Appendices – Volume I
Common Background Material

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Appendix A
Air Quality Monitors

ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY MONITORING PROGRAM

Introduction

Arizona Department of Environmental Quality (ADEQ) relies on the data (air quality and meteorological) generated by the monitors in the ADEQ monitoring network to document, flag, and analyze exceptional events that occur throughout Arizona. This paper provides a concise description of the monitoring network operated by ADEQ.

ADEQ Program and Network Description

ADEQ operates ambient air quality equipment for a variety of Federal and State monitoring programs. General information about the monitoring programs ADEQ participates is provided below.

NAAQS Compliance Network

The largest compliance network in Arizona consists of monitoring sites operated for the purpose of demonstrating compliance with the National Ambient Air Quality Standards (NAAQS) for the criteria pollutants: carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), particulate matter (PM_{10} and $PM_{2.5}$), and lead (Pb). The criteria pollutants are measured using instruments that have been certified by the EPA as Federal Reference Methods (FRM) or Federal Equivalent Methods (FEM). 40 CFR Part 58 specifies the minimum requirements that these monitors must meet to determine NAAQS compliance.

State Implementation Plan (SIP) and Maintenance Area Network

ADEQ maintains several air monitoring sites for the purpose of tracking compliance in areas that are currently not attaining one or more of the NAAQS and in areas where the NAAQS has been met, but ongoing demonstration of compliance is required. Monitoring requirements for these areas are described in their individual state implementation plans (SIPs).

Source Oriented Network

Historically, ADEQ has required several of the major point sources in the State to conduct ambient monitoring for criteria pollutants, primarily PM_{10} and SO_2, in and around specific facilities. Sources located near some Class I areas are required to collect particulate data to assess impacts on visibility. These monitors constitute a subset of the compliance monitoring network described above.

NCore Network

EPA describes the nationwide NCore network composed of approximately 70 urban and 20 rural sites as a multipollutant network that integrates several advanced measurement systems for particles, pollutant gases, and meteorology. Some of the missions of the NCore network are:

- Tracking long-term trends of criteria and non-criteria pollutants;
- Support for long-term health assessments that contribute to ongoing reviews of the NAAQS;
- Support to scientific studies ranging across technological, health, and atmospheric process disciplines; and
- Support to ecosystem assessments recognizing that national air quality networks benefit ecosystem assessments and, in turn, benefit from data specifically designed to address ecosystem analyses.

Meteorological Network

ADEQ collects meteorological data at sites throughout the State to support the analysis of pollutant data and to provide support for exceptional event reporting. Meteorological measurements are also required for the NCore and PAMS networks.

Photochemical Assessment Monitoring Stations (PAMS)

Revisions to 40 CFR 58 (1993) required states to establish PAMS as part of their SIP monitoring networks in O_3 nonattainment areas classified as serious, severe, or extreme. The principal reasons for requiring the collection of additional ambient air pollutant and meteorological data are the widespread nonattainment of the O_3 NAAQS and the need for a more comprehensive air quality database for O_3 and its precursors. ADEQ operates two PAMS sites, JLG Supersite and Queen Valley, to represent the Phoenix metropolitan area.

National Air Toxics Trend Sites (NATTS)

The NATTS network was designed to monitor and record the concentrations of certain air toxics on a national scale. Data from EPA's national monitoring activities are used to estimate national average concentrations for these air toxics compounds and to detect trends. Using this information, EPA, states, and local agencies can estimate changes in the risks of human exposure. The ADEQ JLG Supersite is the designated NATTS site for the Phoenix metropolitan area.

Chemical Speciation Network (CSN)

The CSN was established to meet the regulatory requirements for monitoring speciated $PM_{2.5}$ to determine the chemical composition of these particles. The purpose of the CSN is to determine, over a period of several years, trends in concentration levels of selected ions, metals, carbon species, and organic compounds in $PM_{2.5}$. The program began in 1999 with 54 Speciation Trends Network (STN) sites across the nation located primarily in or near larger Metropolitan Statistical Areas (MSAs). It has increased to 200 sites nationwide. Monitoring at JLG Supersite includes one STN speciation sampler and two IMPROVE samplers as part of the CSN network.

Class I Area Network and IMPROVE Program

Visibility monitoring networks track impairment in specified national parks and wilderness areas. These parks and wilderness areas are called Class I Areas and were designated based on an evaluation required by Congress in the 1977 federal CAA Amendments. Twelve Class I Areas are located in Arizona. EPA initiated the nationally-operated IMPROVE monitoring network in 1987 whose purpose is to characterize broad regional trends and visibility conditions using monitoring data collected in or near Class I Areas across the United States. ADEQ currently operates 11 sites with IMPROVE instrumentation.

AIRNow Reporting

ADEQ currently utilizes three urban nephelometers to approximate and report $PM_{2.5}$ data to the AIRNow Web site to provide near real-time data for public use in the Phoenix metropolitan area. The program is voluntary and was originally intended to fill gaps in the AIRNow network until actual continuous methods were available.

Urban Haze Network

ADEQ operates an urban haze network in the Phoenix and Tucson metropolitan areas and provides funding for operation of the Tucson area network by the Pima Department of Environmental Quality (PDEQ). The purpose of the networks is to provide policymakers and the public with information regarding urban haze levels, track short-term and long-term urban haze trends, assess source contributions to urban haze, and better evaluate the effectiveness of air pollution control strategies on urban haze.

E-BAM Network of PM_{10} Special Purpose Monitors

The current network of E-BAM continuous particulate special purpose monitors is composed of lightweight, portable monitors typically enclosed in self-contained, environmentally sealed containers. E-BAM monitors have been used by many agencies, particularly in the western United Sates, to provide continuous, real-time particulate concentration data that are useful for making informed smoke management decisions related to prescribed burns. E-BAM instruments are used for special purpose monitoring only. They are not classified as FRMs or FEMs and may not be used to demonstrate NAAQS compliance.

ADEQ Monitor Cited in June 4, 2008 Exceptional Events Request

The Yuma Courthouse monitor is located in Yuma, Arizona in Yuma County, approximately 185 miles southwest of downtown Phoenix (see following satellite image). Detailed information on the one ADEQ monitor, cited in ADEQ's Exceptional Event Request for June 4, 2008, is listed in the following table.

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Yuma Courthouse	
Operator: Arizona DEQ	**Operator ID:** 17027

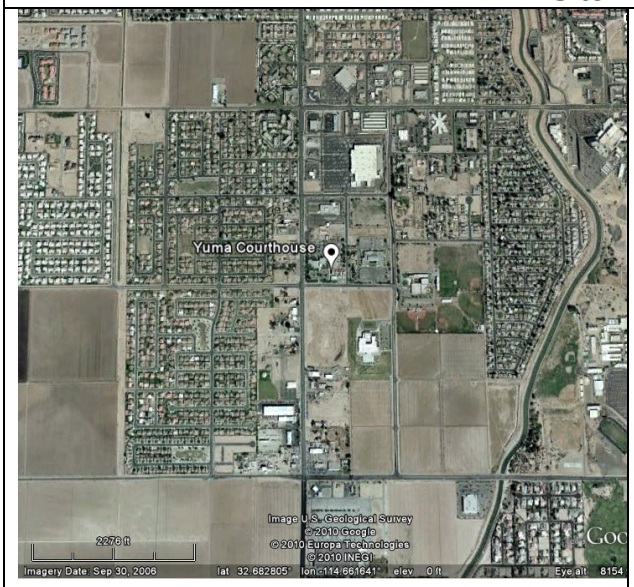
Site Purpose: population exposure

The site is located on the rooftop of the Courthouse. The surrounding area is a mixture of government and private offices, residential areas, and agricultural fields.

Site Information			
AQS ID	04-027-0004		
Address	2440 W. 28th St., Yuma, AZ 85364		
County	Yuma	Groundcover	Rooftop
MSA	Yuma	Latitude	32.6772
Surrounding Area	Residential	Longitude	-114.6489
Distance to road	28 m	Elevation	40 m
Traffic count (ADT)	26,573	Site Established Date	07/30/02

Monitoring Information			
Pollutant/Atmospheric parameter	PM_{10}	PM_{10} collocated	PM_{10}
Network or Program	SLAMS	SLAMS	SLAMS
Spatial Scale	Neighborhood	Neighborhood	Neighborhood
Parameter start date at site	07/30/02	07/30/02	07/30/02

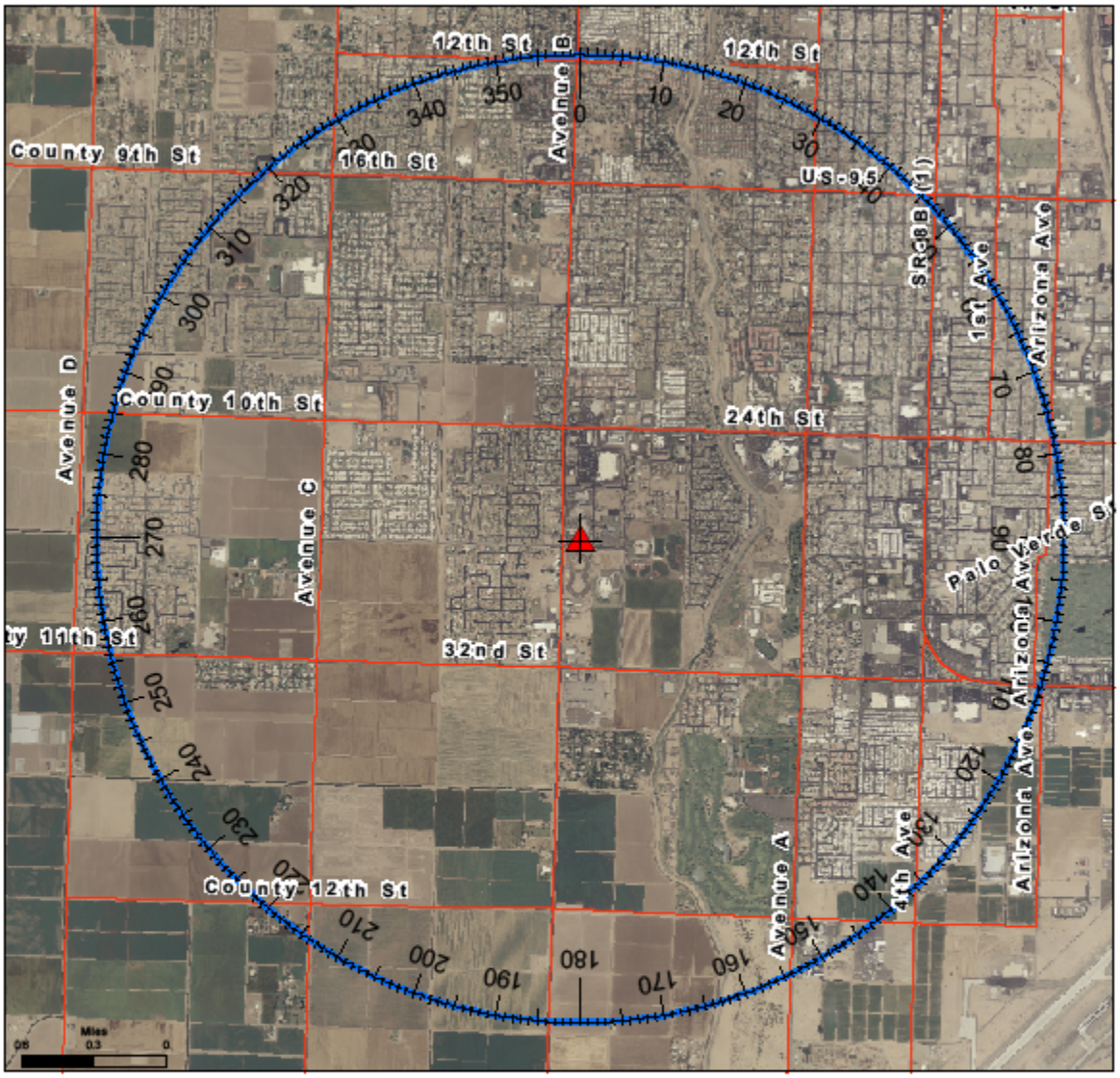
Site Photos



Aerial view of Yuma Courthouse site

Monitor site

Permitted Facilities in 2-Mile Buffer Around Yuma Courthouse PM10 Monitor



2-mile Buffer around Monitoring Site

Yuma Courthouse Monitoring Site

Roadway

Note: Source data not available at this time for Yuma

MARICOPA COUNTY AIR QUALITY DEPARTMENT MONITORING PROGRAM

Introduction

The Arizona Department of Environmental Quality (ADEQ) relies on the data (air quality and meteorological) generated by the monitors in the Maricopa County monitoring network to document, flag, and analyze exceptional events that occur in the Greater Phoenix Area. The following discussion provides a concise description of the monitoring network operated by Maricopa County Air Quality Department (MCAQD).

MCAQD monitors for criteria pollutants by maintaining twenty-four ambient air-monitoring sites throughout Maricopa County. The dates that the sites were established range from 1961 (Central Phoenix) to 2009 (Zuni Hills). Land use patterns around these sites vary from heavy populated urban areas to sparsely populated rural settings. Site elevations range from 845 feet above sea level (Buckeye) to 5,190 feet above sea level at the top of Humboldt Mountain. Not all pollutants are measured at all sites; some sites measure most of the pollutants, while others only measure one or two pollutants.

The following section describes how the Department designs its air monitoring network to obtain representative samples of these air pollutants.

Purpose and Objective of Monitoring Network

The purpose of the ambient air monitoring network is to assess the extent of air pollution, ensure compliance with national legislation, evaluate control options, and provide data for air quality modeling. In general, six basic monitoring objectives and five measuring scales are used to determine the network design (see Table 1 and Table 2). Additional considerations such as availability of power, accessibility to site, security, geographic location, and fiscal and personnel resources are also considered in determining the feasibility of the network design.

Table 1 **Site Monitoring Objectives**
1. Determine highest concentrations expected to occur in the area covered by the network.
2. Determine representative concentrations in areas of high population density.
3. Determine the impact on ambient pollution levels of significant sources or source categories.
4. Determine general background concentration levels.
5. Determine the extent of regional pollutant transport from populated areas, with regards to the secondary standards (such as visibility impairment and effects on vegetation).
6. Determine the welfare-related impacts in more rural and remote areas.

SOURCE: Maricopa County 2009 Air Monitoring Network Review

To establish or evaluate a site, one must link its monitoring objectives to the physical location of the site. This can be done by matching the spatial scale, which represents the sample of air around the monitor where pollutant concentrations are reasonably uniform with the most appropriate monitoring objective. Thus, spatial scale represents the physical dimensions of the air parcel around the monitor, and monitoring objective represents the overall purpose of the monitor. Combining the proper spatial scale with the monitoring objective explains why air monitoring sites are located in particular areas.

Table 2
Spatial Measurement Scales Defined Parameter (radius)

Scale	**Defined parameter (radius)**
Micro Scale	0 to 100 meters
Middle Scale	100 to 500 meters
Neighborhood Scale	0.4 to 4 kilometers
Urban Scale	4 to 50 kilometers
Regional Scale	10 to 100s of kilometers

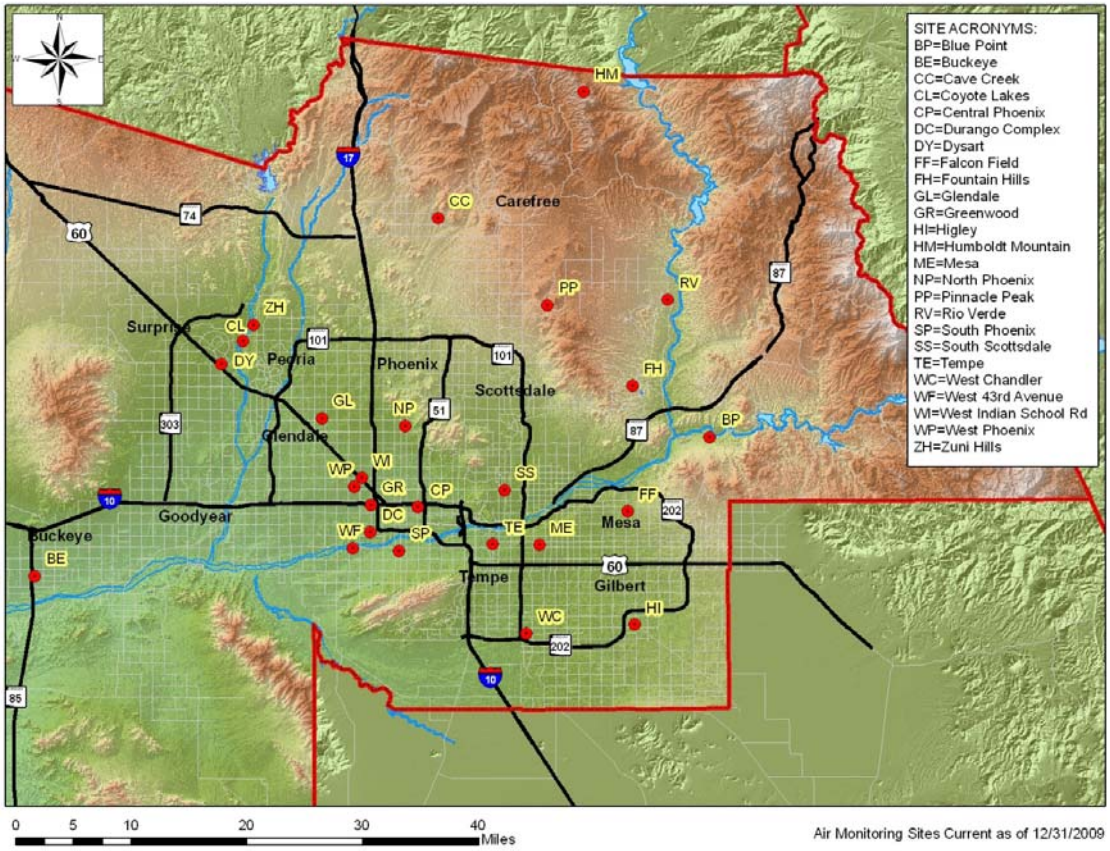
SOURCE: Maricopa County 2009 Air Monitoring Network Review

Since it is physically and fiscally impossible to monitor air quality in every location, representative samples must be obtained. The optimal locations for obtaining these samples are determined by using the monitoring objectives and the spatial measurement scales described above. For example, there might be numerous locations where the highest concentration of PM_{10} may occur. Using these principles, only one or two sites will be established to represent all of the high-concentration areas. The same reasoning can be used for different types of pollutants. This does not mean that the number of monitoring sites is fixed. To the contrary, the network must be dynamic enough to maintain a current representative sample of the air quality.

Overview of the MCAQD's Air Monitoring Network

The Phoenix Metropolitan Area has a population of over 4.2 million people (2009 US census estimate). The EPA has mandated a minimum number of monitors required to properly represent this population. MCAQD has designed its network, using the concepts of scale and objective mentioned previously, to meet and in most cases exceed EPA requirements. Altogether, the Department operated a network of 25 monitoring sites in 2009. The following image details the location of these sites and gives the abbreviation symbols used by Maricopa County. Table 3 and Table 4 give the Air Quality System (AQS) code assigned to each site and reveal which criteria pollutant is monitored at which site along with the monitor designation, respectively. Table 5 gives more specific information about the location of the sites.

Figure 1 Maricopa County Air Monitoring Sites for 2009



SOURCE: Maricopa County 2009 Air Monitoring Network Review

Figure 1. MCAQD Monitoring Network

Table 3
Maricopa County Ambient Air Monitoring Sites for 2009

Site Name	Site Abbr.	AQS Code		Site Name	Site Abbr.	AQS Code
Blue Point	BP	04-013-9701		Mesa	ME	04-013-1003
Buckeye	BE	04-013-4011		North Phoenix	NP	04-013-1004
Cave Creek	CC	04-013-4008		Pinnacle Peak	PP	04-013-2005
Central Phoenix	CP	04-013-3002		Rio Verde	RV	04-013-9706
Coyote Lakes	CL	04-013-4014		South Phoenix	SP	04-013-4003
Durango Complex	DC	04-013-9812		South Scottsdale	SS	04-013-3003
Dysart	DY	04-013-4010		Tempe	TE	04-013-4005
Falcon Field	FF	04-013-1010		West Chandler	WC	04-013-4004
Fountain Hills	FH	04-013-9704		West 43rd Ave.	WF	04-013-4009
Glendale	GL	04-013-2001		W. Indian School Rd.	WI	04-013-0016
Greenwood	GR	04-013-3010		West Phoenix	WP	04-013-0019
Higley	HI	04-013-4006		Zuni Hills	ZH	04-013-4016
Humboldt Mountain	HM	04-013-9508				

SOURCE: Maricopa County 2009 Air Monitoring Network Review

Table 4 Criteria Pollutants Monitored, by Site and Network

Table 4 Criteria Pollutants Monitored, by Site and Network							
Site Abbr.	**Site**	**O_3**	**CO**	**$PM_{2.5}$**	**PM_{10}**	**NO_2**	**SO_2**
BP	Blue Point	SLAMS					
BE	Buckeye	SLAMS	SLAMS		SLAMS	SLAMS	
CC	Cave Creek	SLAMS					
CP	Central Phoenix	SLAMS	SLAMS		SLAMS	SLAMS	SLAMS
CL	Coyote Lakes				SPEC		
DC	Durango Complex			SLAMS	SLAMS		
DY	Dysart	SLAMS	SLAMS		SLAMS		
FF	Falcon Field	SLAMS					
FH	Fountain Hills	SLAMS					
GL	Glendale	SLAMS	SLAMS		SLAMS		
GR	Greenwood		SLAMS		SLAMS	SLAMS	
HI	Higley				SLAMS		
HM	Humboldt Mountain	SLAMS					
ME	Mesa		SLAMS	SLAMS	SLAMS		
NP	North Phoenix	SLAMS	SLAMS		SLAMS		
PP	Pinnacle Peak	SLAMS					
RV	Rio Verde	SLAMS					
SP	South Phoenix	SLAMS	SLAMS	SLAMS	SLAMS		
SS	South Scottsdale	SLAMS	SLAMS		SLAMS	SLAMS	SLAMS
TE	Tempe	SLAMS	SLAMS				
WC	West Chandler	SLAMS	SLAMS		SLAMS		
WF	West 43rd Ave.				SLAMS		
WI	W. Indian School Rd.		SLAMS				
WP	West Phoenix	SLAMS	SLAMS	SLAMS	SLAMS	SLAMS	SLAMS
ZH	Zuni Hills				SPEC		

SOURCE: Maricopa County 2009 Air Monitoring Network Review

Table 5 Site Locations				
Site	**AQS Code**	**Latitude**	**Longitude**	**Site Location**
BP	04-013-9702	33.54549	-111.60925	Usery Pass & Bush Highway
BE	04-013-4001	33.37005	-112.62070	MC85 & HWY 85
CC	04-013-4008	33.82169	-112.01739	32nd St. & Carefree Highway
CP	04-013-3002	33.45793	-112.04601	19th St & Roosevelt
CL	04-013-4014	33.66628	-112.31042	Beardsley Road and 115th Ave.
DC	04-013-9812	33.42650	-112.11814	27th Ave. & Durango St.
DY	04-013-4010	33.63713	-112.34184	Bell Rd. & Dysart Rd.
FF	04-013-1010	33.45223	-111.73331	McKellips & Greenfield
FH	04-013-9704	33.61103	-111.72529	Palisades & Fountain Hills Blvd.
GL	04-013-2001	33.56936	-112.19153	59th Ave & W. Olive
GR	04-013-3010	33.46093	-112.11748	27th Ave. & Interstate 10
HI	04-013-4006	33.31074	-111.72255	Higley Rd. & Chandler Blvd
HM	04-013-9508	33.98280	-111.79870	Top of Humboldt Mountain
ME	04-013-1003	33.41045	-111.86507	Broadway Rd. & Alma School Rd.
NP	04-013-1004	33.56033	-112.06626	7th Street & Dunlap Avenue
PP	04-013-2005	33.71231	-111.85272	Pima Rd & Pinnacle Peakq
RV	04-013-9706	33.71881	-111.67183	Forest Rd & Del Ray Ave.
SP	04-013-4003	33.40316	-112.07533	Central Ave. & Broadway Rd.
SS	04-013-3003	33.47968	-111.91721	Scottsdale Rd. & Thomas Rd.
TE	04-013-4005	33.4124	-111.93473	College Ave. & Apache Blvd.
WC	04-013-4004	33.29898	-111.88431	Ellis St. & Frye Rd.
WF	04-013-4009	33.40642	-112.14434	43rd Ave. & Broadway Rd.
WI	04-013-0016	33.49462	-112.13098	33rd Ave. & Indian School Rd.
WP	04-013-0019	33.48385	-112.14257	39th Ave. & Earll Dr.
ZH	04-013-4016	33.686738	-112.294171	109th Ave & Deer Valley Rd.

SOURCE: Maricopa County 2009 Air Monitoring Network Review

MCAQD Monitors

Detailed information on the individual monitors in the MCAQD network cited in ADEQ's Exceptional Events Request for June 4, 2008 are listed in the following section. This section also contains a map showing the location of permitted sources within a 2-mile buffer around each monitor.

Buckeye	
Operator: Maricopa County AQD	**Operator ID:** BE

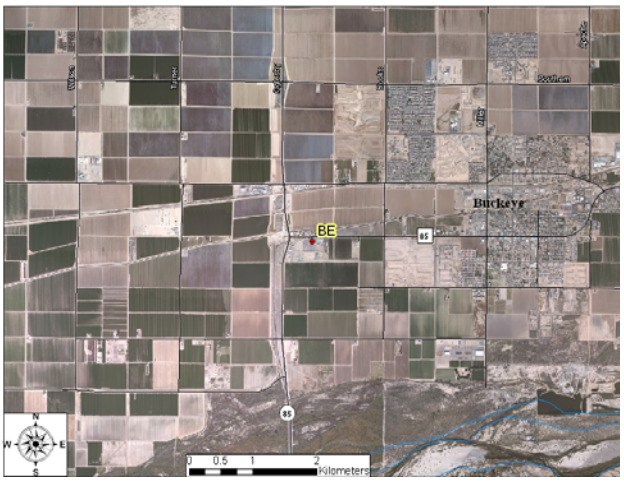
Site Purpose: population/source impact

This site is a SLAMS location for carbon monoxide, ozone, PM_{10}, and NO_2 criteria pollutants. The site is located in the Maricopa County Department of Transportation Southwest Facility. The immediate area is agriculture and encroaching residential development.

Site Information			
AQS ID	04-013-4011	ADEQ ID	21525
Address	26449 W. 100th Dr., Buckeye, AZ		
County	Maricopa	Groundcover	Paved
CBSA	Phoenix-Mesa-Scottsdale	Latitude	33.3700
Surrounding Area	agriculture/residential development	Longitude	-111.6207
Distance to road	31 meters	Elevation	Unknown
Traffic count (ADT)	3,000	Site Established Date	08/01/04

Monitoring Information			
Pollutant/Atmospheric parameter	CO, NO_2, O_3, PM_{10}, MET		
Network or Program	SLAMS		
Spatial Scale	Neighborhood/Urban		
Parameter start date at site	08/01/04		

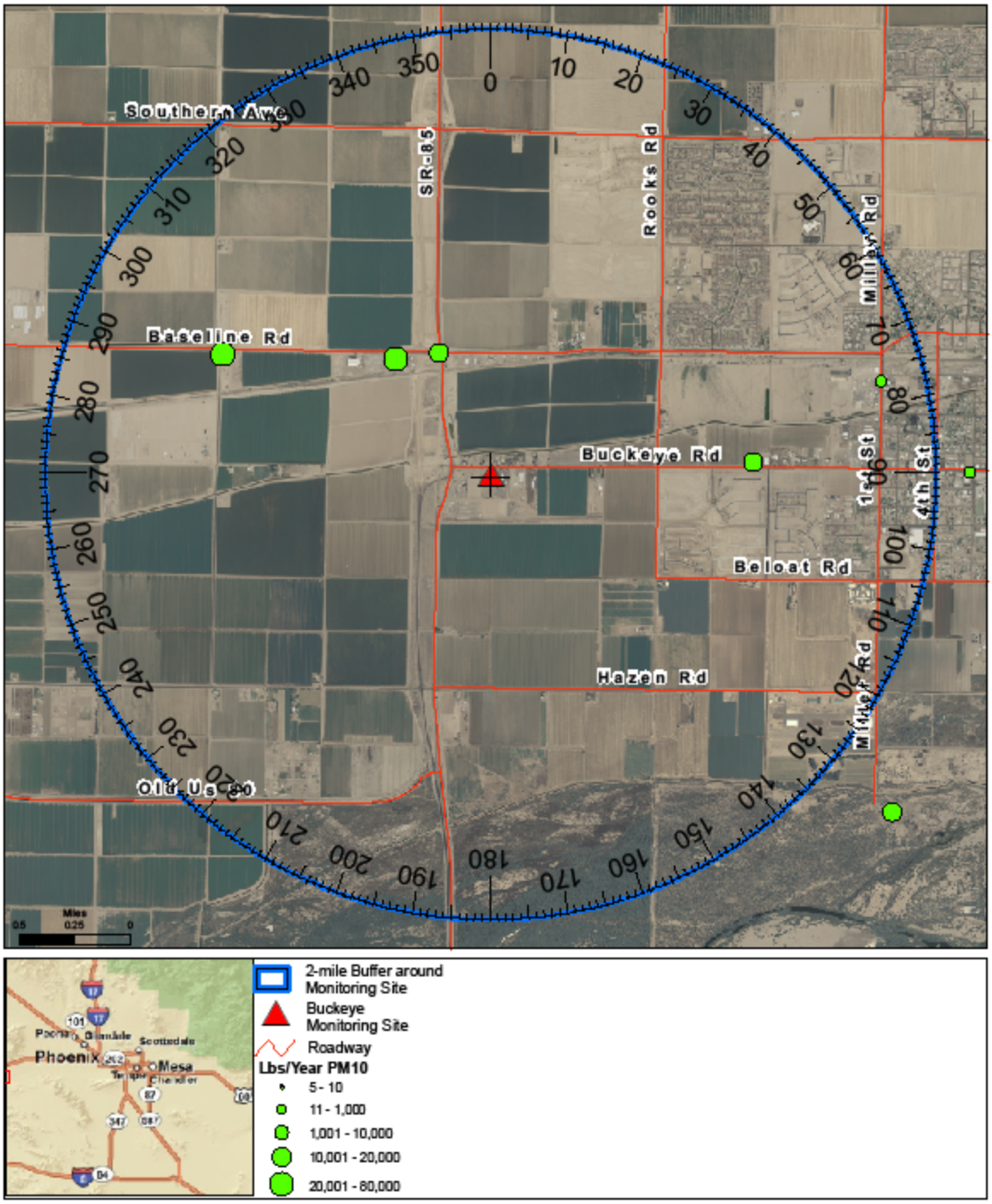
Site Photos



Aerial view of Buckeye site

Monitor site

Permitted Facilities in 2-Mile Buffer Around Buckeye PM10 Monitor



**Permitted facilities in 2-mile buffer around monitor not available at this time.

Coyote Lakes	
Operator: Maricopa County AQD	**Operator ID:** CL

Site Purpose: source oriented

The site is located within the Agua Fria river channel which has several sand & gravel mining operations, among other sources such as unpaved roads. Wind speed and direction, temperature, and atmospheric pressure are also monitored at this site.

Site Information			
AQS ID	04-013-4014	ADEQ ID	127530
Address	20010 N. Coyote Lakes Pkwy., Surprise, AZ		
County	Maricopa	Groundcover	Gravel/Dirt
CBSA	Phoenix-Mesa-Scottsdale	Latitude	33.6662
Surrounding Area	river channel/sand & gravel mining/unpaved roads	Longitude	-112.3104
Distance to road	54 meters	Elevation	Unknown
Traffic count (ADT)	Unknown	Site Established Date	04/02/07

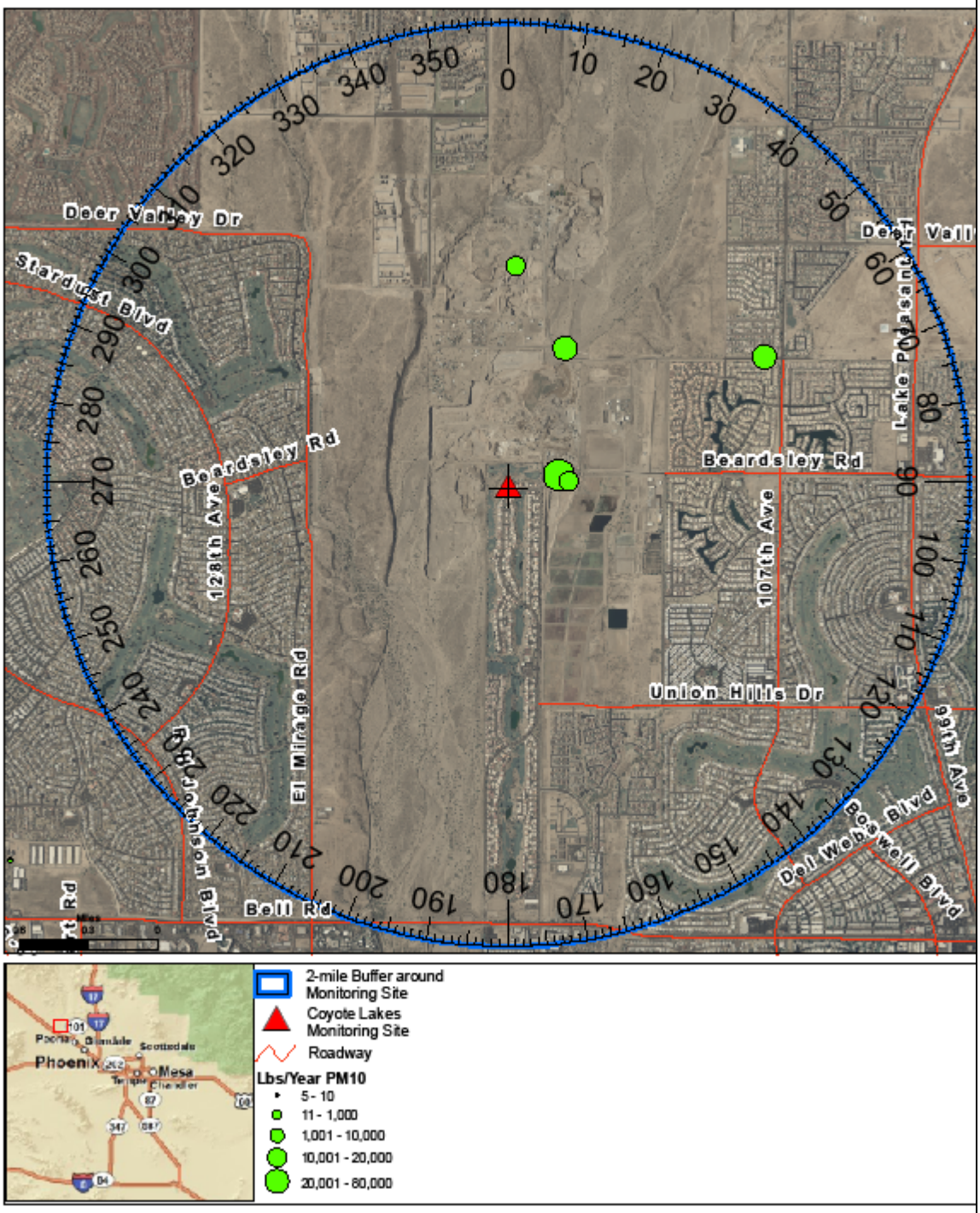
Monitoring Information			
Pollutant/Atmospheric parameter	PM_{10}, MET		
Network or Program	SLAMS		
Spatial Scale	Middle		
Parameter start date at site	04/02/07		

Site Photos

Aerial view of Coyote Lakes site

Monitor site

Permitted Facilities in 2-Mile Buffer Around Coyote Lakes PM10 Monitor



** Permitted facilities in 2-mile buffer around monitor are not available at this time.

Durango Complex	
Operator: Maricopa County AQD	**Operator ID:** DC

Site Purpose: Maximum concentration

This site is located in the Maricopa County Flood Control District storage yard which is one mile northwest from the former Salt River site. Sampling began on January 6, 1999. There are also meteorological monitors (wind speed/direction and atmospheric pressure) located at the site.

Site Information			
AQS ID	04-013-9812	ADEQ ID	16375
Address	2702 RC Esterbrook Blvd., Phoenix, AZ		
County	Maricopa	Groundcover	Paved
CBSA	Phoenix-Mesa-Scottsdale	Latitude	33.4265
Surrounding Area	County storage yard	Longitude	-112.1181
Distance to road	78 meters	Elevation	Unknown
Traffic count (ADT)	16,000	Site Established Date	01/06/99

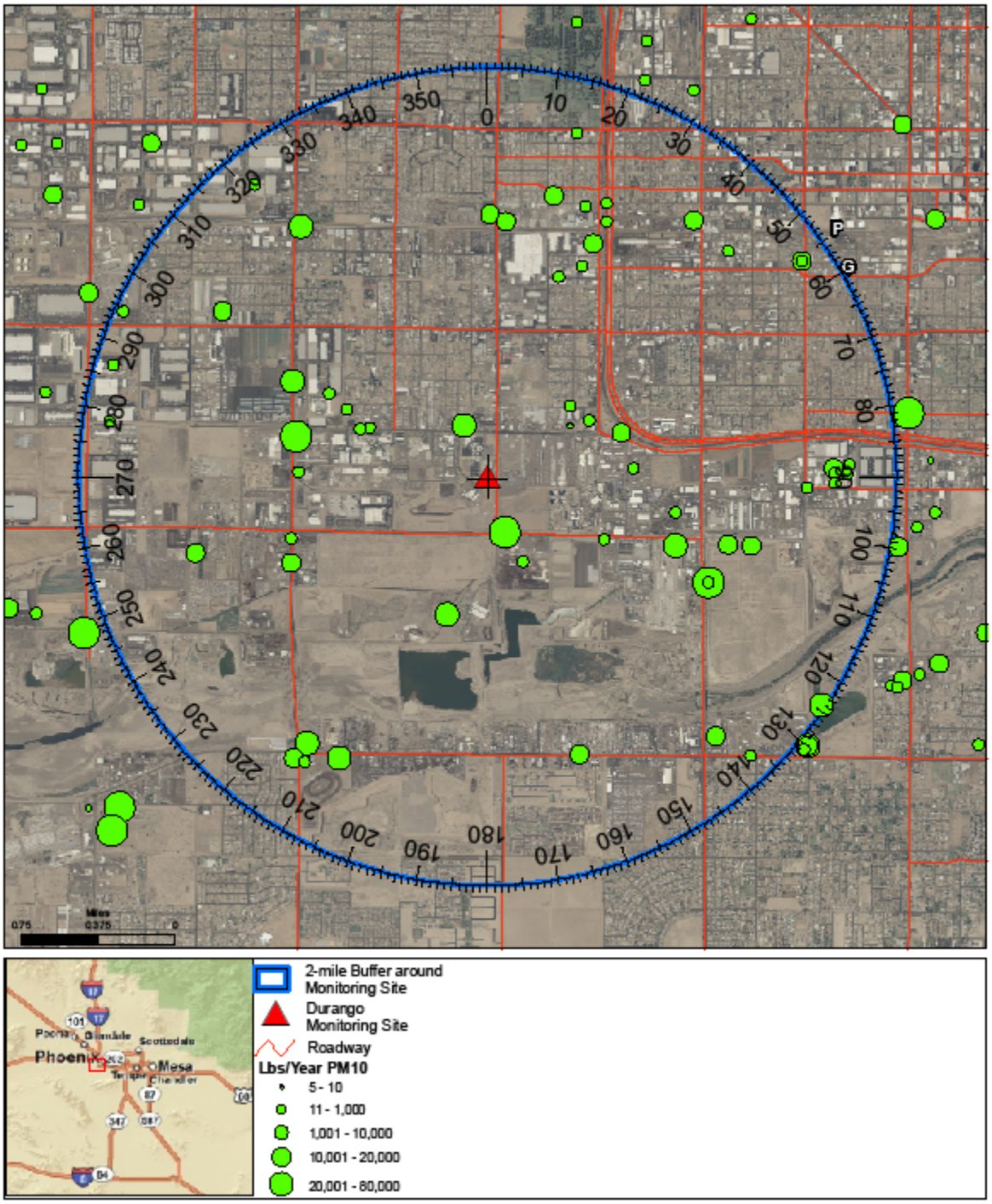
Monitoring Information			
Pollutant/Atmospheric parameter	PM_{10}, $PM_{2.5}$		
Network or Program	SLAMS		
Spatial Scale	Middle		
Parameter start date at site	01/06/99		

Site Photos

Aerial view of Durango Complex site

Monitoring site

Permitted Facilities in 2-Mile Buffer Around Durango PM10 Monitor



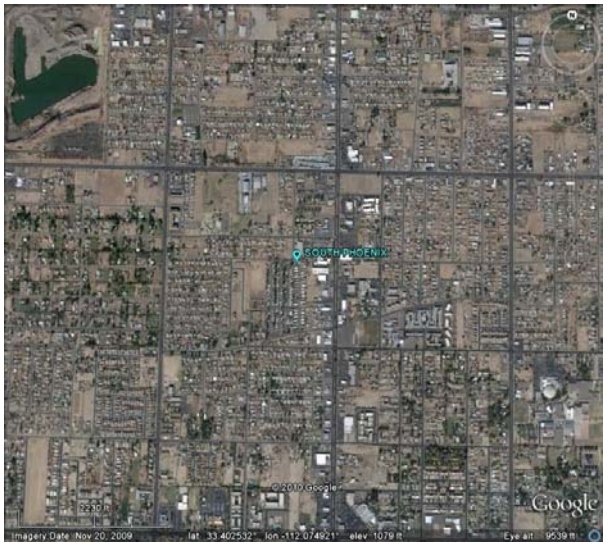
**Permitted facilities in 2-mile buffer around monitor are not available at this time.

South Phoenix	
Operator: Arizona DEQ / Maricopa County AQD	**Operator ID:** SP
Site Purpose: population exposure The site is owned by MCAQD. ADEQ operates the toxics sampler at the site. The site is situated in South Phoenix, at the edge of a high population area, bordering a mixture of residential and commercial properties. Two high population areas are located north and west of the site.	

Site Information			
AQS ID	04-013-4003	ADEQ ID	16377
Address	33 W. Tamarisk St. Phoenix, AZ 85041		
County	Maricopa	Groundcover	Asphalt
CBSA	Phoenix-Mesa-Scottsdale	Latitude	33.4030
Surrounding Area	residential/commercial	Longitude	-112.0750
Distance to road	83 m	Elevation	330 m
Traffic count (ADT)	19,110	Site Established Date	01/01/1997

Monitoring Information			
Pollutant/Atmospheric parameter	CO, O3, Toxics, PM_{10}, $PM_{2.5}$, MET		
Network or Program	SLAMS		
Spatial Scale	Neighborhood		
Parameter start date at site	08/05/2001		

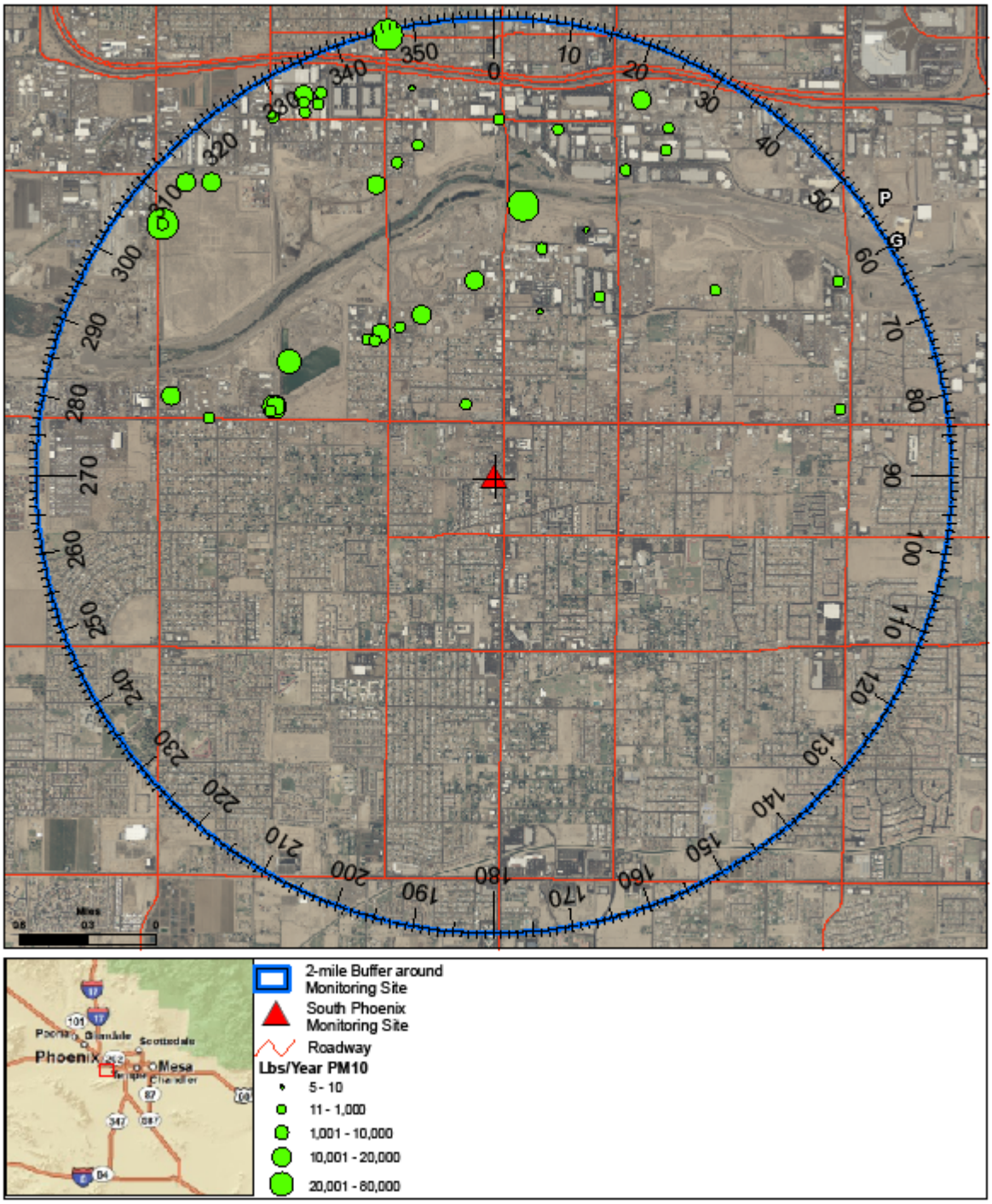
Site Photos



Aerial view of South Phoenix

Shelter and meteorological tower at South Phoenix site – 04/2005

Permitted Facilities in 2-Mile Buffer Around South Phoenix PM10 Monitor



**Permitted facilities in 2-mile buffer around monitor are not available at this time.

West Forty Third Ave	
Operator: Maricopa County AQD	**Operator ID:** WF

Site Purpose: maximum concentration; impact on ambient pollution levels of significant sources or source categories

The site is located at a Maricopa County Department of Transportation storage lot. The sources around the site include sand and gravel operations, auto and metal recycling, landfills, paved and unpaved haul roads, and cement casting.

Site Information			
AQS ID	04-013-4009	ADEQ ID	16659
Address	3940 W Broadway, Phoenix, AZ		
County	Maricopa	Groundcover	Gravel
CBSA	Phoenix-Mesa-Scottsdale	Latitude	33.4064
Surrounding Area	sand and gravel operations	Longitude	-112.1443
Distance to road	37 meters	Elevation	Unknown
Traffic count (ADT)	Unknown	Site Established Date	04/01/2002

Monitoring Information			
Pollutant/Atmospheric parameter	PM_{10}		
Network or Program	SLAMS		
Spatial Scale	Middle		
Parameter start date at site	04/01/2002		

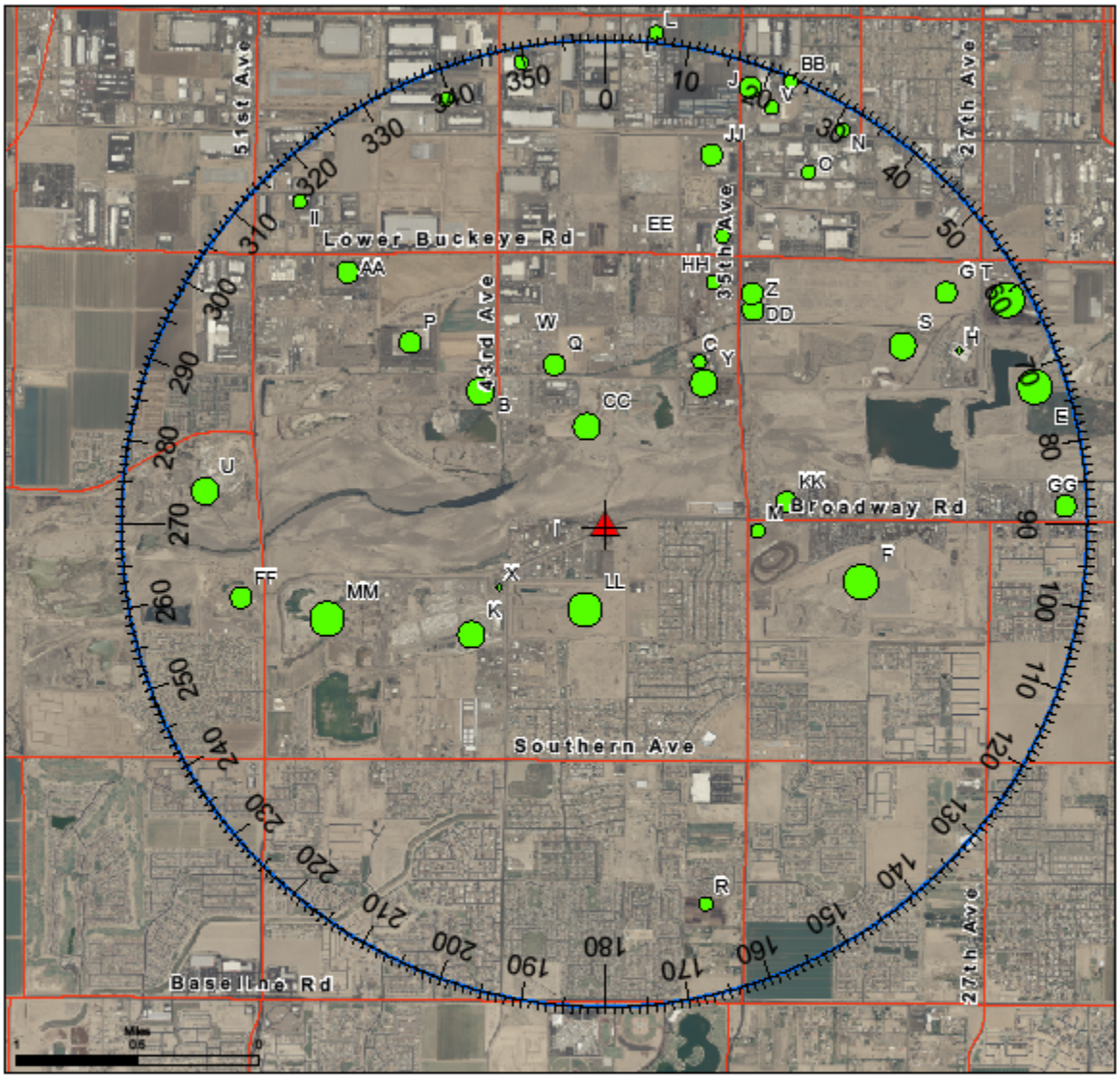
Site Photos

Aerial view of W. 43rd Ave. site

Monitor site

Permitted Facilities in 2-Mile Buffer Around West 43rd Avenue PM10 Monitor

ADEQ
Arizona Department of Environmental Quality



Facility Name	Map Letter
AMERICA TEXTILE SERVICES	A
ARIZONA MATERIALS	B
BAKER COMMODITIES	C
CAVCO INDUSTRIES	D
CMMX - 19TH AVE PLANT (NORTH)	E
CMMX - 19TH AVE PLANT (SOUTH)	F
CITY OF PHOENIX - 27TH AVE LANDFILL	G
CITY OF PHOENIX - SOLID WASTE MGMT	H
COATING SPECIALISTS INC	I
COMPACTIX WINDOW FASHIONS, INC	J
CONSLAB STRUCTURES (ANIZ) INC	K
CRISLINE-WEST INC	L
DESERT POWDER COATING	M
DURANGO COMPLEX - CENTRAL SERVICES	N
DURANGO CORRECTIONAL FACILITY	O
EAGLE ROOFING PRODUCTS	P
EDWIN WEINBERGER TOPSOIL INC	Q
GREEN WASTE RECYCLING	R
GRO-WELL BRANDS INC	S
GRO-WELL BRANDS INC	T

Facility Name	Map Letter
EDWIN WEINBERGER TOPSOIL INC	Q
GREEN WASTE RECYCLING	R
GRO-WELL BRANDS INC	S
GRO-WELL BRANDS INC	T
HANSON AGGREGATES OF ARIZONA INC	U
INSULFOAM	V
KIM GARDNER PAINTING & PAINTING	W
MAY ROCKERY CONSTRUCTION	X
METAL MANUFACTURE ARIZONA INC	Y
MILLER PRECAST OF ARIZONA INC	Z
PARADISE WASTE SITE TRANSFER FACILITY	AA
PARTNERS PACKAGING & CONTAINER	BB
PIM PR INC	CC
QUALITY ROCK INC	DD
REUTER EQUIPMENT CO	EE
RIO GRANDE MATERIAL	FF
SAFER PRODUCT	GG
SOUTHWEST FOREST PRODUCTS INC	HH
THE DUNBOR COMPANY INC	II
VOSS STONE & GRAVEL PTS CO	JJ
UNIVERSAL ENTECH INC	KK
VULCAN MATERIALS CO - (EAST)	LL
VULCAN MATERIALS CO - (WEST)	MM
WEYERHAEUSER HB COMPANY	NN

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Appendix B
Meteorological Network

The following sections provide an overview of the National Weather Service Network and the AZMET Network in Maricopa County.

NATIONAL WEATHER SERVICE NETWORK

The Arizona Department of Environmental Quality (ADEQ) relies on meteorological data from a variety of networks that are operated by Federal, state, and local governmental agencies. This section gives a description of the National Weather Service (NWS) stations from which ADEQ obtains data in documenting exceptional/natural events that occur in Arizona.

National Weather Service Data

The National Weather Service (NWS) provides weather and climate forecasts and warnings for the United States and its territories for the protection of life and property and the enhancement of the national economy. NWS data form a national information database and infrastructure that is used by other governmental agencies, the private sector, the public, and the global community. NWS stations provide meteorological data on time (hour), sky conditions, visibility, weather type, dry bulb temperature, wet bulb temperature, dew point temperature, relative humidity, wind speed (mph), wind direction, wind gusts (mph), station pressure (in. hg), pressure trend, net 3-hour change (mb), sea level pressure (in. hg), report type, precipitation total (in.), and altimeter (in. hg). Figure 1 shows the location of NWS stations that provide the meteorological data that ADEQ staff relies upon to document exceptional/natural events in Arizona. Table 1 lists these stations according to geographic region.

Table 1
National Weather Service Stations Providing Meteorological Data For The Documentation Of Exceptional/Natural Events In Arizona

California/Western Arizona Stations			
Call Sign	**Station**	**Latitude/Longitude**	**Distance/Direction to Downtown Phoenix**
BLH	Blythe Airport, CA	33.63ºN, 114.71ºW	158 mi W
CZZ	Campo, CA	32.62ºN, 116.47ºW	299 mi WSW
EED	Needles Airport, CA	34.77ºN, 114.62ºW	251 mi NW
IFP	Laughlin Bullhead International Airport, AZ-NV	35.15ºN, 114.56ºW	216 mi NW
IGM	Kingman Airport, AZ	35.22ºN, 114ºW	185 mi NW
IPL	Imperial County Airport, CA	32.83ºN, 115.57ºW	241 mi WSW
NJK	El Centro NAF, CA	32.81ºN, 115.68ºW	246 mi WSW
NYL	Yuma Marine Corp Air Station, AZ	32.65ºN, 114.62ºW	183 mi WSW
NXP	Twenty-Nine Palms, CA	34.28ºN, 116.16ºW	312 mi W
YUM	Yuma International Airport, AZ	32.67ºN, 114.6ºW	181 mi WSW

Table 1
National Weather Service Stations Providing Meteorological Data For The Documentation Of Exceptional/Natural Events In Arizona

Greater Phoenix Area Stations

Call Sign	Station	Latitude/Longitude	Distance/Direction to Downtown Phoenix
CHD	Chandler Municipal Airport, AZ	33.27ºN, 111.81ºW	26 mi SE
DVT	Phoenix Deer Valley Municipal Airport, AZ	33.69ºN, 112.08ºW	20 mi N
FFZ	Mesa Falcon Field, AZ	33.47ºN, 111.73ºW	26.5 mi E
GBN	Gila Bend Army Air Field, AZ	32.88ºN, 112.72ºW	65 mi WSW
GEU	Glendale Municipal Airport, AZ	33.52ºN, 112.29ºW	18 mi NW
GYR	Phoenix Goodyear Airport, AZ	33.42ºN, 112.38ºW	20 mi W
IWA	Phoenix Williams Gateway Airport, AZ	33.3ºN, 111.67ºW	39 mi SE
LUF	Phoenix Luke Air Force Base, AZ	33.55ºN, 112.37ºW	23 mi NW
PHX	Phoenix Sky Harbor International Airport, AZ	33.42ºN, 112ºW	3 mi E
SDL	Scottsdale Municipal Airport, AZ	33.62ºN, 111.91ºW	28 mi NE

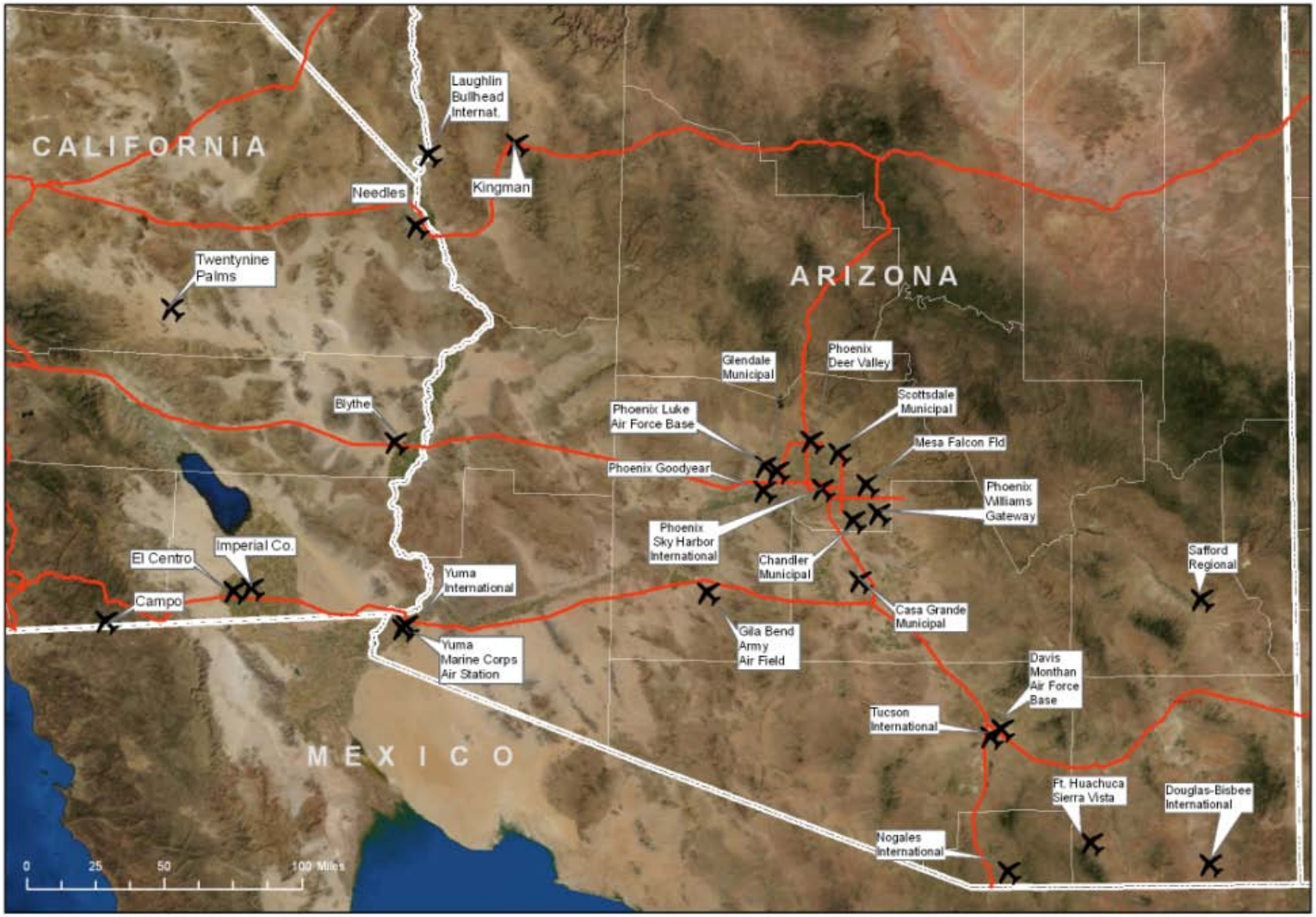
Greater Tucson Area Stations

Call Sign	Station	Latitude/Longitude	Distance/Direction to Downtown Phoenix
CGZ	Casa Grande Municipal Airport, AZ	32.95ºN, 111.77ºW	47 mi SSE
DMA	Davis Monthan Air Force Base, AZ	32.17ºN, 110.88ºW	118 mi SE
TUS	Tucson International Airport, AZ	32.13ºN, 110.95ºW	119 mi SE

Southern Arizona Stations

Call Sign	Station	Latitude/Longitude	Distance/Direction to Downtown Phoenix
DUG	Douglas Bisbee International Airport, AZ	31.45ºN, 109.6ºW	241 mi SSE
FHU	Fort Huachuca/Sierra Vista, AZ	31.57ºN, 110.33º	183 mi SSE
OLS	Nogales International Airport, AZ	31.42ºN, 110.84ºW	183 mi SSE
SAD	Safford Regional Airport, AZ	32.85ºN, 109.63ºW	173 mi E

Figure 1. National Weather Service Stations



National Weather Service Stations
Arizona / SE California

Author: N. Caroli, July 15, 2010

California and Western Arizona

Figure 2 shows the location of NWS weather stations in California and western Arizona that provide ADEQ staff with meteorological data used to document exceptional events that impact or originate in Arizona. The stations are described in detail below.

Campo, CA (03164/CZZ)
The weather station is at an approximate road distance of 52 miles southeast of downtown San Diego, CA and 299 miles west southwest of Phoenix. The station is located in the community of Campo in San Diego County. The station is a land surface cooperative station that utilizes an automated surface observation system (ASOS). It is operated by the Federal Aviation Administration (FAA). The site is situated in the Coast Ranges of California and the topography consists of rolling hills. The site is found at 32.62°N latitude and 116.47°W at an elevation of 2,630 feet above sea level. It has been in operation since January 1, 1931.

Twenty-Nine Palms, CA (93121/NXP)
The weather station is at an approximate driving distance of 70 miles north of Indio, CA and 312 miles west of Phoenix. The station is located at Twenty-Nine Palms Marine Corps in San Bernardino County. It is a land surface cooperative station. The weather station is found at 34.28°N latitude and 116.16°W longitude at an elevation of 2,110 feet above sea level. There is no information on when it began operating.

Imperial County Airport, CA (03144/IPL)
The Imperial County Airport weather station is at a driving distance of 4 miles north of El Centro, CA and 241 miles west southwest from Phoenix. It is located in Imperial. It is a land surface station that utilizes an automated surface observation system (ASOS). The station is located in the Imperial Valley and, consequently, the immediate terrain is flat. It is found at 32.83°N latitude and 115.57°W at an elevation of 58 feet below sea level. It has been in operation since March 7, 1959.

El Centro NAF, CA (23199/NJK)
The El Centro Naval Air Facility (NAF) weather station is at an approximate road distance of 7 miles west of El Centro, CA and 246 miles west southwest from Phoenix. It is located in the City of El Centro, CA. The station is a land surface station that utilizes an automated surface observation system (ASOS). The weather station is found in the Imperial Valley and, consequently, the terrain is flat in the immediate vicinity. It is found at 32.81°N latitude and 115.68°W at an elevation of 43 feet below sea level. The weather station has been in operation since April 1, 1943.

Needles Airport, CA (23179/EED)
The weather station is at an approximate driving distance of 251 miles northwest of Phoenix. It is located at the airport in Needles, CA. It is a land surface cooperative station that utilizes an automated surface observation system (ASOS). The station is located on the western bank of the Colorado River in San Bernardino County. It is found at 34.77°N latitude and 114.62°W longitude at an elevation of 890 feet above sea level. It has been in operation since March 10, 1942.

Figure 2. National Weather Service Stations along the Arizona/SE California border.

National Weather Service Stations
Arizona / SE California Border

Author: N. Caroli, July 15, 2010

Laughlin Bullhead International Airport, AZ-NV (53135/IFP)
This weather station is approximately 216 miles northwest of Phoenix. It is located in Bullhead City, AZ, just east of the Colorado River. It is an airway weather observation (AWOS) station operated by the Federal Aviation Administration. The station is in the Lower Colorado River Valley. It is found at 35.15°N latitude and 114.56°W longitude at an elevation of 695 feet above sea level. It has been in operation since April 7, 2005.

Blythe Airport, CA (23158/BLH)
The weather station is found at a driving distance of 7 miles west of Blythe, CA and 158 miles west of Phoenix. It is located at the airport at Blythe. The station is a land surface cooperative station that utilizes an automated surface observation system (ASOS). The station is found in the Palo Verde Valley, a stretch of the Lower Colorado River Valley, and the immediate topography is low desert. It is found at 33.63ºN latitude and 114.71ºW longitude at an elevation of 395 feet above sea level. It has been in operation since June 1, 1931.

Yuma Marine Corp Air Station, AZ (03145/NYL)
The weather station is approximately 183 miles west southwest of Phoenix. The station is located at the Marine Corp Air Station in Yuma, AZ. It is a land surface cooperative station. It is located in the part of the Lower Colorado River Valley known as the Yuma Valley and the terrain is generally flat. It is found at 32.65°N latitude and 114.62°W longitude at an elevation of 213 feet above sea level. It has been in operation since July 1, 1960.

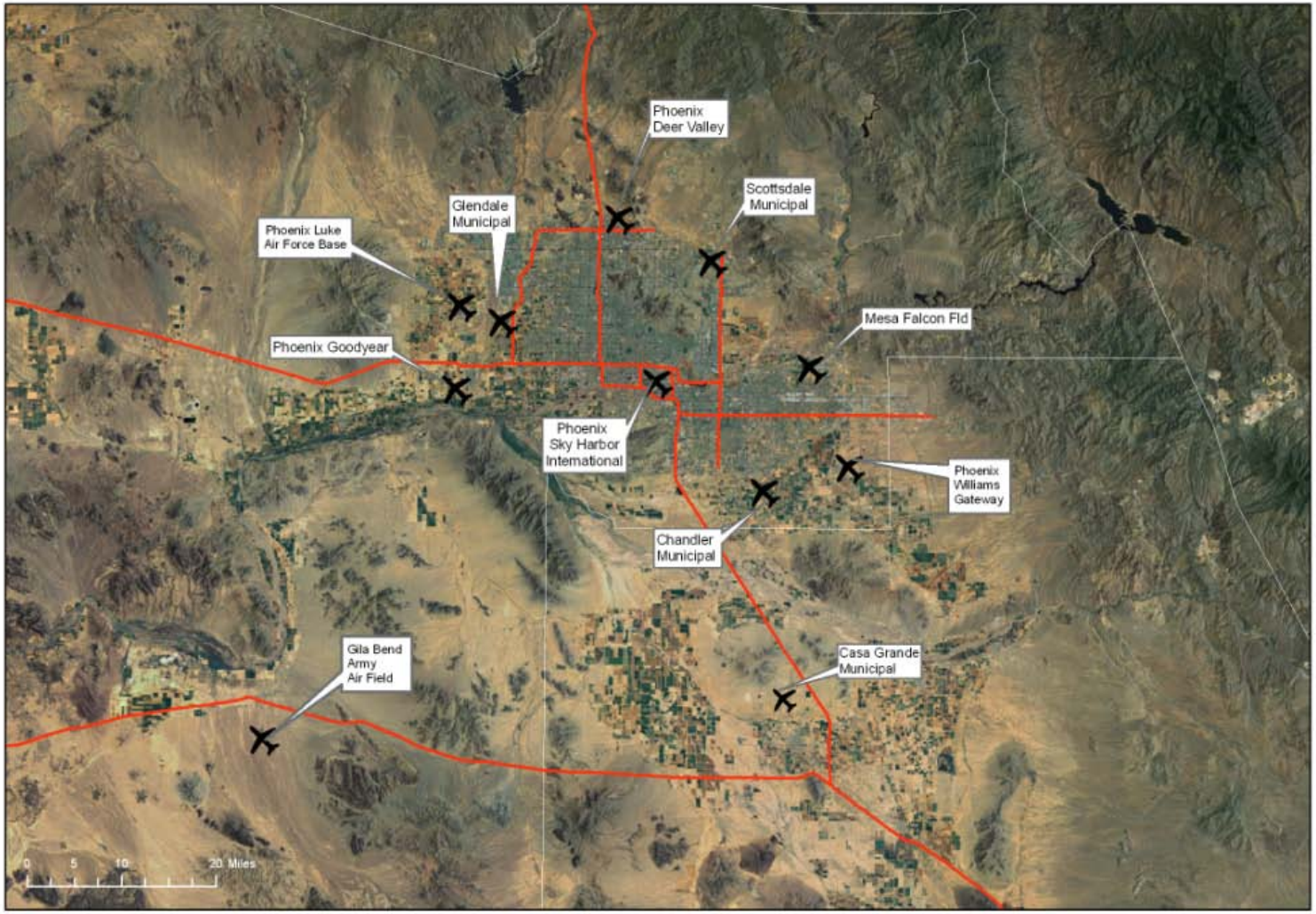
Yuma International Airport, AZ (23195/YUM)
The weather station is approximately 181 miles west southwest of Phoenix. The station is located at the Yuma Marine Corp Air Station/International Airport in Yuma, AZ. It is a land surface cooperative weather station. It is located in the part of the Lower Colorado River Valley known as the Yuma Valley and the terrain is generally flat. It is found at 32.67°N latitude and 114.6°W longitude at an elevation of 206 feet above sea level. It has been in operation since January 1, 1946.

Kingman Airport, AZ (93167/IGM)
The weather station is approximately 185 miles northwest of Phoenix. It is located at the airport in Kingman, AZ. It is a land surface cooperative station that uses an automated surface observation system (ASOS). It is operated by the Civil Aeronautics Administration. The weather station is in Arizona's high desert. It is found at 35.22°N latitude and 114°W longitude at an elevation of 3,435 feet above sea level. It has been in operation since May 31, 1944.

Greater Phoenix Area

Figure 3 shows the location of NWS weather stations in the Greater Phoenix area that provide ADEQ staff with meteorological data used to document exceptional events that impact or originate in Arizona. The stations are described in detail below.

Figure 3. National Weather Service stations in the Greater Phoenix area.



National Weather Service Stations in the Greater Phoenix Area

Author: N. Caroli, July 15, 2010

ADEQ Arizona Department of Environmental Quality

Gila Bend Army Air Field, AZ (03148/GBN)
The weather station is approximately 65 miles west southwest of Phoenix. The station is located in Gila Bend, AZ. It is a land surface army air field. The station is located in the Gila River Valley; consequently, the immediate terrain is flat. It is found at 32.88°N latitude and 112.72°W longitude at an elevation of 859 feet above sea level. It has been in operation since January 1, 1944.

Phoenix Goodyear Airport, AZ (03186/GYR)
The weather station is approximately 20 miles west of downtown Phoenix. The station is located in at the airport in Goodyear, AZ in the Greater Phoenix Area. It is a land surface airway weather observation station (AWOS). The station is located in the West Valley — a sub-region of the Valley of the Sun; consequently, the surrounding terrain is flat. It is found at 33.42°N latitude and 112.38°W longitude at an elevation of 968 feet above sea level. It has been in operation since January 1, 1986.

Phoenix Luke Air Force Base, AZ (23111/LUF)
The weather station is approximately 23 miles northwest of downtown Phoenix. The station is located in Glendale, AZ in the Greater Phoenix Area. It is a land surface air force base weather station. The station is located in the Valley of the Sun and, consequently, the surrounding terrain is flat. It is found at 33.55°N latitude and 112.37°W longitude at an elevation of 1,086 feet above sea level. It has been in operation since July 1, 1941.

Glendale Municipal Airport, AZ (53126/GEU)
The weather station is approximately 18 miles northwest of downtown Phoenix. The station is located at the Glendale Municipal Airport in the Greater Phoenix Area. It is an airway weather observation station (AWOS). The station is located in the West Valley — a sub-region of the Valley of the Sun; consequently, the surrounding terrain is flat. It is found at 33.52°N latitude and 112.29°W longitude at an elevation of 1,066 feet above sea level. There is no information as to when the station began operating.

Phoenix Deer Valley Municipal Airport, AZ (03184/DVT)
The weather station is 20 miles north of downtown Phoenix. It is located at the Deer Valley Airport in Phoenix. It is a land surface automated surface observation system (ASOS) operated by the Federal Aviation Administration. It is located in Deer Valley — a sub-region of the Valley of the Sun; consequently, the immediate terrain is generally flat. It is found at 33.69°N latitude and 112.08°W longitude at an elevation of 1,455 feet above sea level. It has been in operation since December 1, 1975.

Phoenix Sky Harbor International Airport, AZ (23183/PHX)
The weather station is 3 miles east of downtown Phoenix. It is located at Phoenix Sky Harbor International Airport. It is a land surface cooperative station that utilizes an automated surface observation system (ASOS). It is operated by the National Weather Service (NWS). The station is located in the Valley of the Sun and, consequently, the surrounding terrain is flat. It is found at 33.42°N latitude and 112°W longitude at an elevation of 1,107 feet above sea level. It has been in operation since October 1, 1930.

Scottsdale Municipal Airport, AZ (03192/SDL)
The weather station is approximately 28 miles northeast of downtown Phoenix. It is located at the municipal airport in Scottsdale, AZ in the Greater Phoenix Area. It is a land automated surface observation system (ASOS) limited aviation weather reporting station (LAWRS) operated by the Federal Aviation Administration. The station is located in the East Valley — a sub-region of the Valley of the Sun; consequently, the surrounding terrain is flat. It is found at 33.62°N latitude and 111.91°W longitude at an elevation of 1,473 feet above sea level. The station has been in operation since October 1, 1975.

Chandler Municipal Airport, AZ (53128/CHD)
The weather station is approximately 26 miles southeast of downtown Phoenix. It is located at the Chandler Municipal Airport in the Greater Phoenix Area. It is an airway weather observation station (AWOS). It is located in the Valley of the Sun and, consequently, the surrounding terrain is flat. It is found at 33.27°N latitude and 111.81°W longitude at an elevation of 1,243 feet above sea level. There is no information as to when the station became operational.

Mesa Falcon Field, AZ (03185/FFZ)
The weather station is approximately 26.5 miles east of downtown Phoenix. It is located at Falcon Field in Mesa in the Greater Phoenix Area. It is land surface limited aviation weather reporting station (LAWRS). The station is located in the East Valley — a sub-region of the Valley of the Sun; consequently, the surrounding terrain is flat. It is found at 33.47°N and 111.73°W longitude at an elevation of 1,380 feet above sea level. The station has been in operation since February 1, 1980.

Phoenix Williams Gateway Airport, AZ (23104/IWA)
The weather station is approximately 39 miles southeast of downtown Phoenix. It is located at Williams Gateway Airport in Chandler, AZ in the Greater Phoenix Area. It is a land surface airway weather observation station (AWOS). The station is located in the East Valley — a sub-region of the Valley of the Sun; consequently, the surrounding terrain is flat. It is found at 33.3°N latitude and 111.67°W longitude at an elevation of 1,352 feet above sea level. It has been in operation since March 1, 1942.

Greater Tucson Area

Casa Grande Municipal Airport, AZ (03914/CGZ)
The weather station is approximately 47 miles south southeast of Phoenix. It is located at the municipal airport in Casa Grande, AZ. It is a land surface airway weather observation station (AWOS). The station is located in the Santa Cruz River Valley; consequently, the immediate terrain is flat. It is found at 32.95°N latitude and 111.77°W longitude at an elevation of 1,462 feet above sea level. It has been in operation since June 1, 1991.

Tucson International Airport, AZ (23160/TUS)
The weather station is located approximately 7 miles south of downtown Tucson and 119 miles southeast of Phoenix. It is located at the international airport in Tucson, AZ. It is a land surface aviation and cooperative station that utilizes an automated surface observation system (ASOS). It is operated by the National Weather Service (NWS). It is located in the Santa Cruz River Valley;

consequently, the surrounding terrain is generally flat. It is found at 32.13°N latitude and 110.95°W longitude at an elevation of 2,549 feet above sea level. It has been in operation since October 14, 1948.

Davis Monthan Air Force Base, AZ (23109/DMA)
The weather station is located approximately 6 miles southeast of downtown Tucson and 118 miles southeast of Phoenix. It is located on Davis Monthan Air Force Base in Tucson, AZ. It is a land surface system. It is located in the Santa Cruz River Valley; consequently, the surrounding terrain is generally flat. The station is found at 32.17°N latitude and 110.88°W longitude at an elevation of 2,654 feet above sea level. It has been in operation since January 5, 1928.

Southern Arizona

Nogales International Airport, AZ (03196/OLS)
The weather station is approximately 183 miles south southeast of Phoenix. It is located approximately 10 miles northeast of the City of Nogales, AZ on Highway 82. It is a land surface automated surface observation system (ASOS) operated by the Federal Aviation Administration (FAA). The station is located in the Santa Cruz River Valley. The immediate terrain is flat, but much of the surrounding terrain is hilly. It is found at 31.42°N latitude and 110.84°W longitude at an elevation of 3,932 feet above sea level. The station has been in operation since August 1, 1950.

Fort Huachuca/Sierra Vista, AZ (03124/FHU)
The weather station is located in southeastern Arizona approximately 183 miles south southeast of Phoenix. It is located at the Sierra Vista Libby Municipal Airport just north of Fort Huachuca. It is a cooperative land surface and army aviation air field station. The station is located in the San Pedro River Valley; consequently, the immediate terrain is flat. It is found at 31.57°N latitude and 110.33°W longitude at an elevation of 4,665 feet above sea level. It has been in operation since September 1, 1954.

Safford Regional Airport, AZ (93084/SAD)
The weather station is approximately 173 miles east of Phoenix. It is located at the municipal airport at Stafford, AZ. It is a land surface automated surface observation system (ASOS) operated by the Federal Aviation Administration (FAA). The station is located in the Gila River Valley; consequently, the immediate terrain is flat. It is found at 32.85°N latitude and109.63°W longitude at an elevation of 3,176 feet above sea level. The station has been in operation since July 1, 1950.

Douglas Bisbee International Airport, AZ (93026/DUG)
The weather station is located in southeastern Arizona approximately 241 miles south southeast of Phoenix. It is located at the Douglas Bisbee International Airport just north of Douglas. It is a cooperative land surface station that utilizes an automated surface observation system (ASOS). It is operated by the National Weather Service (NWS). The station is located in the Sulphur Springs Valley; consequently, the immediate terrain is flat. It is found at 31.45°N latitude and 109.60°W at an elevation of 4,105 feet above sea level. It has been in operation since November 1, 1931.

ARIZONA METEOROLOGICAL NETWORK

ADEQ relies on meteorological data from a variety of networks that are operated by Federal, state, and local governmental agencies. This section gives a description of the Arizona Meteorological Network (AMET) stations from which ADEQ obtains data in documenting exceptional/natural events that occur in Arizona.

Arizona Meteorological Network Data

The University of Arizona College of Agriculture established an automated weather data collection network to monitor conditions in Arizona. This network is known as the Arizona Meteorological Network (AZMET). The weather stations in the network are jointly operated with other agencies. AZMET provides meteorological data and weather-based information to agricultural and horticultural interests operating in southern and central Arizona. Meteorological data is collected from a network of automated weather stations located in both rural and urban settings. Meteorological data collected by AZMET include temperature (air and soil), humidity, solar radiation, wind (speed and direction), and precipitation. AZMET also provides a variety of computed variables, including heat units (degree-days), chill hours, and reference crop evapotranspiration (ETo). AZMET began operating on January 1, 1987. Figure 4 shows the location of AZMET stations that provide the meteorological data that ADEQ staff relies upon to document exceptional/natural events in Arizona. Table 1 lists these stations according to geographic region.

Table 1
Arizona Meteorological Network (AZMET) Weather Stations Providing Meteorological Data For The Documentation Of Exceptional/Natural Events In Arizona

Western Arizona Stations			
Identifier	**Station**	**Latitude/Longitude**	**Distance/Direction to Downtown Phoenix**
36-YumaSouth	Yuma South	32.55ºN, 114.74ºW	196 mi SW
02-YumaValley	Yuma Valley	32.71ºN, 114.71ºW	186 mi SW
14-YumaNorthGila	Yuma North Gila	32.55ºN, 114.53ºW	180 mi SW
20-Mohave	Mohave	35.0ºN, 114.61ºW	256 mi NW
28-Mohave #2	Mohave #2	34.93ºN, 114.56ºW	216 mi NW
08-Parker	Parker	33.97ºN, 111.48ºW	177 mi NW
35-Parker #2	Parker #2	33.88ºN, 114.45ºW	181 mi NW
24-Roll	Roll	32.74ºN, 113.96ºW	145 mi SW
23-Harquahala	Harquahala	33.48ºN, 113.11ºW	62.5 mi W
07-Aguila	Aguila	33.94ºN, 113.19ºW	80 mi NW
19-Paloma	Paloma	32.93ºN, 112.90ºW	74 mi SW
31-Prescott	Prescott	34.36ºN, 112.42ºW	101 mi N

Table 1 (Continued) **Arizona Meteorological Network (AZMET) Weather Stations Providing Meteorological Data For The Documentation Of Exceptional/Natural Events In Arizona**			
Greater Phoenix Area Stations			
Identifier	**Station**	**Latitude/Longitude**	**Distance/Direction to Downtown Phoenix**
26-Buckeye	Buckeye	33.4ºN, 112.68ºW	40 mi W
10-Waddell	Waddell	33.62ºN, 112.46ºW	23 mi NW
15-PHXEncanto	Phoenix Encanto	33.48ºN, 112.1ºW	3.7 mi NW
12-PHXGreenway	Phoenix Greenway	33.62ºN, 112.11ºW	15 mi N
06-Maricopa	Maricopa	33.07ºN, 111.97ºW	37 mi SE
27-DesertRidge	Desert Ridge	33.73ºN, 111.97ºW	21 mi N
29-Mesa	Mesa	33.39ºN, 111.87ºW	12.5 mi SE
22-QueenCreek	Queen Creek	33.19ºN, 111.53ºW	35 mi SE
Greater Tucson Area Stations			
Identifier	**Station**	**Latitude/Longitude**	**Distance/Direction to Downtown Phoenix**
05-Coolidge	Coolidge	32.97ºN, 111.6ºW	60 mi SE
13-Marana	Marana	32.42ºN, 111.15ºW	85 mi ESE
01-Tucson	Tucson	32.28ºN, 110.95ºW	183 mi SSE
Southern Arizona			
Identifier	**Station**	**Latitude/Longitude**	**Distance/Direction to Downtown Phoenix**
09-Bonita	Bonita	32.46ºN, 109.92ºW	201 mi SE
34-KansasSettlement	Kansas Settlement	32.05ºN, 109.73ºW	216 mi SE
04-Safford	Safford	32.81ºN, 109.68ºW	168 mi SE
33-Bowie	Bowie	32.33ºN, 109.48ºW	222 mi SE
Other AZMET Stations			
Identifier	**Station**	**Latitude/Longitude**	**Distance/Direction to Downtown Phoenix**
32-Payson	Payson	34.23ºN, 111.34ºW	92 mi NE

Figure 4. AZMET stations relied used in evaluating natural/exceptional events.

Arizona Meteorological Network (AZMET)
Weather Stations

Author: N. Caroli, July 16, 2010

Western Arizona

Figure 5 shows the location of AZMET weather stations in western Arizona that provide ADEQ staff with meteorological data used to document exceptional events that impact or originate in Arizona. The stations are described in detail below.

Yuma South (36-YumaSouth)
The weather station is located at an approximate road distance of 196 miles southwest of Phoenix. It is located 3 miles south of the Town of Somerton, AZ. The weather station is found at 32.55°N latitude and 114.74°W longitude at an elevation of 97 feet above sea level. It is jointly operated with the Yuma Vegetable Growers Association. It began operating on November 18, 2009.

Yuma Valley (02-YumaValley)
The weather station is located at an approximate road distance of 186 miles southwest of Phoenix. It is located approximately 5 miles west of Yuma, AZ on the property of the University of Arizona Yuma Agricultural Center Valley Station. The weather station is found at 32.71°N latitude and 114.71°W longitude at an elevation of 105 feet above sea level. It is jointly operated with the Yuma Agricultural Center. It came on line on January 1, 1987.

Yuma North Gila (14-YumaNorthGila)
The weather station is approximately 180 miles southwest of Phoenix. The weather station is located 5.6 miles east of Yuma, AZ on U.S. Highway 95. It is found at 32.55°N latitude and 114.53°W longitude at an elevation of 144 feet above sea level. It is jointly operated with Bruce Church Farms. It came on line on January 22, 1988.

Mohave (20-Mohave)
The AZMET station is located approximately 256 miles northwest of Phoenix. It is located 14.2 miles south of Bullhead City, AZ on Arizona State Route 95. It is found at 35.0°N latitude and 114.61°W longitude at an elevation of 495 feet above sea level. It is jointly operated with the Fort Mohave Indian Tribe. It came on line on January 1, 1992.

Mohave #2 (28-Mohave #2)
The weather station is approximately 216 miles northwest of Phoenix. The weather station is located in the vicinity of Bullhead City, AZ in Mohave County. It is found at 34.93°N latitude and 114.56°W longitude at an elevation of approximately 492 feet above sea level. It is a cooperative station jointly operated by Hancock Farm and the Bureau of Reclamation (BOR). It began operating on January 1, 2003.

Parker (08-Parker)
The AZMET station is located at an approximate road distance of 177 miles northwest of Phoenix. The weather station is located 4 miles west of Poston, AZ and approximately 0.5 miles east of the Colorado River. It is found at 33.97°N latitude and 111.48°W longitude at an elevation of 322 feet above sea level. It is jointly operated with the Colorado River Indian Tribes (C.R.I.T.) Farm. It originally came on line on January 1, 1987.

Figure 5. Western Arizona AZMET stations.

Arizona Meteorological Network (AZMET)
Weather Stations in Western Arizona

Author: N. Caroli, July 16, 2010

Parker #2 (35-Parker #2)
The weather station is located approximately 181 miles northwest of Phoenix and 8 miles south of Poston, AZ. It is found at 33.88°N latitude and 114.45°W longitude at an elevation of 308 feet above sea level. It is jointly operated with the Colorado River Indian Tribes (C.R.I.T.) Farm. It began operating on January 24, 2009.

Roll (24-Roll)
The weather station is approximately 145 miles southwest of Phoenix. It is located approximately 42 miles east of Yuma, AZ. It is found at 32.74°N latitude and 113.96°W longitude at an approximate elevation of 299 feet above sea level. It is jointly operated with the Growers Mohawk Gin. It came on line on February 20, 1997.

Harquahala (23-Harquahala)
The weather station is located approximately 10.5 miles west of Tonopah, AZ. It is a cooperative station jointly operated with the Harquahala Irrigation District and Phoenix Agro-Invest, Inc. (PAI). It is found at 33.48°N latitude and 113.11°W longitude at an elevation of 1,150 feet above sea level. The station is located in Maricopa County at a road distance of approximately 62.5 miles west of Phoenix. It came on line on March 9, 1996.

Aguila (07-Aguila)
The AZMET station is located in Maricopa County at a road distance of approximately 80 miles northwest of Phoenix. It is located 0.6 miles northwest of Aguila city limits on the north side of a wash. It is found at 33.94°N latitude and 113.19°W longitude at an elevation of 2,149 feet above sea level. It is a cooperative station jointly operated by Phoenix Agro-Invest, Inc. (PAI) and the Aguila Irrigation District. The station has been in operation since January 1, 1987.

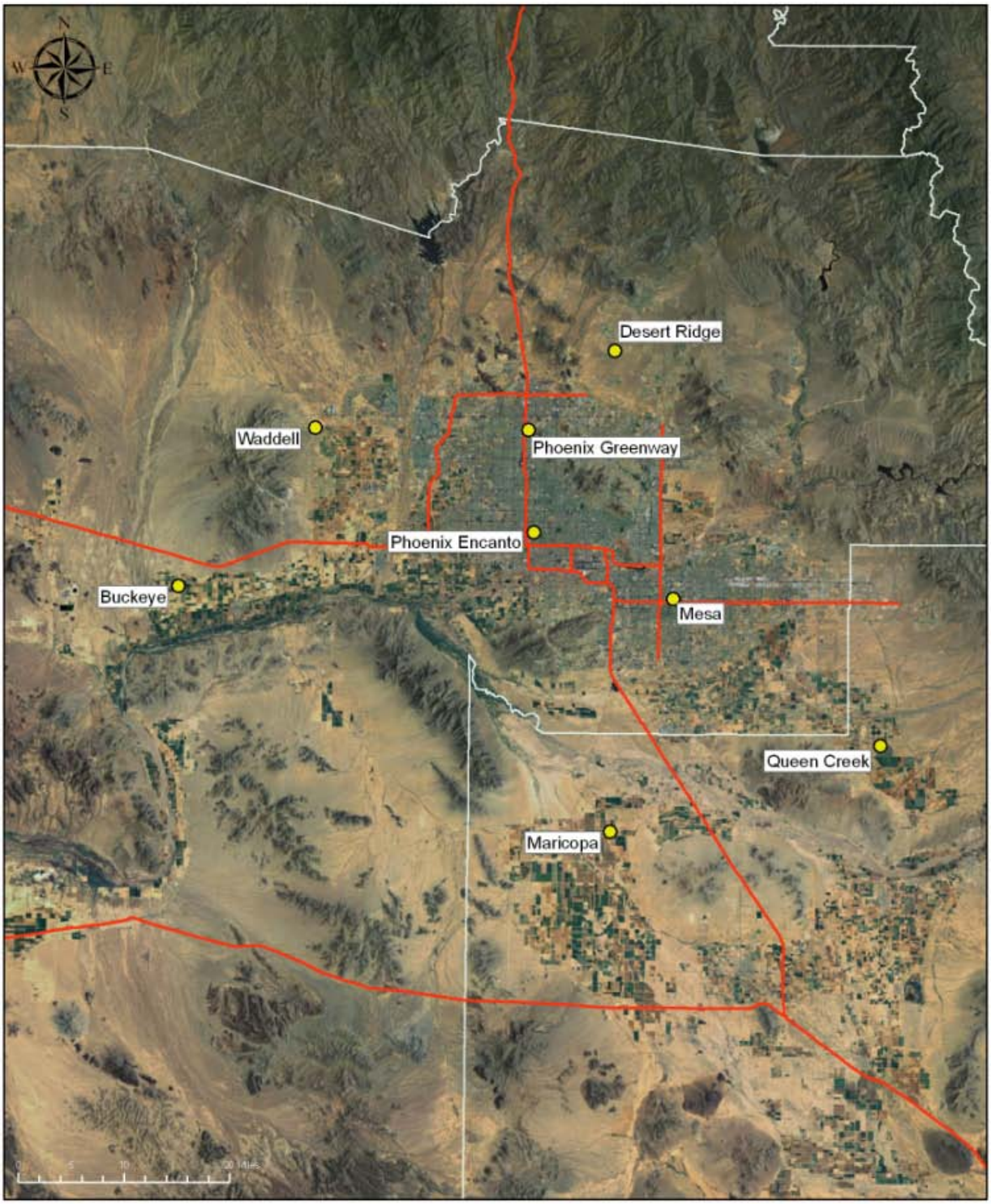
Paloma (19-Paloma)
The weather station is located approximately 74 miles southwest of Phoenix. It is located 9 miles west of Gila Bend in the vicinity of the Paloma exit off Interstate-8. It is found at 32.93°N latitude and 112.90°W longitude at an elevation of 719 feet above sea level. It is a cooperative station jointly operated with the Paloma Ranch. It came on line July 13, 1991.

Prescott (31-Prescott)
The weather station is located at an approximate road distance of 101 miles north of Phoenix. It is found at approximately 34.36°N latitude and 112.42°W longitude and an approximate elevation of 5,192 feet above sea level. The weather station is jointly operated with the City of Prescott Parks and Recreation Department. It began operating on November 8, 2003.

Greater Phoenix Area

Figure 6 shows the location of AZMET weather stations in the Greater Phoenix area that provide ADEQ staff with meteorological data used to document exceptional events that impact or originate in Arizona. The stations are described in detail below.

Figure 6. Greater Phoenix area AZMET stations.



Arizona Meteorological Network (AZMET)
Weather Stations in the Greater Phoenix Area

Author: N. Caroli, July 16, 2010

Buckeye (26-Buckeye)
The AZMET station is located at the Roosevelt Canal approximately 40 miles west of downtown Phoenix. The weather station is located in the Town of Buckeye in the Greater Phoenix Area. It is found at 33.4°N latitude and 112.68°W longitude at an elevation of 1,000 feet above sea level. It is jointly operated with the Roosevelt Irrigation District. The station came on line on January 24, 1998.

Waddell (10-Waddell)
The weather station is approximately 23 miles northwest of downtown Phoenix. It is located on the east side of the White Tank Mountains northwest of the community of Waddell, AZ. It is found at 33.62°N latitude and 112.46°W longitude at an elevation of 1,335 feet above sea level. The weather station is operated by the University of Arizona Citrus Farm and the University of Arizona College of Agriculture. It began operating on May 12, 1987.

Phoenix Encanto (15-PHXEncanto)
The AZMET station is located 3.7 miles northwest of downtown Phoenix. The weather station is located on the Encanto Golf Course in central Phoenix. It is found at 33.48°N latitude and 112.1°W longitude at an elevation of 1,099 feet above sea level. It is jointly operated with the City of Phoenix Water Conservation and Resources Division. It came on line August 26, 1988.

Phoenix Greenway (12-PHXGreenway)
The weather station is located approximately 15 miles north of downtown Phoenix. It is located on the Cave Creek Golf Course in north Phoenix. It is found at 33.62°N latitude and 112.11°W longitude at an elevation of 1,316 feet above sea level. It is jointly operated with the City of Phoenix Water Conservation and Resources Division. It began operating on July 29, 1987.

Maricopa (06-Maricopa)
The weather station is approximately 37 miles southeast of Phoenix; it is 3 miles east of Maricopa, AZ in Pinal County. It is found at 33.07ºN latitude and 111.97ºW longitude at an elevation of 1,184 feet above sea level. It is a cooperative station jointly operated with the Maricopa Agricultural Center (MAC). It came on line on January 1, 1987.

Desert Ridge (27-DesertRidge)
The weather station is approximately 21 miles north of downtown Phoenix. It is located on the Wildfire Golf Course in Phoenix. It is approximately found at 33.73ºN latitude and 111.97ºW longitude at an elevation of 1,700 feet above sea level. It is jointly operated with the City of Phoenix Water Conservation Department. It began operating on August 13, 2002.

Mesa (29-Mesa)
The AZMET station is approximately 12.5 miles southeast of downtown Phoenix. The weather station is located in the vicinity of the intersection of US 60 and Dobson Road on the south side of Mesa Community College campus. It is found at approximately 33.39ºN latitude and 111.87ºW longitude at an elevation of 1,202 feet above sea level. It is jointly operated with Mesa Community College. It has been in operation since July 25, 2003.

Queen Creek (22-QueenCreek)
The station is located at an approximate distance of 35 miles southeast of downtown Phoenix. It is found at 33.19°N latitude and 111.53°W longitude at an elevation of 1,500 feet above sea level. The weather station is jointly operated with the New Magma Irrigation & Drainage District in Queen Creek, AZ. This site originally began operating in 1995.

Greater Tucson Area

Coolidge (05-Coolidge)
The AZMET station is approximately 60 miles southeast of Phoenix and 4.3 miles west of Coolidge. It is found at 32.97ºN latitude and 111.6ºW longitude at an elevation of 1,385 feet above sea level. The station is jointly operated with Sundance Farms, Inc. It has been in operation since January 1, 1987.

Marana (13-Marana)
The weather station is around 85 miles southeast of Phoenix and approximately 27 miles northwest of Tucson. It is located in northern Pima County in the Town of Marana, AZ. The station is found at 32.42°N latitude and 111.15°W longitude at an elevation of 2,042 feet above sea level. It is jointly operated with the Cortoro Marana Irrigation District (CMID). It came on line on September 29, 2006.

Tucson (01-Tucson)
The AZMET station is approximately 115 miles southeast of Phoenix. It is located in Tucson in the vicinity of the intersection of Campbell Avenue and Roger Road. It is found at 32.28°N latitude and 110.95° W longitude at an elevation of 2,339 feet above sea level. The weather station is operated by the University of Arizona Campus Agricultural Center (CAC) and the University of Arizona College of Agriculture. It began operating on January 1, 1987.

Southern Arizona

Bonita (09-Bonita)
The weather station is located in southeastern Arizona approximately 201 miles from Phoenix. The weather station is located on Rex Allen Drive at Interstate-10 18 miles north of Willcox. It is found at 32.46°N latitude and 109.92°W longitude at an elevation of 4,416 feet above sea level. It is jointly operated with Spring Valley Farms. The station has been in operation since January 1, 1987.

Kansas Settlement (34-KansasSettlement)
The AZMET station is located in southeastern Arizona approximately 216 miles southeast of Phoenix. The weather station is located 16 miles south of Willcox. It is found approximately at 32.05ºN latitude and 109.73ºW longitude at an approximate elevation of 4,200 feet above sea level. It is a cooperative station jointly operated with the Willcox-San Simone Natural Resource Conservation District and Alan Robbs. It came on line on July 19, 2006.

Safford (04-Safford)
The weather station is approximately 168 miles east of Phoenix. It is located 2 miles east of Safford, just southeast of the intersection of Lone Star Road and Montierth Road. It is found at 32.81ºN latitude and 109.68ºW longitude at an elevation of 2,956 feet above sea level. It began operating on January 1, 1987.

Bowie (33-Bowie)
The weather station is located in southeastern Arizona approximately 222 miles from Phoenix. It is located 1 mile east of the Bowie exit on Interstate-10. It is found approximately at 32.33ºN latitude and 109.48ºW longitude at an approximate elevation of 3,800 feet above sea level. It is jointly operated with Pecan Grove, Inc. It has been in operation since July 31, 2004.

Other AZMET Stations

Payson (32-Payson)
The AZMET station is located approximately 92 miles northeast of Phoenix. It is found at approximately 34.23°N latitude and 111.34°W longitude at an approximate elevation of 4,849 feet above sea level. The Payson AZMET station is jointly operated by the University of Arizona and the City of Payson Parks and Recreation Department. It came on line on November 8, 2003.

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Appendix C
Background on Phoenix Visibility Network

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The following sections provide an overview of the Arizona Department of Environmental Quality's (ADEQ) Phoenix Visibility Camera Network.

PHOENIX VISIBILITY CAMERA NETWORK

The website *www.phoenixvis.net* provides the public with live pictures and corresponding air quality conditions for Phoenix, AZ and its surrounding areas. Current air quality is given as a "Visibility Index" which was designed to characterize regional visibility conditions. The Phoenix Region Visibility Index is calculated from measurements made by a transmissometer in downtown Phoenix, and the daily visibility index categories are tallied annually and used by the Arizona Department of Environmental Quality (ADEQ) staff to analyze visibility trends in the Phoenix area. The index is not used to affect short-term actions because other programs, such as the High Pollution Advisory Program, are currently in place at ADEQ to address any short-term pollution issues in the Phoenix metropolitan area.

In addition to the Visibility Index, photographic visual documentation is an important aspect of evaluating both visibility and air quality concerns in the Phoenix Metro area. Digital Photography can be an effective way to document times of poor air quality, and the images collected can provide viewers with a quick way to visually interpret an event. The digital cameras used in the Phoenix visibility network are capable of capturing, storing, and transmitting high-resolution digital images from monitoring sites in the Phoenix area. Each camera system consists of a high-resolution digital camera housed in a weatherproof, temperature controlled environmental enclosure, and a supporting image capture computer, powered by a low voltage power supply. Currently, digital images are taken every 15 minutes. These images are stored on the system's internal hard drive and uploaded to the website. Whenever we have a windblown dust event in the Phoenix area, these images are catalogued by ADEQ staff, analyzed, and select images are often used to provide visual evidence of a windblown dust event. This can aid in showing the timing of reduced visibility, depicting the propagation of a dust event across areas of the Valley, and comparing the timing of elevated PM levels recorded at monitoring locations to any reduction in visibility. For comparison, images depicting "pristine conditions" are also included for each camera view on the website, and it is possible to add landmarks to the images in order to help determine how badly visibility is being impacted.

There are five digital cameras currently positioned across the Phoenix Metro area to provide views of the terrain surrounding the valley. The current camera views include South Mountain, the Estrella Mountains, the White Tank Mountains, Camelback Mountain, and the Superstition Mountains. Daytime digital imagery from these cameras have been used in the past to see the propagation of windblown dust across the valley and analyze which areas of the valley are visually impacted by windblown dust events. During nighttime hours the images will often appear as black or will only display city lights. These nighttime images can still prove useful as dust can sometimes be tracked in the photographs when city lights become obscured during high wind events. A supplemental network of cameras, being used to better focus on the West 43rd Ave. monitor area, is collecting images during 2010.

South Mountain Camera
The South Mountain Camera is located on North Mountain looking toward the downtown Phoenix area with South Mountain visible in the background.

Landmarks

Pristine Conditions

South Mountain Visibility Examples

Good

Typical good visibility day in March with a slight milky appearance of regional haze over the South Mountain monitoring vista.

Fair

Typical fair visibility day in February with a moderate appearance of regional haze over the South Mountain monitoring vista.

Poor

Poor visibility day with significant enough regional haze throughout the South Mountain monitoring vista that the South Mountain ridgeline is no longer visible, February.

Very Poor

Very Poor visibility day in October with significant regional haze throughout the South Mountain monitoring vista. Note the South Mountain ridgeline and much of the downtown area is no longer visible.

Map of South Mountain Camera Location and View

Estrella Mountains Camera
The Estrella Mountains Camera is located west of the Phoenix Metro area in Avondale and looks south toward the mountains.

Landmarks

Pristine Conditions

Estrella Mountain Visibility Examples

Good

Typical good visibility day in November with a slight milky appearance of regional haze over the Estrella Mountains monitoring vista.

Fair

Typical fair visibility day in November with a moderate appearance of regional haze over the Estrella Mountains monitoring vista.

Poor

Poor visibility day with significant regional haze throughout the Estrella Mountains monitoring vista, November.

Very Poor

Very Poor visibility day in November with significant enough regional haze throughout the vista that the Sierra Estrella Mountains are barely visible.

Map of Estrella Mountains Camera Location and View

White Tank Mountains Camera
The White Tank Mountains camera is located west of the Phoenix Metro area in Avondale and looks west toward the mountains.

Landmarks

Pristine Conditions

White Tank Mountains Visibility Examples

Good

Typical good visibility day in November with a slight milky appearance of regional haze over the White Tank Mountains monitoring vista.

Fair

Typical fair visibility day in November with a moderate appearance of regional haze over the White Tank Mountains monitoring vista.

Poor

Poor visibility day with significant regional haze throughout the White Tank Mountains monitoring vista, November.

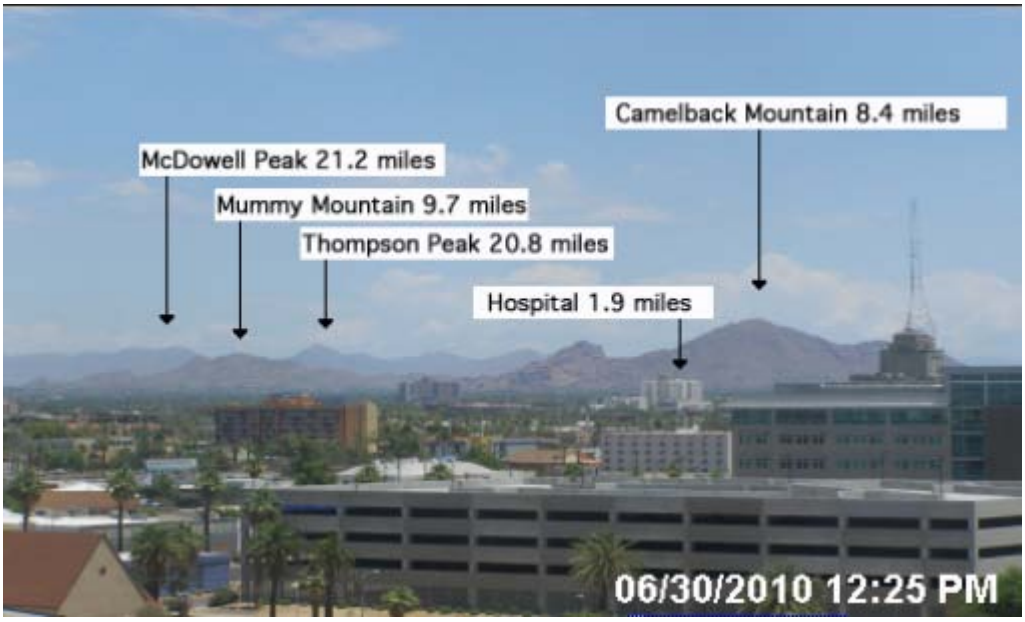
Very Poor

Very Poor visibility day in March with significant enough regional haze throughout the vista that the White Tank Mountains are barely visible.

Map of White Tank Mountains Camera Location and View

Camelback Mountain Camera
The Camelback Mountain camera is located in downtown phoenix and looks northeast towards the mountain.

Landmarks



Pristine Conditions

Camelback Mountain Visibility Examples

Good

Typical good visibility day in March with a slight milky appearance of regional haze over the Camelback Mountain monitoring vista.

Fair

Typical fair visibility day in April with a moderate appearance of regional haze over the Camelback Mountain monitoring vista.

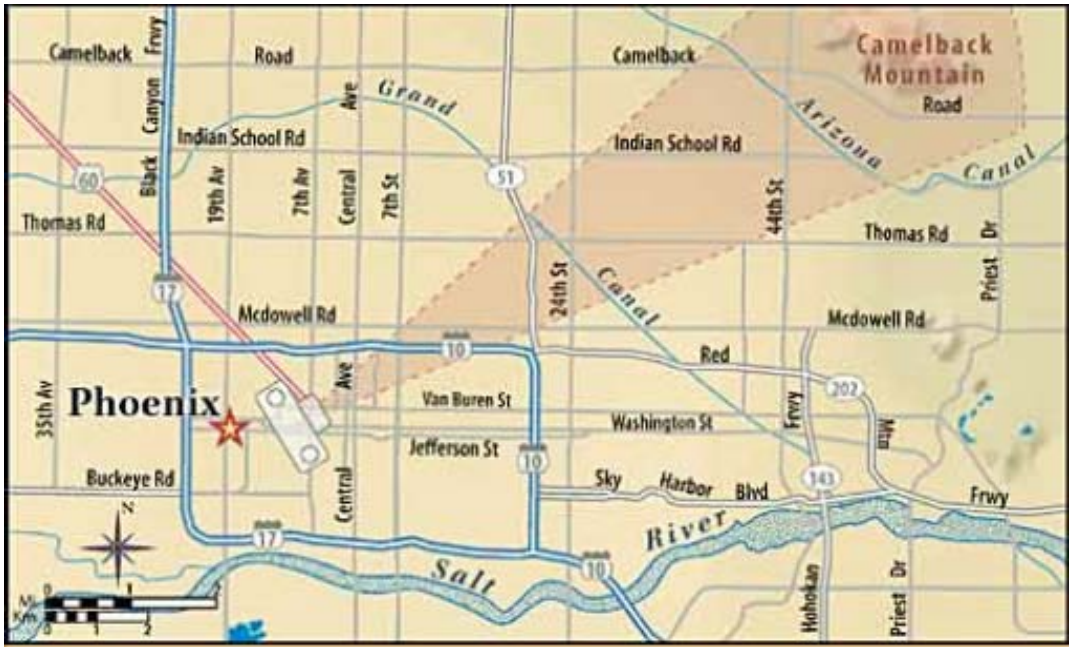
Poor

Poor visibility day with significant enough regional haze throughout the Camelback Mountain monitoring vista that Saddleback Mountain (23 miles) is no longer visible, April.

Very Poor

Very Poor visibility day in March with significant regional haze throughout the Camelback Mountain monitoring vista that Camelback Mountain (8.4 miles) is barely visible.

Map of Camelback Mountain Camera Location and View



Superstition Mountains Camera
The Superstition Mountains camera is located in downtown Mesa which is east of the Phoenix Metro area. The camera looks east with the community of Apache Junction between the camera the mountain range.

Landmarks

Pristine Conditions

Superstition Mountain Visibility Examples

Good

Typical good visibility day in February with a slight milky appearance of regional haze over the Superstition Mountains monitoring vista.

Fair

Typical fair visibility day in October with a moderate appearance of regional haze over the Superstition Mountains monitoring vista.

Poor

Poor visibility day with significant enough regional haze throughout the Superstition Mountains monitoring vista that the Superstition Mountains ridgeline is barely visible, April.

Very Poor

Very poor visibility day in April with significant regional haze throughout the Superstition Mountains monitoring vista. Note the Superstition Mountains ridgeline is no longer visible.

Map of Superstition Mountains Camera Location and View

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Appendix D
Background on Air Quality Advisory Process

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APPENDIX D

BACKGROUND ON AIR QUALITY ADVISORY PROCESS

Background on Air Quality Forecast and Advisory Process

In October of 2003, ADEQ began issuing daily ensemble pollution forecasts which included PM10. Prior to that, ADEQ air quality forecasters were responsible for issuing only summer season ozone forecasts while providing Maricopa County support in the form of weather synopses which the county would then use to aid in its issuance of particulate season (winter) PM_{10} forecasts. ADEQ took over the PM_{10} forecasts in October of 2003, and began issuing Dust Control Forecasts for Maricopa County in April of 2005. These forecasts were necessary due to extended periods where Maricopa County experienced a lack of significant precipitation resulting in dry soils and increased PM_{10}. The dust control forecasts served not only to inform the general public of potential windblown dust events, but also to notify county inspectors as well as warn those working on construction sites of potential high PM_{10} wind events.

When ADEQ air quality meteorologists see conditions which are conducive to creating PM_{10} dust events, namely dry conditions in conjunction with strong or gusty winds, they may set the risk of exceeding the 24-hr PM_{10} health standard in and around the Phoenix metropolitan area to medium or high in the Dust Control Action Forecast for Maricopa County. Additionally, ADEQ air meteorologists can issue a PM_{10} Health Watch when concentrations are expected to approach the 24-hr PM_{10} health standard or a High Pollution Advisory if levels are expected to exceed the health standard due to high winds and windblown dust. Because of the unpredictable nature of monsoon storms during the summer months, forecasting wind-blown dust events can be difficult. When the possibility of these storms exists, air quality meteorologists will often mention it in the Daily Air Quality Forecast or include it as a note in the Dust Control Action Forecast. It is possible that these storms, even when occurring over 100 miles from the Phoenix area, can produce strong outflow boundaries which can travel large distances and cause periods of strong gusty winds and dense blowing dust. This fact is mentioned frequently in the ADEQ Dust Control Action Forecasts.

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Appendix E
Background on Air Quality Programs

APPENDIX E

BACKGROUND ON AIR QUALITY PROGRAMS

The following sections provide a background of the air quality programs in the Maricopa County PM_{10} Nonattainment Area.

The agencies involved in air quality planning, development, implementation and enforcement of actions necessary to attain and maintain the National Ambient Air Quality Standards (NAAQS) in Maricopa County are the Arizona Department of Environmental Quality, the Arizona Department of Transportation, the Maricopa County Air Quality Department, and the Maricopa Association of Governments. The air quality roles and responsibilities of these agencies are described in the first four sections of this Appendix. These relationships are formally defined in the 1992 Air Quality Memorandum of Agreement contained in Appendix A, Exhibit 2, of the MAG 2007 Five Percent Plan for PM_{10} for the Maricopa County Nonattainment Area.

The fifth section of this Appendix provides background on the PM_{10} plans and control measures that have been the focus of air quality programs in Maricopa County for more than a decade. The sixth section discusses the best available control measures (BACM) and most stringent measures (MSMs) included in the Revised MAG 1999 Serious Area Particulate Plan for PM_{10} for the Maricopa County Nonattainment Area that was approved by EPA on June 25, 2002. The final section addresses ongoing efforts to track the implementation of PM_{10} control measures needed to achieve attainment of the PM_{10} NAAQS in the region.

ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY

The Arizona Department of Environmental Quality (ADEQ) has the primary authority to maintain the State Implementation Plan (SIP). Revisions to Arizona's SIP must be submitted to the Environmental Protection Agency (EPA) by the director of ADEQ on behalf of the governor.

ADEQ also recommends to the Governor boundary designations for areas of the state with respect to compliance with the NAAQS. ADEQ has original jurisdiction and control over portable sources Statewide and stationary sources outside of Maricopa, Pima and Pinal Counties. In addition, ADEQ is responsible for developing stationary source permitting procedures and standards.

Some air pollution programs in Maricopa County are reserved for State jurisdiction by the Arizona Legislature; these programs are implemented and enforced by ADEQ, rather than the Maricopa County Air Quality Department. For example, ADEQ implements the Vehicle Emissions Inspection Program in the Maricopa County area.

ARIZONA DEPARTMENT OF TRANSPORTATION

The Arizona Department of Transportation (ADOT) has exclusive control over State highways and all other State owned transportation systems. This includes responsibility for multi-modal state transportation planning and investigation of new transportation systems. ADOT coordinates and cooperates with local governments in transportation planning and developing and operating public transit systems. The ADOT Director may enter into agreements with political subdivisions to improve, maintain and construct mass transit systems and provide rules for the application for and expenditure of mass transit funds. ADOT is also authorized to conduct demonstration projects to evaluate the effectiveness of new, extended, improved or integrated public transportation services and carpooling or vanpooling activities in meeting regional transportation needs or improving air quality.

MARICOPA COUNTY AIR QUALITY DEPARTMENT

The Maricopa County Air Quality Department (MCAQD) is the local air pollution control regulatory agency governed by the Maricopa County Board of Supervisors. The Director of MCAQD is designated as the Air Pollution Control Officer and has the authority to enforce Article 3, Chapter 3, Title 49, "County Air Pollution Control" of Arizona Revised Statutes.

The agency has jurisdiction over all air pollution sources not explicitly reserved for State jurisdiction. MCAQD is responsible for administering the Maricopa County Travel Reduction Program. The agency is also responsible for monitoring the ambient air quality of the region by collecting and analyzing air quality data.

MARICOPA ASSOCIATION OF GOVERNMENTS

The Maricopa Association of Governments (MAG) is a nonprofit Arizona corporation composed of twenty-five cities and towns within Maricopa County and the contiguous urbanized area, the County of Maricopa, the Gila River Indian Community, the Salt River Pima-Maricopa Indian Community, Fort McDowell Yavapai Nation, and the Arizona Department of Transportation. MAG was designated by Governor Raul Castro as the lead air quality planning organization for Maricopa County on February 7, 1978. Together with the State, MAG is responsible for determining which elements of the State Implementation Plan revision will be planned, implemented, and enforced by State and local governments in Arizona. In 1992, the Arizona Legislature recertified MAG as the regional planning agency in accordance with Section 174 of the 1990 Clean Air Act Amendments (A.R.S. Section 49-406 A.).

MAG is also the officially designated metropolitan planning organization (MPO) for transportation, as well as the designated agency for preparing population estimates and projections for the Maricopa County area. As the MPO, MAG is responsible for making transportation/air quality conformity determinations, subject to the consultation procedures provided by law.

All regional air quality plans are prepared through a coordinated effort among the Arizona Department of Environmental Quality, Arizona Department of Transportation, Maricopa County Air Quality Department, and the Maricopa Association of Governments. The regional air quality planning technical process is coordinated through the MAG Air Quality Policy Team and MAG Air Quality Planning Team. Figure 1 contains a description of the generalized roles and areas of expertise of the agencies that participate on the MAG Air Quality Planning Team.

The MAG decision making structure is illustrated in Figure 2. The decision making body for MAG is the Regional Council, which is composed of elected officials from the member agencies. The MAG Management Committee, which is comprised of managers from the member agencies, makes recommendations to the Regional Council. The MAG Air Quality Technical Advisory Committee was established by the MAG Regional Council in 1995. The purpose of the Committee is to review and comment on technical information generated during the planning process and make technical recommendations to the MAG Management Committee.

As indicated above, MAG develops the air quality plans in technical coordination with the Air Quality Policy and Planning Teams. Every draft plan then undergoes a 30-day public comment period and hearing, followed by a review and approval process involving the MAG Air Quality Technical Advisory Committee, the MAG Management Committee, and the MAG Regional Council. After the Regional Council approves an air quality plan, it is submitted to ADEQ. ADEQ then submits the plan to EPA as a revision to the State Implementation Plan. Every plan contains legally-enforceable air quality control measures; those included in the two PM_{10} Plans most recently submitted to EPA are discussed in the next section.

PM_{10} PLANS AND CONTROL MEASURES

Under Section 107(d)(4) of the Clean Air Act, the PM_{10} nonattainment area in the Maricopa County area was initially classified as "Moderate" with an attainment date of December 31, 1994. The PM_{10} standard was not achieved by that date. By operation of law, the nonattainment area was reclassified to Serious, effective June 10, 1996, with a new attainment date of December 31, 2001. In coordination with the Air Quality Policy and Planning Teams, MAG prepared the Revised MAG 1999 Serious Area Particulate Plan for PM_{10} for the Maricopa County Nonattainment Area. The Serious Area PM_{10} Plan was submitted to EPA in February 2000. In addition to an attainment demonstration, the Plan contained a request for an extension of the attainment date to December 31, 2006. Collectively, the Serious Area Plan contained seventy-seven committed control measures from the State, Maricopa County and local governments. EPA approved the Serious Area Plan and extension request on July 25, 2002.

On May 25, 2007, EPA issued a final ruling that the Maricopa County nonattainment area did not attain the PM_{10} standard by December 31, 2006. In accordance with Section 189(d) of the Clean Air Act, MAG prepared the MAG 2007 Five Percent Plan for PM_{10} for the Maricopa County Nonattainment Area that was submitted to EPA by December 31, 2007. The Plan included fifty-three committed control measures from the State, Maricopa County, and local governments. As required by Section 189(d), the Plan demonstrated reductions in PM_{10}

FIGURE 1
MAG REGIONAL AIR QUALITY PLANNING TECHNICAL PROCESS

MAG AIR QUALITY POLICY TEAM

Composition: Director of Arizona Department of Environmental Quality; Director of Arizona Department of Transportation; Air Pollution Control Officer of Maricopa County; MAG Executive Director

- Oversees preparation of plans and overall technical planning effort
- Resolves technical problems and issues

MAG AIR QUALITY PLANNING TEAM

Composition: Staff from the Arizona Department of Environmental Quality, Arizona Department of Transportation; Maricopa County Air Quality Department; Maricopa Association of Governments

Agency Roles

- Arizona Department of Environmental Quality - air quality modeling and technical assistance, mobile source emissions research and inventory, input for the comprehensive list of measures and feasibility analysis, information, relating to the Vehicle Emission Inspection Maintenance Program, stationary and portable source control strategies, air quality research studies, State Air Quality Fund administration, adoption and submittal of State Implementation Plans to the Environmental Protection Agency, tracking plan implementation, assurances, special purpose air quality and meteorological monitoring for plan development and compliance
- Arizona Department of Transportation - State Transportation Improvement Program, other transportation plans and programs, input for the comprehensive list of measures and feasibility analysis
- Maricopa County Air Quality Department - stationary source emissions inventory and controls, coordinating the comprehensive emissions, inventory, air quality monitoring data, input for comprehensive list of measures and feasibility analysis, mandatory travel reduction program, trip reduction data, voluntary no drive days program, tracking plan implementation, reasonable further progress, assurances, special purpose air quality and meteorological monitoring for plan development and compliance
- Maricopa Association of Governments - demographic projections and socioeconomic data, transportation modeling, air quality modeling, Regional Transportation improvement Program, Regional Transportation Plan, other transportation plans and programs, congestion management system, conformity, input for comprehensive list of measures and feasibility analysis, development of the air quality plans, interface with state, county, and local entities, recommending future year travel reduction goals, policies, and standards to Maricopa County, assistance to Maricopa County for the mandatory travel reduction program, review reasonable further progress made to reduce air pollution and plan adjustments if necessary, review plan implementation

The technical planning work is closely coordinated with EPA Region IX staff, Federal Highway Administration, and Federal Transit Administration.

FIGURE 2
MAG REGIONAL AIR QUALITY PLANNING PROCESS

MAG REGIONAL COUNCIL

Composition: Elected officials from 25 cities and towns within Maricopa County and the contiguous urbanized area, the County of Maricopa, the Gila River Indian Community, the Salt River Pima-Maricopa Indian Community, Fort McDowell Yavapai Nation, Arizona Department of Transportation, and Citizens Transportation Oversight Committee.

MAG MANAGEMENT COMMITTEE

Composition: Managers from 25 cities and towns within Maricopa County and the contiguous urbanized area, the County of Maricopa, the Gila River Indian Community, the Salt River Pima-Maricopa Indian Community, Fort McDowell Yavapai Nation, Arizona Department of Transportation, and Regional Public Transportation Committee.

MAG AIR QUALITY TECHNICAL ADVISORY COMMITTEE

Composition: MAG member agencies, citizens, and representatives from the following interests: health, environment, automobile industry, fuel industry and utilities, public transit, trucking industry, rock products industry, construction firms, housing industry, agriculture, industry, business, biogenics, parties to the Air Quality Memorandum of Agreement, other State and Federal entities.

emissions of five percent per year until the standard is attained, as measured at the monitors, by December 31, 2010. As specified in the Clean Air Act, the plan was based upon the most recent emissions inventory for the area and included a modeling demonstration of attainment.

During the process of developing the Serious Area and Five Percent Plans, the State, Maricopa County, and local governments reviewed the measures from a Suggested List of Measures to Reduce PM_{10} Particulate Matter which were under their respective authorities. Each entity then determined which measures were technologically and economically feasible for implementation by that entity.

MAG received formal resolutions with commitments to implement PM_{10} control measures from the State, Maricopa County, and the local governments in the PM_{10} nonattainment area. These resolutions were reviewed in order to determine which measures received firm commitments for inclusion in the MAG Serious Area or Five Percent Plans for PM_{10}. According to the Arizona Department of Environmental Quality, the criteria for a firm commitment include: measures with the implementation, funding and time frame specified; ongoing programs; commitments to implement measures without a specific funding source identified; commitments to draft documents; and commitments to conduct feasibility studies. Jurisdictional support for a measure is not a firm commitment unless the jurisdiction also agrees to enforce the measure. Measures were also analyzed by MAG to determine which could be used for numeric credit towards the attainment demonstration (and the five percent per year requirement, in the case of the Five Percent Plan).

For the Serious Area PM_{10} Plan, the Arizona Legislature passed legislation for several air quality measures in 1996, 1997 and 1998. The primary pieces of legislation included Senate Bill 1002 passed in a 1996 Special Session; House Bills 2237 and 2307 passed during the 1997 Regular Session; Senate Bills 1427 and 1269 and House Bill 2347 passed during the 1998 Regular Session; House Bill 2001 passed in a December 1998 Special Session, and House Bill 2254 passed during the 1999 Regular Session. Since legislation constitutes a firm commitment, these measures were included in the Serious Area PM_{10} Plan.

For the Five Percent Plan, the Arizona Legislature passed Senate Bill 1552 in 2007 which included numerous air quality measures designed to reduce PM_{10}. Since legislation constitutes a firm commitment, these measures were also included in the Five Percent Plan for PM_{10}.

ADEQ was the implementing entity for a number of measures in the Five Percent Plan, including Certification Program for Dust Free Developments (Measure 5), Leafblower Outreach Program (Measure 22), Agricultural Best Management Practices (Measures 41, 42 and 50), and Outreach to Off-road Vehicle Purchasers (Measure 46).

In the Five Percent Plan, ADOT committed to Replace or Overlay Paved Roads with Rubberized Asphalt on 5.14 miles of Interstate and State highways. In addition, ADOT committed to support the Public Education and Outreach Program (Measure 1), Sweep State Highways with PM_{10} Certified Street Sweepers (Measure 24), Pave or Stabilize Unpaved Shoulders on State Highways (Measure 28), and Coordinate Public Transit Services with Pinal County (Measure 52).

MCAQD committed to implement 39 control measures in the Five Percent Plan, including an Extensive Dust Control Training Program (Measure 2), Dust Managers Required at Construction Sites > 5 Acres (Measures 3 and 16), Conduct Night-time and Weekend Inspections (Measure 8), Develop a Program for Subcontractors (Measure 13), Vacant Lot Controls (Measures 30-33), No Visible Emissions Across the Property Line (Measure 38), and Woodburning Restrictions (Measures 35, 47 and 48). Many of these measures required MCAQD to strengthen existing County Rules and increase their enforcement; e.g., Rule 310 for Fugitive Dust from Dust Generating Operations; Rule 310.01 for Fugitive Dust from Non-Traditional Sources of Fugitive Dust; and Rule 316 for Nonmetallic Mineral Processing.

MAG and the local governments in the PM_{10} nonattainment area also made commitments to implement a number of control measures in the Five Percent Plan. MAG committed to allocate an additional $5 million for paving unpaved roads and shoulders in FY 2007 (Measure 43). Local governments committed to implement 15 measures, including Paving or Stabilizing Existing Unpaved Parking Lots (Measure 25), Public Dirt Roads and Alleys (Measure 26), and Unpaved Shoulders (Measure 28).

Collectively, a broad range of commitments were received from the State, Maricopa County and local governments in the PM_{10} nonattainment area for the Serious Area and Five Percent Plans. These extensive commitments demonstrate the level of effort that is being made to improve air quality. The control measures in the Serious Area and Five Percent Plans address every anthropogenic source of PM_{10} emissions and are being implemented throughout the entire PM_{10} nonattainment area.

Table 1 lists the seventy-seven committed measures contained in the EPA-approved Revised MAG 1999 Serious Area Particulate Plan for PM_{10} for the Maricopa County Nonattainment Area. Table 2 contains the fifty-three additional committed measures in the MAG 2007 Five Percent Plan for PM_{10} for the Maricopa County Nonattainment Area. The right-hand column of Tables 1 and 2 contains the page references to the detailed descriptions of the PM_{10} measures in the Serious Area Plan and Five Percent Plan, respectively. The Executive Summaries from each of these Plans are attached as Exhibits 1 and 2. The next section discusses the analysis that was conducted to demonstrate that the committed control measures in the Serious Area PM_{10} Plan represent best available control measures (BACM) and most stringent measures (MSMs).

TABLE 1
SERIOUS AREA PARTICULATE PLAN FOR PM_{10}
COMMITTED MEASURES

PART 1: NEW MEASURES

1. Phased -In Emission Test Cutpoints 7-2
2. Enhanced Emission Testing of Constant Four-Wheel Drive Vehicles 7-8
3. One-Time Waiver from Vehicle Emissions Test 7-10
4. Increased Waiver Repair Limit Options 7-10
5. Gross Polluter Option for I/M Program Waivers 7-10
6. Catalytic Converter Replacement Program 7-11
7. Vehicle Repair Grant Program 7-11
8. Voluntary Vehicle Repair and Retrofit Program 7-11
9. Tougher Enforcement of Vehicle Registration and Emissions Test Compliance 7-13
10. Random Roadside Testing of Diesel Vehicles 7-14
11. Snap Acceleration Test for Heavy-Duty Diesel 7-15
12. Require Pre-1988 Heavy-Duty Diesel Commercial Vehicles Registered in the Nonattainment Area to Meet 1988 Federal Emissions Standards; Provide Incentives to Encourage Voluntary Accelerated Vehicle Replacement By the Year 2004 7-15
13. Short-Term Reformulation: June 1, 1998 - September 30, 1998 7-16
14. Long - Term Fuel Reformulation: From and After May 1, 1999 7-16
15. Winter Fuel Reformulation: California Phase 2 Reformulated Gasoline with 3.5 Percent Oxygen Content November 1 through March 31 7-17
16. Limit Sulfur Content of Diesel Fuel Oil to 500 ppm 7-19
17. Diesel Fuel Sampling and Reporting 7-19
18. Alternative Fuel Vehicles for Local Governments, School Districts and Federal Government/Low Emission Vehicle Requirements 7-19
19. Alternative Fuel Vehicles for State Government/Low Emission Vehicle Requirements 7-21
20. Alternative Fuel Vehicle and Equipment Tax Incentives/Low Emission Vehicle Requirements 7-22
21. Public Awareness Program for Alternative Fuels 7-24
22. National Low Emission Vehicle Program 7-24
23. Voluntary Gasoline Vehicle Retirement Program/Maricopa County Travel Reduction Program 7-24
24. Oxidation Catalyst for Heavy Duty Diesel Vehicles 7-25
25. Mass Transit Alternatives 7-26
26. Develop Intelligent Transportation Systems 7-31
27. Special Event Controls-Required Implementation from List of Approved Strategies 7-37
28. Voluntary Lawn Mower Emissions Reduction Program 7-41
29. Off-Road Vehicle and Engine Standards 7-42
30. Encourage the Use of Temporary Electrical Power Lines Rather than Portable Generators at Construction Sites 7-43

TABLE 1
SERIOUS AREA PARTICULATE PLAN FOR PM_{10}
COMMITTED MEASURES (Continued)

PART 1: NEW MEASURES

31. Defer Emissions Associated With Governmental Activities 7-48
32. Clean Burning Fireplace Ordinances 7-54
33. Public Information Program on Wood Stoves and Wood Heat 7-64
34. Encourage Limitations on Vehicle Idling 7-66
35. Expansion of Area A Boundaries 7-66
36. Voluntary No-Drive Days 7-70
37. Analysis of Intersource Credit Trading and Banking Program 7-70
38. PM_{10} Best Available Control Technology (BACT) Determinations for Stationary Sources 7-70
39. Strengthening and Better Enforcement of Fugitive Dust Control Rules 7-71
40. Reduce Particulate Emissions from Unpaved Roads and Alleys 7-76
41. Reduce Particulate Emissions from Unpaved Shoulders on Targeted Arterials 7-96
42. Low Speed Limit for Unpaved Roads 7-111
43. Use of Petroleum Products for Public Road and Street Maintenance 7-111
44. Crack Seal Equipment 7-111
45. Reduce Particulate Emissions from Unpaved Parking Lots 7-111
46. Reduce Particulate Emissions from Vacant Disturbed Lots 7-128
47. Dust Control Plans for Construction/Land Clearing and Industrial Sites (Including Active Landfills), With Elements Addressing Trackout Prevention, Site and Material Maintenance, Construction Staging, and High Wind Operating Restrictions .. 7-156
48. Dust Abatement and Management Plan for State Lands 7-156
49. Agricultural Best Management Practices 7-156
50. PM_{10} Efficient Street Sweepers 7-158
51. Research in Areas with High Particulate Emissions 7-182
52. Restaurant Charbroiler Controls 7-183
53. PM_{10} Episode Thresholds 7-184

PART 2: EXISTING MEASURES WHICH ARE BEING STRENGTHENED

54. Remote Sensing 1-185
55. Expansion of Public Transportation Programs 7-185
56. Employer Rideshare Program Incentives 7-192
57. Preferential Parking for Carpools and Vanpools 7-198
58. Coordinate Traffic Signal Systems 7-204
59. Reduce Traffic Congestion at Major Intersections 7-208
60. Site-Specific Transportation Control Measures 7-213
61. Encouragement of Bicycle Travel 7-218

TABLE 1
SERIOUS AREA PARTICULATE PLAN FOR PM_{10}
COMMITTED MEASURES (Continued)

PART 2: EXISTING MEASURES WHICH ARE BEING STRENGTHENED

62. Development of Bicycle Travel Facilities 7-226
63. Alternative Work Schedules 7-232
64. Land Use/Development Alternatives 7-238
65. Encouragement of Pedestrian Travel 7-245
66. Restrictions on the Use of Gasoline-Powered Blowers for Landscaping Maintenance . 7-253
67. Alternative Fuels for Fleets 7-256
68. Areawide Public Awareness Programs 7-256
69. Paving, Vegetating and Chemically Stabilizing Unpaved Access Points Onto Paved Roads (Especially Adjacent to Construction/Industrial Sites) 7-257
70. Curbing, Paving or Stabilizing Shoulders on Paved Roads (Includes Painting Stripe on Outside of Travel Lane) 7-265
71. Frequent Routine Sweeping or Cleaning of Paved Roads 7-271

PART 3: ADDITIONAL COMMITMENTS FOR MEASURES NOT ON THE SUGGESTED LIST

72. Encouragement of Vanpooling 7-278
73. Trip Reduction Program 7-278
74. Park and Ride Lots 7-279
75. Encouragement of Telecommuting, Teleworking and Teleconferencing 7-279
76. Promotion of High Occupancy Vehicle Lanes and By-Pass Ramps 7-281
77. Additional Dust Control Measures 7-281

TABLE 2
FIVE PERCENT PLAN FOR PM_{10} COMMITTED MEASURES

PART 1: MEASURES RELATED TO THE SUGGESTED LIST

1. Public education and outreach with assistance from local governments 6-2
2. Extensive Dust Control Training Program 6-20
3. Dust Managers required at construction sites of 50 acres and greater 6-24
4. Dedicated enforcement coordinator for unpaved roads, unpaved parking, and vacant lots 6-27
5. Establish a certification program for Dust-Free Development to serve as an industry Standard 6-29
6. Better defined tarping requirements in Rule 310 to include enclosure of the bed 6-30
7. Conduct mobile monitoring to measure PM_{10} and issue NOVs 6-32
8. Conduct nighttime and weekend consistent inspections 6-33
9. Increase consistent inspection frequency for permitted sources 6-34
10. Increase number of proactive consistent inspections in areas of highest PM_{10} Emissions densities 6-37
11. Notify violators more rapidly to promote immediate compliance 6-40
12. Provide timely notification regarding high pollution days 6-41
13. Develop a program for subcontractors 6-42
14. Reduce dragout and trackout emissions from nonpermitted sources 6-44
15. Cover loads/haul trucks in Apache Junction 6-45
16. Require dust coordinator at earthmoving sites of 5-50 acres 6-46
17. Fully implement Rule 316 6-49
18. Ban or discourage use of leaf blowers on high pollution advisory days 6-50
19. Reduce off-road vehicle use in areas with high off-road vehicle activity impoundment or confiscation of vehicles for repeat violations 6-53
20. Provide incentives to retrofit nonroad diesel engines and encourage early replacements with advance technologies 6-67
21. Ban leaf blowers from blowing debris into streets 6-69
22. Implement a leaf blower outreach program 6-70
23. Ban ATV use on high pollution days 6-71
24. Sweep street with PM_{10} certified street sweepers 6-72
25. Pave or stabilize existing unpaved parking lots 6-86
26. Pave or stabilize existing public dirt roads and alleys 6-103
27. Limit speeds to 15 miles per hour on high traffic dirt roads 6-119
28. Pave or stabilize unpaved shoulders 6-124
29. Create a fund for paving and stabilizing in high pollution areas 6-138
30. Strengthen and increase enforcement of 310.01 for vacant lots 6-139
31. Restrict vehicular use and parking on vacant lots 6-141
32. Enhanced enforcement of trespass ordinances and codes 6-157
33. Ability to assess liens on parcels to cover the cost of stabilizing them (Recover costs of stabilizing vacant lots) 6-169

TABLE 2
FIVE PERCENT PLAN FOR PM_{10} COMMITTED MEASURES (Continued)

PART 1: MEASURES RELATED TO THE SUGGESTED LIST

34. Increase fines for open burning..... 6-172
35. Restrict use of outdoor fireplaces and pits and ambience fireplaces in the hospitality industry..... 6-174
36. Require barriers in addition to Rule 310 stabilization requirements for construction where all activity has ceased, except for sites in compliance with storm water permits..... 6-175
37. Reduce the tolerance of trackout to 25 feet before immediate cleanup is required for construction sites be placed in Maricopa County Rule 310..... 6-177
38. No visible emissions across the property line be placed in Maricopa County Rule 310 and 310.01, and in local ordinances for nonpermitted source appropriate..... 6-180
39. Modeling cumulative impacts-The measure would need further definition by Maricopa County and the Arizona Department of Environmental Quality and be subject to input to ensure that unintended consequences for temporary uses are not created..... 6-184
40. MAG member agencies reexamine existing ordinances to ensure that nonpermitted sources, such as unpaved parking, unpaved staging areas, unpaved roads, unpaved shoulders, vacant lots and open areas, receive priority attention..... 6-185
41. Forward to Governor's Agricultural Best Management Practices Committee that cessation of tilling be required on high wind days and that agricultural best management practices be required in existing Area A..... 6-185
42. The Arizona State Legislature provide funding to the Arizona Department of Environmental Quality for four agriculture dust compliance officers for a total of five inspectors..... 6-186
43. MAG allocate $5 million in FY 2007 MAG federal funds matched on a 50/50 basis by MAG member agencies for paving dirt roads and shoulder projects and that these projects be immediately submitted to MAG for consideration at the July meetings of the MAG Management Committee and Regional Council for an amendment to the Transportation Improvement Program. These funds would be on a nonsupplanting basis for new projects..... 6-186
44. Maricopa County should increase consistent enforcement in areas where PM_{10} violations continue to occur, along with efforts throughout the region. When an area continually experiences higher PM_{10} concentrations than other areas, increased enforcement in areas experiencing high monitor readings is needed to protect public health..... 6-186

TABLE 2
FIVE PERCENT PLAN FOR PM_{10} COMMITTED MEASURES (Continued)

PART 2: ADDITIONAL COMMITMENTS FOR MEASURES NOT ON THE SUGGESTED LIST

45. Prohibit use of leaf blowers on unstabilized surfaces 6-189
46. Outreach to off-road vehicle purchasers 6-190
47. Ban open burning during the ozone season 6-190
48. Require residential woodburning ordinances to include no burn restrictions on high pollution advisory days 6-191
49. Allow Peace Officer enforcement of load covering 6-191
50. Require two agricultural best management practices 6-191
51. Conduct an inventory of dirt roads, alleys and estimated traffic counts 6-192
52. Coordinate public transit services with Pinal County 6-192
53. Repave or overlay paved roads with rubberized asphalt 6-193

BEST AVAILABLE CONTROL MEASURES AND MOST STRINGENT MEASURES

In the Serious Area PM_{10} Plan, the committed control measures were evaluated to determine if they represented Best Available Control Measures (BACM). The process used by MAG to determine if the measures in the Serious Area Plan were BACM is illustrated in Figure 3. This analysis is documented in Chapter Nine of the Serious Area PM_{10} Plan.

The Clean Air Act required each Serious PM_{10} nonattainment area to attain air quality standards by December 31, 2001. For those areas that could not reach attainment by this date, section 188(e) of the Act allows the deadline to be extended for up to five years. Therefore, the Serious Area PM_{10} Plan included a request for extension of the PM_{10} attainment date from December 31, 2001 to December 31, 2006. Among other requirements, the Clean Air Act requires that the extension request demonstrate that the State Implementation Plan for that area includes the most stringent measures that are included in the implementation plan of any state or are achieved in practice in any state, and can feasibly be implemented in the area. After an exhaustive search and evaluation process, fourteen potential measures were identified as most stringent measures and implementing jurisdictions have committed to implement those determined to be feasible for implementation in the Maricopa County nonattainment area. The most stringent measures (MSMs) are shown in Table 3. The extension request and the MSM analysis are documented in Chapter Ten of the Serious Area PM_{10} Plan.

FIGURE 3

Process Used to Determine Best Available Control Measures

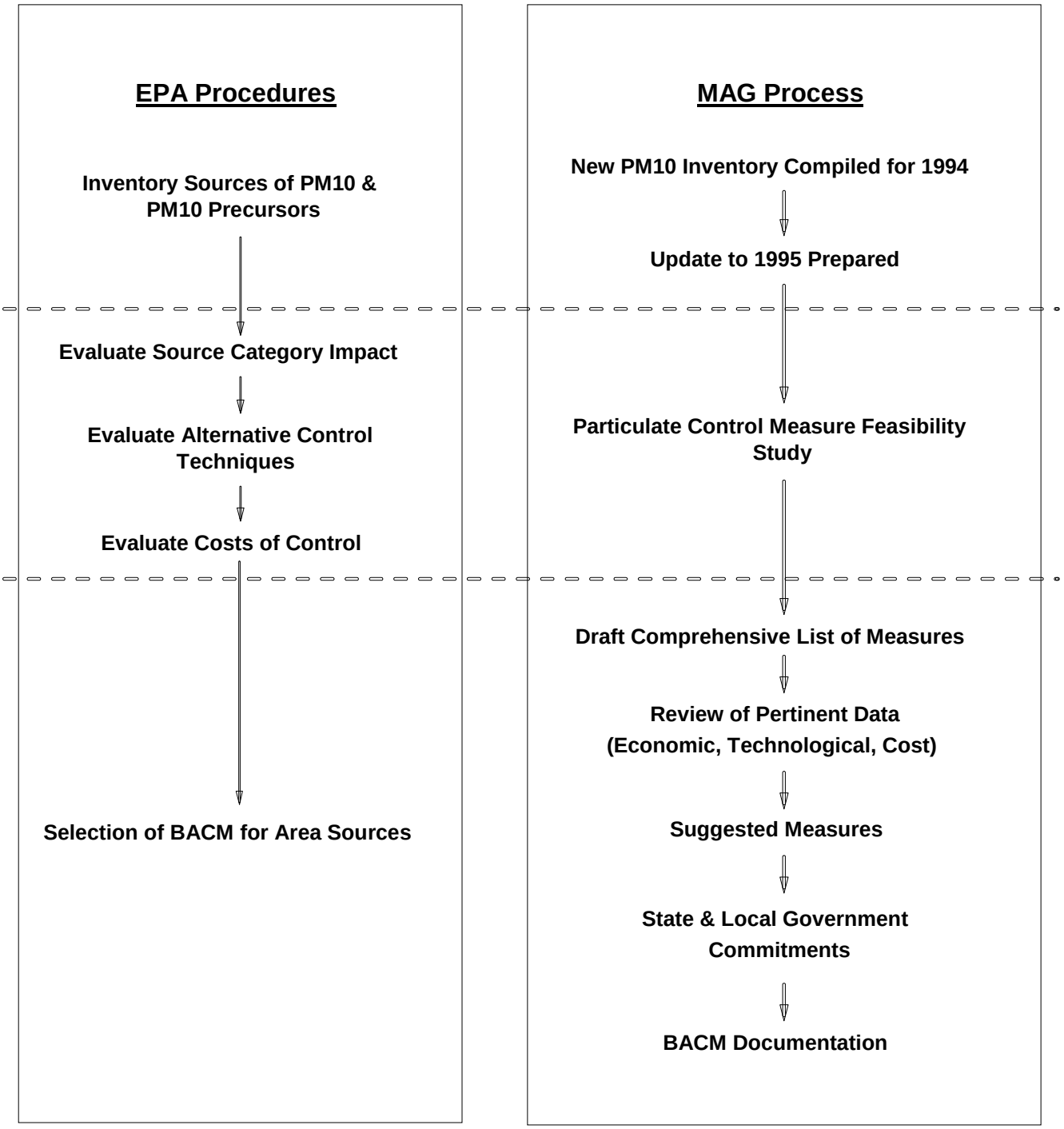


TABLE 3
MOST STRINGENT PM_{10} CONTROL MEASURE SUMMARY

Control Measure *(Where Implemented)*	***PM_{10} Reduction in 2006 (m-tons/day) (margin of error)***	***Cost Effectiveness of PM_{10} Reduction ($/m-ton) (margin of error)***	***Potential Implementing Entity***
1. Restaurant Charbroiler Controls (South Coast, California)	0.07 *(± 20%)*	5,620 *(± 40%)*	Maricopa County
2. *PM_{10}* Episode Thresholds *(State of Washington)*	0.27 *(± 30%)*	726 *(± 50%)*	Maricopa County
3. Firewood Moisture Limits *(State of Washington)*	0.00	-	(Infeasible - No Benefit)
4. Ban on Solid Fuel Burning Devices in New & Modified Construction *(San Miguel County, Colorado)*	0.23 *(± 30%)*	41 *(± 50%)*	Maricopa County
5. Limit Emissions of New Woodstoves & Inserts to 60% of EPA Phase II Standards *(State of Washington)*	0.003 *(± 50%)*	226,000 *(± 50%)*	Maricopa County
6. Retrofit of Fireplaces & Uncertified Woodstoves *(Telluride, Colorado)*	0.64 *(± 20%)*	172,000 *(± 20%)*	Maricopa County
7. Curtailment of Woodheating *(Missoula, Montana)*	0.002 *(± 30%)*	120,000 *(± 30%)*	Maricopa County
8. Cessation of High Wind Tilling *(Coachella Valley, California)*	0.06 *(± 50%)*	1,720 *(± 75%)*	State of Arizona
9. Implement High-Wind Condition BACMs *(South Coast, California)*	0.27 *(± 50%)*	247,000 *(± 50%)*	Maricopa County
10. *PM_{10}* Efficient Street Sweeping *(South Coast, California)*	3.15 *(± 50%)*	668 *(± 100%)*	Cities, ADOT, Maricopa County
11. Agricultural Soil Erosion Plans *(South Coast, California)*	0.11 *(± 75%)*	220,000 *(± 75%)*	State of Arizona
12. Bulk Material Rapid Stabilization *(Coachella Valley Blowsand Zone)*	0.08 *(± 75%)*	12,300 *(± 50%)*	Maricopa County
13. Zero-Opacity Emissions *(Clark County, Nevada)*	0.44 *(± 30%)*	998 *(± 50%)*	Maricopa County
14. CARB Diesel or Other Clean Diesel Fuel *(State of California)*	0.83 *(± 20%)*	86,923 *(± 100%)*	State of Arizona

TRACKING PM_{10} PLAN IMPLEMENTATION

The Maricopa County Air Quality Department has the responsibility of determining reasonable further progress and reviewing the implementation status of the measures contained in the air quality plans. In order to accurately monitor implementation of the measures in the Five Percent Plan, the Maricopa Association of Governments is providing assistance to the Maricopa County Air Quality Department by requesting that the implementing agencies and jurisdictions provide information on the status of measure implementation. An implementation status report will be prepared by MAG in 2008, 2009 and 2010. On February 24, 2010, the MAG Regional Council took action to forward the 2008 Implementation Status of Committed Measures in the MAG 2007 Five Percent Plan for PM_{10} for the Maricopa County Nonattainment Area to the Governor's Office, the Arizona Legislature, the Arizona Department of Environmental Quality and the Environmental Protection Agency. In general, the implementation results for 2008 meet or exceed the commitments made to implement the measures in the Five Percent Plan. The Maricopa County Air Quality Department continues to have the responsibility for conducting ambient air quality monitoring.

In addition, the Arizona Legislature passed S.B. 1552 in 2007 which includes reporting requirements for the enforcement of PM_{10} measures. Any city, town and county located in a Serious PM_{10} Nonattainment Area or a Maintenance Area that was a Serious PM_{10} Nonattainment Area is required to submit reports on particulate enforcement to the Joint Legislative Budget Committee on June 1 and December 1 in 2008 and 2009. The reports will include the number of notices of violation issued, fines or penalties assessed or other sanctions imposed for particulate violations; number of inspectors or other enforcement personnel employed for purposes of enforcing statutes, rules or ordinances related to particulates; the number of miles of streets, roads, alleys, shoulders and vacant areas paved or otherwise stabilized; and other information relevant to enforcement of particulate measures in the legislation (S.B. 1552, Section 23).

Supplemental to these tracking efforts, the Maricopa Association of Governments publishes regional traffic flow maps and calculates regional vehicle miles of travel from these flow maps. MAG also conducts vehicle occupancy studies and performs special traffic volume and speed studies, as needed. Phoenix Public Transit continuously monitors transit ridership for each month. The Regional Public Transportation Authority collects transit and carpooling ridership information. The Arizona Department of Environmental Quality continuously monitors the number of vehicles inspected in the Vehicle Emissions Inspection Maintenance Program, the number of vehicles failing the test, and the improvement in tailpipe emissions after failed vehicles are repaired.

In addition, the MAG Air Quality Technical Advisory Committee reviews the information pertaining to the implementation of measures. The committee also reviews the air quality monitoring data to assist in tracking air quality improvement over time.

Practically, effectiveness of a control measure can be examined for a specific event or condition in which the degree of implementation, overall effectiveness, and level of enforcement can be determined. This can be achieved by periodic review of rule effectiveness, a record of field

observations or inspections and catalogued enforcement actions. Tracking implementation without periodic review of on-the-ground application and enforcement could provide a false sense of reliance on control measures; a detailed review of control measures under specific circumstances that test overall effectiveness of a measure is essential (e.g., the review completed for an exceptional event demonstration; see *High Wind Exceptional Events and Control Measures for PM_{10} Areas*, October 13, 2009).

EXHIBIT 1

EXECUTIVE SUMMARY

REVISED MAG 1999 SERIOUS AREA PARTICULATE PLAN FOR PM_{10} FOR THE MARICOPA COUNTY NONATTAINMENT AREA

REVISED MAG 1999 SERIOUS AREA PARTICULATE PLAN FOR PM-10 FOR THE MARICOPA COUNTY NONATTAINMENT AREA

EXECUTIVE SUMMARY

MARICOPA ASSOCIATION of GOVERNMENTS

REVISED MAG 1999 SERIOUS AREA PARTICULATE PLAN FOR PM-10
EXECUTIVE SUMMARY

Within the Maricopa County nonattainment area, the National Ambient Air Quality Standards have not yet been attained for three pollutants: particulates (PM-10) carbon monoxide, and ozone. The Maricopa Association of Governments was designated by the Governor of Arizona in 1978 and recertified by the Arizona Legislature in 1992 to serve as the Regional Air Quality Planning Agency to develop plans to address these pollution problems.

In accordance with the 1990 Clean Air Act Amendments, the Maricopa County nonattainment area was initially classified as Moderate for PM-10 particulate pollution. However, on May 10, 1996, the nonattainment area was reclassified to Serious due to failure to attain the particulate standard by December 31, 1994. The Serious Area reclassification was effective on June 10, 1996.

The Clean Air Act requires that a Serious Area Particulate Plan be submitted within eighteen months of the reclassification date. The plan is required to include Best Available Control Measures which are designed to achieve the maximum degree of emissions reduction from a PM-10 source. The Best Available Control Measures are required to be implemented no later than four years after reclassification or by June 10, 2000. Also, the definition of major source is changed from 100 tons to 70 tons per year.

The attainment date for Serious Areas is December 31, 2001. The Clean Air Act also allows the Environmental Protection Agency to extend the attainment date for up to five years if the following requirements are met:

- Attainment by December 31, 2001 is impracticable.
- Compliance with all requirements and commitments in the plan.
- Plan includes the most stringent measures that are included in the plan of any state or are achieved in practice in any state, and can feasibly be implemented in the area.
- Attainment no later than December 31, 2006.

Particulate air pollution can occur throughout the year. The formation of particulate pollution is dependent upon several factors. Among these factors are stagnant masses, severe temperature inversions in the winter, high winds in the summer, and fine, silty soils characteristic of desert locations. In the Maricopa County nonattainment area, fine particulate matter (PM-10) concentrations are elevated during various seasons of the year and under different weather conditions. The variability is due to the diverse composition of PM-10 and the sources contributing to this diversity.

The trend in PM-10 levels for the Maricopa County nonattainment area is presented in Figures ES-1 and ES-2. The annual PM-10 standard is 50 micrograms per cubic meter. In 1996 and 1997, there were five exceedances of the annual standard in each of those years. In 1998, there was one exceedance of the annual standard. The 24-hour PM-10 standard is 150 micrograms per cubic meter. In 1996, there were 11 exceedance days of the 24-hour standard and 12 exceedance days in 1997. In 1998, there were four exceedance days of the 24-hour standard.

Based upon the 1995 base year regional emissions inventory, the primary sources of PM-10 are: Nonroad Sources (construction/earthmoving dust, construction trackout, nonroad engine exhaust, and construction windblown dust) 43.0 percent; Onroad Sources (paved road dust, unpaved road dust, and onroad vehicle exhaust) 32.9 percent; Area Sources (disturbed vacant land and agricultural windblown dust, agricultural dust, other area sources, and residential wood burning) 22.6 percent; and Point Sources 1.5 percent. The sources are depicted in Figure ES-3.

On August 29, 1997, the initial air quality modeling analysis was completed. The modeling did not demonstrate attainment by December 31, 2001 with the committed control measures. A shortfall of a 16.4 percent reduction in PM-10 concentration was identified. Since it appeared that attainment by 2001 was impracticable, an extension request for a later attainment date would be necessary.

On October 29, 1997, the MAG Regional Council took action to direct staff to prepare a request for up to a five-year extension of the attainment date to be included in the Serious Area Particulate Plan for PM-10, for submittal following action by the Legislature. Additional committed measures were needed from the State and local governments to meet the Clean Air Act requirements for the extension request.

On December 3, 1997, the MAG Regional Council approved the submittal of the Serious Area Particulate Control Measures for PM-10 and Support Technical Analysis to EPA by December 10, 1997. This document contained a total of 49 committed control measures designed to reduce particulate pollution.

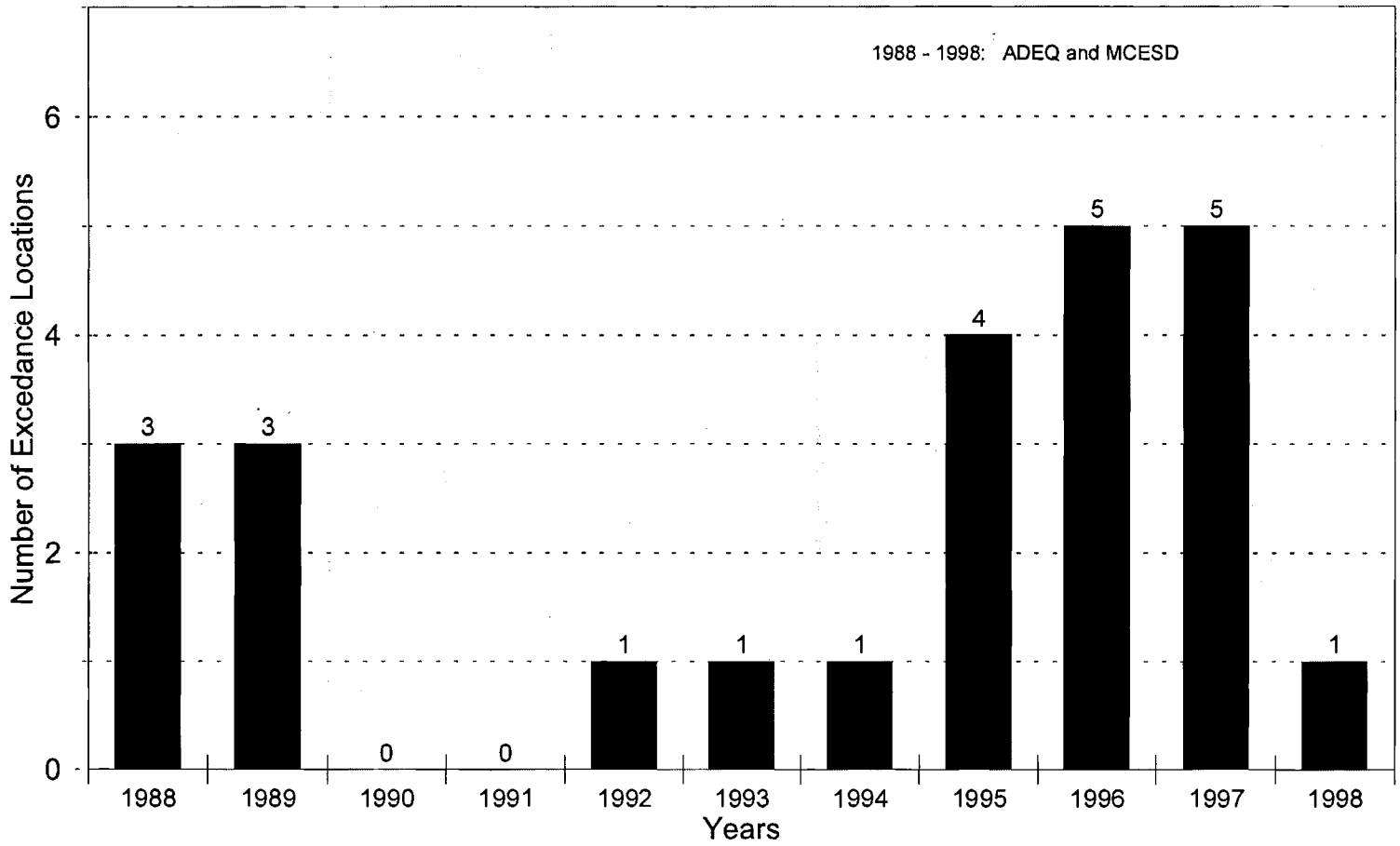
During the next year and a half, a rigorous planning effort was conducted to prepare the extension request elements of the plan and to revise the Maricopa County Fugitive Dust Control Rule 310. On June 16, 1999, the Maricopa County Board of Supervisors approved the Revised Rule 310, for inclusion in the Serious Area Particulate Plan for PM-10.

On June 23, 1999, MAG Regional Council adopted the MAG 1999 Serious Area Particulate Plan for PM-10. Collectively, the plan contained approximately 77 committed control measures from the State and local governments. It is important to note that all of the commitments received are at least Best Available Control Measures (BACM). In general, BACM are required for significant source categories. However, commitments have been received for insignificant source categories, as well. In addition, commitments have been received in support of the Most Stringent Control Measures, as documented in the plan. On July 9, 1999, the Arizona Department of Environmental Quality submitted the Serious Area Particulate Plan for PM-10 to the Environmental Protection Agency. A completeness finding was then issued by EPA on August 4, 1999.

FIGURE ES-1

NUMBER OF EXCEEDANCES OF THE ANNUAL PM-10 STANDARD

Maricopa County, Arizona

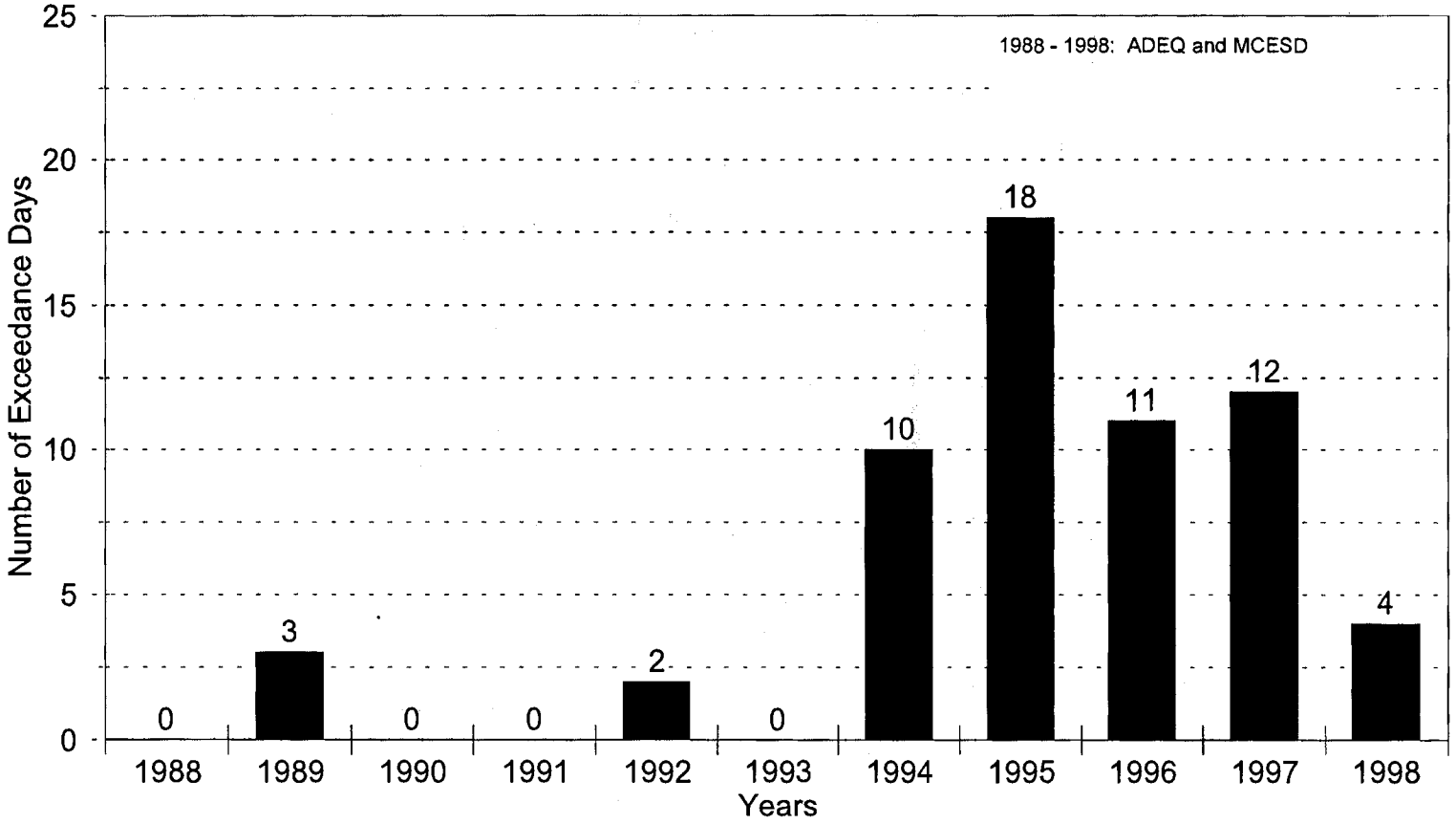


Reported by the Maricopa
Association of Governments
April 7, 1999

ADEQ data for 1998 not available.

FIGURE ES-2

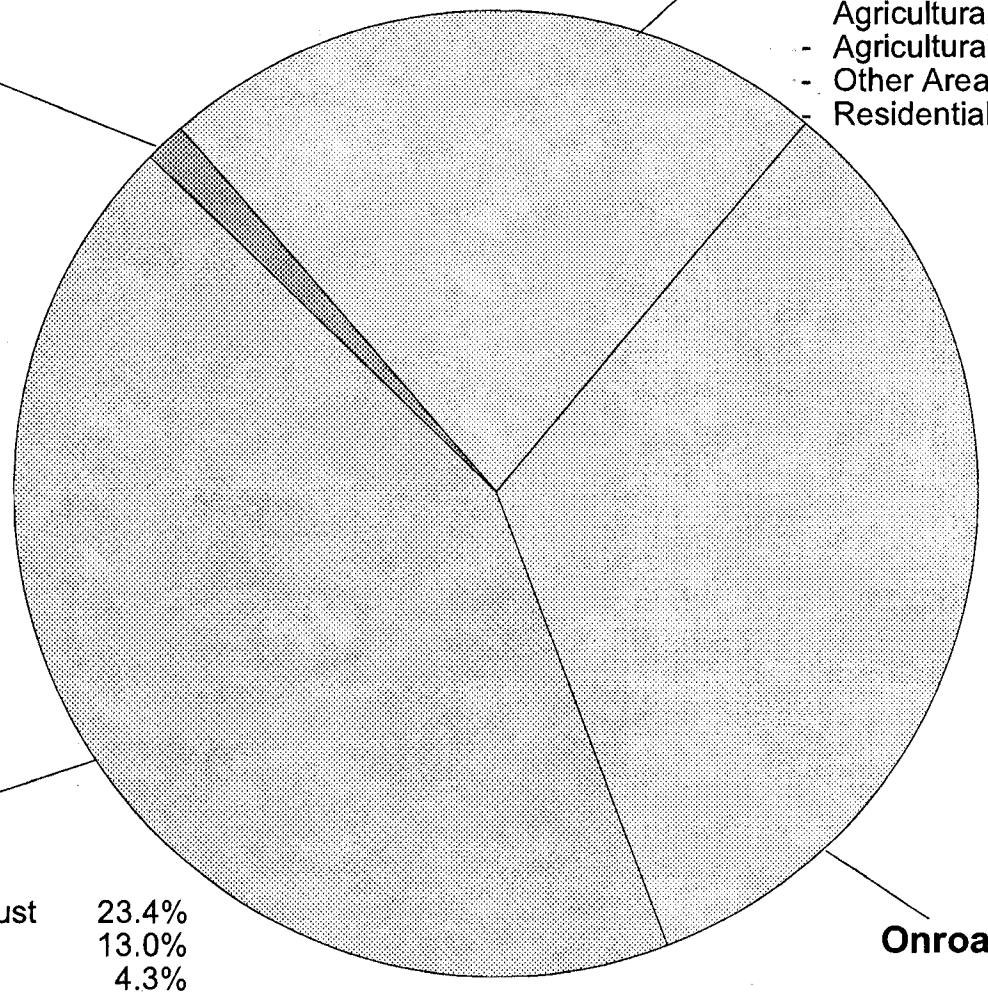
NUMBER OF 24-HR PM-10 EXCEEDANCE DAYS
Maricopa County, Arizona



ADEQ data to 3rd quarter 1998 only.

Reported by the Maricopa
Association of Governments
April 7, 1999

FIGURE ES-3
1995 REGIONAL PM-10 EMISSIONS
(Percent Total Emissions)



On November 9, 1999, EPA notified MAG by telephone and Arizona Governor, Jane Hull, by letter that there is an approvability problem with the 1999 Serious Area Particulate Plan for PM-10. According to EPA, the approvability problem is that the plan assumes that Maricopa County's two fugitive dust control rules will achieve 90 percent compliance by 2006. EPA believes the compliance rate is unrealistic. In addition, EPA believes that the plan barely addresses dust from paved roads and there is no strategy in the plan for reducing dust on private unpaved roads.

To address the approvability problem, the FY 2000-2004 MAG Transportation Improvement Program (TIP) has been amended to include Maricopa County paving dirt road projects and funding to purchase PM-10 certified street sweepers. It is important to note that the Maricopa County paving projects address unpaved roads including private roads that are publicly maintained. The Resolution to Adopt the Revised MAG 1999 Serious Area Particulate Plan for PM-10 for the Maricopa County Area includes a commitment from MAG for PM-10 Efficient Street Sweepers. In addition, the Maricopa County Board of Supervisors has submitted a new commitment to address the approvability issues with the County fugitive dust control rules. The commitment includes steps to strengthen the enforcement of the program.

The air quality modeling previously submitted to EPA has been revised to reflect a lower compliance rate (80 percent) for the County dust control rules. The remodeling also includes the paving of unpaved roads (including private roads that are publicly maintained). The revised modeling assumptions for the control measures used for numeric credit are documented in Chapter V of the Technical Support Document. In addition, the attainment demonstration, reasonable further progress analysis, and impracticability demonstration in Chapter VI of the Technical Support Document have been updated to reflect the revised control measure assumptions.

For the attainment demonstration, the initial "modified rollback" analysis has been replaced with the UAM-LC analysis, a more sophisticated modeling approach. The revised air quality modeling analysis supports the previous initial modeling conclusion that attainment by December 31, 2001 is impracticable.

According to the revised air quality modeling, the committed measures are expected to result in attainment of both the 50 micrograms per cubic meter annual average PM-10 standard and the 150 micrograms per cubic meter 24-hour PM-10 standard in 2006. Specifically, the committed measure package results in an annual PM-10 concentration of 49.68 micrograms per cubic meter and a 24-hour PM-10 concentration of 149.3 micrograms per cubic meter in the attainment year of 2006.

The key measures in the Revised MAG 1999 Serious Area Particulate Plan for PM-10 used for the attainment demonstration include: Strengthening and Better Enforcement of Fugitive Dust Control Rules; Reduce Particulate Emissions from Unpaved Roads and Alleys; Reduce Particulate Emissions from Unpaved Parking Lots; Reduce Particulate Emissions from Vacant Disturbed Lots; PM-10 Efficient Street Sweepers; Curbing, Paving, or Stabilizing Shoulders on Paved Roads; Paving, Vegetating, and Chemically Stabilizing Unpaved Access Points Onto Paved Roads; PM-10 Episode Thresholds; Restaurant Charbroiler Controls; Clean Gasoline (long-term and winter fuel reformulation); Pre-1988

Heavy-Duty Diesel Commercial Vehicle Standards; and Coordinate Traffic Signal Systems. The impacts of these measures are depicted in Figure ES-4.

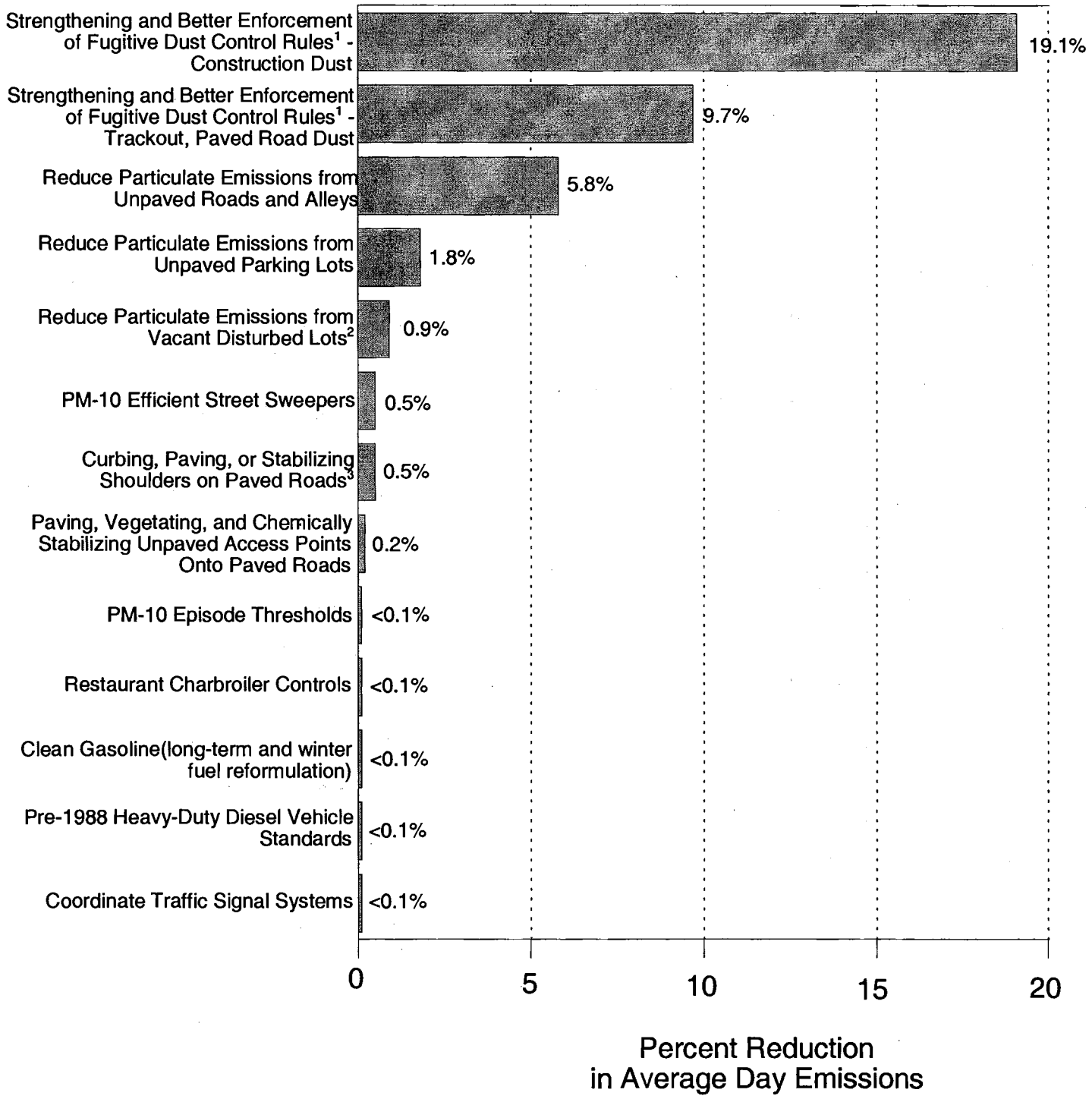
The Revised MAG 1999 Serious Area Particulate Plan for PM-10 also contains contingency measures sufficient to provide emission reductions to off-set one year's reasonable further progress which is 4.6 metric tons per day. Collectively, the impact of the contingency measures is approximately 5.4 metric tons per day.

The key contingency measures in the plan are: Agricultural Best Management Practices; Off-Road Vehicle and Engine Standards; Clean Burning Fireplace Ordinances; and Additional Dust Control Measures (Cities of Phoenix and Tempe). The impacts of these measures are depicted in Figure ES-5.

Consequently, the Revised MAG 1999 Serious Area Particulate Plan for PM-10 demonstrates attainment of the annual and 24-hour PM-10 standard by the December 31, 2006 attainment date. The resulting 2006 PM-10 Attainment Emissions are depicted in Figure ES-6. For conformity analyses, the motor vehicle emissions budget includes reentrained dust from travel on paved roads, vehicular exhaust, travel on unpaved roads, and road construction. Together, these emissions comprise the motor vehicle emissions budget for PM-10 of 59.7 metric tons per day.

FIGURE ES-4

2006 PM-10 Emission Reductions From Committed Control Measures



[1]In addition, the emission reduction includes Dust Control Plans for Construction/Land Clearing and Industrial Sites
[2]In addition, the emission reduction includes Dust Abatement and Management Plan for State Lands
[3]In addition, the emission reduction includes Reduce Particulate Emissions from Unpaved Shoulders on Targeted Arterials

FIGURE ES-5

2006 PM-10 Emission Reductions From Committed Contingency Measures

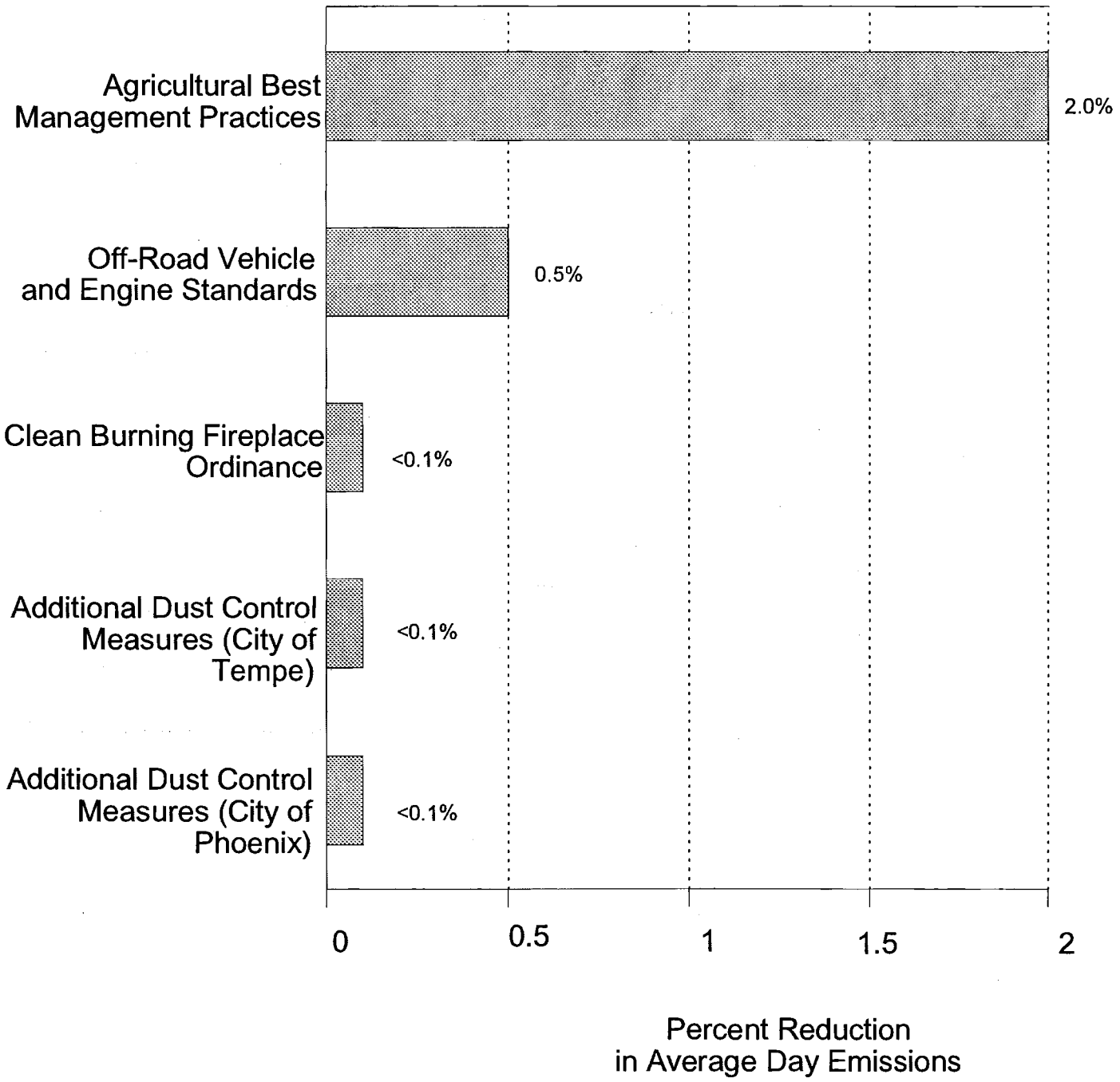


FIGURE ES-6

2006 REGIONAL PM-10 EMISSIONS REFLECTING COMMITTED MEASURES (Percent Total Emissions)

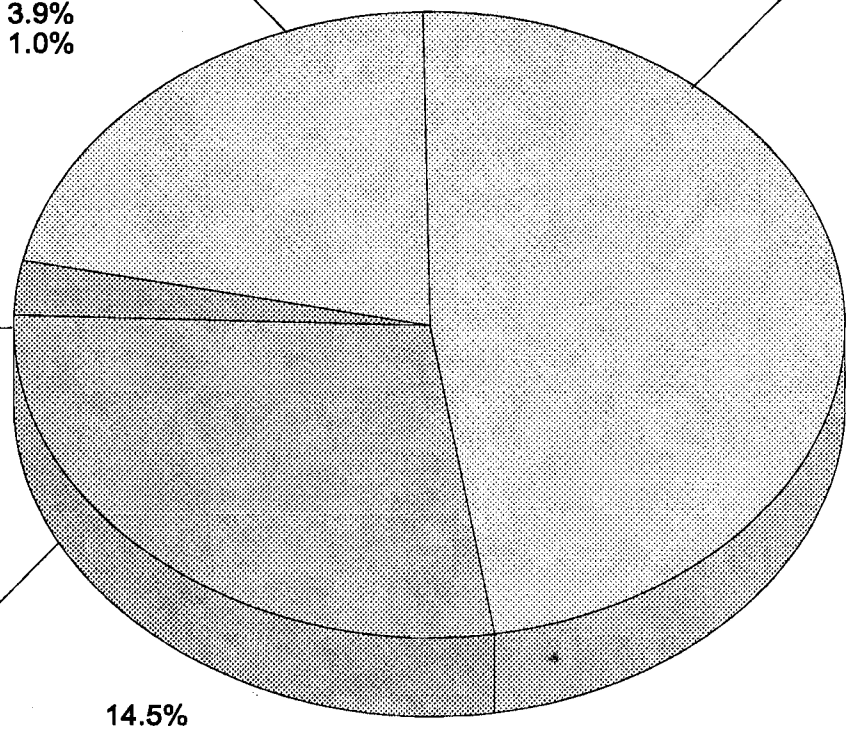


EXHIBIT 2

EXECUTIVE SUMMARY

MAG 2007 FIVE PERCENT PLAN FOR PM_{10} FOR THE MARICOPA COUNTY NONATTAINMENT AREA

MAG 2007 FIVE PERCENT PLAN FOR PM-10 FOR THE MARICOPA COUNTY NONATTAINMENT AREA

EXECUTIVE SUMMARY

MARICOPA ASSOCIATION of GOVERNMENTS

MAG 2007 FIVE PERCENT PLAN FOR PM-10
EXECUTIVE SUMMARY

Within the Maricopa County nonattainment area, the National Ambient Air Quality Standard has not yet been attained for PM-10 particulate pollution. The Maricopa Association of Governments was designated by the Governor of Arizona in 1978 and recertified by the Arizona Legislature in 1992 to serve as the Regional Air Quality Planning Agency to develop plans to address air pollution problems.

Based upon the 1990 Clean Air Act Amendments, the Maricopa County nonattainment area was initially classified as Moderate for PM-10 particulate pollution. However, on May 10, 1996, the nonattainment area was reclassified to Serious due to failure to attain the particulate standard by December 31, 1994. The Serious Area reclassification was effective on June 10, 1996.

The Revised MAG 1999 Serious Area Particulate Plan for PM-10 for the Maricopa County Nonattainment Area was submitted to the Environmental Protection Agency (EPA) in February 2000. On July 25, 2002, EPA published a notice of final approval for the plan. Collectively, the plan contained approximately seventy-seven committed control measures from the State and local governments. The plan demonstrated attainment of the PM-10 standard by December 31, 2006.

In order to be in attainment, the region needed three years of clean data at the monitors for 2004, 2005, and 2006. However, there were numerous exceedances of the 24-hour standard in 2005 and 2006. On June 6, 2007, EPA published a final notice with its findings that the Maricopa County nonattainment area had failed to attain the PM-10 standard by the federal deadline of December 31, 2006.

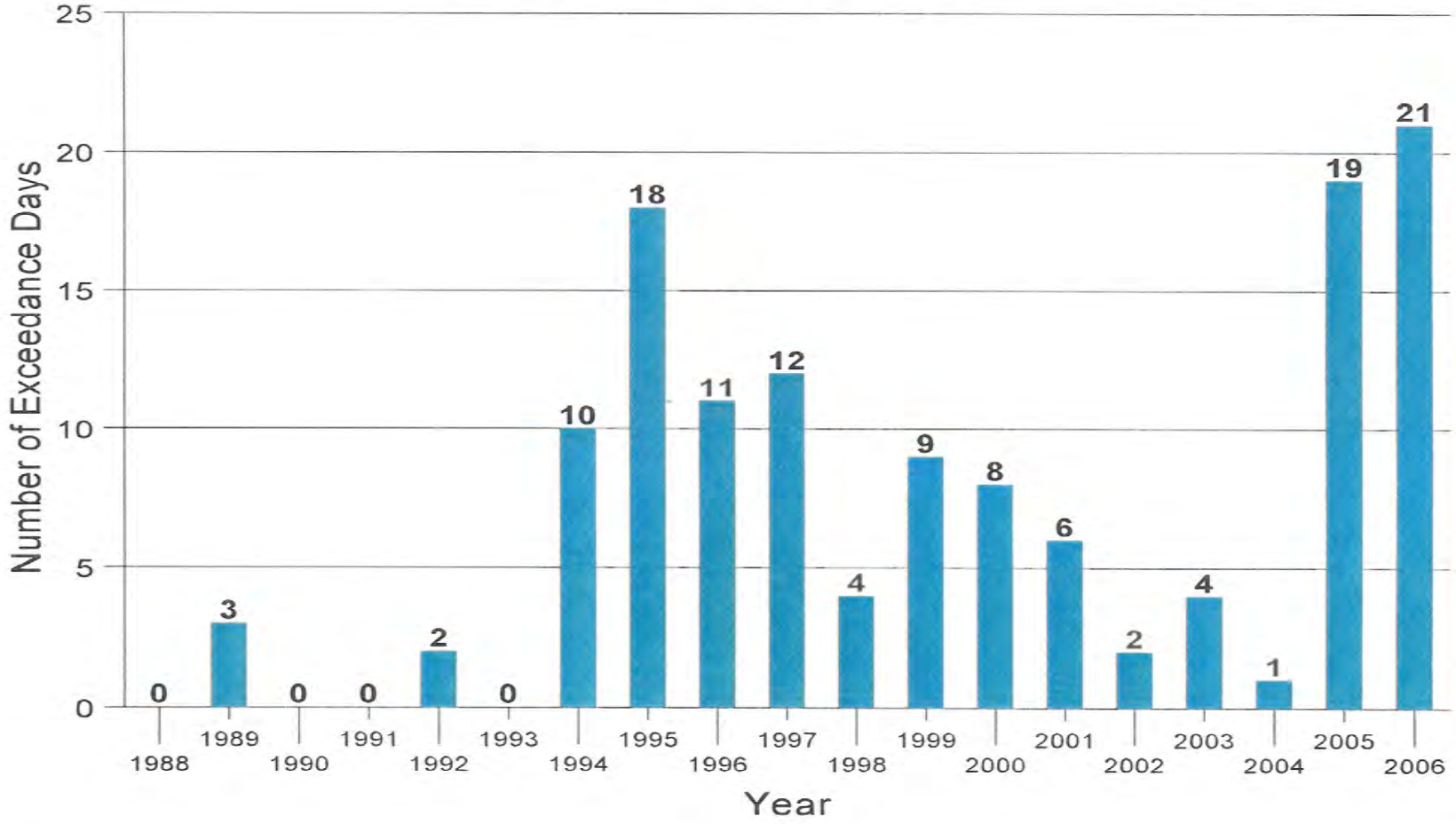
In accordance with Section 189 (d) of the Clean Air Act, the Five Percent Plan for PM-10 is due to the Environmental Protection Agency by December 31, 2007. The plan is required to reduce PM-10 emissions by at least five percent per year until the standard is attained as measured by the monitors. The Clean Air Act specifies that the plan must be based upon the most recent emissions inventory for the area and also include a modeling demonstration of attainment.

Particulate air pollution can occur throughout the year. The formation of PM-10 particulate pollution is dependent upon several factors. Among these factors are stagnant masses, severe temperature inversions in the winter, high winds in the summer, and fine, silty soils characteristic of desert locations. In the Maricopa County nonattainment area, particulate matter (PM-10) concentrations are elevated during various seasons of the year and under different weather conditions. The variability is due to the diverse composition of PM-10 and the sources contributing to this diversity.

The trend in PM-10 levels for the Maricopa County nonattainment area is presented in Figure ES-1. The 24-hour PM-10 standard is 150 micrograms per cubic meter. In 2004,

FIGURE ES-1

NUMBER OF 24-HOUR PM-10 EXCEEDANCE DAYS



Note: The Arizona Department of Environmental Quality began flagging natural and exceptional events in 2004. Exceedances that have been approved or are pending approval by EPA as natural or exceptional events have been removed from this chart.

Sources: 1988 - 1997 - Revised MAG 1999 Serious Area Particulate Plan for PM-10 for the Maricopa County Nonattainment Area, February 2000.
1998 - 2006 - EPA Air Quality System; Maricopa County Network Reviews; ADEQ Air Quality Reports.

there was one exceedance day of the 24-hour standard. However, in 2005 there were 19 exceedance days and in 2006 there were 21 exceedance days of the 24-hour standard. Figure ES-2 indicates the monitors where exceedances occurred. The violations of the standard at the Bethune Elementary School, Durango Complex, and West 43rd Avenue monitors caused the region to fail to attain the PM-10 standard by the December 31, 2006 attainment date.

A rigorous planning effort was conducted to prepare the MAG 2007 Five Percent Plan for PM-10. An extensive Preliminary Draft Comprehensive List of Measures was compiled for evaluation. The MAG Analysis of Particulate Control Measure Cost Effectiveness report provided an evaluation of forty-six control measures. For each measure, the following information was prepared: narrative description; suggested implementing entity; estimate of the cost of implementation; estimate of the PM-10 emission reduction potential; estimate of the cost effectiveness ($/ton of PM-10 reduced); and discussion of implementation issues and comments. In preparing the information for the analysis, measures from other PM-10 Serious Areas were reviewed and contacts were established. Relevant dust control literature reviews were performed to obtain data on measured emission reductions. Contacts were established with local agencies and businesses in Maricopa County to determine the cost of labor, equipment, materials, etc.

The MAG PM-10 Source Attribution and Deposition Study was another major study which provided information for the evaluation of control measures. The study was designed to identify the sources of emissions contributing to violations of the PM-10 standard at monitors in the nonattainment area during stagnant conditions and characterize the deposition of PM-10 particles emitted by these sources. The MAG consultants for the study were T&B Systems and Sierra Research. The key questions addressed in the study were:

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

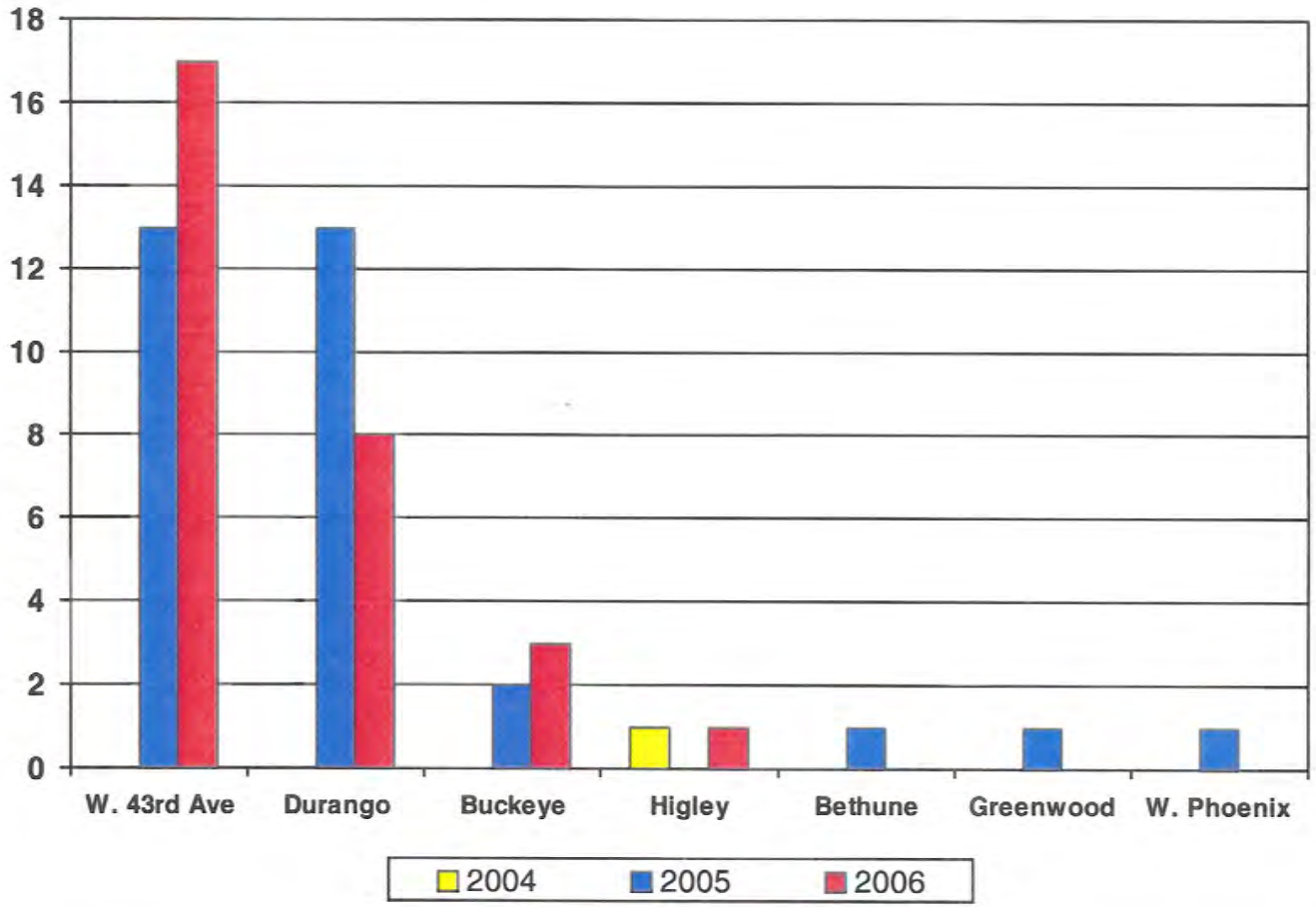
2. To obtain useful results from models such as AERMOD, can the regional particle size distribution be characterized on an area basis (i.e., is there an area of uniformity that can be generalized?)

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

The approach used for the study involved assessing existing meteorological and PM data; selecting monitoring tools; establishing a sampling plan; defining routes for mobile sampling; determining locations of meteorological data collection; selecting locations to investigate dispersion of roadway sources; conducting sampling in two phases;

FIGURE ES-2

EXCEEDANCES OF THE 24-HOUR PM-10 STANDARD AT MONITORS IN MARICOPA COUNTY



Notes: 1. Exceedances are based on data from the EPA Air Quality System (AQS). Exceedances due to natural events have been removed from the AQS by EPA.

2. The exceedance at the Bethune, Greenwood, and W. Phoenix monitors occurred on 12/12/05.

coordinating with local agencies for related data; and performing daily review of collected data to identify insights, opportunities and problems. The monitoring tools for the study included: a particle lidar; mobile monitoring; DustTrak optical PM-10 monitors; DustTrak optical PM-2.5 monitors; an aerodynamic particle size analyzer; MiniVol filter based samplers; a sodar; and a SCAMPER vehicle. The SCAMPER (System for Continuous Aerosol Monitoring of Particulate Emissions from Roadways) vehicle was used to measure PM-10 from paved roads. From November 15, 2006 through December 14, 2006, extensive measurements were taken in the Salt River area using state-of-the-art technologies.

In general, the study identified a number of sources of PM-10 in the Salt River area. They included: trackout; dragout from unpaved or poorly maintained paved roads or parking lots; unpaved shoulders; unpaved roads; open burning; agriculture; and vehicle activity on unpaved parking areas and vacant lots. Preliminary results from the study were used in the evaluation of control measures and the final results were used in the modeling attainment demonstration.

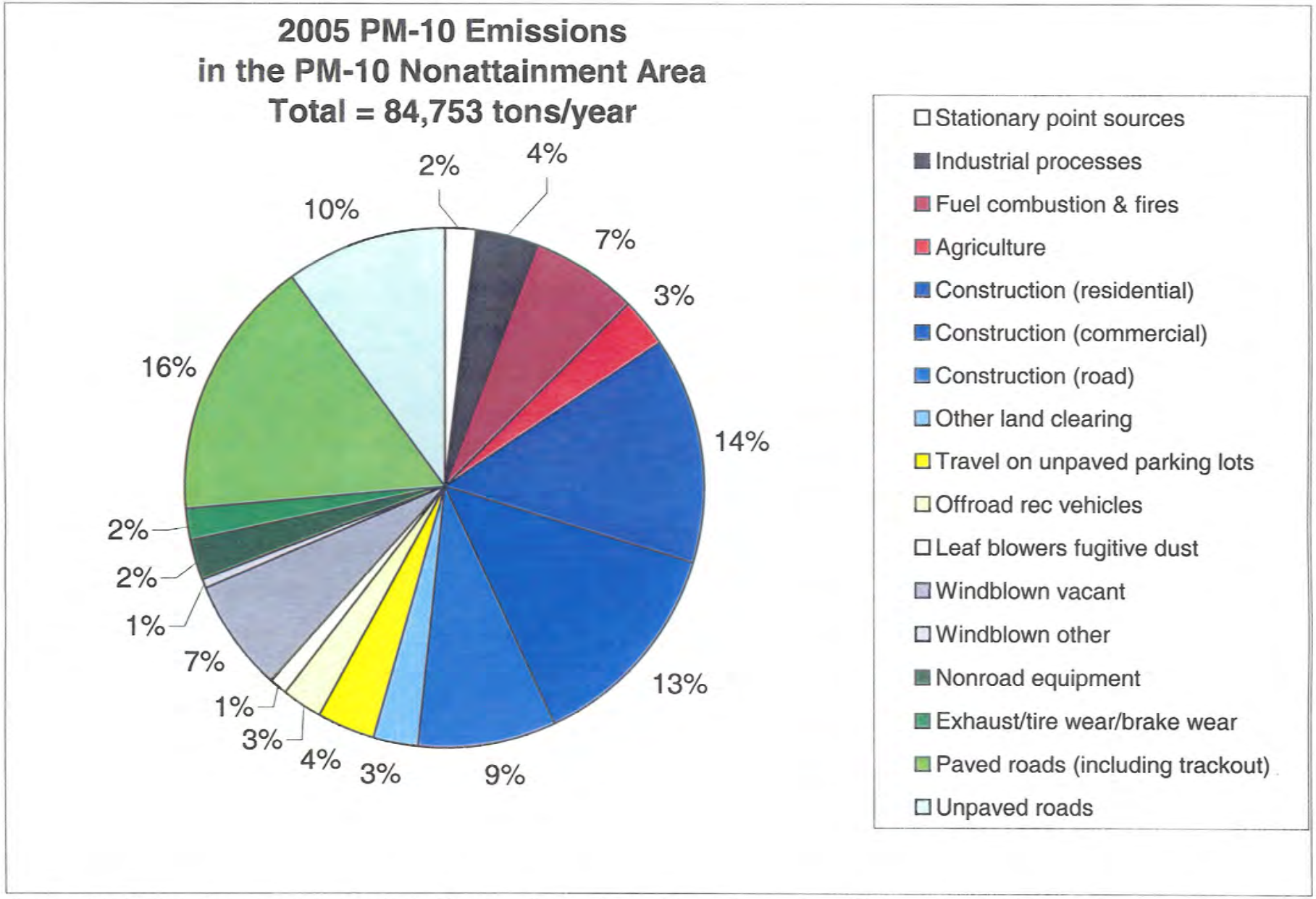
Based upon the Maricopa County Air Quality Department 2005 Periodic Emissions Inventory for PM-10 for the Maricopa County Nonattainment Area, the primary sources of PM-10 are: Paved Roads (including trackout) 16 percent; Construction (residential) 14 percent; Construction (commercial) 13 percent; Unpaved Roads 10 percent; Construction (road) 9 percent; Fuel Combustion and Fires (industrial natural gas and fuel oil, commericial/institutional natural gas and fuel oil, and residential natural gas, wood and fuel oil) 7 percent; and Windblown Vacant (vacant lots) 7 percent. The sources are depicted in Figure ES-3.

The emissions in the 2005 Periodic Emissions Inventory for PM-10 were projected to 2007, 2008, 2009, and 2010. The total controlled emissions of 97,436 tons in the 2007 projected inventory were used to calculate the five percent reduction target in emissions (see Figure ES-4). This number was multiplied by five percent to determine the PM-10 emissions reduction target of 4,872 tons per year. To meet this annual target, the 2008 emissions with committed control measures must be at least 4,872 tons less than the base case 2008 emissions; the controlled 2009 emissions must be at least 9,744 tons less than the 2009 base case emissions; and the controlled 2010 emissions must be at least 14,616 tons less than the 2010 base case emissions.

In order to reduce PM-10, a broad range of commitments to implement measures were received from the State, Maricopa County, and the twenty-three local governments in the PM-10 nonattainment area. Collectively, the MAG 2007 Five Percent Plan for PM-10 includes fifty-three committed measures.

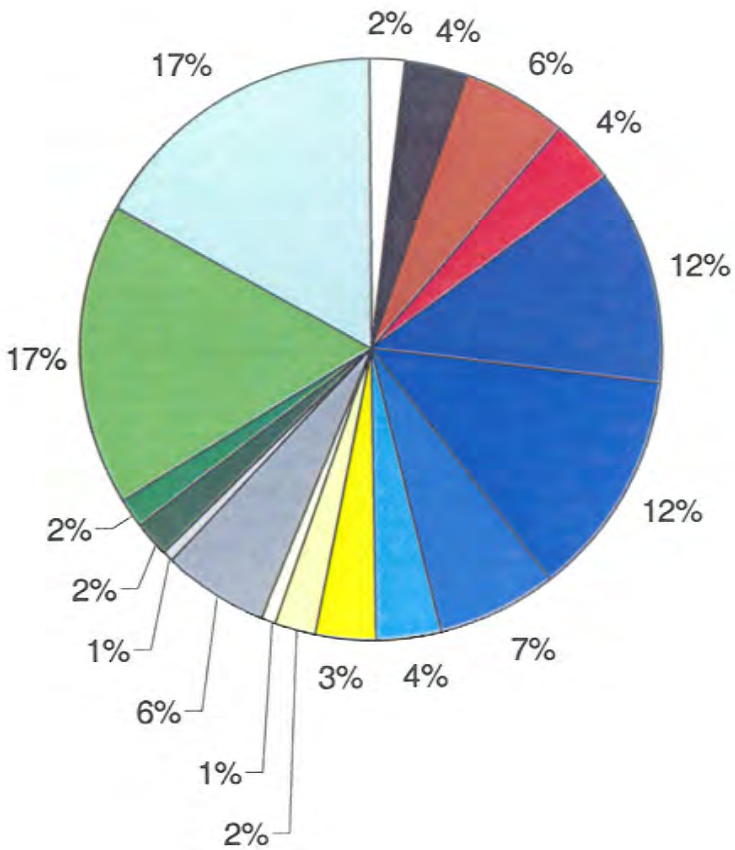
The key committed measures that were quantified as control measures include: Dust Managers/Coordinators at Earthmoving Sites; Increase Rule 310 and 316 Inspections; Extensive Dust Control Training; Conduct Nighttime and Weekend Inspections; Strengthen Rule 310 to Promote Continuous Compliance; Pave or Stabilize Dirt Shoulders; Pave or

FIGURE ES-3



Source: 2005 Periodic Emissions Inventory for the Maricopa County, Arizona Nonattainment Area. Maricopa County Air Quality Department. May 2007.

Figure ES-4
2007 PM-10 Emissions
with Committed Control Measures
Total = 97,436 tons/year



- Stationary point sources
- Industrial processes
- Fuel combustion & fires
- Agriculture
- Construction (residential)
- Construction (commercial)
- Construction (road)
- Other land clearing
- Travel on unpaved parking lots
- Offroad rec vehicles
- Leaf blowers fugitive dust
- Windblown vacant
- Windblown other
- Nonroad equipment
- Exhaust/tire wear/brake wear
- Paved roads (including trackout)
- Unpaved roads

Source: Maricopa Association of Governments, 2007

Stabilize Unpaved Parking Lots; Restrict Vehicle Use on Vacant Lots; Strengthen Rule 310.01 for Vacant Lots; and Recover the Cost of Stabilizing Vacant Lots.

The committed control measures were quantified in order to model attainment and meet the five percent reduction targets. The PM-10 emissions reductions for the committed control measures are shown in Figure ES-5.

With the implementation of the committed control measures, the total PM-10 emissions in 2010 are 82,829 tons (See Figure ES-6), which represents a 19.3 percent reduction in the 2010 base case emissions. These reductions are necessary to model attainment of the PM-10 standard at all monitors as expeditiously as practicable, which is 2010. The total reductions due to the committed control measures also exceed the annual five percent reduction targets in 2008, 2009 and 2010, as indicated in Table ES-1.

In accordance with the Clean Air Act, the MAG 2007 Five Percent Plan for PM-10 also contains contingency measures. The contingency measures are committed measures in the adopted plan which achieve emissions reductions beyond those measures relied upon to model attainment of the standard and demonstrate progress toward attainment (i.e., five percent reductions, reasonable further progress, and milestones).

The key committed measures in the Five Percent Plan that were quantified as contingency measures are: Pave or Stabilize Dirt Roads and Alleys; Sweep with PM-10 Certified Street Sweepers; Reduce Trackout Onto Paved Roads; Additional Five Million Dollars in FY 2007 MAG Federal Funds for Paving Dirt Roads and Shoulders; Agricultural Best Management Practices; 15 Mile Per Hour Speed Limits on Dirt Roads; Reduce Offroad Vehicle Use; Certification for Dust Free Developments; and Public Education and Outreach Program.

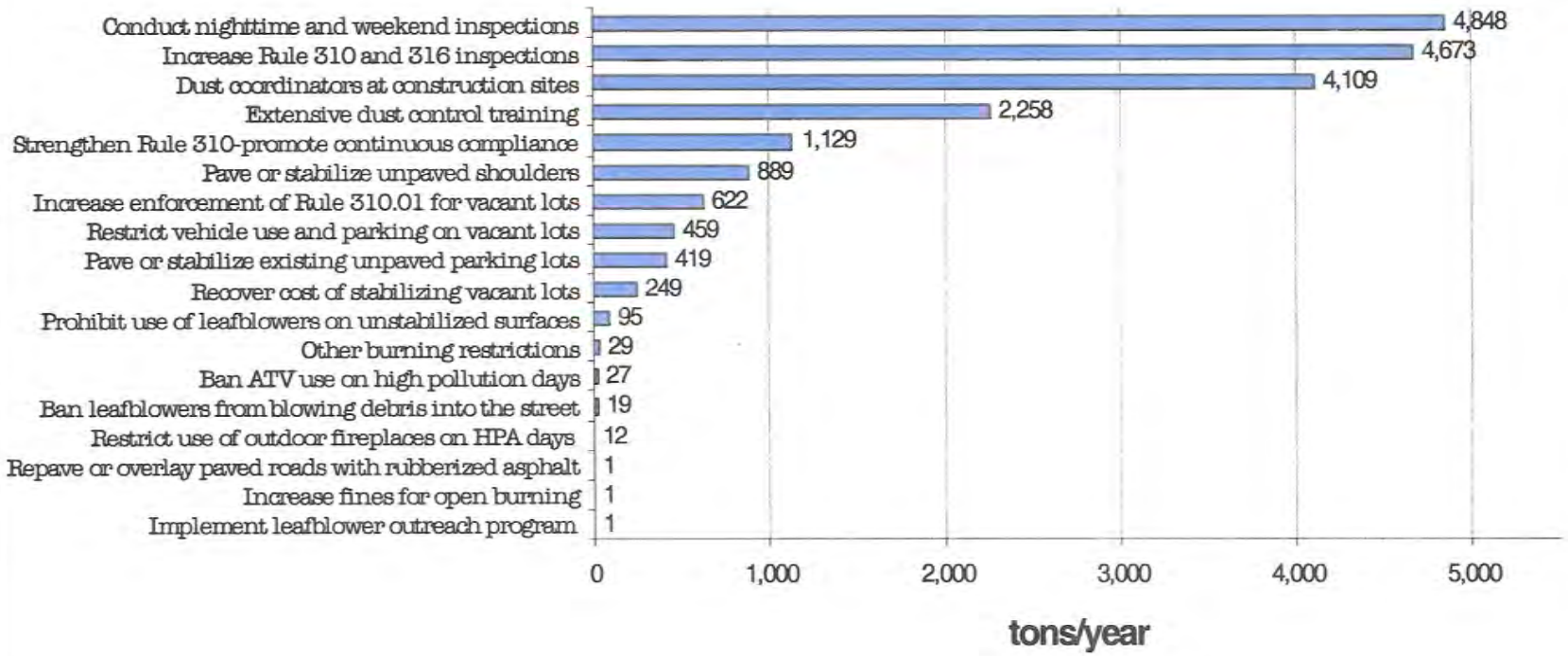
EPA guidance indicates that contingency measures should provide emissions reductions equivalent to one year of reasonable further progress. The reasonable further progress requirements for Serious PM-10 nonattainment areas are included in Section 189(c) of the Clean Air Act. For the Five Percent Plan, one year of reasonable further progress is equivalent to a reduction in PM-10 emissions of 4,869 tons.

Figure ES-7 shows the impacts of the individual contingency measures in 2010. Collectively, the contingency measures reduce PM-10 emissions by 5,223 tons in 2008, 7,213 tons in 2009, and 9,159 tons in 2010 versus the contingency target of 4,869 tons per year, as shown in Table ES-1.

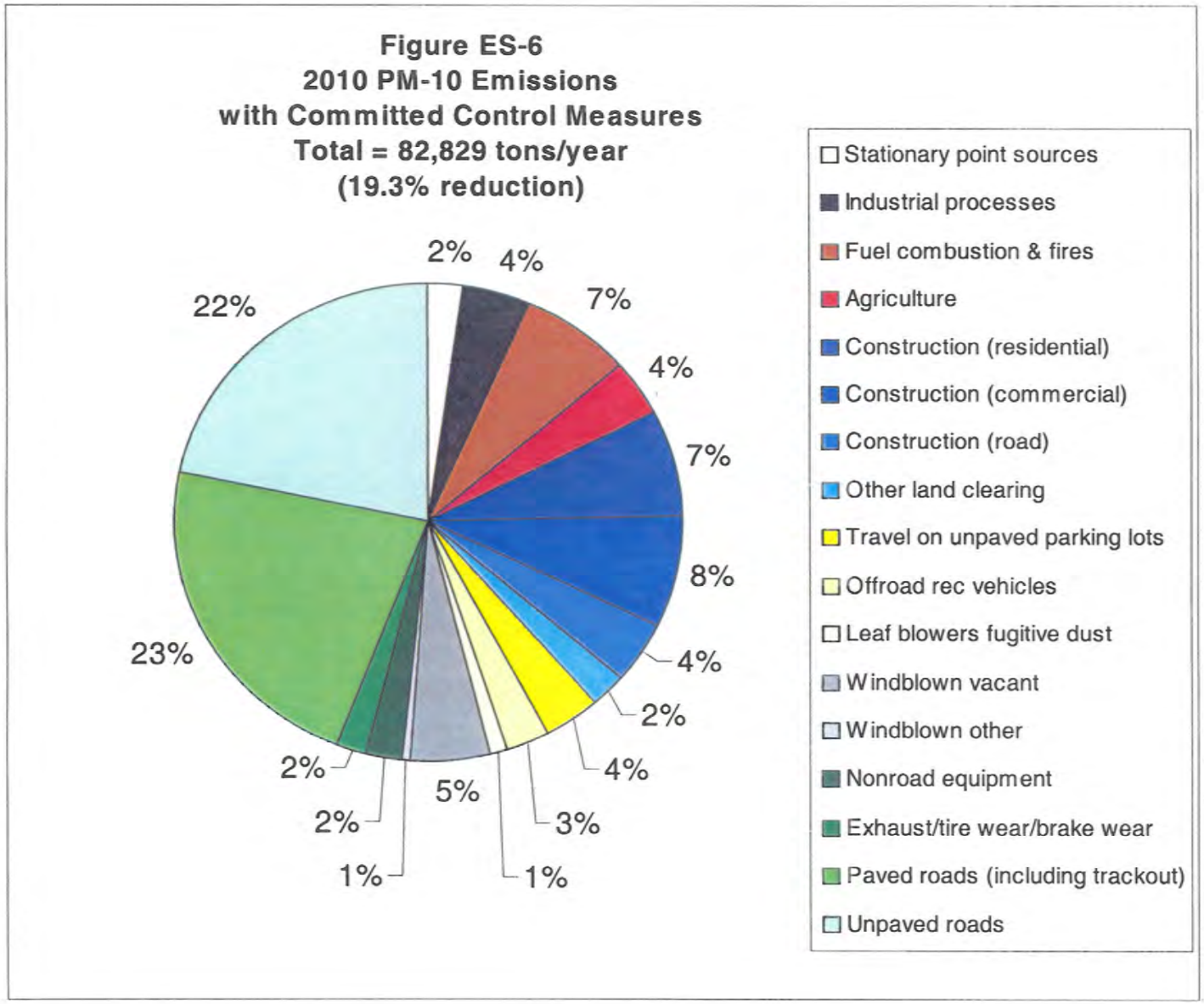
The total 2010 PM-10 emissions with committed control measures and committed contingency measures are 73,670 tons (see Figure ES-8). Together, these measures reduce base case PM-10 emissions by 28.2 percent in 2010.

For conformity analyses, the onroad mobile source emissions budget includes reentrained dust from travel on paved roads; vehicular exhaust, tire wear, and brake wear; travel on unpaved roads; and road construction. In 2010, the PM-10 emissions from these four source categories total 103.3 metric tons per day. This represents the onroad mobile source emissions budget for conformity.

Figure ES-5
Reductions in 2010 for Committed Control Measures in the Five Percent Plan for PM-10



Source: Maricopa Association of Governments, 2007



Source: Maricopa Association of Governments, 2007

TABLE ES-1

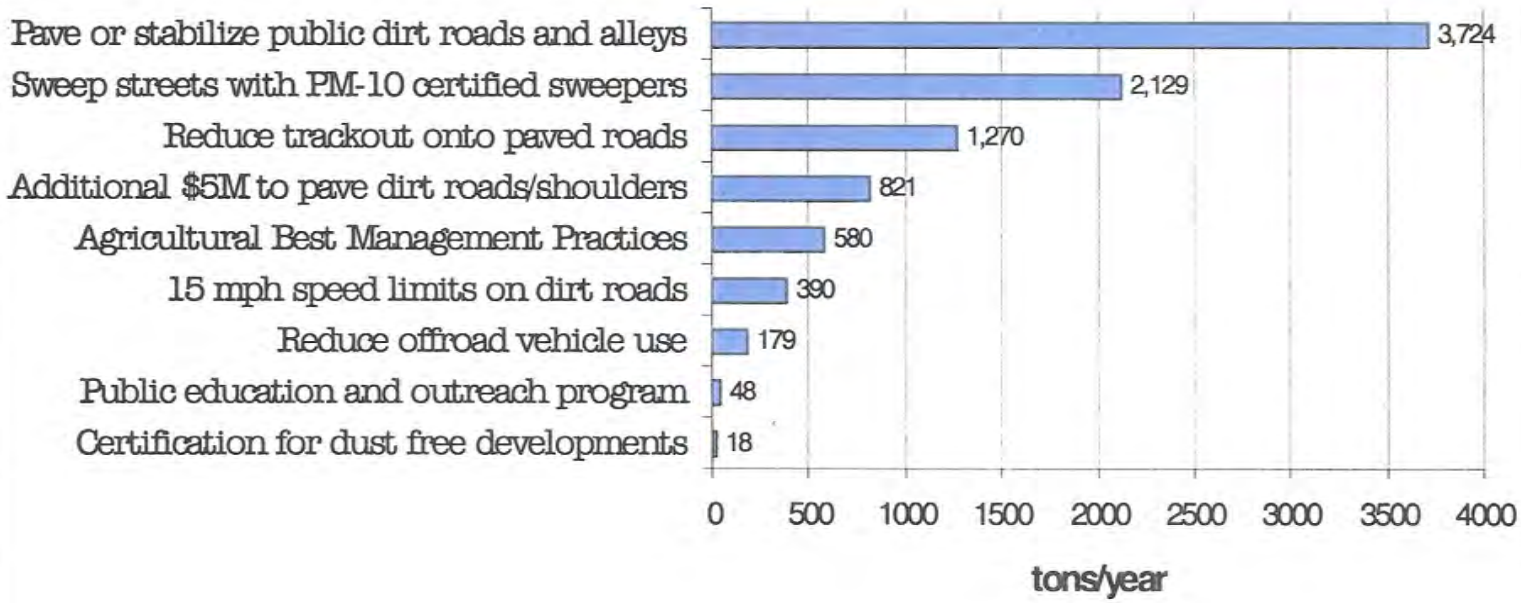
EMISSIONS REDUCTIONS FOR COMMITTED CONTROL MEASURES QUANTIFIED TO MODEL ATTAINMENT AND MEET THE FIVE PERCENT REDUCTION REQUIREMENT

- 6,605 tons vs. five percent reduction target of 4,872 tons in 2008
- 15,423 tons vs. five percent reduction target of 9,744 tons in 2009
- 19,840 tons vs. five percent reduction target of 14,616 tons in 2010

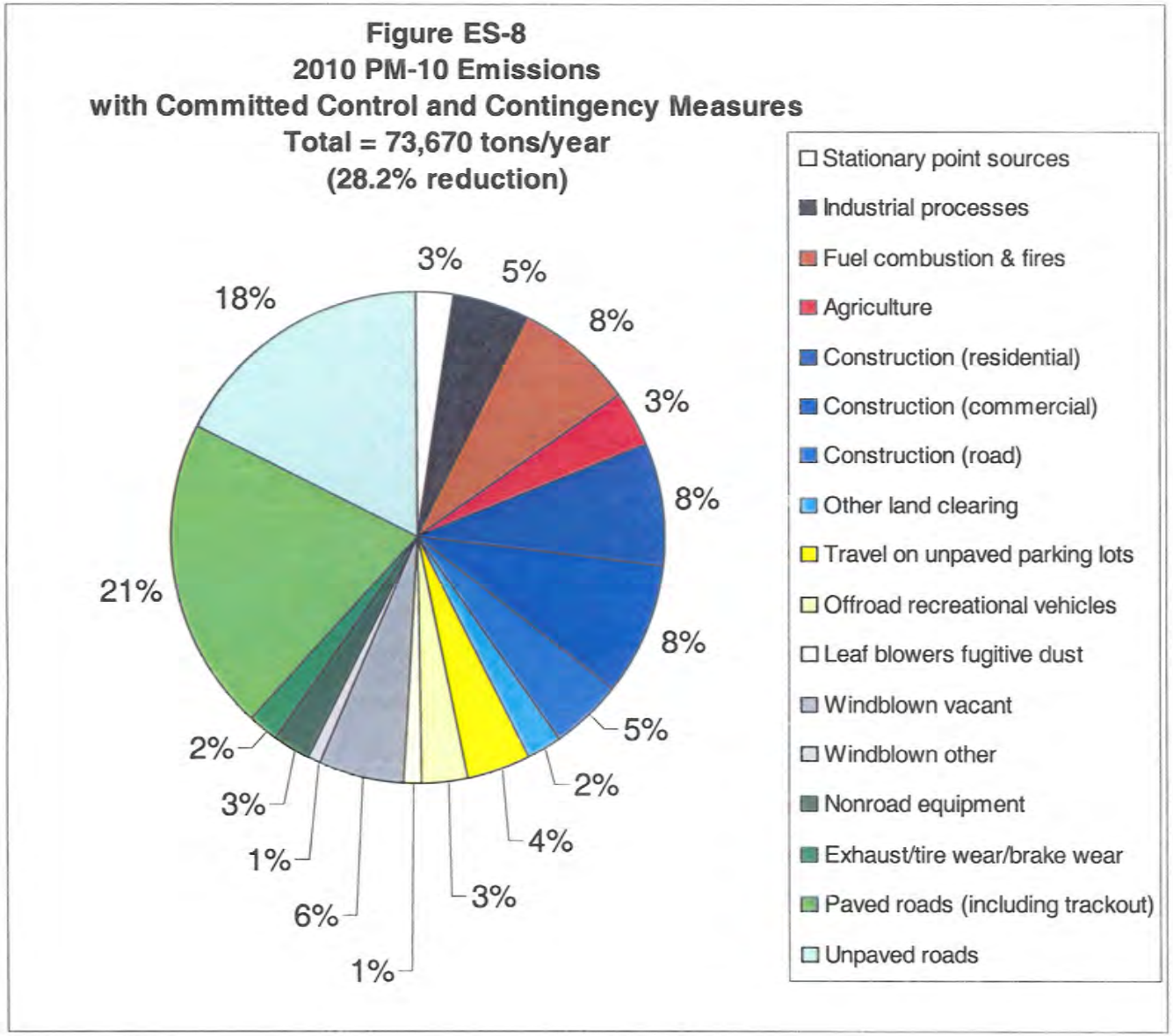
EMISSIONS REDUCTIONS FOR COMMITTED CONTINGENCY MEASURES QUANTIFIED TO MEET THE CONTINGENCY MEASURE REQUIREMENT

- 5,223 tons vs. contingency reduction target of 4,869 tons in 2008
- 7,213 tons vs. contingency reduction target of 4,869 tons in 2009
- 9,159 tons vs. contingency reduction target of 4,869 tons in 2010

Figure ES-7
Reductions in 2010 for Contingency Measures in the Five Percent Plan for PM-10



Source: Maricopa Association of Governments, 2007



Source: Maricopa Association of Governments, 2007

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Appendix F
Background on Potential Sources

APPENDIX F

BACKGROUND ON POTENTIAL SOURCES

The most recent inventory of particulate matter and secondary precursors to particulate matter was released by the Maricopa County Air Quality Department (MCAQD) in June 2010. The inventory details calendar year 2008 annual and typical daily emissions of particulate matter in Maricopa County and the Maricopa County PM-10 nonattainment area. Access to the complete inventory report produced by MCAQD can be viewed on the department's website at (http://www.maricopa.gov/aq/divisions/planning_analysis/emissions_inventory/reports/Default.aspx).

The inventory provides emission estimates from point, area, nonroad mobile, onroad mobile and biogenic sources. The point source category includes stationary sources which emit a significant amount of pollution into the air. Examples of point sources include power plants, industrial processes, and large manufacturing facilities. Area sources are stationary sources which are too small or too numerous to be treated as point sources. Examples include residential wood burning, commercial cooking, waste incineration, and wildfires. Nonroad mobile sources include off-highway vehicles and engines that move or are moved in a 12-month period such as construction and mining equipment and lawn and garden equipment. The onroad mobile sources category includes exhaust, paved road fugitive dust, unpaved road fugitive dust, tire wear, and break wear from road travel. Biogenic sources (plant life) contribute NOx as a precursor to PM-10 formation.

Based upon the MCAQD inventory, Exhibit 1 of this appendix contains a pie chart of annual PM-10 emissions for calendar year 2008 in the PM-10 nonattainment area. The four categories containing the largest percentages of annual PM-10 emissions shown in Exhibit 1 are: windblown dust (25%), paved road fugitive dust (23%), unpaved road fugitive dust (16%) and construction activities (14%). All other individual categories shown in Exhibit 1 comprise 4% or less of annual PM-10 emissions. Exhibit 2 provides a detailed summary of 2008 annual and typical daily PM-10, PM-2.5 and secondary precursor (NOx, SOx, and NH3) emissions from all reported source categories within the PM-10 nonattainment area.

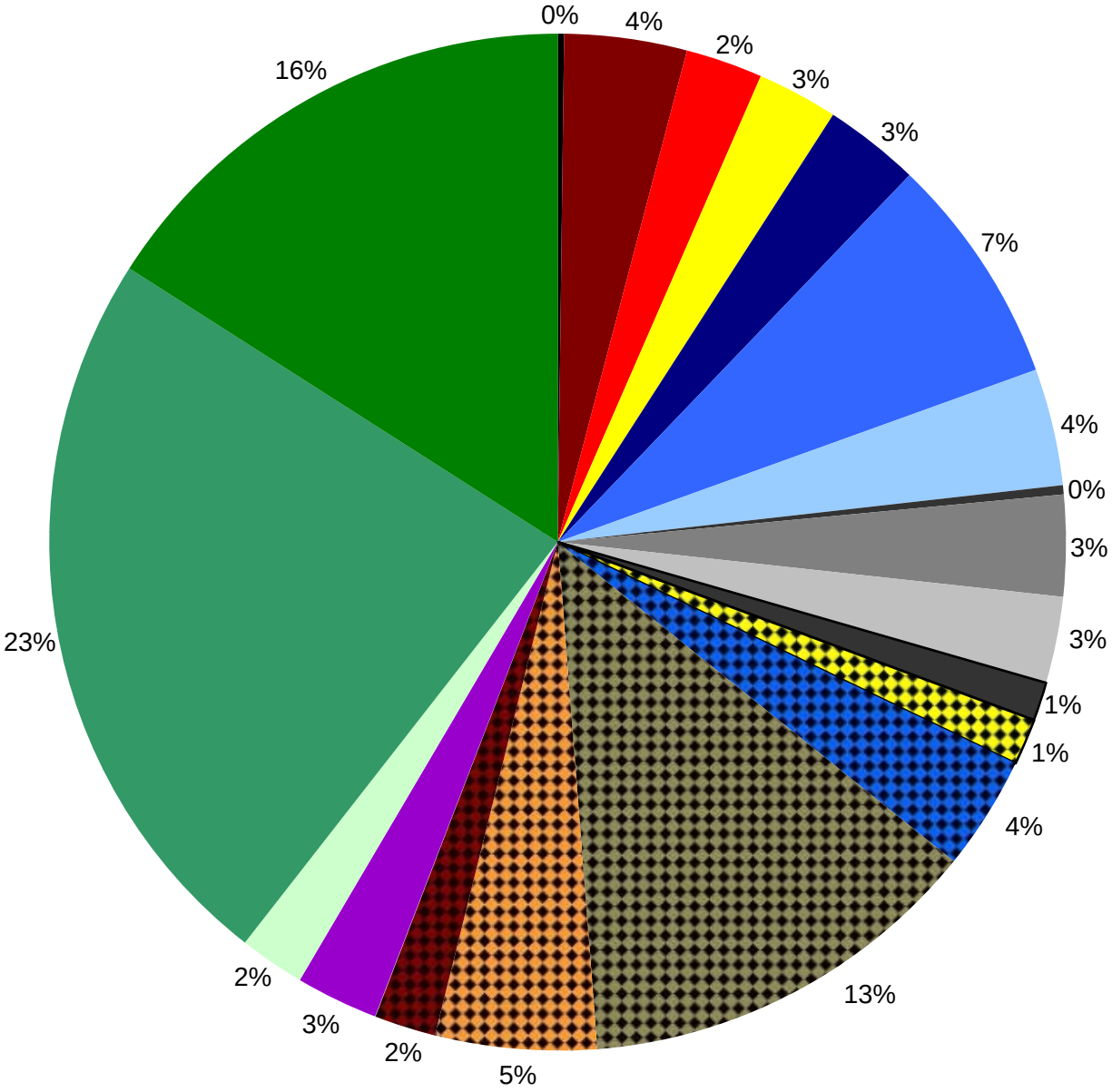
In addition to the area-wide inventory produced by MCAQD, specific spatial and temporal source contributions have been developed. Appendix A (Background on Air Quality Monitors) contains maps of PM-10 producing industrial sources within 2 miles of relevant PM-10 monitoring stations. A detailed breakdown of windblown dust sources on event days developed from back trajectory analysis of high wind periods is contained in Appendix O (Event Source Contribution Analysis).

EXHIBIT 1

2008 PM-10 EMISSIONS INVENTORY PIE CHART FOR PM-10 THE MARICOPA COUNTY NONATTAINMENT AREA

2008 PM_{10} Emissions Inventory

(PM_{10} Nonattainment Area Total = 73,410 tons/yr)



Source Categories	%
Major stationary point sources	(<0.5%)
All other industrial processes	(4%)
Fuel combustion and fires	(2%)
Agriculture	(3%)
Construction, residential	(3%)
Construction, commercial	(7%)
Construction, road	(4%)
Other earthmvg: trenching, weed control	(<0.5%)
Travel on unpaved parking lots	(3%)
Offroad rec. vehicles fugitive dust	(3%)
Leaf blowers fugitive dust	(1%)
Windblown: agricultural land	(1%)
Windblown: developing land	(4%)
Windblown: vacant land	(13%)
Windblown: open areas	(5%)
Windblown: S&G, landfills, test tracks	(2%)
Nonroad mobile sources	(3%)
Exhaust/tire wear/brake wear	(2%)
Paved road fugitive dust, including trackout	(23%)
Unpaved road fugitive dust	(16%)

EXHIBIT 2

2008 ANNUAL AND TYPICAL DAILY EMISSIONS OF PARTICULATE MATTER AND ASSOCIATED SECONDARY PRECURSORS FROM ALL SOURCES IN THE MARICOPA COUNTY NONATTAINMENT AREA

2008 PM_{10} Emission Inventory

2008 Annual and typical daily emissions from all sources in PM_{10} NAA

Rept. §	Source Category	Annual (tons / year) PM_{10}	$PM_{2.5}$	NO_x	SO_x	NH_3	Daily (pounds / average day) PM_{10}	$PM_{2.5}$	NO_x	SO_x	NH_3
2	**Point Sources**										
	Facility totals	148.04	132.94	1,309.85	28.60	132.18	831.4	747.7	7,210.6	157.3	727.0
	Emission reduction credits	1.80		9.80	0.16		9.8		53.6	0.9	
	All Point Sources	**149.84**	**132.94**	**1,319.65**	**28.76**	**132.18**	**841.2**	**747.7**	**7,264.2**	**158.2**	**727.0**
3.2	**Fuel combustion**										
3.2.1	Industrial natural gas	30.70	30.70	573.79	2.41	12.66	196.8	196.8	3,678.2	15.5	81.2
3.2.2	Industrial fuel oil	457.60	457.60	6,358.50	608.03	26.19	2,933.3	2,933.3	40,759.6	3,897.6	167.9
3.2.3	Comm./Inst. natural gas	66.20	66.20	1,260.65	5.20	4.18	424.4	424.4	8,081.1	33.3	26.8
3.2.4	Comm./Inst. fuel oil	223.00	223.00	3,256.70	269.88	8.09	1,429.5	1,429.5	20,876.3	1,730.0	51.8
3.2.5	Residential natural gas	61.73	61.73	763.51	4.87		337.3	337.3	4,172.2	26.6	
3.2.6	Residential wood	461.41	429.11	34.67	5.33		4,332.5	4,029.2	325.6	50.1	
3.2.7	Residential fuel oil	0.01	0.01	0.25	0.10		0.1	0.1	2.3	0.9	
3.2.8	**All combustion**	1,300.65	1,268.35	12,248.07	895.83	51.11	9,653.8	9,350.6	77,895.2	5,754.1	327.6
3.3	**Industrial Processes**										
3.3.1	Chemical manufacturing	186.94	151.03	0.00	0.34	0.03	1,442.0	1,161.5	0.0	2.6	0.9
3.3.2	Food & kindred products:										
3.3.2.1	Commercial cooking	993.04	920.94				5,456.3	5,060.1			
3.3.2.2	Grain handling/processing	16.73	5.68				125.3	43.0			
3.3.2.3	Ammonia cold storage					1,674.07					10,731.2
3.3.3	Secondary metal production	60.56	52.16	49.73	18.65	0.04	442.7	386.2	358.8	142.7	0.0
3.3.4	Mineral procs. (concrete)	190.45	93.72				1,320.7	647.9			
3.3.5	Mining/quarry (sand/gravel)	184.25	50.64				1,266.6	331.9			
3.3.6	Wood product mfg.	216.69	202.72				1,664.3	1,544.3			
3.3.7	Rubber/plastic product mfg.	140.57	105.68				950.9	697.0			
3.3.8	Fabricated metal	51.35	42.51			4.49	536.7	459.4			28.8
3.3.9.1	Residential construction	2,245.39	224.54				14,465.2	1,446.5			
3.3.9.2	Commercial construction	5,380.95	538.10				34,382.4	3,438.2			
3.3.9.3	Road construction	2,724.87	272.49				17,471.4	1,747.1			
3.3.9.4	Construction – other	215.70	21.57				1,385.5	138.6			
3.3.10	Machinery (electrical)	13.94	9.64	20.45	0.18	31.55	76.9	53.2	112.4	1.1	193.7
3.3.11	DEQ-permitted portable sources	59.00	29.50	282.18	88.93		492.9	246.5	2,275.7	721.7	
3.3.12	Unpaved road travel	511.29	227.58				3,551.3	1,573.8			
3.3.13	Industrial procs. NEC	136.00	99.12	8.12	21.47	14.10	906.0	681.7	55.4	137.6	79.8
3.3.14	**All Industrial Processes**	13,327.74	3,047.62	360.48	129.58	1,724.27	85,937.0	19,656.9	2,802.3	1,005.7	11,034.4
3.4	**Waste Treatment/Disposal**										
3.4.1	On-site incineration	0.06	0.04	5.01	0.01		0.7	0.4	38.9	0.1	
3.4.2	Open burning	27.67	27.67	7.44			232.6	232.6	62.5		
3.4.3	Landfills	60.25	50.78	19.47	6.22		342.4	286.6	107.4	34.3	
3.4.4	POTWs					1,494.12					8,164.6
3.4.5	Other waste	32.78	16.93	18.39	50.62		224.1	110.9	101.0	278.1	
3.4.6	**All Waste Treat/Disposal**	120.77	95.42	50.30	56.85	1,494.12	799.8	630.5	309.9	312.6	8,164.6
3.5	**Misc. Area Sources**										
3.5.1	Other combustion:										
3.5.1.1	Wildfires	423.56	363.27	93.46	25.62	19.60	9,412.5	8,072.7	2,076.8	569.4	435.5
3.5.1.2	Prescribed fires	0.21	0.21	0.16	0.04	0.01	104.0	104.0	80.6	22.1	6.5
3.5.1.3	Structure fires	15.10	15.10	1.96			82.5	82.5	10.7		
3.5.1.4	Vehicle fires	30.16	30.16	1.21			164.8	164.8	6.6		
3.5.1.5	Aircraft engine testing	0.18	0.17	6.74	2.49		1.3	1.2	50.5	19.0	
3.5.2.1	Tilling	834.20	125.13				9,327.3	1,399.1			
3.5.2.2	Harvesting	54.14	8.12				1,560.0	234.0			
3.5.2.3	Travel on unpaved ag. roads	731.03	73.10				4,686.1	468.6			
3.5.2.4	Cotton ginning	4.86	1.39				26.7	7.6			
3.5.2.5	Fertilizer application					1,004.82					5,490.8
3.5.3	Livestock	260.95	28.70			5,486.90	1,426.0	156.9			30,065.2
3.5.4	Crematories	0.93	0.62	12.36	1.58		7.0	4.6	92.6	11.8	
3.5.5	Accidental releases	0.01	0.01	0.06			0.1	0.1	0.3		
3.5.6	Humans					1,181.71					6,457.5
3.5.7	Leaf blowers fugitive dust	894.98	337.78				4,890.6	1,845.8			
3.5.8	Offroad rec. vehicles fug. dust	2,014.17	200.09				11,006.4	1,093.4			
3.5.9	Travel on unpaved parking lots	2,365.07	237.45				12,923.9	1,297.5			
3.5.10	Windblown dust	18,468.36	1,846.84				100,920.0	10,092.0			
3.5.11	**All Misc. Area Sources**	26,097.92	3,268.14	115.94	29.74	7,693.04	156,539.2	25,024.8	2,318.0	622.4	42,455.4
3.2	**Fuel Combustion**	1,300.65	1,268.35	12,248.07	895.83	51.11	9,653.8	9,350.6	77,895.2	5,754.1	327.6
3.3	**Industrial Processes**	13,327.74	3,047.62	360.48	129.58	1,724.27	85,937.0	19,656.9	2,802.3	1,005.7	11,034.4
3.4	**Waste Treatment/Disposal**	120.77	95.42	50.30	56.85	1,494.12	799.8	630.5	309.9	312.6	8,164.6
3.5	**Misc. Area Sources**	26,097.92	3,268.14	115.94	29.74	7,693.04	156,539.2	25,024.8	2,318.0	622.4	42,455.4
	All Area Sources	**40,847.1**	**7,679.5**	**12,774.8**	**1,112.0**	**10,962.54**	**252,929.8**	**54,662.7**	**83,325.3**	**7,694.7**	**61,982.0**
4	**Nonroad Mobile**										
4.2	Agricultural equipment	15.13	14.67	161.35	0.06	0.30	97.0	94.0	1,034.3	0.4	1.9
4.3	Airport GSE (+APU)	26.99	26.48	578.95	26.22		147.5	144.7	3,163.7	143.3	
4.4	Commercial equipment	117.66	112.69	1,391.61	2.39	21.06	754.2	722.4	8,920.6	15.3	135.0
4.5	Constr. & mining equipmt	1,249.88	1,210.00	14,666.42	6.55	27.85	8,012.1	7,756.4	94,015.6	42.0	178.5
4.6	Industrial equipment	101.42	98.71	2,586.39	3.21	56.09	650.1	632.7	16,579.4	20.6	359.5
4.7	Lawn and garden equipment	183.02	169.48	801.41	3.17	19.71	1,255.3	1,161.6	5,594.4	23.2	145.2
4.9	Pleasure craft	7.02	6.48	59.03	0.64	1.32	94.5	87.3	794.6	8.6	17.7
4.10	Railway maint. equipment	1.13	1.10	9.26	0.00	0.02	7.8	7.6	64.1	0.0	0.1
4.11	Recreational equipment	7.68	7.08	10.76	0.07	0.35	65.7	60.5	91.9	0.6	3.0
4.12	Aircraft	183.80	177.60	2,620.31	316.00		1,004.3	970.5	14,318.6	1,726.8	
4.13	Locomotives	34.16	31.88	907.76	9.11	2.16	186.7	174.2	4,960.4	49.8	11.8
	All Nonroad Sources	**1,927.89**	**1,856.17**	**23,793.26**	**367.42**	**128.87**	**12,275.2**	**11,811.9**	**149,537.7**	**2,030.5**	**852.9**
5	**Onroad Mobile**										
	Exhaust / tire wear / brake wear	1,529.54	954.23	49,142.49	295.90	3,180.66	8,357.7	5,213.8	268,538.4	1,616.4	17,380.4
	Paved road fugitive dust	17,245.1	547.9				94,235.7	2,994.2			
	Unpaved road fugitive dust	11,710.7	1,169.0				63,993.1	6,387.8			
	All Onroad Mobile Sources	**30,485.34**	**2,671.13**	**49,142.49**	**295.90**	**3,180.66**	**166,586.5**	**14,595.8**	**268,538.4**	**1,616.4**	**17,380.4**
6	**Biogenics**			**332.77**					**1,815.3**		
	TOTAL, All Categories	**73,410.15**	**12,339.77**	**87,030.19**	**1,804.08**	**14,404.25**	**432,632.7**	**81,818.2**	**508,665.6**	**11,499.8**	**80,942.3**

Appendix G
Background Control Programs “White Paper”

High Wind Exceptional Events And Control Measures for PM_{10} Areas

Air Quality Division

October 13, 2009

High Wind Exceptional Events and Control Measures for PM_{10} Areas

1.0 Background

Under the authority of the Clean Air Act (CAA), the Environmental Protection Agency (EPA) develops National Ambient Air Quality Standards (NAAQS) for each of the criteria pollutants (carbon monoxide, lead, nitrogen oxides, ozone, particulate matter, and sulfur dioxide). For each of these pollutants, EPA tracks air concentrations based on actual measurements of pollutant concentrations in the ambient (outside) air at selected monitoring sites throughout the country. Once an air quality standard for a particular pollutant is established, monitors record when ambient concentrations of that pollutant exceed a level at which human health is no longer protected.[1] Should these exceedances continue or grow in intensity, the regulatory remedy is to declare the area in violation of the standard and designate the area nonattainment for that pollutant. The only time an exceedance would not count toward a violation of a standard is if that exceedance could be classified as an exceptional event.

Exceptional Events impact air quality when their influence results in ambient air concentrations of particulate matter that fall outside the range of normal statistical fluctuations. For particulate matter, these events can be the result of large fires, high winds, man-made events such as explosions, or natural events such as volcanic eruptions. In the Western United States, high winds can accompany large storms (e.g., haboobs) that move across a regional or state-wide swath of land, or high winds can accompany "micro-bursts" with or without rain that descend upon a small, localized area. When a monitor within a planning area registers an exceedance of the PM_{10} NAAQS – or 150 micrograms per cubic meter ($\mu g/m^3$) over 24 hours – the exceedance is flagged in the EPA Air Quality System (AQS) database and an examination of the event begins to determine if the event could be classified as exceptional.[2] More than three exceedances at the same particulate matter monitor within three consecutive years add up to a violation of the NAAQS. A violation has a consequence to a planning area of either preventing an area from reaching attainment or returning an area to nonattainment that was previously redesignated to attainment. If an exceedance is flagged as an exceptional event, however, and the EPA's Regional Office concurs, the exceedance is not counted toward a violation of the NAAQS.

Control measures are established to bring a nonattainment area into attainment for a particular NAAQS; the control measures are to remain in place even after the area is redesignated to attainment. These control measures can include Best Available Control Measures (BACM) or Technology (BACT), Reasonable Control Measures (RACM) or Technology (RACT), Most Stringent Measures (MSM), and Lowest Achievable Emission Rate (LAER). Other control measures can be case-by-case control measures or practices that have been shown to be effective in reducing pollution from a particular source; for PM_{10} examples include Agricultural Best Management Practices (AgBMPs), stabilization of vacant lots, or paving unpaved roads or shoulders. A nonattainment area can be classified as Moderate, Serious, or Severe. The CAA requires areas designated as serious nonattainment for PM_{10} to implement BACM and BACT on all significant sources of PM_{10}.

1.1 PM_{10} Planning Areas in Arizona

[1] A primary NAAQS standard prevents damage to human health; a secondary standard prevents environmental and property damage.

[2] Areas redesignated to attainment are subject to maintenance plans. An exceedance of the NAAQS is treated the same way as a nonattainment area; however, maintenance plan design values can be flagged as well but are not addressed by the federal Exceptional Events Rule. Maintenance plans are in place for 20 years.

Arizona has nine PM_{10} planning areas:

Ajo	Nonattainment; new plan under development
Bullhead City	Redesignated to attainment under a Limited Maintenance Plan
Douglas-Paul Spur	Nonattainment; new plan under development
Hayden	Nonattainment; plan to be revised[3]
Maricopa County	Nonattainment; under Five Percent Plan[4]
Miami	Nonattainment; Limited Maintenance Plan submitted to EPA
Nogales	Nonattainment; plan to be revised; also nonattainment for $PM_{2.5}$
Payson	Redesignated to attainment under a Limited Maintenance Plan
Rillito	Nonattainment; Limited Maintenance Plan submitted to EPA
Yuma	Nonattainment; Maintenance Plan submitted to EPA

Detailed information about the planning areas can be obtained by going to ADEQ's Web site at http://www.azdeq.gov/environ/air/plan/index.html.

1.2 High Wind Exceptional Events Versus Fire Events

As previously stated, exceptional events can include among other events, fire events and high wind events. For the purposes of this discussion, however, the focus is on high wind events as they are often the more prevalent cause of exceedances in areas throughout Arizona as well as other parts of the Western United States due to complex terrain and unique weather patterns. The characteristics of these high wind events are discussed further in a white paper titled, *Impact of Exceptional Events 'Unusual Winds' on PM_{10} Concentrations*.

2.0 Control Measures

The development of a state implementation plan (SIP) for an area designated as nonattainment for PM_{10} includes at the minimum:

- a review of all relevant monitoring sites and ambient monitoring data;
- development of an emissions inventory of all contributing sources of PM_{10};
- application of emission factors to the ambient concentrations recorded in the emissions inventory; any controls already in place for PM_{10} emissions;
- any controls in place in areas throughout the country, particularly the West, with similar characteristics to the planning area;
- any current research on effective control measures; current level of enforcement for any control measures already in place;
- and any modeling that shows the effectiveness of control measures on PM_{10} emissions.

Fortunately, there is a moderate amount of information about control measures for PM_{10}; unfortunately, much of the information is source and area-specific. Information on the relative effectiveness of control measures is not as abundant, nor is it easily applicable to the specific conditions in most of the PM_{10} planning areas in Arizona. Because the demonstrations required to obtain a concurrence on an exceptional event should account for the relative complexity of the emitting source mix, parsing out a specific source or source category along with the applicable control measure for a determination of relative effectiveness can be difficult and may even be counter-productive. This is compounded by the

[3] The Hayden area was previously included with the Miami area; split into two planning areas later approved by EPA.
[4] Maricopa County nonattainment area also include Apache Junction portion of Pinal County.

fact that PM_{10} cannot be characterized by a specific source category through routine examination of the particulates deposited on a monitor's filter. Through the SIP development process, however, the overall make-up of the planning area is known and fairly reliable assumptions about source contribution and implemented control measure effectiveness can be made in most cases.

2.1 Evaluating the Effectiveness of Control Measures; Implementation and Enforcement

There are several ways to evaluate the effectiveness of a control measure. The most direct approach is actual field testing. Planners can also query representatives of other planning areas for examples of effective control measures, sharing testing data, or replicating specific field tests. Another approach is to research control measures that have been recognized as BACM by EPA, other states, source emitters, or in some cases by the courts. Regardless of how a control measure is chosen and its relative effectiveness evaluated, it is often subjected to a computer model to demonstrate whether the control measure or measures actually show a reduction in emissions or prevent an increase in the concentration of emissions (i.e., reasonable further progress toward attaining the NAAQS).

Optimum effectiveness is measured by the degree of control efficiency; efficiency can be a set percentage or a range (i.e., the range can represent how the control measure is to be implemented over time) in relation to the level of compliance, or control efficiency multiplied by the compliance level. In the case where a control measure is a one-time, succinct action such as paving an unpaved road, the effectiveness should be high.[5] Other calculations of effectiveness can be less straightforward due to the variables in implementation and enforcement. Degree, range and timing of control measure implementation coupled with a variable level of enforcement make field inspections of vital importance to determine the true effectiveness of certain control measures. Without reliable or complete reporting of the implementation of control measures, the lower or lowest range of control efficiency is most likely reflective of actual field situations. It is difficult to calculate other types of control measure effectiveness when the implementation is more qualitative than quantitative in nature, even though the measure has proven effective in field tests (e.g., actions required only when special circumstances arise, or actions that rely on training and advanced communication). Field inspections, reporting, and a noticeable reduction in emissions provide verification of projected control efficiency for a particular control measure. A pattern of non-compliance would provide verification that the control efficiency has been compromised or the control measure itself was perhaps unenforceable as currently designed or implemented.

Due to the varied nature of control measures, a planning approach that commits to a series of control measures rather than relying solely on only a few is often the best way to gain an overall high level of control effectiveness for a planning area. The commitment to implement these measures suggests that an optimal level of enforcement will be in place, often strengthened further by permit conditions, rules, and ordinances with specific consequences for non-compliance. Control measures that are voluntary in nature can also have a high degree of effectiveness but often rely on ongoing outreach and inspections. Contingency measures are designed to provide additional emission reductions should the committed control measures fail to provide sufficient reductions. These measures are often not modeled toward progress in reducing emissions of a particular pollutant, but they can be effective should sources not wish to move to the higher degree of control these measures can represent.

By considering a control measure or suite of control measures in place around the time of an exceptional event, such as those triggered by high winds, it should be possible to determine the following: either (a) the control measure effectiveness was insufficient to control the background concentration of emissions thereby contributing to cumulative emissions sufficient to exceed the NAAQS when coupled with high

[5] In areas where a maintenance plan is in place, control measures that may appear permanent must be routinely revisited to assure that they are in good condition, or authority to enforce certain measures is still in place.

winds, or (b) the wind conditions were unique and severe enough to overwhelm the control measures regardless of control effectiveness.

3.0 Effect of Exceptional Events (High Winds) on Control Measures; Overwhelmed Controls

In parts of the Western United States high wind events can generally be classified as one of two types: mesoscale events or synoptic scale events. Mesoscale high winds associated with thunderstorm development are localized events that are often initially devoid of rain and cause a reduction in visibility due to lofted particles from disturbed arid land or certain soil types. Synoptic scale high wind events, on the other hand, have a greater tendency to transport particles over long distances. Both types of high wind events are capable of transporting particles into an area from distances outside of a specific planning area. This paper does not attempt to explain in detail the effect of these types of high winds, but in relation to planning area control measures it is important to note that at times these winds can overwhelm or greatly reduce the effectiveness of a control measure or suite of control measures.

Unfortunately, information on the effects of high wind events on control measures, specifically measures for the control of particulate matter, is not readily available. Most of the information is anecdotal in nature, observations after the fact. There are studies on the effects of high winds on particulate matter itself – effects of particle size bombardment and particle size relative to transport – but the information does not always translate well to control measure applications or is too case-specific. More to the point, however, is an understanding that certain measured high wind speeds do cause lifting of certain soil types or increase background concentrations of already existing particulates. There is a fair amount of agreement and observations to support that high winds over a certain speed can overwhelm most controls regardless of the level of implementation or enforcement. The phenomenon is discussed further in a corresponding white paper titled, *Impact of Exceptional Events 'Unusual Winds' on PM_{10} Concentrations*.

4.0 Tracking Relative Effectiveness of Implemented Control Measures During High Winds

As stated previously, it is essential that the control measures for a planning area be routinely inspected for implementation and level of enforcement in order to have a meaningful sense of control measure effectiveness. Text of permit conditions needs to be periodically reviewed, dust complaints need to be properly logged and the subject of timely and appropriate response, inspections and any enforcement actions that resulted need to be reported, along with any other action necessary to determine the full implementation of a control measure. When comparing the control measures to the effects of a high wind event, it is helpful to know what the conditions were on the ground and in the air prior to the high wind event, the day of the high wind event, and after the high wind event. The time before the event can determine possible contributors to elevated PM_{10} concentrations while the time after the event could expose non-compliance patterns that would not otherwise be directly tied to the event.

In order to obtain a better picture of what control measures are in place during the intervals of a high wind event, a simple reporting form has been constructed. This form, when reviewed by analysts of the high wind event, should provide a clearer picture of what could have contributed to the exceedance and could add to an argument that the event was indeed exceptional. The form requires several pieces of useful information. (1) Because some, but not all, planning areas have High Pollution Advisory (HPA) notification procedures, including high wind watches for particulate matter pollution, noting the existence of a HPA action on the day of or days prior to the event is important.[6] (2) Complaints are useful bits of

[6] For areas that do not have a HPA program in place, the National Weather Service issues storm watches and warnings to alert the public to possible heavy rain, flooding, gusty winds and blowing dust. Airports, both large and small regional air fields, also have data sources that register high winds and reduced visibility so aircraft warnings can be issued.

information as they often reveal insufficient implementation or enforcement of control measures, especially if the complaints are for the same source or group of sources; in the case of voluntary measures they can be the only available measure of effectiveness. (3) Inspections completed routinely or for special purposes (e.g., nighttime inspections) give specific information on what is happening in and around the planning area, particularly inspections required during a HPA. (4) Finally, any record of notices or actual enforcement actions on a source in the planning area tells a story of serious non-compliance with implemented control measures, or it tells of control measures that have been insufficiently implemented.

A sample form is attached to this paper. Each party responsible (i.e., State, County, or any other relevant public officer/agency) for sources in the planning area would complete the form, which would then be reviewed by those preparing the analysis that demonstrates whether the high wind event is truly an exceptional event. For those events that are obviously of such severity that control measures would be overwhelmed, it is still useful to note the control measure actions for the planning area, especially an issuance of a HPA or pertinent weather forecast. The reverse side of the form contains the committed control measures for the planning area. Control measures can vary considerably for particular planning areas, but including them on the form reminds everyone that they need to be considered in the exceptional event analysis.

5.0 Conclusion

A demonstration that a high wind event is in fact an exceptional event requires a robust analysis of the wind conditions coupled with an examination of the control measures in place in and around the area in which the monitor registered an exceedance. This demonstration must not only pass the scrutiny of regulators but also the general public. Should the high wind event that caused the exceedance truly reflect an influence that resulted in ambient air concentrations of particulate matter that fell outside the range of normal statistical fluctuations, then EPA's concurrence with the demonstration allows for a focus on PM_{10} emissions that can be controlled.

PM_{10} Control Measures Reporting Form
High Wind Exceptional Event Demonstration

Date of Flagged Event _____

PM_{10} Planning Area _____

Exceeding Monitor(s) _____

AQI/High Wind/Dust Forecast (rolling three day forecast) Issued?

Yes	No
☐	☐

Type: _____

In the spaces below, please provide information about the 72-hour period preceding the event, the day of the event, and the 72-hour period following the event. For a list of control measures for the planning area, see back of this form. Account for minimum 2 mile area around exceeding monitor(s). *Please attach additional information if necessary*.

Complaints:

_____
_____
_____

Inspections:

_____
_____
_____

Notices or Enforcement Actions:

_____
_____
_____

Regulating Agency _____

Information Supplied By _____

Date Completed _____

FOR INTERNAL PURPOSES ONLY
Reviewed by / date: _____

Appendix H
Background on Unusual Winds “White Paper”

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ADEQ
Arizona Department of Environmental Quality

The Impact of Exceptional Events 'Unusual Winds' on PM_{10} Concentrations in Arizona

Air Quality Division

Updated July 28, 2010

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TABLE OF CONTENTS

Introduction 1

Spatial and Temporal Variability of Windblown Dust Events 1

Threshold Friction Velocities and Threshold Wind Speeds 4

Best Available Control Measures (BACM) Effectiveness 9

Other Influential Factors in the Formation and Impact of Windblown Dust 10

The Effect of Particle Size and Turbulence on Dust Settling Rates 11

Literature Conclusion 11

Examination of Historical Wind & Particulate Matter Data in AZ – Wind Threshold Effect 12

Identifying PM_{10} Producing Threshold for High Wind Speed Based upon Local Data 23

Further Examination of the Joint Effects of Topography, Threshold Friction Velocity, and Surface Roughness 24

Summary 24

REFERENCES 26

EXHIBIT 1

(Technical Demonstration of the Impact of Terrain, Threshold Friction Velocity, and Surface Roughness on PM10 Generation by Winds) 29

ATTACHMENT

(*High PM-10 Associated with High Wind Events in the Salt River Basin of Phoenix*

Feng Lui, Maricopa Association of Governments) 44

LIST OF TABLES

Table 1 – Frequency of Dust Episodes from Various Studies for Yuma, AZ 2

Table 2 – Threshold Friction Velocities for Typical Desert Surface Types 5

Table 3 – Aerosol Emission Test Results 5

Table 4 – Site Surface and Textural Characteristics 7

LIST OF TABLES – Continued

Table 5 – Threshold Dust-lofting Wind Speed in Various Desert Environments 9

Table 6 – Inhomogeneity of Wind Gusts Reported in the Phoenix Metro Area 13

Table 7 – Crosstabulation of Average Wind Speed and PM Concentrations 15

Table 8 – Crosstabulation of Hourly Maximum Wind Gust and PM Concentrations 16

Table 9a – Expanded Seasonal Crosstabulation of Hourly Maximum Wind Gust and PM Concentrations-Winter (Dec-Feb) 18

Table 9b – Expanded Seasonal Crosstabulation of Hourly Maximum Wind Gust and PM Concentrations-Spring (Mar-May) 19

Table 9c – Expanded Seasonal Crosstabulation of Hourly Maximum Wind Gust and PM Concentrations-Summer(Jun-Aug) 20

Table 9d – Expanded Seasonal Crosstabulation of Hourly Maximum Wind Gust and PM Concentrations-Autumn (Sep-Nov) 21

Table 9e – Expanded Seasonal Crosstabulation of Hourly Maximum Wind Gust and PM Concentrations-Annual Recap 22

LIST OF FIGURES

Figure 1. Graph showing the highly correlated distribution of hourly maximum wind speed and 5-minute average wind speed 24

Introduction

Windblown dust has been and continues to be a pollutant of concern throughout the deserts of Arizona and southeastern California. The Arizona Department of Environmental Quality (ADEQ) requests that these dust episodes are excluded from regulatory decisions when the dust is associated with non-anthropogenic emissions or when control measures are overwhelmed by strong winds. During the last several years, these requests have increased substantially due to a greater deployment of continuous particulate matter (PM) monitors throughout Arizona. To supplement the exceptional event analyses for high wind and blowing dust events in Arizona, a review of historical meteorological and environmental data was conducted. Additionally, literature concerning the effects of strong winds on particulate emissions was examined. This literature review focused on (1) the theory behind dust suspension caused by wind; (2) laboratory experiments documenting wind speed thresholds that suspend soil particles; and (3) the frequency with which blowing dust occurs in the desert southwest as determined from meteorological data and observations of blowing dust.

The Western Regional Air Partnership (WRAP) conducted a thorough review of literature relating to impacts of fugitive dust on air quality. Much of this information was compiled into WRAP's *Fugitive Dust Handbook* (FDH) (WRAP FDH, 2006). While the handbook does not apply to ambient air quality monitoring, it does include specific information about various control measures for agricultural activity, construction activity, paved and unpaved roads, and more. Sections of this handbook cover the windblown suspension of dust from both anthropogenic and natural, barren areas. The FDH (2006) defines anthropogenic dust as "solids and dissolved solids entrained by wind passing over surfaces that have been disturbed or altered by humans beyond a natural range". The handbook gives examples of such anthropogenic sources of dust including construction and mining sites, agricultural activities, material storage piles, landfills, vacant lots, roadways, and parking lots. The FDH defines natural dust as "solids and dissolved solids entrained by wind passing over surfaces that have not been disturbed or altered by humans beyond a natural range" (WRAP FDH, 2006). Examples of these natural dust sources include naturally dry riverbeds and lakebeds, barren lands, sand dunes, and non-agricultural grass, range, or forest lands. It is important to note that "natural and anthropogenic dust will often be indistinguishable and may occur simultaneously", which means that while natural areas may emit dust during high wind events, those same areas will emit more dust when their surfaces have been or are in the process of being disturbed by human activities (WRAP FDH, 2006). One example of this would be a dry riverbed (a natural dust source) that has recently been the site of all-terrain vehicle activity (an anthropogenic influence).

While wind generated emissions may result from open dust sources during high wind events, those emissions can exhibit a high degree of variability from one site to another, and may fluctuate widely at any given site. This is especially true in areas where terrain and/or urban development play a role and may influence the wind. The FDH gives two groups of site characteristics that can cause such variability:

(a) Properties of the exposed surface material from which the dust originates
(b) Measures of energy expended by wind interacting with the erodible surface

In addition to these site specific characteristics, the spatial and temporal variances in the interaction of the atmosphere with the surface also contribute to the variability of windblown dust emissions.

Spatial and Temporal Variability of Windblown Dust Events

Several studies have been conducted on the spatial and temporal variability of dust episodes associated with high wind events in Arizona and California. Dust events have been defined by a reduction in visibility to less than 11 km (Orgill and Sehmel, 1976; McTanish and Pitblado, 1987). Additionally,

events with visibilities ≤ 1 km may have significant impacts on atmospheric pollution, health hazards, and environmental air quality (Jauregui, 1989a cited by Bach et al. 1996; Middleton, 1989a cited by Bach et al. 1996). Many studies have used these < 11 km and≤1 km visibi lity criteria to assess the temporal and spatial variability of windblown dust events. From the literature reviewed, the one location that overlaps a majority of the studies is Yuma, AZ. Descriptive statistics of annual average dust events in Yuma range from 9.6 events per year to 27 events per year (Bach et al. 1996; Holcombe et al. 1996; Brazel and Nickling 1987; Brazel and Nickling 1984). Brazel and Nickling's (1984) calculation of 9.6 events per year appears to be a low outlier in view of other studies. The disparity is likely due to differences in data and/or methodology and does not appear to be associated with the temporal coverage of the analyses. Brazel and Nickling's (1984) results are likely an underestimate of blowing dust events in Arizona (personal communication, Brazel). When using the 11 km visibility criteria, most studies report annual dust episodes in Yuma to range from 22.4 to 27 events per year (Bach et al. 1996; Holcombe et al. 1996; Brazel and Nickling 1987). When using the 1 km visibility criteria, annual average dust episodes in Yuma range from 1.6 events per year to 4.7 events per year (Bach et al. 1996; Brazel and Nickling 1987; Brazel and Nickling 1984). The use of the different criteria indicates that the occurrence of dust episodes of varying severity in the desert southwest has been an ongoing phenomenon since observations have been taken. The more severe 1 km visibility criteria episodes likely make up a majority of the windblown dust PM_{10} exceedances in Yuma, AZ. While these events do not occur every day, it is not uncommon for blowing dust episodes to affect a single location several times over the course of any given year.

Table 1 –
Frequency of Dust Episodes from Various Studies for Yuma, AZ

Source	Time Period	Annual Average Dust Episodes	
		Vis < 11 km	***Vis < 1 km***
Bach et al (1996)	1973-1984	22.4	2.6
Holcombe et al (1996)	1948-1978	27	N/A
Brazel and Nickling (1986)	1942-1982	23.9	4.7
Nickling and Brazel (1984)	1965-1980	9.4	1.6

While much of the research on dust episodes in Arizona has focused on Yuma, AZ, Brazel and Nickling (1984) also analyzed data for other regions of Arizona (i.e., Winslow, Tucson, and Phoenix). Their analysis determined that dust episodes occur more frequently in Yuma and Phoenix in comparison to Tucson and Winslow. While Phoenix and Yuma experience blowing dust episodes on a yearly basis, the characteristics of these episodes can be quite different between the two locations. For example, while Yuma experiences more moderately intense dust storms (i.e. visibilities < 11 km but ≥ 1 km) in any given year, Phoenix experiences more intense dust storms (i.e. visibility≤ 1 km). On the other hand, Phoenix and Yuma contain a similar distribution in dust episodes throughout a given year with peak occurrences in August and April respectively. Brazel and Nickling (1986) further analyzed these dust episodes and associated them with differing weather types. In general, dust episodes in Yuma are most often associated with synoptic weather patterns, specifically frontal passages. These episodes occur most often in the spring months when the mid latitude storm track reaches furthest south. Phoenix is affected most by dust episodes associated with thunderstorm outflow boundaries during the monsoon season in July and August. Phoenix is more often affected by short duration, high intensity dust storms due to its proximity to the Mogollon Rim and SE Arizona, where thunderstorms develop more frequently. Typical storm motion during the monsoon season is from east to west, but storms can also approach from the north and south. Essentially, storms can approach from an area starting at 0° (north) and rotating clockwise to the 180° (south) azimuth. This is illustrated well in Brazel and Nickling's (1986) Figure 9(c). It should be noted, however, that dust episodes in Yuma are also associated with thunderstorm outflow boundaries during the monsoon season. Similarly, Phoenix is also affected by non-monsoonal dust storms associated with frontal passages. While dust episodes caused by high winds are most common in the spring and

summer for Yuma and Phoenix, respectively, these dust events can occur throughout the year for either location.

Dust storms associated with different weather types will have differing characteristics based on the weather type. For example, dust storms associated with synoptic scale weather types (i.e. frontal passages or trough passages) typically are longer in duration (on the order of several hours to 10 hours) and less intense (i.e. visibilities between 2 and 11 km). Dust storms that are associated with mesoscale weather types (i.e. thunderstorm outflow boundaries) tend to be shorter in duration (1 hour to several hours) but are more intense (visibilities between ¼ mile and 5 miles). While each hour of a synoptic scale driven dust storm may be less intense than an hour in a mesoscale driven dust storm, the effect on human health when averaged over the entire day may be very similar (i.e. 24-hr average PM_{10} concentrations may be similar for the two types of dust storms). It should be noted that dust storms produced by synoptic type weather patterns are deemed synoptic because the area of high winds is typically fairly large. In many cases, however, the area of blowing dust may be much smaller than the extent of high winds due to the variability in soil characteristics throughout the region or the influences of local topography which can enhance wind speeds at a particular location. This is most often seen in areas such as El Centro, CA and Imperial, CA, and to a lesser degree, Yuma, AZ.

Blowing dust will vary spatially and temporally based upon variations in the speed and timing of winds throughout a region. "Wind-generated emissions from open dust sources also exhibit a high degree of variability from one site to another, and emissions at any one site tend to fluctuate widely" (WRAP FDH, 2006). Because threshold wind speeds may vary over a region and must be exceeded to trigger a potential dust event, the dependence of erosion potential on wind speed cannot be represented by any simple linear function. For this reason, the use of an average wind speed as it relates to windblown dust is inappropriate.

Maximum wind gusts serve as a better indicator of windblown dust potential than do hourly averaged wind speeds (Holcombe et al., 1996; WRAP FDH, 2006). Because erosion potential has been found to increase rapidly with increasing wind speed, emissions are more related to maximum wind gusts (WRAP FDH, 2006). The Federal Meteorological Handbook defines 'wind gusts' as the "maximum instantaneous wind speed" and they are "indicated by rapid fluctuations in wind speed with a variation of 10 knots or more between peaks and lulls" (Federal Meteorological Handbook No. 1, 2005). This definition of, and reporting process for, wind gusts by the National Weather Service (NWS) is very similar to the 'maximum winds' that are recorded by the Maricopa County monitors, Arizona Department of Environmental Quality (ADEQ) monitors, and the Arizona Meteorological Network (AzMET) monitors frequently included in ADEQ's Exceptional Event analyses. These monitors report a maximum instantaneous wind speed for each hour in much the same way the NWS wind gusts are reported. The way in which maximum winds or wind gusts are recorded by these monitors results in the wind gust and maximum wind data from each being comparable.

The susceptibility to blowing dust varies greatly over the Sonoran Desert region of the southwestern United States, and dust emissions due to wind erosion have been shown to be strongly dependent on the moisture level of the surface soil. Holcombe, Ley, and Gillette (1996) determined that mountains, irrigated agricultural areas, wetlands, rivers and lakes, and urban areas all can be characterized as having a low susceptibility to blowing dust. Meanwhile, basin areas have susceptibilities ranging from low to moderate while dry riverbeds and lakebeds and non-irrigated portions of the Colorado River delta are highly susceptible to blowing dust, especially in areas where desert pavement is disturbed exposing fine-grained sediments from beneath (Holcombe et al., 1996).

Threshold Friction Velocities and Threshold Wind Speeds

Another factor that has received some attention in the literature is the dependence of soil type characteristics on particle movement by wind (e.g. Nickling, 1988; Gillette et al., 1980; Gillette et al., 1982; Gillette, 1988; Nickling and Gillies, 1989; WRAP, 2006). There are three ways by which wind can transport soil particles: saltation, surface creep and suspension (Lyles 1988; Nickling 1988). Saltation normally occurs with particles that are too large to be suspended for a long period of time in the atmosphere. The process of saltation involves particles ranging from about 75 to 500 µm in diameter that are lifted from the surface and bounce within a layer close to the boundary between the air and the surface. Particles that are transported by surface creep can range from about 500 to 1,000 µm in diameter and move very close to the ground due to their larger size. Both wind friction and saltating particles can provide the mechanism for particles to move by surface creep (WRAP FDH, 2006).

Generally, particles less than about 75 µm in diameter may be suspended in the atmosphere, and these particles tend to follow air currents given strong enough surface winds. The threshold wind speed for the onset of saltation, which helps cause wind erosion leading to windblown dust emissions, is dependant on soil texture and particle size (Nickling, 1988). Thus, smaller dimension particles tend to have the lowest threshold friction velocities and threshold wind speeds at 10m above the surface. The saltation process causes particles to collide resulting in the release of particles in the PM_{10} size range that are typically bound by surface forces to larger clusters of sediment (WRAP FDH, 2006; Lyles, 1988).

WRAP developed a wind blown dust model in addition to creating the FDH. The model was based upon the characterization of various land types and soil conditions. To create this model, a number of assumptions were made, including a threshold wind velocity of 20 mph that is independent of land use and soil texture. This threshold wind speed assumption was based upon previous research measuring both surface and ten meter threshold friction velocities and threshold wind speeds (WRAP, 2006; Lyles 1988). In order to calculate friction velocities or threshold wind speeds the Prandtl Equation is used:

$$\left(\frac{u_z}{u_*}\right) = \frac{1}{\kappa}\left(\frac{z}{z_o}\right) \qquad \text{Equation (1)}$$

Where uz is the wind velocity at height z ($m^{-1}s$), u_* is the friction velocity (ms^{-1}), κ is von Karman's constant (~0.4), and zo is the aerodynamic roughness height (m) (Nickling and Gillies, 1989). Information about a surface's aerodynamic roughness is needed in order to apply the relationship shown in Equation 1 and determine the threshold friction velocity of a surface or the corresponding 10m wind speed. Unfortunately, this roughness height information is not generally available or reported in land use databases. It is possible, however, to use the land use designation of varying surfaces to determine estimated aerodynamic roughness lengths based on previously reported values for the same or similar surfaces. Factors such as the presence of vegetation on a surface, as well as the height and period of cover of the vegetation, can introduce a degree of uncertainty to assigning an aerodynamic roughness length to a surface (WRAP, 2006).

A number of studies have been conducted in an attempt to determine what threshold friction velocity is necessary to loft and transport dust from various soil types and under differing soil conditions. The WRAP (2006) Wind Blown Dust model study compiled threshold friction velocities that had been measured and estimated by some of this previous work. Table 2 shows one such compilation of data that compares threshold friction velocities for typical desert surfaces for two different surface conditions. The "Undisturbed" column presents surface threshold friction velocities for the natural state of each surface while the "Disturbed" column provides the threshold friction velocities for each surface that has undergone significant anthropogenic disturbance. In each case, the threshold friction velocity for

disturbed soil is lowered significantly from the threshold friction velocity for undisturbed soil (WRAP, 2006). The effect that anthropogenic disturbances have on the threshold friction velocity at each site type is significant and ranges from a low of a 17% decrease for the alluvial fan type soils to a 92% decrease for the prairie site type. The average percent change in threshold friction velocity when comparing undisturbed surfaces to disturbed surfaces across all site types is a 55% drop from the undisturbed value (WRAP, 2006).

Table 2 – Threshold Friction Velocities for Typical Desert Surface Types

Site Type	Average u_{*_t} (ms⁻¹) Undisturbed	Number of Data Points	Average u_{*_t} (ms⁻¹) Disturbed	Number of Data Points	% Change
Agricultural Fields	1.29	41	0.55	37	57
Alluvial Fans	0.72	2	0.60	2	17
Desert Flat	0.75	4	0.51	4	32
Desert Pavement	2.17	4	0.59	5	73
Fan Surface	1.43	5	0.47	5	67
Playa, Crusted	2.13	4	0.63	15	70
Playa	1.46	12	0.58	25	60
Prairie	2.90	1	0.24	3	92
Sand Dune	0.44	4	0.32	4	27

Sources: Gillette et al. (1980, 1982), Gillette (1988), and Nickling and Gillies (1989), WRAP (2006).

Nickling and Gillies (1989) used a portable wind tunnel at thirteen study sites, twelve of which were located in Arizona with one in Algodones, California, in order to analyze threshold friction velocities at sites exhibiting an array of different characteristics. Threshold friction velocities were determined by slowly raising the wind velocity in the portable wind tunnel until movement of particles was noted by observers. This process was repeated multiple times at each site to produce a reliable dataset. Resultant velocities were found to vary significantly across the 13 sampled surfaces. Surface threshold friction velocities ranged from 17.2 cms⁻¹ to 58.2 cms⁻¹. These threshold friction velocities were then used to calculate the equivalent 10m threshold friction velocities. The threshold wind velocities at the 10m level varied from lows of 5.11 ms⁻¹ (11.43 mph) at a mine tailings site in Hayden , AZ and 6.68 ms⁻¹ (14.94 mph) in the dry Salt River channel in Mesa, AZ to highs of 16.59 ms⁻¹ (37.11 mph) at a Yuma, AZ agricultural site and 18.31 ms⁻¹ (40.96 mph) at the dune flats of Algodones, CA (Nickling and Gillies, 1989). Full descriptions of the test sites and results of the wind tunnel studies conducted by Nickling and Gillies (1989) are included in Table 3 and Table 4 below.

Table 3 – Aerosol Emission Test Results

Site	u* (m/sec)	u_{10m} (m/sec)	zo (cm)	Mean Grain Size (µm)	% Silt & Clay	% Aggregates > .84 mm
Mesa, AZ (Agricultural)	0.569	15.63	0.0331	1077.0	18.6	26.8
Maricopa, AZ (Agricultural)	0.578	13.82	0.1255	749.3	11.2	37.3
Yuma, AZ (Agricultural)	0.582	16.59	0.0224	642.6	8.8	18.5

Casa Grande, AZ (Abandoned Agricultural)	0.246	7.80	0.0067	234.4	26.6	2.4
Glendale, AZ (Construction Site)	0.530	14.69	0.0301	1275.1	24.7	27.9
Tucson, AZ (Construction Site)	0.251	7.26	0.0191	1010.9	14.3	21.0
Ajo, AZ (Mine Tailings)	0.228	6.68	0.0176	335.3	8.9	0.5
Hayden, AZ (Mine Tailings)	0.172	5.11	0.0141	271.8	27.3	3.0
Algodones, CA (Dune Flats)	0.625	18.31	0.0166	2794.0	15.2	60.3
Yuma, AZ (Scrub Desert)	0.386	11.33	0.0163	1038.8	17.2	22.4
Yuma, AZ (Disturbed Scrub)	0.320	8.11	0.0731	591.8	3.2	7.7
Tucson, AZ (Santa Cruz River Terrace)	0.180	7.26	0.0204	1950.7	20.9	37.4
Mesa, AZ (Salt River Channel)	0.218	6.68	0.0100	398.7	27.7	11.3

Source: Nickling and Gillies, 1989.

Looking at the u_{10m} values in Table 3, it is apparent that there is a substantial grouping of 10m threshold wind velocities around 7.0 ms^{-1} with more than half of the study sites falling between 5.11 ms^{-1} and 8.11 ms^{-1}. Taking the average of the seven 10m threshold velocities falling between 5.11 m/s and 8.11 m/s results in a value of 6.98 ms^{-1}. This value was referenced in the May 31, 2000 TCD for Determination of Exceptional Events which states that "desert soils became suspended at about 7.0 meters per second (15.7 miles per hour)". Thus, the 7 ms^{-1} value (about 15 mph) was derived from Table 3 above from the Nickling and Gillies 1989 study and may serve as a reasonable baseline for the initiation of windblown dust.

It is interesting to note that of the four agricultural sites tested, the abandoned site in Casa Grande had the lowest threshold friction velocity (Table 3). Based upon the site descriptions, this may be a result of the abandoned field being relatively smooth with a weakly crusted surface. In addition, the abandoned field appears to have lacked the large clods covering its surface that the other three active agricultural fields possessed. Equally interesting is that the sand dune flats of Algodones, California had the highest average threshold friction velocity and 10m wind speed (Table 3). The authors note a relation between aggregate grain size distribution and threshold velocities, and this may explain why the dune flats threshold velocity was found to be so high. The dune flats site had the highest percentage of aggregate particles greater than 0.84mm in size of all the test sites. Interestingly, previous research has suggested that the Algodones Dunes are likely the source for blowing dust that is commonly reported in Yuma, AZ (Brazel and Nickling 1986). Holcombe et al. (1996), on the other hand, hypothesized that the source for observational reports of blowing dust in Yuma may be the East Mesa area instead. All studies show that observational reports of blowing dust in Yuma were associated with wind speeds substantially lower than the Algodones 10m threshold velocity reported by Nickling and Gillies (1989). With the source areas in such close proximity to one another, it becomes difficult to determine which source area is responsible for blowing dust in Yuma, AZ. Other potential explanations for the above results may lie in the soil moisture content of each site, which would tend to vary both by site and by time of year. Neither of these important pieces of information was examined nor reported in the Nickling & Gillies (1989) study.

Upon first glance, the threshold velocity results from Nickling & Gillies (1989) might lead one to believe that wind erosion could be initiated at many of the sites under normally occurring winds, but a number of relatively high threshold values at three of the agricultural sites as well as test sites in Mesa, Maricopa, Yuma, AZ and a construction area in Glendale, AZ suggest that a major wind blown dust event would be a relatively infrequent occurrence. It is unclear from the study as to what extent the higher threshold values at these sites can be attributed to any specific control measures that may have been in place. Additionally, natural factors such as recent precipitation, mean grain size, or soil type may have played a role in causing the higher threshold values. It should also be noted that these threshold friction velocities are meant to show the lowest wind speed for which surface particle movement (and potentially windblown dust production) is likely to begin.

Table 4 –
Site Surface and Textural Characteristics

Site	Site Characteristics
Mesa, AZ (Agricultural)	Flat, laser leveled for irrigation; no vegetation or surface trash; double disked 2 days prior to testing; large clods of varying size covering the surface.
Maricopa, AZ (Agricultural)	Flat, laser leveled for irrigation; no vegetation or surface trash; secondary tillage operations in preparation for cotton planting; large clods of varying size covered the surface.
Yuma, AZ (Agricultural)	Flat, laser leveled for irrigation; no vegetation or surface trash; surface was loose and friable with few large clods.
Casa Grande, AZ (Abandoned Agricultural)	Flat, smooth, laser leveled at some previous time; sparse vegetation; primarily annual grasses; weakly crusted surface; easily disturbed.
Glendale, AZ (Construction Site)	Flat, smooth, machine-leveled surface; no vegetation; surface soil heavily pulverized by earthmoving machinery and regularly watered for dust control; easily disturbed by vehicular traffic.
Tucson, AZ (Construction Site)	Very flat, machine-leveled surface; no vegetation; surface soil heavily pulverized by earthmoving; fetch length over 1 km in all directions; regularly watered for dust control.
Ajo, AZ (Mine Tailings)	Extremely flat, extensive copper mine tailings; no vegetation; mainly unconsolidated sediment with some sparsely intermixed crusted areas; fetch lengths greater than 1 km.
Hayden, AZ (Mine Tailings)	Extremely flat copper tailings; no vegetation; light crust is easily disturbed; fetch lengths greater than 1 km.
Algodones, CA (Dune Flats)	Relatively flat, extensive outwash deposits adjacent to Algodones Dune complex; sparse vegetation cover; surface weakly crusted; lag of fine pebbles; heavily disturbed by off-road vehicles.
Yuma, AZ (Scrub Desert)	Relatively flat; sparse vegetation cover; surface is weakly crusted; lag of fine pebbles; heavily disturbed by off-road vehicles.
Yuma, AZ (Disturbed Scrub)	Slightly undulating surface; sparse vegetation cover; primarily annual grasses, sagebrush and creosote bush; surface soil is very loose with little cohesive structure; heavily disturbed by off-road vehicles.
Tucson, AZ (Santa Cruz River Terrace)	Flat terrace deposits adjacent to river; sparse vegetation cover; high silt content with fin gravel lag deposit.
Mesa, AZ (Salt River Channel)	Slightly undulating river bed; no vegetation; surface is very loose with no evidence of crusting; heavily disturbed by off-road vehicles.

Source: Nickling and Gillies, 1989.

Nickling and Gillies (1989) stresses an increased potential for aerosol (lofted dust) production at those sites which experience a periodic disturbance of soil such as the river channels and mine tailing sites, as they tended to exhibit lower threshold friction velocities. This was also a point of emphasis in the WRAP (2006) Wind Blown Dust model work that compared threshold friction velocities for disturbed and undisturbed soil of various study sites by compiling available data from previous research such as that done by Nickling and Gillies. Precipitation is another factor to consider, as periodic rains help to build up and maintain a surface crust on the soil by redistributing clay particles on the surface, creating a seal as they are left behind after infiltration and evaporation processes occur (Nickling and Gillies (1989). It is also possible that severe precipitation in the form of brief heavy rain or hail may serve to break up an already developed surface crust and naturally disturb the soil, leading to a greater possibility of a windblown dust event. It has also been shown that individual sites can have vastly different soil conditions based upon any soil vegetation, moisture, or the overall proportion of larger sized grains. That is to say that not all agricultural fields, construction sites, and sand dune areas will experience the same threshold friction velocities as all other agricultural fields, construction sites, and sand dunes.

The University Corporation for Atmospheric Research (UCAR) maintains an educational website at http://www.meted.ucar.edu/mesoprim/dust that provides a comprehensive overview of the forecasting of dust storms while including a detailed explanation of the physical processes involved in the wind transport of sediment. It gives 15 knots (~17 mph) as a rule of thumb as to the minimum wind speed that is necessary for mobilizing dust without regard to varying soil types. After winds decrease below the initiation levels dust storms can continue and maintain the same intensity due to the breakdown in the bonds between dust particles and the surface. Once this bond is broken the saltation process can continue to allow dust to lift (UCAR, 2003). While 17 mph is given as an approximate baseline minimum for generating wind-blown dust, more detailed breakdowns of threshold wind speeds for various desert environments are also given in the UCAR educational website for the forecasting of dust storms (Table 5). These threshold wind speeds range from near 15 mph for fine to medium sand dune areas up to 40 mph in desert areas where desert pavement has been well-developed. "Desert pavement" is the term given for the thin veneer of rocks that is left behind once wind and other erosive processes remove finer grained material from the desert surface leaving only larger grains and stones on the surface. The formation of desert pavement thus suppresses windblown dust as fewer finer grained particles are available on the surface for transport.

There is a large difference between the threshold wind speed given for sand dune areas on the UCAR webpage and that given in the Nickling and Gillies (1989) study. As previously mentioned, particle size (and possibly moisture content) provides a possible explanation for this disparity in threshold wind speeds. Additionally, the Nickling and Gillies (1989) study looked at a site on an outwash area adjacent to a sand dune complex composed of a significant percentage of larger sized grains whereas the UCAR page describes the sand grains of the dune area they studied as being fine to medium sized. This may account for the greater than twenty mph disparity in threshold wind velocities given for sand dune areas between the two studies. In Arizona, the most common source environments for windblown dust are likely to range from varying degrees of desert pavement to desert flats, salt flats, and dry river channels, but dune areas outside of the state both to the south and west can also serve as potential particulate sources, particularly for Yuma, AZ. The minimum wind speeds necessary for dust transport in these types of source environments, according to the bulk of the research, has been shown to range from approximately 15 mph to 35 mph.

Table 5 – Threshold Dust-lofting Wind Speed in Various Desert Environments	
Environment	**Threshold Wind Speed**
Fine to medium sand in dune-covered areas	10-15 mph
Sandy areas with poorly developed desert pavement	20 mph
Fine material, desert flats	20-25 mph
Alluvial fans and crusted salt flats (dry lake beds)	30-35 mph
Well-developed desert pavement	40 mph

Source: UCAR, 2003.

Research by Holcombe et al. (1996) focuses on the effect that both prior precipitation and particulate source area characteristics can have on threshold friction velocities for wind blown dust events. In their study, they mention that "threshold friction velocities computed from mean hourly wind speeds (MHWS) recorded during dust events are significantly lower than those obtained from wind tunnel experiments over loose desert soils" (Holcombe et al., 1996). However, the authors determine that when threshold friction velocities are computed from mean extreme wind speeds (maximum gusts) they are comparable to resultant threshold wind speeds obtained from wind tunnel experiments. That is to say that the friction velocities computed from mean extreme winds, i.e., maximum wind gusts, are more in line with wind tunnel studies than are threshold friction velocities computed from MHWS, and thus maximum wind gust data may be a better predictor of windblown dust (or at least the threshold friction velocities that are required to begin the saltation process which can lead to dust emissions) than are mean hourly wind speeds (Holcombe et al., 1996). The findings of the research by Holcombe et al. (1996) are in line with the findings of the WRAP FDH (2006) in demonstrating that wind gusts are more important, and show a better relation, to dust emissions than are hourly average wind speeds.

Best Available Control Measures (BACM) Effectiveness

WRAP's Fugitive Dust Handbook (FDH, 2006) contains a plethora of information relating to the numerous strategies available to control dust emissions. The FDH goes into great detail in describing the different control measures and breaks them down into several source categories. Common control strategies for wind erosion include:

- Planting trees or shrubs as a windbreak
- Create cross-wind ridges
- Erect artificial wind barriers
- Apply dust suppressant or gravel
- Revegetate; apply cover crop
- Water exposed area before high winds

These control measures have differing reported control efficiencies ranging from 25% (planting trees or shrubs) to 90% (revegetating and watering exposed areas before high winds). In addition to the control efficiencies reported in the FDH, two field studies were performed for the South Coast Air Quality Management District (Fitz, 1996; MRI, 1995) that specifically mention wind speeds at which BACM becomes overwhelmed. Fitz (1996) concluded that BACM appeared to be effective at reducing PM_{10} emissions at wind speeds up to 18 m/s (about 40 mph); however, the small sample size in this study makes it difficult for these results to be conclusive. Additionally, this study was specific to emissions generated from a local landfill in California. It is not clear how factors mentioned in sections 2.0, 3.0, and 5.0 would affect this defined wind speed. Information from Tables 3 and 4 (specifically data and metadata from the Tucson and Glendale construction sites) may suggest that wind speeds at which

BACM becomes overwhelmed would also be highly variable from one site to another. In another study on the effectiveness of BACM, the Midwest Research Institute (MRI, 1995) simply concluded that even moist soils became erodible at higher wind speeds. The emissions from moist soils became similar to that of dry soils when the moist soils were subjected to wind speeds 15-20 mph higher than winds impinging on dry soil. However, by looking at the data tables from this study, it is difficult to determine the different threshold velocities for moist and dry soils. With the limited research that has been conducted on this specific topic and the lack of detail in the few studies that have been performed, it does not seem appropriate to define a critical wind speed in which BACM becomes overwhelmed. Furthermore, such a critical wind speed would likely differ for each soil type and/or land use type. A more detailed review of general BACM effectiveness and control efficiencies can be found in "High Wind Exceptional Events and Control Measures for PM_{10} Areas".

Other Influential Factors in the Formation and Impact of Windblown Dust

Data from Holcombe et al. (1996) suggest that a wide range of wind speeds is capable of producing blowing and/or suspended dust in the Yuma area. Of the dust episodes in Yuma, 95% contain hourly mean wind speeds that range from 2.9 m/s to 12.96 m/s. This compares to a range of 3.8 m/s to 15.7 m/s at Blythe, indicating that dust may become suspended more easily in the Yuma area compared to Blythe. This may be a factor of Yuma receiving slightly less precipitation and/or various differences in soil characteristics and available dust sources between Yuma and Blythe. In an attempt to determine the effect of prior precipitation on blowing dust episodes in Yuma, MacKinnon et al. (1990) used Nickling's (1988) wind tunnel data to calculate a 10 meter threshold wind speed of 9 m/s, which is similar to the median wind speed obtained from observational reports in the Holcombe et al. (1996) study. In general, dust episodes in Yuma are most common with 10 meter wind speeds between 5 m/s and 13 m/s with a median of 9 m/s. The large range in wind speeds is likely due to the variability in precipitation, prevailing wind direction, vegetation, anthropogenic sources, and other factors.

Bach et al. (1987) reported that annual precipitation explains about 20% of the variance in the incidence of blowing dust. When antecedent precipitation (previous winter's rainfall) is taken into consideration the explained variance increases to 26.5%. When taking the winter precipitation from previous 2 years into account, the explained variance increases to 42.3%. This effect of antecedent precipitation likely also includes a vegetative coverage factor with it. The general rule appears to be that the more rainfall a region receives the more vegetation grows and the greater its ability to keep soils from becoming suspended by high winds. Holcombe et al. (1996) concludes that precipitation can be an important factor in limiting soil suspension. They do, however, note that in places like Yuma where threshold MHWSs lie well below MHWSs recorded during most dust events, local mean annual precipitation could likely increase substantially without significantly reducing the occurrence of blowing dust episodes. While prior precipitation events do help explain some of the variance in dust events, there is a fair amount of variance that is still not explained by precipitation. This variance can likely be attributed to other factors such as soil type, prevailing wind direction, anthropogenic activity, control measures, and changes in land use / land cover.

While wind speed is obviously important for dust suspension, a number of articles also point out that the directional component of the wind is also important as it is an indicator of potential dust sources (MacKinnon et al. 1990; Holcombe et al. 1996; Brazel and Nickling 1986). The Holcombe et al. (1996) paper is particularly interesting as it attempts to apply a vulnerability index to each of the 16 directions. This type of analysis seems to be fairly effective at determining potential dust sources. Several articles indicate that for Yuma, the west and west-northwest directions are associated with high vulnerability and high frequency, while high winds from the east contain a high vulnerability but a low frequency. Conversely, high winds from the south-southeast and northerly directions frequently occur, but have a low vulnerability. The differences in vulnerability in relation to wind direction are an indication that soil

characteristics may be an important factor in dust episodes. While not explicitly stated in the study, one could even define differing threshold friction velocities for each direction. It is also possible that terrain surrounding a monitor might have a shielding effect given certain wind directions, and thus, varying terrain may need to be given consideration when analyzing variances in wind speeds or dust emissions recorded over a region.

The Effect of Particle Size and Turbulence on Dust Settling Rates

Thus far the literature has suggested that the meteorological phenomena required to produce dust events in the desert southwest are highly variable. In fact, factors such as wind speed, wind direction, antecedent precipitation, vegetation coverage, anthropogenic activity, and the location of dust sources all may potentially contribute to the variability in blowing dust episodes. The UCAR dust forecasting education website discusses dispersion and settling rates of lofted dust in relation to buoyancy turbulence (UCAR, 2003). While such turbulence can work to help disperse an existing dust plume, it can also act to keep dust particles in suspension for a longer period of time. Given extremely turbulent flow, it is possible for dust to be lofted to heights well above 3000m (10000 ft.). As long as the upward lift acting on a particle is greater than that particles terminal velocity, the particle should remain aloft. The terminal velocity of a particle is directly proportional to its size, and as gravity acts to accelerate a dust particle downwards, atmospheric resistance acts against it as it falls. Acceleration continues only until the particle reaches its terminal velocity, and from that point on, the particle falls at a constant rate so long as no other factors such as atmospheric turbulence or precipitation influence it (Bagnold, 1984 cited by Wilkerson, 1991). UCAR (2003) states that "without sustained turbulence, dust generally settles at a rate of 1000 feet per hour". This means that if dust is lofted to 5000 ft in extremely turbulent flow (i.e. downdrafts from thunderstorms), it may take the at least 5 hours to settle once turbulent winds decrease to below terminal velocity (i.e., light and variable winds). This can result in dust, once initially suspended by turbulent flow, remaining elevated in the atmosphere and being transported by light winds to impact areas that do not experience the extremely turbulent winds that initialized the dust event. This scenario most often occurs during the monsoon season in July and August when turbulent flow produced by thunderstorms is highly variable across space and time. While dust episodes driven by synoptic scale weather types would likely have similar wind speeds at the source area compared to the point where wind measurements are taken, this assumption may not apply to dust produced from mesoscale storms as the wind speed at the source area may be substantially different than the wind speed measured at the observation point (MacKinnon et al. 1990). The 1000 ft/hr settling rate has been reported for particles between the sizes of 10 to 50 micrometers; however this rate is highly dependent upon various environmental conditions (Larson, 1971 cited in Wilkerson, 1991). These dust settling rate factors include turbulence, humidity, and precipitation. Other studies have reported settling rates ranging from over 10000 ft/hr for particles greater than 150 microns to 36 ft/hr for particles as small as 5 microns (Greveris, 1977 cited in Wilkerson, 1991). Moisture is especially important in limiting the ability of dust to remain lofted in the atmosphere given the hygroscopic nature of most dust particles.

Literature Conclusion

In reviewing the literature, most studies have focused on the meteorological conditions that produce blowing dust. Specifically, wind speed is the most important factor; however, wind direction and antecedent precipitation also contribute to characteristics of dust emissions. There is also speculation that other factors such as vegetation and soil types affect dust emissions as well by raising threshold friction velocities and thus threshold wind speeds at 10m above the surface. While this information is important, for exceptional event purposes one must be able to show that a dust event is 'natural and unavoidable' or at least that there was an attempt to control dust emissions. For the 'natural and unavoidable' case, the prior studies contain some very useful information, particularly in the case of Yuma, AZ where the Algodones dunes (a natural dust source) are the suspected source of dust emissions. However, within an

urban setting where Best Available Control Measures (BACM) are required to suppress dust emissions, it no longer becomes important to simply determine the wind speed at which dust emissions occur, but instead, the speed at which BACM is overwhelmed. While there is some literature on the effectiveness of BACM (i.e. WRAP Fugitive Dust Handbook, 2006), there appears to be very few studies that relate this effectiveness to wind speeds. With several factors influencing threshold friction velocities, defining exact wind speeds for overwhelming BACM or even dust suspension in general becomes a complicated process. Perhaps, the results from this literature review are best summarized by Nickling's (1988) conclusion which states, "The observations of this study suggest that the threshold of most natural sediments should not be defined by a finite value but by a range of threshold shear velocities."

Examination of Historical Wind & Particulate Matter Data in AZ – Wind Threshold Effect

Part of the justification for flagging a particulate matter event associated with blowing dust, is to show the winds were "unusual." This term is used in the preamble of the Exceptional Events Rule. The literature review provided significant justification for what constitutes unusual from various contexts. In order to place perspective on the issue for monitors in Arizona, an analysis of wind and particulate matter information is needed.

Table 6 shows a break down of the frequency of reporting of average winds and of wind gust occurrences considering nine NWS stations located throughout the Phoenix Metropolitan area. While the literature has shown that wind gusts exhibit a higher correlation to windblown dust emissions than do hourly averaged wind speeds, occurrences of wind gusts can be quite varied over the Phoenix Metro area. Data analyzed to compile Table 6 include hourly observations from Jan. 1, 2005 through Aug. 31, 2009. It is important to note that there are a number of stations in the Phoenix area that only report daytime observations and go "off air" during the evening and overnight hours. For the purposes of this analysis, a station can be considered to be "on air" when it is reporting average wind speeds, and columns in the table are divided into breakdowns when all nine stations were "on air", when eight stations were "on air", when seven stations were "on air", or when any other number of stations were "on air" and reporting average wind speed at the very least. Rows in the table are broken down into the number of stations that were reporting a wind gust, and the values within the table represent the number of hours that fall into the given categories and also the percent of hours with reported wind gusts. Table 6 shows that wind gusts can be very localized within the area. Of the hours when all nine stations were reporting valid winds in Phoenix, 74.8 percent of the time, no stations reported a wind gust. Only one station of the nine reported a gust 9.2% of the time, 5.0% of the time two stations reported a gust during the same hour, and only 0.6% of the time (6 in 1000) did all the stations report a gust during the same hour. For hours when any "on air" station reported any wind gusts, one of the stations reported a gust 7.3% of the time. Thus, it is incredibly rare for all nine stations throughout the Phoenix Metro area to be both online reporting hourly average winds and for all nine stations to have reported a wind gust for the same hour. Even for two, three, or four stations to all report a wind gust at the same time is fairly uncommon with each occurring less than about 5% of the time. These data help reveal the nature of these "regional events (wind frontal passage)" which are shown to have local effects that differ from hour to hour and from place to place. While winds may eventually experience high gusts at many of the NWS weather stations during a regional wind event, for more than a few Phoenix area stations to report wind gusts during the same reporting hour is exceedingly rare.

Table 6 –
Inhomogeneity of Wind Gusts Reported in the Phoenix Metro Area

# STATIONS REPORTING AVERAGE SPEED>>		COUNT OF HOURS REPORTED				PERCENT OF HOURS REPORTED			
		9	8	7	ANY	9	8	7	ANY
# OF STATIONS REPORTING WIND GUSTS	9	37			37	0.6%			0.1%
	8	60	72		135	0.9%	0.8%		0.3%
	7	69	85	44	196	1.0%	1.0%	0.9%	0.5%
	6	78	113	39	245	1.2%	1.3%	0.8%	0.6%
	5	126	139	81	378	1.9%	1.6%	1.7%	0.9%
	4	147	191	113	548	2.2%	2.2%	2.4%	1.3%
	3	216	331	128	890	3.2%	3.8%	2.7%	2.2%
	2	338	444	195	1,384	5.0%	5.0%	4.1%	3.4%
	1	616	882	422	2,995	9.2%	10.0%	8.9%	7.3%
	0	5,040	6,536	3,738	33,994	74.8%	74.3%	78.5%	83.4%
TOTAL		6,727	8,793	4,760	40,802	100.0%	100.0%	100.0%	100.0%

An examination of the measurements from several monitors with hourly measurements of the average wind speed, the maximum wind gust during the hour, and the particulate matter (PM_{10}) from TEOM monitors was performed. Data from April 1, 2005, through August 31, 2009, for four monitors operated by the Maricopa County Air Quality Department over a broad geographic region, were used in the analysis. These monitors were chosen because of the availability of a very long continuous record of data (38,000+ hours) for each monitor. The monitors included a monitor to the far west of the the Phoenix area (Buckeye), two monitors in the central basin near the Salt River (West Forty Third Avenue and Durango Complex), and one monitor in the far east valley (Higley). All of these monitors have experienced high ambient concentrations of particulate matter.

The monitoring data was extracted from the ADEQ Air Assessment Ambient Database (AAAD) which archives these readings on a daily basis. The winds speeds were rounded to the nearest 1 mile per hour, and the ambient concentrations rounded to the nearest 1 microgram per cubic meter. The ambient concentration data tends to be log-normally distributed. It was decided to create a simple cross-tabulation of the raw wind speed and particulate matter data for each monitor. In order to develop a useful consolidation of the data, wind and particulate matter values were transformed into categories. The following transformations were used to compute the categories:

For Wind: WindCat = 10.0*Log10(Speed_mph + 1.0) (rounded to the nearest whole number)
For PM10: PMCat = 5.0*Log10(PM_ug/m3 + 1.0) (rounded to the nearest whole number)

The choice of the scaling was to generate approximately 17 categories over the normal range of values found in the database.

In examining the cross-tabulated information, one would expect to observe two phenomenon. For monitors in the central part of the valley, there could be a slight "stagnation" effect observed in the data. This would be where the mode of the distribution for a given wind speed category would go down as the wind speed increased from very low levels to moderate levels. Also, for all monitors there should be a threshold effect, where the mode of the particulate matter concentration for a given wind speed category should increase as the wind speed category increases. Between these two extremes there would be little correlation between wind speed and particulate matter concentration.

Table 7 presents the cross-tabulated information for hourly average wind speed versus the particulate matter concentration for the four monitors. The orange/pink highlighting in the table is where the mode of the distribution occurs for each wind speed category, the yellow shows the range where about 80% of the data reside. The green highlighting shows the frequency of the higher wind speeds. It is noted that these represent approximately the highest 5% of the wind data (approximately 2,000 out of 40,000 observations). All four monitors demonstrate a strong "threshold" effect for wind speed when hourly average wind speeds exceed the 11-13 miles per hour bin. Also, the West Forty Third Avenue and Durango Complex monitors appear to have a slight "stagnation" effect compared to the Buckeye and Higley monitors.

Table 8 present the cross-tabulated information for maximum hourly wind gusts versus the particulate matter concentration for the four monitors. The orange/pink highlighting in the table is where the mode of the distribution occurs for each wind speed category, the yellow shows the range where about 80% of the data reside. The green highlighting shows the frequency of the higher wind gusts. It is noted that these represent approximately the highest 5% of the wind data (approximately 2,000 out of 40,000 observations). All four monitors demonstrate a strong "threshold" effect for wind speed when hourly wind speed gusts exceed the 17-21 miles per hour bin.

It should be noted that there is not a "bright-line" in this type of data, only statistical tendencies. During some events, relatively low local wind speeds could be associated with very high particulate matter concentrations if dust is transported over a long distance. This is typical of a haboob, where local winds in the area of the storm may exceed 70 miles per hour, and create a wall of dust. The wind speed diminishes during transport but the suspended dust can be delivered over very large distances.

Table 7. Crosstabulation of Average Wind Speed and PM Concentrations

STATION — WIND SPEED CATEGORY (HOURLY AVERAGE WINDS - miles per hour)

BUCKEYE

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	TOTAL
1995-3161 ug/m3	-	-	-	-	-	-	-	-	1	-	1	2	-	4
1258-1994 ug/m3	-	-	1	-	-	1	-	3	-	-	1	-	-	6
794-1257 ug/m3	-	-	3	4	3	-	1	-	-	1	2	5	-	19
501-793 ug/m3	1	5	6	6	3	5	1	5	14	10	13	6	-	75
316-500 ug/m3	5	19	11	9	6	6	4	17	26	19	28	3	1	154
199-315 ug/m3	24	43	40	31	27	32	7	22	30	48	42	8	1	355
125-198 ug/m3	65	206	186	167	128	149	48	89	65	87	37	9	-	1,236
79-124 ug/m3	228	522	607	520	415	575	171	296	170	77	53	4	-	3,638
50-78 ug/m3	436	998	1,183	1,076	859	1,193	401	741	260	94	27	3	-	7,271
31-49 ug/m3	438	1,218	1,546	1,438	1,282	1,852	605	1,091	330	80	21	-	-	9,901
19-30 ug/m3	298	942	1,220	1,253	1,136	1,735	599	956	254	54	12	1	-	8,460
12-18 ug/m3	122	505	603	679	552	1,091	350	544	121	23	4	2	-	4,596
7-11 ug/m3	58	189	258	258	267	397	133	217	64	16	2	-	-	1,859
5-6 ug/m3	7	40	53	45	46	86	34	56	24	8	-	1	-	400
3-4 ug/m3	9	21	27	29	29	54	19	31	6	7	1	-	-	233
1-2 ug/m3	1	12	16	11	16	34	9	20	8	1	1	-	-	129
<1 ug/m3	1	7	13	12	8	20	16	13	8	2	2	-	-	102
TOTAL	1,693	4,727	5,773	5,538	4,777	7,230	2,398	4,101	1,381	527	247	44	2	38,438

WEST 43RD AVE

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	TOTAL
1995-3161 ug/m3	-	-	-	-	-	-	-	-	1	-	-	-		1
1258-1994 ug/m3	-	-	-	-	-	-	1	1	-	1	4	2		9
794-1257 ug/m3	-	1	2	4	1	-	1	1	1	5	21	5		42
501-793 ug/m3	2	13	6	1	-	4	1	6	7	22	38	4		104
316-500 ug/m3	20	101	74	25	9	9	4	10	24	50	28	2		356
199-315 ug/m3	68	380	349	153	54	39	9	32	70	72	22	1		1,249
125-198 ug/m3	106	794	883	470	165	169	29	88	158	98	21	1		2,982
79-124 ug/m3	193	1,384	1,547	850	403	438	112	288	235	72	6	-		5,528
50-78 ug/m3	255	1,515	1,754	1,274	828	847	272	634	274	48	1	-		7,702
31-49 ug/m3	192	1,333	1,791	1,383	1,165	1,519	441	894	232	28	1	-		8,979
19-30 ug/m3	114	777	1,080	1,120	906	1,367	432	655	109	16	-	-		6,576
12-18 ug/m3	49	362	454	492	451	567	194	271	47	11	-	-		2,898
7-11 ug/m3	11	134	183	190	161	235	65	120	25	4	2	-		1,130
5-6 ug/m3	5	26	34	36	32	40	25	26	5	1	-	-		230
3-4 ug/m3	2	12	22	22	20	32	18	22	5	2	-	-		157
1-2 ug/m3	-	8	14	9	9	14	8	8	3	-	-	-		73
<1 ug/m3	1	8	4	6	6	9	4	5	4	-	-	-		47
TOTAL	1,018	6,848	8,197	6,035	4,210	5,289	1,616	3,061	1,200	430	144	15		38,063

DURANGO COMPLEX

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	TOTAL
1995-3161 ug/m3	-	1	-	-	-	-	-	-	1	1	-	-		3
1258-1994 ug/m3	-	1	-	-	-	-	-	-	-	-	-	-		1
794-1257 ug/m3	-	2	3	1	-	-	1	1	-	3	6	3		20
501-793 ug/m3	2	7	4	-	-	2	3	10	7	9	13	-		57
316-500 ug/m3	36	67	46	13	3	5	3	14	26	19	10	1		243
199-315 ug/m3	82	310	169	56	12	16	7	33	47	32	26	-		790
125-198 ug/m3	187	932	526	198	89	66	19	85	67	65	14	-		2,248
79-124 ug/m3	377	1,622	1,123	535	298	321	80	178	126	72	6	-		4,738
50-78 ug/m3	314	1,942	1,724	1,034	686	916	284	535	238	38	-	-		7,711
31-49 ug/m3	310	1,713	1,866	1,451	1,142	1,615	542	948	247	21	-	-		9,855
19-30 ug/m3	142	927	1,288	1,150	1,033	1,510	515	785	151	9	-	-		7,510
12-18 ug/m3	44	354	531	545	488	707	228	317	57	3	-	-		3,274
7-11 ug/m3	16	162	203	204	197	258	86	115	16	5	-	-		1,262
5-6 ug/m3	2	21	50	41	40	60	25	27	8	1	-	-		275
3-4 ug/m3	1	18	24	33	19	36	18	29	3	1	-	-		182
1-2 ug/m3	-	11	9	18	11	22	8	11	4	-	-	-		94
<1 ug/m3	-	11	14	12	7	11	-	17	1	-	-	-		73
TOTAL	1,513	8,101	7,580	5,291	4,025	5,545	1,819	3,105	999	279	75	4		38,336

HIGLEY

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	TOTAL
3162+ ug/m3	-	-	-	-	-	-	-	-	-	-	1	-	-	1
1995-3161 ug/m3	-	-	-	-	-	-	-	-	2	-	1	1	-	4
1258-1994 ug/m3	-	-	-	-	-	-	-	1	-	-	1	-	-	2
794-1257 ug/m3	-	-	1	-	1	-	-	1	2	2	5	2	1	15
501-793 ug/m3	1	1	2	3	3	8	-	6	11	17	14	-	-	66
316-500 ug/m3	3	30	19	16	11	15	8	22	20	28	20	-	-	192
199-315 ug/m3	10	79	97	72	63	71	14	31	43	40	13	-	-	533
125-198 ug/m3	52	240	264	240	196	276	58	89	68	53	9	-	-	1,545
79-124 ug/m3	76	427	656	618	533	595	132	189	133	54	6	-	-	3,419
50-78 ug/m3	110	772	1,233	1,356	1,135	1,244	236	399	135	31	9	-	-	6,660
31-49 ug/m3	128	845	1,596	1,933	1,769	2,031	460	582	172	36	1	-	-	9,553
19-30 ug/m3	73	680	1,308	1,681	1,638	2,071	501	582	109	10	1	-	-	8,654
12-18 ug/m3	49	388	704	876	876	1,092	232	314	57	15	-	-	-	4,603
7-11 ug/m3	24	190	322	351	353	432	124	160	27	9	1	-	-	1,993
5-6 ug/m3	4	40	54	68	70	107	31	55	10	2	-	-	-	441
3-4 ug/m3	4	13	34	33	40	66	17	38	6	2	-	-	-	253
1-2 ug/m3	3	4	14	23	12	30	10	16	2	-	-	-	-	114
<1 ug/m3	-	7	6	9	9	10	10	9	1	-	-	-	-	61
TOTAL	537	3,716	6,310	7,279	6,709	8,048	1,833	2,494	798	299	82	3	1	38,109

Table 8. Crosstabulation of Hourly Maximum Wind Gust and PM Concentrations

STATION — WIND GUST CATEGORY (MAXIMUM WIND GUST DURING HOUR - miles per hour)

BUCKEYE

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	2
1258-1994 ug/m3	-	-	-	-	-	-	-	1	1	1	-	2	-	-	1	6
794-1257 ug/m3	-	-	-	-	-	3	-	7	-	1	-	-	-	3	5	19
501-793 ug/m3	-	-	-	3	1	7	4	8	1	-	2	9	16	16	8	75
316-500 ug/m3	-	-	1	4	9	21	9	10	5	6	2	11	43	29	3	153
199-315 ug/m3	1	2	3	15	26	68	23	35	13	9	16	36	60	41	6	354
125-198 ug/m3	3	9	9	43	121	285	112	216	102	66	53	92	101	23	1	1,236
79-124 ug/m3	7	10	29	123	318	879	348	738	415	225	237	178	112	19	-	3,638
50-78 ug/m3	18	20	48	230	535	1,704	793	1,558	941	512	522	301	76	13	-	7,271
31-49 ug/m3	10	15	47	247	581	2,063	1,051	2,402	1,497	894	718	310	61	7	-	9,903
19-30 ug/m3	13	7	45	145	369	1,449	866	2,186	1,512	908	689	227	39	5	-	8,460
12-18 ug/m3	-	1	10	54	183	700	423	1,124	933	586	457	110	13	2	2	4,598
7-11 ug/m3	3	1	5	19	87	245	162	469	375	239	192	52	9	1	-	1,859
5-6 ug/m3	-	1	1	3	16	41	28	91	91	55	49	22	1	1	-	400
3-4 ug/m3	-	-	1	3	10	28	19	54	48	32	24	11	2	1	-	233
1-2 ug/m3	-	-	-	-	3	10	6	36	30	14	24	5	1	-	-	129
<1 ug/m3	-	-	-	-	1	6	7	23	21	14	15	10	3	2	-	102
TOTAL	55	66	199	889	2,260	7,509	3,851	8,958	5,985	3,562	3,000	1,376	538	163	27	38,438

WEST 43RD AVE

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	2	-	-	7	-	9
794-1257 ug/m3	-	-	1	-	-	3	1	-	1	-	3	1	12	14	5	41
501-793 ug/m3	-	1	2	5	8	5	1	-	1	2	6	6	33	27	6	103
316-500 ug/m3	-	1	1	25	74	94	11	19	4	2	5	25	59	25	6	351
199-315 ug/m3	-	4	9	93	252	468	89	91	14	9	25	82	86	16	1	1,239
125-198 ug/m3	1	4	31	214	562	1,054	242	358	90	42	70	181	103	13	1	2,966
79-124 ug/m3	-	15	60	399	912	1,738	528	758	320	159	275	263	60	8	-	5,495
50-78 ug/m3	-	29	63	393	951	1,897	721	1,399	732	470	654	275	47	3	1	7,635
31-49 ug/m3	-	21	68	277	656	1,640	715	1,912	1,414	992	976	235	17	5	2	8,930
19-30 ug/m3	-	20	27	138	287	780	461	1,511	1,443	1,006	714	117	13	3	1	6,521
12-18 ug/m3	-	10	16	59	127	340	185	679	647	450	286	57	12	-	-	2,868
7-11 ug/m3	-	8	5	15	34	129	97	276	228	169	117	34	3	1	-	1,116
5-6 ug/m3	-	1	1	7	10	24	19	57	50	28	21	9	-	-	-	227
3-4 ug/m3	-	-	1	1	7	14	9	35	35	25	23	7	-	-	-	157
1-2 ug/m3	-	1	-	-	3	12	2	10	22	10	11	2	-	-	-	73
<1 ug/m3	-	-	-	-	1	7	3	9	7	7	10	2	-	-	-	46
TOTAL	1	115	285	1,626	3,884	8,205	3,084	7,114	5,008	3,371	3,198	1,296	445	122	23	37,777

DURANGO COMPLEX

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	2
1258-1994 ug/m3	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
794-1257 ug/m3	-	-	-	-	-	3	2	-	1	-	2	-	2	5	3	18
501-793 ug/m3	-	-	1	2	5	4	-	-	-	4	7	4	10	16	4	57
316-500 ug/m3	-	-	7	39	57	34	13	9	4	1	7	18	29	22	3	243
199-315 ug/m3	1	4	35	109	175	204	43	44	13	6	18	47	67	20	2	788
125-198 ug/m3	2	4	90	355	490	608	164	186	64	29	61	94	84	15	2	2,248
79-124 ug/m3	-	1	169	659	809	1,210	394	657	306	111	164	166	79	11	2	4,738
50-78 ug/m3	-	3	127	634	909	1,670	660	1,514	838	474	501	315	60	5	1	7,711
31-49 ug/m3	-	3	91	429	732	1,575	721	2,199	1,700	1,090	945	333	31	5	1	9,855
19-30 ug/m3	-	2	31	159	313	809	498	1,685	1,631	1,207	946	209	18	3	-	7,511
12-18 ug/m3	-	-	11	47	109	275	197	740	779	571	457	75	9	3	-	3,273
7-11 ug/m3	-	-	5	16	36	110	92	325	282	217	150	25	2	2	-	1,262
5-6 ug/m3	-	-	-	1	5	17	17	71	69	48	35	10	2	-	-	275
3-4 ug/m3	-	-	-	2	2	15	10	36	51	24	31	10	1	-	-	182
1-2 ug/m3	-	-	-	1	2	4	3	26	20	13	20	5	-	-	-	94
<1 ug/m3	-	-	-	-	-	11	1	20	15	13	11	2	-	-	-	73
TOTAL	3	17	568	2,453	3,645	6,549	2,815	7,512	5,773	3,808	3,355	1,313	394	107	19	38,331

HIGLEY

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
3162+ ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	4
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
794-1257 ug/m3	-	-	-	-	-	-	-	1	-	-	1	-	4	5	3	14
501-793 ug/m3	-	-	-	1	1	4	-	6	1	2	4	6	20	16	4	65
316-500 ug/m3	-	-	2	12	14	29	5	19	4	4	8	21	42	24	5	189
199-315 ug/m3	-	1	4	26	50	113	50	99	40	12	17	51	52	16	2	533
125-198 ug/m3	4	-	17	78	129	356	193	382	111	41	52	96	69	15	1	1,544
79-124 ug/m3	5	2	30	127	255	862	423	898	289	115	156	162	76	14	1	3,415
50-78 ug/m3	-	1	25	204	444	1,603	884	1,933	617	297	353	234	54	8	-	6,657
31-49 ug/m3	3	-	30	187	510	1,755	1,145	2,760	1,354	815	647	297	40	4	-	9,547
19-30 ug/m3	1	-	11	113	327	1,233	789	2,374	1,702	1,058	814	205	22	3	-	8,652
12-18 ug/m3	2	-	3	54	153	622	422	1,210	940	664	426	96	8	2	1	4,603
7-11 ug/m3	-	-	4	24	68	290	187	562	391	270	149	42	6	2	-	1,995
5-6 ug/m3	-	-	-	4	17	51	40	107	101	63	36	16	6	-	-	441
3-4 ug/m3	-	-	-	1	6	24	21	63	52	47	29	8	2	-	-	253
1-2 ug/m3	-	-	-	1	1	15	9	23	26	21	16	2	-	-	-	114
<1 ug/m3	-	-	-	-	-	5	2	16	13	9	16	-	-	-	-	61
TOTAL	15	4	126	832	1,975	6,962	4,170	10453	5,641	3,418	2,724	1,236	402	111	20	38,089

In response to EPA concerns about seasonal PM10 concentration impacts and patterns, an additional analysis was performed on seasonal data for the same four stations that were used in the annual analysis. The new seasonal analysis had the advantage of using more recent data that spanned from 2003 to the end of 2009. While the annual analysis used winds speeds that were rounded to the nearest whole mile per hour, the seasonal analysis used more detailed wind speeds out to a tenth of a mile per hour. The only real impact of this change is that there were slight adjustments in the distribution of values in the cross-tabulation; the overall pattern, however, remained the same.

Table 9 presents cross-tabulated information for seasonal maximum hourly wind gusts versus the particulate matter concentration for the four monitors. The color coded highlighting pattern found in Table 8 was transferred and left unchanged in Table 9. This was done in order to allow easy comparison between the seasonal data results and the pattern previously found using the annual data. For Table 8, the orange/pink highlighting in the table was where the mode of the distribution occurs for each wind speed category; the yellow showed the range where about 80% of the data reside. The green highlighting showed the frequency of the higher wind gusts. The new data in Table 9 falls generally into the same pattern and color categorization that was found when using the annual data for Table 8. The results of the seasonal wind gust analysis mirror the results found using the annual wind gust dataset. Table 9 shows that both the annual and seasonal methods for analyzing wind gusts versus PM10 concentrations provide the same result, with all four monitors demonstrating a strong "threshold" effect for wind speed when hourly wind speed gusts exceed 17-21 miles per hour.

Table 9a. Expanded Seasonal Crosstabulation of Hourly Maximum Wind Gust and PM Concentrations-Winter (Dec-Feb)

STATION — WIND GUST CATEGORY (MAXIMUM WIND GUST DURING HOUR - miles per hour)

BUCKEYE

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
794-1257 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
501-793 ug/m3	-	-	-	1	1	2	6	2	-	-	-	2	1	1	1	17
316-500 ug/m3	-	-	1	2	4	4	5	2	3	-	-	2	5	2	1	31
199-315 ug/m3	-	2	1	5	10	12	13	8	2	1	1	7	12	2	-	76
125-198 ug/m3	7	2	3	10	42	50	40	21	9	11	5	12	14	1	-	227
79-124 ug/m3	7	4	9	36	96	161	123	96	59	48	26	38	14	1	-	718
50-78 ug/m3	12	8	14	55	162	290	297	178	154	106	105	52	12	4	-	1,449
31-49 ug/m3	7	9	17	71	215	369	433	307	282	187	118	58	6	-	-	2,079
19-30 ug/m3	6	8	24	58	187	376	425	360	273	165	107	45	9	2	-	2,045
12-18 ug/m3	1	1	8	33	139	221	333	262	216	149	92	29	10	2	1	1,497
7-11 ug/m3	-	1	1	8	46	88	157	136	121	82	52	25	5	1	-	723
5-6 ug/m3	-	1	-	3	16	29	46	52	51	36	34	16	3	3	-	290
3-4 ug/m3	-	-	1	1	2	14	11	20	18	11	7	7	1	-	-	93
1-2 ug/m3	-	-	-	-	-	1	3	3	7	3	1	-	-	-	-	18
<1 ug/m3	-	-	-	-	-	1	2	3	5	3	6	2	5	2	-	29
TOTAL	40	36	79	283	920	1,618	1,894	1,450	1,200	802	554	295	97	21	3	9,292

WEST 43RD AVE

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
794-1257 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2
501-793 ug/m3	-	-	1	4	7	2	1	-	-	-	-	2	3	-	-	20
316-500 ug/m3	-	-	1	9	41	23	10	2	-	-	-	5	4	1	-	96
199-315 ug/m3	-	-	3	24	117	99	53	7	1	2	6	8	2	-	-	322
125-198 ug/m3	-	-	13	60	245	277	144	35	14	10	10	27	9	-	1	845
79-124 ug/m3	-	3	18	125	379	414	252	75	33	29	34	22	8	1	1	1,394
50-78 ug/m3	-	3	22	190	468	436	285	157	63	68	61	21	5	1	-	1,780
31-49 ug/m3	1	3	29	159	414	432	366	198	119	81	56	22	6	2	-	1,888
19-30 ug/m3	-	1	14	77	220	240	270	215	140	90	52	15	6	1	-	1,341
12-18 ug/m3	-	-	6	30	89	149	181	154	134	54	44	19	12	-	-	872
7-11 ug/m3	-	-	-	6	31	60	96	83	71	52	36	19	5	-	-	459
5-6 ug/m3	-	-	-	6	13	15	23	28	37	26	9	6	1	1	-	165
3-4 ug/m3	-	-	1	1	7	10	14	7	10	7	9	3	-	-	-	69
1-2 ug/m3	-	-	-	-	1	2	1	3	6	1	1	-	-	-	-	15
<1 ug/m3	-	-	-	-	-	1	4	9	4	5	2	-	1	-	-	26
TOTAL	1	10	108	691	2,032	2,160	1,700	973	632	425	320	169	64	7	2	9,294

DURANGO COMPLEX

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
794-1257 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
501-793 ug/m3	-	-	-	1	2	-	-	-	-	-	-	-	2	-	-	5
316-500 ug/m3	-	-	6	20	31	15	10	2	-	-	1	7	4	-	-	96
199-315 ug/m3	-	1	19	51	94	70	29	3	-	-	3	11	2	-	1	284
125-198 ug/m3	-	1	42	114	234	183	61	28	14	7	9	16	1	1	-	711
79-124 ug/m3	-	5	62	258	393	292	169	72	28	20	26	9	3	3	-	1,340
50-78 ug/m3	1	7	74	286	477	381	283	182	101	74	38	26	5	1	-	1,936
31-49 ug/m3	-	7	51	193	366	364	337	224	136	110	60	25	8	2	-	1,883
19-30 ug/m3	1	4	21	78	176	211	303	219	168	92	57	33	7	-	-	1,370
12-18 ug/m3	-	-	7	20	60	114	176	183	140	84	56	22	8	2	-	872
7-11 ug/m3	-	-	4	12	32	39	85	101	78	50	33	10	3	2	-	449
5-6 ug/m3	-	-	1	2	6	16	27	35	40	25	15	7	3	-	-	177
3-4 ug/m3	-	-	-	1	2	9	10	15	10	9	9	5	-	-	-	70
1-2 ug/m3	-	-	-	-	-	-	3	5	3	1	5	-	-	-	-	17
<1 ug/m3	-	-	-	-	-	7	6	11	9	10	1	2	1	1	-	48
TOTAL	2	25	287	1,036	1,873	1,701	1,499	1,080	727	482	313	173	48	12	1	9,259

HIGLEY

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
3162+ ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
794-1257 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
501-793 ug/m3	-	-	-	-	-	2	-	-	-	-	1	-	5	1	1	10
316-500 ug/m3	-	-	-	5	9	6	6	3	-	-	-	3	3	-	-	35
199-315 ug/m3	-	1	2	8	21	33	40	15	4	4	3	5	5	-	1	142
125-198 ug/m3	-	-	7	36	63	79	93	40	10	9	7	10	4	-	-	358
79-124 ug/m3	-	3	8	33	93	147	177	106	27	14	14	14	2	-	-	638
50-78 ug/m3	1	3	15	63	172	266	322	197	56	36	46	24	6	5	-	1,212
31-49 ug/m3	3	3	15	75	227	367	451	306	111	64	46	25	4	1	-	1,698
19-30 ug/m3	-	2	11	56	214	368	516	375	180	74	50	23	5	1	-	1,875
12-18 ug/m3	2	2	5	43	179	308	461	389	182	97	66	26	5	1	1	1,767
7-11 ug/m3	-	-	4	20	71	132	217	199	118	95	41	21	6	2	-	926
5-6 ug/m3	-	-	-	3	23	39	67	68	66	42	26	16	7	-	-	357
3-4 ug/m3	-	-	-	1	3	11	20	24	16	18	16	4	2	-	-	115
1-2 ug/m3	-	-	-	-	1	6	3	5	1	3	4	-	-	-	-	23
<1 ug/m3	-	-	-	-	-	1	2	3	2	1	-	-	-	-	-	9
TOTAL	6	14	67	343	1,076	1,765	2,375	1,730	773	457	320	171	55	11	3	9,166

Table 9b. Expanded Seasonal Crosstabulation of Hourly Maximum Wind Gust and PM Concentrations-Spring (Mar-May)

STATION — WIND GUST CATEGORY (MAXIMUM WIND GUST DURING HOUR - miles per hour)

BUCKEYE

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
794-1257 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	4
501-793 ug/m3	-	-	-	2	-	2	2	-	-	-	-	-	2	3	3	14
316-500 ug/m3	-	-	-	-	1	5	4	1	-	1	-	2	14	10	1	39
199-315 ug/m3	-	-	-	-	4	6	8	4	3	4	3	10	25	16	1	84
125-198 ug/m3	-	-	-	8	29	25	32	27	13	9	14	25	51	14	1	248
79-124 ug/m3	-	1	6	27	66	124	154	127	106	60	61	60	65	10	-	867
50-78 ug/m3	2	4	10	45	140	280	386	302	263	163	124	116	48	3	-	1,886
31-49 ug/m3	-	2	9	56	169	343	530	515	395	297	216	135	35	3	-	2,705
19-30 ug/m3	-	-	6	30	123	254	451	441	463	352	211	93	18	3	-	2,445
12-18 ug/m3	-	-	3	7	57	104	208	234	284	250	152	47	5	-	-	1,351
7-11 ug/m3	-	1	-	4	18	30	41	70	70	87	52	13	3	-	-	389
5-6 ug/m3	-	-	-	-	3	5	3	12	21	18	12	5	-	-	-	79
3-4 ug/m3	-	-	-	-	-	2	3	4	7	10	5	2	1	-	-	34
1-2 ug/m3	-	-	-	-	-	-	-	3	1	1	2	-	-	-	-	7
<1 ug/m3	-	-	-	-	-	-	2	2	3	3	1	1	-	-	-	12
TOTAL	2	8	34	179	610	1,180	1,824	1,742	1,629	1,255	853	509	267	65	7	10,164

WEST 43RD AVE

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2
794-1257 ug/m3	-	-	-	-	-	-	-	-	-	-	1	-	7	11	4	23
501-793 ug/m3	-	-	-	1	1	-	-	-	-	1	2	3	15	16	1	40
316-500 ug/m3	-	-	-	4	10	9	6	4	1	-	-	7	32	10	3	86
199-315 ug/m3	-	-	2	17	56	58	37	15	4	1	5	33	48	8	1	285
125-198 ug/m3	-	-	5	30	117	147	122	73	25	9	28	64	63	3	1	687
79-124 ug/m3	-	1	12	77	241	268	266	155	96	55	90	106	28	3	-	1,398
50-78 ug/m3	-	1	13	75	305	377	409	302	235	181	211	130	21	1	-	2,261
31-49 ug/m3	-	-	6	43	166	308	400	440	418	397	298	93	6	1	-	2,576
19-30 ug/m3	-	-	1	10	59	104	208	317	413	371	191	49	3	1	-	1,727
12-18 ug/m3	-	-	1	9	24	41	75	160	208	176	96	21	-	-	-	811
7-11 ug/m3	-	-	-	2	5	10	19	32	37	46	30	8	-	-	-	189
5-6 ug/m3	-	-	-	-	-	3	2	9	12	13	5	5	-	-	-	49
3-4 ug/m3	-	-	-	-	-	1	4	4	7	4	5	2	-	-	-	27
1-2 ug/m3	-	-	-	-	-	-	-	1	2	3	1	1	-	-	-	8
<1 ug/m3	-	-	-	-	-	-	-	2	1	1	2	-	-	-	-	6
TOTAL	-	2	40	268	984	1,326	1,548	1,514	1,459	1,258	965	522	223	56	10	10,175

DURANGO COMPLEX

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
794-1257 ug/m3	-	-	-	-	-	-	-	-	-	-	1	-	1	2	2	6
501-793 ug/m3	-	-	-	-	-	-	-	-	-	1	3	1	3	7	2	17
316-500 ug/m3	-	-	-	-	5	2	-	1	-	-	1	1	6	9	-	25
199-315 ug/m3	-	-	6	9	17	15	6	6	-	1	-	11	26	12	1	110
125-198 ug/m3	-	2	9	27	77	81	48	33	11	1	7	26	46	9	2	379
79-124 ug/m3	-	4	34	90	154	171	197	138	106	29	37	61	54	4	1	1,080
50-78 ug/m3	-	4	26	127	273	314	354	355	244	152	162	124	41	-	-	2,176
31-49 ug/m3	-	4	18	81	210	296	392	508	540	391	280	151	12	3	-	2,886
19-30 ug/m3	-	1	7	22	100	124	248	372	479	462	274	82	4	-	-	2,175
12-18 ug/m3	-	-	1	7	21	38	88	168	229	241	141	22	1	-	-	957
7-11 ug/m3	-	-	-	1	1	10	23	37	74	65	31	9	1	-	-	252
5-6 ug/m3	-	-	-	-	1	2	3	13	22	19	16	1	-	-	-	77
3-4 ug/m3	-	-	-	-	1	-	2	5	7	8	7	3	-	-	-	33
1-2 ug/m3	-	-	-	-	-	-	-	1	1	3	1	-	-	-	-	6
<1 ug/m3	-	-	-	-	-	-	-	1	1	1	2	-	-	-	-	5
TOTAL	-	15	101	364	860	1,053	1,361	1,638	1,714	1,374	963	492	195	46	8	10,184

HIGLEY

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
3162+ ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
794-1257 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2
501-793 ug/m3	-	-	-	-	-	1	-	6	-	-	1	1	1	6	1	17
316-500 ug/m3	-	-	1	-	2	3	4	-	1	1	1	-	12	3	2	30
199-315 ug/m3	-	-	1	2	8	11	16	21	10	1	4	8	11	7	2	102
125-198 ug/m3	-	-	1	5	14	44	58	60	38	10	15	20	35	8	-	308
79-124 ug/m3	1	-	5	18	54	102	180	187	112	42	49	66	46	7	-	869
50-78 ug/m3	1	1	8	35	113	281	455	465	245	126	108	103	27	2	-	1,970
31-49 ug/m3	-	2	7	32	141	279	568	685	489	292	230	137	22	-	-	2,884
19-30 ug/m3	-	-	6	18	63	163	351	511	525	426	245	87	7	-	-	2,402
12-18 ug/m3	-	-	1	6	18	46	136	210	285	268	104	36	1	-	-	1,111
7-11 ug/m3	-	1	-	1	4	11	31	73	94	81	25	9	-	-	-	330
5-6 ug/m3	-	-	-	1	-	4	8	15	30	24	7	1	-	-	-	90
3-4 ug/m3	-	-	-	-	-	-	5	6	11	6	7	-	-	-	-	35
1-2 ug/m3	-	-	-	-	-	-	2	2	3	3	1	-	-	-	-	11
<1 ug/m3	-	-	-	-	-	-	1	-	2	-	3	-	-	-	-	6
TOTAL	2	4	30	118	417	945	1,815	2,241	1,845	1,280	800	468	162	33	7	10,167

Table 9c. Expanded Seasonal Crosstabulation of Hourly Maximum Wind Gust and PM Concentrations-Summer(Jun-Aug)

STATION

WIND GUST CATEGORY (MAXIMUM WIND GUST DURING HOUR - miles per hour)

BUCKEYE

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	3
1258-1994 ug/m3	-	-	-	-	-	-	-	1	1	1	-	2	-	-	1	6
794-1257 ug/m3	-	-	-	-	-	1	2	6	-	1	-	-	-	-	3	13
501-793 ug/m3	-	-	-	-	-	-	2	1	1	-	1	4	9	5	5	28
316-500 ug/m3	-	-	-	1	3	5	2	-	1	3	1	5	10	16	1	48
199-315 ug/m3	-	-	2	4	10	13	12	7	3	6	5	10	11	15	2	100
125-198 ug/m3	-	-	1	13	41	62	62	60	43	28	11	24	17	5	-	367
79-124 ug/m3	-	-	2	23	93	159	196	156	125	59	58	31	24	8	-	934
50-78 ug/m3	1	-	5	35	150	274	399	368	318	200	122	67	17	4	-	1,960
31-49 ug/m3	-	-	8	32	156	339	553	599	522	390	172	56	14	2	1	2,844
19-30 ug/m3	1	1	5	31	105	244	445	548	559	404	183	52	4	-	-	2,582
12-18 ug/m3	-	-	3	7	46	110	224	289	367	281	146	18	1	-	-	1,492
7-11 ug/m3	-	-	-	-	14	20	49	81	102	45	29	7	-	-	-	347
5-6 ug/m3	-	-	-	-	5	4	12	22	26	18	2	3	-	-	-	92
3-4 ug/m3	-	-	-	-	2	1	4	8	5	2	3	1	-	-	-	26
1-2 ug/m3	-	-	-	-	-	-	1	4	2	3	1	-	-	-	-	11
<1 ug/m3	-	-	-	-	-	1	5	4	4	-	2	1	-	-	-	17
TOTAL	2	1	26	146	625	1,233	1,968	2,154	2,079	1,441	736	281	108	55	15	10,870

WEST 43RD AVE

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	2	-	-	3	-	5
794-1257 ug/m3	-	-	-	-	-	3	1	-	1	1	1	1	2	2	2	14
501-793 ug/m3	-	-	-	-	-	-	-	-	1	1	2	-	7	11	5	27
316-500 ug/m3	-	-	-	2	9	9	8	6	2	1	2	10	18	14	3	84
199-315 ug/m3	-	-	2	10	24	46	37	24	7	4	4	20	30	7	1	216
125-198 ug/m3	-	-	1	11	69	91	84	62	33	23	19	49	23	9	-	474
79-124 ug/m3	-	-	9	29	117	194	217	197	150	77	92	99	21	2	-	1,204
50-78 ug/m3	-	2	9	51	181	267	365	352	328	251	250	105	22	3	1	2,187
31-49 ug/m3	-	-	6	36	148	222	385	489	566	566	396	87	4	1	2	2,908
19-30 ug/m3	-	-	7	32	61	123	247	371	544	541	283	43	5	1	2	2,260
12-18 ug/m3	-	1	7	10	24	48	104	147	249	232	79	13	1	-	-	915
7-11 ug/m3	-	1	1	1	1	12	22	58	53	54	16	3	-	-	-	222
5-6 ug/m3	-	-	-	-	1	2	4	10	13	6	4	-	-	-	-	40
3-4 ug/m3	-	-	-	-	-	-	1	3	6	4	2	-	-	-	-	16
1-2 ug/m3	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	2
<1 ug/m3	-	-	-	-	-	-	-	1	1	2	-	-	-	-	-	4
TOTAL	-	4	42	182	635	1,017	1,475	1,720	1,955	1,764	1,152	430	133	53	17	10,579

DURANGO COMPLEX

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
794-1257 ug/m3	-	-	-	-	-	3	1	-	1	-	1	-	-	1	3	10
501-793 ug/m3	-	-	-	1	1	-	1	-	-	3	4	2	4	8	2	26
316-500 ug/m3	-	-	-	-	5	1	1	2	3	3	2	6	12	10	2	47
199-315 ug/m3	-	-	-	3	18	18	12	12	7	2	5	10	28	7	3	125
125-198 ug/m3	-	-	3	27	56	42	54	30	16	11	18	28	29	6	-	320
79-124 ug/m3	-	1	6	48	79	125	161	141	109	57	57	61	19	5	1	870
50-78 ug/m3	-	1	14	63	143	194	329	341	327	238	184	112	16	3	1	1,966
31-49 ug/m3	-	2	12	69	170	231	361	585	695	573	414	123	13	-	1	3,249
19-30 ug/m3	-	-	5	26	67	136	244	406	621	651	395	67	4	3	1	2,626
12-18 ug/m3	-	-	3	9	35	31	83	181	289	280	187	25	1	1	-	1,125
7-11 ug/m3	-	-	-	2	7	8	30	52	70	73	35	6	1	-	-	284
5-6 ug/m3	-	-	-	-	-	1	7	13	22	15	6	1	-	-	-	65
3-4 ug/m3	-	-	-	-	-	-	1	5	7	6	6	-	-	-	-	25
1-2 ug/m3	-	-	-	-	-	-	-	4	7	2	2	1	-	-	-	16
<1 ug/m3	-	-	-	-	-	1	1	7	7	1	3	-	-	-	-	20
TOTAL	-	4	43	248	581	791	1,286	1,779	2,181	1,915	1,319	442	127	44	16	10,776

HIGLEY

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
3162+ ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	3
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	2
794-1257 ug/m3	-	-	-	-	-	-	-	1	-	-	1	-	1	4	2	9
501-793 ug/m3	-	-	-	-	-	-	1	-	1	2	1	4	12	9	1	31
316-500 ug/m3	-	-	-	1	-	2	5	2	1	2	4	12	20	20	4	73
199-315 ug/m3	-	-	-	4	6	4	16	19	14	7	6	20	24	6	-	126
125-198 ug/m3	-	1	2	3	19	33	96	97	42	19	15	38	17	6	1	389
79-124 ug/m3	-	-	2	12	44	126	211	200	104	46	45	36	21	6	1	854
50-78 ug/m3	-	-	3	37	125	292	473	422	239	155	118	63	16	3	-	1,946
31-49 ug/m3	-	2	3	33	109	254	520	588	526	439	218	68	15	2	-	2,777
19-30 ug/m3	-	-	3	19	78	168	329	488	656	605	327	62	9	2	-	2,746
12-18 ug/m3	-	-	2	10	28	64	153	221	345	371	173	27	1	1	-	1,396
7-11 ug/m3	-	-	-	3	9	29	48	82	87	77	30	5	1	-	-	371
5-6 ug/m3	-	-	-	-	2	4	8	23	13	27	5	1	-	-	-	83
3-4 ug/m3	-	-	-	-	1	-	1	6	12	9	5	-	-	-	-	34
1-2 ug/m3	-	-	-	-	-	1	1	-	-	4	1	-	-	-	-	7
<1 ug/m3	-	-	-	-	-	-	-	3	2	1	-	-	-	-	-	6
TOTAL	-	3	15	122	421	977	1,862	2,152	2,042	1,764	949	336	138	60	13	10,854

Table 9d. Expanded Seasonal Crosstabulation of Hourly Maximum Wind Gust and PM Concentrations-Autumn(Sep-Nov)

STATION — WIND GUST CATEGORY (MAXIMUM WIND GUST DURING HOUR - miles per hour)

BUCKEYE

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
794-1257 ug/m3	-	-	-	-	-	1	1	-	-	1	-	-	-	1	-	4
501-793 ug/m3	-	-	-	-	-	-	1	2	-	-	1	1	6	8	-	19
316-500 ug/m3	-	-	-	2	7	4	7	5	1	2	1	2	15	4	-	50
199-315 ug/m3	-	-	1	5	14	14	13	10	5	5	4	8	17	11	-	107
125-198 ug/m3	-	3	3	16	44	76	87	57	36	32	19	28	32	5	-	438
79-124 ug/m3	2	6	10	50	167	263	255	191	169	131	77	50	21	2	-	1,394
50-78 ug/m3	1	10	21	100	294	486	570	388	294	253	156	88	17	2	-	2,680
31-49 ug/m3	-	7	16	95	291	516	599	520	403	246	176	81	16	1	-	2,967
19-30 ug/m3	-	3	7	30	112	268	375	353	314	246	132	53	10	1	-	1,904
12-18 ug/m3	-	-	2	11	46	85	131	185	150	115	66	23	2	-	-	816
7-11 ug/m3	-	-	-	5	19	22	35	55	58	52	29	6	1	-	-	282
5-6 ug/m3	-	-	1	1	6	3	10	8	20	13	10	4	-	-	-	76
3-4 ug/m3	-	-	-	2	4	2	2	6	8	6	4	-	-	-	-	34
1-2 ug/m3	-	-	-	-	-	2	-	2	4	2	2	-	-	-	-	12
<1 ug/m3	-	-	-	-	-	1	1	4	1	2	1	-	-	-	-	10
TOTAL	3	29	61	317	1,004	1,743	2,087	1,786	1,463	1,106	678	344	137	35	1	10,794

WEST 43RD AVE

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	3
794-1257 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	3	1	-	4
501-793 ug/m3	-	-	-	-	2	1	-	-	-	-	2	1	8	-	1	15
316-500 ug/m3	-	-	-	11	31	25	6	1	1	1	3	2	8	1	1	91
199-315 ug/m3	-	-	8	38	130	139	63	16	3	5	4	18	15	1	1	441
125-198 ug/m3	-	1	19	134	322	280	157	68	27	9	10	39	22	3	-	1,091
79-124 ug/m3	-	-	39	200	548	515	302	135	67	47	55	50	12	1	-	1,971
50-78 ug/m3	-	-	38	144	423	457	430	252	180	109	116	40	8	-	-	2,197
31-49 ug/m3	-	-	14	68	213	316	336	378	343	208	149	38	1	3	-	2,067
19-30 ug/m3	-	-	6	27	75	126	208	341	397	236	115	25	-	1	-	1,557
12-18 ug/m3	-	-	1	10	30	33	74	140	178	105	64	12	-	-	-	647
7-11 ug/m3	-	1	-	4	7	5	17	27	46	41	16	3	-	-	-	167
5-6 ug/m3	-	-	-	1	2	3	9	12	10	11	10	1	-	-	-	59
3-4 ug/m3	-	-	-	-	-	1	-	7	12	6	2	1	-	-	-	29
1-2 ug/m3	-	-	-	-	-	1	-	1	-	4	2	-	-	-	-	8
<1 ug/m3	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
TOTAL	-	-	-	-	-	-	-	3	-	2	1	-	-	-	-	ERROR

DURANGO COMPLEX

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	2
1258-1994 ug/m3	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
794-1257 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2
501-793 ug/m3	-	-	1	-	2	3	-	-	-	-	-	1	3	1	-	11
316-500 ug/m3	-	-	4	16	23	6	9	-	-	-	1	3	9	4	-	75
199-315 ug/m3	-	1	14	44	74	60	29	10	7	2	9	12	14	1	-	277
125-198 ug/m3	1	12	60	184	249	162	128	49	24	12	22	21	14	-	-	938
79-124 ug/m3	-	9	110	318	477	351	242	142	97	45	34	37	19	1	-	1,882
50-78 ug/m3	-	4	62	222	381	448	459	306	214	154	99	73	10	2	-	2,434
31-49 ug/m3	1	3	32	118	215	340	373	433	386	241	155	49	3	-	-	2,349
19-30 ug/m3	-	-	7	40	92	138	230	357	404	273	129	37	3	-	-	1,710
12-18 ug/m3	-	-	4	13	23	43	83	153	218	156	87	11	-	-	-	791
7-11 ug/m3	-	-	-	-	-	4	22	47	57	48	16	2	-	-	-	196
5-6 ug/m3	-	-	-	-	1	4	7	14	12	10	12	3	-	-	-	63
3-4 ug/m3	-	-	1	1	5	1	1	7	9	4	1	2	-	-	-	32
1-2 ug/m3	-	-	-	-	1	-	1	1	8	4	1	-	-	-	-	16
<1 ug/m3	-	-	-	-	-	-	-	2	4	3	1	-	-	-	-	10
TOTAL	2	29	296	956	1,544	1,560	1,584	1,521	1,440	952	567	251	75	12	-	10,789

HIGLEY

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
3162+ ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
794-1257 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	3	1	-	4
501-793 ug/m3	-	-	-	1	1	-	-	-	-	-	-	1	7	1	1	12
316-500 ug/m3	-	-	2	5	4	10	2	9	3	1	3	5	8	1	1	54
199-315 ug/m3	-	-	4	12	28	31	32	16	12	5	3	17	18	3	-	181
125-198 ug/m3	-	2	6	32	76	99	107	86	33	9	15	27	20	1	-	513
79-124 ug/m3	-	3	21	71	178	266	302	194	83	37	45	60	16	-	-	1,276
50-78 ug/m3	1	3	16	92	249	449	638	415	168	62	80	65	12	-	-	2,250
31-49 ug/m3	-	-	11	64	227	409	745	618	325	189	125	70	5	1	-	2,789
19-30 ug/m3	-	1	2	25	96	218	438	512	348	198	118	38	3	-	-	1,997
12-18 ug/m3	-	-	1	4	24	68	164	212	213	151	56	17	1	-	-	911
7-11 ug/m3	-	-	-	-	10	22	50	66	85	43	21	4	1	-	-	302
5-6 ug/m3	-	-	-	-	2	5	8	10	17	13	8	1	-	-	-	64
3-4 ug/m3	-	-	-	1	1	3	3	8	9	6	1	2	-	-	-	34
1-2 ug/m3	-	-	-	-	-	-	-	4	6	2	-	-	-	-	-	12
<1 ug/m3	-	-	-	-	-	1	-	3	2	2	3	-	-	-	-	11
TOTAL	1	9	63	307	896	1,581	2,489	2,153	1,304	718	478	307	94	9	2	10,411

Table 9e. Expanded Seasonal Crosstabulation of Hourly Maximum Wind Gust and PM Concentrations-Annual Recap

STATION

WIND GUST CATEGORY (MAXIMUM WIND GUST DURING HOUR - miles per hour)

BUCKEYE

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	3	4
1258-1994 ug/m3	-	-	-	-	-	-	-	1	1	1	-	2	-	-	1	6
794-1257 ug/m3	-	-	-	-	-	2	3	6	-	2	-	-	-	4	4	21
501-793 ug/m3	-	-	-	3	1	4	11	5	1	-	2	7	18	17	9	78
316-500 ug/m3	-	-	1	5	15	18	18	8	5	6	2	11	44	32	3	168
199-315 ug/m3	-	2	4	14	38	45	46	29	13	16	13	35	65	44	3	367
125-198 ug/m3	7	5	7	47	156	213	221	165	101	80	49	89	114	25	1	1,280
79-124 ug/m3	9	11	27	136	422	707	728	570	459	298	222	179	124	21	-	3,913
50-78 ug/m3	16	22	50	235	746	1,330	1,652	1,236	1,029	722	507	323	94	13	-	7,975
31-49 ug/m3	7	18	50	254	831	1,567	2,115	1,941	1,602	1,120	682	330	71	6	1	10,595
19-30 ug/m3	7	12	42	149	527	1,142	1,696	1,702	1,609	1,167	633	243	41	6	-	8,976
12-18 ug/m3	1	1	16	58	288	520	896	970	1,017	795	456	117	18	2	1	5,156
7-11 ug/m3	-	2	1	17	97	160	282	342	351	266	162	51	9	1	-	1,741
5-6 ug/m3	-	1	1	4	30	41	71	94	118	85	58	28	3	3	-	537
3-4 ug/m3	-	-	1	3	8	19	20	38	38	29	19	10	2	-	-	187
1-2 ug/m3	-	-	-	-	-	3	4	12	14	9	6	-	-	-	-	48
<1 ug/m3	-	-	-	-	-	3	10	13	13	8	10	4	5	2	-	68
TOTAL	47	74	200	925	3,159	5,774	7,773	7,132	6,371	4,604	2,821	1,429	609	176	26	41,120

WEST 43RD AVE

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	2	-	-	8	-	10
794-1257 ug/m3	-	-	-	-	-	3	1	-	1	1	2	1	14	14	6	43
501-793 ug/m3	-	-	1	5	10	3	1	-	1	2	6	6	33	27	7	102
316-500 ug/m3	-	-	1	26	91	66	30	13	4	2	5	24	62	26	7	357
199-315 ug/m3	-	-	15	89	327	342	190	62	15	12	19	79	95	16	3	1,264
125-198 ug/m3	-	1	38	235	753	795	507	238	99	51	67	179	117	15	2	3,097
79-124 ug/m3	-	4	78	431	1,285	1,391	1,037	562	346	208	271	277	69	7	1	5,967
50-78 ug/m3	-	6	82	460	1,377	1,537	1,489	1,063	806	609	638	296	56	5	1	8,425
31-49 ug/m3	1	3	55	306	941	1,278	1,487	1,505	1,446	1,252	899	240	17	7	2	9,439
19-30 ug/m3	-	1	28	146	415	593	933	1,244	1,494	1,238	641	132	14	4	2	6,885
12-18 ug/m3	-	1	15	59	167	271	434	601	769	567	283	65	13	-	-	3,245
7-11 ug/m3	-	2	1	13	44	87	154	200	207	193	98	33	5	-	-	1,037
5-6 ug/m3	-	-	-	7	16	23	38	59	72	56	28	12	1	1	-	313
3-4 ug/m3	-	-	1	1	7	12	19	21	35	21	18	6	-	-	-	141
1-2 ug/m3	-	-	-	-	1	3	1	5	9	9	4	1	-	-	-	33
<1 ug/m3	-	-	-	-	-	1	4	15	6	11	5	-	1	-	-	43
TOTAL	1	18	315	1,778	5,434	6,405	6,325	5,588	5,310	4,232	2,986	1,351	497	131	32	40,403

DURANGO COMPLEX

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
1995-3161 ug/m3	-	-	-	-	1	-	-	-	-	-	-	-	-	1	2	4
1258-1994 ug/m3	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
794-1257 ug/m3	-	-	-	-	-	3	1	-	1	-	2	-	2	5	5	19
501-793 ug/m3	-	-	1	2	5	3	1	-	-	4	7	4	12	16	4	59
316-500 ug/m3	-	-	10	36	64	24	20	5	3	3	5	17	31	23	2	243
199-315 ug/m3	-	2	39	107	203	163	76	31	14	5	17	44	70	20	5	796
125-198 ug/m3	1	15	114	352	616	468	291	140	65	31	56	91	90	16	2	2,348
79-124 ug/m3	-	19	212	714	1,103	939	769	493	340	151	154	168	95	13	2	5,172
50-78 ug/m3	1	16	176	698	1,274	1,337	1,425	1,184	886	618	483	335	72	6	1	8,512
31-49 ug/m3	1	16	113	461	961	1,231	1,463	1,750	1,757	1,315	909	348	36	5	1	10,367
19-30 ug/m3	1	5	40	166	435	609	1,025	1,354	1,672	1,478	855	219	18	3	1	7,881
12-18 ug/m3	-	-	15	49	139	226	430	685	876	761	471	80	10	3	-	3,745
7-11 ug/m3	-	-	4	15	40	61	160	237	279	236	115	27	5	2	-	1,181
5-6 ug/m3	-	-	1	2	8	23	44	75	96	69	49	12	3	-	-	382
3-4 ug/m3	-	-	1	2	8	10	14	32	33	27	23	10	-	-	-	160
1-2 ug/m3	-	-	-	-	1	-	4	11	19	10	9	1	-	-	-	55
<1 ug/m3	-	-	-	-	-	8	7	21	21	15	7	2	1	1	-	83
TOTAL	4	73	727	2,604	4,858	5,105	5,730	6,018	6,062	4,723	3,162	1,358	445	114	25	41,008

HIGLEY

PM10 Category	< 1	1 mph	2 mph	3 mph	4 mph	5-6	7 mph	8-10	11-13	14-16	17-21	22-27	28-34	35-43	44+	TOTAL
3162+ ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
1995-3161 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	4
1258-1994 ug/m3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	2
794-1257 ug/m3	-	-	-	-	-	-	-	1	-	-	1	-	5	5	4	16
501-793 ug/m3	-	-	-	1	1	3	1	6	1	2	3	6	25	17	4	70
316-500 ug/m3	-	-	3	11	15	21	17	14	5	4	8	20	43	24	7	192
199-315 ug/m3	-	1	7	26	63	79	104	71	40	17	16	50	58	16	3	551
125-198 ug/m3	-	3	16	76	172	255	354	283	123	47	52	95	76	15	1	1,568
79-124 ug/m3	1	6	36	134	369	641	870	687	326	139	153	176	85	13	1	3,637
50-78 ug/m3	3	7	42	227	659	1,288	1,888	1,499	708	379	352	255	61	10	-	7,378
31-49 ug/m3	3	7	36	204	704	1,309	2,284	2,197	1,451	984	619	300	46	4	-	10,148
19-30 ug/m3	-	3	22	118	451	917	1,634	1,886	1,709	1,303	740	210	24	3	-	9,020
12-18 ug/m3	2	2	9	63	249	486	914	1,032	1,025	887	399	106	8	2	1	5,185
7-11 ug/m3	-	1	4	24	94	194	346	420	384	296	117	39	8	2	-	1,929
5-6 ug/m3	-	-	-	4	27	52	91	116	126	106	46	19	7	-	-	594
3-4 ug/m3	-	-	-	2	5	14	29	44	48	39	29	6	2	-	-	218
1-2 ug/m3	-	-	-	-	1	7	6	11	10	12	6	-	-	-	-	53
<1 ug/m3	-	-	-	-	-	2	3	9	8	4	6	-	-	-	-	32
TOTAL	9	30	175	890	2,810	5,268	8,541	8,276	5,964	4,219	2,547	1,282	449	113	25	40,598

Identifying PM_{10} Producing Threshold for High Wind Speed Based upon Local Data

Local measurements of the effect of wind shear on the entrainment and transport of soil particles from undisturbed and anthropogenically disturbed surfaces were collected by Nickling and Gillies in the mid-1980s. Their study sampled agricultural land, natural scrub desert, disturbed desert, fluvial channels, construction sites, and mine tailings in Arizona. Several of the measurements, including dry river beds and agricultural land, were collected in Maricopa County. Analysis of the collected data established threshold velocities necessary to initiate emissions of PM_{10} for each of the above categories of land. The lowest threshold velocity for PM_{10} was determined to be 13 mph (as measured at a height of 10 meters above the ground) for disturbed river beds and for mine tailings. All other land uses were found to have higher threshold velocities (Nickling and Gillies, 1986). Based on this information, 13 mph was selected as the threshold speed for which winds could initiate the entrainment of PM_{10} impacting monitors in the Salt River Area.

There are different averaging times and techniques for wind speeds which are commonly available. These range from hourly vector-average wind speeds which can understate the true wind velocity when winds vary in direction considerably during the hour, to short term gust which may overstate the magnitude of the winds in general. To the degree that winds are consistent and steady, all averaging methods tend to agree. To determine which of these measurements is most appropriate for the selection of high wind hours, a review of the test procedures employed by Nickling and Gillies was conducted. The following text summarizes the relevant elements of the test procedures.

> *The length of the individual test was dependent on the amount of sediment transported and was longer for surfaces with lower flux rates.* ***Duration of individual tests ranged from 10 to 30 minutes****… Since the soil surface may become depleted of erodible grains during the test, it was necessary to move the tunnel to a new location for each sample run… In general five or six runs were carried out at each of the 13 selected sites. (emphasis added)*

Given the fact that the tests were relatively short duration, considerably less than an hour in length, short-term average (5-10 minute) velocity values, if available would be preferred for identifying periods with potential for wind blown dust. Recognizing these measurements are not generally available, reliance on slightly lower long-term averages (full hour), or slightly higher wind gust velocities may also be appropriate. Thus, each hour containing one or more five-minute periods with an average wind speed of 13 mph or higher could be designated as a high wind hour. The analysis of wind speed and wind gust data from several monitors in the Phoenix area (as shown in Tables 7 – 9) found that hours with hourly average winds speeds over 11-13 mph, or hours with wind gusts over 17-21 mph have similar characteristics. The use of these alternative thresholds are conservative since many seconds of winds exceeding the 13 mph threshold would have to occur to produce five-minute average values greater than or equal to 13 mph, or hourly average wind speeds exceeding 11-13 mph, or wind gusts over 17-21 mph.

Additional evidence supporting the above thresholds is established through a translation between a wind speed threshold defined on a 5-minute basis and one based on the maximum gust recorded during the hour. This was done by examining the meteorological data collected since January 2007, in which 5-minute average wind speeds have been recorded, and matching the values for each 5-minute period to the maximum wind gust recorded for the hour to which the period belongs. Figure 1 shows the distribution of 5-minute average and maximum hourly wind gust speeds for the period. It is clear that, on average, the hourly wind gust speed increases as the 5-minute average speed increases. Further, it is clear that there is an effective minimum hourly wind gust speed for any value of the 5-minute average wind speed. When the 5-minute wind speed exceeds 13 mph, there are very few instances in which the hourly wind gust does not exceed 21 mph. The translation between 5-minute and hourly wind gust speeds can be established by examining the distribution of the data to the right of the vertical red line in the figure. When the 5-minute

average wind speed exceeds 13 mph, the maximum hourly wind gust will exceed 21 mph 96 percent of the time and it will exceed 22 mph 92 percent of the time.

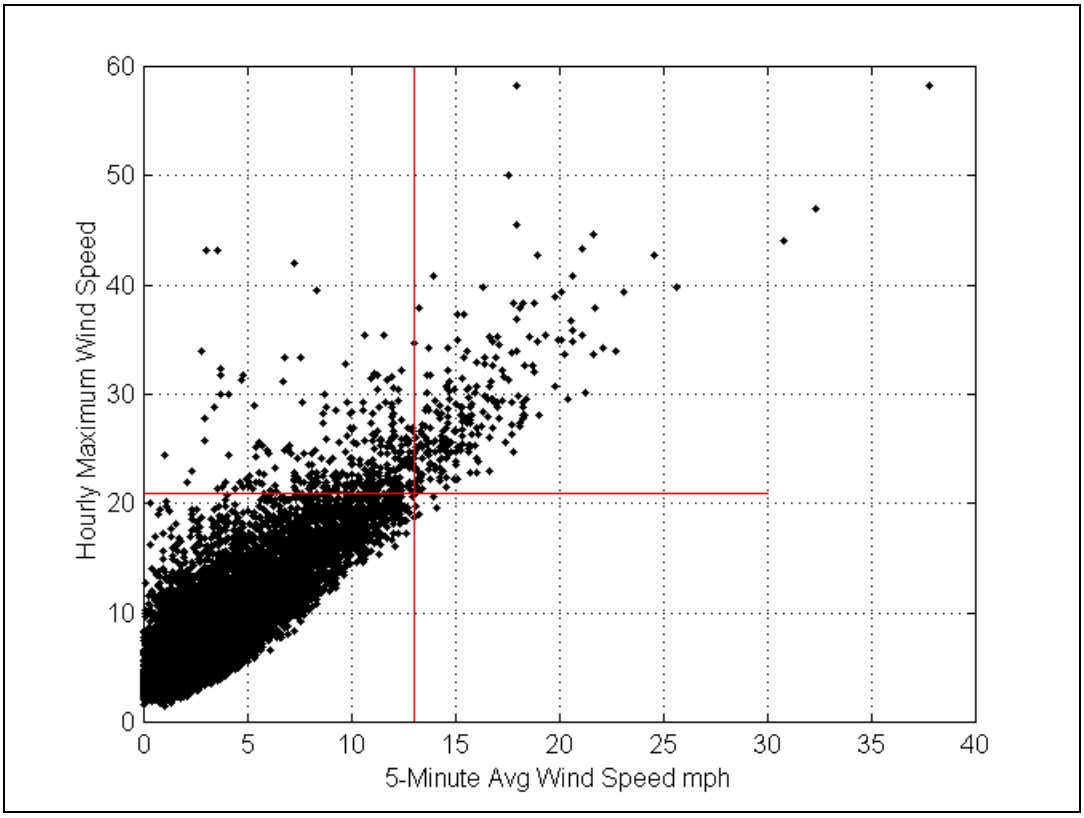

Figure 1. Graph showing the highly correlated distribution of hourly maximum wind speed and 5-minute average wind speed.

Further Examination of the Joint Effects of Topography, Threshold Friction Velocity, and Surface Roughness

Beyond the importance of a threshold wind speed, the generation of PM_{10} by winds at any particular location is strongly influenced by the individual physical characteristics of the terrain that comprises and surrounds the location. Of particular interest is the interaction between variables that determine threshold friction velocities and surface roughness. As an example, areas where the transition between surface roughness heights is pronounced can experience dramatically different levels of PM_{10} concentrations. Exhibit I provides a detailed technical exploration of these effects, both conceptually and empirically, through the use of data collected in the Salt River Basin of Phoenix.

Summary

Local wind tunnel test literature and examination of data from Arizona monitors indicate that the phenomenon of blowing dust can occur over a broad range of wind speeds, but generally is associated with winds that are above 11-13 miles per hour (on average), which are also commonly associated with wind gusts above 17-21 miles per hour.

Data analysis done in tables 7-9 suggests that hourly average winds of greater than 11-13 miles per hour (which are commonly associated with wind gusts over 17-21 miles per hour) not only have the potential

to generate windblown dust, but also occur less than 5% of the time, which strongly suggest wind speeds of this magnitude are also unusual.

The National Weather Service only includes "Wind Gust" information in the routine observations when the observed wind gust exceeds 15 miles per hour and it occurs within the ten minute period preceding the routine hourly report. As such, there is no bright-line indicator as to what constitutes unusual winds from the stand-point of a specific wind velocity, but the National Weather Service generally uses 15 miles per hour as a significance point for wind gusts.

ADEQ has historically adopted the practice of "highlighting" hourly maximum winds in a two-tiered system, calling out winds above 15mph and winds above 25mph. The selection of these hours corresponds well to National Weather Service practice and allows for the continuing analysis of these winds in context of the generation of PM_{10}.

REFERENCES

Bach, A. J., Brazel, A. J., and Lancaster, N. 1996. Temporal and Spatial Aspects of Dust in the Mojave and Colorado Deserts of Southern California, 1973-1994. *Physical Geography* **17**: 329-353.

Brazel, A. J. and Nickling, W. G. 1986. The Relationship of Weather Types to Dust Storm Generation in Arizona (1965-1980). *Journal of Climatology*. **6**: 255 -275.

Gillette, D.A., Adams, J., Endo, E. and Smith, D., 1980. Threshold Velocities for Input of Soil Particles into the Air by Desert Soils, *Journal of Geophysical Research* **85(C10)**: 5621-5630.

Gillette, D.A., Adams, J., Muhs, D. and Kihl, R., 1982. Threshold Friction Velocities and Rupture Moduli for Crusted Desert Soils for the Input of Soil Particles into the Air. *Journal of Geophysical Research* **87(C10)**: 9003-9015

Gillette, D.A., 1988. Threshold Friction Velocities for Dust Production for Agricultural Soils. *Journal of Geophysical Research* **93(D10)**: 12645-12662.

Holcombe, T. L. Ley, T. and Gillette, D. A. 1996. Effects of Prior Precipitation and Source Area Characteristics on Threshold Wind Velocities for Blowing Dust Episodes, Sonoran Desert 1948-1978. *Journal of Applied Meteorology*. **36**: 1160-1175.

Lyles, L. 1988. Basic Wind Erosion Processes. *Agriculture, Ecosystems, and Environment* **22/23**: 91-101.

MacKinnon D. J., Elder, D. F., Helm, P. J., Tuesink, M. F., and Nist, C. A. 1990. A Method of Evaluating Effects of Antecedeant Precipitation on Duststorms and its Application to Yuma, Arizona, 1981-1988. *Climatic Change*. **17**: 331-360.

McTainish G. H. and Pitblado, J. R. 1987. Dust Storms and Related Phenomena Measured from Meteorological records in Australia. *Earth Surface Processes and Landforms* 12: 415-424.

Nickling, W. G. & Brazel, A.J. 1984. Temporal and Spatial Characteristics of Arizona Dust Storms (1965-1980). *Journal of Climatology*. **4**: 645-660.

Nickling, W.G. and Gillies, J.A 1986. Evaluation of Aerosol Production Potential of Type Surfaces in Arizona, EPA Contract No. 68-02-388, September 1986.

Nickling, W. G. 1988. The Initiation of Particle Movement by Wind. *Sedimentology* **35**: 499-511.

Nickling, W.G. and Gillies, J.A., 1989. Emission of Fine Grained Particulate from Desert Soils, in: *Paleoclimatology and Paleometeorology: Modern and Past Patterns of Global Atmospheric Transport*. M. Leinen and M. Sarnthein (Editors), Kluwer Academic Publishers, pp. 133-165.

Orgill, M. M. and Sehmel, G. A. 1976. Frequency and Diurnal Variation of Duststorms in the Continental U.S.A. *Atmospheric Environment* **10**: 310

Wilkerson, W. D., 1991. Dust and sand forecasting in Iraq and adjoining countries, AWS/TN—91/001, Air Weather Service, Scott AFB, IL, 63 pp.

WRAP, 2006. Fugitive Dust Handbook. http://www.wrapair.org/forums/dejf/fdh/.

University Corporation for Atmospheric Research / COMET Program. 2003. Forecasting Dust Storms. http://www.meted.ucar.edu/mesoprim/dust/print.htm.

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EXHIBIT I

TECHNICAL DEMONSTRATION OF THE IMPACT OF TERRAIN, THRESHOLD FRICTION VELOCITY, AND SURFACE ROUGHNESS ON PM_{10} GENERATION BY WINDS

1. Winds at the source versus winds at the monitor

Temporal and spatial variations of wind along downwind direction (X-axis) over complex terrain can be described by the Navier-Stokes equation as follows:

$$\frac{\partial u}{\partial t} = -u\frac{\partial u}{\partial x} + \frac{\partial}{\partial z}\left(K_m \frac{\partial u}{\partial z}\right) \qquad (1)$$

As indicated in equation (1), local variation of wind is mainly governed by horizontal convection and vertical exchange of momentum. In other words, the surface wind is physically controlled by free troposphere dynamics, and modified by local topography, surface characteristics, and thermal circulations.

Wind is described in terms of a vector having both magnitude and direction. The scalar quantity of wind speed must be defined with respect to averaging time (see Figure 1), surface roughness and height above ground, as wind speed is a function of these quantities. It is well-known, however, that dust emission flux is not linearly dependent on wind velocity, but better related to the friction velocity which depends upon wind gust (Marticorena, et al., 1995, 1997, 2006; Shao, et al., 2000, 2002, 2004; Liu, et al., 2001, Zeng, et al., 2007, Choi and Fernando, 2008; Darmenova, et al., 2009; Park et al., 2010). Wind-blown dust emissions are mostly generated by the wind gust represented by the 1-minute average of wind speed. Windblown dust emissions are transported downwind by mean wind. The PM-10 concentration dominated by soil dust is measured when the dust-rich air mass is passing the monitor.

Particulate concentration at a monitoring site can be predicted by equation (2) below.

$$\underbrace{\frac{\partial C}{\partial t}}_{term1} = \underbrace{-C\frac{\partial u}{\partial x}}_{term2} - \underbrace{u\frac{\partial C}{\partial x}}_{term3} + \underbrace{\frac{\partial}{\partial z}\left(K_c \frac{\partial C}{\partial z}\right)}_{term4} + \underbrace{S_c}_{term5} \qquad (2)$$

The temporal variation of concentration at a monitoring site, term 1 of equation (2), depends on wind transport represented by terms 2 and 3, vertical turbulent diffusion described by term 4, and emissions term 5. Terms 2 and 3 are related to wind speed and concentration gradients between the source and the monitor, respectively. Term 4 is associated with wind profile and turbulent exchange rate K_c at a monitoring site, and term 5 is correlated to the intensity of wind gust at the source.

The observation data analysis shows that dust horizontal transport from upwind source to downwind monitoring site ($-C\frac{\partial u}{\partial x} - u\frac{\partial C}{\partial x} = -\frac{\partial uC}{\partial x} > 0$) was responsible for high PM-10 concentrations at West 43rd Avenue during high wind events in 2008 (see the attached report, Liu, 2010). In addition, the data cited in the "Review of Exceptional Event Request" report (USEPA, 2010) demonstrates that high PM-10 concentrations observed at the West 43rd Avenue monitor were preceded by strong wind gusts at Goodyear Airport. This implies that strong

wind gusts in upwind areas resulted in high airborne dust emissions that were transported from the source area to the downwind monitor site. Those observed facts agree with equation (2).

Time scale, mean wind and wind gust

Inasmuch as wind speed is a function of averaged time, there is an obvious need to define the relationships among wind speeds averaged over various periods of time. On the basis of statistical analysis of wind records from different stations, Durst (1960) obtained the results that wind speed may be different from the same wind record if a different time scale is used, as shown in Table 1. Since the wind gust averaged over a small time scale (δt) best represents local wind information, wind gust speeds (δv) between two closer locations (with distance of $\delta l = \delta v * \delta t$) can be significantly different. Figure 1 shows that different time scale running averages from the same record could lead to very different mean values of wind speed. In a similar way, mean wind speeds between two observation stations with distance greater than δl may not be comparable. The scale of δl could be much smaller if wind field is modified by significant changes in surface roughness and topography along the wind path between the source and the monitoring site (see Figure 2). For example, the winds observed at a rural station should be very different from those at an urban station.

Table 1 Ratio of wind speed for average time scale (δt) to mean hourly wind speed (δt=1 hr)

Average time scale (δt)	1 hr	10 min	1 min	30 sec	20 sec	10 sec	2 sec
Ratio	1.0	1.06	1.24	1.33	1.36	1.43	1.59

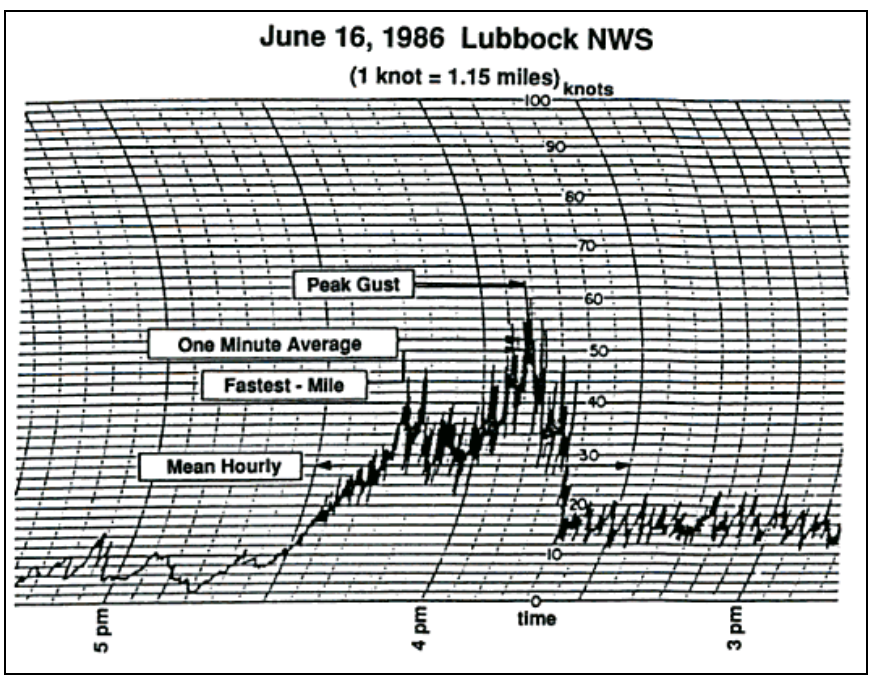


Figure 1 Wind records during a strong wind scenario (adapted from Guidelines for Design of Low-Rise Buildings Subjected to Lateral Forces by Ajaya Kumar Gupta and Peter James Moss, 1993, Page 48).

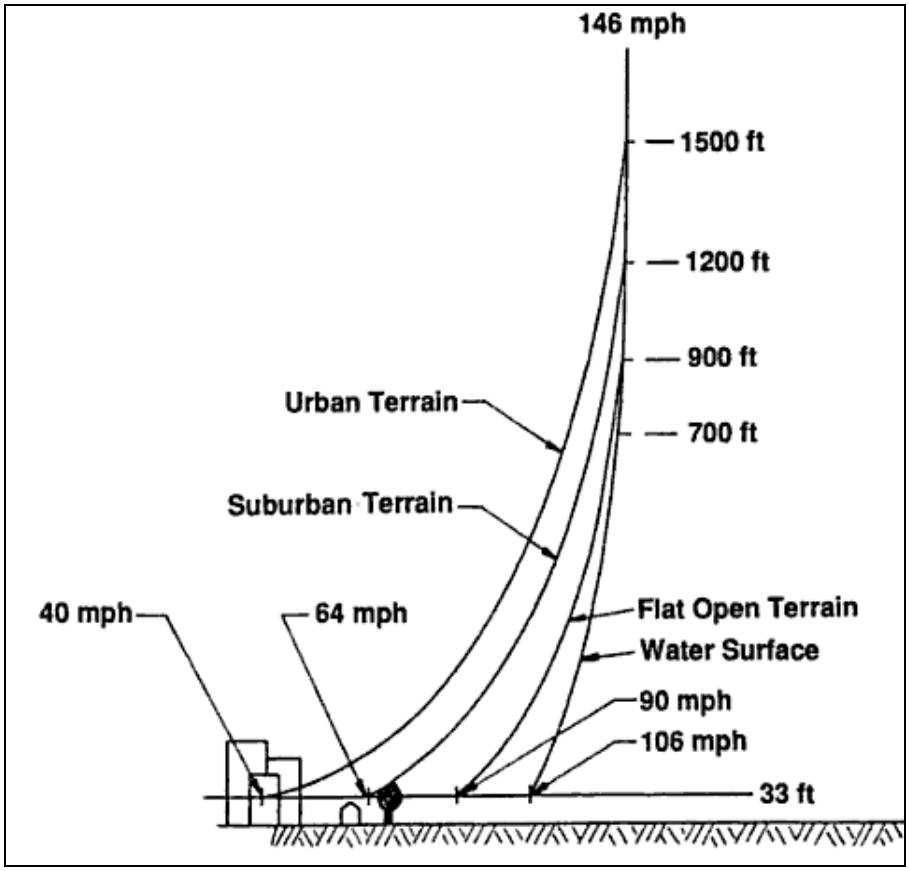


Figure 2 Typical wind profile and wind gradient over complex surface conditions. The surface wind speed from right (rural area) to left (urban area) decreases due to increase of surface roughness length because surface roughness generates a (friction) stress force with counter wind direction, called Reynolds Stress, measured by $\tau = \rho u_*^2$, where ρ is air density and u_* is friction velocity.

2. Emissions are related to wind velocity cubed

Horizontal and vertical flux

In dust emissions modeling, there are two important fluxes to determine: (1) horizontal flux (also called streamwise saltation flux) which quantifies the soil dust flow along unit length per

unit time with dimension of g $m^{-1}s^{-1}$ and (2) vertical flux which quantifies the mass of fine particles passing through a horizontal unit area, measured by g m^{-2} s^{-1}.

Many researchers (Gillette, 1979; Gillette and Stockton, 1989; Sorensen, 1985; Leys and Raupach, 1991; Shao et al.,1993) found that in natural situations and in wind tunnels the horizontal flux depends strongly on the friction velocity. In particular, White's (1979) formulation, which was based on both theoretic work and experiments, most closely agrees with the observational data.

$$Q = C\frac{\rho_p}{g}u_*^3(1+R)(1-R^2) \quad (3)$$

Where: C is a constant, ρ_p is the particle density, g is the acceleration due to gravity, and $R = \frac{u_{*t}}{u_*}$.

Meanwhile, Marticorena and Bergametti (1995) proposed an empirical dust-emission scheme, such that the vertical flux is proportional to the horizontal flux as:

$$F=0.01Q\exp(0.308\eta_c-13.82) \quad (4)$$

where: η_c is the percentage of clay, and F is the vertical flux.

Under high wind conditions, the atmospheric stability condition is neutral. The friction velocity u_* can be determined via wind speed measured at 10 m (U_{10}), i.e.,

$$u_* = k\frac{U_{10}}{ln\frac{1000.0}{z_0}} \quad (5)$$

where: k is a constant (0.4).

By combining Eqs. 3, 4, and 5, the dust vertical flux can be expressed as:

$$F=0.01\exp(0.308\eta_c-13.82)\, C\frac{\rho_p}{g}\left(k\frac{U_{10}}{ln\frac{1000.0}{z_0}}\right)^3 (1+R)(1-R^2) \quad (6)$$

Eq. 6 indicates that the dust vertical flux is proportional to the cube of wind speed. Figure 3 also confirms the relationship between sand flux and the cube of wind speed from Bowker et al. (2007), when field experimental data are used.

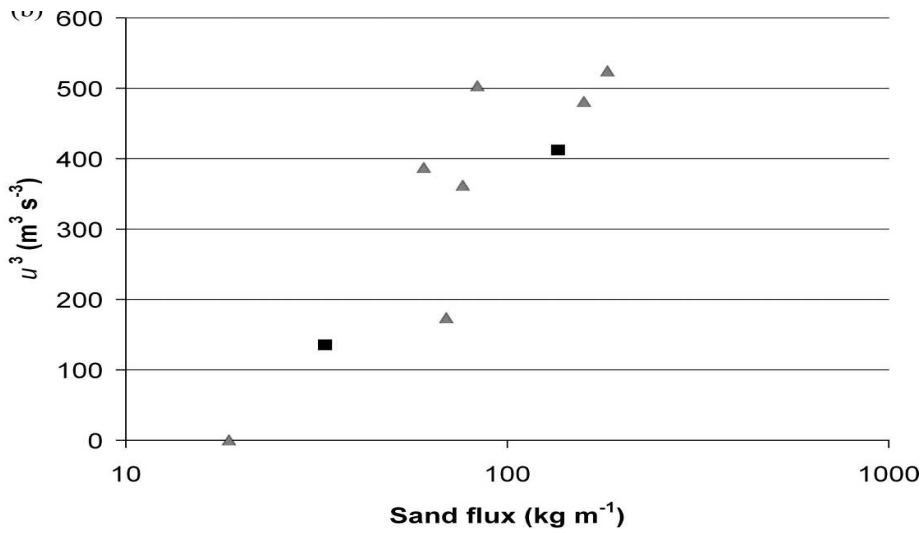


Figure 3: Relationship between u^3 at each BSNE location as simulated by QUIC for a 10-min time period of high winds and BSNE sand flux measurements for the corresponding sandstorm (15 April, 2003) only for BSNE on lines 1 (black squares) and 2 (gray triangles) (*Taken From Bowker et al, 2007: Sand Flux Simulations at a Small Scale over a Heterogeneous Mesquite Area of the Northern Chihuahuan Desert, Journal of Applied Meteorology and climatology, Vol, 46, 1410-1422*)

Sensitivity to the friction velocity

Figure 4 illustrates a high sensitivity of the dust emissions to the accuracy in wind velocity (Bergametti et al, 2007). In this figure, the horizontal flux is normalized to the horizontal flux for $u_* = 35\ cm/s$. If we consider a wind friction velocity of 50 cm/s (corresponding to a 10 m high wind velocity of about 10 m/s for a surface having a roughness length of 0.35 cm) with an accuracy of $\pm 5\%$, this gives a range of wind friction velocities from 47.5 to 52.5 cm/s. The difference in the horizontal flux is in the order of 1.5 (=7.25/4.97). This difference reaches a factor greater than 2 at an accuracy of $\pm 10\%$. This clearly points out that the dust emission modeling is highly dependent on the quality of the surface wind field data.

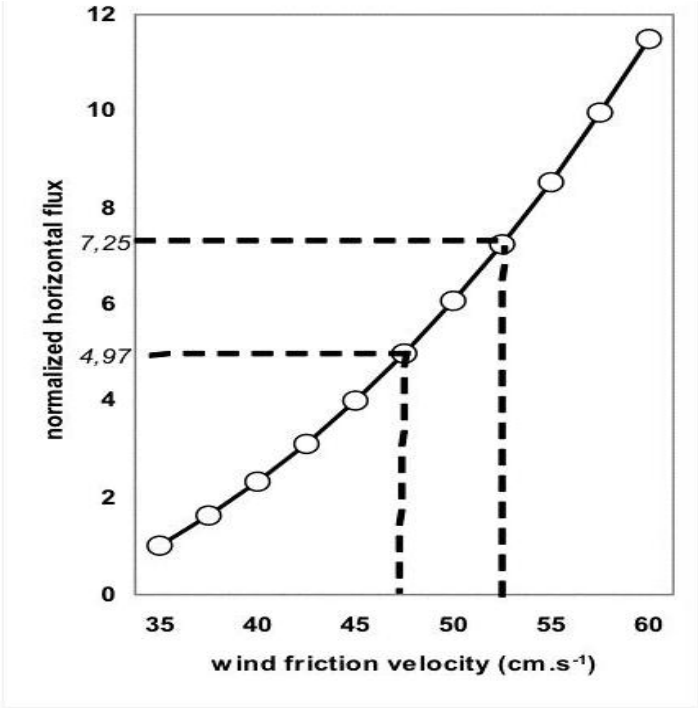


Figure 4. Horizontal fluxes computed using White (1979)'s formulation vs wind friction velocity (u*). Note that the horizontal fluxes are normalized to the horizontal flux for u* = 35 cm.s^{-1}. The dashed lines correspond to horizontal fluxes computed respectively for wind friction velocities equal to 47.5 and 52.5 cm.s^{-1} (see text for details)

3. Impact of surface roughness on PM-10 concentrations during high winds

The surface roughness has a twofold impact on PM-10 concentrations: on the one hand, rougher surface results in suppression of dust emissions. On the other hand, higher surface roughness length reduces wind speed and induces intensive turbulence by absorbing the kinetic energy transferred from the wind shear to turbulent kinetic energy (TKE). Decreased wind speed abates horizontal transport, and enhanced turbulent eddies promote vertical exchange, which in turn effectively controls dry deposition. The wind transport and turbulent diffusion processes described by terms 2 and 3, and term 4 in equation (2), are two important factors governing airborne dust. Lower surface roughness at the upwind area may contribute to higher dust emissions and higher PM-10 concentration at downwind areas. In addition, higher surface roughness in downwind areas results in increased surface PM-10 concentrations caused by reduced wind speeds and enhanced dry deposition. For the West 43rd Avenue monitoring site, surface roughness upwind of the site is much lower than around the monitoring site (see Figure 5). The low surface roughness over upwind erodible areas leads to intensive dust emissions and high wind speeds. The strong positive gradient of surface roughness between the upwind sources and the West 43rd Avenue monitoring site results in decreases in wind speed and increased dry deposition. Both of these factors contribute to high PM-10 concentrations at the

West 43rd monitor during high wind episodes. For the detailed gradient analysis of wind speed and PM-10 concentrations, please refer to the attached report (Liu, 2010).

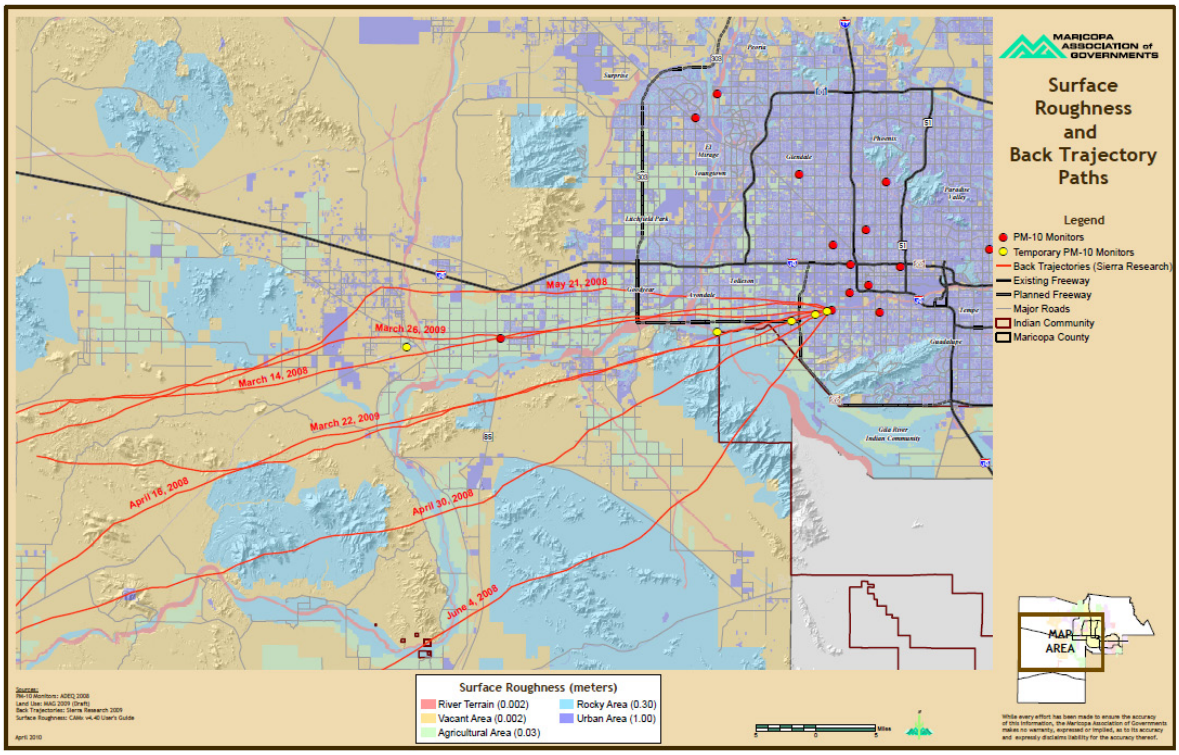


Figure 5. Surface roughness distribution over the Greater Phoenix Area. Since the West 43rd Avenue monitoring site is located at the south-west boundary of the urban area, significant transition of surface roughness occurs around the site.

4. Impact of threshold friction velocity on PM-10 concentrations

Windblown dust emissions can only occur when the wind friction velocity (u_*) exceeds a critical value. This friction velocity value is called threshold friction velocity (u_{*t}). It is a key parameter in quantifying windblown dust emissions. The threshold friction velocity depends primarily on three factors: particle diameter (D_p), surface roughness length (z_0), and soil moisture content (w).

Particle diameter

Figure 6 shows the relationship between the threshold friction velocity and particle diameter for smooth surfaces, according to Iversen and White (1982) and Shao and Lu (2000). The two curves look similar and the threshold friction velocity is at a minimum at an optimum grain size

(~80 μm) according to Iversen and White's (1982) semi-empirical formulation. The threshold friction velocity increases when the particle diameter decreases from the optimum grain size.

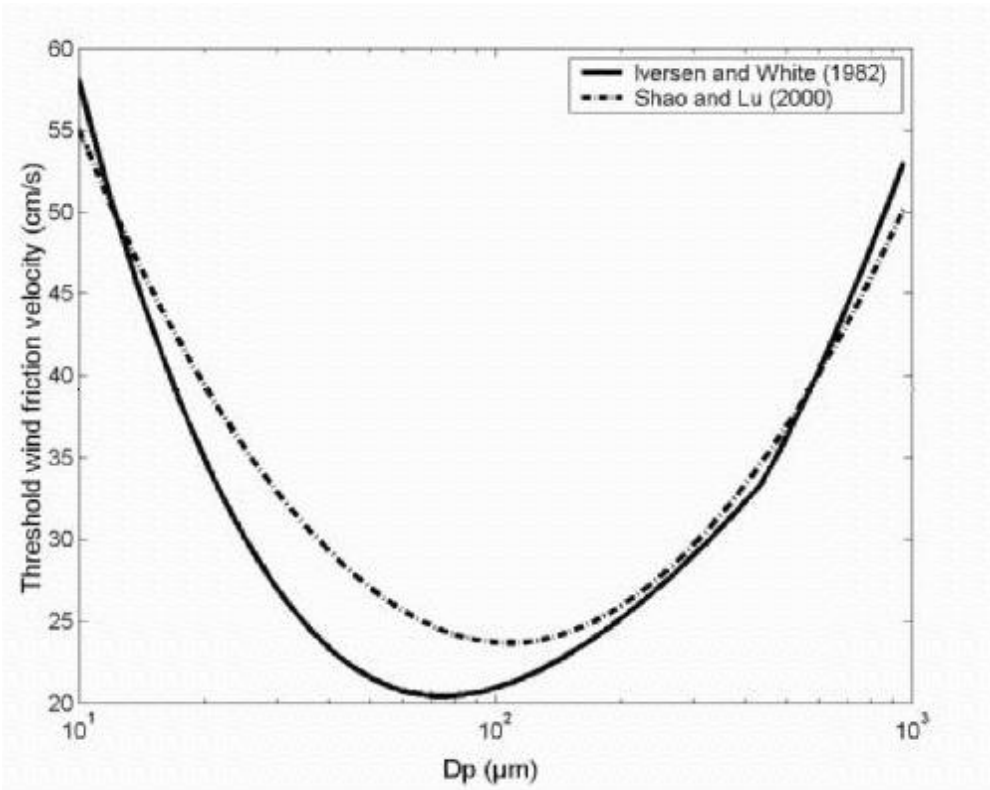


Figure 6. Parameterization of the threshold friction velocity (u_{*ts} in cm/s) versus particle diameter (D_p in μm) for smooth surfaces according to Iversen and White (1982) and Shao and Lu (2000). *This figure is taken from Bergametti et al. (2007)*.

Surface Roughness

The presence of non-erodible elements (pebble, stones, vegetation…) on an erodible surface strongly affects the threshold friction velocity. On the one hand, the roughness elements cover a fraction of the surface and thus protect it from the aeolian erosion; on the other hand, they absorb a part of the wind momentum that will not be available to initiate particle motion. This leads to a net decrease of the wind shear stress acting on the erodible surface and thus of the erosion efficiency.

According to Marticorena and Bergametti (1995), the erosion efficiency, also called drag partition correction, can be expressed as follows:

$$f_{eff} = \frac{u_{*ts}}{u_{*t}} = 1 - \frac{\ln\left(\frac{z_0}{z_{0s}}\right)}{\ln\left[0.35\left(\frac{10cm}{z_{0s}}\right)^{0.8}\right]} \qquad (7)$$

where: z_0(cm) is the surface roughness length, z_{0s} is a local roughness length of the intervening surface, and a typical value is 0.001 cm.

From Eq. (7), it becomes evident that the f_{eff} is smaller for rougher surfaces due to a higher surface roughness length. Figure 7 also displays this relationship.

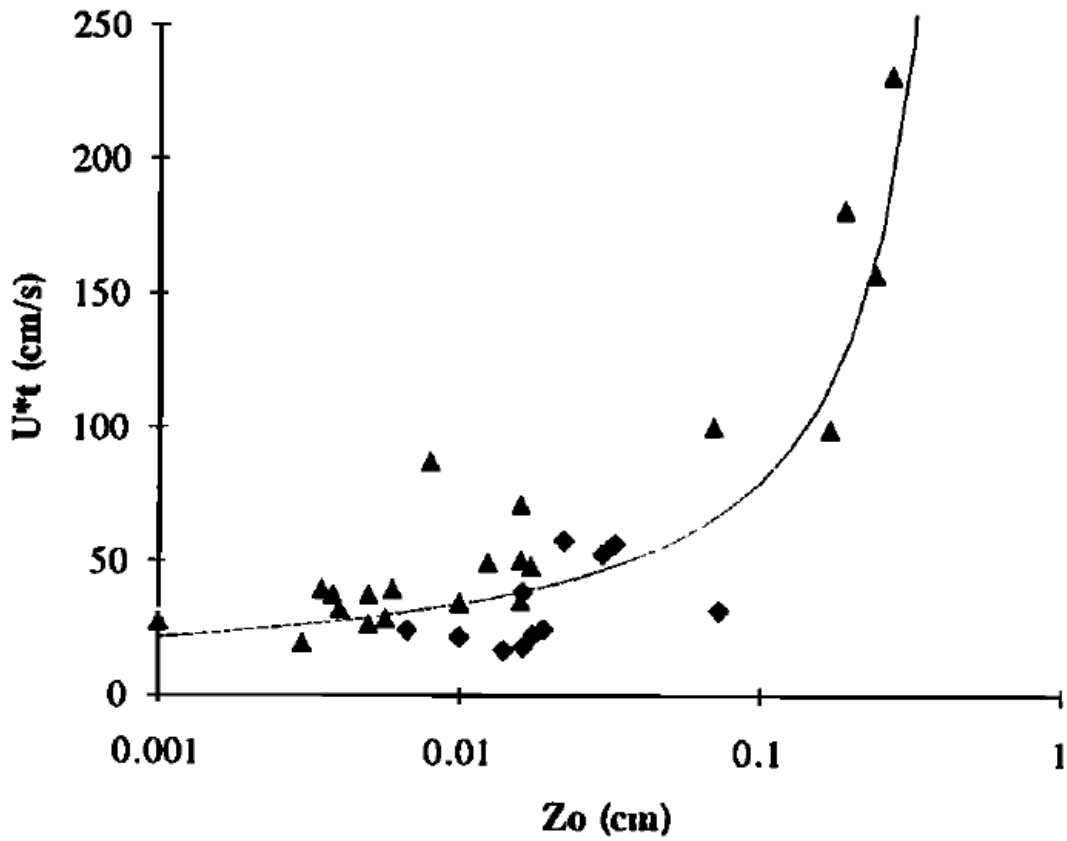


Figure 7. Threshold friction velocity versus roughness lengths (Z0); triangles, Gillette et al. (1982); diamond, Nickling and Gillies (1989); solid curve from Eq. 8. *This Figure is taken from Marticorena and Bergametti, (1995*).

Soil Moisture Content

The third factor affecting the threshold friction velocity is the soil moisture. The soil water reinforces the cohesive forces between the soil grains and thus increases the erosion threshold. Basically, the inter-particle capillary forces are responsible for the increase of the wind erosion threshold when the soil moisture increases. Below a critical value of w', these capillary forces are considered as being not strong enough to increase the erosion threshold. The w' depends on the soil texture.

A parameterization scheme proposed by Fecan et al. (1999) is used to calculate the effect.

$$H(w) = \frac{u_{*tw}}{u_{*td}} = [1 + 1.21(w - w')^{0.68}]^{0.5} \quad (8)$$

where: u_{*td} is the threshold friction velocity at dry condition, u_{*tw} is the threshold friction velocity at wet condition; w is the soil moisture; and $w' = 0.0014(\%\ clay)^2 + 0.17(\%\ clay)$ is the threshold soil moisture.

Finally, by considering the three major factors, the threshold friction velocity for a particular particle diameter on a rough surface with a certain soil moisture can be determined (Darmenova, et. al., 2009) with the equation:

$$u_{*t}(D_p, z_0, z_{0s}, w) = \frac{u_{*ts(D_p)}}{f_{eff}(z_s, z_{0s})} H(w) \quad (9)$$

Overall, as Eq. 9 indicates, it is difficult to generate dust emissions for smaller particles (diameter < 80□m) over rougher surface with wetter soil surface.

Under high wind conditions, the atmospheric stability condition is neutral. There is a simple logarithm for these conditions as shown below:

$$U_{10} = \frac{u_*}{k} ln \frac{1000.0}{z_0} \quad (10)$$

Where: U_{10} is the wind speed at 10 meter height, friction velocity in cm/s, roughness length in cm; and k is a constant (0.4).

From Eq. 10, we can calculate the threshold velocity at a 10 meter height. Figure 8 displays the map for U_{10} in the Greater Phoenix Area.

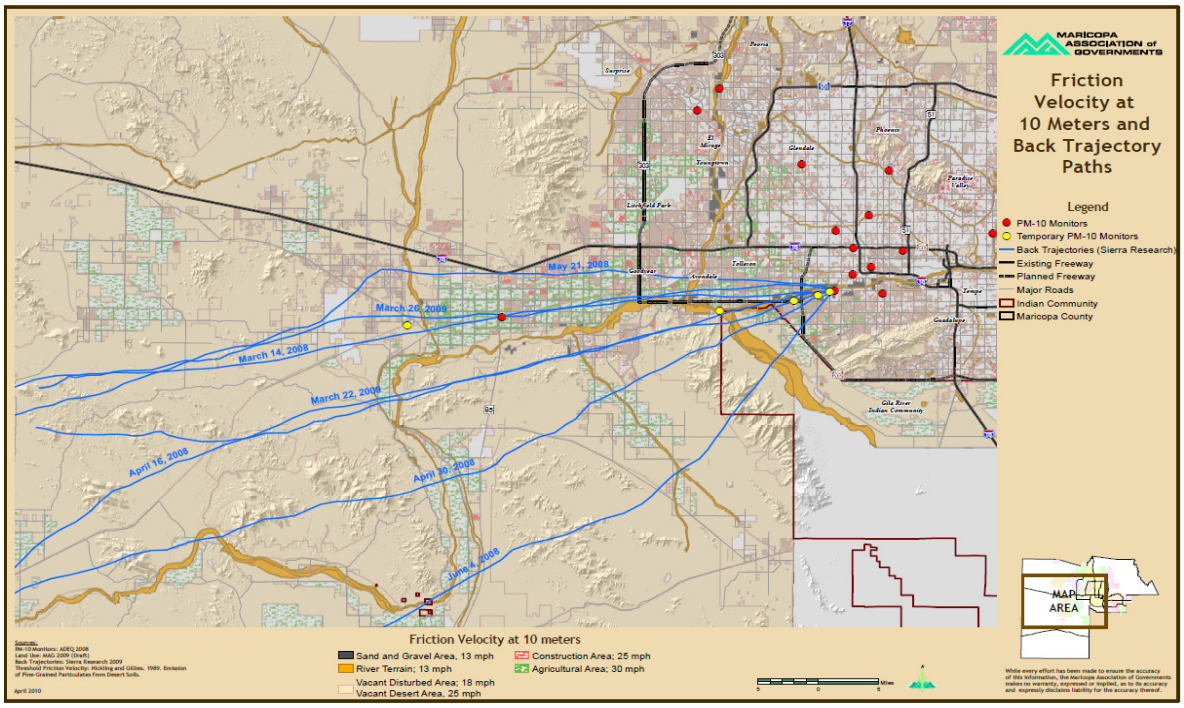


Figure 8: Map for threshold friction velocity at a 10 meter height (U_{10}) in the Greater Phoenix Area.

References

Ajaya Kumar Gupta and Peter James Moss (1993), Guidelines for Design of Low-Rise Buildings Subjected to Lateral Forces, Library of Congress Card Number 93-4733, International Standard Book Number 0-8493-8969-0, CRC Press, Inc, U.S.A.

Bergametti G., B. Marticorena, and B.Laurent, (2007), Key Processes for Dust Emissions and their Modeling, NATO Science Series Regional Climate Variability and its Impacts in The Mediterranean Area, A. Mellouki and A. R. Ravishankara (Ed.,).

Bowker et al, (2007), Sand Flux Simulations at a Small Scale over a Heterogeneous Mesquite Area of the Northern Chihuahuan Desert, Journal of Applied Meteorology and Climatology, Vol, 46, 1410-1422.

Choi, Yu-Jin, H. J. S. Fernanado (2008), Implementation of a windblown dust parameterization into MODELS-3/CMAQ: Application to episodic PM events in the US/Mexico border, Atmospheric Environment, 42, 6039-6046.

Darmenova, K., I. N. Sokolik, Y. Shao, B. Marticorena, and G. Bergametti (2009), Development of a physically based dust emission module within the Weather Research and Forecasting (WRF) model: Assessment of dust emission parameterizations and input parameters for source regions in Central and East Asia, J. Geophys. Res., 114, D14201, doi:10.1029/2008JD011236.

Durst, C. D. (1960), Wind speeds over short periods of time, Meteorology Magazine, 89, 181-186.

Fécan, F., Marticorena, B. and Bergametti, G. (1999), Parameterization of the increase of the aeolian erosion threshold wind friction velocity due to soil moisture for arid and semi-arid areas. Annales Geophysicae 17, 149–57.

Gillette, D. A., (1979), Environmental factors affecting dust emission by wind erosion. Saharan Dust, SCOPE 14, C. Morales,Ed., John Wiley and Sons, 71–91.

Gillette D.A. and Stockton P., (1989), The effect of nonerodible particles on wind erosion of erodible surfaces J. Geophys. Res. 94, 12885-12893.

Iversen, J.D. and White, B.R. (1982), Saltation threshold on Earth, Mars and Venus. Sedimentology 29,111–19.

Leys, J. F., and M. R. Raupach, (1991), Soil flux measurements using a portable wind erosion tunnel. Aust. J. Soil Res., 29, 533–552.

Liu, Feng (2010), High PM-10 associated with high wind events in the Salt River Basin of Phoenix, Maricopa Association of Governments, July 2010.

Liu, Min and Douglas L. Westphal (2001), A study of the sensitivity of simulated mineral dust production to model resolution, J. Geophys. Res., 106, D16, 18,099-18,112.

Marticorena, B. and Bergametti, G. (1995), Modeling the atmospheric dust cycle: 1. Design of a soil derived dust emission scheme. Journal of Geophysical Research 100(D8), 16,415–30.

Marticorena, B., G. Bergametti, B. Aumont, Y. Callot, C. N'Doume´, and M. Legrand (1997), Modeling the atmospheric dust cycle: 2. Simulation of Saharan dust sources, J. Geophys. Res., 102, 4387 – 4404, doi:10.1029/96JD02964.

Marticorena, B., et. al. (2006), Surface and aerodynamic roughness in arid and semiarid areas and their relation to radar backscatter coefficient, J. Geophys. Res., 111, F03017, doi: 10.1029/2006JF000462.

Park, Y-K and Park, S-H (2010), Development of a New Wind-Blown-Dust Emission Module Using Comparative Assessment of Existing Dust Models, Particulate Science and Technology, 28: 267-286, 2010.

Shao, Y., M.R. Raupach, and P. A. Findlater, (1993a), Effect of saltation bombardment on the entrainment of dust by wind. J. Geophys. Res., 98, 12,719–12,726.

Shao, Y., and H. Lu (2000), A simple expression for wind erosion threshold friction velocity, J. Geophys. Res., 105, 22,437-22,443, doi:10.1029/2000JD900304.

Shao, Y., E. Jung, and L. M. Leslie (2002), Numerical prediction of northeast Asian dust storms using an integrated wind erosion modeling system, J. Geophys. Res., 107(D24), 4814, doi:10.1029/2001JD001493.

Shao, Y. (2004), Simplification of a dust emission scheme and comparison with data, J. Geophys. Res., 109, D10202, oi:10.1029/2003JD004372.

Sörensen, M. (1985), Estimation of some Aeolian saltation transport parameters from transport rate profiles. Proc. Int. Workshop on the Physics of Blown Sand, Vol. 1, Aarhus, Denmark,University of Aarhus, 141–190.

USEPA (2010), Review of Exceptional Event Request, Maricopa County, AZ, May 12, 2010.

Zeng, Qingcun, Cheng Xueling, Hu Fei, and Peng Zhen (2007), Gustiness and coherent structure of strong winds and their role in dust emission and entrainment, Adv. Atmos. Sci., 27(1), 1-13.

ATTACHMENT

HIGH PM-10 ASSOCIATED WITH HIGH WIND EVENTS IN THE SALT RIVER BASIN OF PHOENIX

FENG LIU, MARICOPA ASSOCIATION OF GOVERNMENTS

High PM-10 Associated with High Wind Events in the Salt River Basin of Phoenix

Feng Liu
Maricopa Association of Governments

1. The observed facts

High PM-10 concentrations associated with high westerly/southwesterly winds were observed at the West 43rd Avenue monitoring site in the Salt River Basin of Phoenix (see monitor locations in Figure 1) on seven days in 2008 and 2009 (i.e., 3/14/2008, 4/16/2008, 4/30/2008, 5/21/2008, 6/4/2008, 3/22/2009 and 3/26/2009). These seven windy days are unique in that the West 43rd Avenue monitor exceeded the PM-10 standard, but nearby downwind monitors (i.e., Durango Complex and South Phoenix) did not exceed the standard. The temporal variations and scattering relationships between PM-10 concentrations and wind direction and speed at these three monitors are discussed and illustrated in Figures 2 -5.

2. Model simulations of meteorology

An example of large-scale weather systems causing high wind conditions on 3/14/2008 is illustrated in Figure 6. The impacts of the synoptic weather systems on the Valley were simulated by applying the nested Weather Research and Forecasting (WRF) model. The modeled wind fields in the 12-km and 1.3-km domains for 3/14/2008 and 4/16/2008 shown in Figures 7 and 8, respectively, are in good agreement with the observations illustrated in the corresponding weather maps.

3. Data analysis

On the seven high wind days, analysis of the data reveals that there is a significant correlation between PM-10 concentrations, wind speed and wind direction. The maximum PM-10 recorded at each of the three monitoring sites was associated with high wind speeds. During the high wind hours, westerly or southwesterly winds predominated, which was also demonstrated by the WRF model simulations. High winds during the seven days resulted from passing cold fronts that were moving from west to east, carrying dry air mass, and producing no measurable precipitation.

4. Theoretical Explanation of High PM-10 at West 43rd Avenue Monitor

High winds blowing from smoother terrain in the rural area to rougher terrain in the urban area create a transition zone. Within the transition zone, the air mass above the surface layer is transported downward toward the surface (i.e., turbulent exchange), which increases particle dry deposition. In addition, the velocity of winds traveling through the transition zone is reduced as a result of the increased surface roughness (i.e., momentum convergence). When winds are blowing from a westerly or southwesterly direction, substantial increases in surface roughness, due to the transition from rural to urban terrain, create a transition zone between the West 43rd Avenue and downwind monitors. This explains why lower wind speeds and PM-10 concentrations were recorded at the Durango Complex and South Phoenix monitors during most hours on the seven high wind days of interest.

Wind component "u" from the prognostic equation (simplified Navier-Stokes equation in one dimension, ignoring the Coriolis force due to effects of the Earth's rotation):

$$\frac{\partial u}{\partial t} = -u\frac{\partial u}{\partial x} + \frac{\partial}{\partial z}\left(K_m \frac{\partial u}{\partial z}\right) \qquad (1)$$

Where: the transient term, $\frac{\partial u}{\partial t}$, represents the change rate of wind speed at a specific location; the convection term, $u\frac{\partial u}{\partial x}$, is a nonlinear term accounting for momentum transport in the "x" direction; the diffusion term, $\frac{\partial}{\partial z}\left(K_m \frac{\partial u}{\partial z}\right)$, accounts for transport due to turbulence, where $\boldsymbol{K_m}$ is the diffusivity for momentum which is related to the surface stress or friction velocity parameter U_*.

The governing equation in estimating mass concentrations of a scalar property such as PM-10 under conditions of dominant westerly or southwesterly winds in the turbulent boundary layer is:

$$\frac{\partial C}{\partial t} = -C\frac{\partial u}{\partial x} - u\frac{\partial C}{\partial x} + \frac{\partial}{\partial z}\left(K_c \frac{\partial C}{\partial z}\right) + S_c \qquad (2)$$

Where: the transient term, $\frac{\partial C}{\partial t}$, accounts for the change rate of mass concentration "C" in the unit of mass/volume (i.e., PM-10 in ug/m^3) at a specific location. The first term on the right-hand side of the equation is the transport term, which accounts for transport of the property "C" due to its concentration gradient along the direction of x. The second term is the convection term that represents the momentum transport of "C" in the x direction. The third term accounts for the transport of "C" due to turbulent diffusion, where, $\boldsymbol{K_c}$ is the diffusivity for "C" which is also related to the friction velocity parameter U_* but is not equal to $\boldsymbol{K_m}$. The source term, S_c, accounts for any sources and sinks that either create or destroy the scalar property.

Two hypotheses are proposed to explain why PM-10 concentrations are higher at the West 43rd Avenue monitor (WF) than the two closest downwind monitors, Durango Complex (DC) and South Phoenix (SP).

4.1 The momentum convergence hypothesis:

When winds blow over areas with sharply increasing surface roughness, the forward wind speed is reduced in the transition zone.

$$c\frac{\partial u}{\partial x} < 0 \qquad (3)$$

Equation (3) indicates that the winds transporting PM-10 in the "X" direction will decrease due to suddenly increasing surface roughness length in the transition zone between low and high roughness areas. The area of the transition zone is proportional to the fetch distance, which is defined as the length of the field with known and similar surface characteristics. According to USGS data, the surface roughness lengths at the location of the three monitors are $Z0_{WF}$ = 0.11 meters, $Z0_{DC}$ = 0.50 meters, and $Z0_{SP}$ = 0.56 meters. Note that the surface roughness lengths at the Durango and South Phoenix monitors are similar and significantly higher (i.e., 400%) than the West 43rd Avenue monitor. When winds blow from the west/southwest, this sharp increase in Z0, signifying a transition from predominantly rural to predominantly urban terrain, creates a transition zone between the West 43rd Avenue monitor and the Durango Complex and South Phoenix monitors.

4.2 The windblown PM-10 hypothesis:

High PM-10 concentrations at the West 43rd Avenue monitor on the seven days of interest in 2008 and 2009 are due to high winds that are transporting soil dust from upwind areas to the west/southwest. If this is true, a significant PM-10 concentration gradient along the wind direction should exist:

$$u\frac{\partial c}{\partial x} < 0 \qquad (4)$$

Equation (4) implies that PM-10 concentrations are decreasing in the "X" wind direction. Combining Equations (3) and (4) produces the horizontal mass flux relationship represented by:

$$\frac{\partial (uC)}{\partial x} < 0 \qquad (5)$$

Equation (5) indicates that both PM-10 and wind speeds are decreasing in the downwind "X" direction.

5. Verification of the hypotheses

In order to test the hypotheses defined by Equations (3) - (5), the normalized wind gradient, PM-10 concentration gradient, and mass flux gradient were calculated, based on the observations from the West 43rd Avenue monitor and the South Phoenix or Durango Complex monitor, using the following equation:

$$\frac{VAR(SP) - VAR(WF)}{VAR(WF)} \qquad (6)$$

Where: VAR represents any one of variables including wind speed, wind direction or PM-10 concentration; VAR (SP) is the variable at South Phoenix monitor; and VAR (WF) is the variable at West 43rd Avenue Monitor. A conceptual diagram of the change in surface roughness and wind profile is provided in Figure 9.

The friction velocities, wind speeds and wind directions output by the WRF model for March 14, April 16, April 30, and June 4, 2008 are shown in Figures 10 through 12. The friction velocities are based on surface roughness. The maps demonstrate that there is a high correlation between surface roughness and wind speeds at the regional level. Unfortunately, the USGS land use input to WRF is too outdated to be useful for analysis at a sub-regional scale.

The normalized westerly wind speeds, PM-10 concentrations, and PM-10 mass fluxes at West 43rd Avenue and South Phoenix for the seven high wind days in 2008 and 2009 are illustrated in Figures 13 through 16. Figure 16 also shows the normalized values for April 30, 2008 between West 43rd Avenue and the Durango Complex monitor, when the winds were predominantly southwesterly. The graphs show that, in general, the gradients of wind speed, PM-10 concentration, and horizontal PM-10 mass flux from West 43rd Avenue to South Phoenix are negative under conditions of high westerly or southwesterly winds. A negative value means that the variable is decreasing between the West 43rd Avenue monitor and the South Phoenix monitor (or the Durango Complex monitor, in the case of the lower panel in Figure 16).

Therefore, the hypotheses described by Equations (3) - (5) are supported by the observed data. The generally negative gradients for wind speeds, PM-10 concentrations, and mass fluxes imply that high westerly/southwesterly winds transporting PM-10 from upwind sources encounter increases in surface roughness between the West 43rd Avenue monitor and the Durango Complex and South Phoenix monitors, due to the transition from predominantly rural to predominantly urban terrain. The increased surface roughness causes momentum convergence and turbulent exchange enhancement within the transition zone. These dynamic processes decrease wind speeds and expedite particle dry deposition upwind of the Durango Complex and South Phoenix monitors. The increased particle deposition reduces the PM-10 concentrations in the air that eventually reaches these monitors.

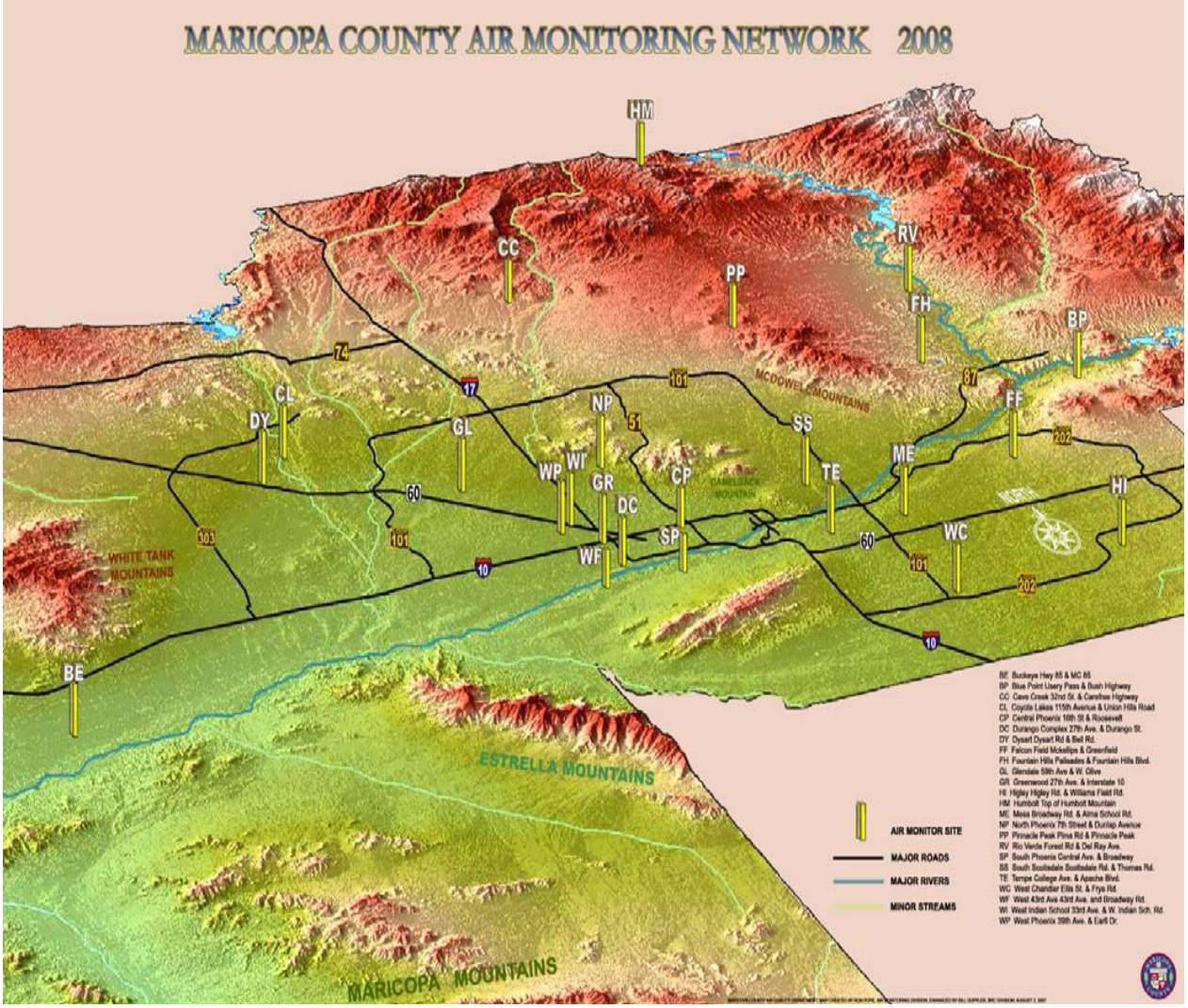


Figure 1 - The Maricopa County Air Monitoring Network for 2008 (Source: Maricopa County Air Quality Department). This analysis focuses on high winds and PM-10 concentrations at three monitoring sites: West 43rd Avenue (WF), Durango Complex (DC), and South Phoenix (SP).

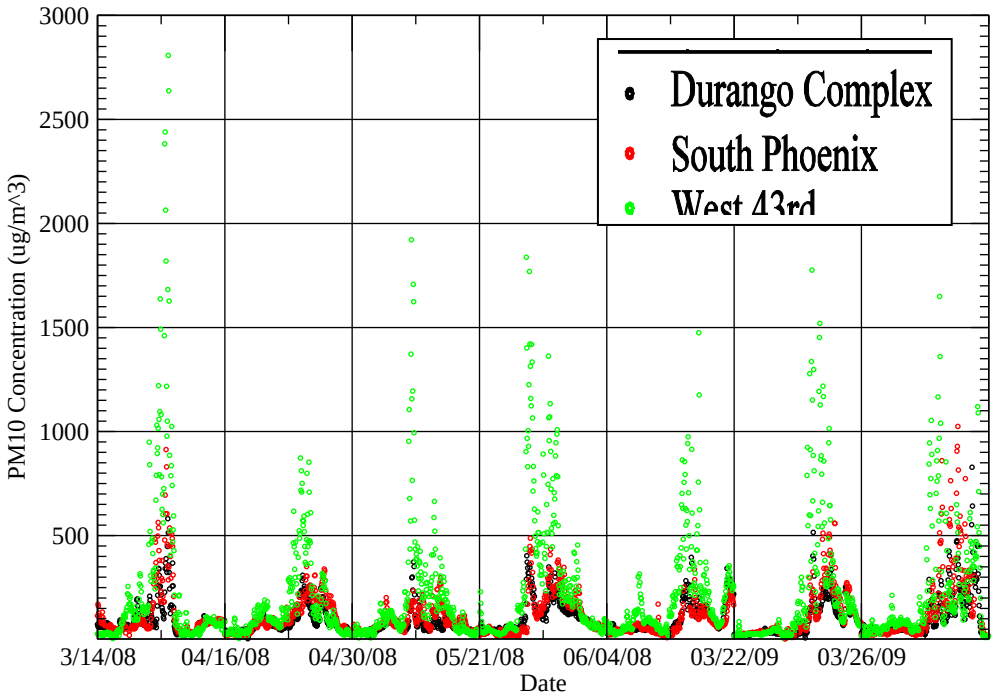


Figure 2 - Time series of 5-minute mean PM-10 concentrations for 7 days of interest at West 43rd Avenue (green dots), Durango Complex (black dots), and South Phoenix (red dots). PM-10 concentrations exceeded 200 ug/m^3 during the daytime at all three sites. The maximum PM-10 concentrations at WF reached 1650-2800 ug/m^3.

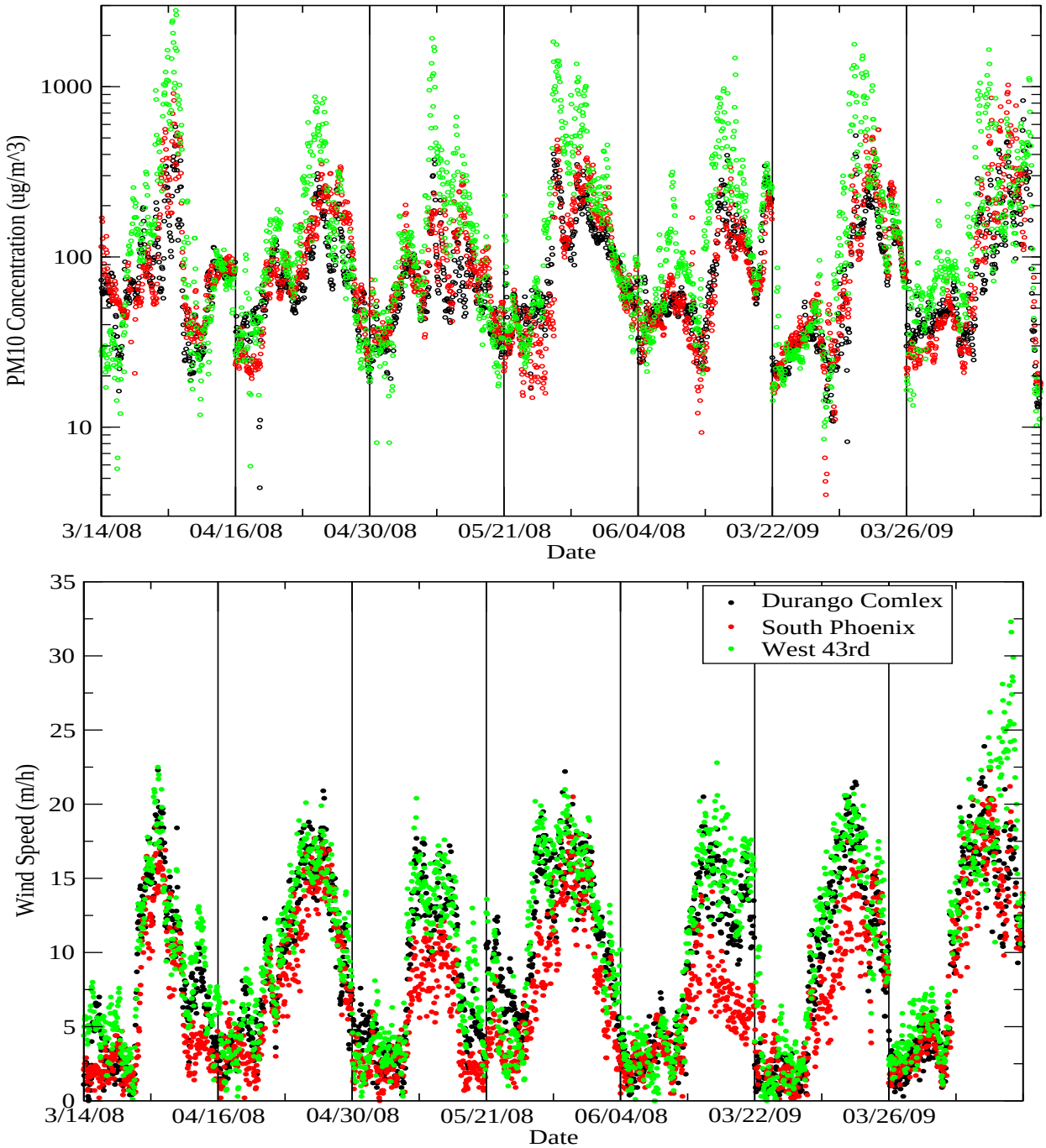


Figure 3 - Temporal variations of PM-10 concentrations in ug/m3 (top panel) and wind speeds in miles/hour (bottom) on the 7 windy days. The PM-10 concentrations are presented on a logarithmic scale in order to show the detailed structure. The peak PM-10 generally occurs around noon time around the same time as the westerly or southwesterly winds with the highest speeds.

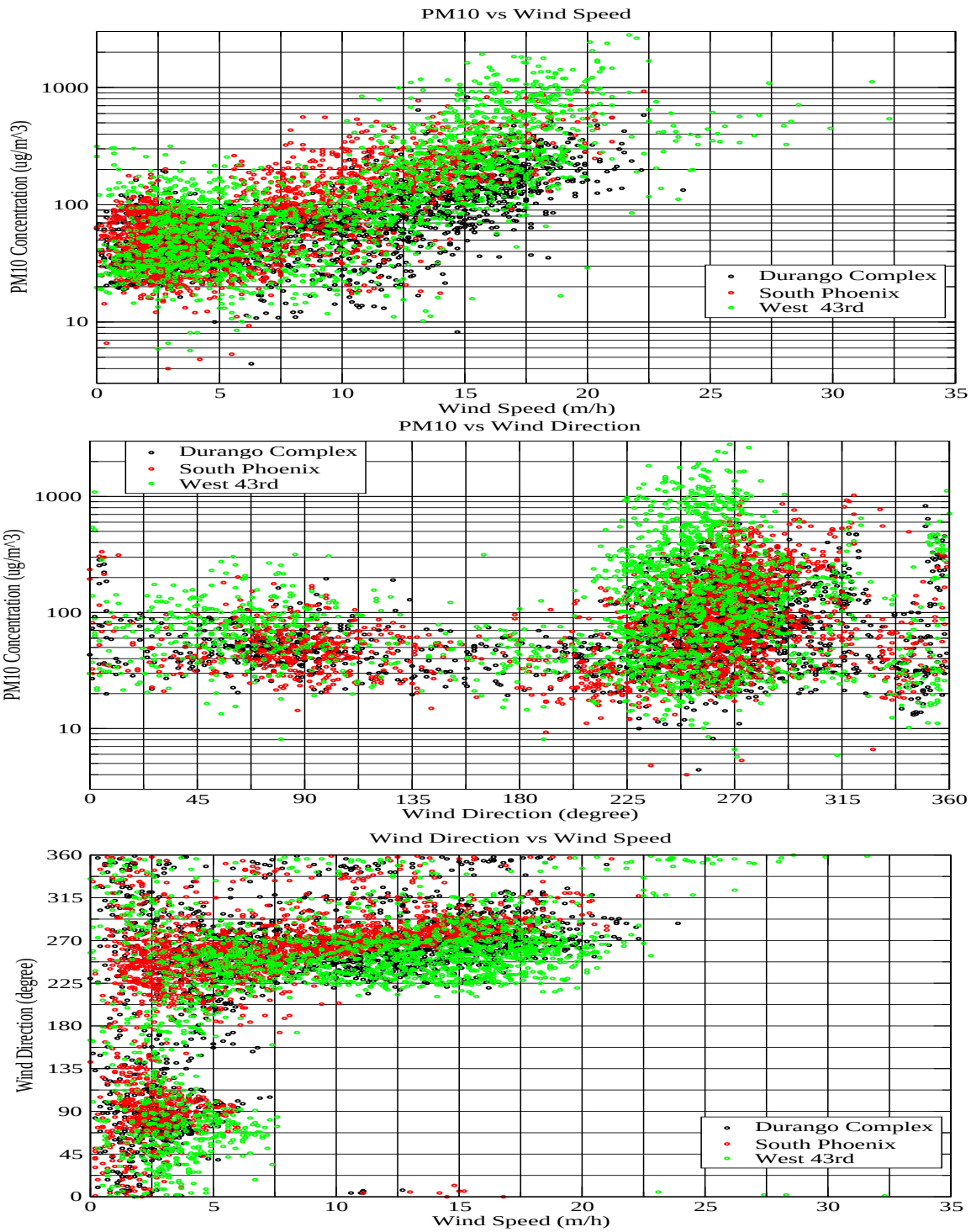


Figure 4 - Scattering relationships between PM-10 concentrations and wind speed (top panel), PM-10 and wind direction (middle), wind direction and wind speed (bottom) based on observations at the three sites. In general, PM-10 concentrations increased with wind speed. All PM-10 concentrations above 150 ug/m^3 were accompanied by high winds (see top panel). Peak PM-10 concentrations were generally observed at all stations when westerly winds were dominant (see middle panel). Wind speeds above 10 miles/hour were dominated by westerly winds at all sites (see bottom panel).

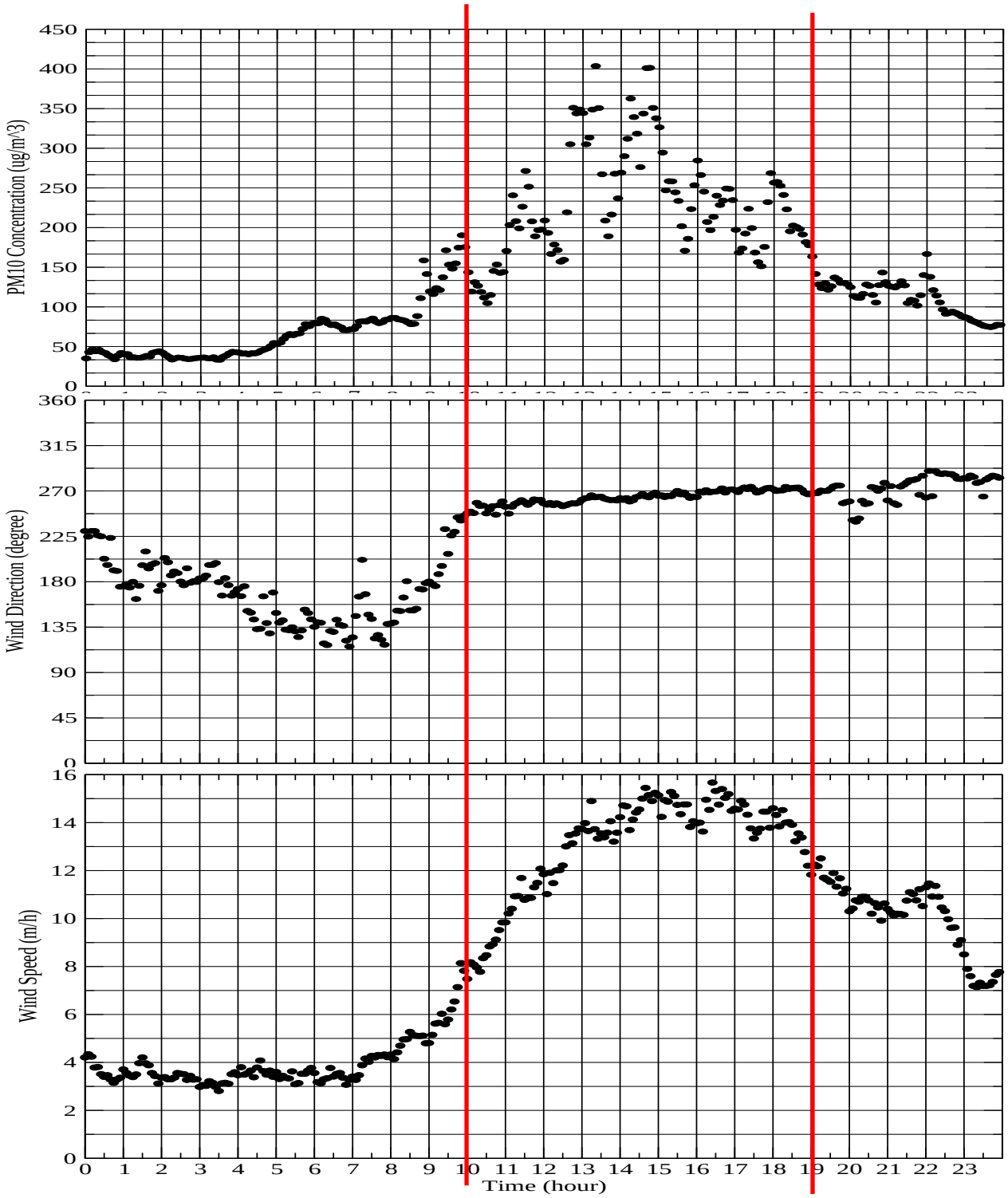
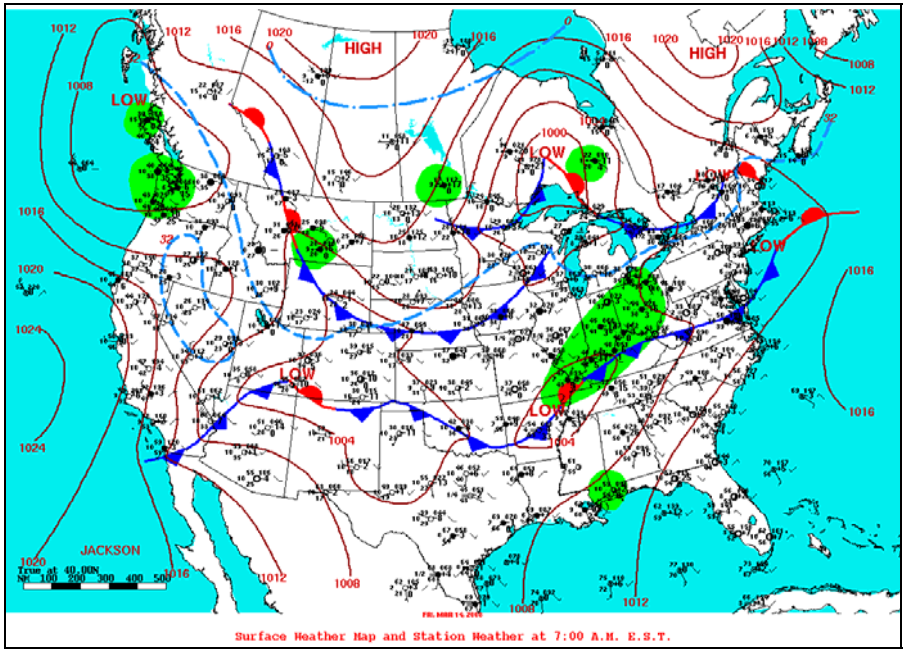


Figure 5 The PM-10 concentrations (top panel), wind directions (middle) and wind speeds (bottom) averaged over 7 days and the 3 sites. The average wind speed exceeded 8 miles/hour after 10:00 LST (see red line at the left), the wind direction was predominately westerly and the PM-10, in turn, went up rapidly. High westerly winds persisted until 19:00 LST (see red line on the right). Since the peak PM-10 is correlated with peak wind speeds, it can be concluded that high PM-10 concentrations are caused by dust transported by high westerly winds.



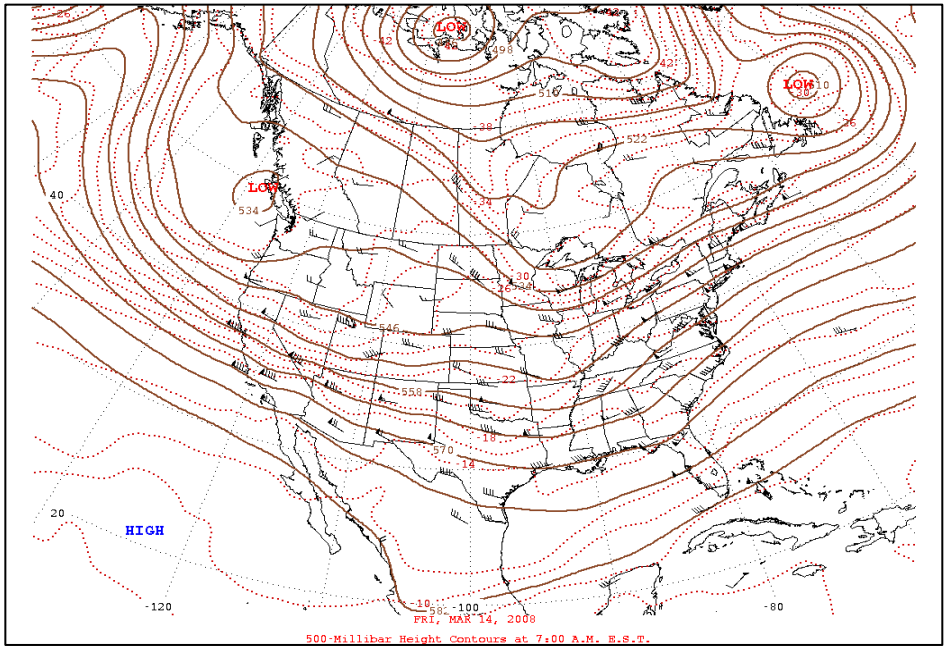


Figure 6 - The surface weather map at 7:00 EST on March 14, 2008 (left panel). A high pressure system was developing over the Pacific Ocean close to the west coastline. One low pressure center, accompanied with precipitation, was located in the southwest corner of Canada. The cold front (blue arrows connected by solid blue line) associated with the large scale meteorological systems was propagated east across Arizona in the late afternoon and early evening of the same day. The entire southwest U.S. was dominated by a west wind belt where the high geopotential height gradient led to high wind speeds. Wind speeds over Arizona at this level were greater than 60 mph. A dry air mass blew into Arizona when the high PM-10 concentrations occurred in Phoenix. The other six high wind events were accompanied by a similar weather pattern.

The height of 500 hectopascals (hPa) pressure surface, about 5.6 km above ground, is shown in the right panel. The patterns at 500-hPa isobaric surface are commonly used to identify locations of high and low pressure, as well as the elevated jet, that significantly influence surface wind fields due to dynamic processes in the atmosphere.

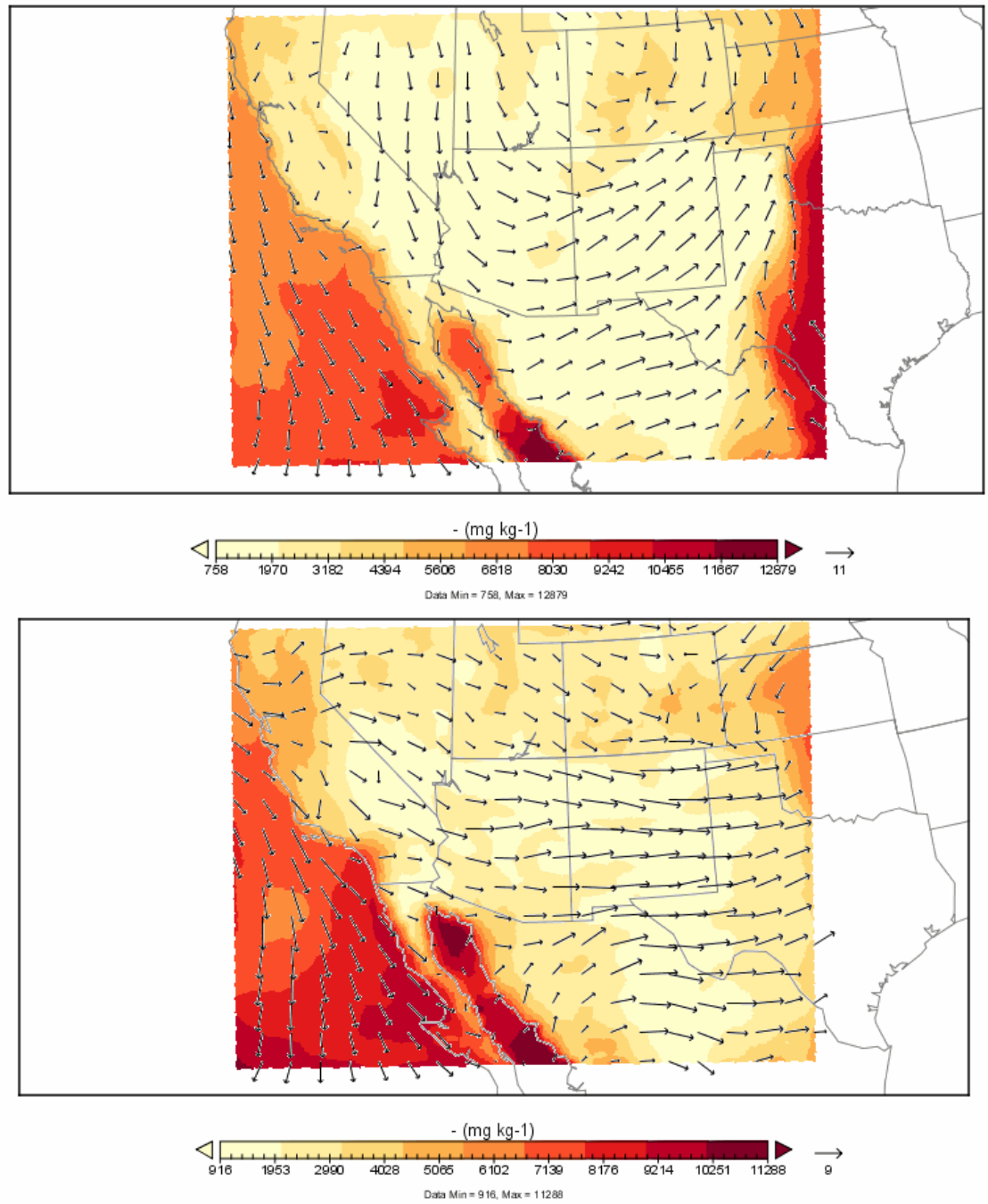


Figure 7 - WRF model simulated wind field on 3/14/2008 at 14:00 LST (top panel) and on 4/16/2008 at 15:00 LST (bottom panel) at 10 meters in the 12 km gridded modeling domain. The color contours represent surface water vapor mixing ratio (mg/kg) in the air. Air humidity plays a key role in the moisture of surface soil that contributes to dust emissions during high wind events. The arrows indicate the direction the wind was blowing. The length of the arrows represents wind speed. The high wind blew cold and dry air into Phoenix from California and Nevada. The westerly wind speed over Arizona exceeded 10 meters per second.

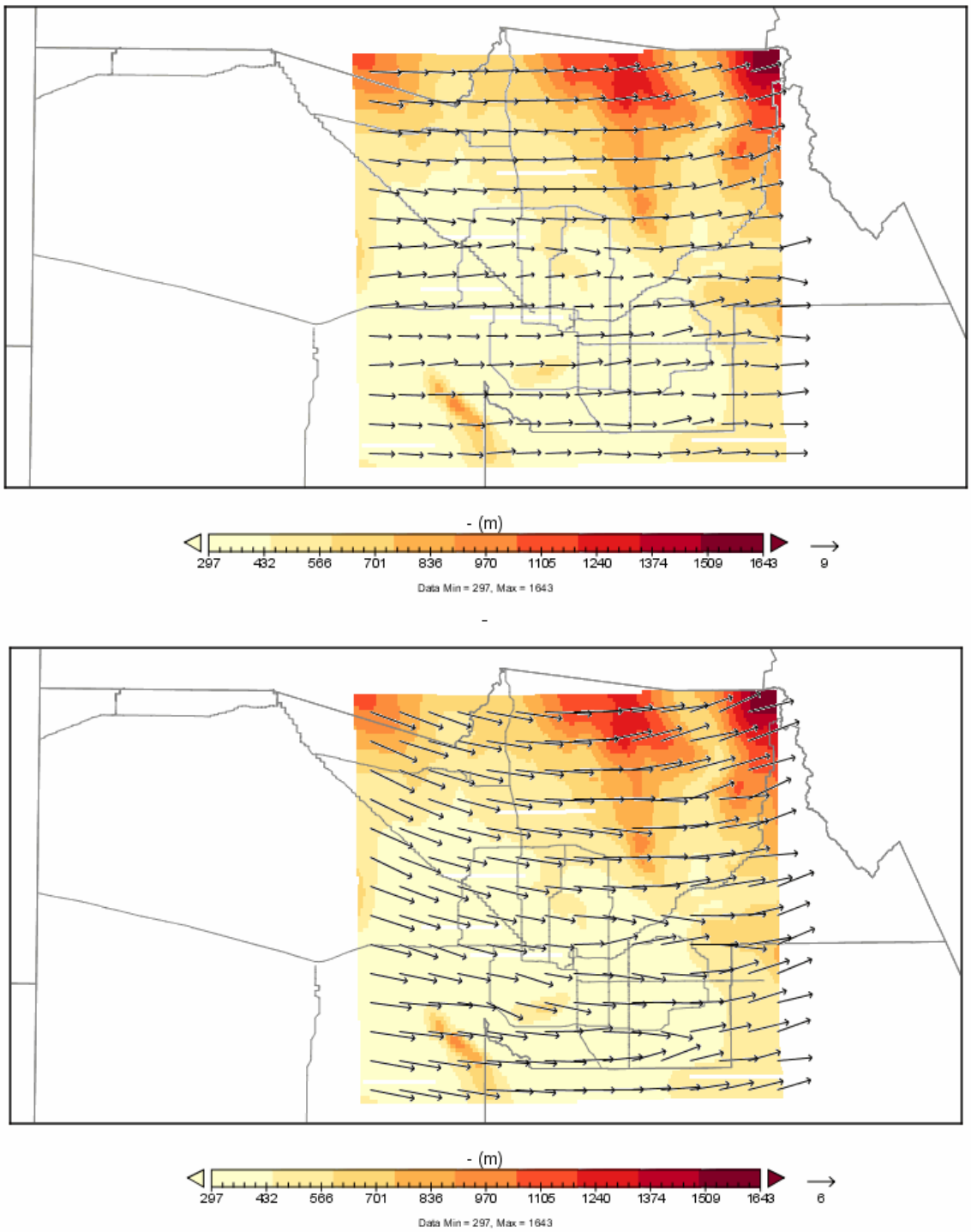


Figure 8 - WRF simulated wind field at 10 meters in the 1.3-km gridded modeling domain corresponding to the same times as described in Figure 7. The entire Valley was dominated by westerly winds and the wind speeds were greater than 10 meters per second. These figures are in agreement with the observed weather system shown in Figure 6.

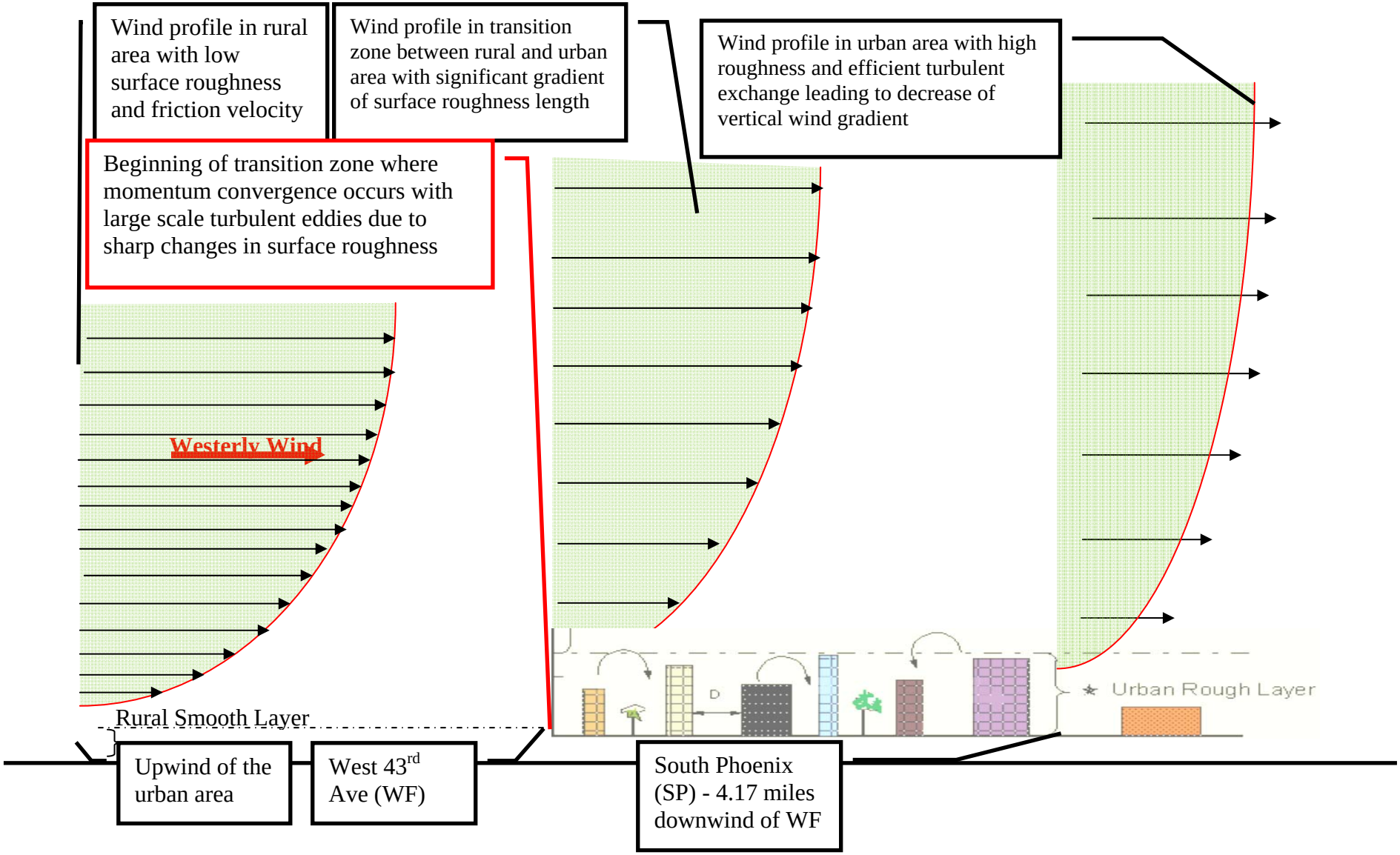


Figure 9 - Conceptual diagram of the relationship between terrain roughness and wind profile. Wind profiles will change due to changes in surface roughness length, Z_0. Increases in surface roughness and friction velocity, U_*, decrease the wind velocity at vertical height "z" according to the following formula: $U(z) = U_*/k \ln(z/Z_0)$, where k =0.4. A sharp increase in surface roughness (i.e., between smooth rural to rough urban terrain) will reduce wind speeds due to the enhanced turbulent exchange and momentum convergence in the transition zone.

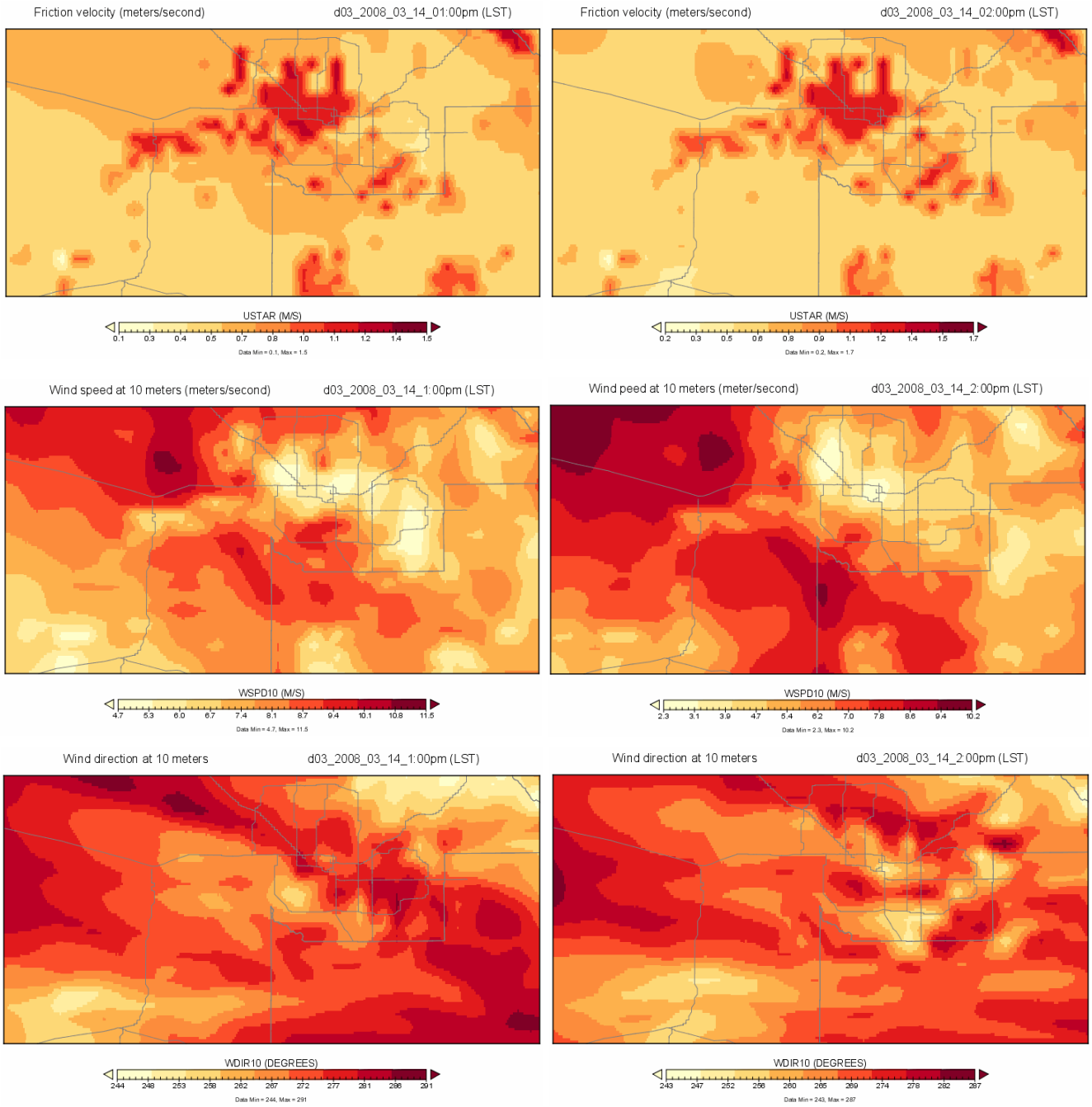


Figure 10 - Modeled friction velocity (top), wind speeds (middle) and wind direction (bottom) at 13:00 (left column) and 14:00 (right column) on March 14, 2008. The wind speeds are lower in the urban area due to higher friction velocities. The friction velocity is dependent on the surface physical properties such as roughness length. The middle and bottom panels illustrate that the westerly wind speeds at 10 meters are highest in the rural areas upwind of the urban area. A significant convergence took place at the transition area from smooth rural area to rough urban area.

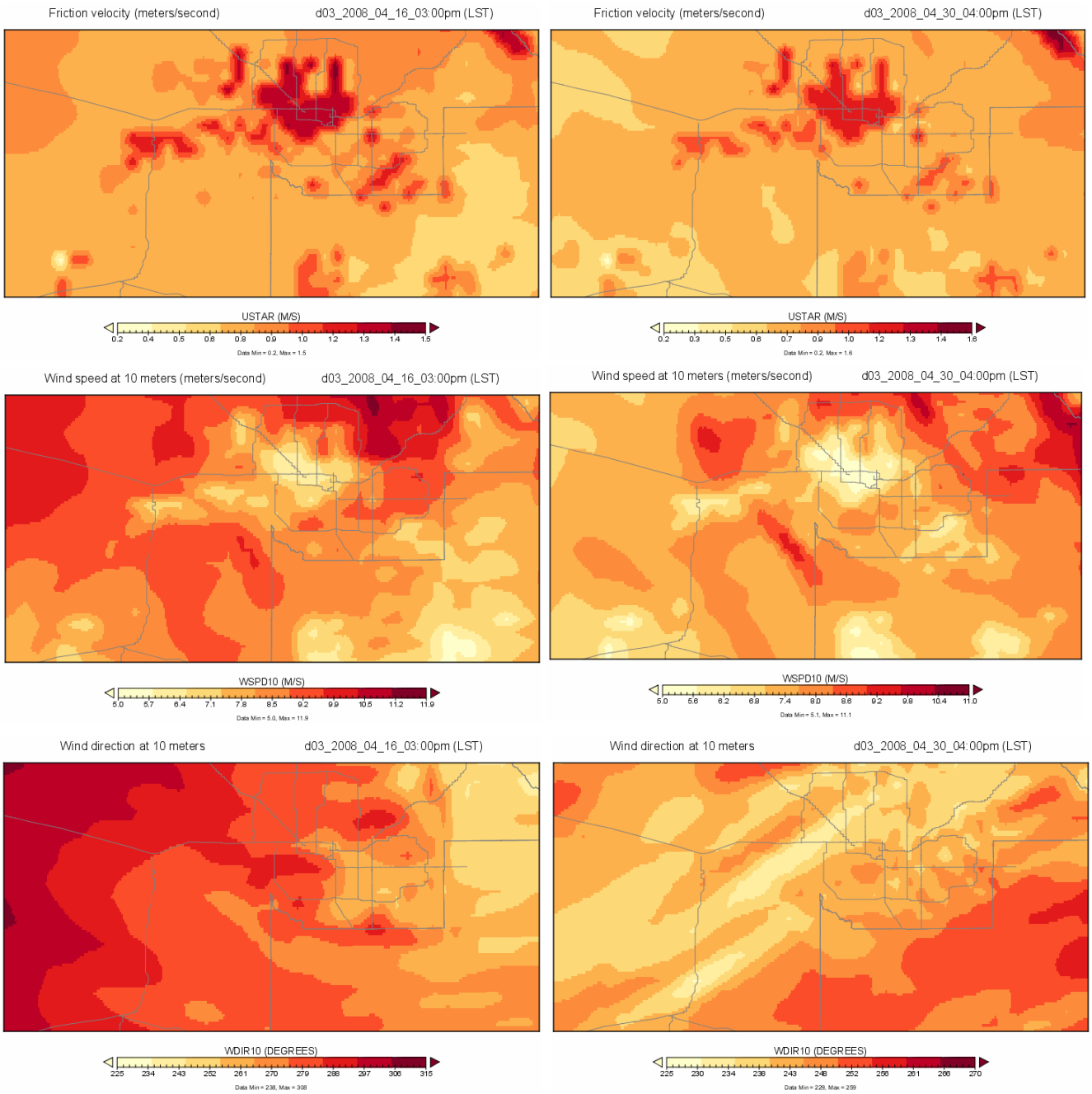


Figure 11 - Friction velocity (top), wind speeds (middle) and wind direction (bottom) at 3:00 p.m. on April 16, 2008 (left column) and 4:00 p.m. on April 30, 2008 (right column). The wind speeds are lower in the urban area due to higher friction velocities.

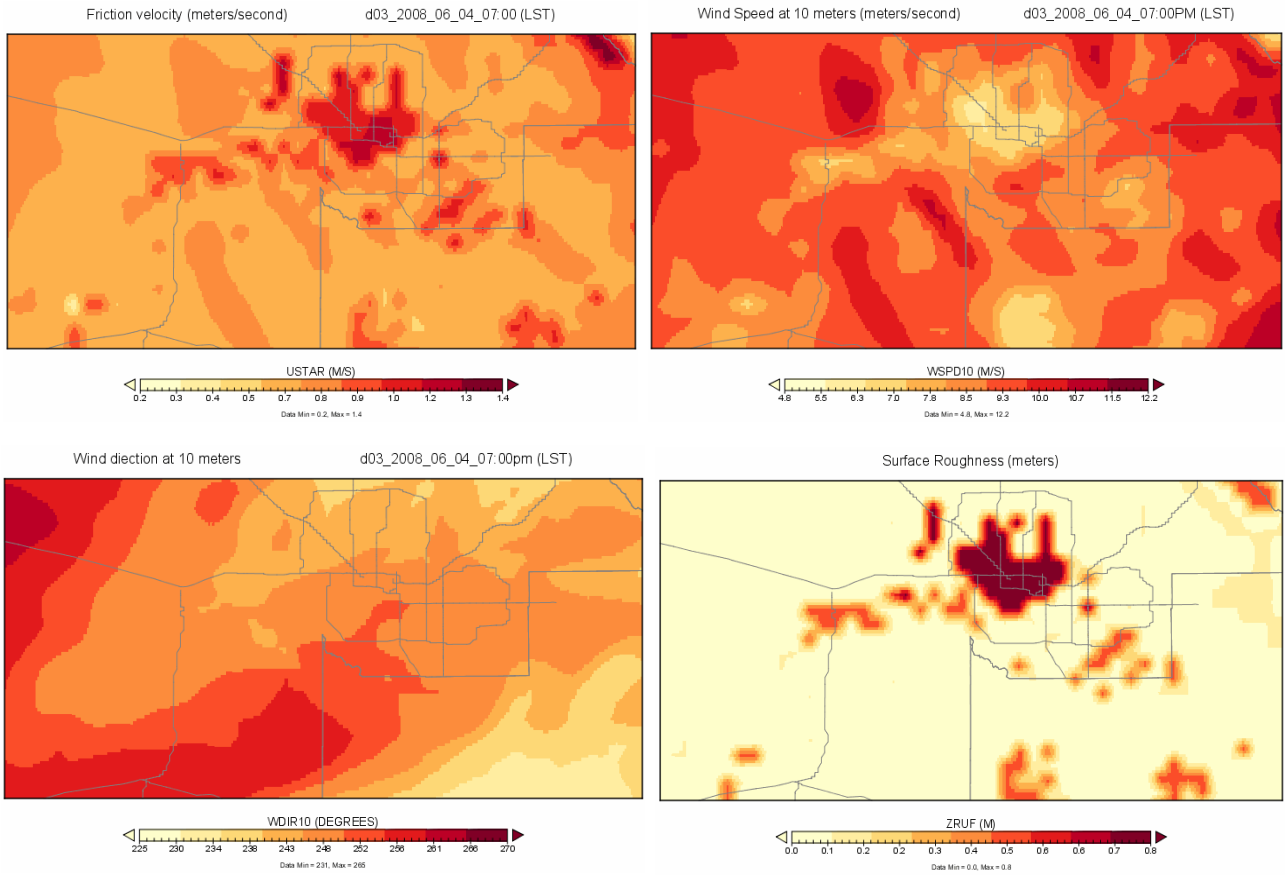


Figure 12 - Friction velocity (left panel at top), wind speed (right panel at top) and wind direction (left panel at bottom) at 07:00 p.m. on June 04, 2008. The surface roughness length is shown in the right panel at the bottom. The high roughness over the urban area is typical of other high wind days. However, the urban area is not currently as small as depicted in Figures 10-12, because the USGS database used by the WRF model is outdated. In addition, the high roughness areas to the southwest of the urban area are attributed to land use category-14 (evergreen needle leaf forest) in the USGS database. This is clearly an error, as there has never, at least in modern times, been an evergreen needle leaf forest southwest of Phoenix.

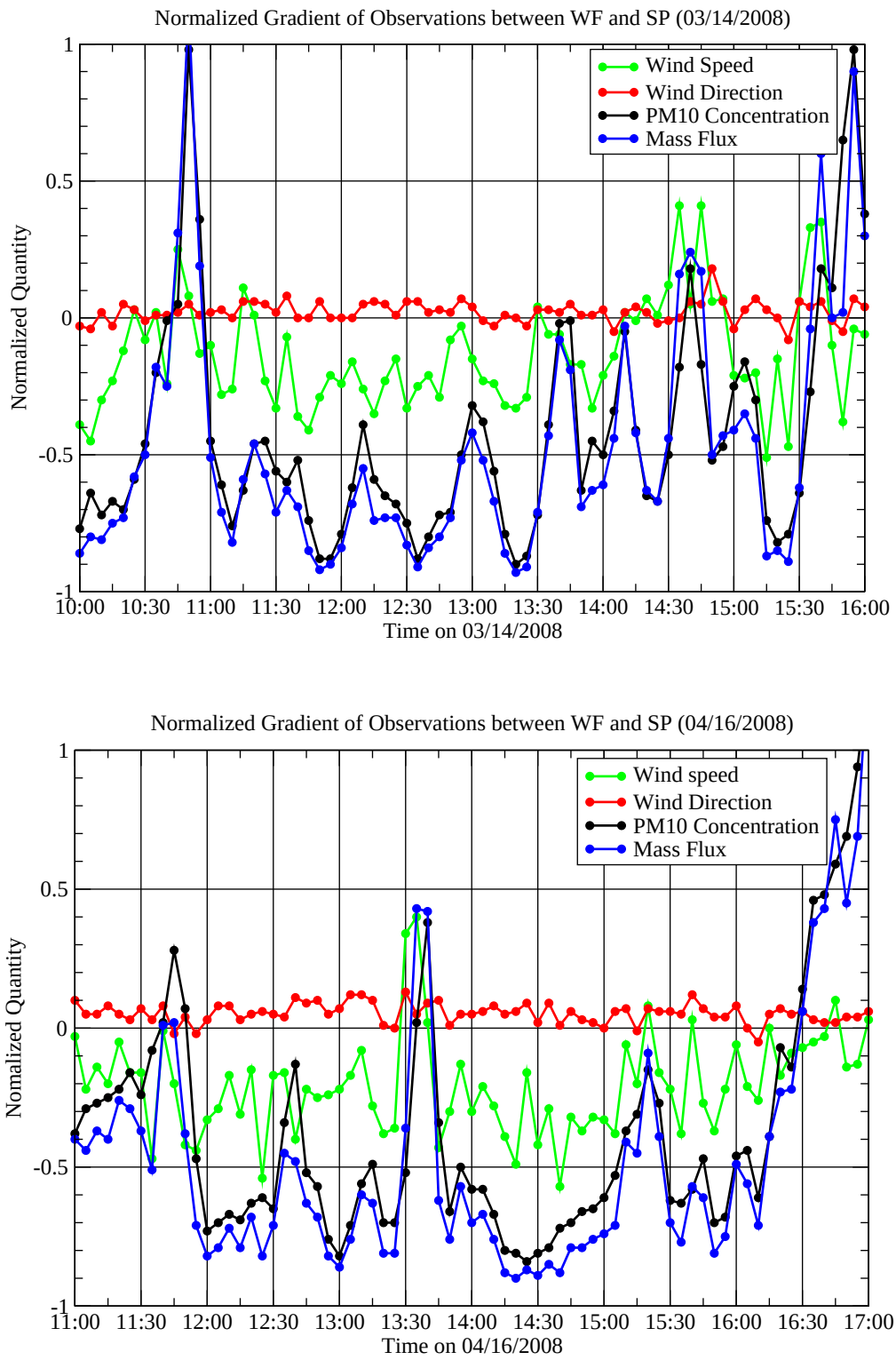


Figure 13 - The normalized gradients of wind direction, wind speed, PM-10 concentration, and PM-10 mass flux between West 43rd Avenue and South Phoenix on 3/14/2008 (top panel) and 4/16/2008 (bottom). The observation data on 3/14/2008 is the ideal case for calculating the gradient, because the wind direction was parallel to a line drawn between the two sites. The gradients for wind speed, PM-10 concentration, and PM-10 mass flux were all negative during the period of highest PM-10 concentrations from 11:00 to 14:30.

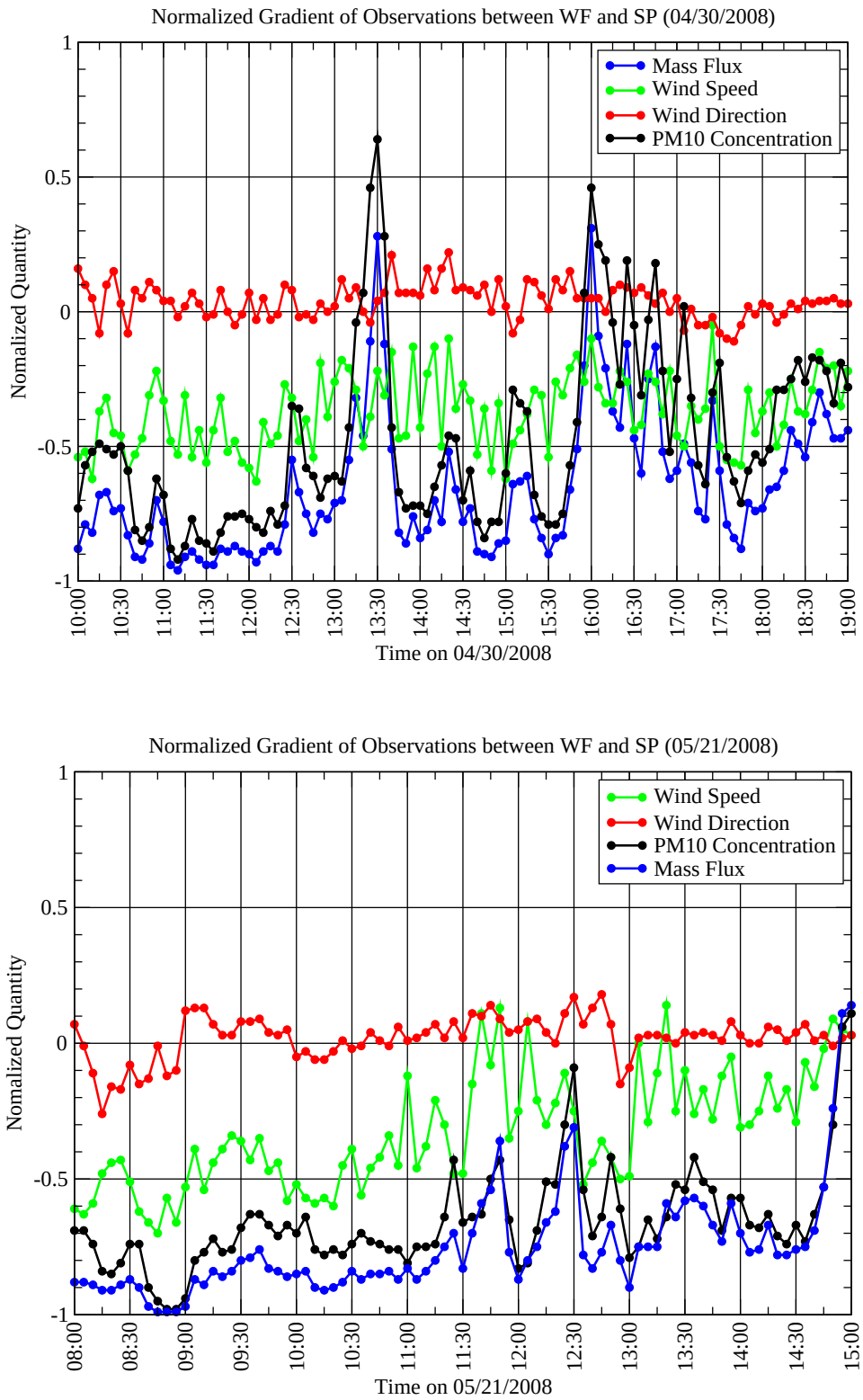


Figure 14 - The normalized gradients of the three parameters between WF and SP on 4/30/2008 (top) and 5/21/2008 (bottom). On 4/30/2008, some gradient values are positive due to a predominantly southwest wind direction before 17:15 LST. After 17:30, when the wind direction switched to the west, the gradients returned to negative. (The bottom panel of Figure 16 shows the gradients between WF and DC on 4/30/2008.)

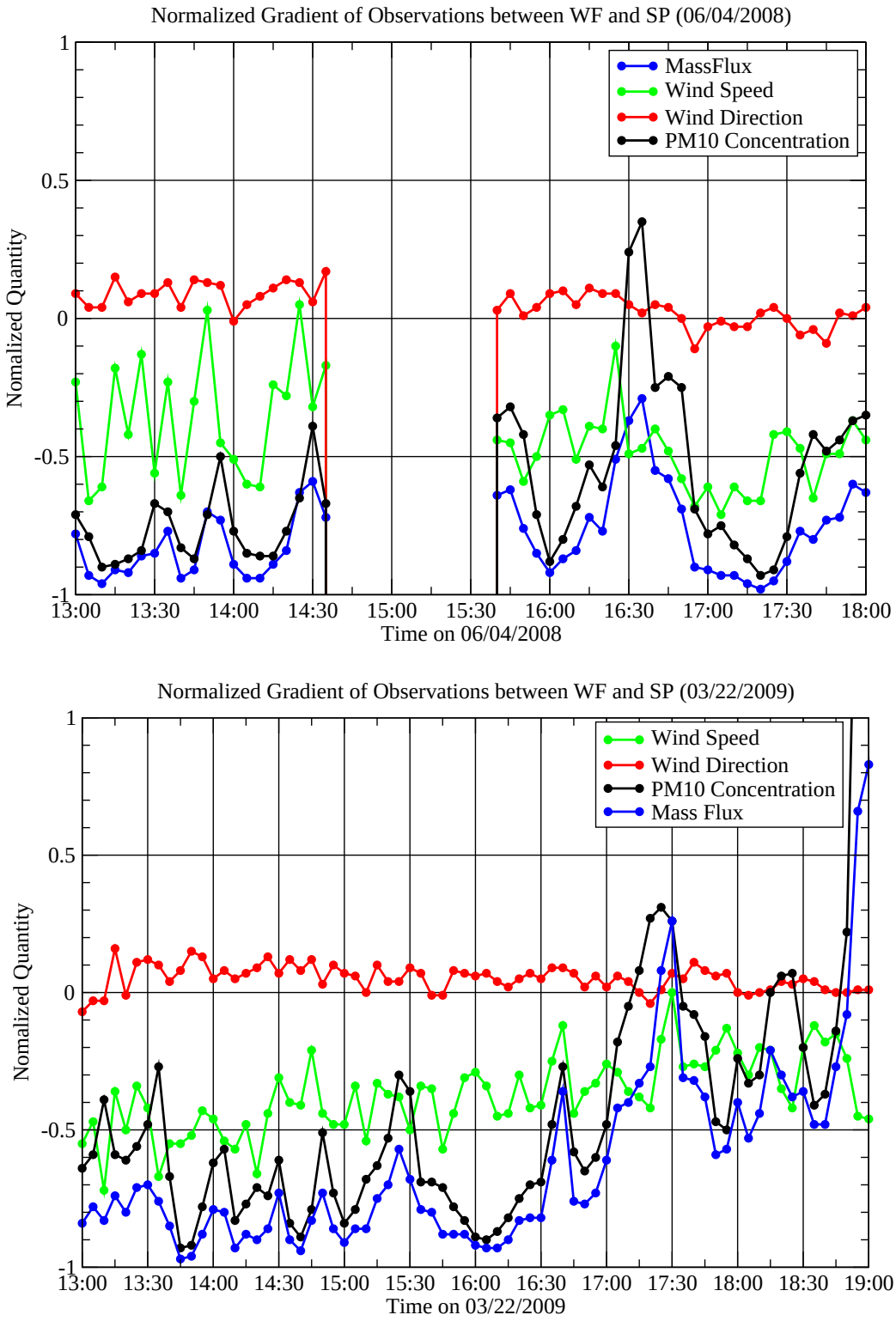


Figure 15 - The normalized gradients of the three parameters between WF and SP on 6/4/2008 (top panel) and 3/22/2009 (bottom). During the period of highest PM-10 concentrations, the negative gradients appear consistently when the winds are from the west. After 16:30 on 6/4/2008 and 17:00 on 3/22/2009, positive gradients occur as a result of a change in the dominant wind direction. When this occurs, the graphs do not portray the gradients accurately, because the wind direction is not parallel to the line connecting WF and SP.

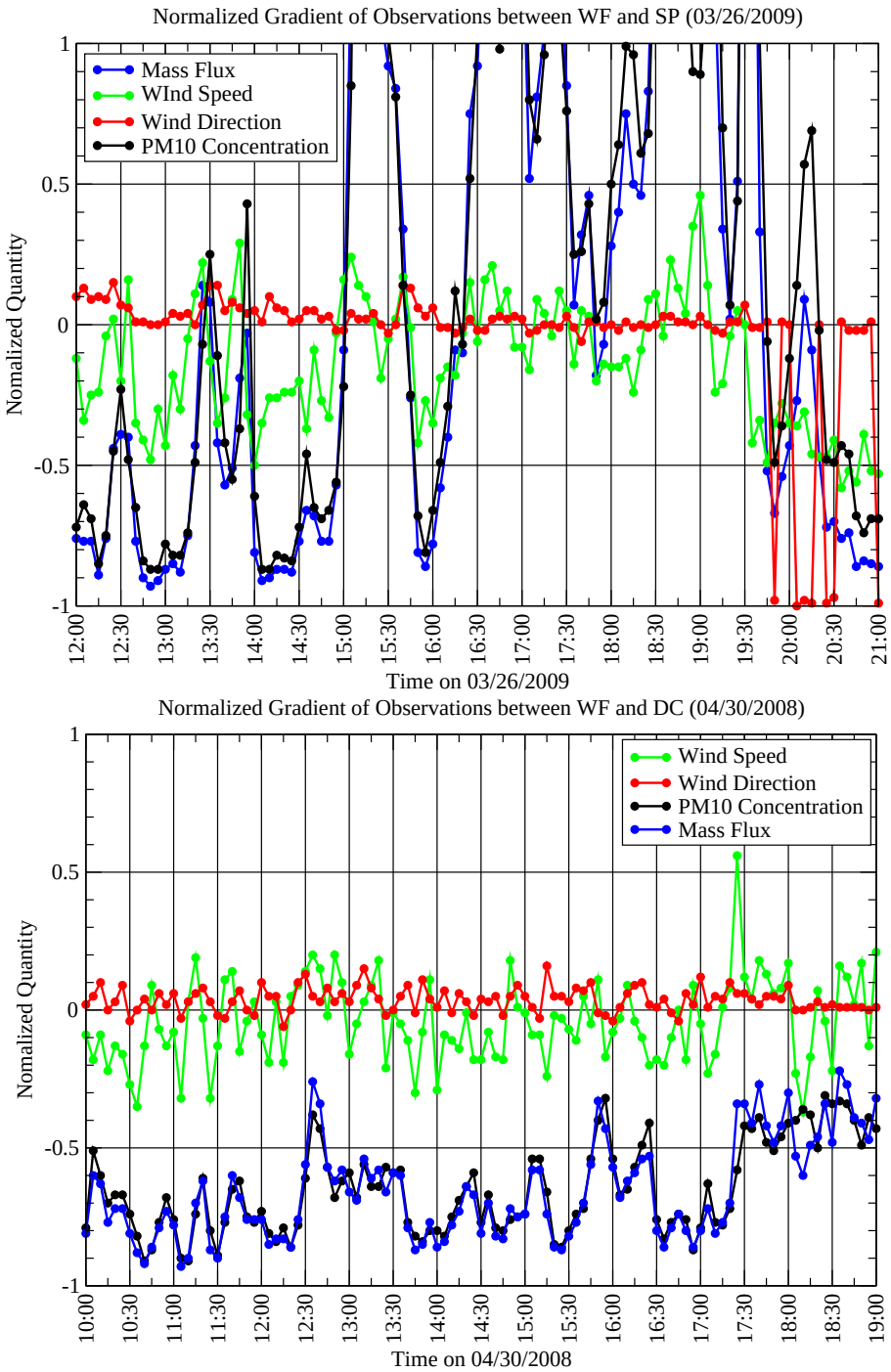


Figure 16 - The normalized gradient of the three parameters between the WF and SP on 3/26/2009 (top panel) and between WF and DC on 4/30/2008 (bottom). The wind directions in the afternoon on 3/26/2009, especially during 13:15 to 14:00 and 15:00 to 16:00, switched from west to northwest. Under this condition, the gradient calculation along WF and SP direction is no longer valid if the variation of wind speed (V) in Y direction (from south to north) is not negligible. The dominant wind direction during the daytime on April 30, 2008 was southwest, which is consistent with the line between WF and DC. The wind direction switched to the west after 17:15. Then the gradient from WF to SP works better for this case, as shown in the top panel of Figure 14. It can be seen from the bottom panel in Figure 16 that the magnitude of the wind speed gradients is less from WF to DC than from WF to SP, because the distance between WF and DC (2.17 miles) is smaller than between WF and SP (4.12 miles).