CHAPTER 2 – DEMONSTRATION OF ATTAINMENT

2.1 Introduction

While demonstrating attainment of an air quality standard is conceptually simple, it remains a data-intensive and computationally complex exercise. In the case of Yuma PM_{10}, the demonstration is eased considerably by the ambient monitoring record, which already shows attainment. What also needs to be demonstrated, however, is that this clean air will last ten years into the future, despite the anticipated growth of the community. This exercise consists of several steps, each one described in the following sections of this chapter:

- Choose several dates, called design days, from the base year 1999 to study, taking into account a variety of different meteorological conditions and all the seasons (Section 2.2).

- Build inventories of emissions for the base year 1999 and the future year 2016, and convert these inventories into a numerical format compatible with an air quality model (Section 2.3).

- For each design day, calculate the background PM_{10} concentrations. These are the concentrations that would have occurred had there been no anthropogenic emissions from within the Yuma modeling domain (Section 2.4).

- Simulate the PM_{10} concentrations of the base year with an air quality model. This model provides predicted concentrations based on the emissions and specific meteorological conditions of each design day (Section 2.5).

- Simulate the PM_{10} concentrations of the future year 2016, with the future year emissions and the base year meteorological conditions (Section 2.6).

- Attainment is demonstrated for the base and future years when the base-year measured concentrations and the concentrations predicted for 2016 are within the standard (Section 2.7).

2.2 Design Days for 1999, the Base Year

PM_{10} monitoring is generally conducted with a filter-based instrument, permanently mounted at a site. This instrument is typically run every sixth day, midnight to midnight, to give about sixty 24-hour averages each year. PM_{10} concentrations for the base year 1999 are shown in Table 2-1. Yuma's monitoring that year was done with two collocated samplers. Data from the "original" sampler was found to be invalid for the second half of the year. The annual average was 37 µg/m^3; the highest 24-hour average was 102 µg/m^3 (standards are 50 µg/m^3 and 150 µg/m^3).

Table 2-1. Yuma PM_{10} Concentrations for 1999 (24-Hour Averages in µg/m^3)

Date	Original	Duplicate	Date	Original	Duplicate
1/6/99	45	45	7/5/99	43	71
1/12/99	55	48	7/11/99	40	44
1/18/99	45	40	7/17/99	19	
1/24/99	35	33	7/23/99		24
1/30/99	35	34	7/29/99		
2/5/99			8/4/99		
2/11/99	19	19	8/10/99		26
2/17/99	61	58	8/16/99		35
2/23/99	28	29	8/22/99		27
3/1/99	64	65	8/28/99		18
3/7/99	28	17	9/3/99		88
3/13/99	38	40	9/9/99		37
3/19/99			9/15/99		38
3/25/99	17	18	9/21/99		34
3/31/99	102	74	9/27/99		28
4/6/99	20	22	10/3/99		31
4/12/99	20	17	10/9/99		67
4/18/99	19	22	10/15/99		47
4/24/99	22	21	10/21/99		43
4/30/99	36	36	10/27/99		37
5/6/99	24	34	11/2/99		65
5/12/99	27	31	11/8/99		32
5/18/99	31	36	11/14/99		46
5/24/99	32	34	11/20/99		50
5/30/99	21	30	11/26/99		54
6/5/99	26	28	12/2/99		15
6/11/99	42	45	12/8/99		46
6/17/99	19	22	12/14/99		35
6/23/99	43	44	12/20/99		19
6/29/99		42	12/26/99		19

The design days chosen, given in Table 2-2, represent all the seasons and a variety of meteorological conditions.

Table 2-2. PM_{10} Design Days for 1999				
Date	PM_{10} ($\mu g/m^3$) Original	PM_{10} ($\mu g/m^3$) Duplicate	Day of Week	Meteorological Conditions and Emissions
1/12/99	55	48	Tuesday	Low Winds, Agricultural Tillage
3/31/99	102	74	Wednesday	High Winds
5/30/99	21	30	Sunday	Low Winds
6/23/99	43	44	Wednesday	Low Winds
7/17/99	19		Saturday	Low Winds
11/8/99		32	Monday	Low Winds
12/8/99		46	Wednesday	Low Winds, Agricultural Tillage

These dates cover both low and high winds, two of the three highest recorded concentrations, and a wide range of low to moderate concentrations, as shown in Figure 2-1.

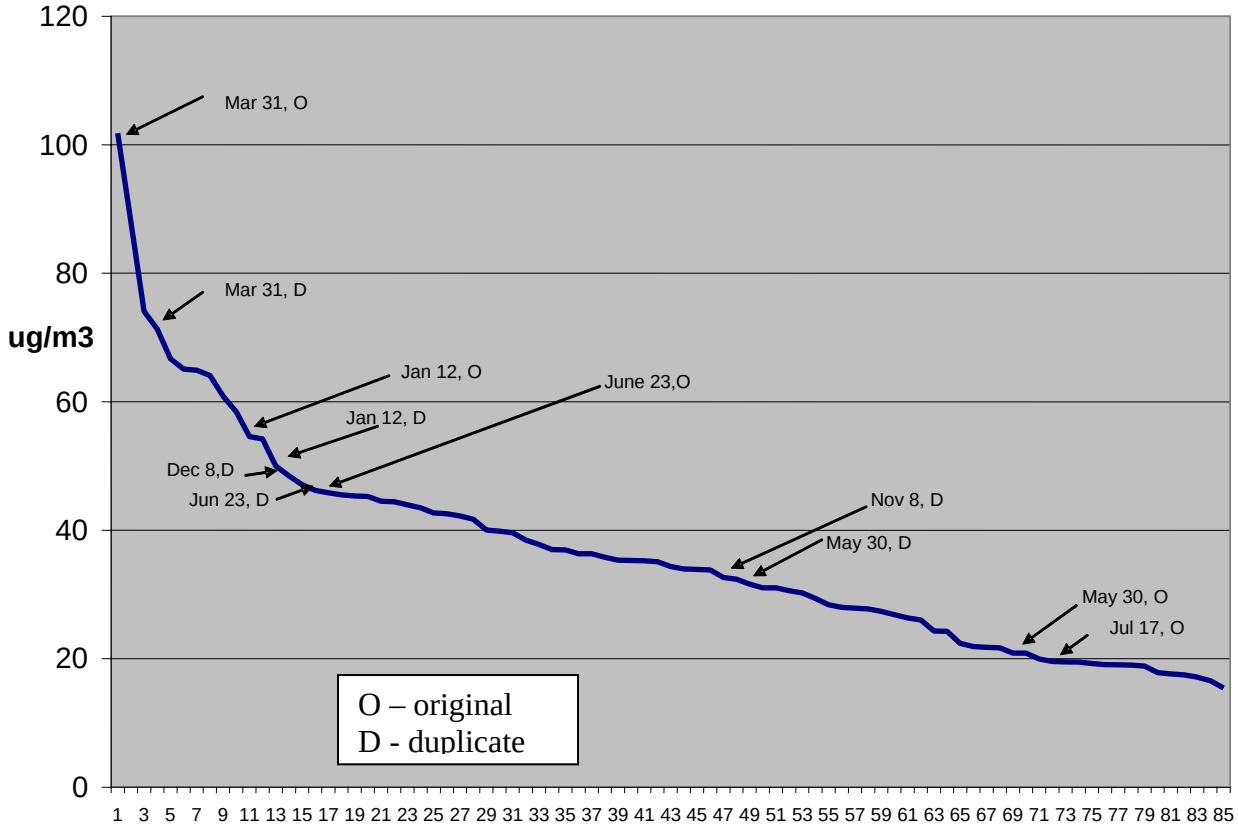

Figure 2-1. Yuma PM_{10} Concentrations for 1999 in $\mu g/m^3$, Plotted from Highest to Lowest, with Design Days Indicated

2.3 Emissions Inventory

2.3.1 Findings from the Inventory

A complete inventory of PM_{10} emissions for the Yuma area was constructed, based on a defined study area, also known as the "modeling domain", shown in Figure 2-2. As discussed later in this section, the PM_{10} emissions inventory for modeling covers eight different dates in 1999 and 2016. The domain footprint is illustrated in this figure and covers 2464 km² (945 square miles), with the city of Yuma located near the center of the domain. The domain is a rectangle aligned east and west, with 14 grids in the east-west direction and 11 grids in the north-south direction. Each grid is a square 4 kilometers on a side. This emissions inventory domain is also the modeling domain, discussed further in sections 2.3.2 and 2.5.

Details of the calculations may be found in Appendix A, E. H. Pechan & Associates, Inc. -- the contractor's report. On-road mobile source calculations, referenced in the Pechan report, are given in Appendix E. This inventory has undergone some revisions, principally in windblown emissions from vacant agricultural fields and general building and road construction. These revisions are presented in Appendix F. What follows are a summary table and two figures to illustrate the findings, which reflect these revisions. Table 2-3 gives the 1999 and 2016 annual PM_{10} emissions by source category. As windblown emissions dominate, Figure 2-3a shows the distribution of emissions on low-wind days by source category. The dominant source categories are unpaved roads, road construction, agricultural tilling, and reentrained dust from paved roads. Windblown dust emissions (Figure 2-3b) are dominated by vacant agricultural fields, unpaved agricultural roads, and miscellaneous disturbed areas.

Table 2-3. Yuma PM_{10} Emissions for 1999 and 2016, Revised			
Source Category	**Annual tons of PM_{10}**		
	1999	**2016**	**% Change***
Windblown Dust	**70,981**	**68,377**	3.7
Unpaved Roads - Re-entrained Dust	**10,174**	**5,532**	45.6
Agricultural Tilling	3,572	3,572	0.0
Paved Roads	3,419	5,839	-70.8
General Building Construction	**955**	**1,558**	-63.0
Road Construction	**901**	**1,427**	-58.3
Lawn & garden	**129**	**207**	-60.0
Stationary Sources	77	119	-54.5
Agricultural and Prescribed Burning	41	34	16.2
Railroad Locomotives	17	15	11.8
Agricultural Cultivation and Harvesting	16	16	0.0
Light Commercial Vehicles (Nonroad)	**16**	**16**	0.0
Aircraft	16	16	-5.8
ATVs	**3.6**	**5.9**	-63.0
Unpaved Airstrips	1	1	-10.0
Total	**90,319**	**86,735**	4.0

% Change: Positive values are decreases in emissions;
Negative values are increases in emissions.

***Note:** The following categories in bold have been revised from the original inventory: windblown dust, unpaved roads, general building construction, and road construction. Three other categories in bold were added to the inventory: lawn & garden, light commercial vehicles, and ATVs.

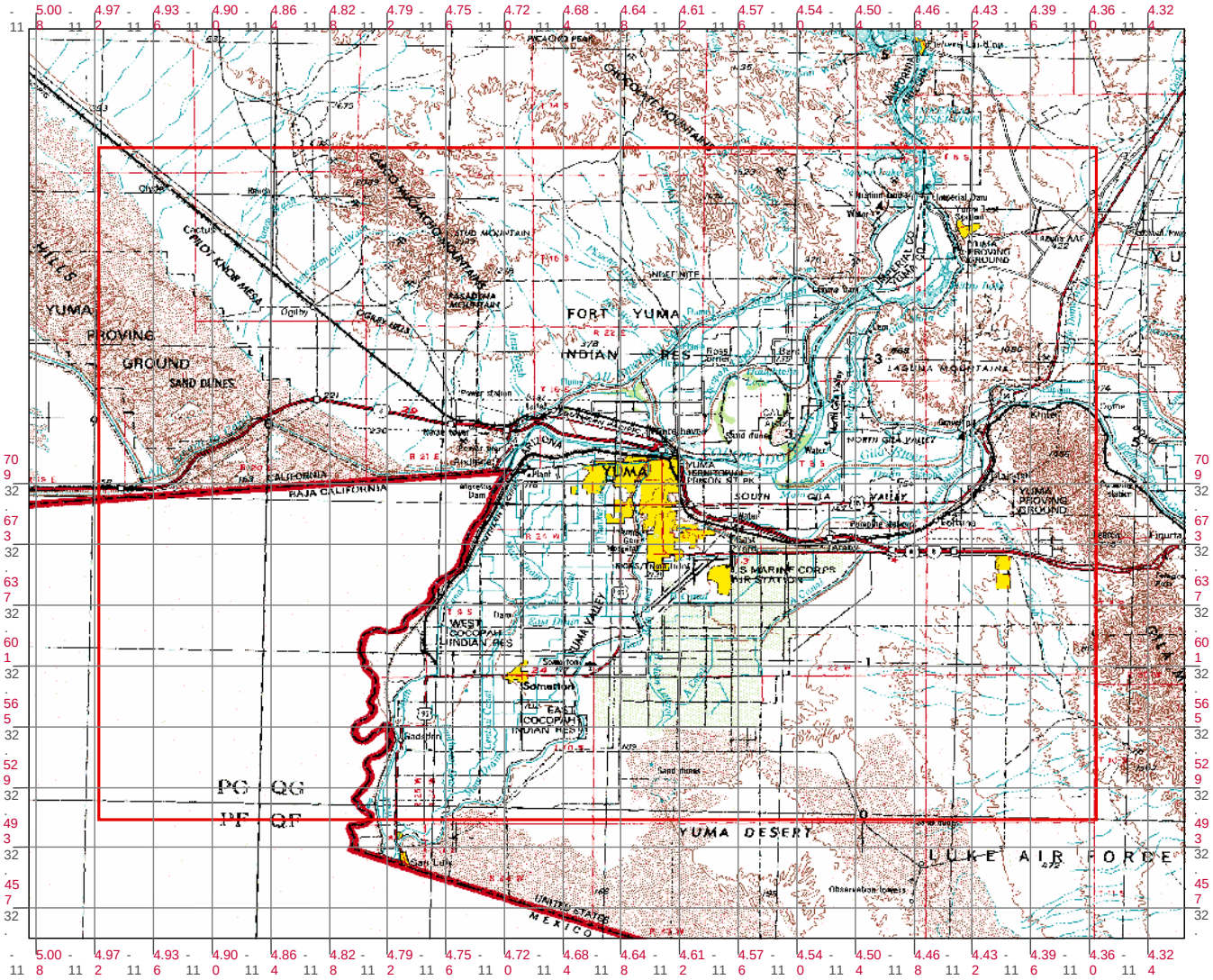

Figure 2-2. Yuma PM_{10} Emissions and Air Quality Modeling Domain (Orange Rectangle)

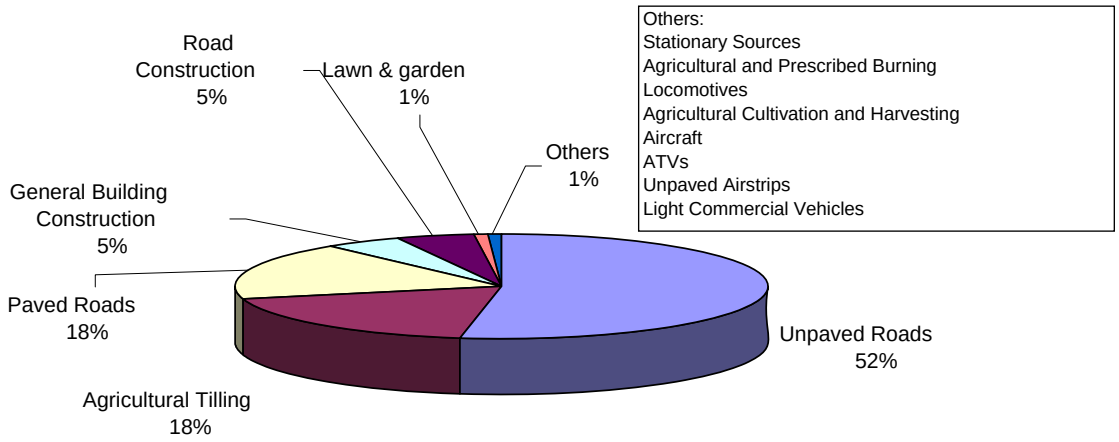

Figure 2-3a. Distribution of 1999 Yuma PM_{10} Emissions Low-Wind Days

The windbown dust category was divided into six categories, as shown in Table 2-4 and Figure 2-4, with vacant agricultural fields, miscellaneous disturbed areas, and unpaved agricultural roads accounting for 94% of the windblown PM_{10} emissions. The wide differences between the surface area of each category and the annual emissions reflect the variable potential of the different land surfaces to produce windblown dust emissions.

Table 2-4. Windblown PM_{10} Emissions

Source Category	Acres	Tons/Yr
Vacant Agricultural Fields	18,100	6,584
Miscellaneous Disturbed Areas	26,000	33,996
Unpaved Agricultural Roads	17,000	22,160
Urban Disturbed Areas	4,100	5,442
Alluvial Plains	141,000	2,517
Native Desert	74,300	282

Agricultural statistics come directly from the emissions inventory and reflect the modeling area, which is much larger than the nonattainment area. Non-citrus acreage in the nonattainment area is 60,000 acres (See Appendix C).

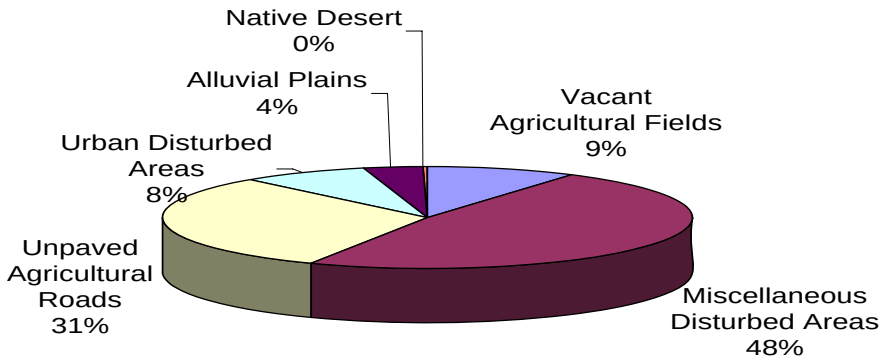

Figure 2-3b. 1999 Yuma PM_{10} Windblown Dust Emissions

2.3.2 Additional Aspects of the Emissions Inventory

This section discusses aspects of the emissions inventory not covered in the Pechan report.

The PM_{10} emissions inventory for modeling, developed for the Yuma study area, covered eight days each for the years 1999 and 2016 (Table 2-5). The inventory was completed before the air quality design dates were chosen. Therefore, these emission inventory dates do not match the chosen air quality dates exactly. The emission inventory date was matched with the most appropriate air quality date, based on season, day-of-week, and presence or absence of agricultural emissions and windblown emissions.

Including design dates with high wind speeds, (see Table 2-2 on page 2-3) was done for the simple reason that these are among the most difficult to show compliance with the standards. For the high-wind day, the emissions fed into the air quality model had windblown emissions for only those hours with average wind speeds in excess of 15 miles per hour. This is the threshold wind speed for dust resuspension. Through this approach, high-wind design dates were chosen which had the right windblown emissions from the inventory on an hourly basis.

Table 2-5. Study Dates for the Emissions Inventory	
Julian Day	**Calendar Date**
99015	Friday, January 15, 1999
99017	Sunday, January 17, 1999
99105	Thursday, April 15, 1999
99107	Saturday, April 17, 1999
99196	Thursday, July 15, 1999
99198	Saturday, July 17, 1999
99288	Friday, October 15, 1999
99290	Sunday, October 17, 1999
16015	Tuesday, January 15, 2016
16020	Sunday, January 20, 2016
16105	Monday, April 15, 2016
16110	Saturday, April 20, 2016
16196	Monday, July 15, 2016
16201	Saturday, July 20, 2016
16288	Tuesday, October 15, 2016
16293	Sunday, October 20, 2016

Pechan, the emissions inventory contractor, used a 4-kilometer (km) by 4-km grid, as shown in Figure 2-2, emission estimates, and support information to develop the modeling inventory. Additional data sources include ADEQ-developed land use data and contacts with local stakeholders. Note that this PM_{10} study area includes all of urbanized and agricultural Yuma, as well as portions of Baja, Mexico and Imperial County, California.

Pechan received 1999 emissions data for Imperial County from the California Air Resources Board. Since these data were for all of Imperial County, Pechan reviewed the data to determine which sources were likely to be within the study area portion of that county. For the Imperial County emissions Pechan retained a 14-digit Source Category Code (SCC) similar to those in the original CARB data. For Yuma County sources, a 10-digit SCC has been assigned to all sources. For emissions from the Mexico portion of the study area, Pechan used a 12-digit SCC. The only source categories for which the conventions described above do not hold are the windblown dust categories. These emission estimates were developed from land use of the entire study area. Therefore, the 10-digit SCCs that were assigned to windblown dust apply to emissions for all three areas within the study area.

Two modeling files were developed that contain the hourly emissions data for each year, 1999 and 2016. The format for these files is provided in Table 2-6. Details on the temporal allocation for each source category can be found in Appendix A.

Table 2-6. Source Categories Included with the Yuma Modeling			
Source Category	**Description**	**Spatial Surrogate**	**Notes**
2103000000	National Defense - Yuma Proving Ground Boilers	Yuma Proving Ground Grid Cells (Built-up Area)	
2200000110	On-Road Vehicles: Interstate - Yuma County	Yuma County I-8 Road Length	Includes re-entrained dust and tire and brake wear.
2200000110	On-Road Vehicles: Interstate Ramps - Yuma County	Yuma County I-8 Road Length	Includes re-entrained dust and tire and brake wear.
2200000130	On-Road Vehicles: Principle Arterials - Yuma County	Urban and Rural Primary Road Length	Includes re-entrained dust and tire and brake wear.
2200000130	On-Road Vehicles: Minor Arterials - Yuma County	Urban and Rural Primary Road Length	Includes re-entrained dust and tire and brake wear.
2200000135	On-Road Vehicles: Urban Collectors - Yuma County	Urban Secondary Road Length	Includes re-entrained dust and tire and brake wear.
2200000135	On-Road Vehicles: Local - Yuma County	Urban Secondary Road Length	Includes re-entrained dust and tire and brake wear.
2200000170	On-Road Vehicles: Rural Major Collectors - Yuma County	Rural Secondary Road Length	Includes re-entrained dust and tire and brake wear.
2200000170	On-Road Vehicles: Rural Minor Collectors - Yuma County	Rural Secondary Road Length	Includes re-entrained dust and tire and brake wear.
2200000170	On-Road Vehicles: Local Roads - Yuma County	Rural Secondary Road Length	Includes re-entrained dust and tire and brake wear.
2275001000	Aircraft: Yuma MCAS	Runway Location	
2275001010	Aircraft: Yuma Proving Ground	Runway Location	
2275020000	Aircraft: Yuma International Airport	Runway Location	
2275050000	Aircraft: U.S. Border Patrol	Runway Location (same as YIA)	
2275085001	Unpaved Airstrips - Somerton Airstrip	Coordinates = 32 degrees 35.90' N, 114 degrees 39.91' W.	No emissions data for Imperial or MX.
2275085002	Unpaved Airstrips - Pierce Aviation	Coordinates = 32 degrees 39.27' N, 114 degrees 42.68' W.	
2285002000	Railroads - Yuma County	Yuma Co. RR Track Length	
2296000000	Unpaved Roads - Re-entrained Dust: Yuma County	Yuma County Urban Area Land Use (500) - ADEQ Shape File	
2300000000	Miscellaneous Manufacturing	Yuma County Urban Area Land Use (500) - ADEQ Shape File	
2311010001	General Building Construction - Yuma County	Locations of Warehouse and New Home Construction in 1999	
2311010002	General Building Construction - City of Yuma	Yuma City Limits	
2311010003	General Building Construction - Somerton	Somerton Town Limits	
2311030001	Road Construction - Somerton	Somerton Town Limits	No emissions data for Imperial or MX.
2311030002	Road Construction - City of Yuma	Yuma City Limits	
2311030003	Road Construction - Yuma County	County Paved Road Lengths (excl. City of Yuma, Somerton, and I-8)	
2311030004	Road Construction - ADOT	Yuma County I-8 Road Length	
2325000000	Miscellaneous Mining & Quarrying	Yuma County Urban Area Land Use (500) - ADEQ Shape File	
2730100260	Yuma Study area Windblown Dust - Vacant Agricultural Fields	Agricultural Crops Landuse (260) - ADEQ Shape File	
2730100265	Yuma Study area Windblown Dust - Unpaved Agricultural Roads	Agricultural Crops Landuse (260) - ADEQ Shape File	
2730100290	Yuma Study area Windblown Dust - Misc. Disturbed Areas	Miscellaneous Disturbed Area Land Use (290) - ADEQ Shape File	
2730100295	Yuma Study area Windblown Dust - Urban Disturbed Areas	Miscellaneous Disturbed Area Land Use (295) - ADEQ Shape File	Disturbed areas within the City of Yuma.

Table 2-6. Source Categories Included with the Yuma Modeling			
Source Category	**Description**	**Spatial Surrogate**	**Notes**
2730100390	Yuma Study area Windblown Dust - Natural Desert Area	Natural Desert Area Land Use (390) - ADEQ Shape File	
2730100440	Yuma Study area Windblown Dust - Alluvial Plain and Channels	Alluvial Fan Stream Channels Landuse (440) - ADEQ Shape File	Includes all alluvial land uses (410, 430, 440)
2801000005	Harvest Operations - Cotton	Yuma Co. Agricultural Crops Land Use (260) - ADEQ Shape File	
2801001003	Tilling - Cotton	Yuma Co. Agricultural Crops Land Use (260) - ADEQ Shape File	
2801002003	Tilling - Barley	Yuma Co. Agricultural Crops Land Use (260) - ADEQ Shape File	
2801003003	Tilling - Hay	Yuma Co. Agricultural Crops Land Use (260) - ADEQ Shape File	
2801004003	Tilling - Wheat	Yuma Co. Agricultural Crops Land Use (260) - ADEQ Shape File	
2801005003	Tilling - Vegetables	Yuma Co. Agricultural Crops Land Use (260) - ADEQ Shape File	
2801006003	Tilling - Corn	Yuma Co. Agricultural Crops Land Use (260) - ADEQ Shape File	
2801100000	Yuma County - Yuco Cotton Gin	Coordinates = 32 degrees 42.27' N, 114 degrees 27.73' W.	
2801500001	Yuma Co. Agricultural Burning: Bermuda Grass	Yuma Co. Agricultural Crops Landuse (260) - ADEQ Shape File	
2801500002	Yuma Co. Agricultural Burning: Wheat	Yuma Co. Agricultural Crops Landuse (260) - ADEQ Shape File	
2801500003	Yuma Co. Agricultural Burning: Citrus	Yuma Co. Agricultural Crops Landuse (260) - ADEQ Shape File	
300000000001	Mexico Agricultural Burning - Wheat/Sudan Grass	Mexico Crop Land	
350000000001	Mexico Wheat Tilling	Mexico Agricultural Crops Land Use (260) - ADEQ Shape File	
350000000002	Mexico Vegetables Tilling	Mexico Agricultural Crops Land Use (260) - ADEQ Shape File	
500000000000	On-Road Vehicles: Mexico Hwy 2	MX Hwy 2 Road Length	Includes re-entrained dust and tire and brake wear.
500000000010	On-Road Vehicles: Other Mexico Paved Roads	Mexico Portion of the Study area	Includes re-entrained dust and tire and brake wear.
62060000000000	Agricultural: Imperial Co. Harvest Operations	Imperial Co. Crops Land Use (260) - ADEQ Shape File	
62060000000000	Agricultural: Imperial Co. Agricultural Tilling	Imperial Co. Crops Land Use (260) - ADEQ Shape File	
62060000000000	Agricultural: Farm Equipment	Imperial Co. Crops Land Use (260) - ADEQ Shape File	
62060000000010	Agricultural: Food and Ag. Industrial Processes	Imperial Co. Crops Land Use (260) - ADEQ Shape File	
62060000000010	Agricultural: Food and Ag. Boilers	Imperial Co. Crops Land Use (260) - ADEQ Shape File	
64564000000000	Unpaved Roads - Re-entrained Dust: Imperial County	Imperial Co. Misc. Disturbed Land Use (290) - ADEQ Shape File	
67066202620000	Imperial County Agricultural Burning Emissions - Total	Imperial County Crop Land	
70000000000000	On-Road Vehicles: Imperial County	Urban and Rural Primary Road Length	Includes re-entrained dust and tire and brake wear.
82082012100000	Railroads - Imperial County	Imperial Co. RR Track Length	

2.3.3. Converting the Contractor's Inventory into Model-Ready Format

This section explains how the contractor's inventory had to be modified to make it ready for the air quality modeling.

Although Pechan had developed the emissions inventory to be "model ready", further work was necessary to enable the ISCST-3 model to read the input values. ISC is limited to an eight character name for the source category. Since the source categories were Source Category Codes (SCC) values and many exceeded the eight character limit, a new system for nomenclature had to be developed. Ultimately, each SCC was modified to reflect the source category location and type while utilizing only four digits. This was achieved by replacing the SCC numbers with alpha numeric codes like AA12, where AA was the source category and 1 = X coordinate and 2 = Y coordinate. This system allowed the modeler to (somewhat more easily then using numbers alone) turn on and off specific source categories in specific locations. This step was necessary in that not only did it provide source category names that ISC could understand, but it also provided more control for the modeler. Because the emissions inventory was unified, it was somewhat difficult to conduct source category contribution modeling without these modifications to the nomenclature.

In addition to the formatting modifications, some changes were made to the modeling days provided. Pechan built the inventory using the days described in Table 2-4. The Yuma air quality modeling work paired each inventory with the most appropriate design day, based on the season, day of week, and presence or absence of agricultural activity. For example, the Pechan inventory day of Friday, January 15, 1999, was used for the design date of December 8, 1999. This matching of the inventory day with the air quality date illustrates how the most appropriate inventory was paired with the air quality observation and modeling date.

Additional details on the modeling inventory not covered by Pechan include:

- For each source category, Pechan included a value for the initial vertical dimension ($S_{z\text{-init}}$) required by ISC3 (i.e., the initial vertical height of the plume before horizontal advection begins). All of the $S_{z\text{-init}}$ assignments were made using engineering judgment. For area sources, this value is given by the vertical dimension divided by 4.3 for sources elevated above the ground and by the vertical dimension divided by 2.15 for sources emanating from the ground surface. The "engineering judgment" comes into play in knowing whether the source is better characterized as coming from the surface or from above the surface, and in having a reasonable idea of what the initial vertical dimension of the plume is. Initial vertical dimensions in the Yuma PM_{10} modeling ranged from 0 to 3 meters, as shown in the Table 2-7.

Table 2-7. Initial Vertical Dimensions of Emission Sources	
Emission Source Category	**$S_{z\text{-init}}$* (Meters)**
On-Road Vehicles Paved & Unpaved	0-1
Aircraft	1-2
Railroads	1-3
Ag Burning	0
Ag Food/Industrial Boilers	0
Windblown -- All Categories	0

*$S_{z\text{-init}}$: the initial vertical dimension of a plume

- For windblown dust emissions, March 31 was selected as the high-wind modeling day, because its PM_{10} concentrations were the highest of the year. For 2016, Pechan assumed that winds would occur on March 31 with the same frequency and magnitude. As for other 1999 days with high winds, there were three days with one or more hours of an average hourly wind speed in excess of 15 miles per hour, and 41 days whose maximum instantaneous wind speed exceeded this value. March 31 was the most severe and had the highest PM_{10} concentrations. In the selection of the seven design dates it is important to have dates throughout the concentration range, including all four seasons, as well as to include a high-wind day. As explained later in this chapter, the modeling for the high wind day was unsuccessful and the day had to be dropped from the analysis. Figure 2-1 illustrates that the choice extends from the highest to the lowest concentrations. Given the frequency of winds high enough to resuspend dust – three days out of 365 in 1999 – modeling a single high wind day was sufficient.

  Limiting the high-wind analysis to the single day with the highest PM concentrations was necessary and sufficient. First, it allowed for a greater effort in modeling the kinds of anthropogenic emissions that were more easily controlled than wind-blown emissions. These would include dust from construction of roads and home sites, dust from unpaved roads, both agricultural and municipal, and dust from paved roads. These are the emissions which, on a day to day basis, need to be controlled to meet air quality standards. Second, the choice of a single high-wind day eliminated some difficult simulations necessary to produce concentrations reasonable when compared to the measurements. As discussed later in this chapter, the modeling system – emissions of windblown dust pegged to an hourly average wind speed of 15 miles per hour, driving an air quality dispersion model – was unable to produce realistic PM_{10} concentrations under these high wind conditions. Third, attempting to simulate similar conditions without extensive applied research would have been unproductive. This research would better quantify the land surfaces associated with windblown emissions, would elicit the temporal decay curves that arise from the depletion of upwind suspendable dust in a multi-hour wind event, and, perhaps, would invoke deposition algorithms in a more effective way. As

such research was beyond the scope of this project, a single high-wind day was modeled. Finally, since the monitored PM concentration for the day modeled was more than 30% below the PM_{10} 24-hour National Ambient Air Quality Standard (NAAQS), modeling additional windy days with lower PM_{10} concentrations add no value to the effort of demonstrating attainment of the NAAQS.

- Pechan evaluated new emissions data for sand dunes. These tests, on sand dunes near Owens Dry Lake, CA, suggest that threshold wind speeds in excess of 35 mph are needed to generate significant PM_{10} emissions from sand dunes. The surface winds evaluated for the Yuma Study area in 1999 did not exceed 30 mph (Yuma Valley AZMET station). Therefore, no emissions were assigned to sand dunes in 1999 or 2016.

- During 1999, agricultural burning in the Bard/Winterhaven area of Imperial County was limited to 50 acres of alfalfa and 4 acres of tree trimmings. All burning was conducted in August of that year; hence, no Imperial County agricultural burning emissions appear in the modeling inventory.

- Pechan estimated Mexican on-road vehicle emissions from information provided by ADEQ. ADEQ provided estimates of roadway length for Mexican Highway 2 and other paved roads, as well as the number of vehicles using these roads each day (10,0000 vehicles on Highway 2 and 3,000 on other paved roads). Pechan found that Mexican Highway 2 fell outside of the study area boundaries. Therefore, these emissions were left out of the modeling inventory. ADEQ's estimate for other paved roads (217 miles) was used to estimate VMT. For 1999, the estimated Mexican on-road emissions were 935 tons from paved roads within the study area. For other paved roads, the emission factors corresponding to major collectors in Yuma County were used. To estimate 2016 emissions, the growth in VMT was estimated from VMT growth estimated for Yuma County. Hence, the on-road Mexican emissions are based on emission factors for a U.S. fleet and do not reflect emissions from a potentially dirtier Mexican fleet. This disparity makes little difference, it should be pointed out, because of the small contribution of tailpipe emissions in the whole of the monitoring domain and the even smaller contribution from those in Baja.

- Vehicle miles traveled (VMT) and emission factor information used by Pechan in building the inventory are included as two reports in Appendix E.

- The 50% reduction in unpaved road emissions from the base to the future year in the Pechan emission inventory is based upon stated assumptions in the two Lima and Associates reports (Appendix C). These assumptions were made in consultation with the Yuma Planning Organization, for whom the reports were written. A reasonable check on this rate of progress would be to determine the dirt roads paved and the emissions reduced in 1999 – 2004. This information is contained in Chapter 3, "Controls," but the paving projects are part of a diverse mix of dust reduction efforts. Table 2-8, which presents this unpaved road paving and emissions information, shows that from 2000 through 2004, unpaved road emissions

have been reduced by about 8% each year. This pace is about twice as fast as the assumption of a 50% reduction in unpaved road emissions between 1999 and 2016 built into the inventory (at an 8% rate, the 2016 unpaved road total would be about 2500 tons, as opposed to the roughly 10,000 tons in 1999 and 5,000 tons in 2016).

- The vehicle miles traveled (VMT) growth rates from 1999 to 2013 and from 2013 to 2016 are described in the second Lima and Associates report that is in Appendix E.

- The suitability of either 1999 or 2005 as a "base year" for the maintenance plan is discussed in Appendix D. Basically the years are equivalent because neither the PM_{10} concentrations nor the emission totals change appreciably in this period.

Table 2-8. Unpaved Roads Paved in 2000 – 2004, with Emission Reductions

Agency	Miles	Tons/Year	%
City of Yuma	8.72	2011	
Somerton	6.16	837	
Yuma County	1.75	345	
Yuma County Water Users	2.50	345	
Marine Corps Air Station	1.33	1.4	
Developers	12.00	306.6	
Yuma, Yuma County, Somerton	1.54	78.7	
Total (2000 - 2004)	34.00	3924.7	
Annual Average	6.8	784.94	
Unpaved Road Total (Pechan)		10183	
Annual as % of Unpaved Road Total			**7.7**

Figures 2-4 and 2-5 are emissions density plots for two days in 1999. Figure 2-4 is a day in which there were no windblown dust emissions in the inventory, while Figure 2-5 is a day in which windblown dust emissions occur. Notice the difference in the scales and density saturation between the two maps. The high wind day has a majority of the domain covered with cells that have a density of 10,000 to 300,000 g/m² PM_{10}, while the low wind day is mostly dominated by lower density cells ranging from 1,000 to 60,000 g/m² PM_{10}. The emission totals for high wind days are roughly five times the PM_{10} emissions on the low wind days. A higher emission density throughout the domain for the high wind day, as compared to the low, would be expected. It's still easy to see that on a low-wind day the domain is dominated by light emission densities except for the area along the I-8 corridor.

Another notable difference in the maps can be seen in their upper right corners. The low wind map has light emission densities (none greater than 30,000 g/m²), while the high wind day has quite dense emissions, with values as high as 600,000 g/m². This

difference can be attributed to the dominance of windblown emissions for those cells. This makes sense, given that a majority of this area consists of miscellaneous disturbed ground surfaces associated with the Yuma Proving Grounds and would not materially affect local emissions unless wind speeds exceeded the resuspension threshold. This threshold was exceeded on the April 15, 1999, high-wind day, but not on the January 15, 1999, low-wind day: hence, the difference in these two maps.

Recommendations for future improvement to the Yuma Study area inventory follow:

- *Improve spatial allocation of agricultural emissions:* Pechan investigated the use of survey information from the U.S. Bureau of Reclamation (USBR) on the location of various crop types in Yuma and Imperial Counties (those using Colorado River water for irrigation). Unfortunately, less than 8,000 acres had survey data (including fallow and vacant fields), representing less than 5% of the Yuma-Imperial crop land. Stakeholders may be able to shed light on which portions of the study area agricultural lands are used to raise certain crop types. Important crop types include citrus, wheat, cotton, and vegetables. In the current inventory, emissions for agricultural tilling, harvesting, and burning operations are spread over the entire county-level crop land use area; and

- *Gather additional information to estimate Mexican emissions:* Missing source categories include unpaved roads and open burning (e.g. household waste). Incorporate refined data to estimate on-road emissions, including emission factors for a Mexican fleet.

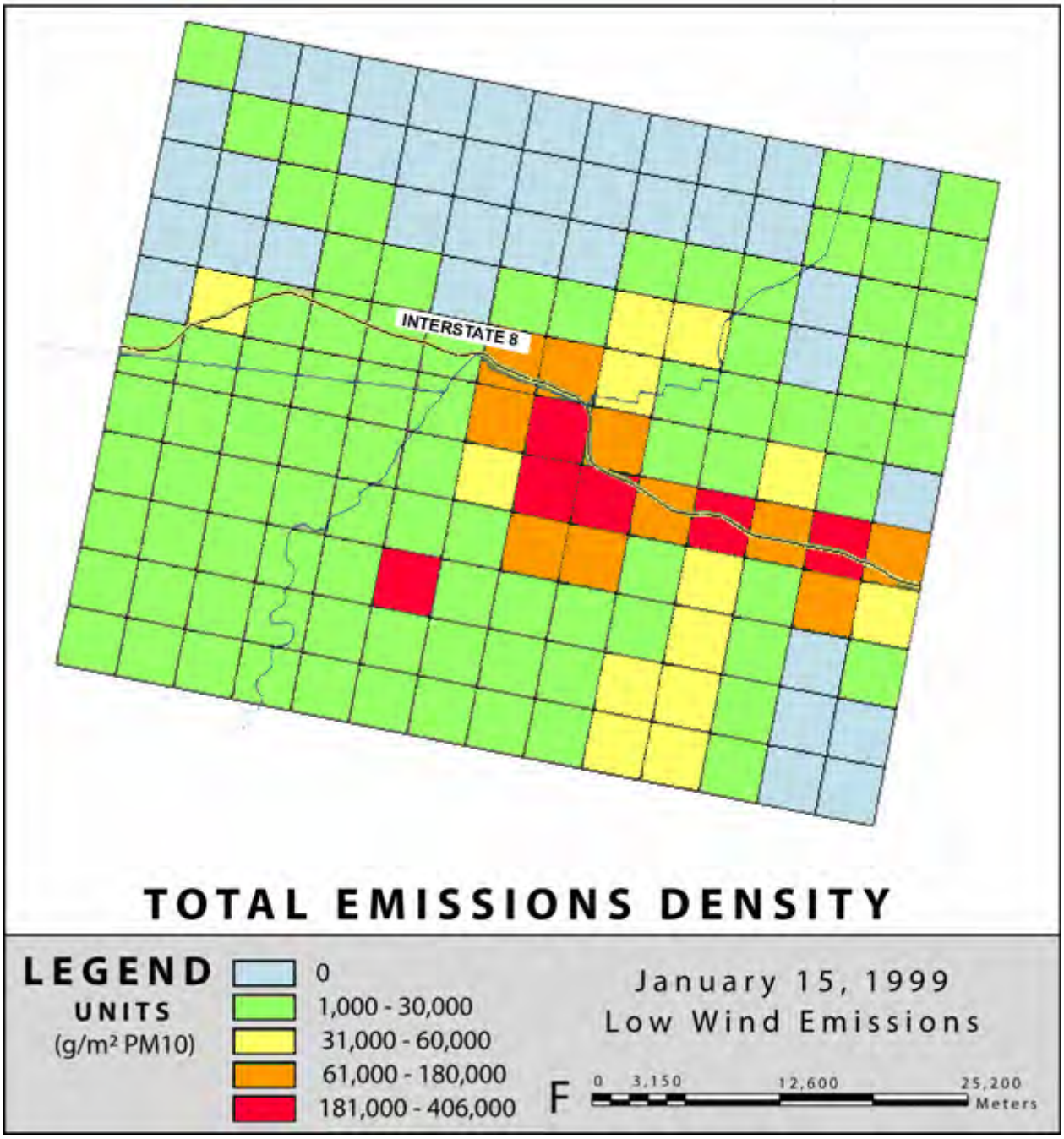

Figure 2-4. Distribution of 1999 Yuma PM_{10} Low Wind Emissions

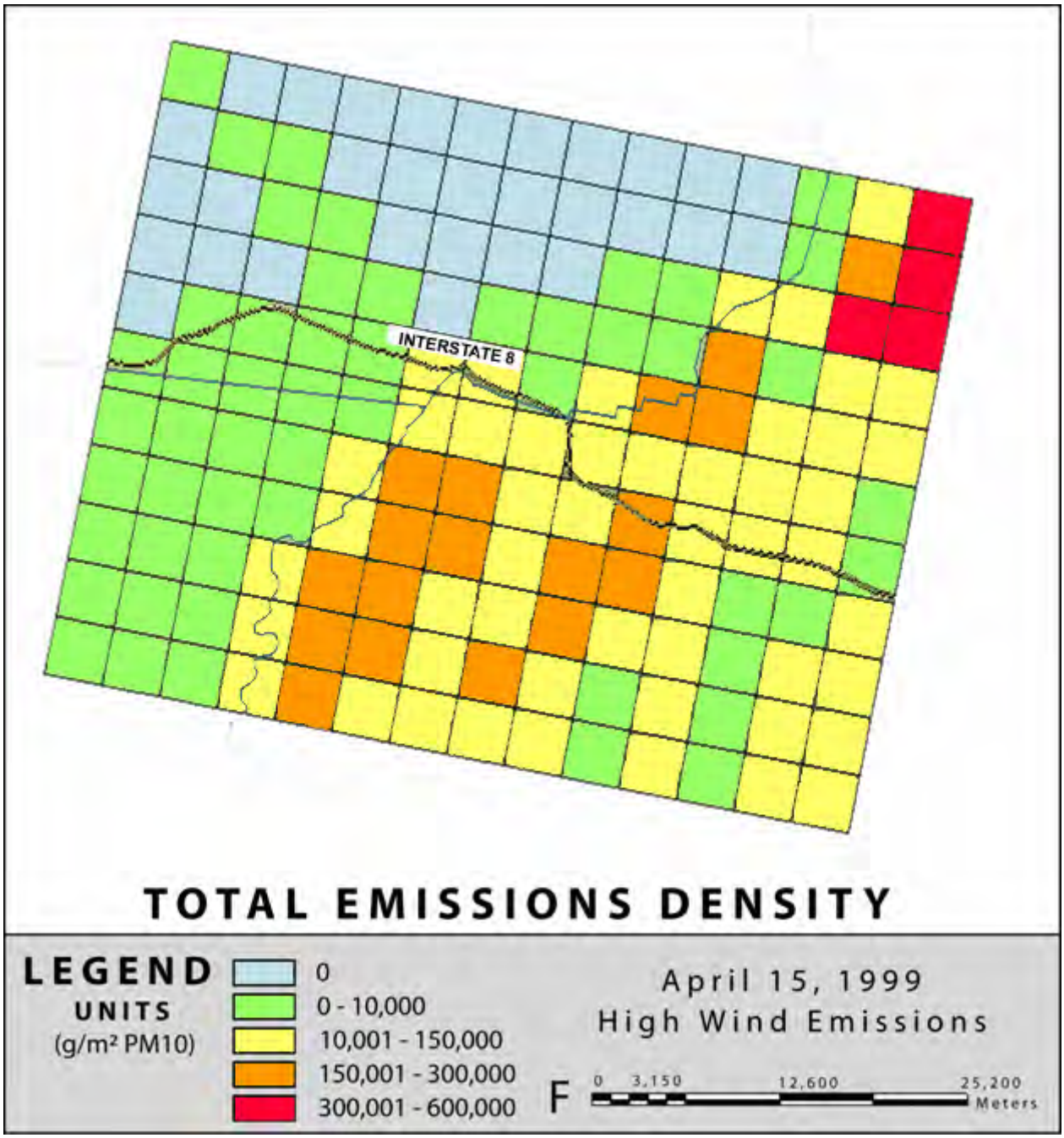

Figure 2-5. Distribution of 1999 Yuma PM_{10} High Wind Emissions

2.4 Background Concentrations

2.4.1 Introduction

Background concentrations of an air pollutant are those concentrations that would be measured in the total absence of any anthropogenic emissions in a particular study area. Outside of any study area both anthropogenic and natural emissions give rise to background concentrations. The Yuma PM_{10} background concentrations arise from both natural and anthropogenic sources in Mexico, California, and other parts of Arizona. These concentrations are transported into Yuma and are considered that part of the total aerosol that is not subject to reduction through local controls.

A slightly different way of looking at this phenomenon would be to imagine a small study area in the heart of a large city with dense emissions of air pollutants. The study area would have emissions that are a small fraction (say 1%) of the city's total. The objective would be to determine how effective reductions of "local emissions" inside the study area would be in lowering local air pollution levels. To achieve this goal, the air pollution arising from the rest of the city's emissions would have to be measured, since the city-wide concentrations would be transported into the study area. These measurements could be done at the boundaries of the study area and would be called "background concentrations." The relationship between local emissions and local concentrations within the study area could be quantified through an inventory of emissions and an air quality model. When this was finished, however, the background concentrations from the rest of the city would have to be taken into account. If the proposed controls were strictly local – that is, within the study area – then it is apparent that with background concentrations kept constant, the local controls would have little effect.

In the technical work for this Yuma PM_{10} maintenance plan, the study area is rather large: 56 x 44 kilometers. In simulating PM_{10} concentrations with a numerical model, it is the "local emissions", those coming from human activities (and high winds) within the modeling domain, that determine its simulations of PM_{10} concentrations. Nonetheless, PM_{10} concentrations prevail outside this modeling domain; they result from both natural and anthropogenic emissions outside the modeling domain; but are transported into it. These "outside" or "background" PM_{10} concentrations contribute to the locally generated concentrations. They have to be accounted for in assessing the air quality in Yuma.

To quantify the Yuma background concentrations, monitored PM_{10} concentrations from outside the Yuma modeling domain, mixing heights, wind speeds and directions, and the hourly distribution of background PM_{10} concentrations were all brought to bear. The calculated background concentrations are added to those predicted by the model, which are based entirely on local Yuma emissions. This sum of concentrations coming from the emissions within the modeling domain plus background PM_{10} concentrations – otherwise known as the "total prediction" -- can then be compared with the measurements.

Accounting for that portion of the PM_{10} concentration, whether measured or modeled, that does not result from emissions within the study area is crucial to predicting accurate outcomes. No amount of emission reductions within the Yuma modeling domain will diminish those PM_{10} concentrations originating from elsewhere. Calculating these imported concentrations allows one to accurately relate the Yuma emissions to the Yuma PM_{10} concentrations. Having this accurate relationship ensures that reductions in the local Yuma emissions will be translated into realistic predictions of air quality, fully accounting for that portion of the PM_{10} concentration – the "background" concentration --- that is independent of and unaffected by local controls.

2.4.2 Data Sources

Ambient PM_{10} monitoring data for the design days was available in 24-hour averages from several locations, all of which were brought into the background calculations (Figure 2-6). The Yuma PM_{10} concentrations were measured with dichotomous samplers, which give separate measurements for fine (particles less than 2.5 microns) and coarse (2.5 – 10 microns) particulates. Hourly PM_{10} concentration profiles were available from Green Valley, Arizona and Calexico, California. Wind speed and direction were available from several sites in the Yuma vicinity. Mixing heights were calculated from the upper air observations in Tucson. These monitoring sites, presented in Table 2-9, provided the information to produce hourly and 24-hour PM_{10} background concentrations as described below.

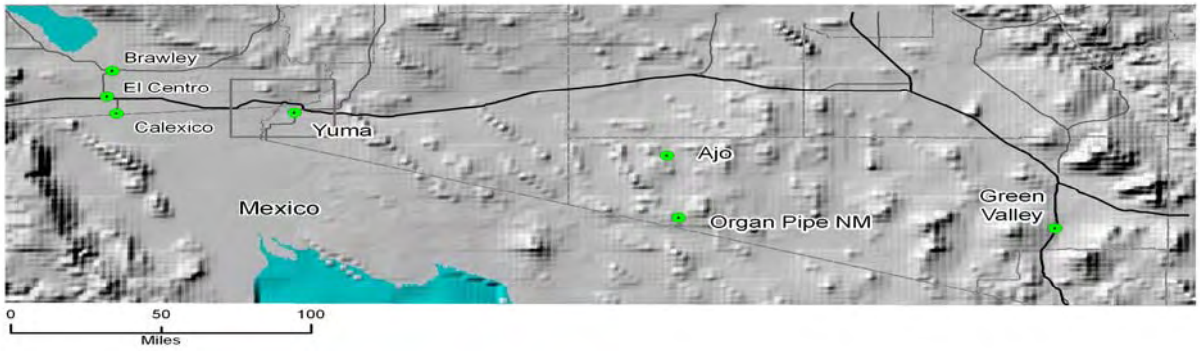

Figure 2-6. Background PM_{10} Sites in the Vicinity of Yuma, Arizona

Table 2-9. Measurement Sites in the Background Calculations Particulate Matter (PM)			
$PM_{2.5}$ and $PM_{2.5-10}$ (24-Hour Averages)	**PM_{10} (24-Hour Averages)**	**PM_{10} Hourly**	**Wind Speed And Direction**
Yuma	Yuma		Yuma
		Green Valley	Many Others
Organ Pipe	Organ Pipe	Calexico, CA	
Ajo			
El Centro, CA			
Brawley, CA			

2.4.3 Overview of PM_{10} Background Calculations

The calculation of background concentrations for Yuma is a multi-step process that accounts for wind direction, wind speed, mixing heights, and gravitational settling of fine and coarse PM. This accounting has to be done on an hourly basis, even though most of the PM measurements are 24-hour average integrated samples.

The hourly PM_{10} concentrations at the various sites in the Yuma vicinity were calculated by applying the urban or rural (Calexico or Green Valley) percent distribution curve to the particular 24-hour PM_{10} average at the site. Hourly wind speeds and directions were used to establish reasonable transport paths. The numerical value of the outlying hourly concentration was not mapped directly onto the Yuma perimeter. Instead, these concentrations were reduced to account for the deposition of the coarse particles. A more sophisticated approach would have included the injection of PM_{10} emissions into the air parcel as it was transported towards Yuma. This approach was not taken because it would have required the use of a dispersion or puff model such as CALPUFF. Furthermore, the trajectory paths from the Imperial Valley and from south-central Arizona overlie land surfaces with minimal human activity.

A slightly different way to look at this method is as follows. First, an hourly PM_{10} concentration from an outlying, background monitor is calculated. Second, instead of assuming that this concentration would be present after transport to the Yuma perimeter, this outlying concentration is reduced to account for the large particle settling or “deposition” that occurs during transport.

An additional complication – not dealt with in this method – concerns obstructions from elevated terrain that affect the transport of PM emissions. Including such terrain effects would have been much too complex for the scope of this study, so flat terrain is assumed. The following sections explain the steps of these calculations.

2.4.4 Hourly PM_{10} Concentrations

The first step in calculating the composite background PM concentration is to obtain the mean hourly percent contribution of PM for any given day per season. These sites were chosen to represent both urban, high-emission areas (Calexico) and rural, and near pristine conditions (Green Valley). The Green Valley site, operated by Pima County, is in what can arguably be called a background area. Green Valley, Arizona, 25 miles south of Tucson, has had annual PM_{10} concentrations from 1989 through 2003 averaging 17 µg/m^3, with a high of 21 and low of 14 µg/m^3. These values are higher than the pristine conditions of Organ Pipe National Monument, which averages 10 µg/m^3, but are either lower than or about equal to other somewhat remote Sonoran desert sites. The Green Valley site is representative of rural, southern Arizona PM_{10} concentrations that are influenced by neither adjacent urban emissions nor by strong, near-field localized emissions. Of all the Arizona sites with continuous PM_{10} records, nearly all of which are in metropolitan Phoenix and Tucson, Green Valley stands out as the most remote with the lowest concentrations.

Using continuous PM_{10} records from Tapered Element Oscillating Microbalance (TEOM) instruments from Calexico (1999) and Green Valley (2001), the hourly percent contribution was calculated (Eq. 1).

Seasonal % Hourly PM = (Total Seasonal Hourly PM / Total Daily PM Seasonal Mass) * 100 (Eq.1)

The total seasonal hourly PM was divided by the total daily PM seasonal mass and multiplied by 100 to yield the mean seasonal hourly percent PM. In other words, on a season-by-season basis, for each hour of the day, the hourly total of PM_{10} concentrations is divided by the daily total. This result multiplied by 100% gives the percentage of PM_{10} that each hour contributes to the daily total.

An example follows. The “total daily PM annual mass” (for the Phoenix Supersite, for 1998) is 712.9 ug/m3. The lowest hourly concentration was 22.9, and the highest, 42.2 ug/m3. Considering a single hour, hour 23, the “Total Hourly PM” is 42.2 ug/m3. Dividing the “Total Hourly PM” of 42.2 by the “Total Daily PM Mass” of 712.9 gives the “Percent Hourly PM of 5.5%. In Figure 2-7, the hour-by-hour variation of PM_{10} concentrations and of the “Percent of Hourly PM” are shown together. Though these figures are for an entire year, the same method applies to a single month or season.

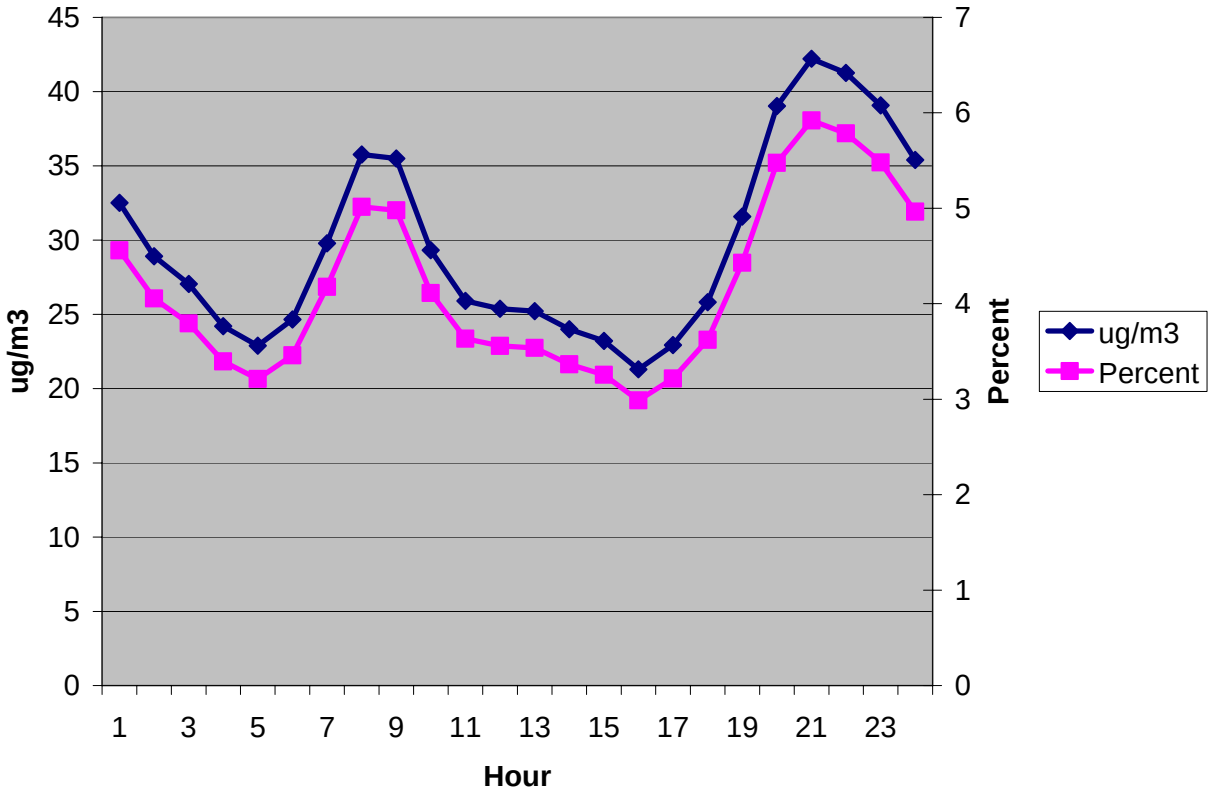

Figure 2-7. PHX Supersite: Hourly Averages in ug/m3 and the Hourly Percentage of the Daily PM_{10}

In the hourly percentage PM curves for the urban and rural sites (Figures 2-8 and 2-9), notice the flatness of the Green Valley hourly curves, in contrast with the Calexico pattern, which has both a pronounced morning and a late afternoon/evening peak. These two patterns are consistent with a near-pristine background site, whose local emissions approach zero, and with a high-emission urban site, whose localized emissions are much stronger and which tend to vary throughout the day in concert with human activities, principally, but by no means entirely, vehicular traffic.

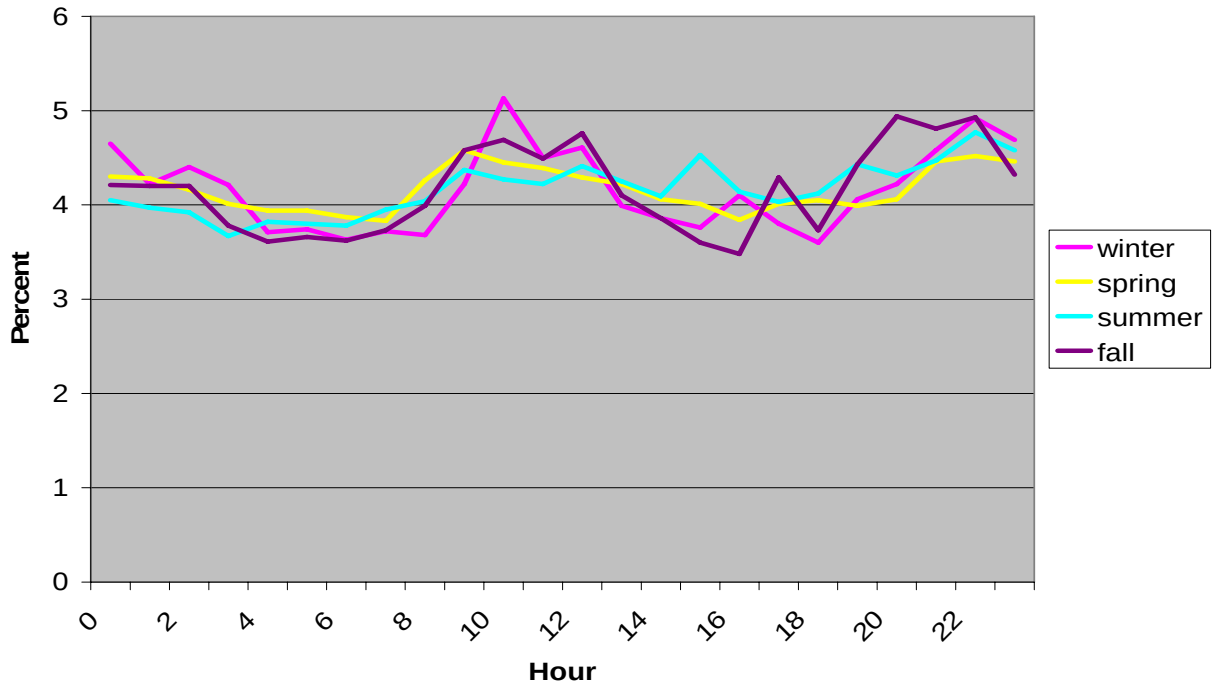

Figure 2-8. PM_{10} Hourly Profile of Remote Desert Sites, Based on Green Valley, AZ

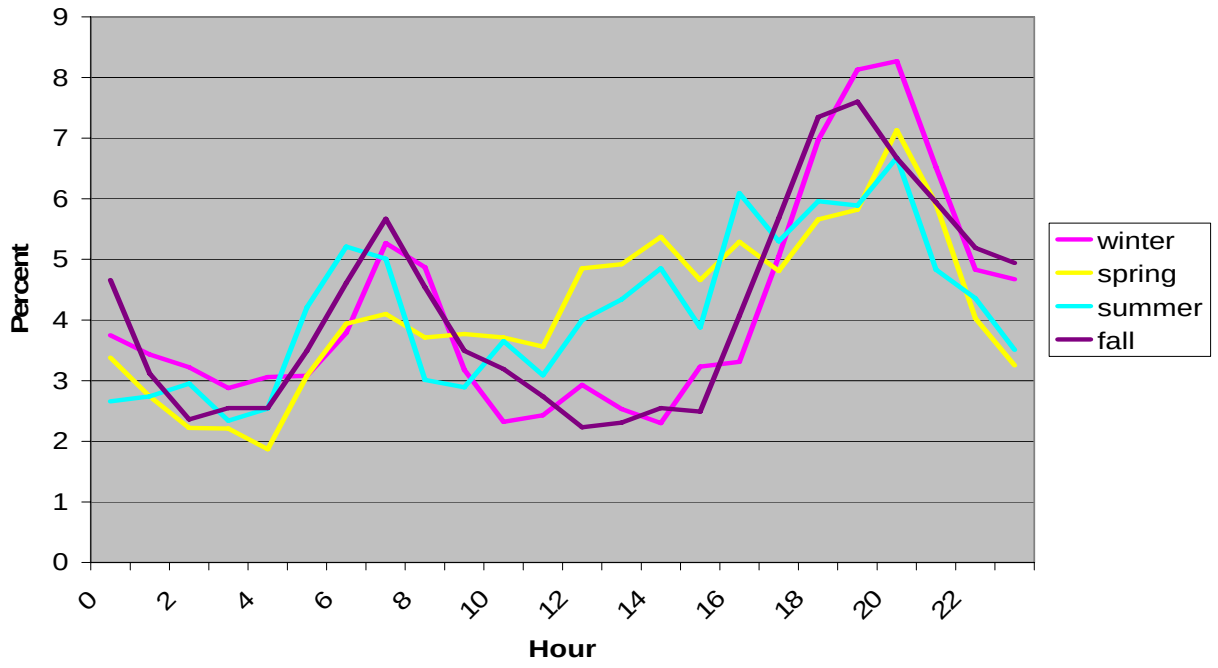

Figure 2-9. PM_{10} Hourly Profile from Urban Desert Sites with Considerable Agricultural and Vehicular Emissions, Based on Calexico, CA

2.4.5 Regional Contribution to Background PM

The contribution to background PM_{10} in Yuma uses wind direction, wind speed, and mixing heights in the composite estimation process. The wind direction is used to identify which source sector contributes for that hour. For example, if the wind direction is out of the south to the west, then the hourly pattern was based on the PM measurements from Calexico. All other sectors were based on Green Valley. Thus, the regional composite PM background concentration – on an hourly basis -- is the 24-hour concentration recorded at a background site, multiplied by the hourly percent value from either the Calexico or Green Valley sectors. If the wind for a given hour was from the west, then the 24-hour PM average from an Imperial Valley site for that specific sampling date would be multiplied by the percent contribution for the given hour from Calexico (Eq. 2) to yield the hourly PM concentration. These hourly concentrations, as explained below, were treated further to account for particle settling.

Hourly PM = 24-hour Average * Seasonal Hourly Percentage (Eq. 2)

2.4.6 Adjusting the Hourly PM Concentration for Deposition During Transport to Yuma

The deposition of particulate matter is a well known phenomenon, with higher deposition rates associated with coarser particles. By PM_{10} being divided into fine and coarse fractions (less than 2.5 microns for “fine” and 2.5 – 10 microns for “coarse”), appropriate deposition rates, and thus removal rates, can be assigned to the two particle size fractions. In their transport towards Yuma from these outlying regions, the particulates are reduced by a simple deposition method. This method consists of reducing the coarse fraction of remote ambient PM_{10} that reaches Yuma. This method takes into account the mixing height and wind speed and therefore transport time of the air parcel. In doing so, it reduces the transported concentrations and thus lowers the background concentration. As discussed previously, it does not attempt to incorporate fresh PM_{10} emissions along the transport paths, which are largely moving over undisturbed desert.

Consider an elevated PM_{10} concentration in Calexico or Brawley, consisting roughly of two thirds coarse, geological particles emitted by some “fugitive dust” activity, such as tilling or driving on unpaved roads. The bulk of these coarse, fugitive emissions, emitted at ground level, will “fall out” of a transported air parcel on its way to Yuma. This method reduces that portion of the coarse particles unlikely to remain suspended in the air during transport to Yuma. Table 2-10 gives both the outlying PM_{10} concentrations and the Yuma background concentrations derived from them.

Table 2-10. Calculated Background PM_{10} Concentrations								
Date	**Upwind PM_{10}**	**Winds**		**Calculated Background PM ($\mu g/m^3$)**			**Yuma PM_{10}**	**Back-ground %***
		Speed	**Dir.**	**$PM_{2.5}$**	**$PM_{2.5-10}$**	**PM_{10}**		
12 Jan	40-60	Low	SSE-WSW	7.1	8.2	15.3	52	30
31 Mar	40-60	High	WNW	10.1	14.4	24.5	88	28
30 May	20-120	Low	SW,NW	10.5	20.7	31.3	26	123
23 Jun	30-50	High	SSW-SSE	10.2	21.4	31.6	44	73
17Jul	25-40	Low	WNW-NNW	10.5	17.9	28.4	19	150
8 Nov	25	Low	WNW	5.9	7.6	13.6	32	43
8 Dec	30-40	Low	NNW	6.8	7.2	14.0	46	30

*%: the background concentration as a percentage of Yuma PM_{10}. The average of the two concentrations was used where available.

This table illustrates that the upwind PM_{10} concentrations have been reduced substantially. This reduction comes through applying a simple model that expresses deposition as a function of particle size (fine or coarse), transport time, and mixing height. The degree of deposition was based on the transport time (i.e. wind speed and distance to the Yuma perimeter), on mixing height, and on the size distribution of PM_{10}. Based on ambient sampling in many sites throughout the state, and understanding that in rural areas the primary source of ambient particulates is geological, one third of the PM_{10} is assigned to the 0 – 2.5 micron range and two thirds of PM_{10} is assigned to the 2.5 – 10 micron range. On an hour by hour basis, then, the PM_{10} in the air parcel on its trajectory towards Yuma was depleted in accordance with the methods described in "Methodology For Estimating Fugitive Windblown And Mechanically Resuspended Road Dust Emissions Applicable for Regional Scale Air Quality Modeling", Western Governors Association Contract No. 30203-9, R. Countess et al, April 2001. Given the wide range of wind speeds and mixing heights, this deposition method depleted the monitored PM_{10} concentrations from five to 85% on an hourly basis.

Table 2-9 contains some perplexing results: for example, why should the background be equal on a low-wind day (May 30) and high-wind day (June 23)? The upwind concentrations on the low wind day of May 30 ranged from 20 to 120 ug/m3, depending on wind direction. The higher concentrations, in the Imperial Valley, were transported by westerly winds into Yuma. On June 23 the upwind concentrations were much lower, ranging from 30 to 50 ug/m3. Faster transport winds decreased the amount of deposition and delivered the same 31-32 ug/m3 to Yuma as on the low-wind day.

2.4.7 Results of Background Calculations

These calculations yielded reasonable background values for five of the seven design days (Table 2-8). For May 30 and July 17, however, the calculated background concentrations exceeded the Yuma measurements. While this is not an impossibility, it does defy the logic of the entire background exercise. The Yuma concentrations on these two days were extremely low: 21 and 30 µg/m^3 on May 30 and 19 µg/m^3 on July 17. Concentrations in the surrounding areas were apparently higher than in Yuma, as calculated by this method.

Part of the anomalously high background concentrations on the two dates could be that the same sources are contributing to both 'background' concentrations and concentrations in Yuma. The distances involved argue against large contributions to Yuma PM_{10} from these outlying sources. The background sites of Palo Verde (107 miles), Ajo (102 miles), and El Centro (65 miles) are too distant from Yuma to make major contributions to its PM_{10} loading. In addition, the Ajo and Palo Verde sites lie east of Yuma, which puts them predominantly downwind due to prevailing daytime westerly and southwesterly winds. As Tables 2-10 and 2-11 show, however, the contributions are on the order of 30% with, on occasion, even higher contributions possible. Sources in the immediate vicinity of these background monitors, as well as sources between them and Yuma, do contribute to both concentrations.

The rationale for using Organ Pipe background on the two days when the calculated values exceeded those in Yuma is that this site is the most pristine, most isolated, monitoring site and it has the lowest PM_{10} concentrations in southern Arizona. That two of the seven background calculations gave illogical values suggests what is already known: that on a particular day there is much about emission patterns and transport that we simply don't know. Concentrations of this magnitude that approach pristine background levels are always more difficult to simulate and, in this background calculation method, prove to be intractable with the surrounding higher concentrations

In place of these calculated values, the 24-hour average PM_{10} concentrations from Organ Pipe National Monument for these two dates have been substituted. These final background values and the percentage they comprise of the Yuma concentrations are shown in Table 2-12.

Table 2-11. Calculated Background PM_{10} Concentrations							
Date	**Winds**	**Measured Yuma PM_{10} ($\mu g/m^3$)**		**Calculated Background PM_{10} ($\mu g/m^3$)**			
		Original	**Duplicate**	**$PM_{2.5}$**	**$PM_{2.5-10}$**	**PM_{10}**	**%***
1/12/99	Low	55	48	7.1	8.2	15.3	29.7
3/31/99	High	102	74	10.1	14.4	24.5	27.8
5/30/99	Low	21	30	10.5	20.7	31.3	122.7
6/23/99	High	43	44	10.2	21.4	31.6	72.6
7/17/99	Low	19		10.5	17.9	28.4	149.5
11/8/99	Low		32	5.9	7.6	13.6	42.5
12/8/99	Low		46	6.8	7.2	14.0	30.4

(May 30 and July 17 are shown with their calculated values, which exceed Yuma's monitored concentrations.)

*%: Background concentration as a percentage of Yuma PM_{10}. The average of the two concentrations was used where available.

Table 2-12. Final Adjusted Background PM_{10} Concentrations							
Date	**Winds**	**Yuma PM_{10} ($\mu g/m^3$)**		**Background PM_{10} ($\mu g/m^3$)**			
		Original	**Duplicate**	**$PM_{2.5}$**	**$PM_{2.5-10}$**	**PM_{10}**	**%***
1/12/99	Low	55	48	7.1	8.2	15.3	29.7
3/31/99	High	102	74	10.1	14.4	24.5	27.8
5/30/99	Low	21	30	**5.9**	**8.1**	**14.0**	53.8
6/23/99	High	43	44	10.2	21.4	31.6	72.6
7/17/99	Low	19		**5.7**	**8.5**	**14.2**	73.7
11/8/99	Low		32	5.9	7.6	13.6	42.5
12/8/99	Low		46	6.8	7.2	14.0	30.4

(Background values for May 30 and July 17 have been set equal to the concentrations measured at Organ Pipe National Monument on these dates.)

*%: Background concentration as a percentage of Yuma PM_{10}. The average of the two concentrations was used where available.

** 24-Hour average Organ Pipe National Monument $PM_{2.5}$, $PM_{2.5-10}$, and PM_{10} concentrations substituted for calculated values, which exceeded the measured PM_{10} concentrations in Yuma

2.5 Model Simulations for the Base Year

PM_{10} concentrations in Yuma, Arizona were simulated using the Industrial Source Complex Short Term (Version-3) – ISCST-3. This numerical model is a steady-state Gaussian dispersion model that has been approved by the U.S. Environmental Protection Agency and has a long history of applications in both the industrial and urban settings. The modeling domain consisted of an array of 4000 x 4000 meter grids, with a total of 154 grids covering the city of Yuma and the vicinity.

Yuma was modeled using the urban parameter for ISCST-3 with flat terrain, a unified emissions file, and the regulatory default modeling option. As for "flat" versus "complex" terrain, the area is flat enough to use the "flat" designation within the Industrial Source Complex (ISC) model. Near the northwest corner of the domain, the Cargo Muchacho Mountains (2129 feet, maximum elevation) and in the far eastern part of the domain, the Gila Mountains (3156 feet, maximum elevation) provide considerable topographical relief. This compares with elevations in the Yuma, Baja valley that range from 120 to 200 feet. Neither of these mountain ranges is in an area that produces any emissions, and being on the perimeter of the modeling domain, they don't materially affect transport in the generally broad, flat Colorado River Valley. If the concern had been predicted concentrations on these mountain peaks, then the complex terrain algorithms of ISC could have been invoked. Since they were not of concern, the flat terrain algorithms sufficed to simulate PM_{10} concentrations within the valley.

The U.S. Environmental Protection Agency (EPA) maintains the guideline on air quality models. This guideline provides the agency's guidance on the regulatory applicability of air quality dispersion models in the review and preparation of new source permits and State Implementation Plan (SIP) revisions. The regulatory default option selected in this modeling work conforms to the EPA guideline for SIP modeling - 40 CFR part 51, while the urban and flat terrain settings best reflect the conditions of the Yuma area. Contributions to overall PM_{10} in the domain were predicted for a 24-hour average using separate, day-specific, emission files consisting of seven design days in 1999 and in 2016. Each day was modeled individually and comparisons were made between the 1999 ISC results and results for each corresponding day in 2016. The Yuma Juvenile Center was used as a reference point within the domain and is the location of the PM_{10} sampler. Data from this sampler were compared to modeling results for each day.

2.5.1 Model Simulations for the Base Year 1999

After some modifications to the contractor inventory, described in section 2.3.2, the hourly emission files were modeled with the day-specific meteorological files to generate day specific 24-hour average predictions for PM_{10}. Table 2-13 illustrates these results. As previously discussed, the air quality date was matched with the closest inventory date that had the weekend/weekday right, the presence or absence of agricultural tillage, and, for one date, the presence of windblown dust. The elevated PM_{10} concentrations on March 31st were caused by high winds above the dust resuspension threshold. Additional discussion of this modeling date is in section 2.5.2.

Although the overall model performance was satisfactory, it did over predict the measured concentration for each of the seven dates, as shown in Table 2-14 and Figure 2-10. The over predictions ranged from 1.8 to 3.2: that is, the model plus background concentrations were from 1.8 to 3.2 times higher than the measured PM_{10}

Table 2-13. Illustrates the 1999 PM_{10} Results at the Yuma Juvenile Center							
Actual 1999 Met & Air Quality Day	1/12/99	3/31/99	5/30/99	6/23/99	7/17/99	11/8/99	12/8/99
Pechan Inventory Day	1/15/99	4/15/99	4/17/99	7/15/99	7/17/99	10/15/99	1/15/99
PM_{10} (µg/m³)	**148**	**138**	**48**	**67**	**46**	**60**	**85**

Table 2-14. PM_{10} Modeling Predictions versus Observations at the Yuma Juvenile Center							
	Observations			**Predictions**			
Date	**#1**	**#2**	**Average**	**Model**	**Back ground**	**Total**	**Total/ Average**
12 Jan 99	45	55	51	148	15	163	3.20
31 Mar 99	74	102	88	93	25	118	1.85
30 May 99	30	21	26	48	14	62	2.38
23 Jun 99	44	43	44	67	32	99	2.24
17 Jul 99	19		19	46	14	60	3.16
8 Nov 99	32		32	60	14	74	2.30
8 Dec 99	46		46	85	14	99	2.15

The output files generated were also used to create day-specific PM_{10} concentration maps for the Yuma domain. Such concentration maps are Figure 2-11 (a low-wind concentration field), and Figure 2-12 (a high-wind PM_{10} concentration field).

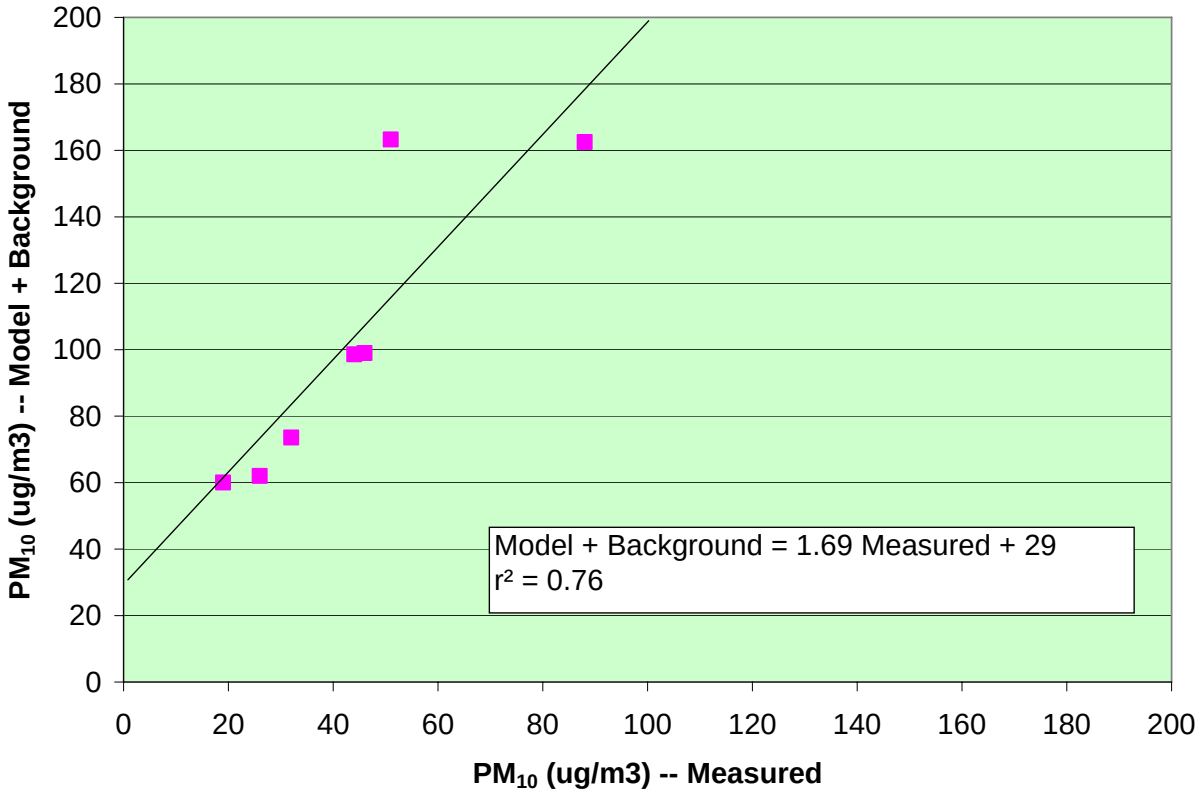

Figure 2-10. Total Prediction (Model + Background) versus Observations of PM_{10} in 1999 – in an X-Y Scatter Plot

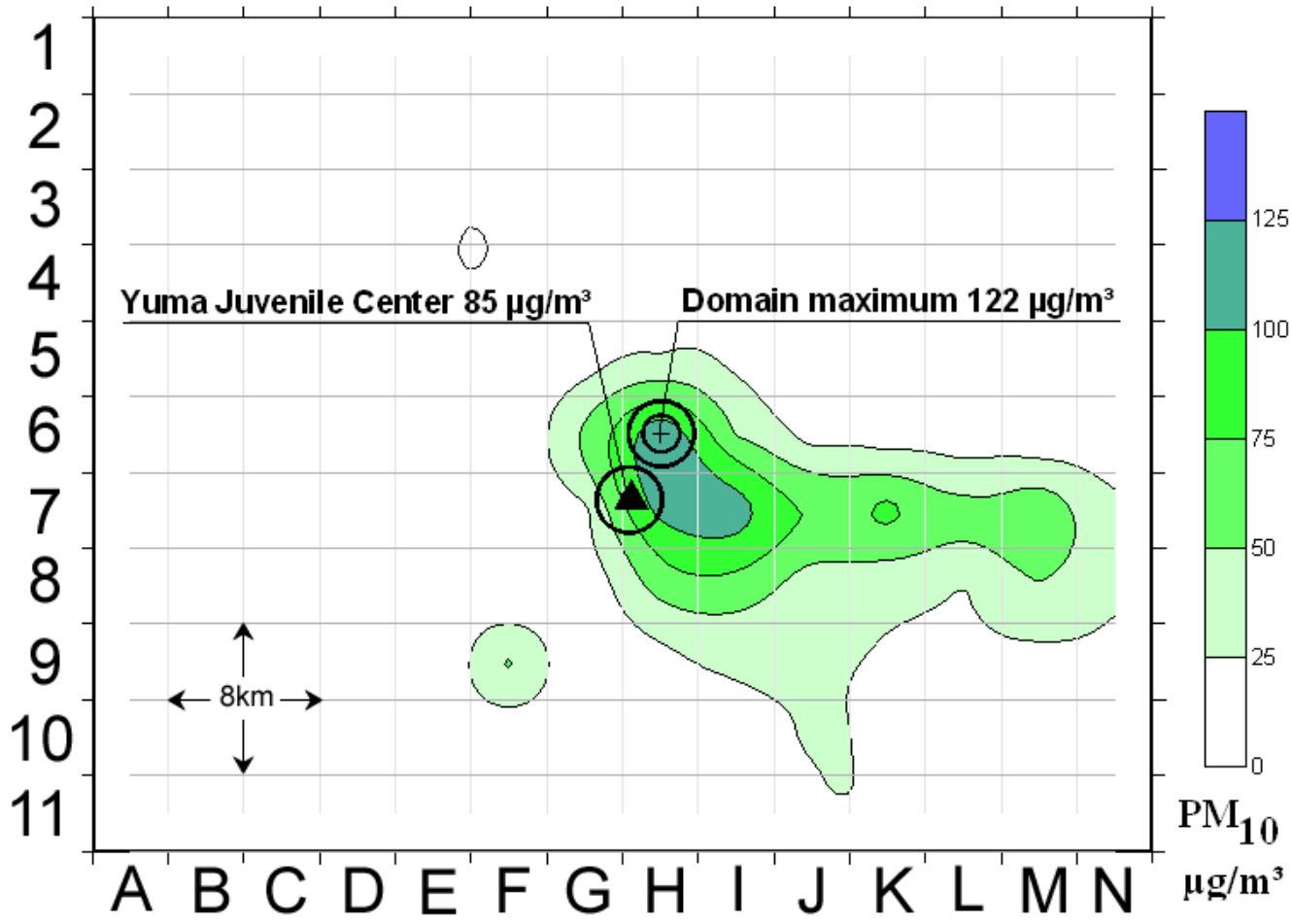

Figure 2-11. Illustrates the December 8, 1999, PM_{10} Results for the Yuma Domain

In Figure 2-11, the low-wind day, the predicted concentrations in the 25 to 50 µg/m^3 range in cell 9F can be attributed to construction emissions: road and general building construction in Somerton. These emissions are evidently high enough to produce these localized concentrations above the 0 to 25 µg/m^3 range. Figure 2-12 shows the PM_{10} concentration distribution on the high-wind day. The highest predicted concentrations are on the order of 800 ug/m3, much higher than is realistic. This eventually led to dropping this date from the analysis, as discussed in the next section.

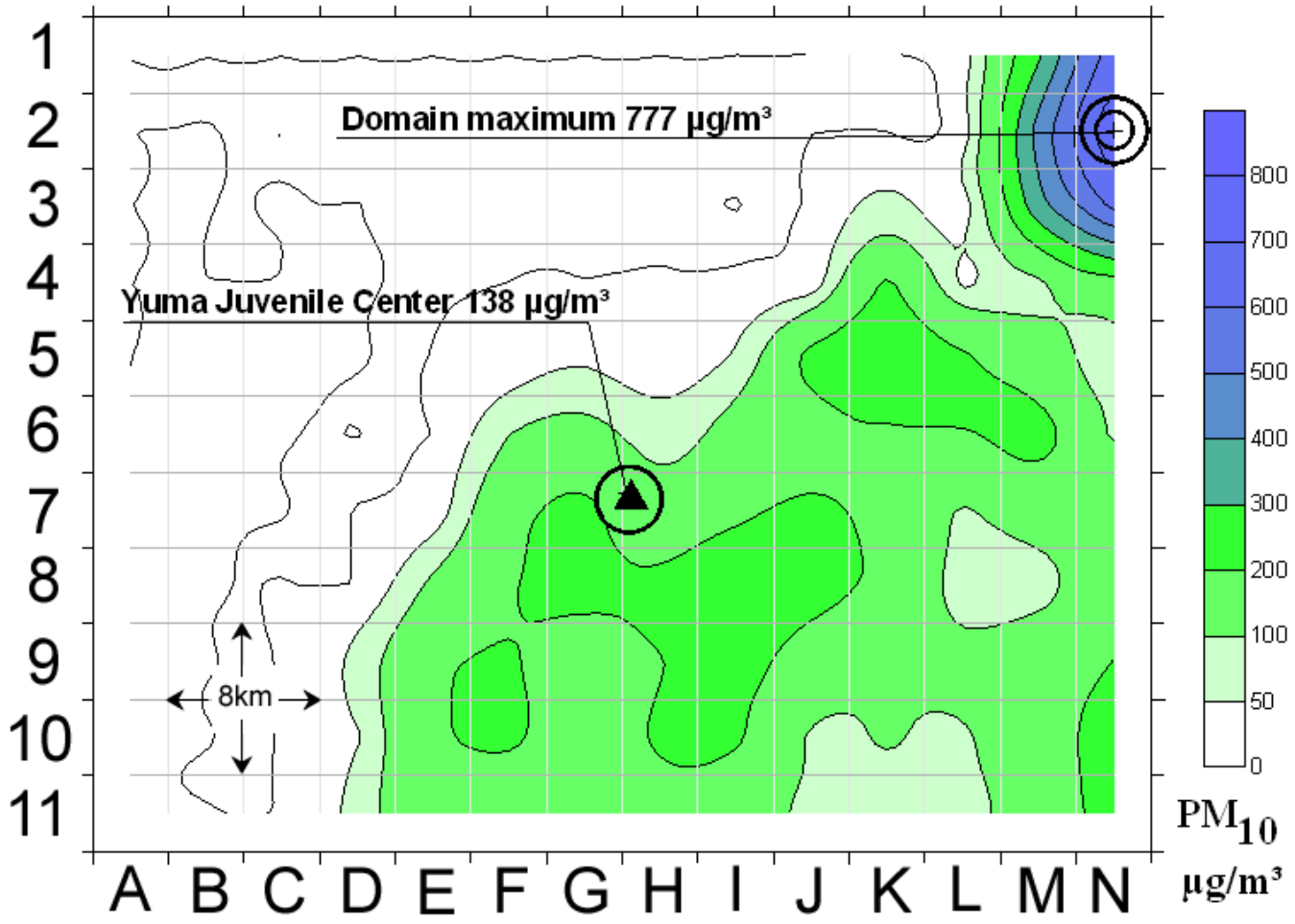

Figure 2-12. Illustrates the March 31, 1999, PM_{10} Results for the Yuma Domain

2.5.2 High-Wind Day Modeling

Numerous sensitivity tests and discussions with EPA Region 9 staff were conducted in the wake of the high-wind day modeling of March 31, 1999, for which the model produced extreme over-predictions. These over-predictions at the monitoring site were tolerable (138 µg/m^3 for the model, 25 µg/m^3 for background, versus a pair of observations of 74 and 102 µg/m^3). Maximum predicted concentrations anywhere in the domain ranged from 300 to nearly 800 µg/m^3. The tests included a limited application of the ISC deposition algorithm, zeroing out emissions in grids near and upwind of the monitor, and adjusting the mixing height. Neither the deposition algorithm nor the mixing height adjustments had any considerable effect on the model output. Zeroing out the emissions, provided the grids were close enough and upwind of the monitor, lowered the predicted concentrations. These sensitivity tests are described in Appendix B.

An attempt was made to derive a semi-empirical relationship between monitored PM_{10} and periods of six to eight hours of high wind speeds. The rationale behind this work lay in a phenomenon called "reservoir depletion." In this phenomenon dust from most land surfaces is resuspended by turbulent winds in large amounts in the first hour or two, but, as the suspendable particles on the surface are depleted, the concentrations of PM_{10} begin to decrease, and do so rapidly. TEOM concentrations of PM_{10} from the Douglas Cemetery and wind speeds taken there in 1999 were examined for several long-duration high-wind events. Although some depletion was observed, there was no consistent pattern and the PM_{10} concentrations seldom fell to near-background levels even by the sixth or seventh hour. The depletion phenomenon fails to occur when the surface dust reservoir is infinite. The classic example of an infinite reservoir is the alluvial surface material of an arroyo or river bottom. In the Douglas site, given the land clearance, road dragging, and vehicular traffic on dirt roads along the border, the land surface might have acted as an infinite reservoir, as well.

A thorough literature search revealed that numerous investigators in laboratory, wind tunnel, and field experiments had attempted to quantify reservoir depletion as an influence on windblown dust concentrations. At this stage, however, the relationships remain qualitative: what's lacking is a firm empirical basis by which to reduce emissions in the latter stages of a multi-hour high wind event. Despite all the effort in modeling PM_{10} concentrations on March 31, 1999, satisfactory answers were never obtained. For the reasons given in the following discussion, this date was dropped from the supporting technical work for the Yuma Maintenance Plan.

If meteorological conditions are so severe as to be classified as "exceptional", then the high concentrations of PM_{10} can be flagged, compliance with the ambient air quality standards is excused, and the community then begins to apply the Best Available Control Measures to those sources contributing to the exceptional concentration. The conditions of March 31, 1999, are exceptional, or fall just short of exceptional, depending on which set of National Weather Service (NWS) winds one uses, since there are differences between what is archived in the ADEQ records and what is

archived in the Web site of the NWS. Discussions based on both sets of data are presented below. In one set, the date does qualify; in the other, it narrowly misses. Whether it is considered officially “exceptional” may not be as important as it was extraordinarily windy.

The measured 24-hour average PM_{10} concentrations at the collocated monitors on March 31, 1999, were 74 and 102 µg/m^3. A trough and frontal passage brought west-northwesterly winds of 20 to 30 miles per hour from 1300 through 2300 hours. Visibility was as low as four to five miles from 1300 to 1600, with blowing dust reported at the National Weather Service station. Hourly average wind speeds are given in Table 2-15. Wind speeds in the two sets of archived data differ significantly, with the result that the first set (Set A) has a 24-hour average wind speed just below the criterion for an exceptional event, while the second set (Set B), has a high enough 24-hour average wind speed for the day to qualify.

Table 2-15. March 31, 1999 Meteorological Records from the Yuma National Weather Service				
Hour	Direction (Degrees)	NWS-A Speed (mph)	NWS-B Speed (mph)	Visibility (Miles)
1	290	13	12	7
2	290	12	14	7
3	300	14	12	7
4	320	12	10	7
5	300	10	8	7
6	300	8	7	7
7	310	7	6	7
8	320	6	9	7
9	300	9	13	7
10	290	13	16	7
11	290	16	17	7
12		**16.5**	**21**	7
13	300	17	25	5
14	300	25	29	5
15	290	29	29	4
16	280	29	29	4
17		**29**	31	7
18	290	29	20	7
19	280	20	20	7
20	300	20	28	7
21	290	28	24	7
22	290	24	24	7
23	290	24	23	7
24	300	23	29	7
	Maximum	29	31	7.00
	Average	18.06	19.00	6.58

The missing observations of wind speed for 1200 and 1700 hours have been interpolated.

According to the May 2000 natural events technical document, a day qualifies as exceptional (and is therefore eligible for flagging and treatment through a Natural Events Action Plan), if it meets either the first two or the first and last three of the following five tests.

1. Three hours must have average wind speeds in excess of 15.7 mph. This date had 14 consecutive hours with wind speeds above this value, which, together, averaged 23.5 mph. This date qualifies.

2. The 24-hour average wind speed is equal to or greater than the 99.9th percentile value, which for Yuma, is 18.6 mph. With Set A, this date falls just short of that (18.1 versus 18.6 mph). For Set B, however, the 19.0 mph average exceeds the 99.9th percentile and the day qualifies.

3. If the 24-hour average wind speed is less than the 99.9th percentile value, does it exceed the 97th percentile value, which for Yuma is 13.6 mph? This date qualifies under this criterion, which keeps it as a qualifying date, provided it can meet the rainfall tests (#4 and/or #5).

4. For a date that passes #1 and #3 but fails #2, the rainfall records are brought to bear. The first rain test is the rainfall in the 60 days before the event, which must be less than the 99th percentile. For Yuma, that figure is 0.00 inches, but in the 60 days before March 31, 1999, the rainfall was 0.42 inches. The date fails this test.

5. For dates failing the 60-day rainfall test, a second rainfall test is invoked that concerns the prior October-March period, which, again, must have rainfall less than the 99th percentile. For Yuma, this figure is 0.20 to 0.28 inches, depending on the station chosen. Rainfall in the October-March period before the March 31, 1999, date was 0.65 inches. The date fails this test.

Of the five tests, a date qualifies if it passes the first two tests, but this date fails the second test with Set A of the wind speed data. With Set B of the wind speed data, the date does qualify as exceptional. If Set A is used, the date then has to pass the third test and one of the two rainfall tests. March 31, 1999, with Set A of the wind speed data, does meet the third test, but ultimately fails because it doesn't pass either of the rainfall tests.

It should be pointed out that these wind speed and rainfall criteria are extremely strict. The fact that the fourth (and fifth) tests do not account for monsoon and other strong frontal conditions that have winds strong enough to overwhelm BACM even if accompanied or followed by rain is one of the reasons why these technical criteria were revised and expanded in 2005. In any case, the meteorology on that date was extraordinary, if not officially exceptional, with its 14 consecutive hours of winds that averaged 24 mph, well above the dust resuspension threshold of 15.7 mph. That the date meets the 24-hour average wind speed criterion and therefore qualifies as exceptional with one set of wind data, but falls just short with the other set, is less important than realizing that wind speeds of this sustained duration are seldom encountered in Yuma.

The exceptional events criteria of February 2005 expand considerably on the earlier version, to account for long range transport of dust (or smoke) under moderate or light winds, and to account for either regional high-wind events or short-lived thunderstorms. Criteria are also spelled out to classify an event as a regional exceptional event, one whose size is large enough to transport blowing dust into an airshed, and whose out-of-airshed emissions are great enough to cause a PM_{10} exceedance (or elevation) and overwhelm Reasonably Available Control Measures (RACM) or Best Available Control Measures (BACM). These criteria adopt a more holistic approach to classifying events as exceptional, employing weight-of-evidence methods. Although March 31, 1999, would not appear to qualify as a regional exceptional event, based on the PM_{10} concentrations recorded in Yuma and vicinity, given in Table 2-16, it may still qualify as "exceptional" through the weight of evidence approach.

Table 2-16. PM_{10} Observations for March 31, 1999

Monitoring Site	PM_{10}
Brawley	33
El Centro	39
Westmoreland	50
Niland	50
Calexico	292
Yuma, original	**102**
Yuma, duplicate	**74**
Ajo	41
Organ Pipe	16
Nogales	37
Mexicali-Cobach	<353
Mexicali-CBTIS	<103
Mexicali-UABC	<160
Mexicali-Progresso	<420

All values are 24-hour PM_{10} concentrations in $\mu g/m^3$ for March 31, 1999; all come from filter-based instruments except Calexico. The "less than sign" (<) figures for the four Mexicali sites arise from the lack of available daily sampling data. For these sites for 1999, only the four highest values and their dates were available. None of the values occurred on March 31, 1999, so all that is known about the PM_{10} on this date is that it is less than the fourth-highest value in the summary report. None of the downwind monitoring sites, east of Yuma, shows any elevation. Only one of the five upwind sites in the Imperial Valley – Calexico – has an elevated 24-hour PM_{10} concentration. Its peak concentration and its moderate late afternoon and evening concentrations are inconsistent with the timing of the high winds in Yuma (Figure 2-13).

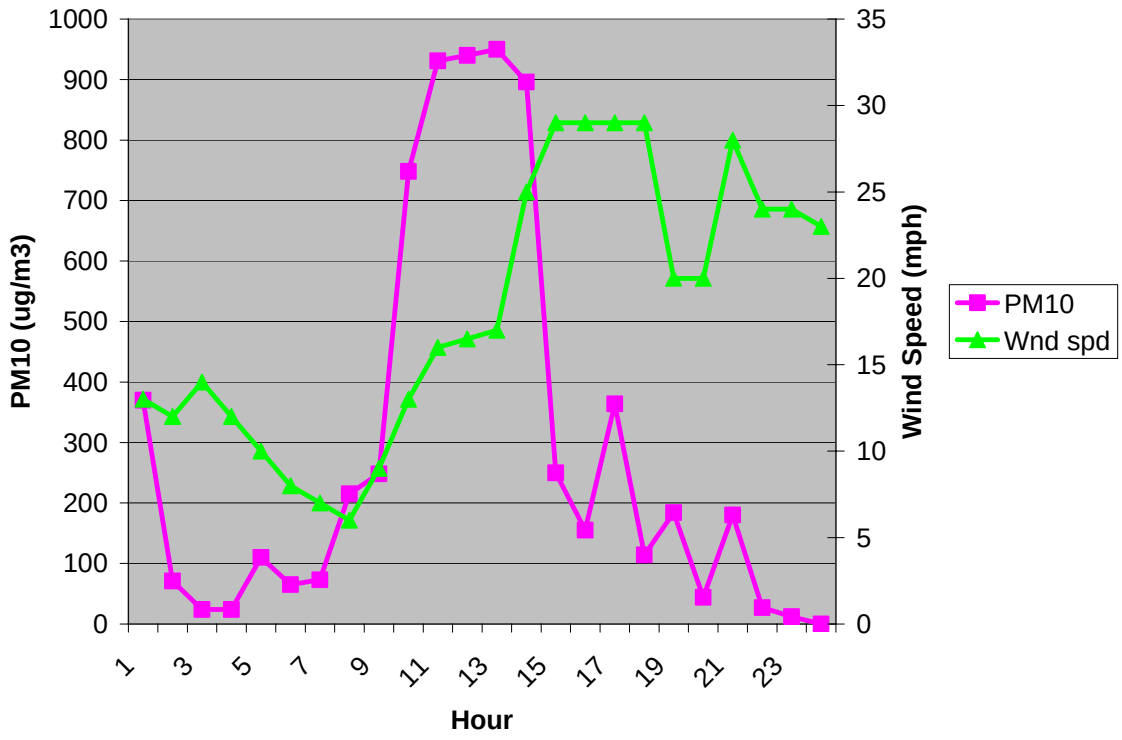

Figure 2-13. March 31, 1999, Wind Speeds from Yuma and Hourly PM_{10} from Calexico

All of this suggests that the blowing dust observed in Yuma on March 31, 1999 was more localized than regional. While the technical criteria include closer examination of meteorology, attribution to emission sources, and the contribution from regional natural sources, the spatial distribution and magnitude of the PM_{10} concentrations on this date do not lend themselves to a regional explanation. The concentrations in the Imperial Valley and southern Arizona were rather low, ranging from 33 to 41 µg/m^3, in contrast to Yuma's 74 and 102 µg/m^3. Calexico was the lone monitoring site with elevated PM_{10} concentrations, averaging 292 µg/m^3 for the 24 hours. The Imperial Valley sites are all within a circle of ten miles radius. Ten miles south of El Centro, Calexico would seem to have been influenced by close-in sources that were absent in the Imperial Valley. Yuma is 55 miles east of Calexico. Although the elevated Yuma concentrations were undoubtedly related to the extremely high Calexico ones, a pattern of regionally elevated values, from the Imperial Valley, through Yuma, and to points east, is simply not there. Thus, this date does not fit in well with the regional exceptional event hypothesis.

Even though the date may or may not qualify as an exceptional event, either local or regional, a number of arguments can be made to exclude it from the modeling analysis in the Yuma Maintenance Plan. These arguments are based on the inability of both the emissions and air quality models to adequately simulate the measured concentrations, as well as on there being no regulatory issues that would be resolved by including this date in the modeling.

The first consideration is the actual wind speeds used in the modeling for the Yuma PM_{10} Maintenance Plan, versus the official National Weather Service (NWS) measurements. Presented in Table 2-17, the NWS measured wind speeds are considerably higher than those used in the model, which come from the AZMET station called Yuma Mesa.

Table 2-17. Wind Speeds on March 31, 1999		
	Wind Speed (mph)	
Hour	National Weather Service (10 m Height)	Yuma-Mesa (3 m Height)
1	13	2.9
2	12	4.0
3	14	4.9
4	12	3.6
5	10	4.3
6	8	3.1
7	7	2.7
8	6	3.6
9	9	8.7
10	13	13.6
11	16	13.2
12	**16.5**	13.4
13	17	13.9
14	25	14.8
15	29	15.0
16	29	17.9
17	**29**	18.3
18	29	14.5
19	20	15.2
20	20	15.7
21	28	15.9
22	24	14.8
23	24	17.7
24	23	13.9
n>=15	14	7
Max	29	18.34
Average	18.06	11.06

With a wind speed threshold of 15.7 mph or greater for causing windblown emissions, the model had seven hours with these windblown emissions, as opposed to the 14 hours had the NWS measurements been used. The Yuma Mesa site has a lower anemometer height (three as opposed to 10 meters), and is somewhat shielded with vegetation and citrus, unlike the open areas of the Marine Corps Air Station with its NWS anemometer. Maximum concentrations predicted from the NWS wind speeds would have been on the order of 1600 µg/m^3 for a 24-hour PM_{10} average, in contrast to the 777 µg/m^3 predicted from the Yuma Mesa wind speeds. By selecting the lower wind speeds from the Yuma-Mesa site for the modeling, Assessment staff were cognizant of the modeling difficulties and were trying to minimize them.

The second consideration is the inherent uncertainty of the emissions modeling. Satellite images were examined for division into six land surface types. This technology is advanced enough that it does an adequate job for all large-scale surface features. The 4x4 kilometer grids employed in the emissions/air quality model were then assigned the corresponding amount of each land surface type, and an emission factor in grams per meter squared per second was assigned commensurate with the area of the erodible land surface. The problem here is not with the image work, but, rather, what emission factor to assign that accurately reflects the wind-driven mass flux from soil surfaces of variable erodibility, of variable soil moisture, and with variable threshold wind speeds for resuspension. Additional uncertainty is introduced by this simple scheme because it has no way to account for either the depletion of erodible particles from the upwind surface or for their deposition and accretion onto the same surface from high-wind advection further upwind. Another simplification in the emissions modeling is the lack of any dependence on wind speed. Higher winds above the threshold will generate more dust emissions, but in this work, the emissions are a constant value for any hour with the threshold wind speed or above. Accurate simulations based on emissions modeling with these uncertainties are difficult to achieve.

The third consideration concerns the dispersion modeling. Can a Gaussian plume model such as the Industrial Source Complex be expected to produce believable simulated concentrations under such turbulent conditions? Can it adequately account for deposition (this was not even attempted, except for some sensitivity tests)? In its area source configuration, used exclusively in the Yuma analysis, the model effectively takes a 4x4 kilometer grid of uniform emissions and disperses it downwind toward the receptors. Given that emissions throughout a 16 square kilometer area are seldom, if ever, uniform, then the model begins with a handicap even before dispersion takes place.

Predicted 24-hour PM_{10} concentrations on this date were 163 µg/m^3 at the monitor, where the observations were 74 and 102 µg/m^3. These figures and the rest in this discussion are the model output plus the background concentration of 25 µg/m^3. Considering the entire domain, the predictions ranged from 54 to 802 µg/m^3. Table 2-18 summarizes the predictions.

Table 2-18. PM_{10} Predictions for March 31, 1999	
Range	**Percent**
>400	7.7
300-400	7.7
200-300	35.9
150-200	16.7
<150	32.1
>150	67.9

Two thirds of the predictions are above the standard of 150 µg/m^3; 15% of the predictions are higher than the highest monitored concentration in the historical record (281 µg/m^3). While the precise degree of over prediction is only known at the monitor receptor, the maximum predicted concentration of 802 µg/m^3 and the percentage of predictions greater than 300 µg/m^3 suggest that

a) The windblown emissions were simply too high and the dispersion model was faithfully simulating them; or

b) The windblown emissions were accurate but the dispersion model was over predicting in these turbulent conditions; or

c) The emissions were over estimated and the dispersion model was over predicting.

Whichever the case, the net result is a set of simulated 24-hour PM_{10} concentrations that is inconsistent with the historical record, cannot be verified by the monitoring network, and cannot support maintenance of the air quality standard.

A fourth consideration is the lack of monitoring data in the Yuma PM_{10} modeling domain: one monitoring site in 154 grids of 4x4 kilometers. Reasonable agreement between the model and the measurements at the monitoring site does not even begin to suggest that in other grids with variable emissions similar performance would be obtained. For example, there is not a way to verify the elevated concentrations predicted by the model in the northeast corner of the domain (Yuma Proving Grounds) for the March 31, 1999, design date.

A fifth consideration is that in over 20 years of PM_{10} monitoring in Yuma, no 24-hour concentration on the order of 800 µg/m^3 has ever been recorded. The annual high and second-high 24-hour average PM_{10} concentrations from 1985 through 2003 are shown in descending order in Figure 2-14.

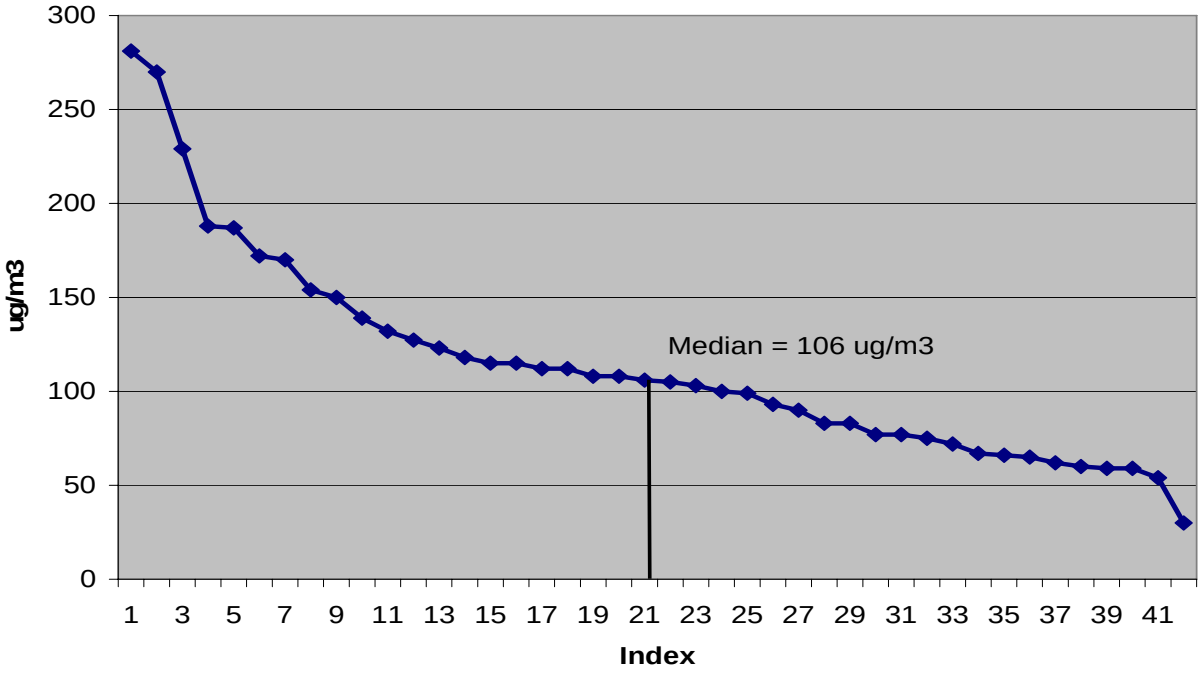

Figure 2-14. Yuma PM_{10} Concentrations: Annual Highs and Second-Highs from 1985 through 2003, Arranged in Descending Order

The top ten values from this figure are shown in Table 2-19 and reveal the following two features of these extreme PM_{10} concentrations:

1. The highest concentrations have remained below 300 µg/m^3, and have not approached the predicted maximum of 802 µg/m^3 from the modeling.

2. With one exception – 2001 -- these highest 24-hour PM_{10} concentrations all occurred 15 to 20 years ago.

Table 2-19. Yuma 24-Hour Average PM_{10} Concentrations: 1985 -2003: the Ten Highest Annual Maximum or Second-Highest Concentrations	
Year	**PM_{10} (ug/m3)**
1985	281
1990	270
1991	229
1991	188
1987	187
1985	172
1987	170
2001	154
1989	150
1989	139

Given the random paths that violent summer thunderstorms take, and given the somewhat more homogeneous wind fields associated with the passage of dry cold fronts (e.g. March 31, 1999), monitoring at a fixed site in north-central Yuma could reasonably be expected to record in 20 years at least a few elevated PM_{10} concentrations considered as domain-wide maxima. If this is the case, then these maxima are in the 200 – 300 µg/m^3 bracket, which is well below the model-predicted maximum of 800 µg/m^3.

The sixth consideration concerns the magnitude of the observations on March 31, 1999 – 74 and 102 µg/m^3. Although these were the highest 24-hour PM_{10} concentrations of 1999 – and formed the rationale for modeling that date -- they were still well within the 24-hour PM_{10} standard. In a Maintenance Plan analysis, then, these concentrations do not in and of themselves compel modeling.

The seventh consideration is that the extremely high and persistent winds of March 31, 1999 – which averaged 24 mph for a 14-hour period – would have overwhelmed the benefits of Best Available Control Measures.

The eighth and last consideration is that this modeling is unnecessary to select additional control strategies, which has already been done for the Natural Events Action Plan (NEAP) analysis for August 18, 2002.

Modeling PM_{10} concentrations for the Yuma PM_{10} modeling domain for this particular high-wind design day, March 31, 1999, has proven to be intractable. Successful simulations would seem to depend on a large scale field research study in which the relationships between soil surface type, moisture content, silt content, wind speed threshold, depletion and accumulation phenomena, and resultant concentrations could be empirically determined. Such a study would be far beyond the scope of this Maintenance Plan and its schedule, and thus that research is out of the question for

now. Instead, based on the preceding arguments, the high-wind day modeling day of March 31, 1999 has been removed from the Yuma Maintenance Plan.

2.5.3. Model Predictions throughout the Domain

The discussions of the last two subsections concern the model-simulated PM_{10} concentrations at a particular point in Yuma: i.e. at the monitoring site located at the Yuma Juvenile Center. While model performance is necessarily limited to the location of the monitoring site, the larger picture of how PM_{10} concentrations are distributed across the modeling domain of Yuma is more important. The Clean Air Act requires that all points within an airshed meet the air quality standards. This section demonstrates that the PM_{10} standards are met throughout the Yuma area.

The simulated concentrations throughout the domain, shown graphically in Figures 2-9 and 2-15, shed some light on how elevated PM_{10} concentrations are distributed throughout the Yuma area on a high-wind and low-wind day. For the low-wind day of December 8, 1999, the measured concentration was 46 $\mu g/m^3$; the model-predicted concentration at the monitor was 85 $\mu g/m^3$; and the maximum prediction anywhere in the domain was 122 $\mu g/m^3$. On that day the highest predicted concentrations and the domain maximum were concentrated in three grid cells (total area of 48 square kilometers) immediately to the northeast and east of the monitor. This close proximity of the monitor with the predicted maximum suggests that under low-wind conditions the model adequately places the highest concentrations in the region near the monitor.

The maximum predicted PM_{10} concentrations anywhere in the domain are now examined in light of the over-predictions at the monitoring site. Table 2-20 begins with the observation ("Obs") of the 24-hour average PM_{10} concentration at the Juvenile Center. On its right is the calculated background value ("Back") from Section 2.4. Because background PM_{10} comes from outside of the Yuma area, it is subtracted from the observation ("Obs – Back"). This difference – the observation with the background subtracted – can then be compared with the ISC model prediction. Dividing this difference by the prediction gives the decimal fractions in the "Ratio" column. For those total predicted concentrations (model plus background) within the standard of 150 $\mu g/m^3$, these fractions are not used. Instead, the model prediction plus the background goes into the far right column called "normalized maximum."

For those predictions that would be above the standard, the fractions are multiplied by the value of the predicted maximum anywhere in the domain (next to last column), with the background added back in to give the "Normalized Maximum". These concentrations are the highest anywhere in the modeling domain. They account for both the background concentration and for the degree of over-prediction by the modeling system. More importantly, these normalized maximum, domain-wide PM_{10} concentrations, reflect the distribution and magnitude of PM_{10} emissions throughout the Yuma area. This set of predicted concentrations demonstrates that all of the Yuma airshed complies with the 24-hour PM_{10} standard, not just the Juvenile Center.

Table 2-20. Domain-Wide PM_{10} Concentrations in Yuma, Based on ISC Model Predictions at the Juvenile Center and Throughout the Domain							
Date	**Yuma Juvenile Center**					**Anywhere in the Modeling Domain**	
	Obs	**Back**	**Obs - Back**	**ISC Model Prediction**	**Ratio (Obs –Back) to Prediction**	**ISC Predicted Maximum**	**Normalized Maximum (with Back-Ground)**
1/12	51	15	36	148	0.24	195	62
5/30	26	14	12	48	0.25	78	92
6/23	44	32	12	67	0.18	97	129
7/17	19	14	5	46	0.11	69	83
11/8	32	14	18	60	0.30	100	114
12/8	46	14	32	85	0.38	122	136

Notes:

Obs	Observation or measurement of PM_{10}
Back	Background PM_{10} concentration (calculated)
Obs – Back	Difference of the two
Ratio	(Observation minus Background) divided by the model prediction
Normalized Maximum	Highest predicted PM_{10} in the domain, normalized for the model over-prediction, and with background added in.

(All values are calculated or measured PM_{10} concentrations in µg/m3 averaged for 24 hours.)

This compliance is shown for the six low-wind days. For the six low-wind days the normalized domain maxima vary from 62 to 136 µg/m^3, within the 150 µg/m^3 standard. el predictions and those predictions that resulted from the emissions rollback described

2.6 Model Simulations for the Projected Year 2016

For the 2016 air quality predictions, Pechan built a set of 2016 emissions files. These files were adjusted and modeled in the same fashion as the 1999 files and generated the PM_{10} predictions of Table 2-21. Figure 2-15 illustrates the low-high wind simulation of December 8, 2016, while Figure 2-18 illustrates high-wind simulation for March 31, 2016.

Table 2-21. Illustrates the 2016 PM_{10} Results at the Yuma Juvenile Center

Actual Met & Air Quality Day	1/12/99	3/31/99	5/30/99	6/23/99	7/17/99	11/8/99	12/8/99
Pechan Inventory Day	1/15/99	4/15/99	4/17/99	7/15/99	7/17/99	10/15/99	1/15/99
PM_{10} (µg/m³)	**107**	**28**	**48**	**49**	**28**	**37**	**61**

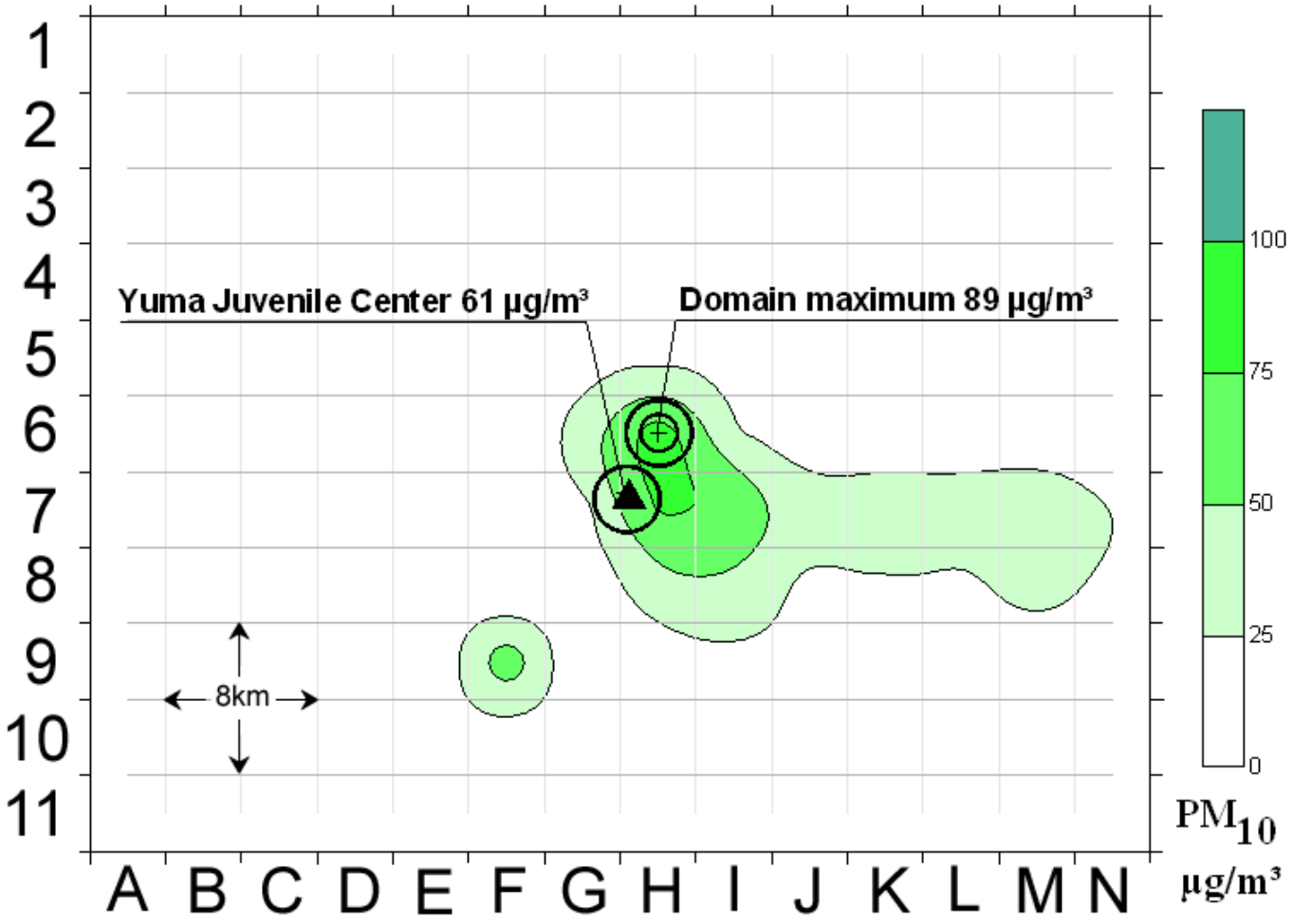

Figure 2-15. Illustrates the December 8, 2016 PM_{10} Results for the Yuma Domain

2.7 Demonstration of Attainment

Attainment in 2016 is shown by examining the 1999 observations, calculating the ratio of the 2016 to 1999 total predictions, and applying these ratios to the base year observations. All of these figures, except the ratios, have been assembled in Table 2-22.

Table 2-22. PM_{10} Concentrations in 1999 and 2016 in Yuma: Observations and Model Results

Date	1999: Observations & Model Results				2016: Model Results	
	Average Observation	Model Prediction	Background	Total Prediction	Model Prediction	Total Prediction
1/12/99	51	148	15	163	107	122
5/30/99	26	48	14	62	48	62
6/23/99	44	67	32	101	49	81
7/17/99	19	46	14	60	28	42
11/8/99	32	60	14	74	37	51
12/8/99	46	85	14	99	61	75

In Table 2-23, the 2016 predicted concentrations are shown in the far right column. These values are merely the 1999 observation less the background, multiplied by the ratio of the 2016 model prediction to the 1999 model prediction, and then with the background added back in. The background is independent of the Yuma emissions profile and is assumed to remain constant between 1999 and 2016. The logic requires that this background be subtracted from the observation, and the model prediction ratio between 2016 and 1999 be applied to this difference. After this ratio is applied to the "local concentration", i.e. the measured PM_{10} less the background – the background needs to be added back in.

As an example, January 12 has a 24-hour average PM_{10} measurement of 51 µg/m^3. Subtracting the background of 15 µg/m^{3}gives 36 µg/m^3. This 36 µg/m^3 can be considered the PM_{10} concentration generated by local Yuma emissions. The air quality dispersion model responds only to local emissions. For 2016 the model prediction is 107 µg/m^3. The 1999 model prediction is 148 µg/m^3. Their ratio is (107/148) = 0.72. This ratio multiplied by 36 µg/m^3 gives 26 µg/m^3. Adding the background to this value gives the 2016 predicted concentration of 41 µg/m^3.

Table 2-23. Yuma PM_{10} Concentrations for 2016							
	1999			Model Predictions		Ratio (2016/1999) Model Predictions	2016 Calculated PM_{10}
Date	Obs	Back	Obs – Back	2016	1999		
1/12/99	51	15	36	107	148	0.72	41
5/30/99	26	14	12	48	48	1.00	26
6/23/99	44	32	12	49	67	0.73	41
7/17/99	19	14	5	28	46	0.61	17
11/8/99	32	14	18	37	60	0.62	25
12/8/99	46	14	32	61	85	0.72	37
Avg	43.7	18.3				0.76	

Notes: (Units are µg/m^3)
Obs is the observation: 24-hour average PM_{10} at the Yuma Juvenile Center
Back is the background concentration
Obs – Back is the background subtracted from the observation

The concentrations in this table demonstrate that Yuma air quality over a ten-year horizon will remain well in compliance with the 24-hour PM_{10} standards. Similar arguments can be invoked for the annual standard. The base-year annual PM_{10} average was 37.0 µg/m^3. This average is based on 56 sampling days, 29 of which had both the original and duplicate samples taken. Based on the background and model predictions for the seven design dates of 1999, this annual average is expected to decrease slightly by 2016 – to 32 µg/m^3. The necessary calculations for this exercise are illustrated in Table 2-24.

Table 2-24. Demonstration of Attainment for the Annual PM_{10} Standard in 2016 in Yuma		
Line #	Description	Statistic
1	Average PM_{10} : 6 Design Days 1999 (µg/m^3)	36.3
2	Average PM_{10} : 6 Background Concentrations (µg/m^3)	17.1
3	Average: 6 Background as a Fraction of Observations	0.47
4	Average: 6 2016/1999 Model Prediction Ratio	0.73
5	1999 Annual Average PM_{10} (Juvenile Center) (µg/m^3)	37.0
6	1999 Average Background Value (µg/m^3) [line 3 x line 5]	15.5
7	1999: Annual Average – Average Background (µg/m^3) [line 5-6]	21.5
8	2016 local PM_{10} (µg/m^3) [line 7 x line 4]	15.8
9	2016 Annual Average (µg/m^3) [line 8 + line 6]	31.3

An examination of annual PM_{10} averages before and after 1999 reveals that this method would predict attainment in 2016 for the range of concentrations in the most recent ten years. The base year of the study – 1999 – is in no way unique or unusual (Table 2-25 and Figure 2-16).

Table 2-25. Yuma PM_{10} Annual Averages: 1985 - 2004

Year	Annual Average
1985	**63**
1986	**56**
1987	50
1988	41
1988	38
1989	**52**
1989	37
1990	**57**
1991	41
1992	29
1993	31
1994	32
1995	35
1996	36
1997	36
1998	47
1999	35
2000	42
2001	41
2002	48
2003	38
2004	40

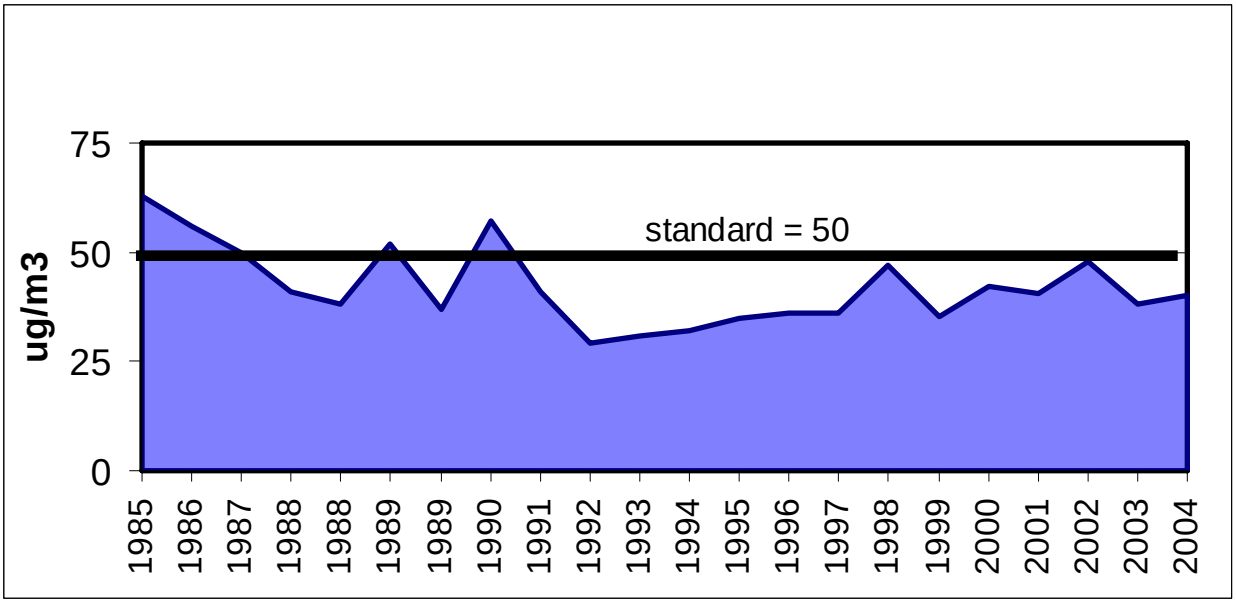

Figure 2-16. Annual PM_{10} Averages for Yuma: 1985 - 2004

2.8 Summary of Attainment Demonstration

- Six representative design dates from 1999 were chosen to include all the seasons, to include days with agricultural tillage, and to include the highest measured PM_{10} concentrations on low-wind days.

- An inventory of PM_{10} emissions was constructed that included all known sources. This inventory was adapted for use in a numerical model.

- This numerical model, called Industrial Source Complex Short Term (ISC), then simulated PM_{10} concentrations for the six design days, based on the emissions in the inventory and meteorological measurements specific to the design day.

- Background concentrations of PM_{10} were calculated from measurements and transport paths from monitors in the Yuma vicinity.

- When background plus model concentrations were compared with measurements at the Yuma Juvenile Center, the modeling system consistently over-predicted the PM_{10} measurements.

- Accounting for these over-predictions, and with a 2016 inventory of emissions, compliance with the PM_{10} standards can be shown at the monitoring site.

- Given the maximum predicted PM_{10} concentrations anywhere in the modeling domain, and again accounting for the over-predictions and for the background, compliance with the standards can be shown throughout the Yuma area through 2016.

- In summary, both the ambient record of the past several years and the modeling exercise described in this chapter, demonstrate attainment of the 24-hour and annual PM_{10} standards from 1999 to 2016 at the Yuma Juvenile Center. This same state of attainment has been shown to prevail throughout the Yuma area by utilizing the spatial distribution of PM_{10} concentrations provided by the ISC model.