

State of Arizona
PM_{2.5} Exceptional Event Documentation Supplement for
the Previously Submitted September 2, 2011
PM₁₀ Windblown Dust Exceptional Event

Produced by:

Arizona Department of Environmental Quality
Maricopa County Air Quality Department
Maricopa Association of Governments

DRAFT Final Report
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1. INTRODUCTION

On September 2, 2011, the JLG Supersite monitor (04-013-9997-88101-3) and the North Phoenix monitor (04-013-1004-81102-3) exceeded both¹ the 24-hour PM_{2.5} and annual PM_{2.5} standards as a result of a high wind exceptional event. The PM₁₀ Exceptional Event documentation for September 2, 2011 was submitted to EPA on January 28, 2013 and the exceedances included therein received concurrence from EPA on May 6, 2013. This supplemental document related to PM_{2.5} exceedances that occurred during the same time period builds upon the initial documentation for the high wind exceptional events that caused eleven Phoenix area monitors to exceed the PM₁₀ standard on September 2, 2011.

The information provided in the following sections of this supplemental document show that the PM_{2.5} exceedances at the JLG Supersite and North Phoenix monitors on September 2, 2011 were due to a high wind exceptional event by showing that:

- a. The event satisfies the criteria set forth in 40 CFR 501(j) that:
 - (1) the event affected air quality,
 - (2) the event was not reasonably controllable or preventable, and
 - (3) the event was caused by human activity unlikely to recur in a particular location or was a natural event;
- b. There is a clear causal relationship between the measurement under consideration and the event;
- c. The event is associated with a measured concentration in excess of normal historical fluctuations; and
- d. There would have been no exceedance or violation but for the event.

¹ As stated in EPA's *Interim Exceptional Events Rule Frequently Asked Questions*, May 2013, on pages 34-35, "The preamble [to the Exceptional Events Rule] states that in the particular case of PM_{2.5}, the direct comparison of a single 24-hour average concentration (determined from a single filter-based measurement or by averaging 24 1-hour measurements from a continuous equivalent instrument) to the level of the annual NAAQS can be the basis for meeting the 'but for' criterion for exceedances or violations of the annual NAAQS.²⁴ In context, it is clear that based on this comparison, a 24-hour concentration can be excluded from the calculation of the annual PM_{2.5} design value, if other rule criteria are also met. It is therefore not necessary to show that the annual average PM_{2.5} concentration was above 12 or 15 µg/m³ with the event and would have been below 12 or 15 µg/m³ 'but for' the single event at issue."

2. CONCEPTUAL MODEL

As explained in detail in Section 2 of the previously approved PM₁₀ main document, on the evening of September 1, 2011, intense thunderstorms developed over the higher terrain of northwestern Mexico and into far southern Arizona. These thunderstorms expanded northward and weakened, but the thunderstorms generated dust-carrying outflow boundaries that propagated towards south-central Arizona including the Phoenix area during the early morning on September 2, 2011. The windblown dust resulted in 24-hour average PM₁₀ concentrations in exceedance of the NAAQS at eleven air quality monitors in the Phoenix area. In addition to generating and transporting high hourly and five-minute concentrations of PM₁₀, windblown dust carried by the outflows produced excessive hourly PM_{2.5} concentrations peaking at 453 µg/m³ at the JLG Supersite monitor and 734 µg/m³ at the North Phoenix monitor. The transported PM_{2.5} from the dust storm ultimately caused both monitors to exceed the PM_{2.5} standard on this date (i.e., 38 µg/m³ and 46 µg/m³ 24-hour averages, respectively). A map of current PM_{2.5} monitors in Maricopa County is provided in Figure 1. As a summary of the event, Table 1 contains PM_{2.5} concentration data from all recorded monitors throughout Maricopa County, as well as PM₁₀ concentrations co-located at PM_{2.5} monitoring sites. Figure 2 and 3 displays hourly graphs of PM_{2.5} and PM₁₀ concentrations, respectively, throughout Maricopa County before, during, and after the September 2, 2011 windblown dust event.

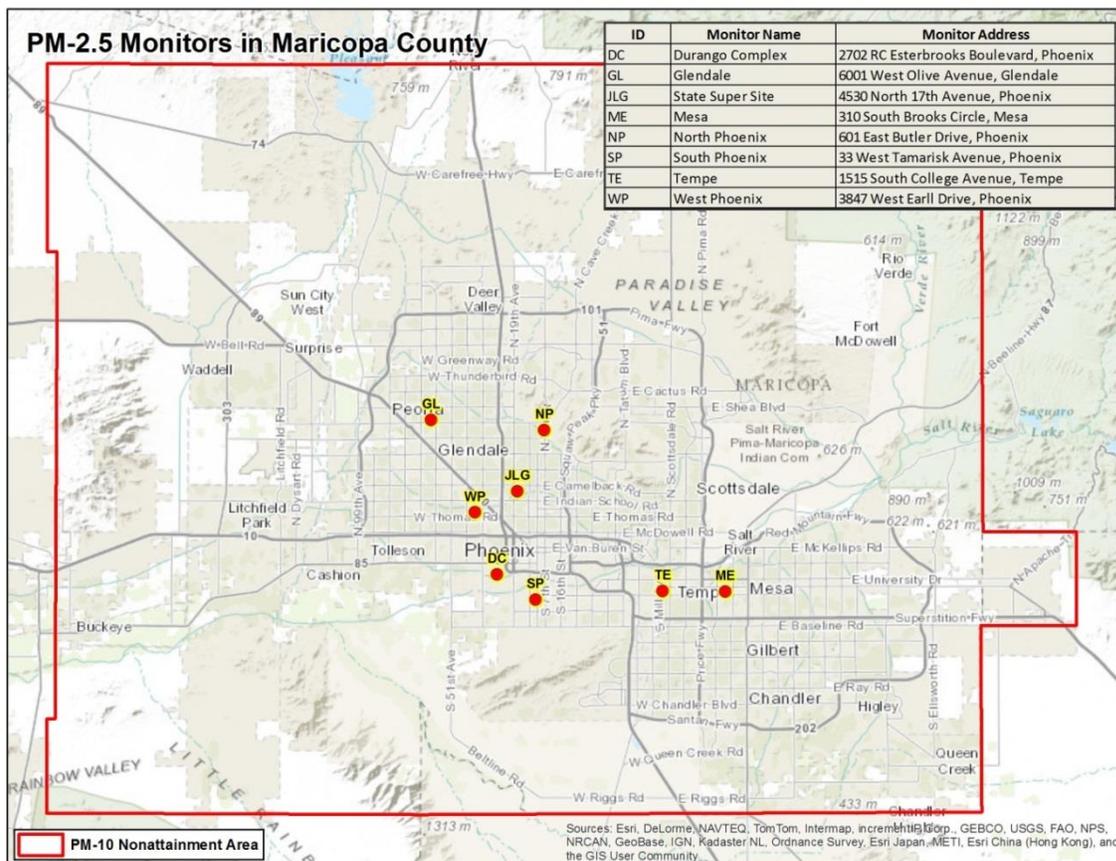


Figure 1. PM_{2.5} monitors in Maricopa County (2013).

Table 1. Summary of PM_{2.5} and PM₁₀ measurements in Maricopa County on September 2, 2011.

MARICOPA COUNTY ¹						
Monitor	AQS Monitor ID	24-Hour Average PM _{2.5} Concentration (µg/m ³)	1-Hour Maximum PM _{2.5} Concentration (µg/m ³)	Maximum PM _{2.5} Concentration Time	24-Hour Average PM ₁₀ Concentration (µg/m ³)	AQS Qualifier Flag
Durango Complex	04-013-9812-88101-3	26.3	321	0200	255.4	
Glendale	04-013-2001-88101-3	20.4	64	2000	132.2	
JLG Supersite-BAM	04-013-9997-88101-3	38.3	453	0200	150.7	RJ
JLG Supersite-TEOM	04-013-9997-88102-4	35.2	310.1	0200	208.9	
North Phoenix	04-013-1004-81102-3	46.9	734.7	0200	115	RJ
South Phoenix	04-013-9997-88101-3	26.1	297	0200	339.3	
West Phoenix	04-013-0019-88101-3	17.2	31.2	0300	133.6	

SOURCE: ¹ Data as reported in EPA's Air Quality System (AQS) database. *Data unavailable for North Phoenix monitor during event.

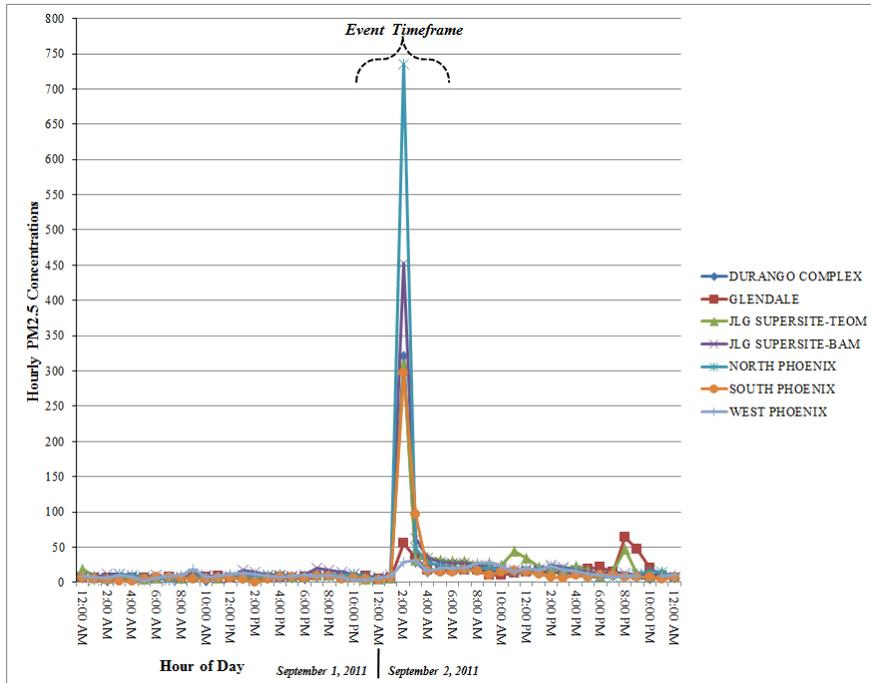


Figure 2. Timeline of hourly average PM_{2.5} concentrations at Maricopa County monitors before, during, and after the September 2, 2011 windblown dust event.

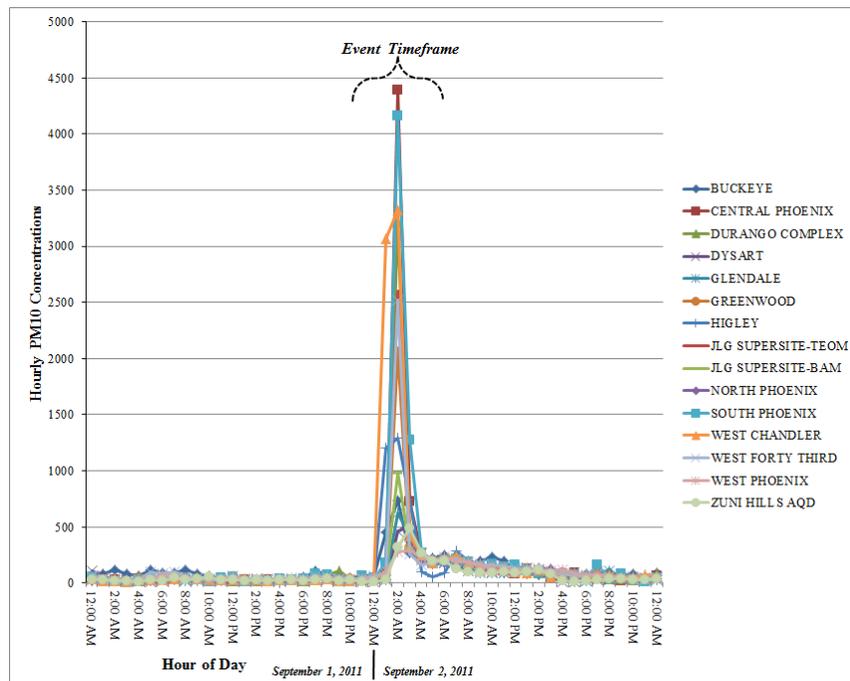


Figure 3. Timeline of hourly average PM₁₀ concentrations at Maricopa County monitors before, during, and after the September 2, 2011 windblown dust event.

3. HISTORICAL FLUCTUATIONS

PM_{2.5} concentrations measured at both the JLG Supersite and North Phoenix monitors on September 2, 2011 were unusual and in excess of normal historical fluctuations. Figure 3 displays a time series plot of the 24-hour PM_{2.5} concentrations for the period of January 1, 2011 (when monitor began reporting to AQS) through June 30, 2013 for the JLG Supersite monitor. Figure 4 displays a time series plot of the 24-hour PM_{2.5} concentrations for the period of September 1, 2011 (when monitor began reporting to AQS) through September 30, 2013 for the North Phoenix monitor. Both figures indicate that exceedances of the 24-hour PM_{2.5} standard have only occurred during the winter holiday season (result of residential and recreational wood burning) and during the monsoon season when high winds from thunderstorm outflows produce dust storms. As such, the PM_{2.5} exceedances on September 2, 2011 were in excess of normal historical fluctuations.

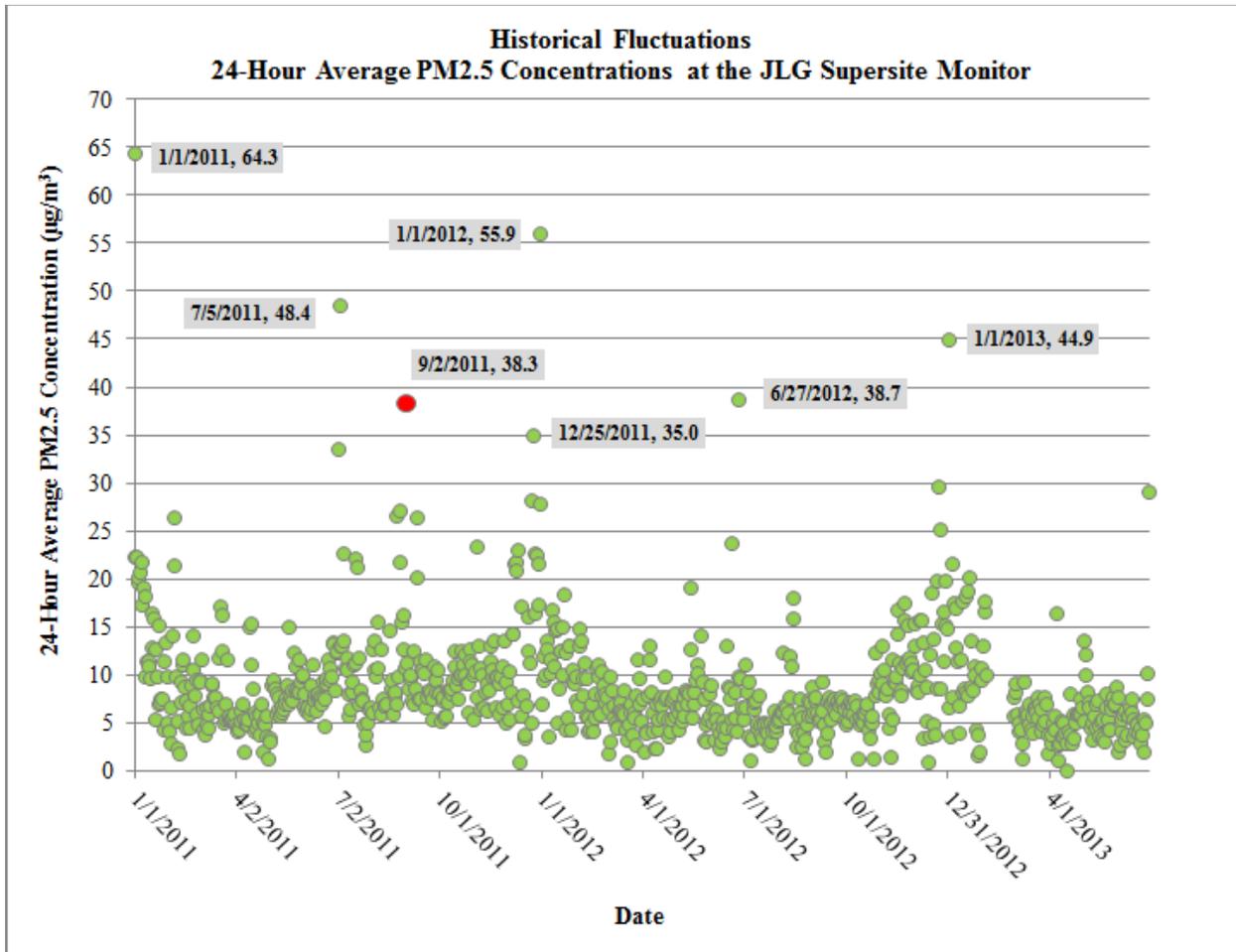


Figure 3. Plot of 24-Hour average PM_{2.5} concentrations (January 2011 – June 2013) at the JLG Supersite monitor.

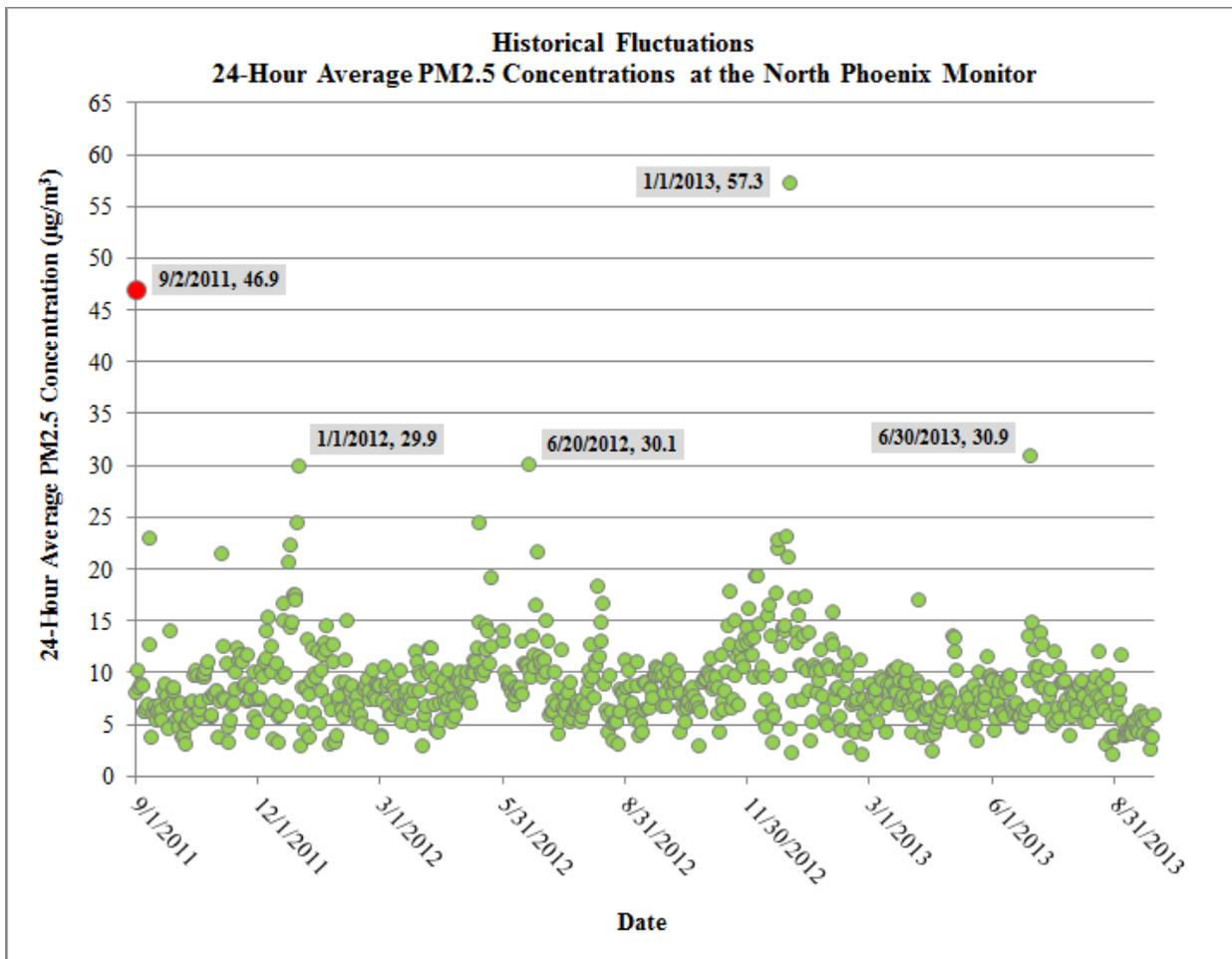


Figure 4. Plot of 24-Hour average PM_{2.5} concentrations (September 2011 – September 2013) at the North Phoenix monitor.

4. NOT REASONABLY CONTROLLABLE OR PREVENTABLE

Maricopa County currently attains both the 24-hour and annual PM_{2.5} National Ambient Air Quality Standards. During a high wind event, PM_{2.5} is generated from windblown fugitive dust sources. The extensive fugitive dust PM₁₀ controls described in Section 5 of the PM₁₀ main document also control the amount of PM_{2.5} generated during a high wind event. When these controls are overwhelmed during a high wind event, exceedances of both the PM₁₀ and PM_{2.5} standards can occur due to fugitive dust emissions that are no longer reasonably controllable or preventable. The PM_{2.5} exceedances on September 2, 2011 were directly related to strong and gusty winds generated by thunderstorm outflows. The gusty outflow winds overwhelmed all reasonably available controls and were also responsible for the transport of PM emissions into Maricopa County.

For September 2, 2011, the Maricopa County Dust Control Forecast indicated a moderate risk level for unhealthy PM₁₀. The Dust Control Forecast also indicated a potential for dense blowing dust throughout the area generated by outflow from thunderstorms.

During the time period of August 30 through September 5, 2011, MCAQD inspectors conducted a total of 112 inspections of permitted facilities, of which 89 were at fugitive dust sources. Additionally, MCAQD conducted 89 inspections on vacant lots and unpaved parking lots during this period. An evaluation of inspection reports and compliance records indicate no evidence of unusual anthropogenic-based particulate emissions or significant violations of particulate matter rules being observed in Maricopa County before, during, or after the high wind blowing dust event that would have impacted PM_{2.5} readings. Detailed information on regulatory measures, control programs, and enforcement activities are described in section 5 of the main PM₁₀ document.

The *WRAP Fugitive Dust Handbook* (September, 2006), estimates the PM_{2.5}/PM₁₀ ratio of windblown fugitive dust to be 0.15. Figures 5 and 6 provide historical 24-hour average ratios of PM_{2.5}/PM₁₀ as observed at the JLG Supersite and North Phoenix monitors. On September 2, 2011, the ratios were observed to be 0.26 and 0.41, respectively. The ratio for North Phoenix on this date was likely much closer to 0.15 than calculated as the 24-hr average PM₁₀ concentration does not include the expected maximum 1-hour concentration due to instrument power failure during the high wind event. The JLG Supersite monitor's ratio value is slightly higher than 0.15, but is within the range expected for a windblown dust event, providing evidence that the 24-hour average PM_{2.5} exceedances recorded on September 2, 2011 were the result of windblown dust emissions, as opposed to other common sources of PM_{2.5} such as combustion and industrial activities.

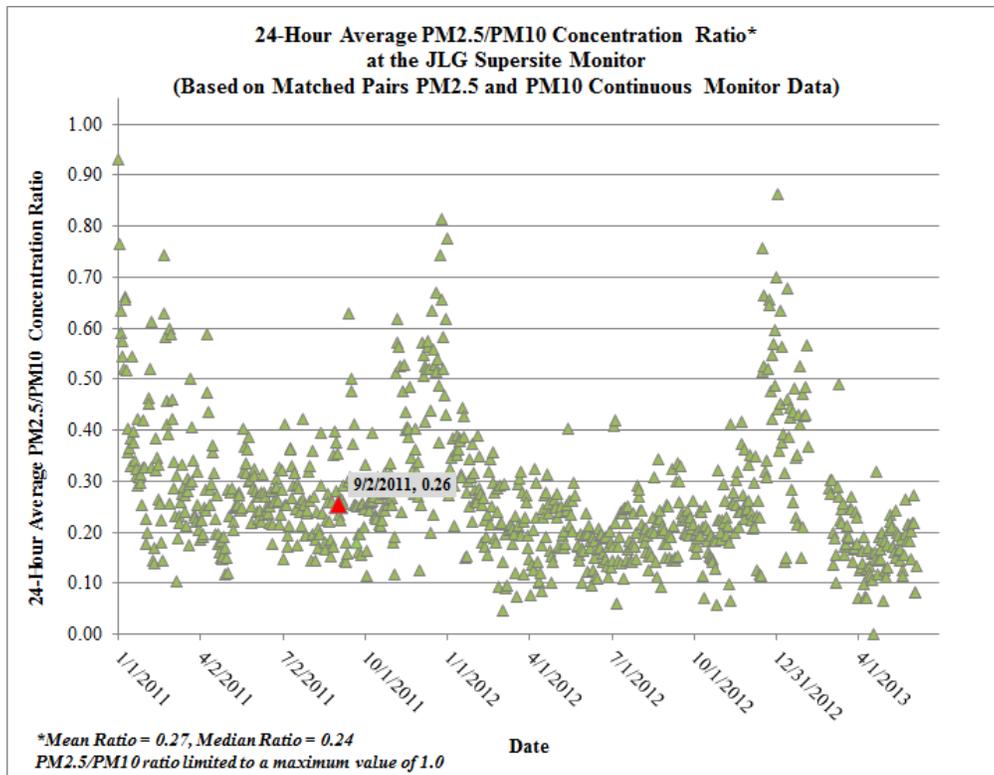


Figure 5. 24-Hour average PM_{2.5}/PM₁₀ concentration ratios at the JLG Supersite monitor.

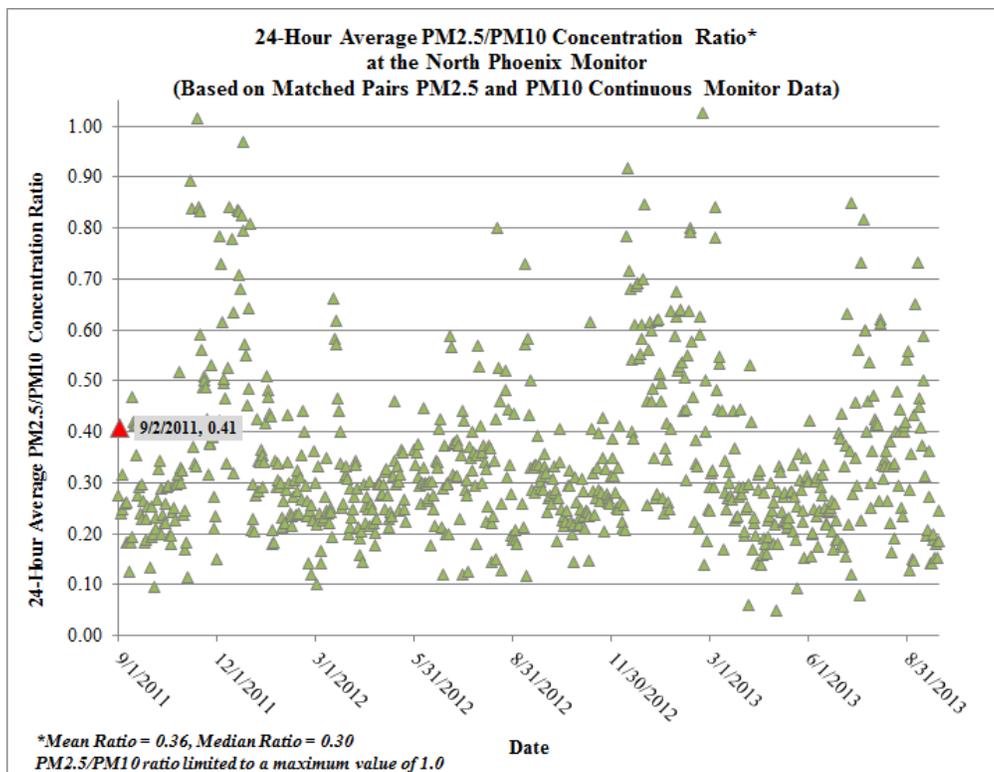


Figure 6. 24-Hour average PM_{2.5}/PM₁₀ concentration ratios at the North Phoenix monitor.

In summary, the same thunderstorm outflow winds that overwhelmed PM₁₀ controls and led to exceedances of the PM₁₀ standard at eleven Maricopa County monitors also caused the PM_{2.5} exceedances at the JLG Supersite and North Phoenix monitors. Despite the deployment of comprehensive control measures and sophisticated response programs, high wind conditions associated with thunderstorms and thunderstorm outflow winds brought high concentrations of both PM₁₀ and PM_{2.5} emissions into, and also overwhelmed controls within, Maricopa County. Sustained wind speeds between 20-30 mph with gusts over 30 were reported at monitors across the Phoenix area as the dust-laden outflow boundary moved through. The dust storm was more than enough to overwhelm all available efforts to limit PM_{2.5} concentrations from fugitive dust sources during the event. The fact that this was a natural event involving strong thunderstorm outflow winds that transported and generated particulate matter emissions into Maricopa County from source regions outside of the county provides strong evidence that the event and PM_{2.5} exceedances of September 2, 2011 for the JLG Supersite and North Phoenix monitors were not reasonably controllable or preventable.

5. CLEAR CAUSAL RELATIONSHIP

A detailed description of the meteorology that caused the natural windblown dust exceedance event at the JLG Supersite and North Phoenix monitors is presented in Section 3 of the PM₁₀ main document via time series graphs, infrared satellite imagery, radar imagery, and links to visibility camera data. In summary, on the evening of September 1, 2011, intense thunderstorms developed over the higher terrain of northwestern Mexico northward into far southern Arizona and by 0100 LST on September 2, 2011 outflows from thunderstorms entrained dust from the natural and open desert areas of Pinal and Pima Counties resulting in a dust storm that progressed northwestward into Maricopa County, while transporting large amounts of PM₁₀ and PM_{2.5}. With the arrival of the dust storm, a) sustained wind speeds across the Phoenix area increased 20-30 mph, with gusts in excess of 30 mph, b) visibility dropped from 10 miles to less than 1 mile for some areas including Phoenix Sky Harbor International Airport, c) weather conditions were reported as “haze” and “blowing dust”, d) and hourly PM₁₀ concentrations increased to over 2000 µg/m³ at seven monitoring sites. Additionally, high PM_{2.5} concentrations were observed with average hourly concentrations reaching 734 µg/m³ at the North Phoenix monitor. Sudden increases in PM₁₀ and PM_{2.5} area wide coincide with the arrival of higher winds and diminished visibilities. Once winds subsided, visibility remained below 10 miles and particulate matter concentrations remained elevated for several hours. In total, eleven monitoring sites in the region exceeded the PM₁₀ NAAQS with JLG Supersite and North Phoenix monitors exceeding the PM_{2.5} 24-hour standard. Without the existence of particulate emissions generated by thunderstorm outflows, there would not have been any exceedances of the 24-hour PM₁₀ or PM_{2.5} standard in the Phoenix PM₁₀ nonattainment area.

Figures 7 and 8 below show the highest hourly PM_{2.5} concentrations at the JLG Supersite and North Phoenix monitors, respectively, coinciding with the arrival of the thunderstorm outflow winds. In addition to the exceedances recorded at these two monitors, all other Phoenix area monitors recorded 24-hour PM_{2.5} concentrations that were elevated as a result of the thunderstorm outflow generated dust storm (see Figure 2).

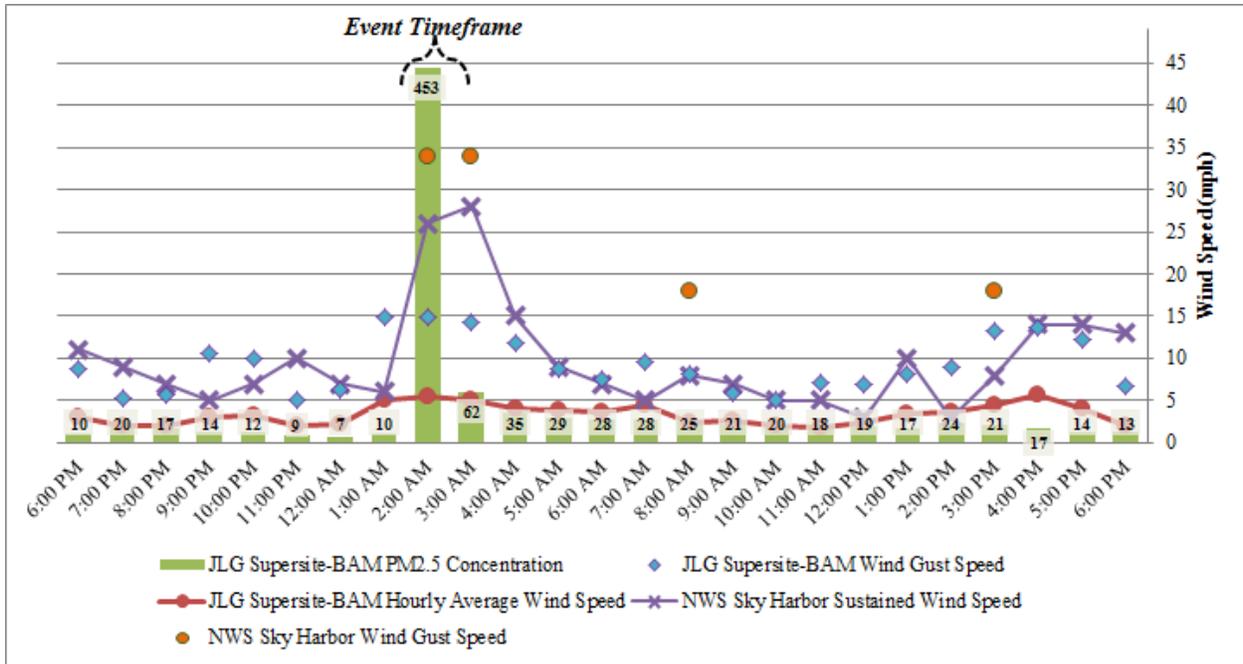


Figure 7. Hourly PM_{2.5} concentrations, wind speeds, and gusts as recorded at the JLG Supersite monitor on September 2, 2011. Additionally, sustained wind speeds and gusts at Sky Harbor International Airport are shown.

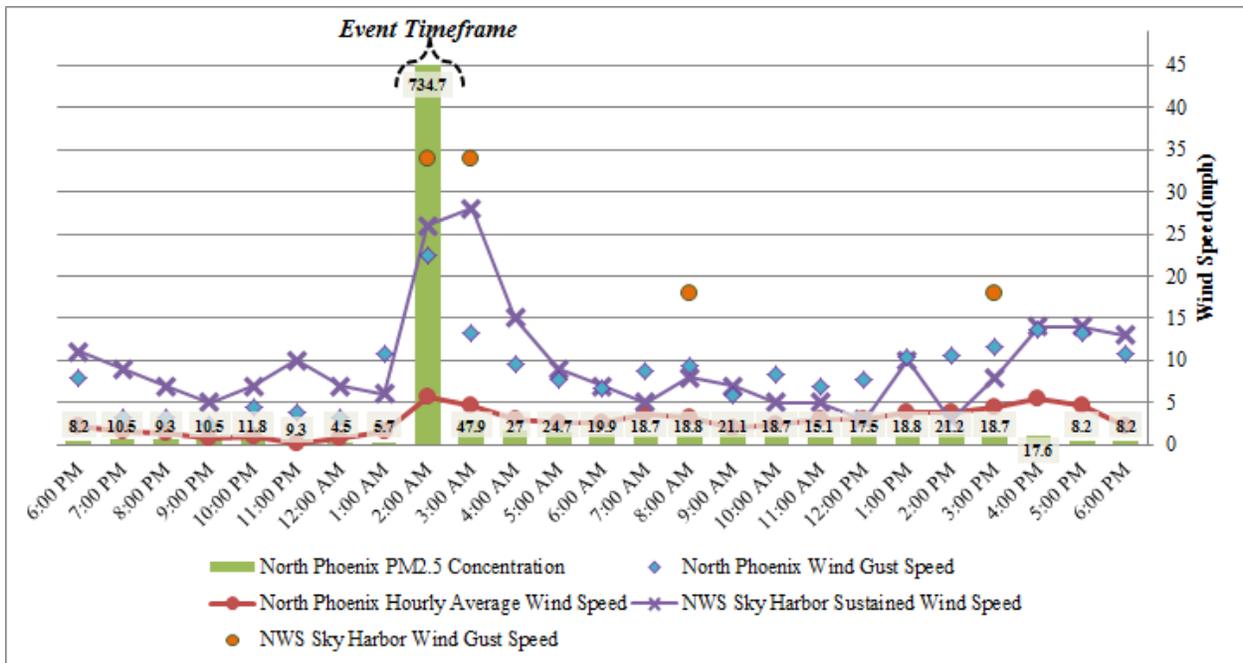


Figure 8. Hourly PM_{2.5} concentrations, wind speeds, and gusts as recorded at the North Phoenix monitor on September 2, 2011. Additionally, sustained wind speeds and gusts at Sky Harbor International Airport are shown.

6. BUT FOR ANALYSIS

Section 50.14(c)(3)(iv)(D) in 40 CFR part 50 requires that an exceptional event demonstration must satisfy that “[t]here would have been no exceedance or violation but for the event.” The prior sections of this PM_{2.5} supplemental document have provided detailed information that the exceedances on September 2, 2011 were not reasonably controllable or preventable and that there is a clear causal relationship between the windblown dust generated and transported by thunderstorm outflow winds and the exceedances at the JLG Supersite and North Phoenix monitors. The weight of evidence in these sections demonstrates that but for the existence of windblown dust emissions generated and transported by thunderstorm outflow winds, there would have been no exceedances of the 24-hour PM_{2.5} standard. It is also clear from Figure 7, that but for the hourly concentrations affected by the high wind event (2:00 am and 3:00 am), the 24-hour average PM_{2.5} concentration for either the JLG Supersite monitor or North Phoenix monitor would have been substantially under 35.5 µg/m³.

EPA’s *Interim Exceptional Events Rule Frequently Asked Questions* (May, 2013) provides procedures for excluding a 24-hour PM_{2.5} exceedance for comparison against the annual PM_{2.5} NAAQS. On pages 34-35, EPA states,

“The preamble [to the Exceptional Events Rule] states that in the particular case of PM_{2.5}, the direct comparison of a single 24-hour average concentration (determined from a single filter-based measurement or by averaging 24 1-hour measurements from a continuous equivalent instrument) to the level of the annual NAAQS can be the basis for meeting the ‘but for’ criterion for exceedances or violations of the annual NAAQS.²⁴ In context, it is clear that based on this comparison, a 24-hour concentration can be excluded from the calculation of the annual PM_{2.5} design value, if other rule criteria are also met. It is therefore not necessary to show that the annual average PM_{2.5} concentration was above 12 or 15 µg/m³ with the event and would have been below 12 or 15 µg/m³ ‘but for’ the single event at issue.”

Additionally, on page 39, EPA states,

“Also, if the 24-hour average concentration based on 1-hour measurements was above 12.0 µg/m³ (after rounding to one decimal digit, per 40 CFR 50 Appendix N section 4.3(a)) but would have been equal or less than 12.0 µg/m³ in the absence of the event, those 1-hour concentration values that were affected by the single event meet the “but for” test for purposes of comparison to 12 µg/m³ annual PM_{2.5} NAAQS.”

Tables 2 and 3 displays the hourly PM_{2.5} concentrations at the JLG Supersite and North Phoenix monitors, respectively, on September 2, 2011, as reported in EPA’s Air Quality System (AQS) database. The tables show that when the two hours affected by the high wind event are excluded (2:00 am and 3:00 am) the 24-hour average concentrations at both exceeding sites would have been near 12.0 µg/m³ in the absence of the event. The exclusion of PM_{2.5} data beginning 2:00 am is valid given this time coincides with rapid increases in both wind speeds and PM_{2.5} concentrations that is indicative of the dust storm approach and passage. By 3:00 am, winds slowly diminish; however, particulate matter remains suspended throughout the day based on

PM_{2.5} hourly concentrations at both exceeding sites failing to return to pre-event concentrations until the evening. This is likely due to lingering and re-entrained dust as well as periodic elevated wind speeds, occasionally gusting near 20 mph, lasting into the evening for the Phoenix area that would have prevented previously transported particulate matter emissions to settle (see Figure 7 and 8). As such, exclusion of the 24-hour average PM_{2.5} exceedances on September 2, 2011 at the JLG Supersite and North Phoenix monitors for comparison against the annual PM_{2.5} NAAQS should be considered under EPA interim guidance.

Table 2. Hourly average PM_{2.5} concentrations at the JLG Supersite monitor on September 2, 2011 and resulting 24-hour average PM_{2.5} concentrations with and without hours affected by the high wind exceptional event.

Hour	PM_{2.5} Concentration (µg/m³)
12:00 AM	7
1:00 AM	10
2:00 AM	453
3:00 AM	62
4:00 AM	35
5:00 AM	29
6:00 AM	28
7:00 AM	28
8:00 AM	25
9:00 AM	21
10:00 AM	20
11:00 AM	18
12:00 PM	19
1:00 PM	17
2:00 PM	24
3:00 PM	21
4:00 PM	17
5:00 PM	14
6:00 PM	13
7:00 PM	14
8:00 PM	13
9:00 PM	11
10:00 PM	11
11:00 PM	10
24-Hour Average	38.3
24-Hour Average Excluding Hours Affected by High Wind Event (2:00 AM through 6:00 AM)	18.4

Table 3. Hourly average PM_{2.5} concentrations at the North Phoenix monitor on September 2, 2011 and resulting 24-hour average PM_{2.5} concentrations with and without hours affected by the high wind exceptional event.

Hour	PM_{2.5} Concentration (µg/m³)
12:00 AM	4.5
1:00 AM	5.7
2:00 AM	734.7
3:00 AM	47.9
4:00 AM	27
5:00 AM	24.7
6:00 AM	19.9
7:00 AM	18.7
8:00 AM	18.8
9:00 AM	21.1
10:00 AM	18.7
11:00 AM	15.1
12:00 PM	17.5
1:00 PM	18.8
2:00 PM	21.2
3:00 PM	18.7
4:00 PM	17.6
5:00 PM	8.2
6:00 PM	8.2
7:00 PM	7
8:00 PM	9.3
9:00 PM	11.9
10:00 PM	16.3
11:00 PM	15
24-Hour Average	46.9
24-Hour Average Excluding Hours Affected by High Wind Event (2:00 AM through 6:00 AM)	15.6

7. CONCLUSION

The PM_{2.5} exceedances that occurred on September 2, 2011 at the JLG Supersite and North Phoenix monitors satisfies the criteria of 40 CFR 50.1(j) and meets the definition of an exceptional event. These criteria are:

- The event affects air quality.
- The event is not reasonably controllable or preventable.
- The event is unlikely to reoccur at a particular location or [is] a natural event.

A. Affects Air Quality

As stated in the preamble to the Exceptional Events Rule, the event in question is considered to have affected air quality if it can be shown that there is a clear causal relationship between the monitored exceedances and the event, and that the event is associated with measured concentrations in excess of normal historical fluctuations. Given the information presented in this PM_{2.5} supplemental document and the PM₁₀ main document, it is reasonable to conclude that the event in question affected air quality.

B. Not Reasonably Controllable or Preventable

Section 50.1(j) of Title 40 CFR Part 50 requires that an event must be “not reasonably controllable or preventable” in order to be defined as an exceptional event. This requirement is met by demonstrating that despite reasonable control measures in place within Maricopa County, high wind conditions overwhelmed all reasonably available controls. Despite the deployment of comprehensive control measures and sophisticated response programs, high wind conditions associated with thunderstorms and thunderstorm outflows generated and brought high concentrations of PM_{2.5} into Maricopa County. Examination of the PM_{2.5}/PM₁₀ ratio on September 2, 2011 is consistent with windblown dust as the source of the PM_{2.5} emissions. The fact that this was a natural event involving strong thunderstorm outflow winds that transported and generated PM_{2.5} emissions into Maricopa County, provides strong evidence that the event and exceedances of September 2, 2011 recorded at the JLG Supersite and North Phoenix monitors were not reasonably controllable or preventable.

C. Natural Event

As discussed above, the event shown to cause these exceedances were emissions of PM_{2.5} generated by high winds caused by thunderstorm activity and related outflow boundaries on September 2, 2011. The event therefore qualifies as a natural event.

In summary, the exceedances of the PM_{2.5} standards on September 2, 2011 would not have occurred but for the monsoonal thunderstorm driven high winds and windblown dust generated and transported from areas inside and outside of Maricopa County, based on the following weight of evidence:

- Historical fluctuation data in Section 3 shows the active record of 24-hour average PM_{2.5} data for both the JLG Supersite and North Phoenix monitors and demonstrates that the values on September 2, 2011 were atypical and in excess of normal historical fluctuations.
- The exceedances of the PM_{2.5} standards recorded on September 2, 2011 are tied to thunderstorm activity and thunderstorm generated outflow winds, as can be seen in data and analyses in Section 3 in the PM₁₀ main document.
- Figures and tables in Section 3 of the PM₁₀ main document show that the timing of thunderstorm generated outflow boundary passage and increases in wind speeds at monitoring locations and National Weather Service stations during each of the events during this period is consistent with the timing of elevated PM₁₀ and PM_{2.5} concentrations recorded at the monitoring locations in the Phoenix PM₁₀ nonattainment area.
- Visibility camera imagery discussed in Section 3 of the PM₁₀ main document indicates that large quantities of PM₁₀ was transported into the Phoenix Metro area during the September 2nd event. The timing of the dust storms depicted in the visibility camera imagery is consistent with the PM₁₀ and PM_{2.5} concentration measurements, elevated winds, and reduced visibility reported during the high wind event.
- Wind directions, thunderstorm generated outflow boundary propagation, and concentration patterns showing elevated levels of PM₁₀ in Pinal County prior to levels increasing in Maricopa County, all depicted in Section 3 of the PM₁₀ main document, help to show that dust originating in Pinal County was transported to Maricopa County.
- Section 5 discusses that the rules in place to control PM₁₀ from fugitive dust sources in Maricopa County are the same rules that control PM_{2.5} emissions during high wind events. Inspections conducted in the area before, during, and after the event verify that no unusual anthropogenic activities affected the PM_{2.5} concentrations observed at the exceeding JLG Supersite and North Phoenix monitors.