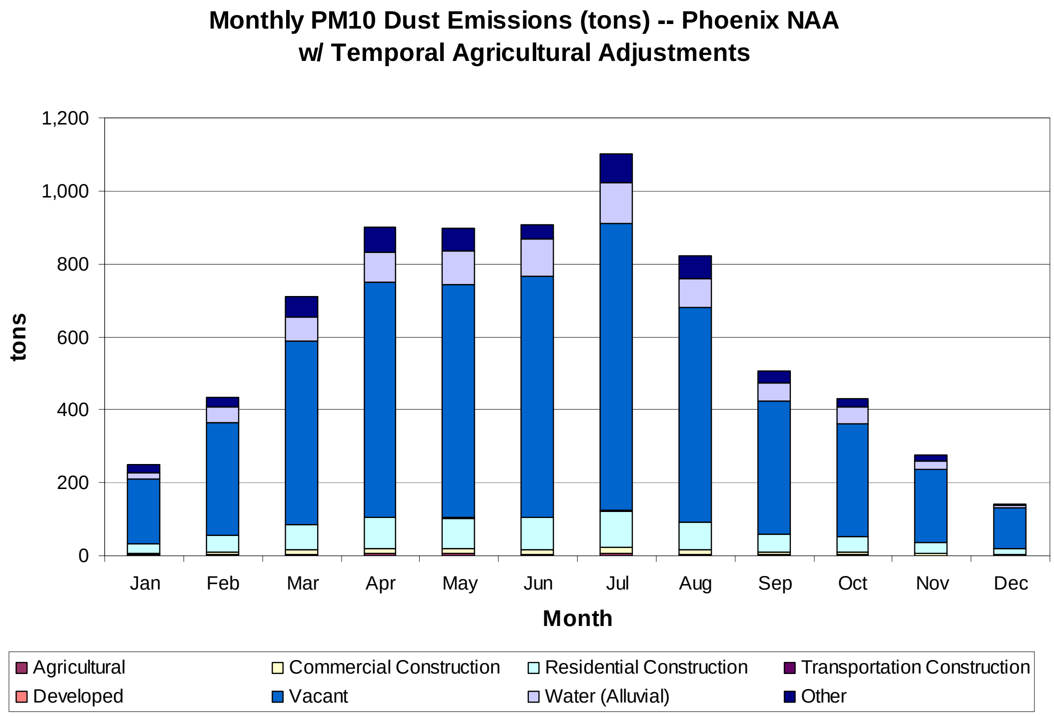

Figure 5-4. Final monthly windblown PM10 dust emissions for the Phoenix NNA.

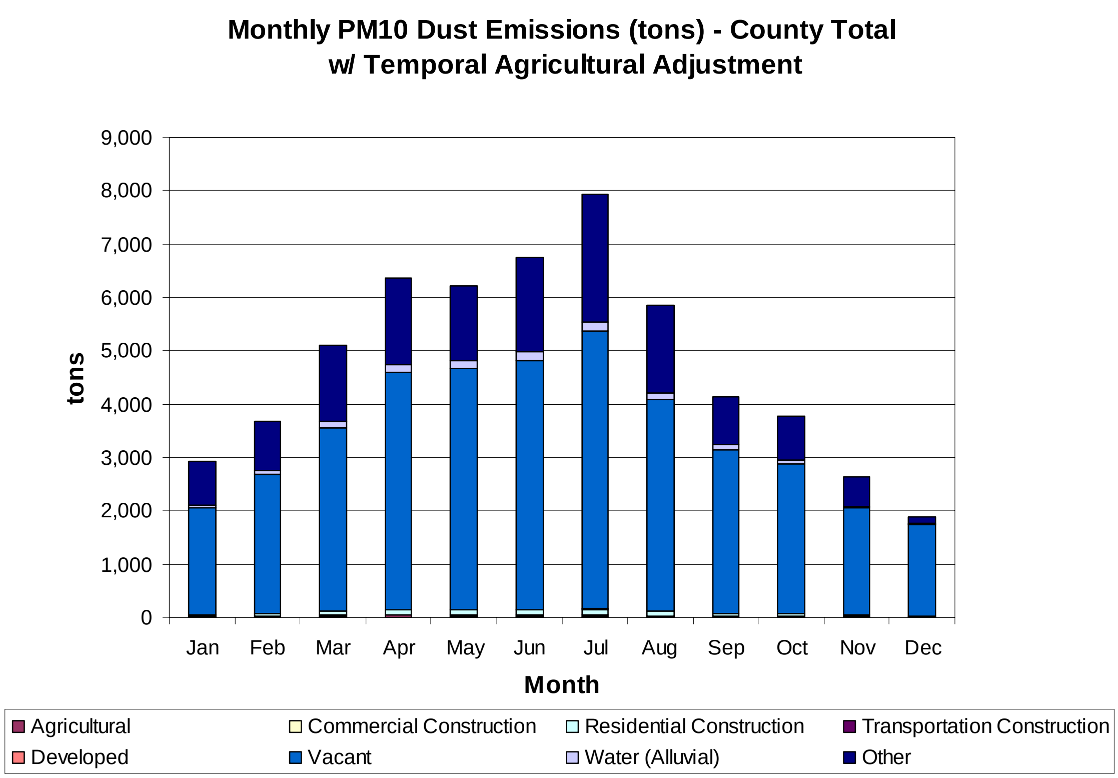

Figure 5-5. Final monthly windblown PM10 dust emissions for Maricopa and Pinal Counties.

Model Sensitivity Simulations

The sensitivity of the model results to variations in meteorology was also investigated as part of the project. For air quality planning and SIP development efforts, databases representative of typical, or average, conditions are often developed based on data from several years. Emission inventories and air quality modeling results obtained using representative conditions allow for a more consistent comparison between baseline future year modeling scenarios.

For the current application, wind speed data from the AZMET database were augmented with observed data archived by the Maricopa County Flood Control District. The hourly wind speed data from each of the monitoring stations were averaged over the 5-year period 2001-2005. Only those monitoring site with a complete five year record were considered. The monitoring station locations are displayed in Figure 5-6. All other input data and modeling assumptions remained unchanged.

The AZMET and Flood Control District monitoring networks provide observed data from different heights above ground level. AZMET station data are obtained at a height of 3 meters, while the Flood Control District monitoring network provides data at a height of 10 meters. Prior to applying the kriging algorithms to these data, the AZMET station data were re-cast to a 10 meter height using a simple power law relation assuming neutral atmospheric conditions. The resulting hourly gridded wind speeds are presented in Figure 5-7 in terms of monthly average wind speeds across the modeling domain.

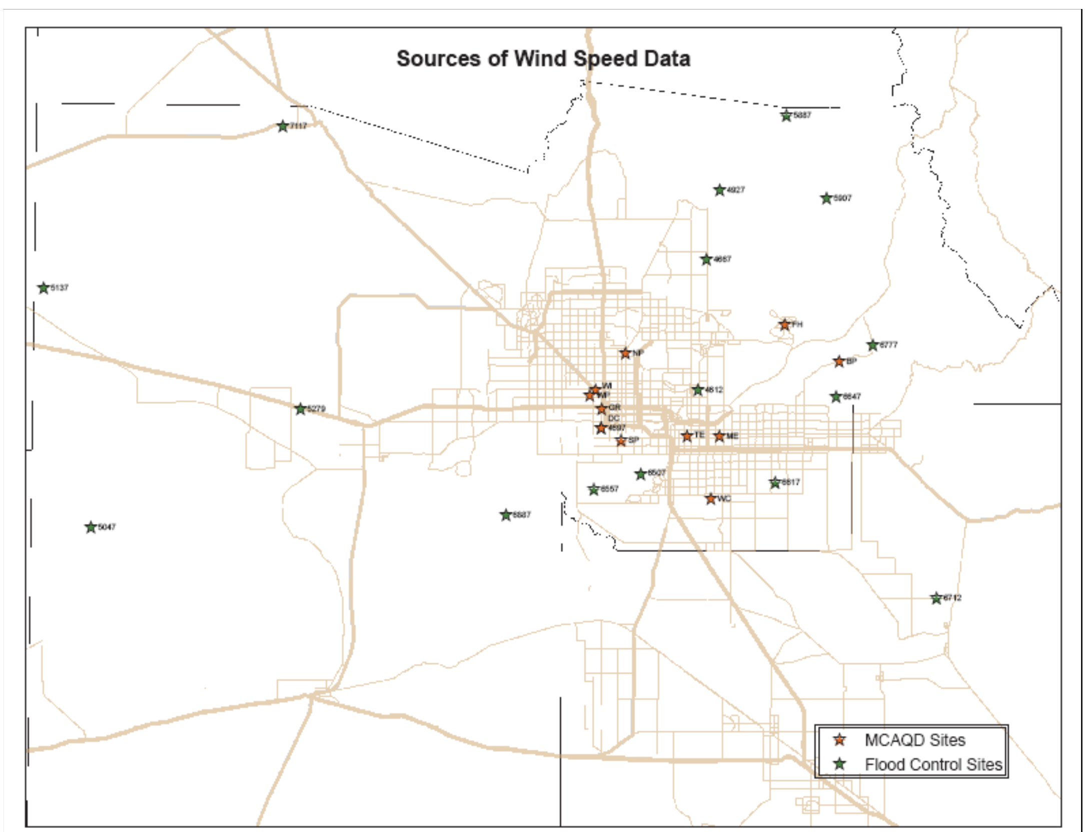

Figure 5-6. Location of meteorological monitoring stations for 5-year average wind speed data.

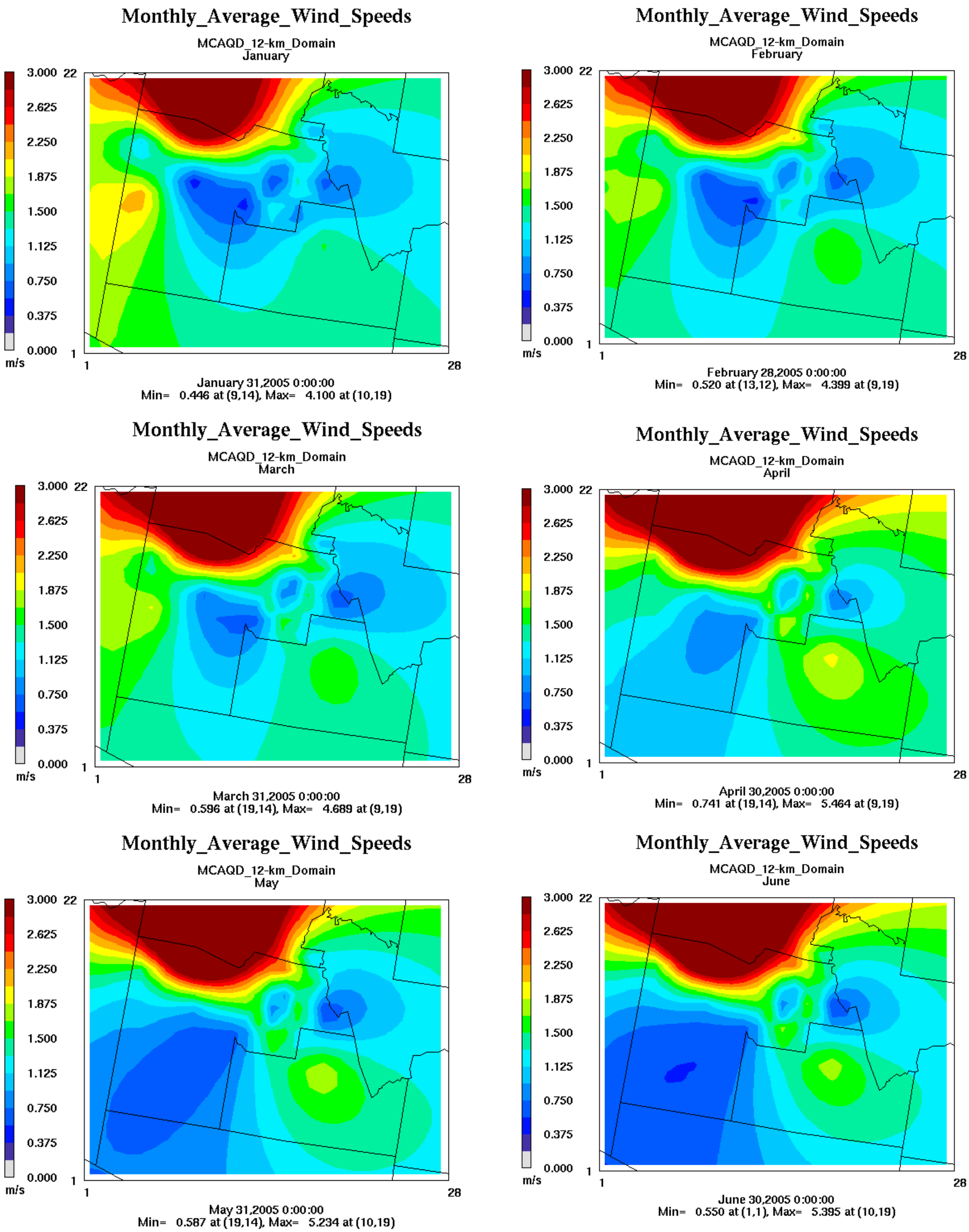

Figure 5-7. Monthly average wind speeds on the 12-km modeling domain. (2001-2005 data)

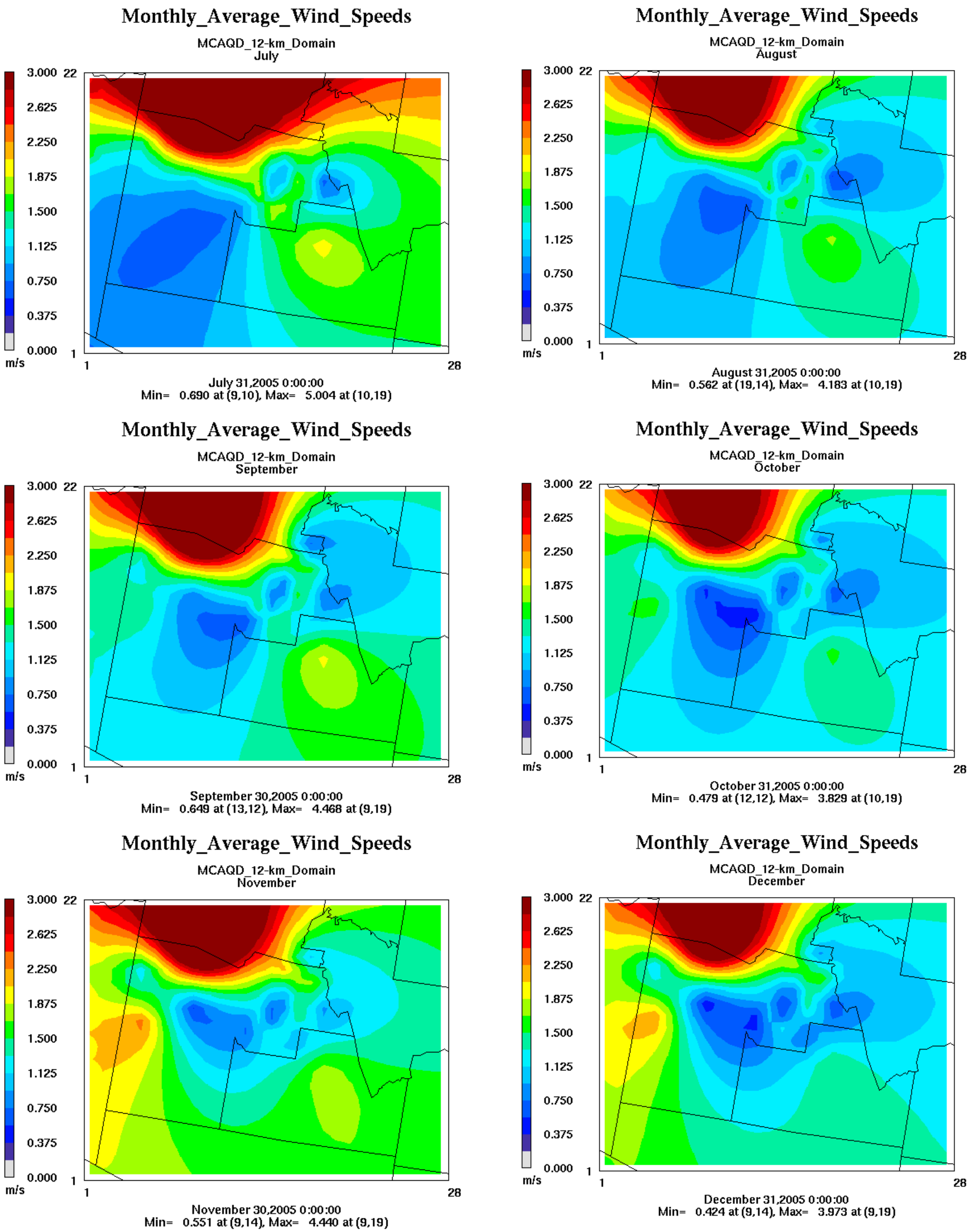

Figure 5-7. (concluded). Monthly average wind speeds on the 12-km modeling domain (2001-2005 data)

The results of the windblown dust model simulation using the 5-year average wind speed data are presented in Tables 5-7 and 5-8. Table 5-7 presents the annual 2005 windblown PM10 dust emissions for the Phoenix Nonattainment area disaggregated into the 8 generalized landuse types defined in Table 4-2. The corresponding results for the entire Maricopa and Pinal Counties are presented in Table 5-8. As seen, the resulting PM10 dust emissions are significantly decreased from those obtained using the 2005 data alone. The large reduction in estimated windblown PM10 dust emissions is directly related to the reduced wind speeds across the modeling domain resulting from the use of 5-year average meteorology.

Table 5-7. 2005 Annual PM10 windblown dust emissions for the Phoenix NAA using 5-year average (2001-2005) wind speed data.

2005 PM10 Dust Emissions (tons)									
Phoenix Non-Attainment Area									
County	Total	Agricultural	Commercial Construction	Residential Construction	Transportation Construction	Developed	Vacant	Water (Aluvial)	Other
Maricopa	2,816	29.5	34.1	218.1	2.2	0.0	2,408.6	91.9	31.8
Pinal	5	0.2	0.0	0.4	0.0	0.0	0.3	0.0	3.7
Total	**2,821**	**30**	**34**	**218**	**2**	**0**	**2,409**	**92**	**36**

Table 5-8. 2005 Annual PM10 windblown dust emissions for Maricopa and Pinal Counties using 5-year average (2001-2005) wind speed data.

2005 PM10 Dust Emissions (tons)									
County Totals									
County	Total	Agricultural	Commercial Construction	Residential Construction	Transportation Construction	Developed	Vacant	Water (Aluvial)	Other
Maricopa	18,405.3	87.0	37.4	253.2	2.2	0.0	17,288.3	163.8	573.4
Pinal	1,977.4	100.1	0.0	1.4	0.0	0.0	11.5	0.0	1,864.3
Total	**20,383**	**187**	**37**	**255**	**2**	**0**	**17,300**	**164**	**2,438**

6. SUMMARY

The WRAP RMC windblown fugitive dust emission model was applied to the Phoenix PM10 Non-Attainment Area to estimate PM10 dust emissions for calendar year 2005. Various improvements to the model input data and assumptions associated with the emission estimation methodology were considered. Summary results of the simulations for Maricopa and Pinal Counties and for the Phoenix PM10 NAA were presented in Section 5.

The modeling domain was defined on a 12-km resolution grid to encompass all of Maricopa and Pinal Counties of Arizona. Model input data were developed from local data as well as regional data sets. Local landuse/landcover data were provided by the Maricopa Association of Governments for use in the project. Landuse data from the Southwest GAP database were used to augment the local landuse data to cover the entire modeling domain. Soils data were developed from a combination of SSURGO and STATSGO databases. The necessary hourly gridded wind fields were derived from AZMET observational datasets using a kriging algorithm. Minor updates to the default agricultural crop information of the model were incorporated for Maricopa County. Assumed disturbance levels of the vacant lands within the modeling domain were also modified for the current application based on knowledge of the local landscapes.

A number of limitations are worth noting with respect to the input data and estimation methodology:

- Threshold surface friction velocities are determined as a function of the aerodynamic surface roughness lengths. In the current implementation, surface roughness lengths are assigned as a function of land types. However, only a limited number of land types are available to characterize vacant lands across the entire domain. A large degree of variation can be found within a given land type which is not being captured by the model due to a lack of detail in the land use data used for the model.

- Although some revisions were incorporated with respect to the soil disturbance of vacant lands, the default implementation of the current model assumes that all soils are loose and undisturbed with no temporal variation of disturbance levels. In addition, the effect that disturbance of soils and vacant lands has on the emission rates of dust due to wind erosion is not well characterized or fully understood.

- The treatment of dust reservoirs is too simplistic in the model. The reservoir characteristics determine the duration of wind blown dust events as well as the effects of precipitation on the erosion potential of exposed surfaces. It has been documented in the literature that depending on the type of soils, a small amount of precipitation can cause a crust to form on the surface effectively preventing dust emissions due to wind erosion. Only after these crusts have been broken does the surface again have the potential to emit dust emissions. These affects can also vary to some degree even for the same types of soils depending on soil moisture content among other factors. The amount of soil available for erosion is also important with respect to determining the duration of emissions during wind events.

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