ADDENDUM

Natural Event Documentation

Corcoran, Oildale and Bakersfield, California
September 22, 2006

San Joaquin Valley Unified
Air Pollution Control District

May 23, 2007

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LIST OF FIGURES AND TABLES

1. SUMMARY

This document is an addendum to the September 22, 2006 Natural Event Documentation for Corcoran, Oildale and Bakersfield, CA submitted to the California Air Resources Board (CARB) on April 5, 2007. The purpose of this addendum is to provide additional analysis to demonstrate that:

- The dust cloud that reached Corcoran during the morning of September 22, 2006 was transported to Oildale/Bakersfield; and
- As the dust cloud moved southeast from Corcoran, additional PM10 was entrained by high winds and transported to Oildale/Bakersfield.

Section 2 presents data to show that wind speeds and directions were sufficient to transport the dust cloud that affected Corcoran to Bakersfield by the early afternoon.

Section 3 demonstrates that winds between Corcoran and Bakersfield were sufficient to entrain more geologic dust that was later deposited in Bakersfield.

Section 4 demonstrates the infrequency of September coarse fraction PM episodes in the Southern San Joaquin Valley, and assesses the correlation between regional wind speeds and PM concentrations.

Figure A-1 is a map showing area of wind blown dust analysis and includes the towns of Corcoran, Alpaugh, Oildale and Bakersfield.

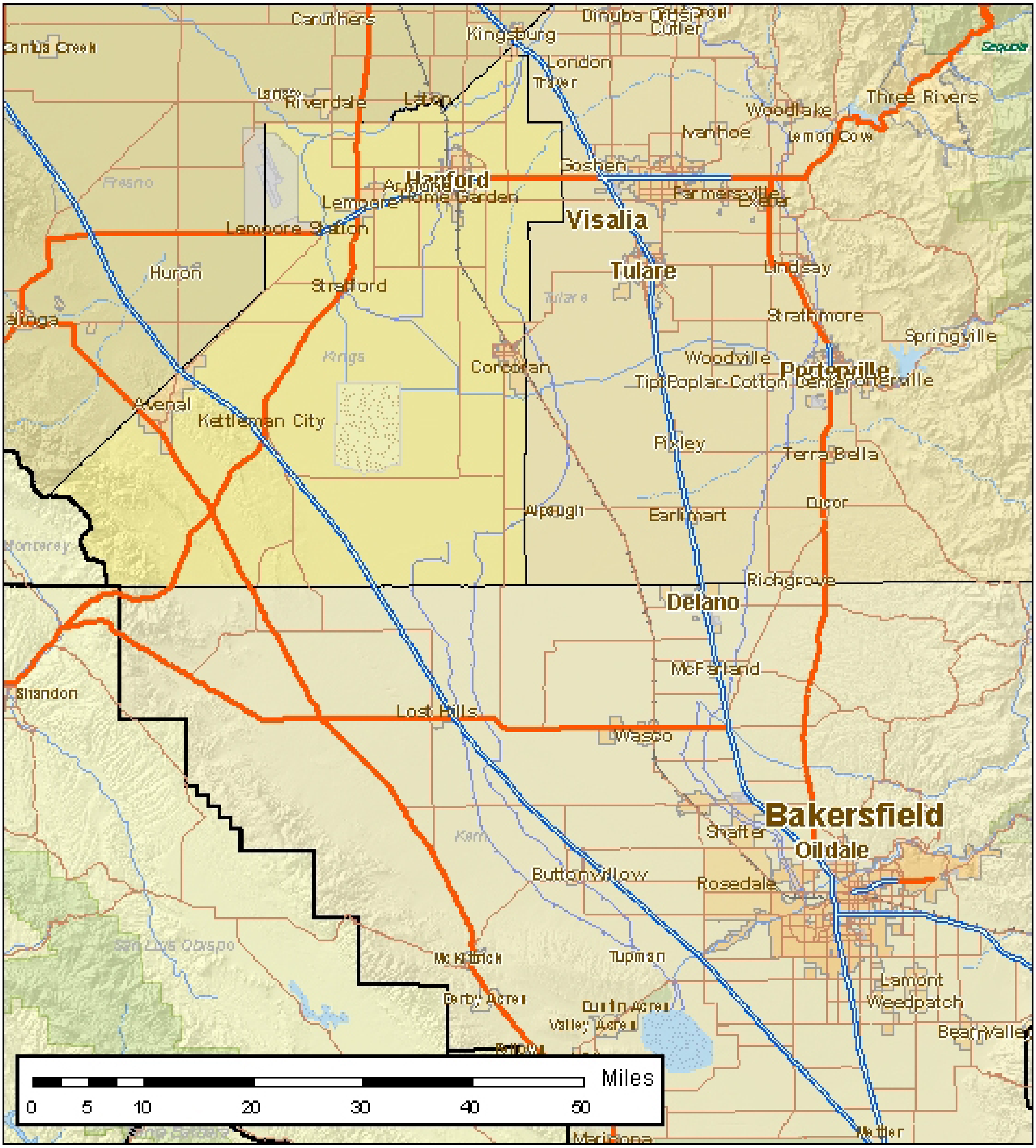


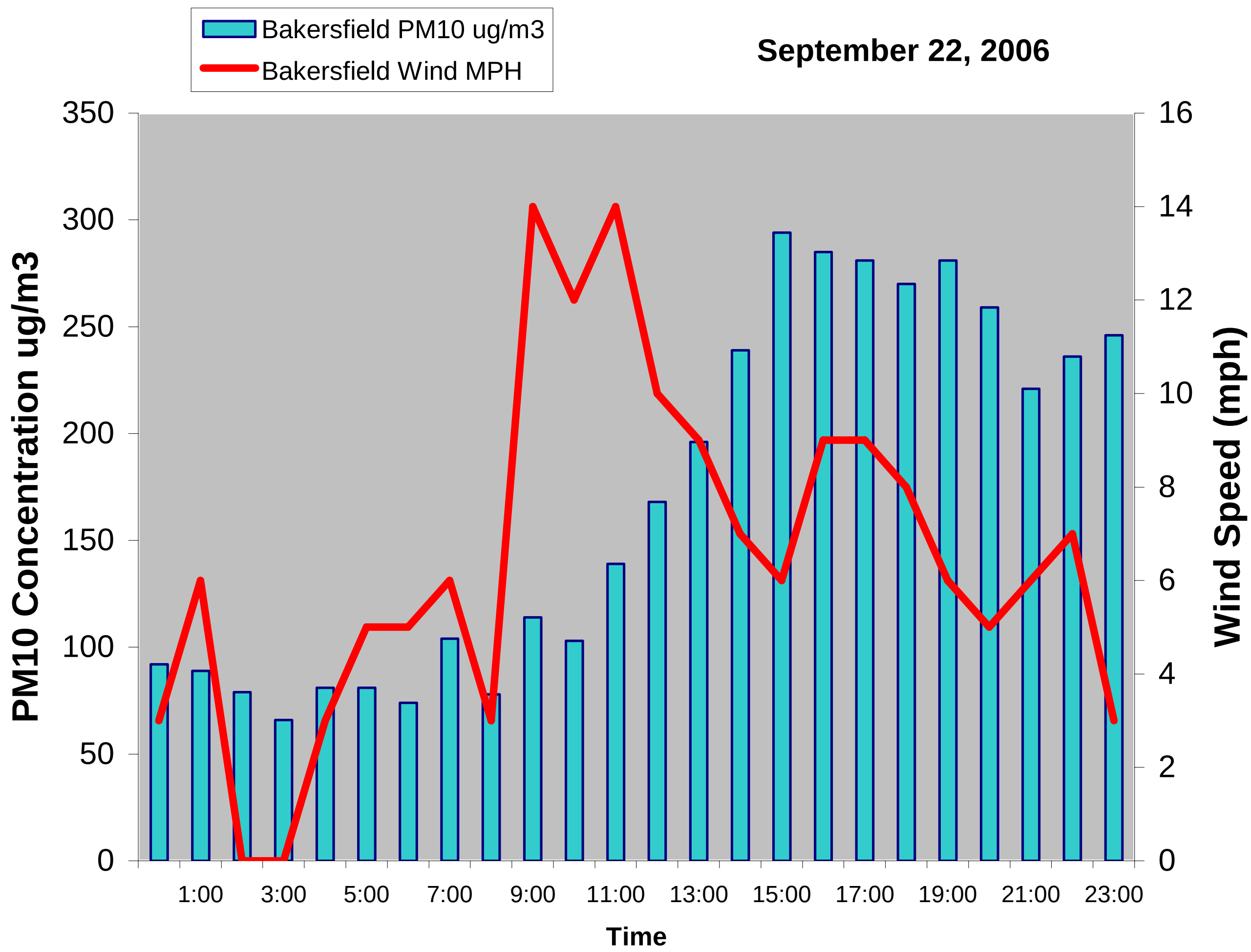
Figure A-1. Map showing area of the wind blown dust analysis.

2. PARTICULATE TRANSPORT FROM CORCORAN TO BAKERSFIELD

This discussion will show that wind speeds were sufficient to transport the dust plume peak from Corcoran to Bakersfield.

To transport the plume peak 55 miles from Corcoran to Oildale and Bakersfield in five hours, the wind speed would need to average at least 11 miles per hour. The five-hour average wind speed at Alpaugh, which is between Corcoran and Bakersfield, was 11.5 mph for the five-hour period from hour 10 to hour 14.

Figure A-2 and Table A-1 demonstrates that the plume peak arrived in Bakersfield by hour 15.



Wind speed is a 10 minute average at the top of the hour, peak gusts are higher than 10 minute averaged data.

Figure A-2. September 22, 2006 hourly PM10 concentrations at Bakersfield - Golden State and sustained 10 minute averaged wind speed at Bakersfield - Meadows.

Table A-1. September 22, 2006 PM10 data for Corcoran and Bakersfield, and relevant wind data.

Hour	Corcoran PM10 (μg/m^3)	Alpaugh Hourly Averaged Wind Speed (mph) and Wind Direction at 2 meters AGL	Bakersfield - Meadows Airport Wind Speed (mph) and Wind Direction at 10 meters AGL	Bakersfield Golden St. PM10 (μg/m^3)	Maricopa Wind Speed (mph) and Wind Direction at 10 meters AGL
0	63	3.7 SSE	3 WNW	92	6 WSW
1	39	3.1 SSE	6 NNW	89	6 WSW
2	51	2.8 SSE	CALM	79	5 WSW
3	64	2.9 SE	CALM	66	7 SW
4	55	3.4 SW	3 ESE	81	6 SW
5	78	4.4 W	5 ESE	81	6 SW
6	170	2.6 WSW	5 ESE	74	7 M15 WSW
7	306	7.7 NNW	6 ENE	104	17 M21 NW
8	519	15.2 NNW	3 NE	78	13 M23 NNW
9	531	12.1 NNW	14 NW	114	7 M13 NE
10	725	12.3 NNW	12 WNW	103	6 M11 ESE
11	695	12.8 NW	14 WNW	139	5 E
12	521	10.8 NW	10 G16 WNW	168	6 ENE
13	318	9.6 NW	9 G17 W	196	6 E
14	276	9.6 NW	7 WNW	239	6 ENE
15	247	8.1 NW	6 W	294	6 ENE
16	269	7.7 NNW	9 NW	285	7 ENE
17	283	4.4 NNW	9 NW	281	6 ENE
18	258	3.5 WSW	8 NW	270	4 SW
19	223	4.0 W	6 NNW	281	5 WSW
20	150	2.5 NNW	5 N	259	4 WSW
21	144	2.7 NW	6 NNE	221	5 WSW
22	138	3.1 W	7 NNE	236	5 WSW
23	144	2.6 SSE	3 NE	246	6 W

Hour 0 is Midnight to 1 AM, Pacific Standard Time. Alpaugh wind data is from the California Irrigation Management Information System (CIMIS) monitors. CIMIS wind speed is an hourly average sampled at 2 meters above ground level (AGL). Hourly averaged winds typically are much lower than peak gusts. Wind speed measured at 2 meters would typically be would be lower than wind speed measured at 10 meters at the same location. For Bakersfield Meadows: G = Hourly peak gust, sustained wind is a 10 minute average at beginning of hour. Weather data at Bakersfield Meadows was obtained through the http://www.met.utah.edu/mesowest/ website. Maricopa wind data is an hourly average. M denotes peak minute average for that hour.

Figure A-3 is a streamline analysis for hour 10 on September 22, 2006 showing strongest winds extending from the area north and west of Corcoran to Bakersfield.

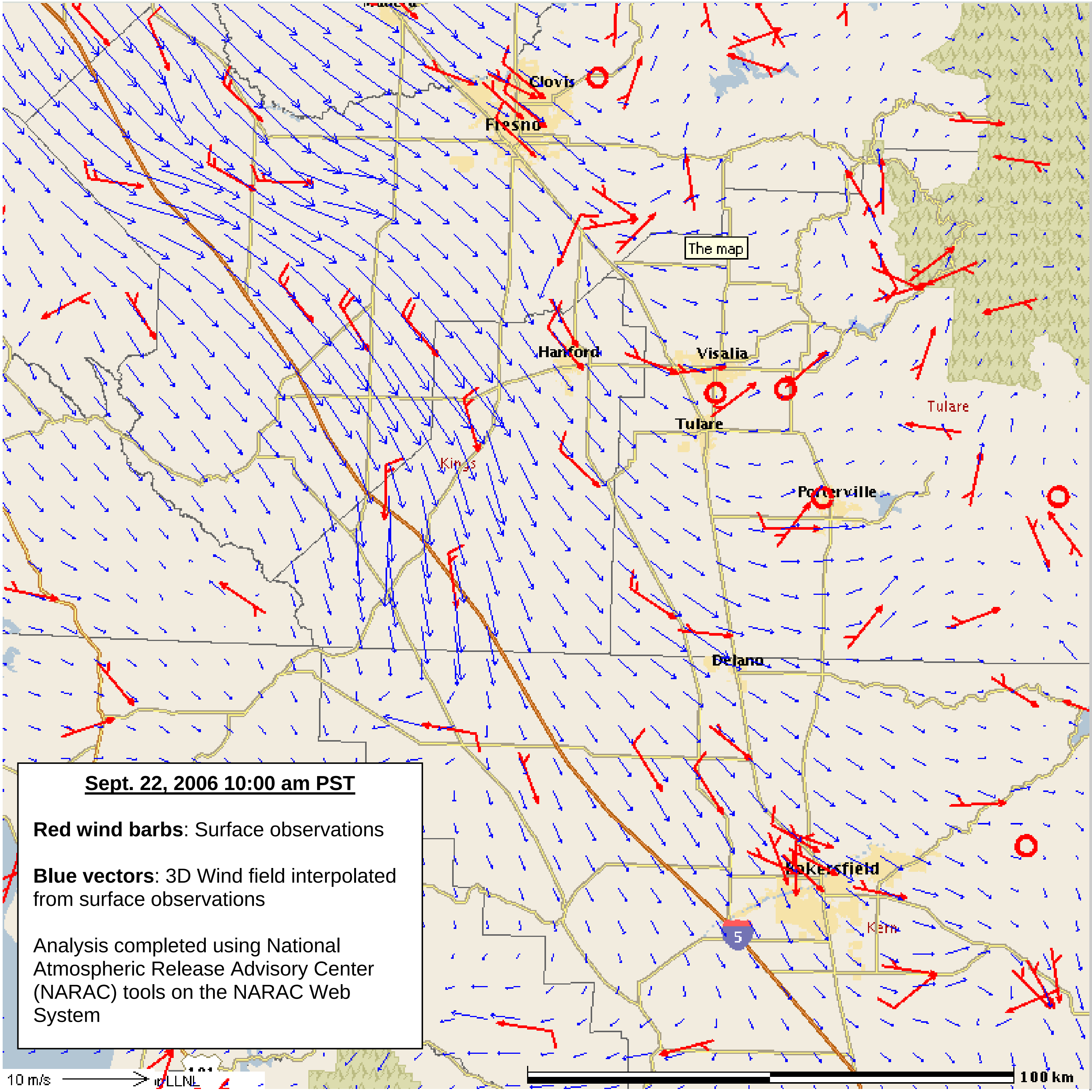


Figure A-3. Streamlines for Hour 10 on September 22, 2006.

A computer simulation has been provided via email to CARB and the Environmental Protection Agency (EPA) that shows that the dust cloud traveled from the Corcoran area to Bakersfield. A technical explanation of the computer simulation follows.

The Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model was run for the natural event to identify the air parcel source regions that contributed to peak particulate concentrations in Bakersfield. HYSPLIT development is a joint effort between the National Oceanic and Atmospheric Administration and Australia's Bureau of Meteorology. This type of modeling is called particle dispersion modeling. The term particle refers to the method by which the air parcels are moved (not particulate concentration). The HYSPLIT model computes air parcel trajectories based on meteorological observation data files from the National Weather Service's Centers for Environmental Prediction (NCEP). The model and full documentation are available at: http://www.arl.noaa.gov/ready/hysplit4.html

The HYSPLIT model was used to simulate the flow field for air parcels that arrived in Bakersfield between 2 PM and 10 PM PST, to identify the areas that contributed to peak particulate concentrations at Bakersfield. The animation indicates that the area north and west of Corcoran was the main source region for air arriving in Bakersfield during peak concentrations recorded from 2 PM to 10 PM PST. Still images from the animation are provided in Figure A-4. Dots on the images indicate air parcel movement, not particulate concentration.

Figure A-4a shows that dust entrained by winds at 4 AM PST, just before Tracy's peak concentration, would have been able to travel to Bakersfield to contribute to peak concentrations.

Figure A-4b shows the regions at 7 AM PST that are contributing to the Bakersfield peaks. The main source of this air mass is just northwest of Corcoran at a time when peak particulate concentrations are beginning to be observed at Corcoran.

Figure A-4c shows the air mass at 10 AM PST in the vicinity of Corcoran during Corcoran's observed peak hour.

Figure A-4d shows the air mass at 2 PM PST, as it arrives in Bakersfield for the beginning hour of Bakersfield concentrations exceeding 200 $\mu g/m^3$.

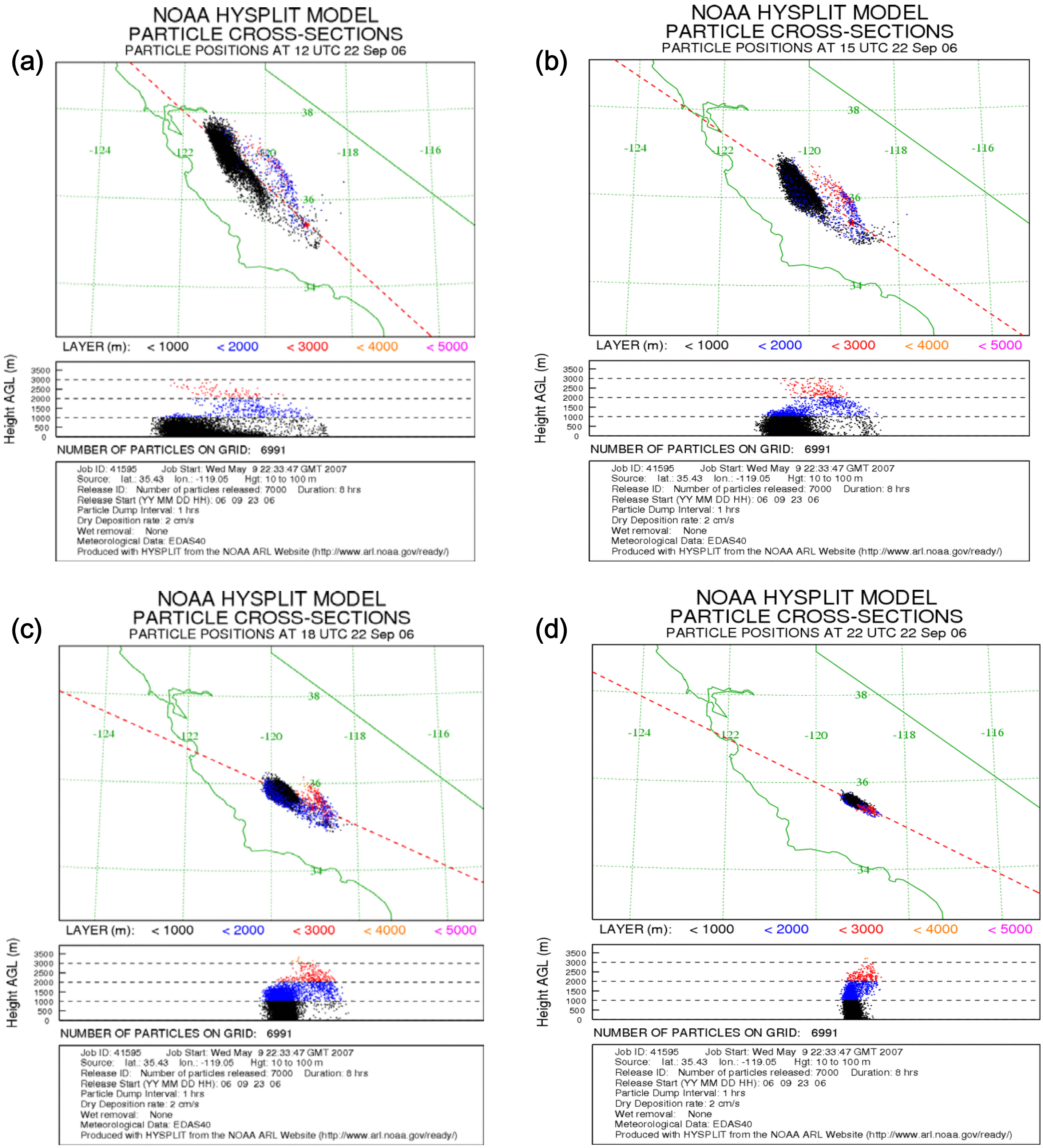


Figure A-4. NOAA HYSPLIT airflow simulation for air parcels that arrived in Bakersfield between 2 pm and 10 pm PST are shown for (a) 4:00 am PST, (b) 7:00 am PST, (c) 10:00 am PST and (d) 2:00 pm PST. Dots on the images indicate air parcel movement, not particulate concentration.

An animation of visual satellite images has been provided to CARB and EPA via email, which shows a cloud of particulate traveling across the San Joaquin Valley midday on September 22. This cloud of particulate had to be very significant to be visible in the satellite image.

3. EVIDENCE OF DUST ENTRAINMENT BETWEEN CORCORAN AND BAKERSFIELD

The following discussion will demonstrate that winds between Corcoran and Bakersfield were sufficient to entrain dust into the atmosphere. The wind speed at Alpaugh, which is located between Corcoran and Bakersfield, is shown to be above the dust entrainment wind speed threshold.

Dust entrainment threshold

A report for the San Joaquin Air Quality Study Agency (Bush, 2004) concluded that wind speeds of 8 m/s (17.6 mph) recorded at 10 meters above ground level could be sufficient to entrain surface soil into the atmosphere.

Variation in wind speed with height

Over a flat surface with no obstructions and a well-mixed atmosphere, wind speed typically varies logarithmically with height above ground. This relationship can be modeled using the equation:

$$V_1 / V_2 = (Z_1 / Z_2)^p$$

where:
V = wind speed,
Z = height above ground,
p is approximately 0.143 for flat terrain and 0.4 for rough terrain,

and the subscripts 1 and 2 denote two different sampling heights above ground level (AGL). In some weather conditions, this equation is not representative of the vertical wind structure. However, it is appropriate to use this equation for the strong wind conditions that occurred on September 22, 2006.

Using this equation, the Alpaugh CIMIS station reported a peak hourly averaged wind speed of 15.2 mph at 2 meters AGL (see Table A-1 and CIMIS data in the appendix). Using the equation provided for flat terrain, the hourly averaged wind speed at 10 meters AGL would be 19.1 mph, as shown below.

$$V_{10\text{ meters}} = V_{2\text{meters}} \, (Z_{10\text{ meters}} / Z_{2\text{ meters}})^{0.143}$$

$$V_{10\text{ meters}} = (15.2\text{ mph})\,(10\text{ meters}/2\text{ meters})^{0.143}$$

$$V_{10\text{ meters}} = 19.1\text{ mph}$$

The wind speed at Alpaugh, which is located between Corcoran and Bakersfield, was above the dust entrainment wind speed threshold of 17.6 mph on September 22, 2006. The equation referenced above is found in a number of documents, including:

- California Department of Water Resources document, *Wind in California,* (*Bulletin No. 185, January 1978*), and
- An Introduction to Boundary Layer Meteorology by Roland Stull, 1997

4. EVIDENCE OF UNUSUAL NATURE OF THE NATURAL EVENT.

This section will demonstrate that the high PM10 concentrations are infrequent in September. Figure A-5 is a plot of maximum daily PM10 concentrations for Corcoran, Bakersfield and Oildale in September for years 2000 to 2006, which indicates that high PM10 concentrations reported on September 22, 2006 are unusual.

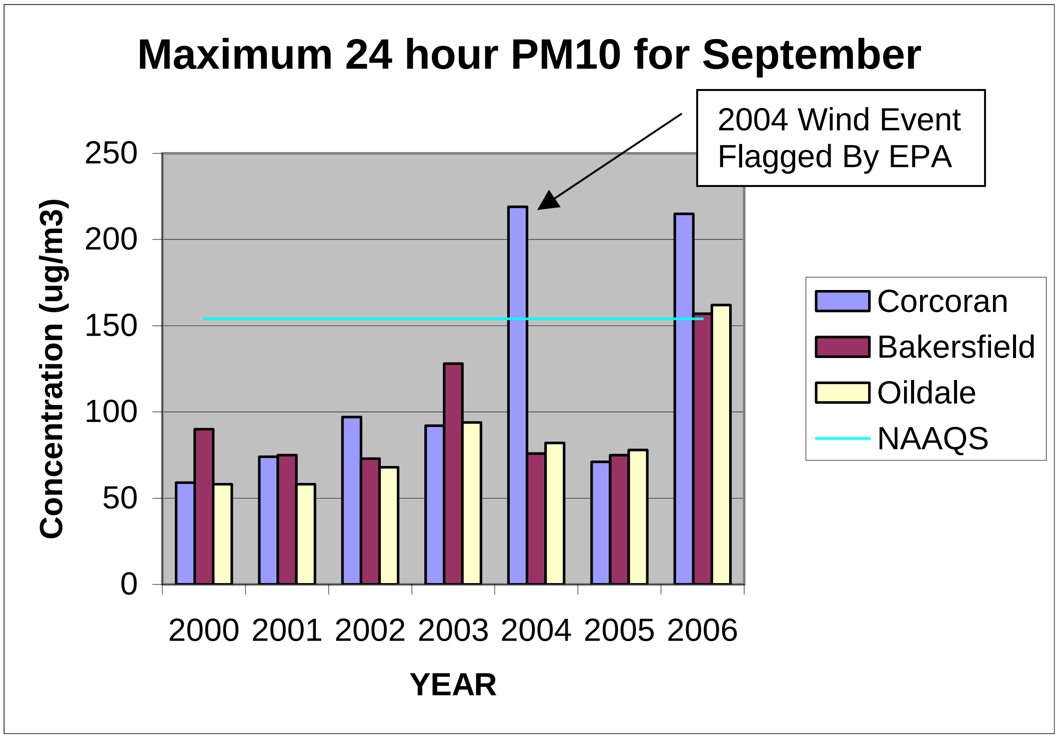


Figure A-5. Maximum daily PM10 concentrations at Corcoran, Bakersfield and Oildale for September.

Figure A-6 presents maximum hourly wind speed data on September PM10 monitoring days in the years 2001 through 2006. With the exception of the September 3, 2004 and September 22, 2006 high wind natural events, maximum hourly winds speeds in September were mostly between 4 to 8 miles per hour. This data demonstrates that PM10 exceedances on September 22, 2006 were unusual and the high PM10 was caused by high winds.

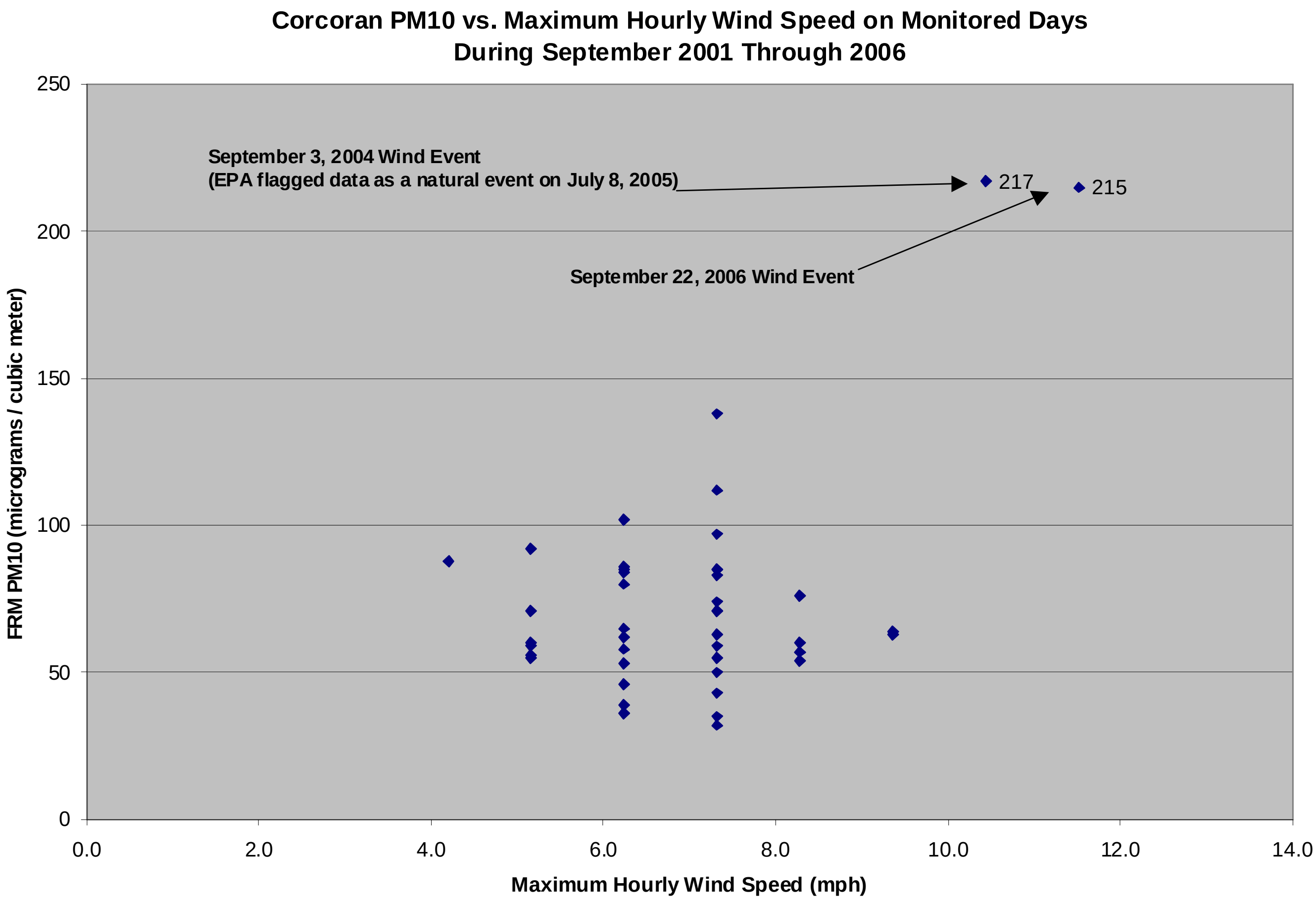


Figure A-6. Corcoran PM10 vs. Maximum Hourly Wind Speed on Monitored Days During September 2001 through 2006

5. REFERENCES

California Department of Water Resources, *Wind in California; Bulletin No. 185,* January 1978

California Department of Water Resources, *California Irrigation Management Information System (CIMIS),* http://wwwcimis.water.ca.gov/cimis/welcome.jsp

David Bush, T&B Systems Contribution to CRPAQS Initial Data
Analysis of Field Program Measurements, Final Report Contract 2002-06PM
Technical & Business Systems, Inc., November 9, 2004
http://www.arb.ca.gov/airways/CRPAQS/DA/Final/TBFinalOverview.pdf

Mesowest historical meteorological data, *Mesowest,* http://www.met.utah.edu/mesowest/

National Oceanic and Atmospheric Administration (NOAA): ARL website, HYSPLIT model, http://www.arl.noaa.gov/ready/cmet.html

National Oceanic and Atmospheric Administration (NOAA): Weather data, http://www.weather.gov

Lawrence Livermore National Laboratory. National Atmospheric Release Advisory Center (NARAC), NARAC Web System

Roland Stull, An Introduction to Boundary Layer Meteorology, Kluwer Academic Publishers, 1997, Page 376, Section 9.7

6. APPENDIX

6.1 Wind data for the Alpaugh CIMIS station on September 22, 2006

Date	Hour	ETo (in)	Precip (in)	Sol Rad (Ly/day)	Vapor Pressure (mBars)	Air Temp (°F)	Rel Hum (%)	Dew Point (°F)	Wind Speed (MPH)	Wind Dir (0-360)	Soil Temp (°F)
09/22/2006	0100	0.00	0.00	0	10.4	56.0	68	45.5	3.7	161.8	74.0
	0200	0.00	0.00	0	10.3	56.8	65	45.3	3.1	158.4	73.6
	0300	0.00	0.00	0	10.0	55.9	66	44.6	2.8	155.6	73.1
	0400	0.00	0.00	0	10.6	53.3	77	46.2	2.9	140.3	72.7
	0500	0.00	0.00	0	9.8	53.9	69	44.0	3.4	235.8	72.2
	0600	0.00	0.00	6	9.9	56.8	63	44.3	4.4	265.2	71.8
	0700	0.00	0.00	184	9.9	59.5	57	44.2	2.6	253.1	71.4
	0800	0.01	0.00	538	7.8	65.7	36	38.2	7.7	341.3	71.0
	0900	0.02	0.00	886	7.1	68.6	30	35.8	15.2	339.3	70.8
	1000	0.02	0.00	1160	7.2	70.7	28	36.0	12.1	338.4	71.0
	1100	0.02	0.00	1371	7.0	72.6	26	35.3	12.3	327.9	71.8
	1200	0.03	0.00	1474	6.7	75.1	23	34.3	12.8	321.2	73.0
	1300	0.03	0.00	1485	6.6	77.7	20	34.1	10.8	314.5	74.2
	1400	0.02	0.00	1352	6.3	79.7	18	32.7	9.6	321.0	75.5
	1500	0.02	0.00	1119	6.0	80.7	17	31.4	9.6	315.8	76.5
	1600	0.02	0.00	780	5.9	80.9	16	31.1	8.1	312.9	77.2
	1700	0.01	0.00	397	6.7	80.3	19	34.3	7.7	332.3	77.3
	1800	0.00	0.00	78	7.2	76.5	23	36.1	4.4	343.2	77.0
	1900	0.00	0.00	0	8.5	70.1	34	40.4	3.5	257.2	76.5
	2000	0.00	0.00	0	9.4	63.9	46	42.9	4.0	270.7	75.8

6.2 Wind data for Bakersfield-Meadows Airport on September 22, 2006

Time(PDT)	Temperature	Dew Point	Wet Bulb Temperature	Relative Humidity	Wind Speed	Wind Gust	Wind Direction	Quality check	Pressure	Sea level pressure	Altimeter	1500 m Pressure	Weather conditions	Visibility
	° F	° F	° F	%	mph	mph			in	in	in	in		miles
22:50	68.0	33.8	50.9	28	3		NE	OK	29.25	29.77	29.79	24.86	clear	
21:50	69.1	32.0	50.8	25	7		NNE	OK	29.24	29.76	29.78	24.85	haze	8.00
20:50	71.1	32.0	51.7	24	6		NNE	OK	29.22	29.75	29.76	24.83	haze	8.00
19:50	73.0	33.1	52.8	23	5		N	OK	29.20	29.72	29.74	24.82	haze	5.00
18:50	75.0	36.0	54.5	24	6		NNW	OK	29.19	29.71	29.73	24.81	haze	5.00
17:50	79.0	35.1	55.8	20	8		NW	OK	29.17	29.69	29.71	24.79	haze	5.00
16:50	80.1	32.0	55.4	17	9		NW	OK	29.17	29.69	29.71	24.79	haze	5.00
15:50	80.1	32.0	55.4	17	9		NW	OK	29.17	29.70	29.71	24.79	haze	5.00
14:50	79.0	34.0	55.5	20	6		W	OK	29.19	29.72	29.73	24.81	haze	5.00
13:50	78.1	33.1	54.9	19	7		WNW	OK	29.21	29.73	29.75	24.83	haze	6.00
12:50	75.9	33.1	54.0	21	9	17	W	OK	29.23	29.75	29.77	24.84	clear	9.00
11:50	73.9	33.1	53.2	22	10	16	WNW	OK	29.24	29.76	29.78	24.85	clear	10.00
10:50	73.0	36.0	53.7	26	14		WNW	OK	29.24	29.76	29.78	24.85	clear	10.00
9:50	71.1	39.0	54.0	31	12		WNW	OK	29.22	29.75	29.76	24.83	clear	10.00
8:50	70.0	42.1	54.7	36	14		NW	OK	29.20	29.73	29.74	24.82	clear	10.00
7:50	69.1	41.0	53.9	36	3		NE	OK	29.18	29.70	29.72	24.80	clear	9.00
6:50	64.9	41.0	52.2	42	6		ENE	OK	29.15	29.68	29.69	24.78	clear	9.00
5:50	64.9	42.1	52.6	43	5		ESE	OK	29.15	29.67	29.69	24.78	clear	10.00
4:50	63.0	42.1	51.8	46	5		ESE	OK	29.15	29.67	29.69	24.78	clear	10.00
3:50	64.9	42.1	52.6	43	3		ESE	OK	29.16	29.68	29.70	24.78	clear	10.00
2:50	66.0	43.0	53.4	43	0			OK	29.17	29.70	29.71	24.79	clear	10.00