



Air Pollution Control District
San Luis Obispo County

TO: Board of Directors, Air Pollution Control District

FROM: Larry R. Allen, *LRA* Air Pollution Control Officer

DATE: July 24, 2013

SUBJECT: Air Quality Trends Report: 1991 - 2011

SUMMARY

The Executive Committee of the Board has requested the Air Quality Trends Report be presented and considered again by the Board due to the accidental loss of the audio recording when this item was originally presented at your March 27, 2013 meeting. Minor changes have been made to the language in the Executive Summary and the Summary and Conclusions sections of the report in response to Board member comments. An addendum has also been added to the report presenting substantial additional staff analyses to address several comments received from a Board member prior to and following the March 27, 2013 meeting.

RECOMMENDATION

It is recommended that your Board review and approve the attached report.

DISCUSSION

At your March 27, 2013 meeting, the Board heard a staff presentation, as well as Board and public comments, on the attached report analyzing trends in ozone and particulate matter measurements throughout the county from 1991 through 2011. Following the presentation and discussion, the Board approved the staff recommendation to receive and file the report. Subsequent to the meeting, it was discovered that the audio feed for that portion of the meeting was accidentally disabled and not available for public review. As a result, the Board Executive Committee at its May 1, 2013 meeting directed staff to put the report back on the agenda for Board reconsideration at this meeting. In addition, the Executive Committee requested the staff recommendation for the report be changed from "receive and file" to "review and approve".

The report (Attachment 1) and its conclusions remain essentially unchanged, with minor language revisions made to a few sentences in the Executive Summary and in the Summary and Conclusions sections of the report, based on Board member comments; Attachment 2 shows these changes. An addendum has also been added to the report presenting substantial additional staff analyses to address several comments received from a Board member prior to and following the March 27, 2013 meeting.

As shown in the data presented in this report, improvements in air quality have been observed in most areas of the county over the past 20 years, despite substantial increases in population and vehicle miles traveled during that period. Ozone levels have fallen countywide, particularly in the areas with the highest historical concentrations. This has resulted from emission reductions achieved through implementation of control measures adopted under the District's Clean Air Plan, as well as reductions achieved by areas outside the county that have reduced the level of pollutant transport responsible for the elevated ozone concentrations measured in the eastern portion of our county.

Airborne particulate levels have also declined in most areas of the County. Emission reductions achieved from District implementation of residential woodburning and open burning control programs have proven effective in reducing wintertime PM levels and exceedances of health standards in the North County and at our inland Nipomo air monitoring site. PM₁₀ and PM_{2.5} levels continue to frequently exceed health standards with no evidence of improvement at our South County monitoring sites closest to the Oceano Dunes. District studies show dust from the Oceano Dunes State Vehicular Recreation Area to be the primary emissions source contributing to this problem. The District is currently working with the California Department of Parks and Recreation on the development of Particulate Matter Reduction Plan for that facility. Implementation of the dust control measures in that plan may begin within the next year.

The attached report provides a comprehensive, detailed analysis of the statistical indicators and other measures used to evaluate long-term air quality trends in our county and our progress toward attaining state and federal standards to protect public health.

Staff recommends the Board review and approve the attached report.

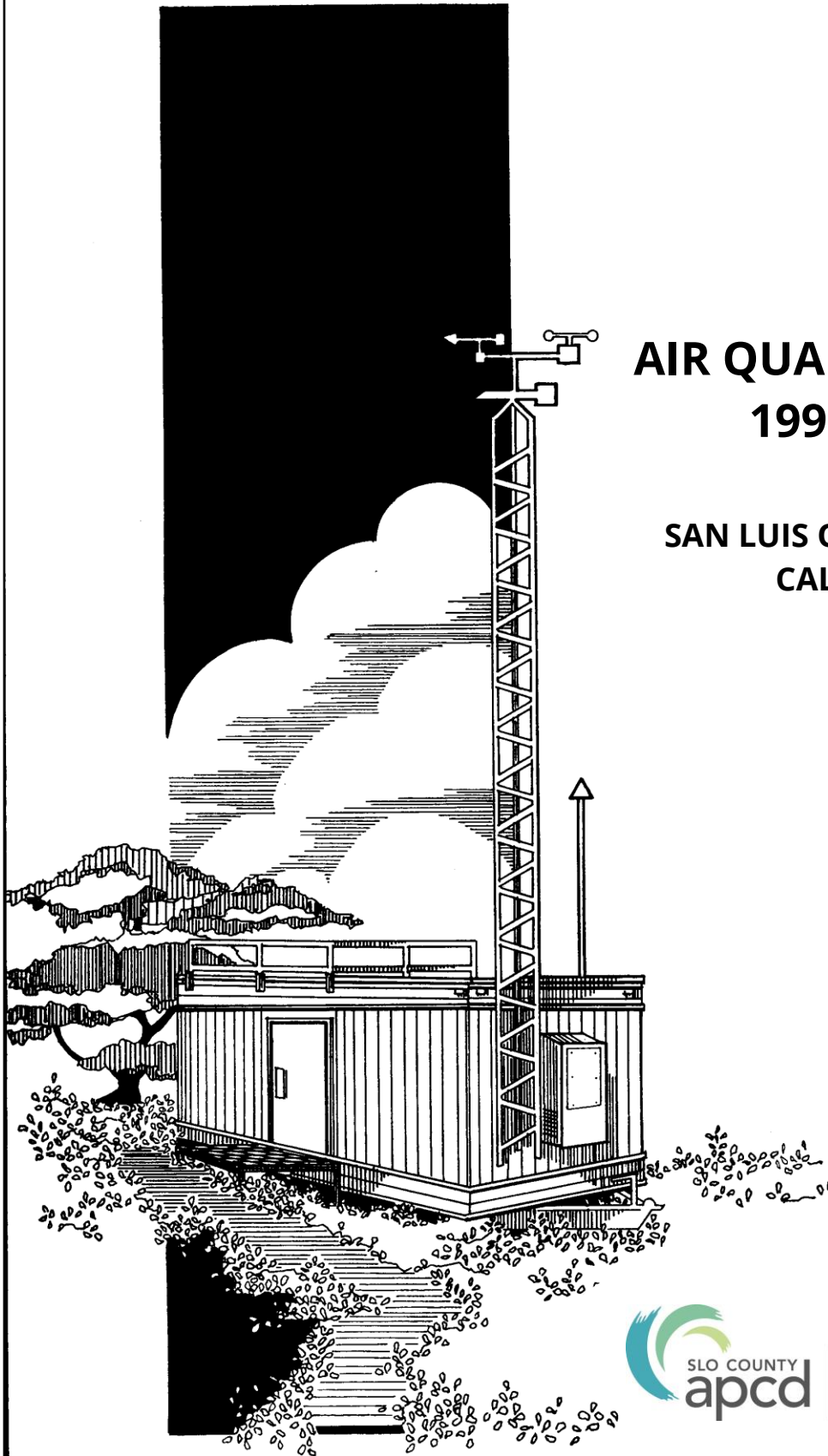
OTHER AGENCY INVOLVEMENT

The California Air Resources Board and the U.S. Environmental Protection Agency provide technical and regulatory oversight of the air quality monitoring conducted by the District and the associated air quality data produced by that monitoring and analyzed in this report.

FINANCIAL CONSIDERATIONS

None.

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AIR QUALITY TRENDS 1991 - 2011

SAN LUIS OBISPO COUNTY
CALIFORNIA



Air Pollution Control District
San Luis Obispo County

AIR QUALITY TRENDS SAN LUIS OBISPO COUNTY 1991 - 2011

Principal Author
Karl Tupper
Air Quality Specialist

SAN LUIS OBISPO COUNTY AIR POLLUTION CONTROL DISTRICT

3433 Roberto Court, San Luis Obispo, California 93401

Phone: (805) 781-5912 Website: www.slocleanair.org

Larry Allen
Air Pollution Control Officer

March 2013

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LIST OF ABBREVIATIONS

AADT	Annual Average Daily Traffic count
AVMT	Annual Vehicle Miles Traveled
AQS	Air Quality System, the official repository of air quality data maintained by the EPA
ARB	Air Resources Board
CDF	California Department of Forestry
EPA	United States Environmental Protection Agency
FEM	Federal Equivalent Method
FRM	Federal Reference Method
GDP	Gross Domestic Product
GPS	Global Positioning System
hr	hour
LC	Local Conditions
MSA	Metropolitan Statistical Area
NAAQS	National Ambient Air Quality Standards
NRP	Nipomo Regional Park
O ₃	Ozone
POC	Pollutant Occurrence Code
PM	Particulate Matter
PM _{2.5}	Fine particulate matter with aerodynamic diameter less than 2.5 micron
PM ₁₀	Particulate matter with aerodynamic diameter less than 10 micron
ppb	Parts per billion
ppm	Parts per million
PST	Pacific Standard Time
SLOCOG	San Luis Obispo Council of Governments
SLOAPCD	San Luis Obispo County Air Pollution Control District
STP	Standard Temperature and Pressure (760 mmHg, 25 °C)
µg/m ³	Micograms per cubic meter

APCD MONITORING SITES

	O ₃	NO	NO ₂	NOx	SO ₂	CO	PM ₁₀	PM _{2.5}	WS	WD	ATM
Atascadero	X	X	X	X			X	X	X	X	X
Carrizo Plains	X								X	X	X
CDF (Nipomo)							X	X	X	X	
Grover Beach									X	X	
Mesa2 (Nipomo)					X		X	X	X	X	X
Morro Bay	X	X	X	X					X	X	
NRP (Nipomo)	X	X	X	X			X		X	X	X
Paso Robles	X						X		X	X	X
Red Hills	X								X	X	X
San Luis Obispo	X						X	X	X	X	X

EXECUTIVE SUMMARY

Air quality monitoring has been conducted in San Luis Obispo County since 1970; this report analyzes trends in ozone and particulate matter measurements looking back to 1991. All currently operating sites are included in the analysis, as well as historical monitoring sites with at least ten years of data available between 1991 and 2011.

As shown in the data presented in this report, significant improvements in air quality have been observed in most areas of the county over the past 20 years, despite significant increases in population and vehicle miles traveled during that period (see **Appendix C**). Ozone levels have fallen countywide, particularly in the areas with the highest historical concentrations. This has resulted from emission reductions achieved through implementation of control measures adopted under the District's Clean Air Plan, as well as reductions achieved by areas outside the county that have reduced the level of pollutant transport responsible for the elevated ozone concentrations measured in the eastern portion of our county.

Ozone is currently measured at seven locations in the county; data is also available from Grover Beach through 2005. For these eight sites, long-term trends in federal 8-hr design values and in the frequencies of federal 8-hr exceedances, state 1-hr exceedances, and hours at or above 65 ppb are all analyzed. Three patterns emerge from these analyses. Coastal areas (Morro Bay, Grover Beach, Nipomo, and San Luis Obispo) have always enjoyed relatively low ozone levels, with state or federal standards only rarely exceeded. While there is no evidence of improvement beyond these already low levels, there is no evidence of deterioration, either. The North County (Atascadero and Paso Robles) has seen substantial improvement in ozone levels over the last 20 years; nonetheless, levels there remain higher than those in coastal areas. Finally, ozone levels are highest in the remote, sparsely populated eastern portion of the county, as measured at our Red Hills and Carrizo Plains monitoring sites. This portion of the county was designated a federal non-attainment area in 2011 (see **Figure 1**, below). Fortunately, this is also the portion of the county where ozone levels are dropping the fastest, as indicated by steep, statistically significant declines in nearly all of the statistics examined.

Airborne particulate levels have also declined significantly in most areas of the County. Emission reductions achieved from District implementation of residential woodburning and open burning control programs have been effective in reducing wintertime PM levels and exceedances of health standards in the North County and at our inland Nipomo site. PM₁₀ and PM_{2.5} levels continue to frequently exceed health standards in the South County with no evidence of improvement. District studies show dust from the Oceano Dunes State Vehicular Recreation Area to be the primary emissions source contributing to this problem. The District is currently working with the California Department of Parks and Recreation on the development of Particulate Matter Reduction Plan for that facility. Implementation of the dust control measures in that plan is scheduled to begin within the next year.

Measurements of PM_{2.5} in our county began in 1999, with monitoring initially confined to San Luis Obispo and Atascadero. PM_{2.5} monitoring on the Nipomo Mesa started more recently, with measurements at our Mesa2 and CDF stations commencing in 2009 and 2010, respectively. Trends in annual average concentrations, exceedances of the federal 24-hr standard, and days exceeding 12 µg/m³ are analyzed in this report. The data shows steady improvement in PM_{2.5} levels at Atascadero and San Luis Obispo, with an average of 7% of days exceeding 12 µg/m³ at these sites for 2010-11; exceedances of standards are rare at these sites. PM_{2.5} levels are highest during the winter in Atascadero, and improvements in wintertime levels are driving the overall decrease in PM_{2.5} observed there; San Luis Obispo shows less seasonality. In contrast, PM_{2.5} levels are much higher on the Nipomo Mesa at the CDF and Mesa2 stations, where on average 23% of days exceeded 12 µg/m³ at these sites for 2010-11, and there is no evidence of improvement. Like Atascadero, PM_{2.5} levels on the

Nipomo Mesa display a strong seasonality, except the pattern is reversed, with the spring wind season showing the highest concentrations while the winter months are generally the cleanest time of the year.

Monitoring of PM₁₀ is currently performed in Paso Robles, Atascadero, San Luis Obispo and on the Nipomo Mesa at Mesa2, CDF, and Nipomo Regional Park; PM₁₀ was also monitored in Morro Bay through 2010. Trends in annual average concentrations and exceedances of state and federal standards are analyzed. As with ozone, three patterns emerge in the PM₁₀ data, though the sites fall into different geographic groups. Exceedances of the state 24-hr PM₁₀ standard have always been rare in San Luis Obispo and Morro Bay, and these cities show either continued improvement in PM₁₀ air quality (San Luis Obispo) or are maintaining historically low levels (Morro Bay). PM₁₀ levels have steadily decreased in the North County, and concentrations in that region now look very similar to those in San Luis Obispo. The greatest degree of PM₁₀ pollution is found on the Nipomo Mesa in the South County, where the state standards for 24-hr and annual average concentrations are routinely exceeded at the CDF and Mesa2 sites. In contrast to the North County and San Luis Obispo, these sites show no improvement. At the Nipomo Regional Park site—also on the Nipomo Mesa but further inland—PM₁₀ levels are not as elevated and some measures analyzed even indicate improvement.

INTRODUCTION AND BACKGROUND

Air Quality Monitoring and Data

Air quality monitoring has been conducted in San Luis Obispo County since 1970, with the San Luis Obispo County Air Pollution Control District (SLOAPCD), the Air Resources Board (ARB) and private industry operating various sites throughout the county. The network has undergone significant changes over these 40 years, including site closures and relocations, establishments of new sites, changes in the pollutants monitored, and updates in monitoring methodology. This report describes long-term trends in ozone and particulate matter (PM), levels of which continue to exceed state and federal health standards in the District. Staff analyzed data from 1991 through 2011 for all permanent monitoring sites operating as of January 1, 2013, as well as former sites that have at least 10 years of ozone and/or PM data during that period. The locations of these sites are depicted in **Figure 1**; **Appendix A** contains basic information about each site, including street address and GPS coordinates.

Monitoring stations in downtown Atascadero and Paso Robles track air quality in the North County Salinas River Valley, providing data on population exposure to the pollutants measured there. In the remote, sparsely populated eastern portion of the county, the Red Hills and Carrizo Plains sites monitor ozone levels primarily caused by transport of pollutants from other areas of the state. The San Luis Obispo station monitors air quality in the county's most highly populated urban center. The station in Morro Bay monitors coastal pollution levels, while three stations on the Nipomo Mesa monitor South County air quality.

Two monitoring sites were moved during the time period covered in this report. In September 1996, the station at 148 S. Wilson St., Nipomo, was closed; in November 1998, a new station began operation 1.4 miles WSW at Nipomo Regional Park (NRP) where it remains today. Since the spatial scale for both sites is considered regional, and their locations are relatively close to one another, data from these sites were aggregated for the purpose of this report. In subsequent tables and graphs, "Nipomo" refers to the Wilson St. site for years up to and including 1996, and NRP for 1998 and later years. Similarly, the San Luis Obispo station moved from 1160 Marsh St., San Luis Obispo to its current location at 3220 S. Higuera in September 2005, with no break in data collection. Thus, in the subsequent tables and graphs, "San Luis Obispo" refers the Marsh St. site for years up to and including 2004, and the S. Higuera site for 2006 and later years. Data for 2005 are a mixture of the two sites.

This report analyzes PM_{2.5}, PM₁₀, and ozone trends since 1991; however, these pollutants were not measured at every site or for every year. For example, PM_{2.5} measurements did not begin until 1999 and were initially monitored only in Atascadero and San Luis Obispo; PM_{2.5} measurements began at Mesa2 and CDF in 2009 and 2010, respectively. Ozone data is available back to 1991 for Paso Robles, Atascadero, SLO, Grover Beach and Nipomo, while measurements at our east county sites at Red Hills and Carrizo did not begin until 2000 and 2006, respectively; and ozone measurement ceased at Grover Beach in 2005. These changes in data availability and others are summarized in **Table 1**, below. Note that incomplete years (i.e. years when a pollutant was not monitored for the entire year) were *not* excluded from **Table 1** nor from subsequent tables and trend analyses unless otherwise noted.

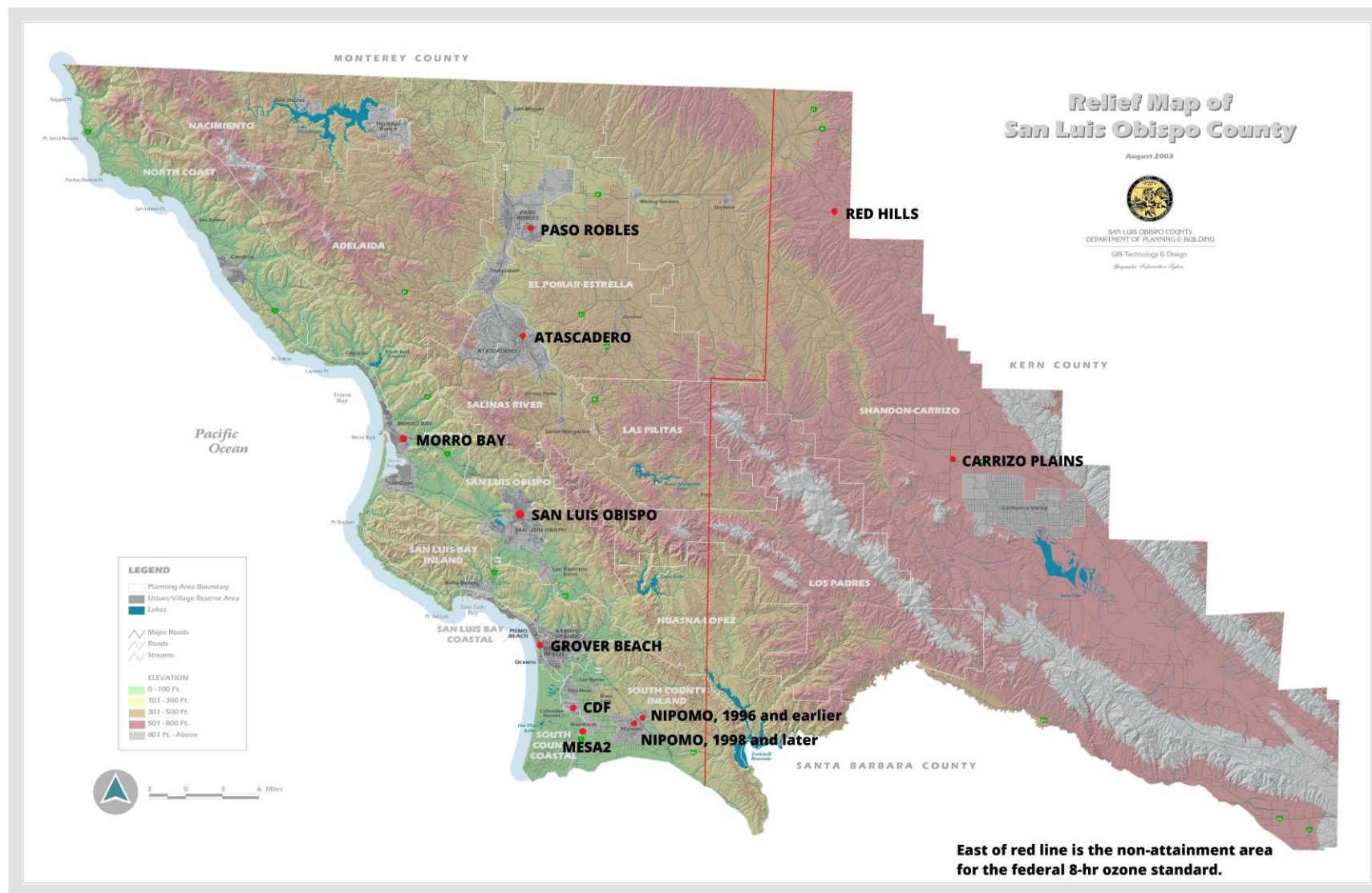
Finally, this report relies on data exported from the Air Quality System (AQS), the EPA's official repository of air quality data, which the agency relies on for regulatory decisions. Monitoring data is uploaded to AQS only after being validated. Currently, SLOAPCD manages the Atascadero, Red Hills, Carrizo Plains, Morro Bay, Grover Beach, Mesa2, CDF, and Nipomo stations, and also validates and uploads the data from these

sites. ARB manages, validates and uploads data from the Paso Robles and San Luis Obispo stations. In earlier years, some current SLOAPCD sites were managed by different organizations or private contractors, so data validation and AQS uploading responsibilities and practices may also have been different. In addition to AQS, air quality data from San Luis Obispo County is available from various other sources including the ARB's website, EPA's AirNow.gov website, local newspapers, and reports produced by the SLOAPCD. Many of these sources are not validated and/or handle data differently than AQS; if there are differences between data from AQS and data another sources, the AQS data takes precedence. For this reason, this report relies exclusively on data extracted from AQS, with the exception of Red Hills ozone data from 2000-2006, which is not available in AQS; thus, these data were extracted from the SLOAPCD's in-house database.

Table 1: Timeline of Data Availability

Site	Pollutant	Table 1: Timeline of Data Availability																				
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Red Hills	O ₃																					
	PM _{2.5}																					
	PM ₁₀																					
Carrizo Plains	O ₃																					
	PM _{2.5}																					
	PM ₁₀																					
Paso Robles	O ₃																					
	PM _{2.5}																					
	PM ₁₀																					
Atascadero	O ₃																					
	PM _{2.5}																					
	PM ₁₀																					
Morro Bay	O ₃																					
	PM _{2.5}																					
	PM ₁₀																					
San Luis Obispo	O ₃																					
	PM _{2.5}																					
	PM ₁₀																					
Grover Beach	O ₃																					
	PM _{2.5}																					
	PM ₁₀																					
CDF	O ₃																					
	PM _{2.5}																					
	PM ₁₀																					
Nipomo	O ₃																					
	PM _{2.5}																					
	PM ₁₀																					
Mesa2	O ₃																					
	PM _{2.5}																					
	PM ₁₀																					

Figure 1: Map of Air Quality Monitoring Sites Used In This Report



Ambient Air Pollutants Of Local Concern

Ozone

Ozone is a gas that is naturally found near the earth's surface at low concentrations, typically 10 to 40 parts per billion (ppb). It is also a principle component of photochemical smog, produced when precursor pollutants such as volatile organic compounds and nitrogen oxides react under the influence of sunlight. Ozone precursors are emitted by many human activities, but industrial processes and the wide use of motor vehicles are the primary sources. The chemistry of atmospheric ozone is complex, and in the absence of sunlight ozone is destroyed by reaction with the same precursor molecules that fuel its formation during the day. As a result, ozone concentrations typically increase as sunlight intensity increases, peaking midday or in the afternoon, and bottoming out in the early morning hours and around sunrise, as shown in **Figure 2**, below.

In addition to this diurnal pattern, ozone levels also vary seasonally. Ozone levels tend to be higher during the summer months when days are longer and warmer than during the winter months with cooler, shorter days. In addition, wildfires can contribute to elevated ozone levels, and these events are more common during the dry summer months. On the other hand, stagnant meteorological conditions and temperature inversions—weather patterns that favor high ozone levels—are more common during the winter in our county. The net effect of these factors is higher ozone levels in the summer than the winter, as shown in **Figure 3**, below.

Figure 2: Example of Diurnal Ozone Pattern

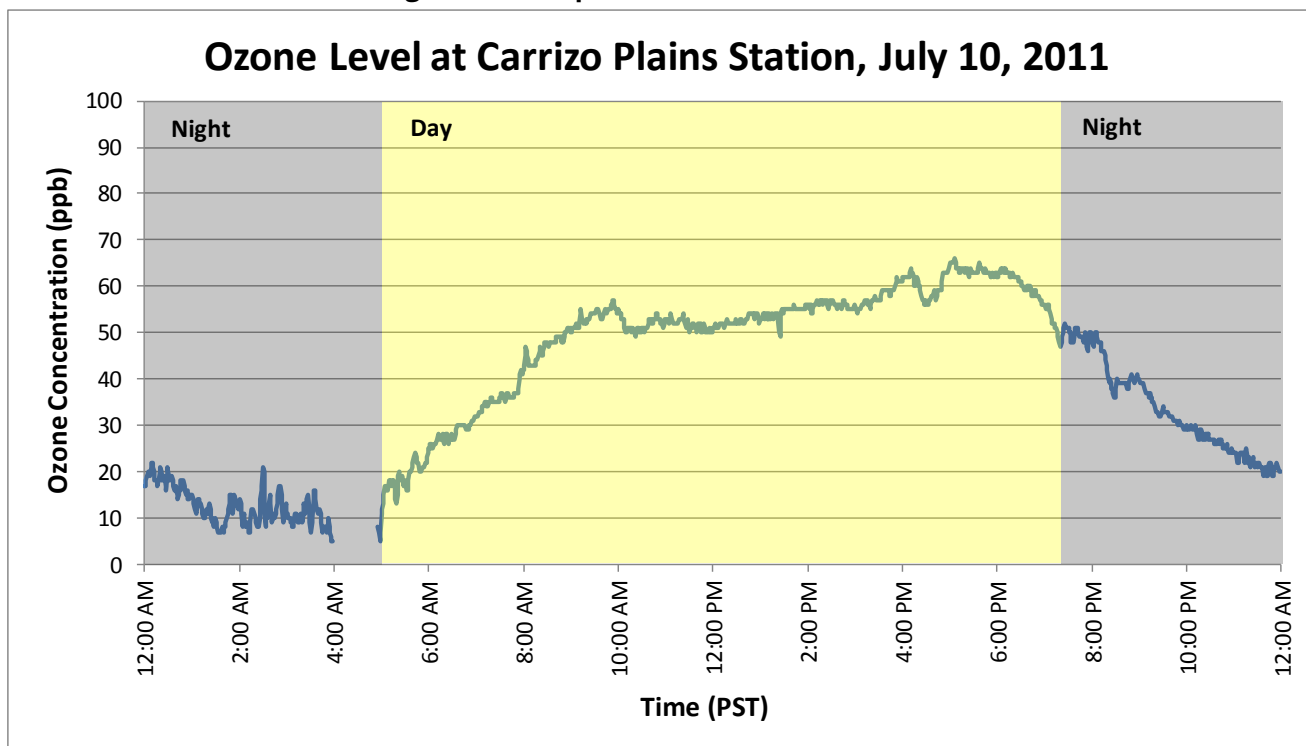
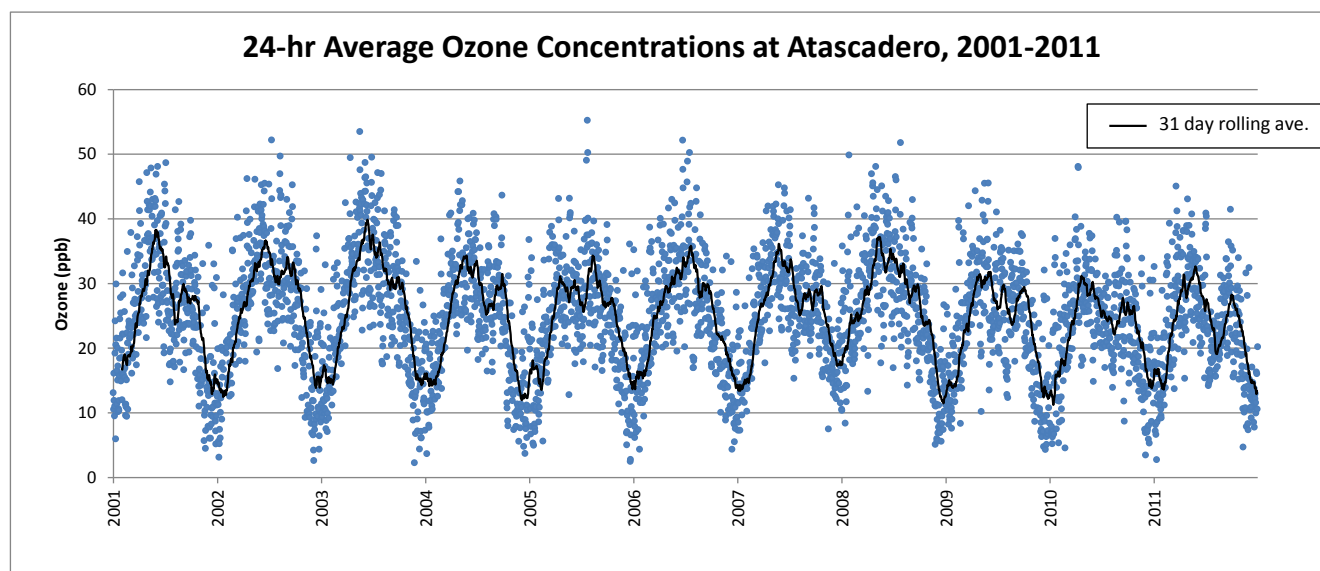


Figure 3: Example of Seasonal Ozone Pattern



As a pollutant, ozone is a strong oxidant gas that attacks plant and animal tissues. It can cause impaired breathing and reduced lung capacity, especially among children, athletes, and persons with compromised respiratory systems; it can also cause significant crop and forest damage. Ozone is a pollutant of particular concern in California, where geography, climate, and high population densities contribute to frequent violations of health-based air quality standards.

Particulate Matter

Ambient air quality standards have been established for two classes of particulate matter: PM₁₀ (respirable particulate matter less than 10 microns in aerodynamic diameter), and PM_{2.5} (fine particulate matter 2.5 microns or less in aerodynamic diameter). Both consist of many different types of particles that vary in their chemical activity and toxicity. PM_{2.5} tends to be a greater health risk since these particles cannot be removed from the lungs once they have been deeply inhaled. Sources of particulate pollution include diesel exhaust; mineral extraction and production; combustion products from industry and motor vehicles; demolition and construction; agricultural operations; smoke from open burning; paved and unpaved roads; condensation of gaseous pollutants into liquid or solid particles; and wind-blown dust from beaches and dunes.

Other Pollutants

Two other pollutants—Nitrogen dioxide (NO₂) and Sulfur dioxide (SO₂)—are also monitored in the county. Trends for these pollutants are not analyzed in this report since their levels are very low. Nitrogen dioxide (NO₂) is the brownish-colored component of smog. NO₂ irritates the eyes, nose and throat, and can damage lung tissues. Sulfur dioxide (SO₂) is a colorless gas with health effects similar to NO₂. Both pollutants are generated by fossil fuel combustion from mobile sources such as vehicles, ships, and aircraft and at stationary sources such as industry, homes, and businesses. SO₂ may also be emitted by petroleum production and refining operations.

State and National Ambient Air Quality Standards and Attainment Status in San Luis Obispo County

Both the State of California and the federal EPA have adopted ambient air quality standards for six common air pollutants of primary public health concern: ozone, particulate matter, NO₂, SO₂, CO and lead. These are called “criteria pollutants” because the standards establish permissible airborne pollutant levels based on criteria developed after careful review of all medical and scientific studies of the effects of each pollutant on public health and welfare.

The National Ambient Air Quality Standards (NAAQS; see **Table 2**) are used by EPA to designate a region as either “attainment” or “non-attainment” for each criteria pollutant. A non-attainment designation can trigger additional regulations for that region aimed at curbing pollution levels and bringing the region into attainment of the standard. For most pollutants, the NAAQS allow a standard to be exceeded a certain number of times each calendar year without resulting in a non-attainment designation. Additionally, exceedances caused by exceptional events (see below) may be excluded from attainment/non-attainment determinations at the discretion of the EPA.

The EPA recently designated the portion of San Luis Obispo County to the east of the red line in **Figure 1** as marginally non-attainment for the federal 8-hour ozone standard. This designation was based on enhanced monitoring over the last decade that revealed previously unrecognized elevated ozone levels in that region; the western portion of the county retains its federal attainment status. The county is in attainment for all of the other NAAQS.

The California Ambient Air Quality Standards are generally more restrictive (i.e. lower) than the NAAQS for most criteria pollutants. As a result, San Luis Obispo County is designated as a non-attainment area for the state one-hour and 8-hour ozone standards, as well as the state 24-hour and annual PM₁₀ standards. Unlike the NAAQS, one exceedance of a California criteria pollutant standard in a three year period can result in a nonattainment designation.

The state and national standards for NO₂ have never been exceeded in this county. The state standard for SO₂ was exceeded periodically on the Nipomo Mesa up until 1993. Equipment and processes at the refinery on the Mesa were upgraded as a result, and the state SO₂ standard has not been exceeded since that time. Exceedances of the federal SO₂ standard have never been measured here. State CO standards have not been exceeded in San Luis Obispo County since 1975.

Exceptional Events

Exceptional events are unusual or naturally occurring events that can affect air quality but are not reasonably controllable or preventable and are unlikely to recur at a particular location. The Clean Air Act has provisions that allow air quality monitoring data influenced by exceptional events to be excluded from regulatory determinations related to violations of the NAAQS. The EPA must approve exceptional events before the associated data can be excluded. Several potential exceptional events have occurred during the time period covered by this report. EPA has yet to approve the exclusion of any data associated with these events, however, so no data has been excluded from the analyses in this report. Thus, the trends discussed on the following pages include influences from wildfires and other unusual events.

Table 2: Ambient Air Quality Standards as of 2012 and Attainment Status*

	Averaging Time	California Standard	National Standard
Ozone (O₃)	8 Hour	0.070 ppm	0.075 ppm
	1 Hour	0.09 ppm	-----
Respirable Particulate Matter (PM₁₀)	24 Hour	50 µg/m³	150 µg/m ³
	Annual Arithmetic Mean	20 µg/m³	-----
Fine Particulate Matter (PM_{2.5})	24 Hour	-----	35 µg/m ³
	Annual Arithmetic Mean	12 µg/m ³	12 µg/m ³ †
Carbon Monoxide (CO)	8 Hour	9.0 ppm	9 ppm
	1 Hour	20 ppm	35 ppm
Nitrogen Dioxide (NO₂)	Annual Arithmetic Mean	0.030 ppm	0.053 ppm
	1 hour	0.18 ppm	100 ppb
Sulfur Dioxide (SO₂)	3 Hour	-----	0.5 ppm (secondary)
	1 Hour	0.25 ppm	75 ppb (primary)
Hydrogen Sulfide (H₂S)	1 Hour	0.03 ppm	-----
Visibility	8 hour	Sufficient amount to reduce the prevailing visibility to less than ten miles when the relative humidity is less than 70 %.	

* Standards in **boldface print** are not attained in San Luis Obispo County as of December 2012.

† On January 15, 2013, the EPA issued a final rule lowering the PM_{2.5} annual standard from 15 µg/m³ to 12 µg/m³. The new standard takes effect on March 18, 2013.

AIR QUALITY TRENDS ANALYSIS

Ozone Trends

As depicted in **Table 1**, above, ozone is currently measured in Paso Robles, Atascadero, San Luis Obispo, Morro Bay, Red Hills, Carrizo Plains, and Nipomo. Trends from each of these sites are included in this analysis, which looks back to 1991. Ozone monitoring was discontinued at Grover Beach in 2005, but this site is nonetheless included since 15 years of data are available. Ozone measurements have been collected at other sites throughout the county since 1991, including Mesa2 and various short-term special purpose sites like Shandon, Camp Roberts, and the summit of Black Mountain. These data are not included due to the limited number of years of data available from each.

The overall picture is that ozone levels are steadily decreasing in the areas where they are highest (Red Hills and Carrizo Plains in the East County and Atascadero and Paso Robles in the North County), and are holding steady in the areas where ambient levels are already low (San Luis Obispo, Morro Bay, Grover Beach and Nipomo.) Due to higher than normal temperatures statewide, 1998 was a particularly bad year for ozone across California. San Luis Obispo County was not spared—this phenomenon is apparent in many of the graphs presented below, and Paso Robles was most affected.

The conclusion that ozone levels are improving is based on the examination of several statistical measures of ozone intensity. Exceedances of the state 1-hr standard (90 ppb) and the federal 8-hr standard (75 ppb) are tracked, since these measures clearly relate to whether or not standards are being attained. Trends in federal 8-hr design values (defined below) are also analyzed, as this is the statistic EPA uses to formally designate attainment status. Finally, hours at or above 65 ppb are tracked. While there are no standards set at this level, it is nonetheless a useful statistic for the purpose of assessing trends, especially for sites with good air quality that have few if any exceedances of air quality standards. See **Appendix B** for the details of any calculations performed to generate these statistics.

Downtime for instrument calibrations and service is unavoidable when operating pollutant monitors; thus, there are always fewer than 365 days each year with valid measurements. In some cases extended outages may occur, for example when sites are moved or equipment is upgraded. New stations may be commissioned mid-year or monitoring discontinued mid-year. With the exception of the design value analysis, no data completeness requirements were applied to these analyses. If ozone measurements were made for any part of a year, that year is included in the trend analyses that follow.

8-hr Design Values

“Design value” is the EPA term for the statistic used to designate an area as attainment or non-attainment for an ambient air quality standard. For ozone, design values are determined by first calculating running 8-hr averages from the hourly ozone data in AQS (monitoring agencies submit only hourly values to AQS, not 8-hr averages or other intervals). This analysis is used to identify the highest 8-hr ozone value for each day and the fourth highest daily maximum 8-hr value for the year. The average of three consecutive years of these fourth highest values is then calculated. This number is the “design value” for the area, and the standard is attained if the design value is equal to or less than the standard (currently 75 ppb).

For a design value to be considered valid (and thus comparable to the ozone NAAQS) certain data completeness requirements must also be met. For example, for an 8-hr average to be valid, at least 75% of the hourly values (i.e. 6 hours) must be valid, and for a day to be valid, at least 75% of the 8-hr averages in

that day must be valid. For a design value to be valid, at least 90% of the days covered by the 3-year period must be valid, with a minimum of 75% of days valid for each individual year. Additional rules cover how significant digits are handled in these calculations.

Due to the complexity of design value calculations, the design values used in this analysis were calculated by AQS. Only valid design values are presented; thus, gaps occur for years during which data completeness requirements were not met. Also, as three consecutive valid years are required, design values do not appear on the following graphs until the third year after a new site is established. Red Hills data is missing in AQS for years prior to 2007, so 2009 is first year for which valid design values are available for this site.

Figure 4, below, displays all valid 8-hr design values from 1991 to 2011 for the eight sites covered in this report. As shown in the graph, the east county sites, Red Hills and Carrizo, have the highest 8-hr design values in the county. Paso Robles and Atascadero in the North County have the next highest, while the remaining sites comprise a third group with design values consistently below the other two groups. This same grouping is evident in the other statistics discussed later. While the design values for Carrizo Plains and Red Hills show non-attainment of the federal standard for all available years, Paso Robles design values have been below the federal ozone standard since 2003, and Atascadero has been below the standard since 1999. Design values for the rest of the county have shown attainment of the standard for the duration of the time period examined in this report.

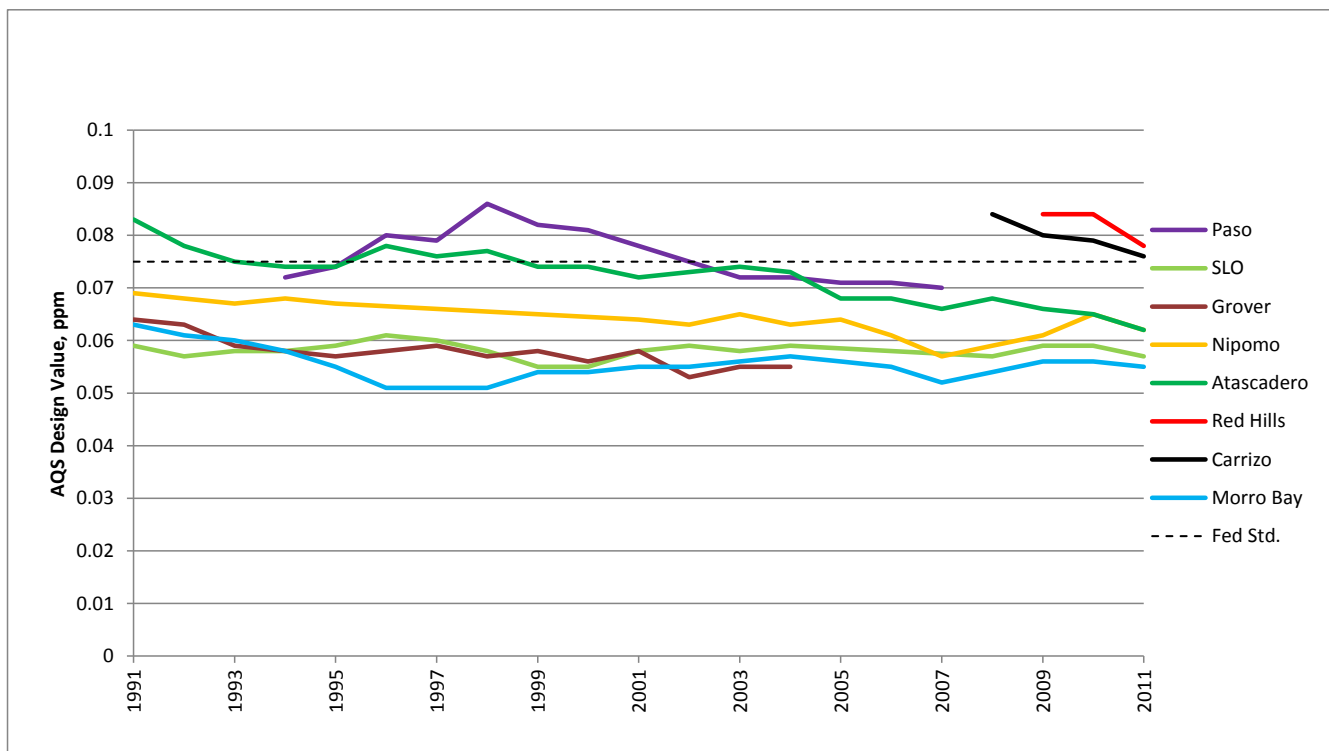
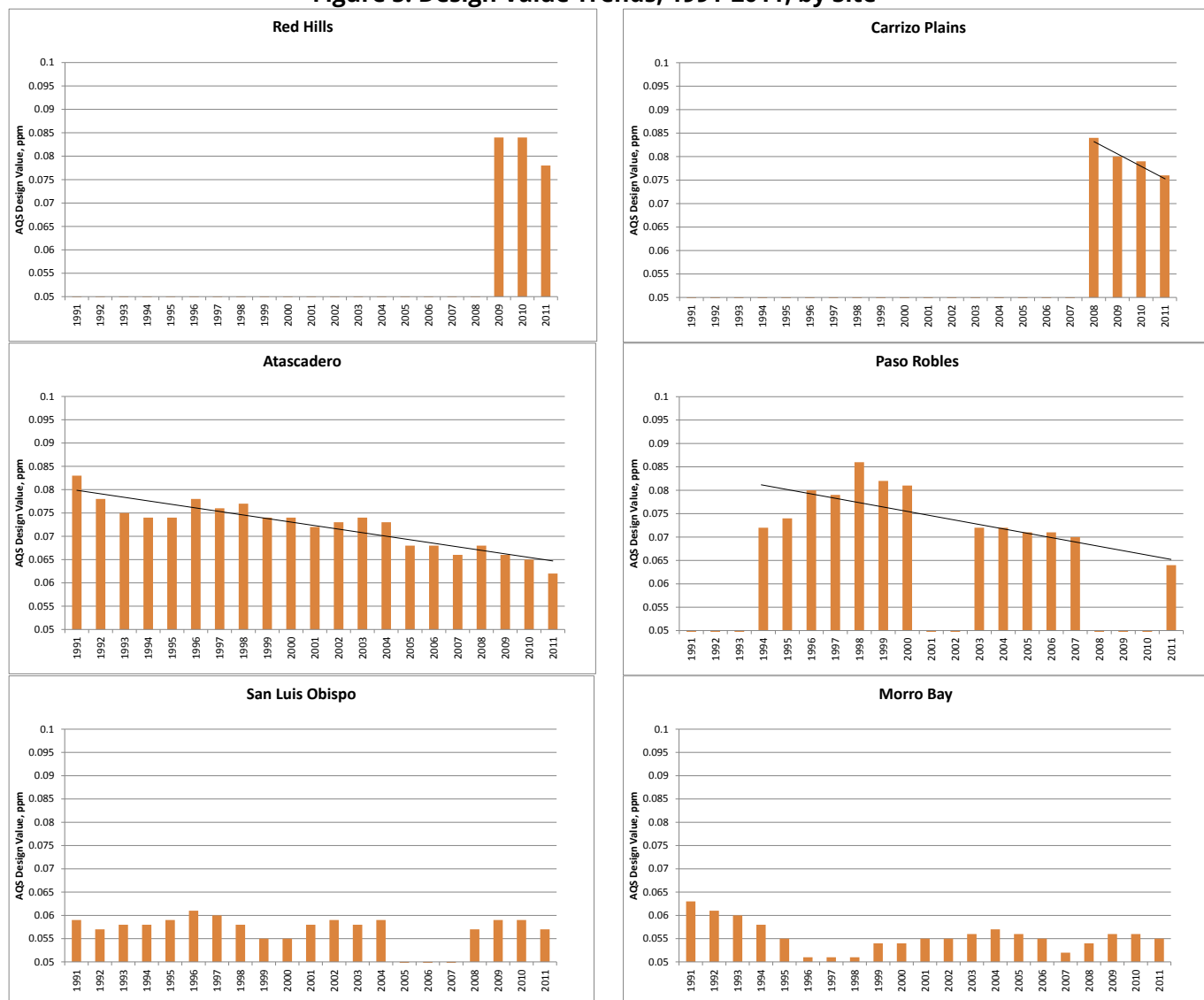


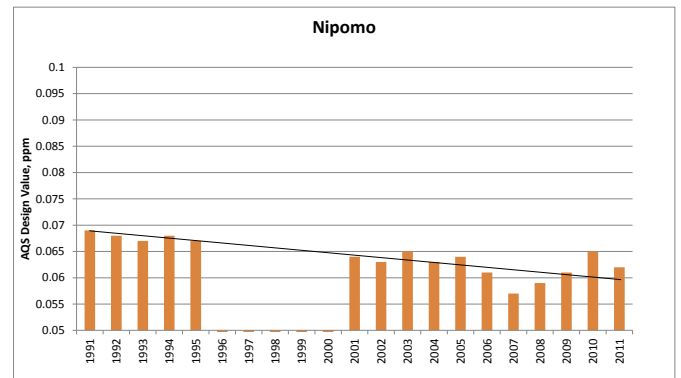
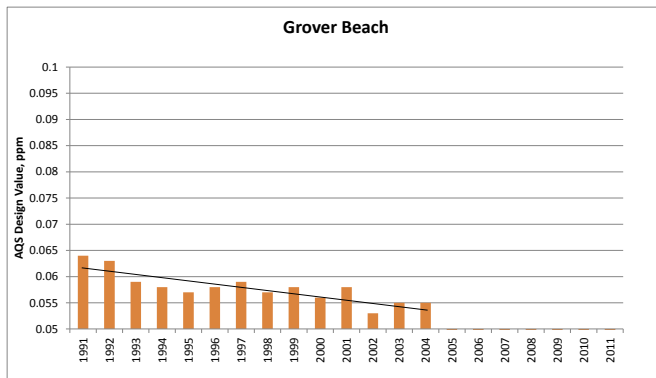
Figure 4: Valid 8-hr Ozone Design Values, 1991-2011

Design value trends are presented in **Figure 5**, below. These charts show decreasing ozone design values for each site, though not all are statistically significant. A trend line is included in the graph only if the trend is statistically significant or borderline significant. As discussed in greater detail in **Appendix B**, trend lines were calculated using least squares linear regression; a P-value of 0.05 for the slope of the trend line was used as the threshold for significance, and P-values between 0.05 and 0.10 were deemed borderline significant.

In the East County, Carrizo Plains shows a statistically significant downward trend in design value of 2.5 ppb/year. The trend for Red Hills is also downward at 3.0 ppb/year, but this trend is not statistically significant, presumably because there are only three data points for this site. In the North County, Paso Robles and Atascadero show nearly identical downward trends of 0.78 and 0.76 ppb/year; both trends are statistically significant. Moving further south and to lower altitude, the trends are less extreme. San Luis Obispo and Morro Bay show very slight downward trends but these are not statistically significant. Note that ozone levels at these sites (and their associated design values) are already quite low; thus, the observed flat-lining of their design values is neither unexpected nor cause for concern. Grover Beach and Nipomo are in an analogous situation, though downward trends at these sites are statistically significant at 0.58 and 0.41 ppb/year.

Figure 5: Design Value Trends, 1991-2011, by Site





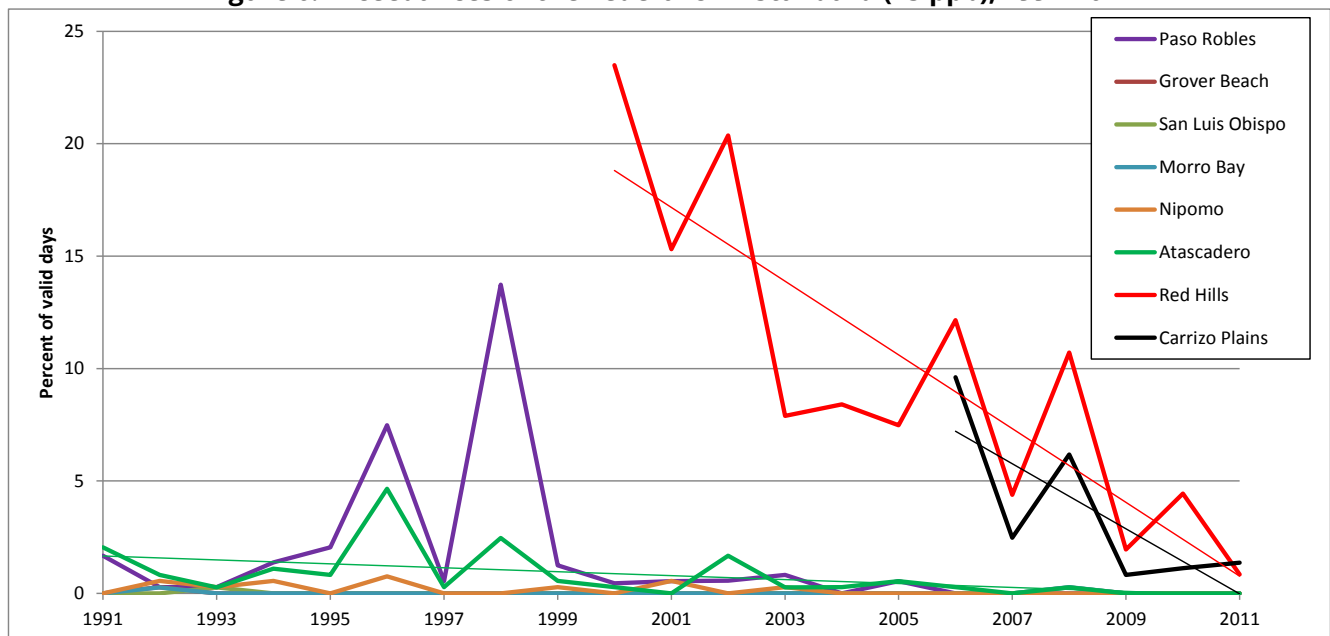
Exceedances of the Federal 8-hr Standard

Days each year exceeding the federal 8-hr standard of 75 ppb are depicted in **Figure 6**. Since the number of days with valid 8-hr averages varies from site to site and year to year, this statistic is expressed as the *percent of valid days each year* exceeding the standard, rather than as simply the *number of days each year* exceeding the standard. For most site/year combinations the number of valid days is at least 350; however, in some instances ozone was measured for a substantially shorter period of time. For example, monitoring began at Red Hills in mid-2000, so there are only 166 valid days for that site that year. Simply comparing the raw count of exceedances from that year to other more complete years would paint an inaccurate picture, since there were less than half as many opportunities to observe an exceedance in 2000 as during a typical year. Expressing exceedances as a percent of valid days rather than the raw count of exceedances remedies this problem. Note that normalizing the data in this manner assumes exceedances occur at the same rate throughout the year; however ozone concentrations are known to exhibit seasonal variation as shown in **Figure 3**. Despite this drawback, this technique is believed to be a better way of dealing with periods of missing data than using the raw count of exceedances or excluding years with partial data.

As was seen with design values in **Figure 4**, the East County (Red Hills and Carrizo Plains) is in a class by itself, with a far greater percentage of days exceeding the standard than other parts of the county (**Figure 6**). For 2009-2011, exceedances were limited to this portion of the county. Comprehensive air quality studies in this area have shown that transport of ozone and ozone precursors from areas outside the county are responsible for the high ozone levels measured there.

Visually, the charts show exceedances are decreasing in the areas with the worst air quality, and statistical analysis bears this out. For Red Hills, the reduction in exceedances is statistically significant, corresponding to 6.0 fewer days per year exceeding the standard. The rate of decline at the Carrizo Plains site is nearly the same with 5.3 fewer days per year exceeding the standard; this trend is borderline significant. The trend for Atascadero, though small (0.3 fewer days/year), is also statistically significant; trends for the other sites are not significant. Note that in **Figure 6** (and all other figures with trend lines), color-coded trend lines are only included for trends that are statistically significant or borderline significant.

Figure 6: Exceedances of the Federal 8-hr Standard (75 ppb), 1991-2011



Exceedances of the State 1-hr Standard

Days exceeding the California 1-hr standard (90 ppb) are shown in **Figure 7**. As with federal 8-hr exceedances, these are expressed as the percent of valid days with an exceedance, rather than as the raw number of exceedances each year. The results are very similar to the previous section: East County most frequently exceeds the standard, but the sites there exhibit a strong, downward trend, with 3.0 fewer exceedances per year seen at Red Hills and 1.8 fewer at Carrizo Plains. The other statistically significant trend is for Atascadero, with 0.2 fewer exceedance per year. Coastal and South County stations have only rarely recorded hourly ozone concentrations in excess of 90 ppb. The San Luis Obispo and Grover Beach stations have each recorded only one exceedance since 1991; Morro Bay has recorded three, and Nipomo six. Since 2007, only two exceedances have been recorded at sites other than Red Hills or Carrizo Plains: one each in San Luis Obispo and Nipomo, both in 2008.

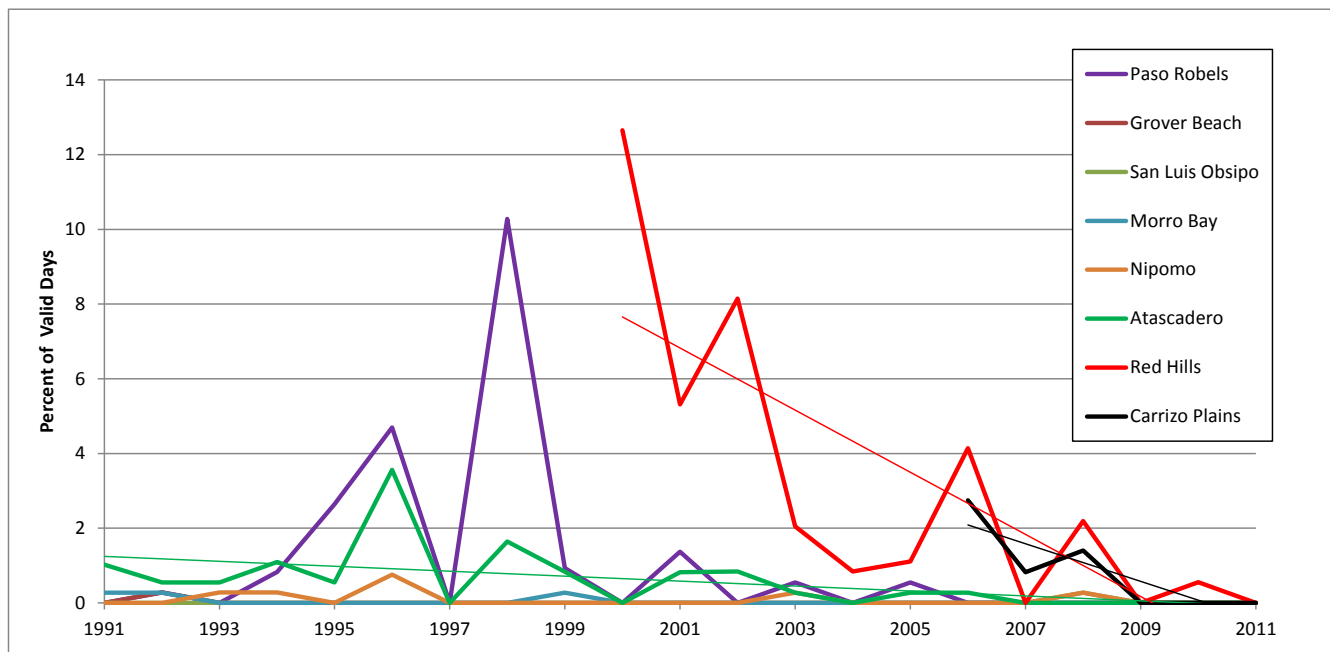


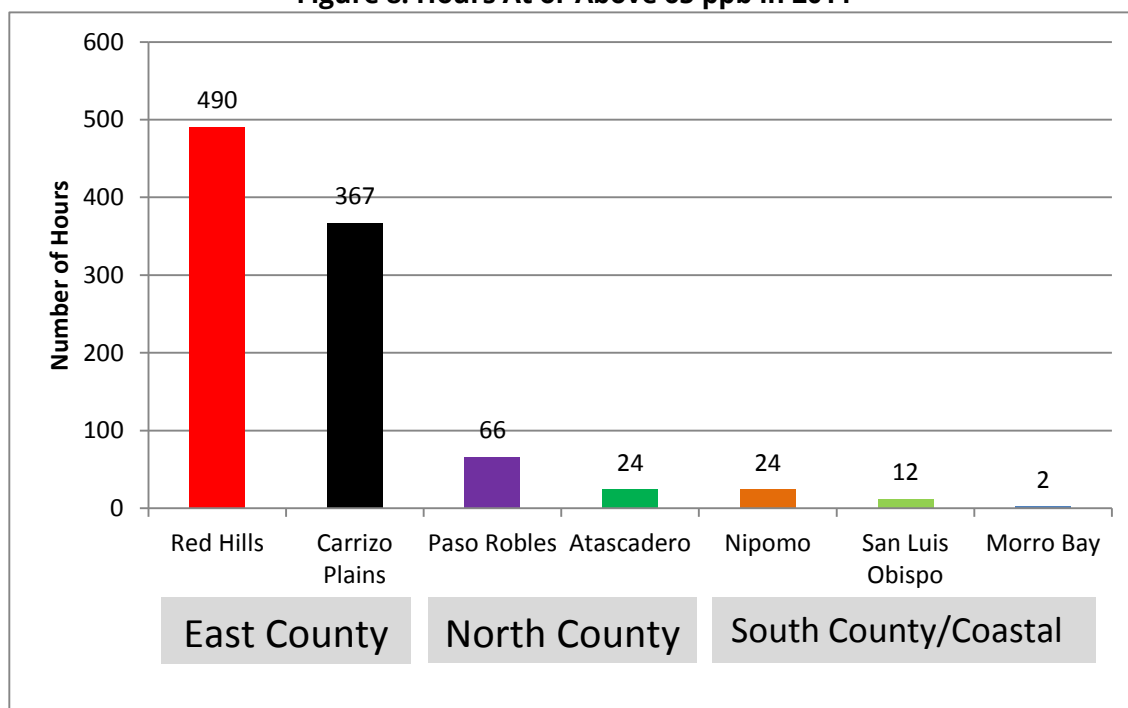
Figure 7: Exceedances of the California 1-hr Standard (90 ppb), 1991-2011

Hours At or Above 65 ppb

In our annual Air Quality Reports, the number of hours each year with ozone levels at or above 65 ppb is typically tracked. This concentration level was found to represent the meteorological and air quality conditions under which ozone formation at elevated concentrations can occur. Although there are no health standards for single-hour exposures to 65 ppb ozone, there are more hours that reach or exceed this level countywide than those exceeding the standards; thus, it is a useful indicator for trend purposes.

Figure 8 shows the number of hours in 2011 at or above 65 ppb for the sites operating that year. Once again, the East County sites stand out, with far more hours at or above 65 ppb measured at these sites than in other parts of the county. North County comprises the next highest group, with the South County and coastal sites showing the lowest levels. (This year Atascadero and Nipomo had the same number of hours at the this level, but—as the following graphs will demonstrate—this is only because air quality has improved so much in Atascadero.)

Figure 8: Hours At or Above 65 ppb in 2011

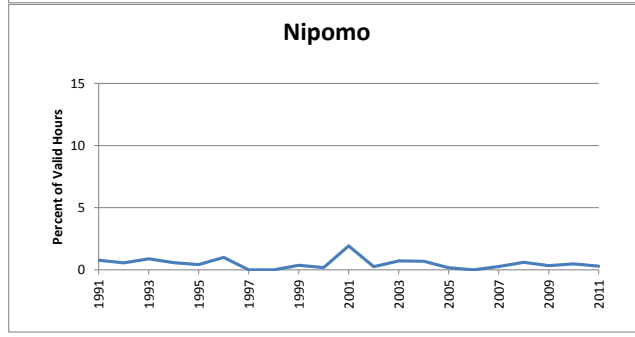
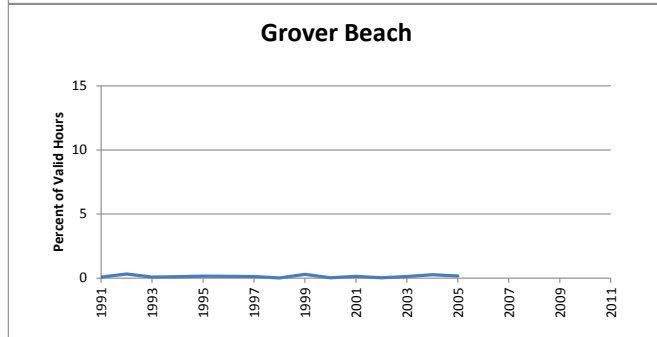
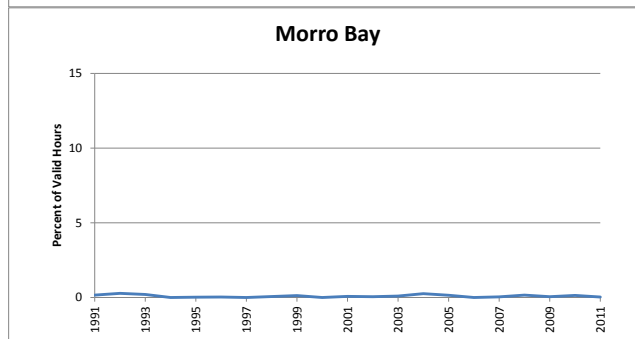
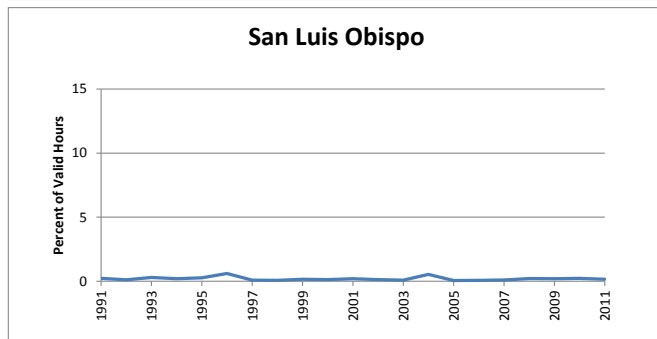
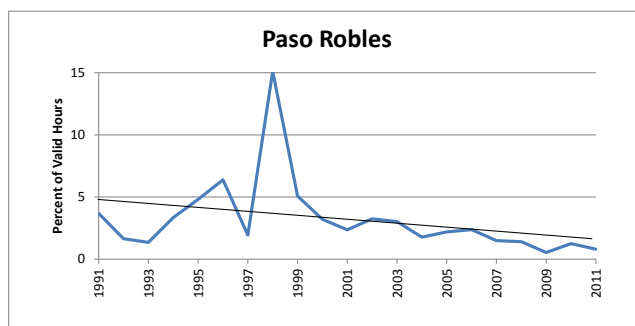
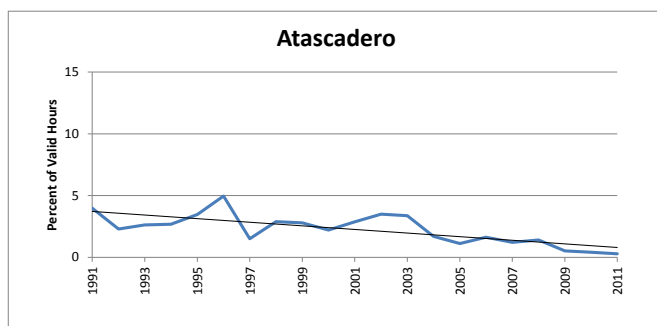
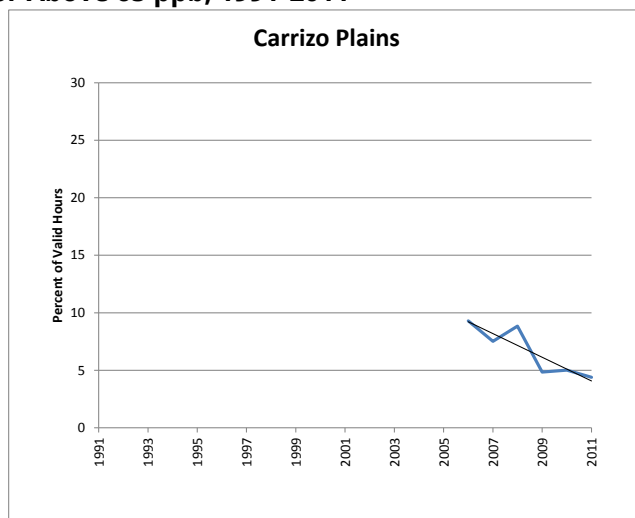
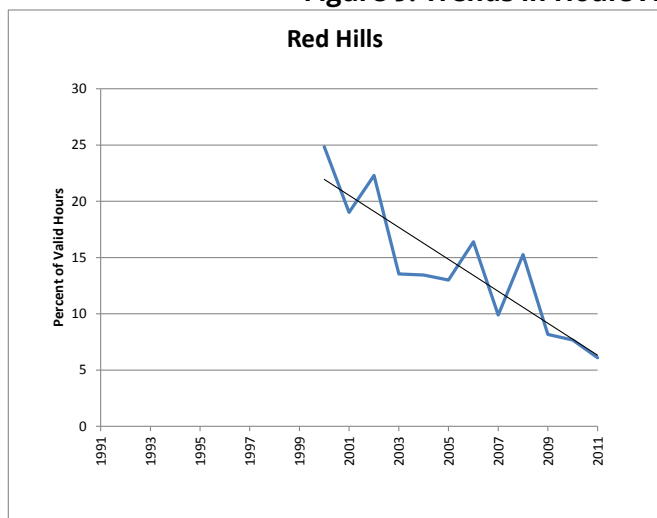


Long term trends in hours at or above 65 ppb are depicted in **Figure 9**, below. As with previous trend graphs, this statistic is expressed as the percent of valid hours for the year, rather than as the raw count of hours. This is done to facilitate comparisons across years when some of the included years may be based on incomplete data. Also in keeping with the convention in previous graphs, trend lines are only included when they are statistically significant or borderline significant.

While hours at or above 65 ppb are most common in the East County, these sites are also trending downward at the fastest rate. At Red Hills, there are on average 119 fewer hours each year at this level, and at Carrizo Plains there are 85 fewer hours per year; both trends are statistically significant. In the North County, Paso Robles and Atascadero also show declines in the number of hours at this level, although the decline is not as steep as for the East County: 15 fewer hours per year in Paso Robles and 12 fewer in Atascadero. The trend for Atascadero is significant; however, because 1998 was so high, the trend for Paso Robles is not statistically significant. Removing this point from the analysis yields a statistically significant trend of 11 fewer hours per year; this shallower trend line is what is depicted in **Figure 9**.

The remainder of the county enjoys good ozone air quality, with relatively few hours each year reaching the 65 ppb level. Measurements in San Luis Obispo, Morro Bay, Nipomo, and Mesa2 do not show significant trends, either downward or upward, meaning residents in these areas can expect low ozone levels to continue.

Figure 9: Trends in Hours At or Above 65 ppb, 1991-2011



PM_{2.5} Trends

As shown in **Table 1**, monitoring for PM_{2.5} did not begin in the county until 1999 and was initially confined to San Luis Obispo and Atascadero. PM_{2.5} monitoring on the Nipomo Mesa did not start until recently, with measurements at Mesa2 commencing in 2009 and at CDF in 2010. In general, PM_{2.5} levels in Atascadero and San Luis Obispo show steady improvement, and exceedances of standards are rare at these sites. Levels are highest during the winter in Atascadero, and improvements in wintertime PM_{2.5} levels are driving the overall decrease in PM_{2.5} observed there; PM_{2.5} levels in San Luis Obispo show less seasonality. In contrast, PM_{2.5} levels are much higher on the Nipomo Mesa at the CDF and Mesa2 stations, and there is no evidence of improvement there. Like Atascadero, PM_{2.5} levels on the Nipomo Mesa display a strong seasonality, but the pattern is reversed, with winter being the cleanest time of the year. Specific trends at each monitoring site are discussed in detail below.

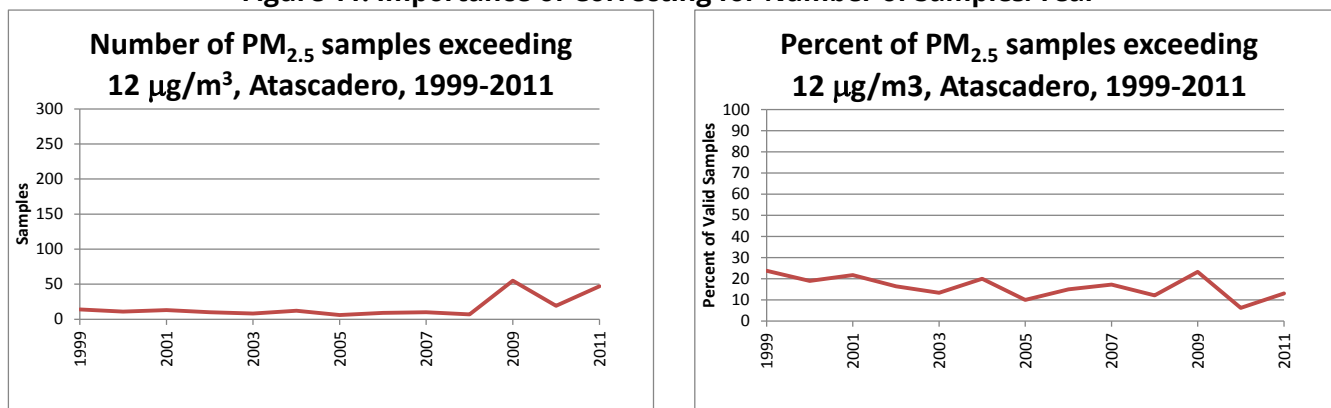
For PM_{2.5} there are federal standards based on the annual average concentration as well as 24-hr averages. Because of this, trends analyzed in this section include the annual average concentration and the number of days each year exceeding the federal 24-hr standard of 35 µg/m³. Out of the entire PM_{2.5} dataset, only a handful of days exceed the federal 24-hr standard, so little if anything meaningful can be said about long-term PM_{2.5} trends based on this statistic. Therefore, another statistic was analyzed—days each year exceeding 12 µg/m³, which is the level set by EPA for the annual PM_{2.5} standard. Although no health-based standards exist for 24-hr PM_{2.5} at this level, there are considerably more days that reach or exceed this level countywide than those exceeding 35 µg/m³; thus, it is a useful indicator for tracking long-term PM_{2.5} trends. Finally, an analysis of the seasonal variation in PM_{2.5} levels is presented.

As with the ozone trends that are based the number of days each year exceeding a certain level, PM_{2.5} statistics (other than the annual average) are expressed as the *percent of valid samples each year* that exceed the criterion (i.e. 35 or 12 µg/m³) rather than as simply the *number of samples each year* exceeding the criterion. This is especially important for PM measurements because sampling methodology underwent significant upgrades in the last few years, resulting in a dramatic increase in the number of valid samples each year. Prior to 2009, all PM measurements (both PM_{2.5} and PM₁₀) were made using a high-volume, filter-based methodology known as the Federal Reference Method (FRM). FRM samplers collected one 24-hr sample every six days, or about 60 samples per year, assuming no missed samples. Starting in 2009, FRM samplers were gradually replaced with “continuous” monitors that make hourly PM measurements and run every day. These continuous monitors, known as Federal Equivalent Methods (FEMs), can potentially yield 24-hr average PM values for every day of the year, though the annual number of valid sample days is invariably reduced to less than 365 due to downtime caused by power failures, routine maintenance, equipment malfunctions, etc.

Figure 11 below illustrates the importance of correcting for the number of valid samples. The raw count of valid samples exceeding 12 µg/m³ each year is shown on the left for Atascadero, while the percent of valid samples per year exceeding this threshold is plotted on the right. In the left figure, it appears that PM_{2.5} pollution has increased in Atascadero in recent years. In fact, this apparent increase is just an artifact of the change in sampling method resulting in increased sampling—in mid-2009 the FRM operating on a 1-in-6 day schedule was replaced with a continuous FEM monitor. Sampling every day rather than every sixth day provides six times as many days to potentially observe an exceedance. This is corrected for in the graph on the right, which plots the percent of valid 24-hr samples exceeding 12 µg/m³ each year. This graph shows a gradual yearly decrease in the frequency of exceedances, and implies an improvement, rather than a decay, in PM_{2.5} levels in Atascadero.

Finally, as with ozone, years with incomplete data are not removed from these trend analyses.

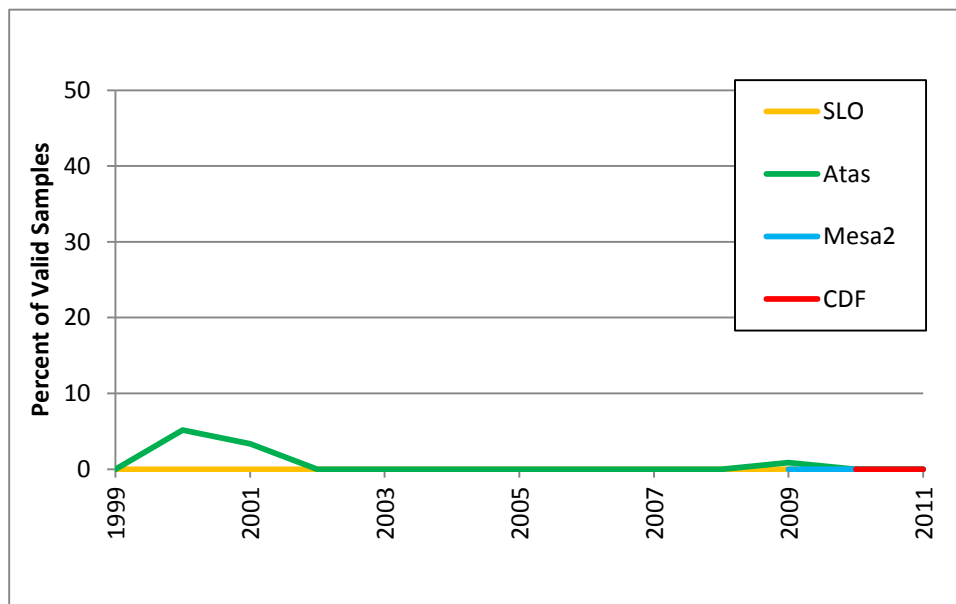
Figure 11: Importance of Correcting for Number of Samples/Year



Exceedances of the Federal 24-hr Standard

As noted in **Table 2**, the federal 24-hr standard for PM_{2.5} is 35 µg/m³. As shown in **Figure 12**, below, this standard has only been exceeded in Atascadero a handful of times during the period studied. (In 2000, 3 of 58 samples from Atascadero exceeded the standard; in 2001, 2 of 60; and in 2009, 2 of 237.) Given the paucity of exceedances, meaningful information on long-term PM_{2.5} trends cannot be gleaned from this statistic.

Figure 12: Exceedances of the Federal 24-hr PM_{2.5} Standard (35 µg/m³), 1999-2011



Days Exceeding 12 µg/m³

Because so few PM_{2.5} samples have exceeded the federal 24-hr standard of 35 µg/m³, the frequency of days exceeding a lower concentration was also examined. The level set by EPA for the annual PM_{2.5} standard—12 µg/m³—proved to be a useful indicator for trend purposes even though there are no health-based standards for daily exposures to PM_{2.5} at this level.

The results of this analysis are shown in **Figures 13** and **14**. **Figure 13** clearly shows PM_{2.5} levels in Atascadero and San Luis Obispo are decreasing. As with all plots in this report, color-coded trend lines are displayed only if the trend is statistically significant or borderline significant. For Atascadero, the trend is borderline significant and corresponds to 2.6 fewer days each year exceeding 12 µg/m³. For San Luis Obispo, the downward trend of 4.1 days/year is statistically significant. In contrast, **Figure 14** shows PM_{2.5} levels on the Nipomo Mesa have increased during the time that it has been measured there. The increase seen at Mesa 2 is statistically significant, but it is difficult to identify the observed increase as a trend given the short time period of PM_{2.5} monitoring in that area.

Figure 13: Days Exceeding 12 µg/m³, Atascadero and San Luis Obispo, 1999-2011

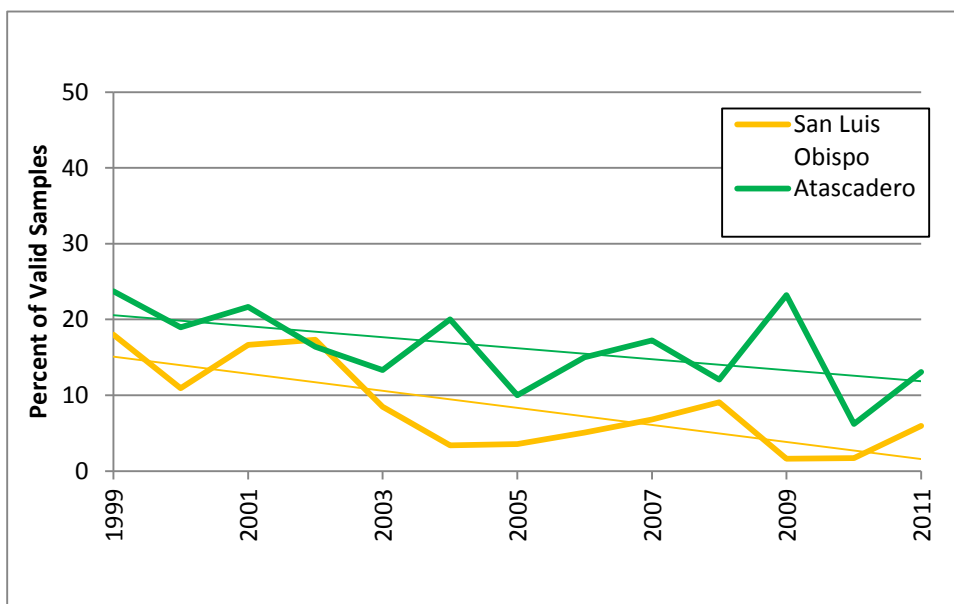
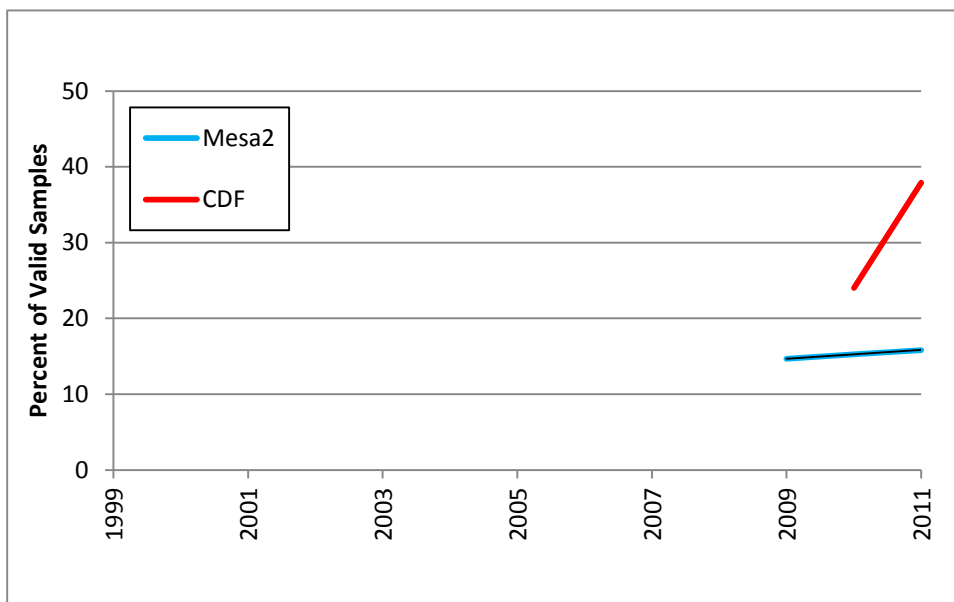


Figure 14: Days Exceeding 12 µg/m³, Mesa2 and CDF, 2009-2011



Annual Averages

Trends in annual average $PM_{2.5}$ values were also analyzed, as there are federal and state standards for this statistic (see **Table 2**). As shown in **Figures 15** and **16**, annual averages in Atascadero and San Luis Obispo have never exceeded the previous federal standard of $15 \mu\text{g}/\text{m}^3$ or the State and current federal standard of $12 \mu\text{g}/\text{m}^3$. Trend analysis indicates that annual averages are decreasing at both sites, and at nearly the same rate: $0.25 \mu\text{g}/\text{m}^3$ per year for Atascadero and $0.21 \mu\text{g}/\text{m}^3$ per year for San Luis Obispo. In contrast, yearly averages on the Nipomo Mesa are both higher than elsewhere in the county and appear to be increasing. For Mesa2, there is a statistically significant upward trend of $0.13 \mu\text{g}/\text{m}^3$ per year. The annual average $PM_{2.5}$ concentration at CDF increased by almost $2.5 \mu\text{g}/\text{m}^3$ from 2010 to 2011, but with only two years of data available it is not possible to analyze whether this trend is significant. Note that CDF's annual average for 2011 was $11.93 \mu\text{g}/\text{m}^3$, so if these levels continue to increase, it will likely bring CDF into violation of the state and federal annual $PM_{2.5}$ standard.

Figure 15: Annual Average $PM_{2.5}$ Levels, Atascadero and San Luis Obispo, 1999-2011

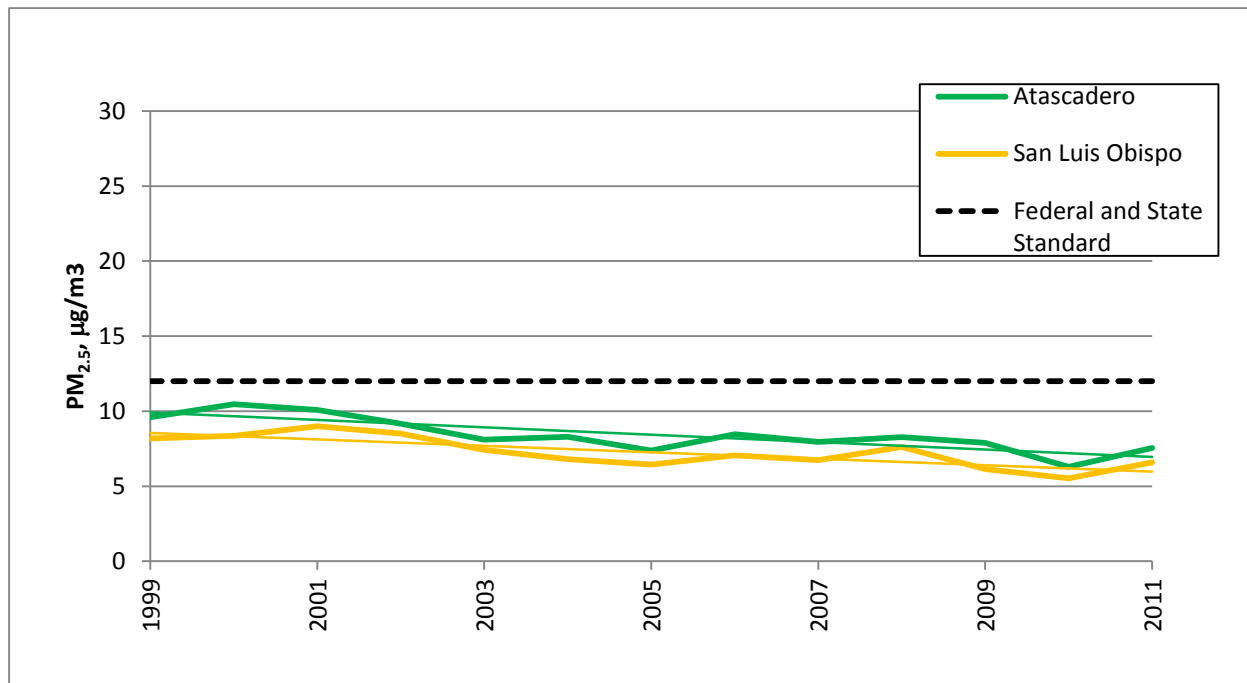
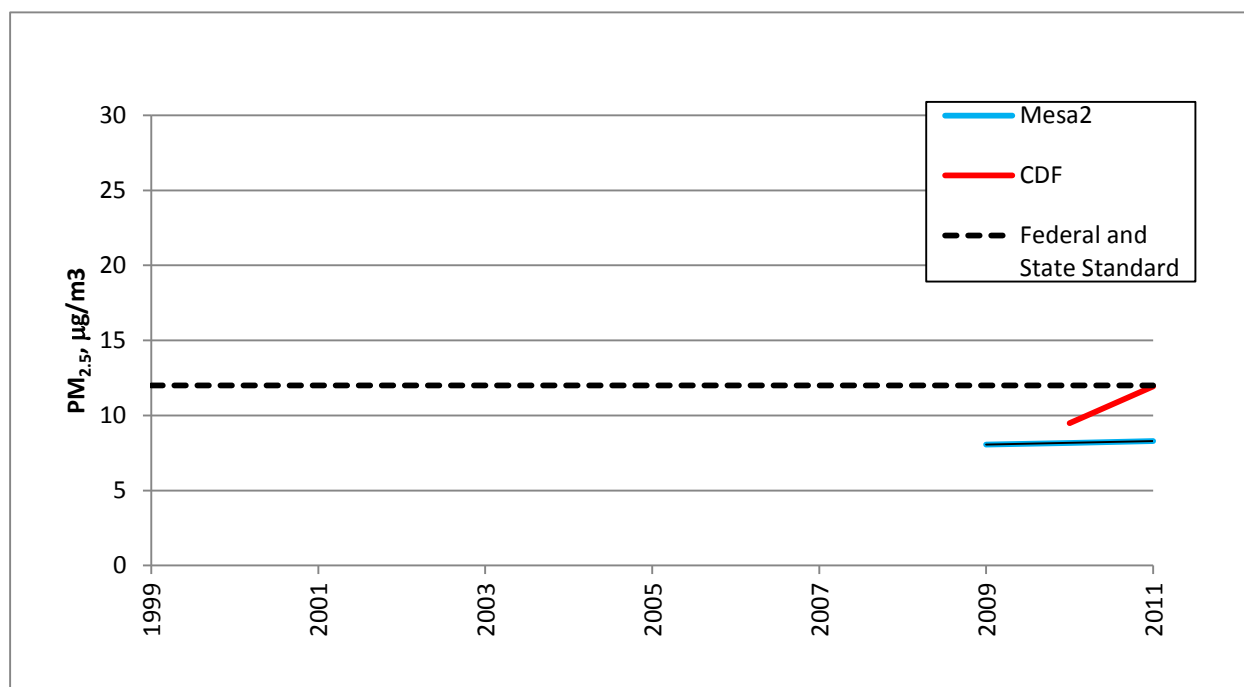


Figure 16: Annual Average PM_{2.5} Levels, Mesa2 and CDF, 2009-2011



Seasonal Variation

Because of the regional nature of ozone pollution and the role of sunlight in its creation, ozone concentrations tend to display the same diurnal and seasonal patterns regardless of where they are measured (see **Figures 2** and **3** above for examples). Particulate pollution behaves differently, largely because it is a more local pollutant and its formation is not driven by sunlight. Therefore, seasonal patterns, when present, can provide insight into the nature of the local emission sources that contribute to the levels observed in the field. The graphs that follow show some of these patterns; to smooth out spikes in the data, a 31-day moving average is plotted alongside the daily PM_{2.5} values.

As shown in **Figure 17** below, PM_{2.5} levels for Atascadero follow an annual cycle, with the highest levels typically occurring in the winter when temperature inversions and residential woodburning are common and combine to trap fine particulates close to the ground. For San Luis Obispo (**Figure 18**) no seasonal pattern is apparent. South County data (**Figures 19** and **20**) show a strong seasonal pattern, with highest peaks seen during the spring and early summer wind season when the dust plume from the Oceano Dunes frequently impacts the Nipomo Mesa and surrounding areas. This seasonal pattern is also apparent in the PM₁₀ data discussed later.

To determine whether the decline in annual average PM_{2.5} levels at Atascadero (**Figure 15**) is driven by reductions in high wintertime levels or by evenly distributed reductions year-round, an analysis of seasonal averages was undertaken. Winter was defined as November through February based on inspection of **Figure 17**, which showed that the high PM_{2.5} season tends to begin in November and end in February. Averages for winter and non-winter months were calculated for each year, and the trends for winter and non-winter months were analyzed by linear regression. For consistency, this analysis was also conducted for the San Luis Obispo site, even though no difference between winter and non-winter trends was expected since PM_{2.5} levels do not show seasonal cycling there. No analysis of winter/non-winter data was performed for Mesa2 or CDF due to the lack of long-term PM_{2.5} monitoring data at those sites.

Figure 17: 24-hr PM_{2.5} Measurements, Atascadero, 1999-2011

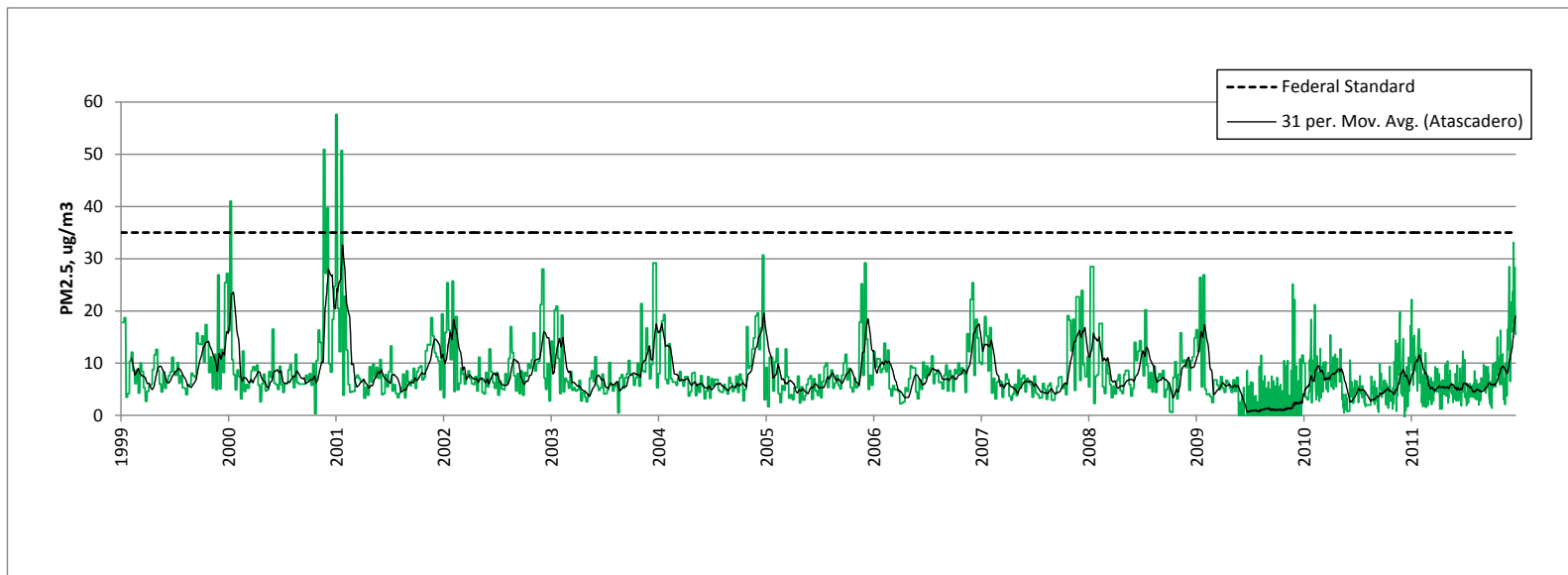


Figure 18: 24-hr PM_{2.5} Measurements, San Luis Obispo, 1999-2011

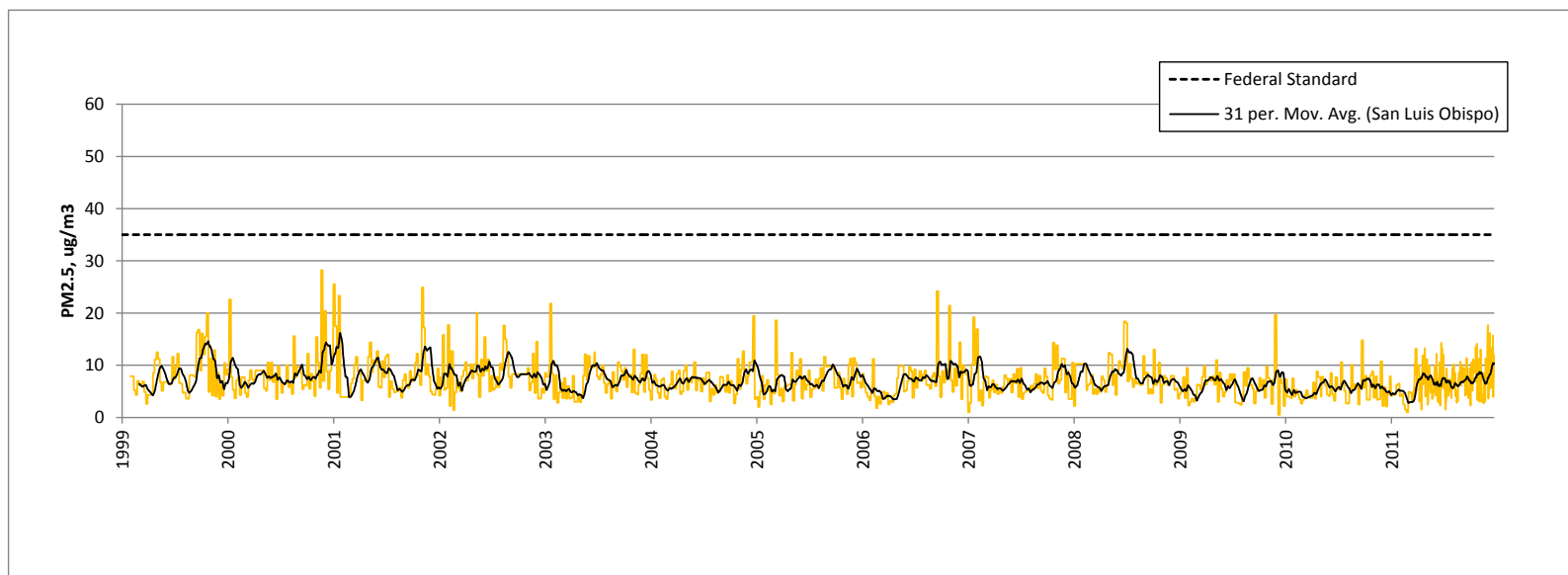


Figure 19: 24-hr PM_{2.5} Measurements, Mesa2, 2009-2011

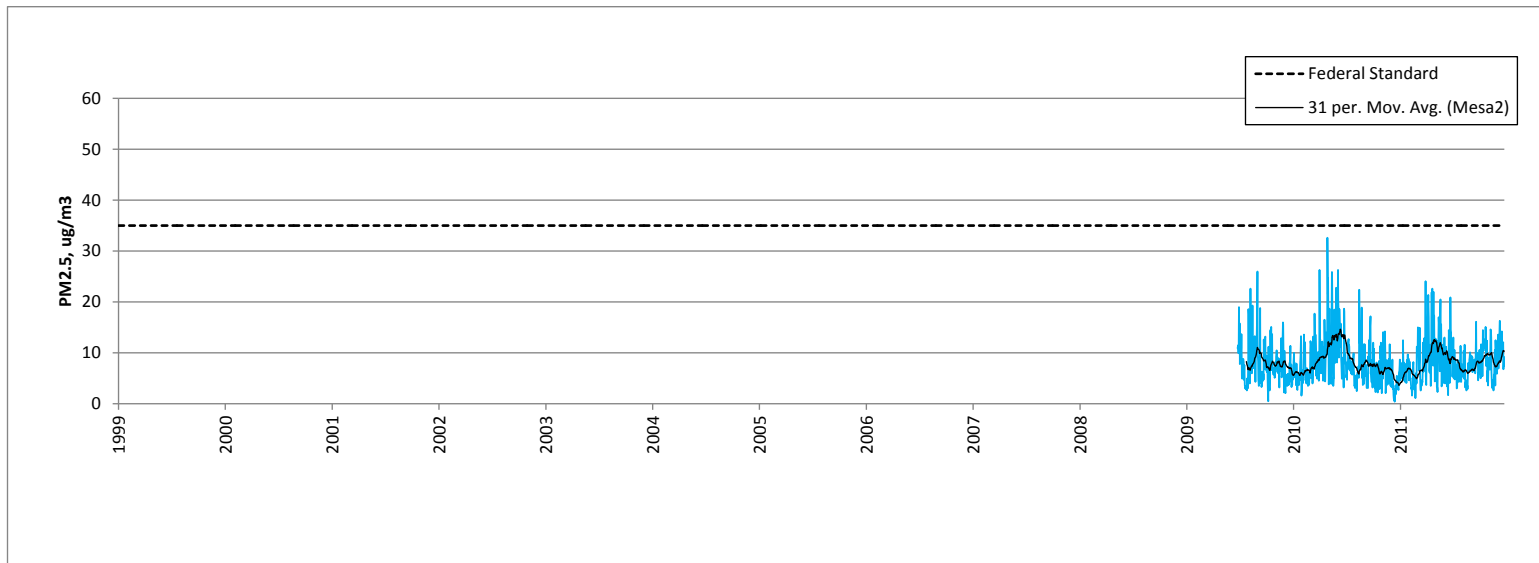


Figure 20: 24-hr PM_{2.5} Measurements, CDF, 2010-2011

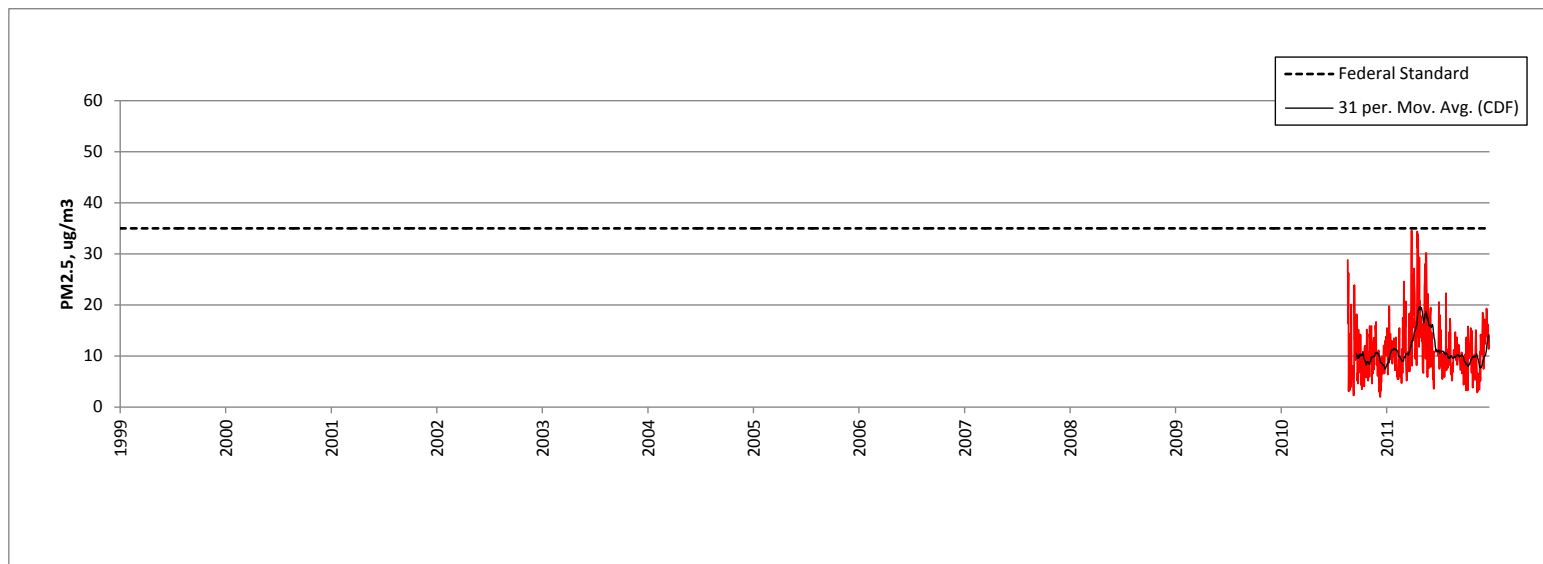
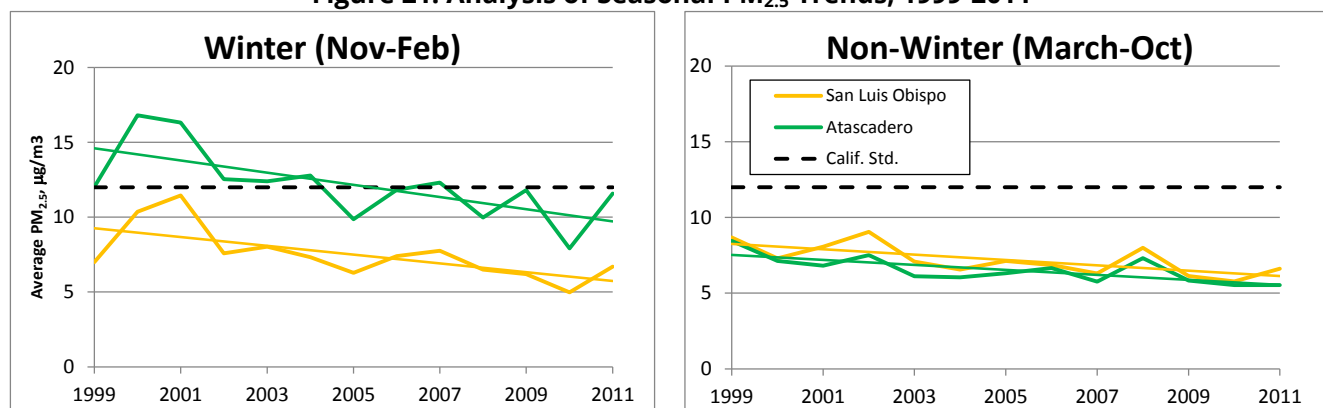


Figure 21: Analysis of Seasonal PM_{2.5} Trends, 1999-2011



As shown in **Figure 21**, PM_{2.5} levels for Atascadero are higher in the winter months (left side plot) than the non-winter months (right side plot). Wintertime levels are also declining faster than during other times of the year, as indicated by the steeper declining slope (0.41 µg/m³ per year) for the wintertime regression (left side) versus the non-winter regression (0.17 µg/m³ per year, right side). Both trends are statistically significant. Taken together, these data indicate that for Atascadero, reductions in wintertime levels of PM_{2.5} are driving the overall decline in annual PM_{2.5} levels there. This improvement in wintertime air quality coincides with the implementation of the District's residential woodburning and open burning regulations that have significantly reduced woodburning particulate emissions over that same period.

For San Luis Obispo, the winter and non-winter average are trending downward at 0.29 µg/m³ per year and 0.18 µg/m³ per year, respectively; both are significant. This shows that the downward trend in PM_{2.5} levels at this site is less seasonal, though wintertime levels are dropping somewhat faster.

PM₁₀ Trends

Measurement of PM₁₀ began in 1980; this report looks back only to 1991. Monitoring is currently performed in Paso Robles, Atascadero, San Luis Obispo, and on the Nipomo Mesa at Mesa2, CDF, and Nipomo Regional Park. In addition to these sites, Morro Bay is also included in this analysis since data is available through 2010. PM₁₀ sampling has also been conducted at other sites throughout the county including on the Carrizo Plains and at various locations on and upwind of the Nipomo Mesa. These data are not included since these monitoring efforts were short-term and the data is not amenable to long-term trend analysis.

As discussed in greater detail below, PM₁₀ levels have steadily decreased in the North County, and today are very similar to those seen in San Luis Obispo. Exceedances of the state 24-hr standard have always been rare in San Luis Obispo and Morro Bay, and these cities show either continued improvement in air quality (San Luis Obispo) or are maintaining historically low levels (Morro Bay). The greatest degree of PM₁₀ pollution is observed on the Nipomo Mesa in the South County, where the state standards for 24-hr and annual average PM₁₀ are routinely exceeded at CDF and Mesa2. In contrast to the North County and San Luis Obispo, these sites show no improvement and may be worsening. At the Nipomo site further inland on the Mesa, PM₁₀ levels are not as elevated and some measures even indicate improvement.

Currently all PM₁₀ monitoring in the county is done by continuous FEMs, but initially all measurements were made by FRMs operating on the 1-in-6 day schedule described previously. The transition in methodology (and thus sampling frequency) occurred between 2009 and 2011. Thus, as was the case with the preceding PM_{2.5} trend analyses, trends in the number of samples exceeding certain thresholds each year are discussed in terms of the percent of valid samples exceeding the criterion, rather than the raw count of exceedances.

For PM₁₀, the trends analyzed are all directly related to the state and federal PM₁₀ standard (**Table 2**). Annual exceedances of the California 24-hr standard (50 µg/m³) and the federal standard (150 µg/m³) are examined, and trends in the annual average are also assessed since California has adopted a standard (20 µg/m³) based on this statistic. Finally, seasonal variation in PM₁₀ is also examined.

Exceedances of the State and Federal 24-hr Standards

Among the sites and years included in this report, the federal 24-hr standard of 150 µg/m³ has only been exceeded once. This was a value of 167 µg/m³ recorded at CDF on May 5, 2010, when hourly PM₁₀ values peaked at more than 500 µg/m³. Given the lack of data points to evaluate, a trend analysis cannot be performed for this statistic.

The California 24-hr standard of 50 µg/m³ has been routinely exceeded throughout the county; thus, a meaningful trend analysis can be performed based on these exceedances. Plots of this statistic—expressed as the percent of valid samples exceeding the standard each year—are displayed in **Figure 22** (North County), **Figure 23** (Morro Bay and San Luis Obispo), and **Figure 24** (South County). Color-coded trend lines are included only when trends are statistically significant or borderline significant.

In recent years, the North County and Morro Bay/San Luis Obispo have looked very similar in terms of the frequency of state exceedances, with 0-2% of 24-hr samples exceeding 50 µg/m³ each year. The difference between these two regions is that San Luis Obispo and Morro Bay have always enjoyed this relatively low level of PM₁₀ pollution, while the North County has only recently achieved this level. The downward trend in state PM₁₀ exceedances is statistically significant for both Paso Robles and Atascadero, and corresponds

to 1.7 and 0.6 fewer exceedance days per year, respectively. For San Luis Obispo there is also a slight downward trend (0.2 fewer exceedances per year) but it is only borderline significant, and for Morro Bay, there is no significant trend. This analysis indicates that these two sites are maintaining their relatively low levels of PM₁₀ pollution.

Figure 22: Exceedances of the California 24-hr PM₁₀ Standard, North County, 1991-2011

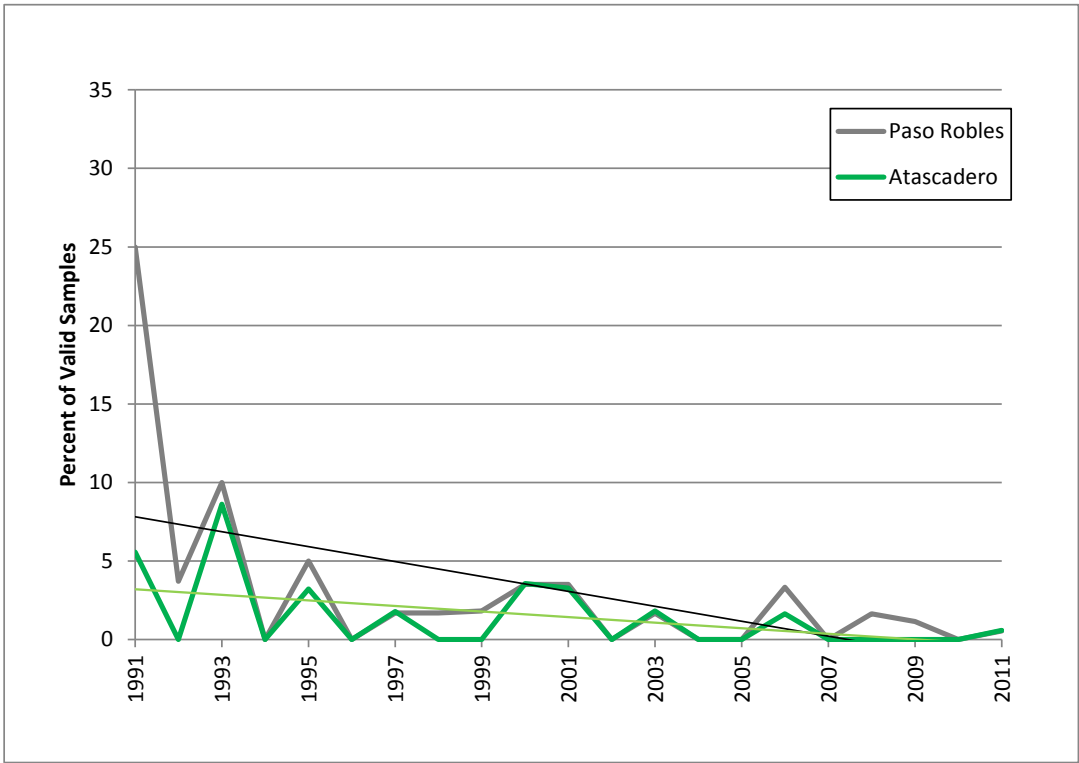


Figure 23: Exceedances of the California 24-hr PM₁₀ Standard, San Luis Obispo and Morro Bay, 1991-2011

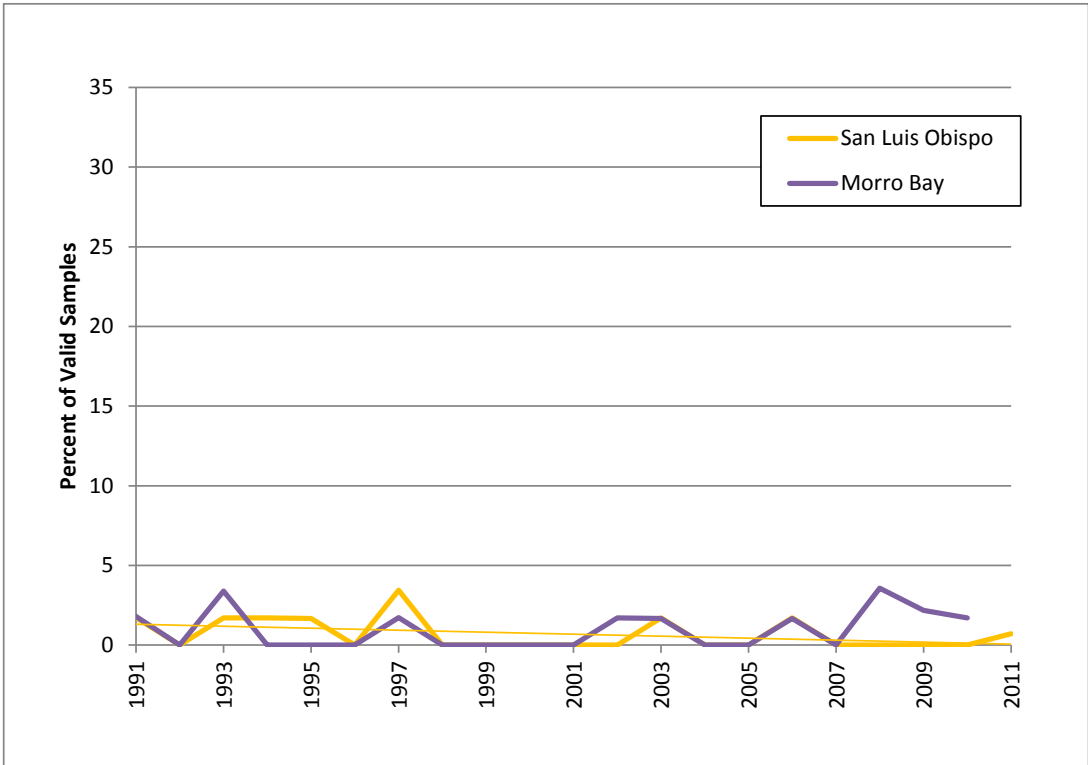
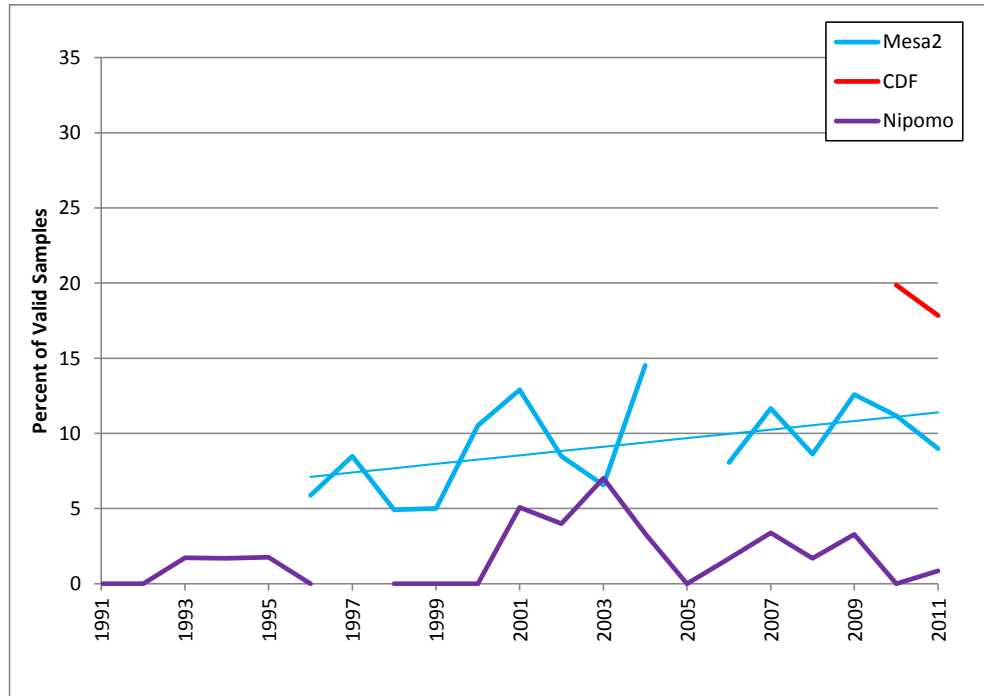


Figure 24: Exceedances of the California 24-hr PM₁₀ Standard, South County, 1991-2011



Parts of South County experience significantly higher levels of PM₁₀ pollution than the rest of the county, with numerous exceedances of the state 24-hour PM₁₀ standard measured there every year. As shown in **Figure 24**, above, 20% and 18% of sample days in 2010 and 2011 exceeded the state standard at CDF, with many exceedances at Mesa2 as well. Sampling at Mesa2 started in October of 1995, but most exceedances of the state standard occur there in the spring and early summer (see below). Including 1995, 8% of sample days at Mesa2 have exceeded the standard each year; with 1995 excluded, 9% of sample days have exceeded the standard. The data also show this high frequency of exceedances is not abating. Including 1995, there is a statistically significant upward trend of 1.4 more exceedances each year at Mesa2. Excluding this year from the trend analysis yields a non-significant upward trend of 1.0 more exceedances each year. Excluding 1995 and 2005—another year with partial data (samples were collected January through April only)—yields a borderline significant upward trend of 1.0 more exceedances per year; this is the trendline depicted in **Figure 24**. With only two years of data available, no trend analysis was performed for CDF.¹

PM₁₀ levels at the Nipomo site further inland more closely resemble those in the rest of the county, with an average 1.8% of sampling days exceeding the standard since 1991; there is no statistically significant trend either upwards or downward at this site.

Annual Averages

While EPA has not established a standard for the annual average, California has an annual standard of 20 µg/m³. As was done for PM_{2.5}, trends in the annual average PM₁₀ concentration were analyzed for each site. The results are shown in **Figures 25-27**.

The North County, as shown in **Figure 25**, has shown steady, statistically significant declines in annual average PM₁₀ concentrations. In Paso Robles, the average is trending downward by 0.38 µg/m³ per year, while Atascadero shows a downward trend of 0.34 µg/m³ per year. While the annual averages at these

¹ See the **Addendum** for detailed discussion of the trend in PM₁₀ exceedances at Mesa2.

sites routinely exceeded the state standard of $20 \mu\text{g}/\text{m}^3$ throughout the 1990s, in recent years Atascadero has been below the standard while Paso Robles is within $\pm 1.5 \mu\text{g}/\text{m}^3$ of the standard.

As shown in **Figure 26**, below, the annual average in San Luis Obispo has typically been less than the averages at both Paso Robles and Atascadero; nonetheless, it continues to decline at a statistically significant rate similar to those seen in the North County: $0.37 \mu\text{g}/\text{m}^3$ per year. Annual average PM_{10} levels in Morro Bay shows no statistically significant trend.

As is the case described above with $\text{PM}_{2.5}$, PM_{10} annual averages are highest on the Nipomo Mesa. **Figure 27** plots these averages, which have always exceeded the state standard at Mesa2 and CDF. Annual average PM_{10} levels at Mesa2 have not shown any noticeable improvement or decline since sampling began there in late 1995 (excluding 1995 and/or 2005 from the trend analysis does not change this conclusion), but there has been a statistically significant decline of $0.20 \mu\text{g}/\text{m}^3$ per year at the Nipomo site further inland. With only two years of data available, the trend at CDF was not analyzed.

Figure 25: Annual Average PM_{10} Levels, North County, 1999-2011

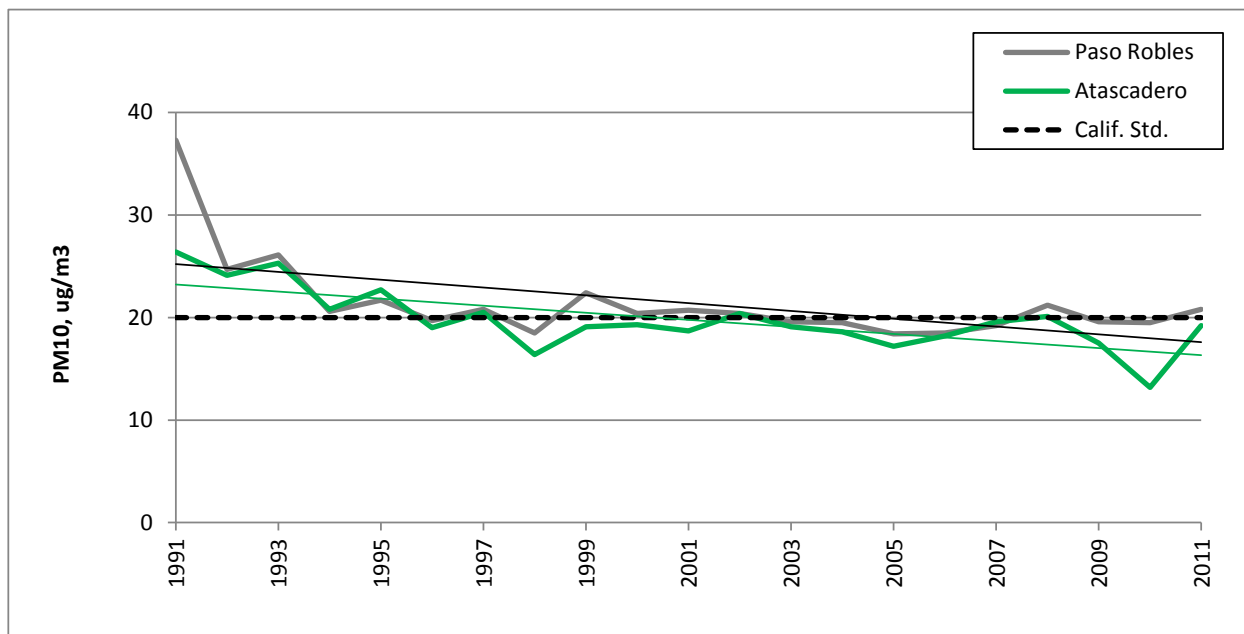


Figure 26: Annual Average PM₁₀ Levels, San Luis Obispo and Morro Bay, 1999-2011

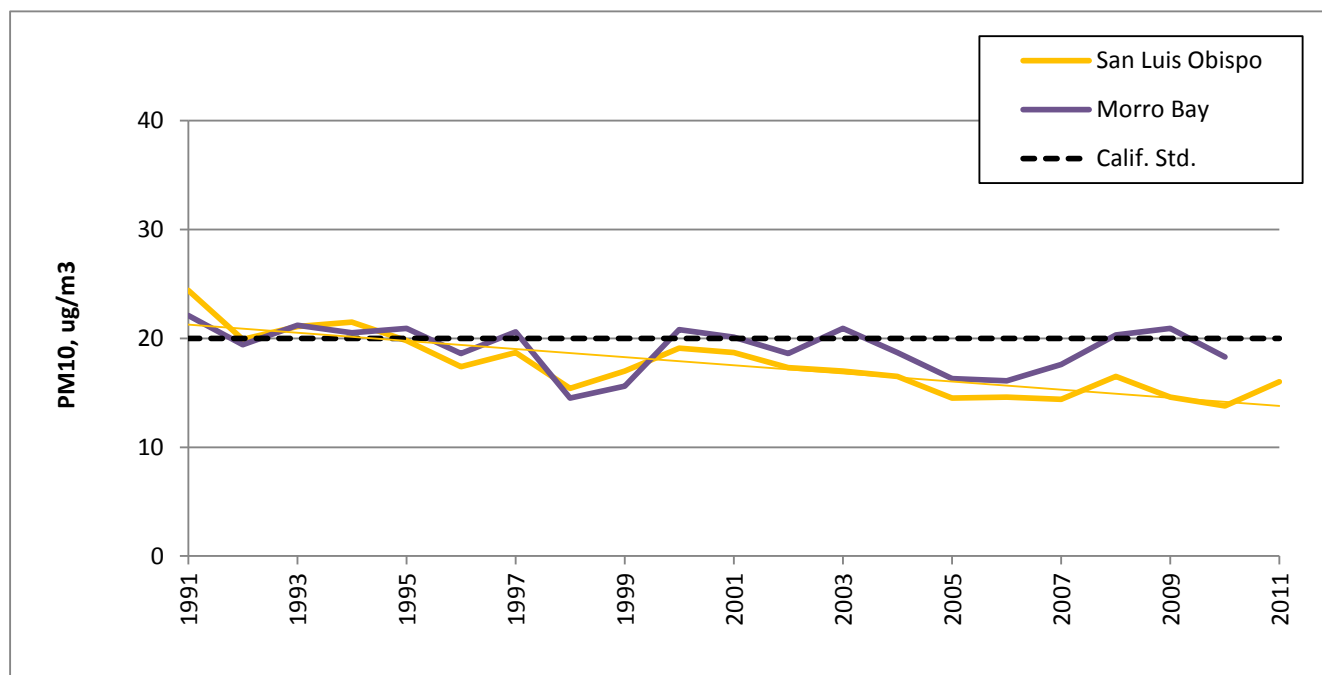
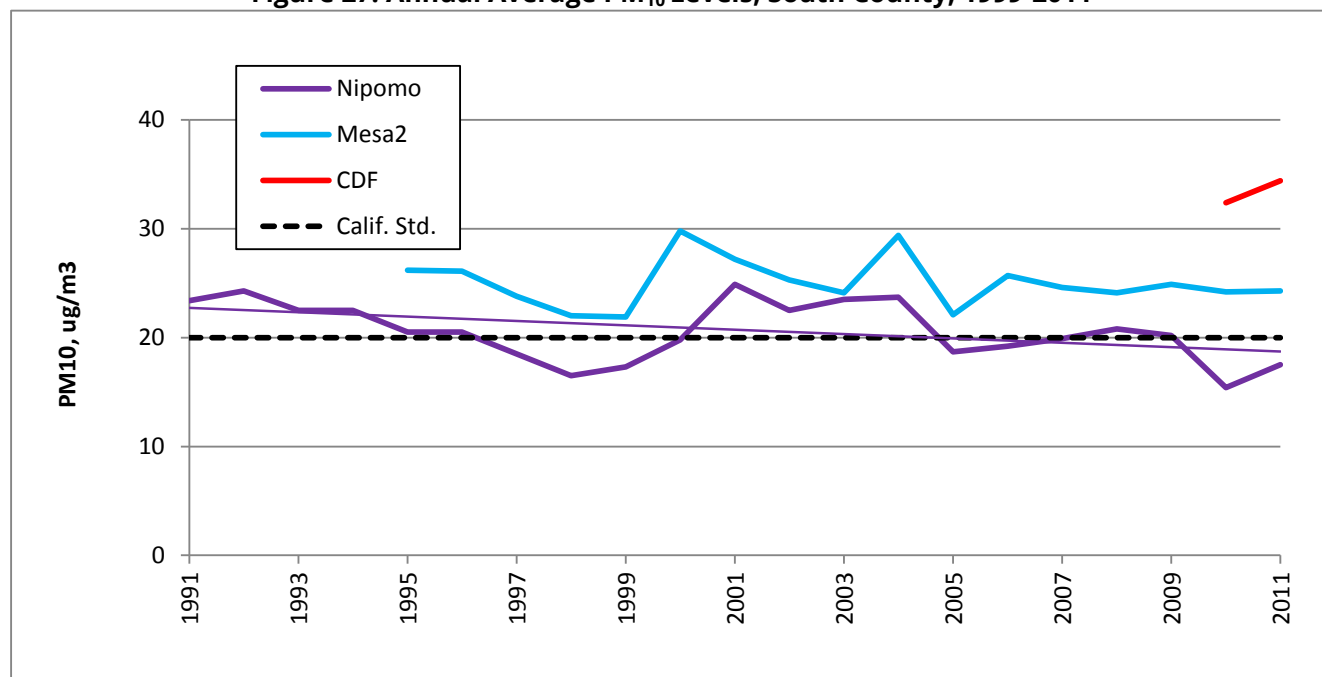


Figure 27: Annual Average PM₁₀ Levels, South County, 1999-2011



Seasonal Variation

In order to reveal seasonal patterns (or lack thereof), the individual 24-hr PM₁₀ values for each site are plotted in **Figures 28-34**. These graphs only look back to 2001, since including the full range of data makes the graphs unwieldy. A 31-day rolling average is included in each graph to smooth out daily variation and make the seasonality more apparent.

For PM₁₀, seasonal cycling appears less pronounced than it does for PM_{2.5}, but it is most apparent in the Mesa2 data, shown in **Figure 32**. In most years, PM₁₀ levels are highest in the spring months and tend to peak in late May, with a secondary peak occurring in late October or early November. January and July typically have the lowest PM₁₀ levels. A similar pattern appears at CDF (**Figure 33**), but not enough data is available to call it a trend. The same pattern is also apparent in the Nipomo data (**Figure 34**), but the difference between the spring and fall peaks is less significant. Overlays of the rolling averages for these 3 sites track one another closely (data not shown) and support these findings.

For Morro Bay and San Luis Obispo (**Figures 30 and 31**) patterns are less apparent, but low points in PM₁₀ levels tend to occur around the New Year and again in July. An overlay of the rolling averages from these sites also shows good alignment. For the North County, a bump in PM₁₀ levels centered on November is present in earlier years (**Figures 28 and 29**) but is not as apparent in the most recent year of data.

As was done for PM_{2.5}, seasonal PM₁₀ averages were calculated and long-term trends in winter vs. non-winter averages were assessed. This was undertaken to determine whether the improvements in the annual averages of Paso Robles, Atascadero, San Luis Obispo, and Nipomo are driven by seasonal PM₁₀ reductions. Even though there were no significant trends in the annual averages for Morro Bay and Mesa2, for consistency, these sites were also assessed. As with the PM_{2.5} analysis, winter was defined as November through February.

The results are shown in **Figure 35**, below. For clarity, the seasonal averages and their corresponding trend lines are plotted on separate graphs. Trend lines are color-coded and are only plotted when statistically significant.

The results of the seasonal analysis are most clear for Nipomo: The winter average (November through February) is trending downward at the statistically significant rate of 0.42 µg/m³ per year, while PM₁₀ levels during other months (March thru October) show only a non-significant decline of 0.1 µg/m³ per year. Thus reductions in winter levels at Nipomo are driving the downward trend observed in the annual average for this site (**Figure 27**).

A similar picture emerges for Paso Robles, where winter and non-winter seasonal averages both show statistically significant declines, but the winter average is declining much more rapidly (0.80 µg/m³ per year) than the non-winter average (0.28 µg/m³ per year). In Atascadero, both winter and non-winter seasonal averages show statistically significant declines, but their rates of decline are more similar: 0.40 and 0.32 µg/m³ per year, respectively. Finally, the downward trend in the annual average for San Luis Obispo does not appear to be more driven by a the winter or non-winter decline, as these decreases are about the same: 0.44 and 0.35 µg/m³ per year, both of which are statistically significant.

In summary, reductions in wintertime PM₁₀ levels seem to be driving the downward trend in annual PM₁₀ averages for Nipomo and Paso Robles. This suggests that controls on winter PM₁₀ sources, such as residential and open burning, are responsible for the improvement in air quality observed there. In Atascadero and San Luis Obispo, non-winter air quality is improving at nearly the same rate as winter air

quality, suggesting that controls on sources that emit year-round are contributing significantly to the improvements observed there. At other sites annual and seasonal averages did not exhibit significant trends.

SUMMARY AND CONCLUSIONS

As shown in the data presented in this report, significant improvements in air quality have been observed in most areas of the county over the past 20 years, despite significant increases in population and vehicle miles traveled during that period (see **Appendix C**). Ozone levels have fallen countywide, particularly in the areas with the highest historical concentrations. This has resulted from emission reductions achieved through implementation of control measures adopted under the District's Clean Air Plan, as well as reductions achieved by areas outside the county that have reduced the level of pollutant transport responsible for the elevated ozone concentrations measured in the eastern portion of our county.

Airborne particulate levels have also declined significantly in most areas of the County. Emission reductions achieved from District implementation of residential woodburning and open burning control programs have been effective in reducing wintertime PM levels and exceedances of health standards in the North County and at our inland Nipomo site. PM₁₀ and PM_{2.5} levels continue to frequently exceed health standards in the South County with no evidence of improvement. District studies show dust from the Oceano Dunes State Vehicular Recreation Area to be the primary emissions source contributing to this problem. The District is currently working with the California Department of Parks and Recreation on the development of Particulate Matter Reduction Plan for that facility. Implementation of the dust control measures in that plan is scheduled to begin within the next year.

Figure 28: 24-hr PM₁₀ Measurements, Paso Robles, 1999-2011

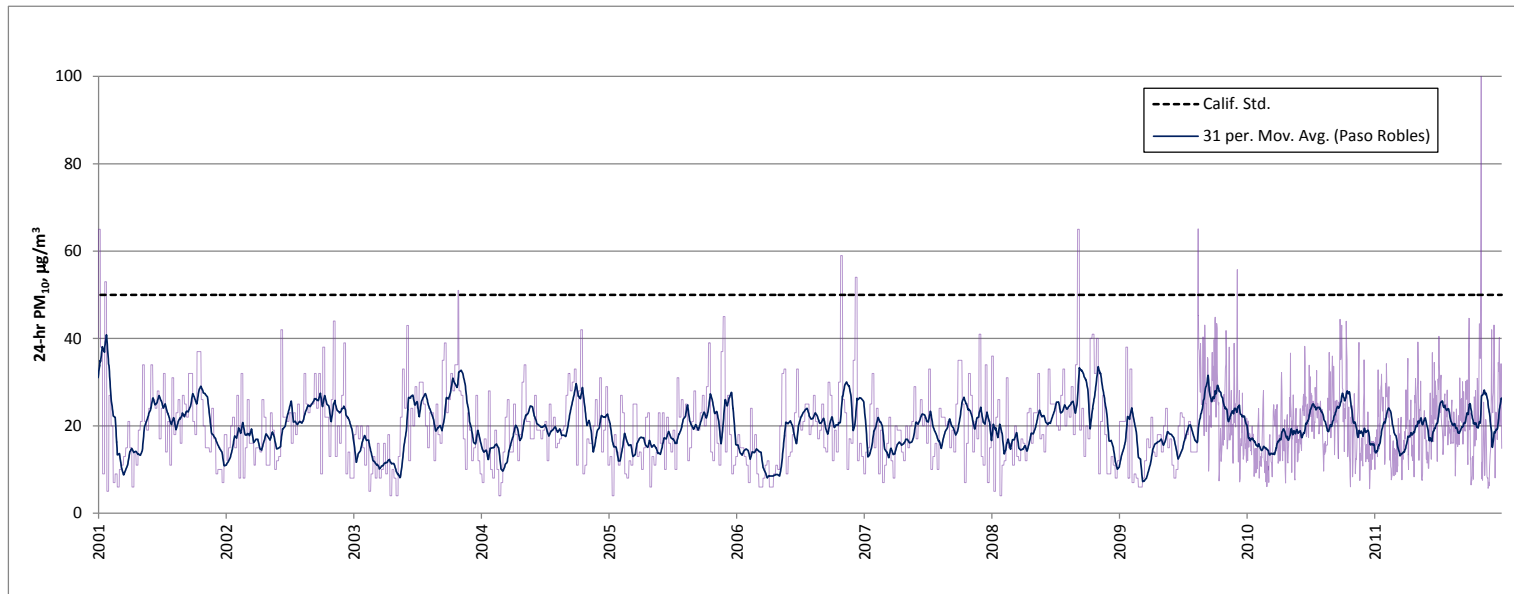


Figure 29: 24-hr PM₁₀ Measurements, Atascadero, 1999-2011

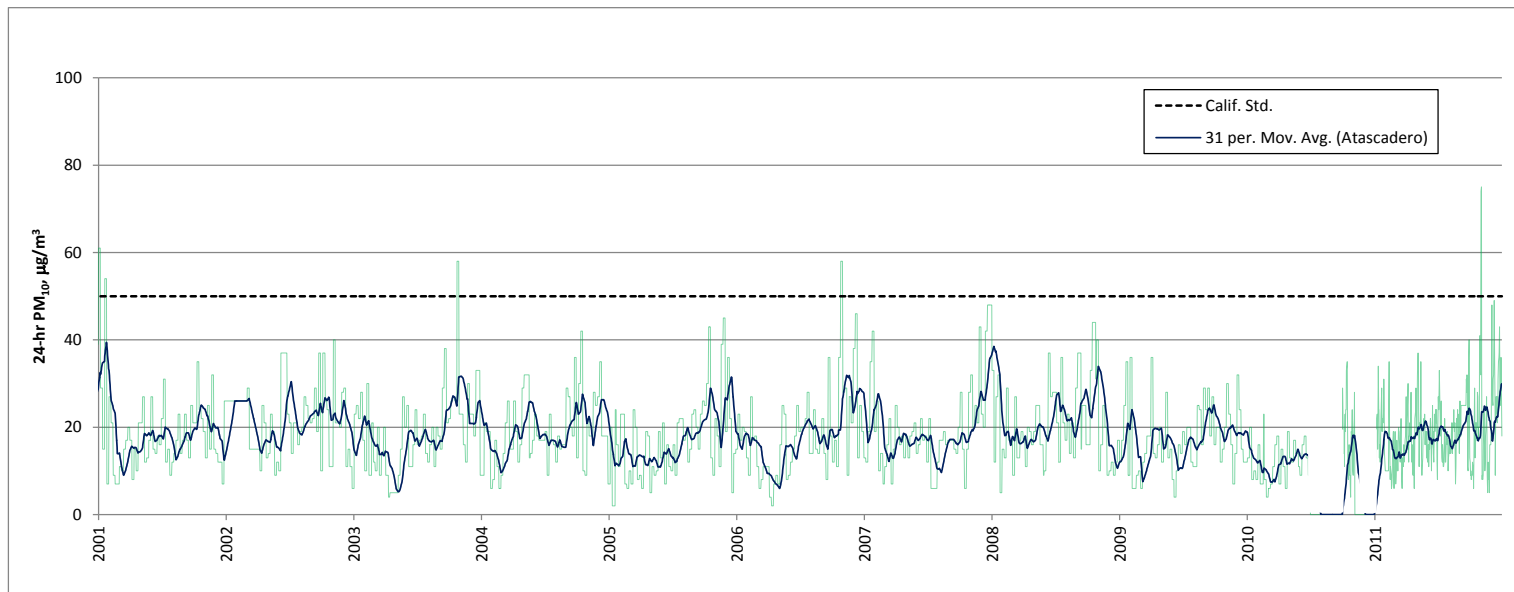


Figure 30: 24-hr PM₁₀ Measurements, San Luis Obispo, 1999-2011

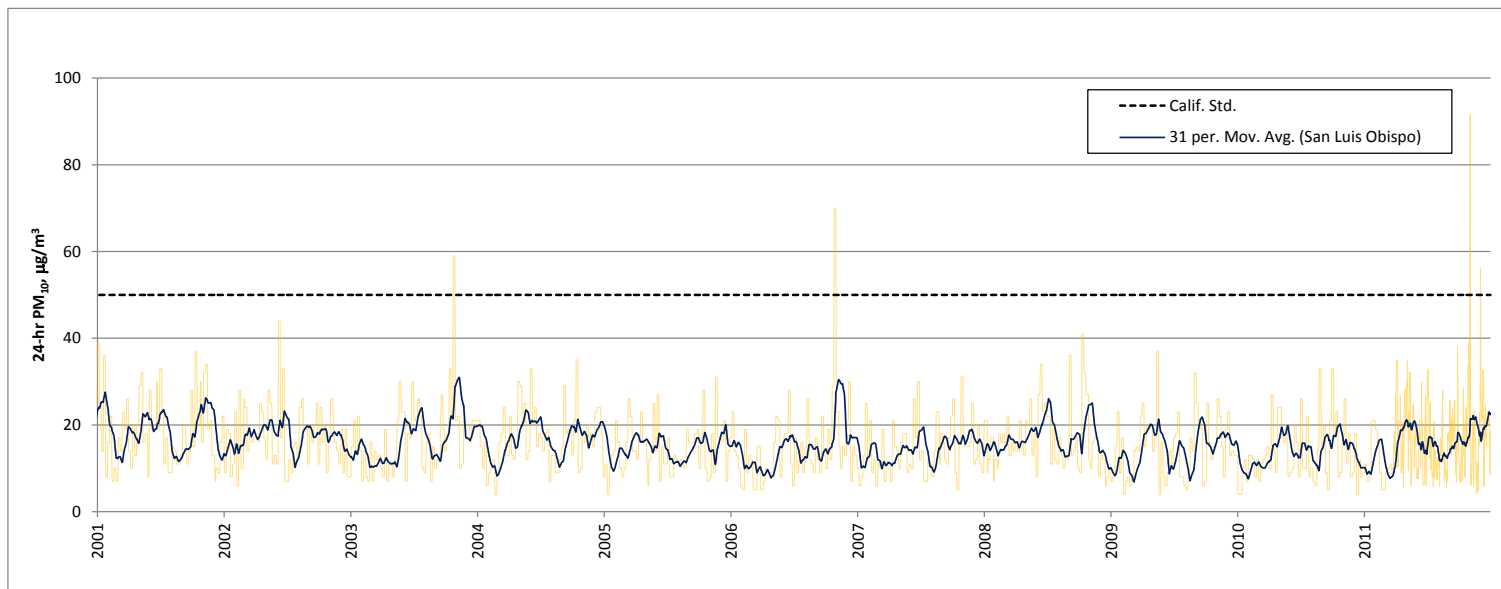


Figure 31: 24-hr PM₁₀ Measurements, Morro Bay, 1999-2010

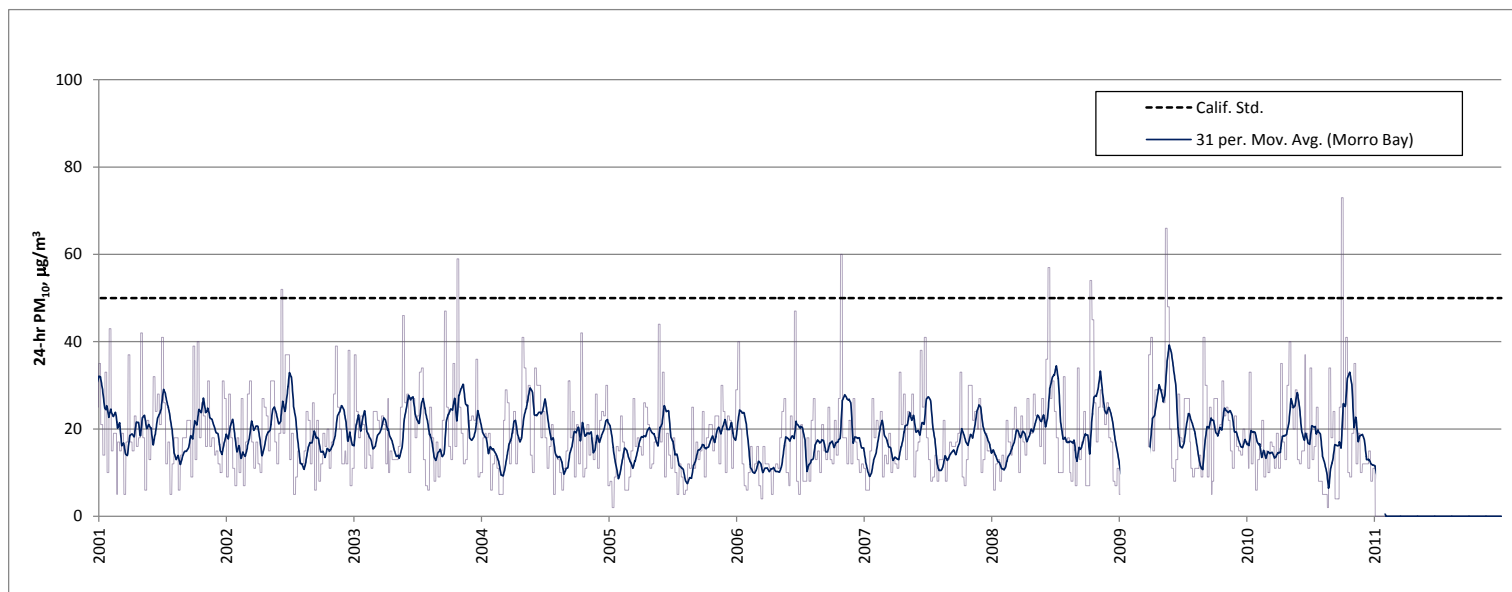


Figure 32: 24-hr PM₁₀ Measurements, Mesa2, 1999-2011

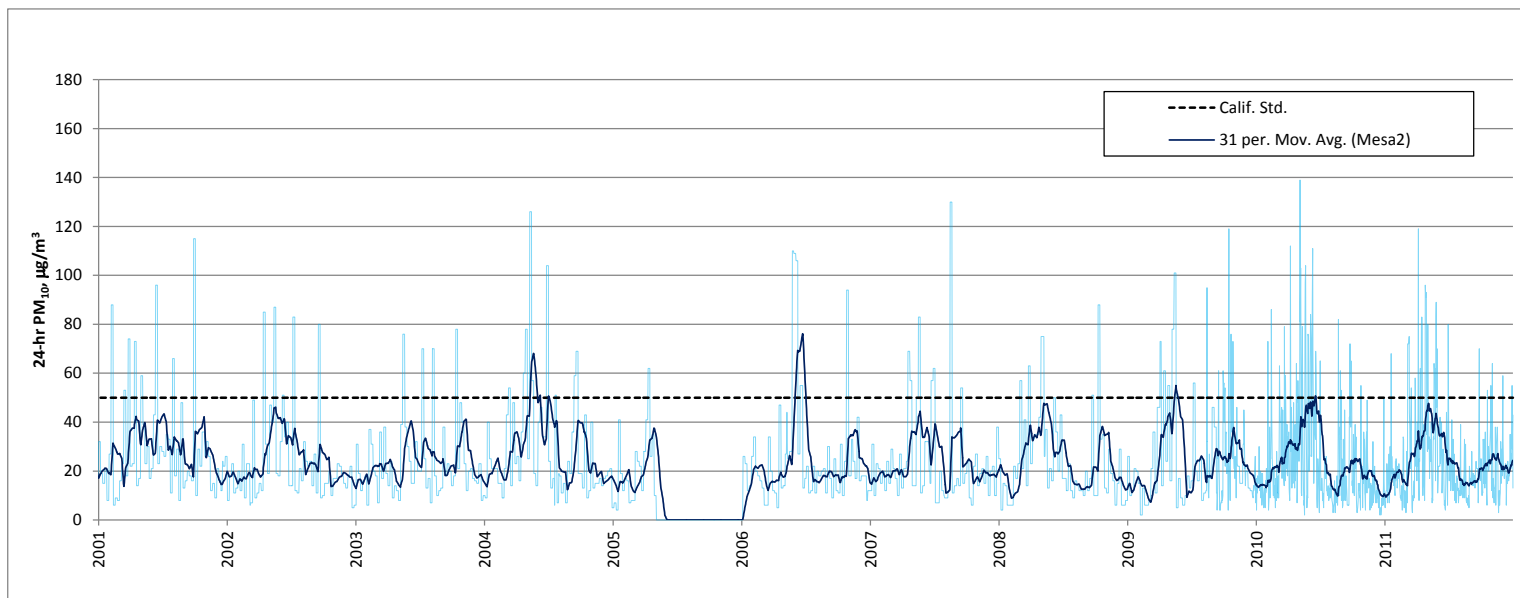


Figure 33: 24-hr PM₁₀ Measurements, CDF, 2010-2011

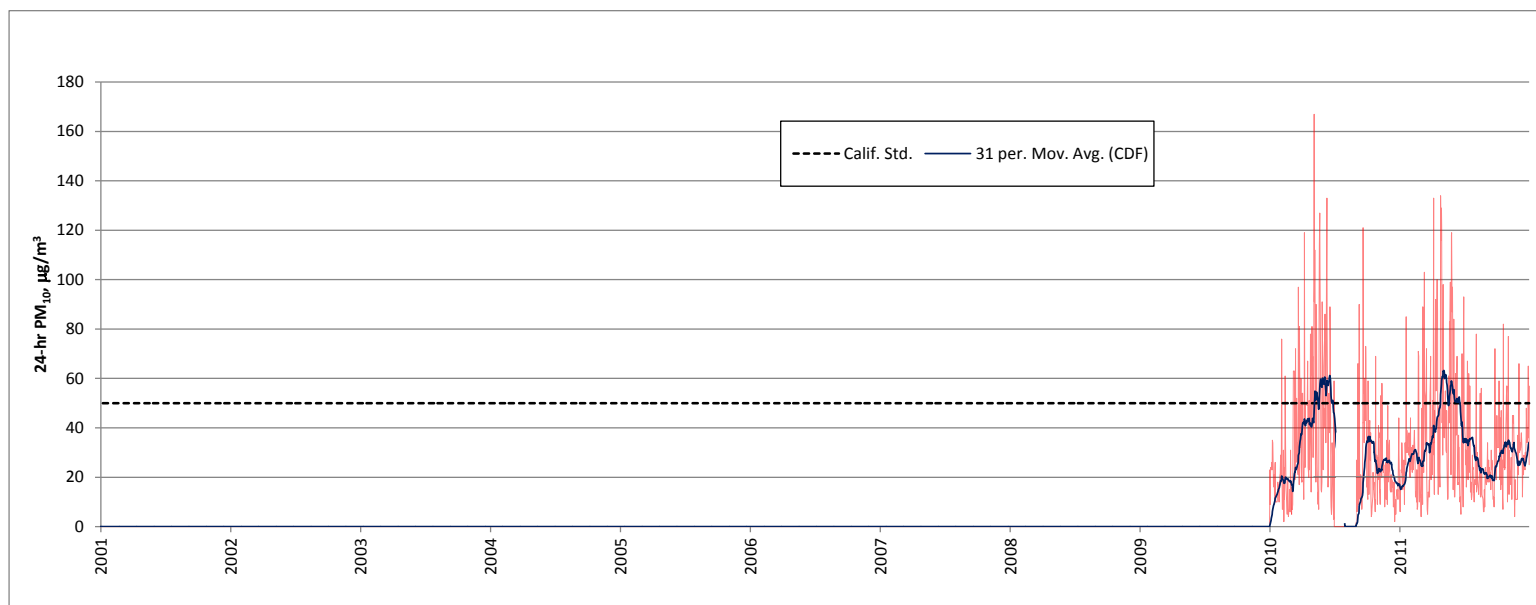


Figure 34: 24-hr PM₁₀ Measurements, Nipomo, 2010-2011

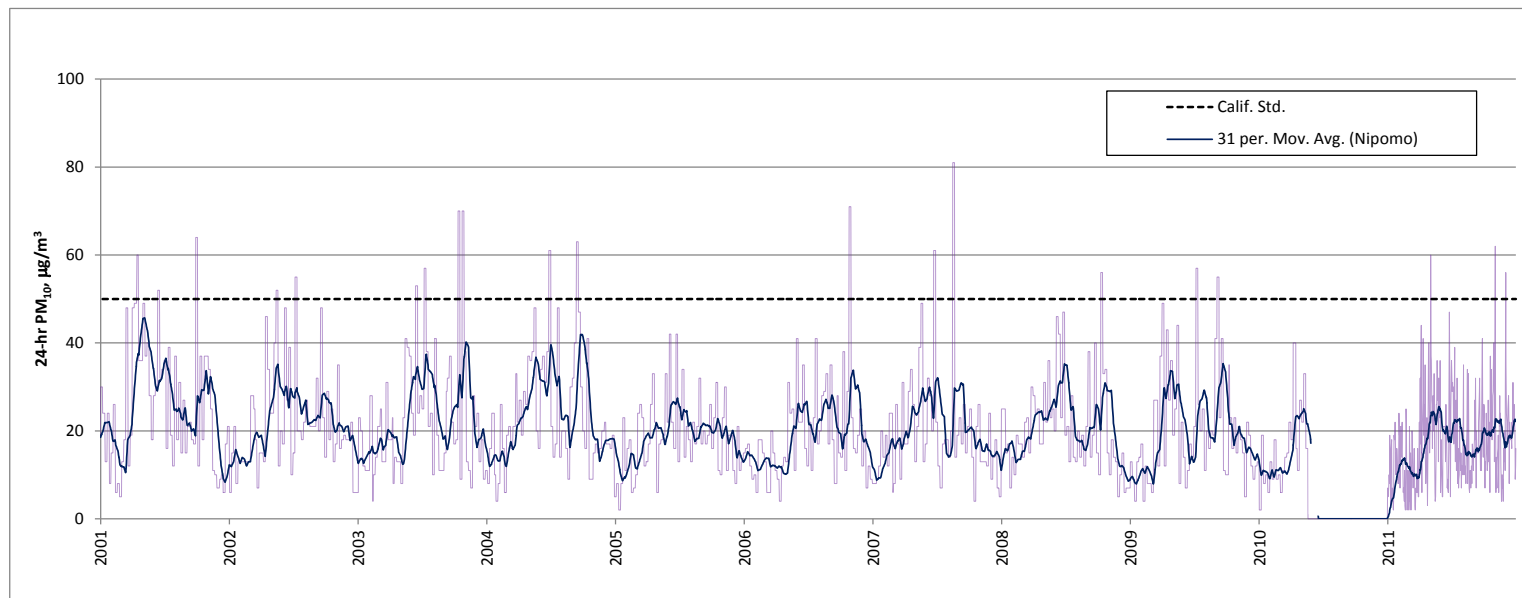
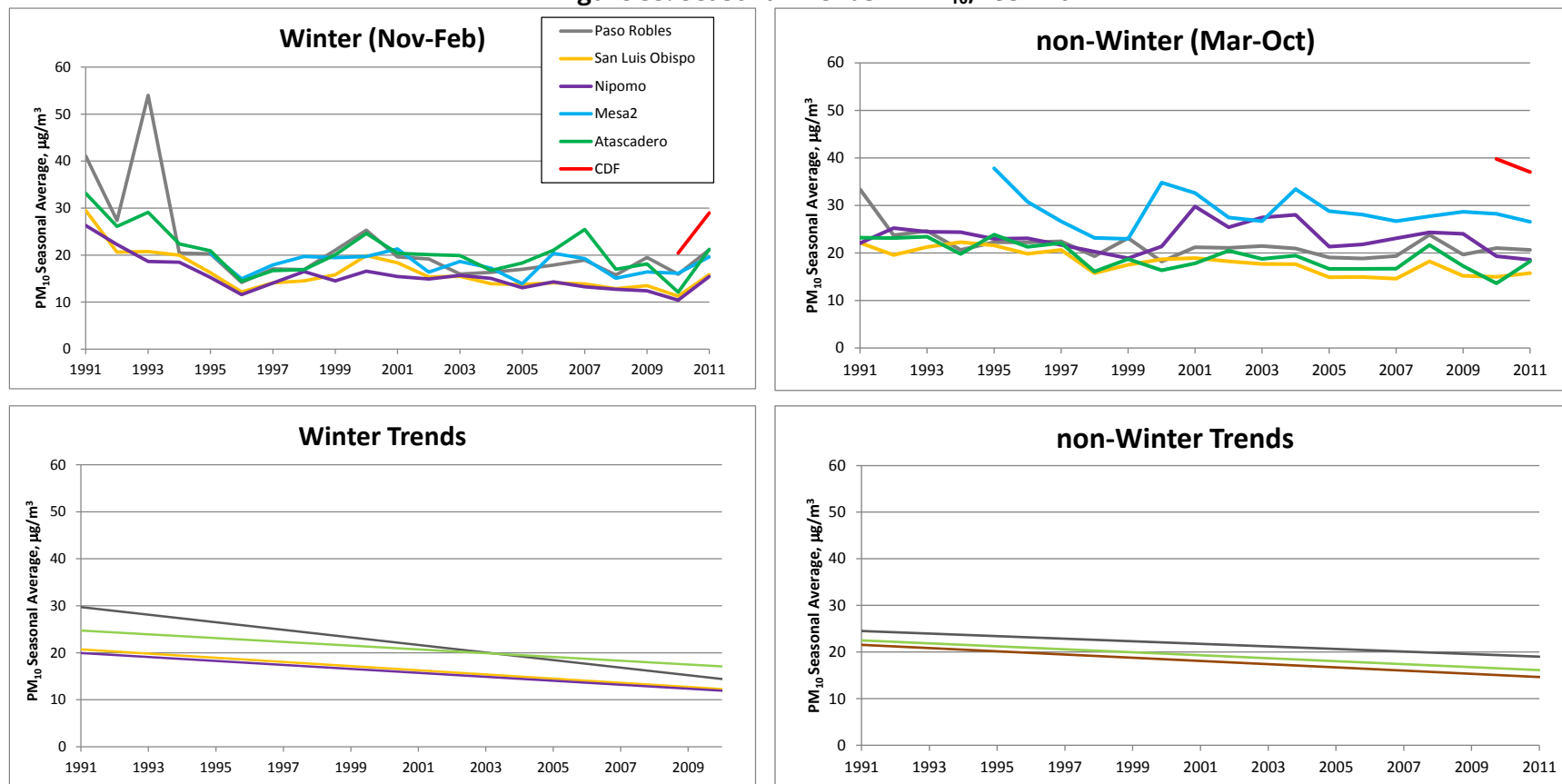


Figure 35: Seasonal Trends in PM₁₀, 1991-2011



APPENDIX A: DETAILED SITE INFORMATION

This appendix tabulates basic information about the monitoring sites discussed in the report. These tables are adapted from SLOAPCD's 2012 Ambient Air Monitoring Network Plan[†] and from information available in AQS.

Local site name	Paso Robles	Grover Beach	San Luis Obispo (1991-2005)	Mesa2	San Luis Obispo (2005-2011)	CDF
AQS site number	06-079-0005	06-079-2001	06-079-2002	06-079-2004	06-079-2006	06-079-2007
GPS Coordinates	35.61467, -120.65691	35.12389, -120.63222	35.283889, -120.654167	35.02079, -120.56389	35.25651, -120.66930	35.04676, -120.58777
Altitude (ft)	810	20	230	130	130	120
Street Address	235 Santa Fe Ave, Paso Robles	9 Le Sage Drive, Grover Beach	1160 Marsh St., San Luis Obispo	1300 Guadalupe Rd., Nipomo	3220 South Higuera St., San Luis Obispo	2391 Willow Rd., Arroyo Grande
Distance to roadways (meters)	92	10	20	80	30	30
Traffic count (AADT, year)	22,600 (2005)	100 (estimated)		6000 (2010)	22,529 (2006)	6000 (2010)
Groundcover (e.g. asphalt, dirt, sand)	Asphalt	Cement	Roof	Vegetated, Sand	Roof	Vegetated, Sand
Basic monitoring objective(s)	NAAQS	NAAQS	NAAQS, Public Information	NAAQS	NAAQS, Public Information	NAAQS
Site type(s)	Population Exposure	General/ Background	Population Exposure	Source Oriented	Population Exposure	Max Concentration, Source Oriented
Monitor type	SLAMS	SLAMS	SLAMS	SLAMS	SLAMS	SLAMA
Spatial Scale	Urban	Neighborhood	Neighborhood	Neighborhood	Neighborhood	Neighborhood

[†] Published July 9, 2012, and available online at <http://www.slocleanair.org/air/annualreport.php>

Local site name	Morro Bay	Nipomo, Wilson St. (1991-1996)	Nipomo, Nipomo Regional Park (1998-2011)	Atascadero	Red Hills	Carrizo Plains
AQS site number	06-079-3001	06-079-4001	06-079-4002	06-079-8001	06-079-8005	06-079-8006
GPS Coordinates	35.36639, -120.84260	35.041667, -120.5	35.03150, -120.50101	35.49153, -120.66799	35.64366, -120.23134	35.35474, -120.04013
Altitude (ft)	140	310	380	860	2330	2000
Street Address	899 Morro Bay Blvd., Morro Bay	148 S. Wilson St., Nipomo	W. Tefft St. and Pomeroy Rd., Nipomo	6005 Lewis Ave., Atascadero, CA	3601 Gillis Canyon Rd., Shandon	9640 Carrizo Highway, California Valley
Distance to roadways (meters)	20	30	200	30	1000	30
Traffic count (AADT, year)	12,400 (2006)		11,000 (2006)	1,000 (estimated)	20 (estimated)	500 (2010)
Groundcover (e.g. asphalt, dirt, sand)	Asphalt		Vegetated	Asphalt	Vegetated	Vegetated
Basic monitoring objective(s)	NAAQS	NAAQS	NAAQS	NAAQS	NAAQS	NAAQS
Site type(s)	General/ Background	General/ Background	General/ Background	Population Exposure	Max Concentration, Regional Transport	General/ Background, Regional Transport
Monitor type	SLAMS	SLAMS	SLAMS	SLAMS	SLAMS	SLAMS
Spatial Scale	Regional	Regional	Regional	Neighborhood	Regional	Regional

APPENDIX B: METHODOLOGY

General

All data analyzed in this report was exported from AQS in October or November 2012, except for Red Hills data from 2000 to 2006; this was extracted from SLOAPCD's in house database since these data were unavailable in AQS. Whenever possible, average values (e.g. rolling 8-hr averages of ozone, 24-hr PM₁₀ values, annual PM averages, etc.) were calculated in AQS. All data manipulation was performed in Excel.

Multi-year trends were assessed by least squares linear regression. A trend was deemed significant if the slope of its regression line was statistically significantly different from zero. Statistical significance was assessed using a two-tailed T-test and selecting a p-value of 0.05 as the threshold for significance. A trend was deemed borderline significant if the resulting p-value was between 0.05 and 0.10. All statistical analyses were performed in Excel.

Ozone Trends: 8-hr Design Values

Design values were calculated in AQS by running a Design Value Report (Report Code AMP480). The report yields design values for all site/year combinations for which there are data, but only those design values flagged by the report as valid (indicated by a D.V. Validity code of Y) were used in the trend analysis. An invalid design value typically results from minimum data completeness requirements not being met. For AQS to calculate a design value for site, each data point in the 3-yr design value window must be associated with the same AQS site code. The San Luis Obispo site moved in 2005, but the old and new locations have different site codes (06-079-2002 and 06-079-2006, respectively). Therefore, there are not valid design values for San Luis Obispo for any design value-year that includes 2005, namely design value-years 2005-2007. Similarly, the Wilson St. Nipomo site was closed in mid-1996, but was replaced by a new site at NRP in late 1998. Thus there are no valid design values for Nipomo for design value-years 1996-2000.

Ozone Trends: Exceedances of the Federal 8-hr Standard

For each site, highest daily 8-hr rolling averages were calculated in AQS by running a Raw Data Max Values Report (AMP350MX). The relevant report criteria were: State Code, 06; County Code, 079; Pollutant Parameter Code, 44201 (ozone); Duration Code, W (8-hr running average); Start Date, 1/1/1991; End Date 12/31/2012. The resulting file contained the maximum 8-hr rolling ozone concentration at each site/day combination with at least 18 valid 8-hr averages. (For an 8-hr average to be valid, it must contain at least 6 valid hourly values; these validity determinations were all performed by AQS.) This file was then imported into an Excel workbook that determined the number of days in each site/year combination in which the maximum daily 8-hr average exceeded the federal standard of 75 ppb. Note that days in which the maximum equaled 75 ppb were not counted. The spreadsheet also determined the number of valid days in each site/year combination. For reference these values are shown in **Table B1**, below. From these two sets of numbers, the percent of valid days exceeding the standard was calculated for each site/year combination.

Red Hills data for 2000 to 2006 is not available in AQS, so these statistics were generated in house. Validated hourly values for these years were exported from the in-house database (E-DAS Ambient) and imported into an Excel workbook. The workbook calculated 8-hr rolling averages starting on each hour, determined the validity of each 8-hr average (i.e. whether it contained at least 6 valid hours), and determined whether each day was valid. For a day to be valid, it needed at least 18 valid hours. The highest valid 8-hr average for each valid day was then determined. Finally, the number of highest daily 8-hr averages exceeding 75 ppb was determined for each year, as well as the number of valid days each year

(see **Table B1**). From these two sets of numbers, the percent of valid days exceeding the standard was calculated.

Trend analyses were performed on this statistic for each site. As the dependent variable in these trend analyses was “percent of valid days” exceeding the standard, the slopes of the resulting trends are in units of percent of valid days per year. These slopes were multiplied by 365 to convert them from percentages to the expected number of exceedances per year. These are values quoted in the main text.

Table B1: Number of Valid Ozone Days Per Site Per Year

Year	Paso Robles	Grover Beach	San Luis Obispo	Morro Bay	NRP	Atascadero	Red Hills	Carrizo Plains
1991	119	359	364	365	365	293	0	0
1992	356	353	355	366	358	366	0	0
1993	353	365	365	365	354	365	0	0
1994	362	365	363	365	358	364	0	0
1995	341	333	365	364	335	365	0	0
1996	361	366	361	361	262	365	0	0
1997	363	364	365	363	0	363	0	0
1998	357	357	365	365	62	365	0	0
1999	321	359	363	365	363	358	0	0
2000	224	360	366	356	361	364	166	0
2001	365	357	365	363	357	364	320	0
2002	353	360	334	363	361	358	270	0
2003	365	365	364	364	361	365	342	0
2004	366	365	366	365	366	364	357	0
2005	365	237	356	365	362	364	361	0
2006	365	0	361	365	360	362	362	364
2007	365	0	364	354	360	359	365	364
2008	253	0	366	364	365	366	364	356
2009	359	0	365	332	363	364	358	365
2010	363	0	365	365	363	361	360	358
2011	364	0	359	365	361	365	354	365

Ozone Trends: Exceedances of the State 1-hr Standard

Exceedances of the 1-hr standard were handled similarly to the 8-hr exceedances discussed above. The highest hourly ozone value for each site/day combination was determined in AQS by running the same AMP350MX report except using a Duration Code of 1 (1 hr) rather than W (8-hr running average). The resulting file contained the maximum hourly ozone concentration at each site/day combination with at least 18 valid hourly measurements. This file was then imported into an Excel workbook that determined the number of days at each site each year in which this value exceeded the state 1-hr standard of 90 ppb. Note that days in which the maximum equaled 90 ppb were not counted. The spreadsheet also counted the number of valid days at each site each year. For this statistic, a day is valid if there are at least 18 valid hourly values. The yearly totals are not shown here, but are very similar to the values in **Table B1**. From these two sets of numbers, the percent of valid days exceeding the standard was calculated for each site/year combination.

As noted in the discussion of 8-hr exceedances, Red Hills data for 2000 to 2006 is not available in AQS. Therefore, the percent of valid days with hourly values exceeding the state standard had to be calculated from data in the in-house database. The same E-DAS Ambient export noted above was imported to an Excel workbook that determined the maximum hourly value for each day and also determined whether each day was valid, based on whether it contained at least 18 valid hours. Finally, the number of days each year with a maximum hourly value exceeding 90 ppb was determined, as well as the number of valid days in each year. From these two sets of numbers, the percent of valid days exceeding the standard was calculated.

Trend analyses were performed on this statistic for each site. As with 8-hr exceedances discussed above, the dependent variable in these trend analyses was “percent of valid days” exceeding the standard, so the slopes of the resulting trends are in units of percent of valid days per year. These slopes were multiplied by 365 to convert them from percentages to the expected number of exceedances per year. These are values quoted in the main text.

Ozone Trends: Hours At or Above 65 ppb

To calculate this statistic, hourly ozone values were exported from AQS via the Extract Raw Data report, AMP501. Separate files were generated for each station. The relevant report criteria were: State Code, 06; County Code, 079; Site ID, various; Pollutant Parameter Code, 44201 (ozone); Duration Code, 1 (1-hr); Start Date, 1/1/1991; End Date 12/31/2012. For Red Hills, 2000-2006, the necessary data was exported from the in-house database, E-DAS Ambient. The resulting files were imported in Excel spreadsheets, which counted up the number of valid hourly measurements each year as well as the number of these hourly measurements that exceeded 64 ppb each year. From these two sets of numbers, the percent of valid days at or above 65 ppb was determined.

Trend analyses were performed on this statistic for each site. Analogous to the treatments of exceedances discussed above, the dependent variable in these trend analyses was “percent of valid hours” meeting or exceeding 65 ppb, so the slopes of the resulting trends are in units of percent of valid hours per year. These slopes were multiplied by 8395 (i.e. 23 hrs/day × 365 days) to convert them from percentages to the expected number of hours at or above 65 ppb per year. These are values quoted in the main text. Twenty three hours per day, rather than 24, were assumed because the monitors typically only sample ambient air 23 hours per day, with the remaining hour used for a daily precision check. These checks are scheduled to occur during the low point in the diurnal ozone cycle (typically 4 a.m.), a time when levels are not expected to exceed 65 ppb.

PM_{2.5} Trends: Exceedances of the Federal 24-hr Standard

As noted in the main body of this report, PM_{2.5} sampling methods changed in recent years. Initially all sampling was conducted via FRMs that collected one 24-hr sample every six days. This FRM data was extracted from AQS via a Raw Data Max Values Report (AMP350MX). The relevant report criteria were: State Code, 06; County Code, 079; Pollutant Parameter Code, 88101 (PM_{2.5}); Duration Code, 7 (24-hr); Start Date, 1/1/1991; End Date 12/31/2012. From 2009-2011, methodology was changed from FRM sampling to FEM sampling. FEMs collect hourly data and operate every day, rather than every sixth day. Hourly PM_{2.5} values were rolled up into 24-hr averages in AQS, which also determined whether the average was valid or invalid based on data completeness criteria (i.e. whether there were at least 18 valid hours). The relevant criteria for the AMP350MX report were: State Code, 06; County Code, 079; Pollutant Parameter Code, 88101 (PM_{2.5}); Duration Code, X (24-hr block average); Start Date, 1/1/1991; End Date 12/31/2012. The resulting files were imported in an Excel workbook for further analysis.

Some sites had more than one PM_{2.5} monitor operating at the same time. When multiple 24-hr PM_{2.5} measurements were available for the same day at a site, the value from the monitor with the lowest Pollutant Occurrence Code (POC) was used in the analysis. Next, the number of valid 24-hr samples (or averages for FEM data) for each site/year combination was determined (**Table B2**), as well as the number of valid 24-hr samples/averages that exceeded the federal standard of 35.0 µg/m³. From these two sets of numbers, the percent of valid samples exceeding the federal standard was determined.

Trend analyses were performed on this statistic for each site. Like the ozone exceedances discussed above, the dependent variable in these trend analyses was “percent of valid samples” exceeding the standard, so the slopes of the resulting trends are in units of percent of valid samples per year. These slopes were multiplied by 365 to convert them from percentages to the expected number of exceedances per year, had sampling been conducted every day. These are values quoted in the main text.

Table B2: Number of Valid 24-hr PM_{2.5} Values Per Site Per Year

Year	San Luis Obispo	Atascadero	Mesa2	CDF
1999	50	59	0	0
2000	55	58	0	0
2001	54	60	0	0
2002	52	61	0	0
2003	59	60	0	0
2004	59	60	0	0
2005	56	60	0	0
2006	59	60	0	0
2007	59	58	0	0
2008	55	58	0	0
2009	61	237	184	0
2010	59	307	360	125
2011	286	360	354	343

PM_{2.5} Trends: Days Exceeding 12 µg/m³

This statistic was generated using the same methodology (and same workbook) as discussed above for federal 24-hr exceedances, except samples greater than 12.0 µg/m³ were counted instead of samples greater than 35.0 µg/m³.

PM_{2.5} Trends: Annual Averages

With the exceptions noted below, annual averages were calculated by AQS. These values were available in the same AMP350MX reports that were generated for the analysis of federal exceedances discussed above. Since AQS calculates separate averages for each site code/POC combination, the 2005 average for San Luis Obispo used in the trend analysis is time weighted average of the portion of the year at Marsh St. location (January 1 through September 1) and the portion of the year at the Higuera St. location (September 25 through December 31). In 2009 at Atascadero, the FRM (POC 1) reported for the entire year, and FEM (POC 3) began reporting mid-year. The FRM value is used in the trend analysis. Finally, for San Luis Obispo, 2011, the value in the trend analysis is the time weighted average of the FRM period (January 1 through March 26) and the FEM period (March 28 through December 31).

PM_{2.5} Trends: Seasonal Variation

For the graphs showing all 24-hr PM_{2.5} values for each site from 1999 to 2011 (**Figures 17-20**), each FRM sample was depicted as lasting several days. If a sample was collected on, for example, January 1, that sample's value was used for January 1 and all following days until the day of next sample (January 7). In most cases, FRM sample values were carried over six days, but in cases when a sample was missed or invalidated, the previous valid sample was carried over for 12 days or sometimes longer. The 31-day rolling averages shown in these graphs were calculated by Excel.

The analysis of seasonal trends (**Figure 21**) was conducted using the same files used for analyzing the federal exceedances. For each site/year combination, a winter average, including all samples collected in January, February, November, and December, was calculated. A non-winter average was similarly calculated. For 2009 data from Atascadero, only the FRM data was used, since it was available for the entire year, while FEM data was available for only part of the year. Seasonal averages for San Luis Obispo for 2011 are composites of FRM and FEM data since neither was available for the whole year; a weighting scheme was applied to these averages to account for data completeness and the change in sampling frequency. To check for errors, annual averages were constructed from these seasonal averages and compared to the AQS-generated averages used in the previous section; agreement was found to be very good. Regression analyses were then performed on the winter and non-winter values for each site, the results of which are quoted in the main text.

PM₁₀ Trends: Exceedances of the State and Federal Standards

PM₁₀ concentrations are commonly expressed in two related but different units: $\mu\text{g}/\text{m}^3$, local conditions (LC), and $\mu\text{g}/\text{m}^3$ corrected to standard temperature and pressure (STP; 760 mmHg and 298 K). **Equation B1** shows the relationship between concentrations reported in LC those reported in STP.

$$\text{PM}_{10} \text{ STP} = \text{PM}_{10} \text{ LC} \times (\text{Standard Pressure} / \text{Actual Pressure}) \times (\text{Actual Temperature} / \text{Standard Temperature}) \quad (\text{B1})$$

Clean Air Act regulations specify that for comparison to the PM₁₀ NAAQS, ambient PM₁₀ measurements must be corrected to STP. For this reason, all PM₁₀ values discussed and analyzed in this are in STP units, with a few exceptions, noted below.

As with PM_{2.5}, sampling methodology for PM₁₀ changed in recent years. Initially all sampling was conducted via FRMs that collected one 24-hr sample every six days. This FRM data was extracted from AQS via a Raw Data Max Values Report (AMP350MX). The relevant report criteria were: State Code, 06; County Code, 079; Pollutant Parameter Code, 81102 (PM₁₀ STP); Duration Code, 7 (24-hr); Start Date, 1/1/1991; End Date, 12/31/2012. From 2009-2011, methodology was changed from FRM sampling to FEM sampling. FEMs collect hourly data and operate every day, rather than every sixth day. For FEMs operated by SLOAPCD (Atascadero, Nipomo, Mesa2, and CDF), hourly PM₁₀ values were rolled up into 24-hr averages in AQS, which also determined whether the resulting 24-hr averages were valid or invalid based on data completeness criteria (i.e. whether there were at least 18 valid hours). The relevant criteria for the AMP350MX report were: State Code, 06; County Code, 079; Pollutant Parameter Code, 81102 (PM₁₀ STP); Duration Code, X (24-hr block average); Start Date, 1/1/1991; End Date 12/31/2012.

For ARB operated FEMs (Paso Robles since August 2009 and San Luis Obispo since March 2011) hourly PM₁₀ values could not be rolled up into 24-hr averages in AQS. This is because AQS will only calculate 24-hr PM₁₀ averages from hourly values expressed in STP units. While most agencies (including SLOAPCD) report hourly PM₁₀ values to AQS in both STP and LC units, ARB reports only in LC units. Therefore, 24-hr PM₁₀ LC averages were calculated in Excel from hourly values exported from AQS. The required hourly data was extracted from AQS via an AMP501 report. The relevant report criteria were: State Code, 06;

County Code, 079; Site IDs, 0005 and 2006; Pollutant Parameter Code, 85101 (PM₁₀ LC); Duration Code, 1 (1-hr); Start Date, 1/1/1991; End Date 12/31/2012. The resulting file was imported in an Excel workbook that calculated 24-hr block averages for each day with at least 18 valid hourly measurements.

The AMP350MX reports were imported to an Excel spreadsheet along with the 24-hr PM₁₀ values for Paso Robles and San Luis Obispo that were calculated from hourly PM_{2.5} LC data. Subsequent data manipulations were carried out in this spreadsheet.

As was the case for PM_{2.5}, some sites had more than one PM₁₀ monitor operating at the same time. When multiple 24-hr values were available for the same day at a site, the value from the monitor with the lowest POC was used in the analysis. Next, the number of valid 24-hr samples (or averages for FEM data) for each site/year combination was determined (**Table B3**), as well as the number of valid 24-hr samples/averages that exceeded the federal standard of 150.0 µg/m³ and the number exceeding the state standard of 50.0 µg/m³. From these sets of numbers, the percentages of valid samples exceeding the federal and state standard were determined.

Tables B3: Number of Valid 24-hr PM₁₀ Values Per Site Per Year

Year	Paso Robles	San Luis Obispo	Morro Bay	Nipomo	Mesa2	Atascadero	CDF
1991	16	58	56	59	0	54	0
1992	54	58	61	60	0	54	0
1993	20	59	59	58	0	58	0
1994	25	59	51	59	0	76	0
1995	60	60	55	57	15	62	0
1996	55	57	59	45	51	58	0
1997	59	58	58	0	59	56	0
1998	59	58	54	10	61	53	0
1999	55	55	57	53	60	58	0
2000	57	59	48	58	57	56	0
2001	57	60	59	59	62	61	0
2002	58	60	59	50	59	44	0
2003	60	59	60	57	61	55	0
2004	60	59	60	60	62	58	0
2005	60	57	60	60	20	61	0
2006	60	59	60	60	62	61	0
2007	60	59	58	59	60	55	0
2008	61	61	56	59	58	59	0
2009	174	61	46	61	135	60	0
2010	360	60	59	23	358	65	292
2011	361	282	0	355	356	341	353

Trend analyses were performed on these statistics for each site. As with exceedances of the 24-hr PM_{2.5} standard, the resulting slopes were multiplied by 365 to convert them from percentages to the expected number of exceedances per year, had sampling been conducted every day. These are values quoted in the main text.

PM₁₀ Trends: Annual Averages

As with the PM_{2.5} annual averages, PM₁₀ annual averages were calculated by AQS, with a few modifications. Most values were available in the same AMP350MX reports that were generated for the analysis of state and federal exceedances discussed above. The 2005 average for San Luis Obispo used in the trend analysis is time weighted average of the portion of the year at Marsh St. location (January 1 through September 1) and the portion of the year at the Higuera St. location (September 19 through December 31). For Paso Robles, the 2009 average is a time-weighted average of the averages from the FRM portion of the year (though June) and FEM portion (August onward). In 2009 at Mesa2, the FRM reported for the entire year, and FEM began reporting mid-year. The FRM annual average is used in the trend analysis. The 2010 annual average for Atascadero is a time-weighted average of the averages from the FRM portion of the year (though June) and FEM portion (October and November). Finally, for San Luis Obispo, 2011, the value used in the trend analysis is the time weighted average of the FRM period (January through March) and the FEM period (April through December).

PM₁₀ Trends: Seasonal Variation

PM₁₀ was treated that same as PM_{2.5}. In the graphs showing all 24-hr PM₁₀ values for each site from 2001 to 2011 (**Figures 28-34**), each FRM sample was depicted as lasting several days. If a sample was collected on, for example, January 1, that sample's value was used for January 1 and all following days until the day of next sample (January 7). In most cases, FRM sample values were carried over six days, but when a sample was missed or invalidated, the value from the previous valid sample was carried, resulting it being depicted for 12 days or sometimes longer. The 31-day rolling averages shown in these graphs were calculated by Excel.

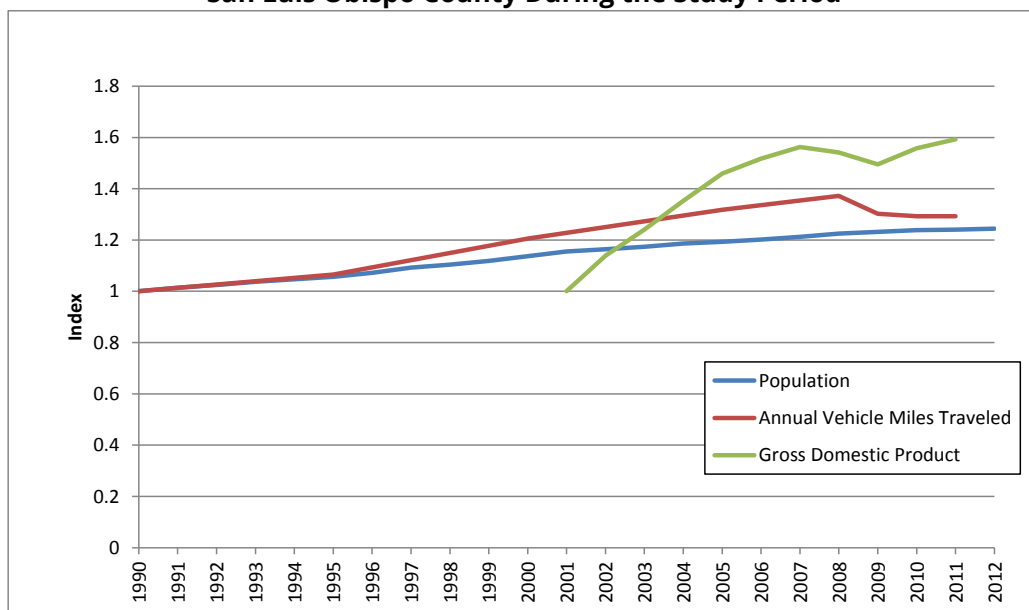
The analysis of seasonal trends (**Figure 35**) was conducted using the same files used for analyzing the federal exceedances. For each site/year combination, a winter average, including all samples collected in January, February, November, and December, was calculated. A non-winter average was similarly calculated. For 2009 data from Mesa2, only the FRM data was used, since a full year of FRM data was available, while the FEM operated only part of the year. The seasonal averages for the following site/year combinations are composites of FRM and FEM data since neither was available for the whole year: Paso Robles, 2009, Atascadero, 2010, and San Luis Obispo, 2011. A weighting scheme applied when calculating these averages to account for data completeness and the change in sample frequency. To check for errors, annual averages were constructed from these seasonal averages and compared to the AQS-generated averages used in the previous section; agreement was found to be very good. Regression analyses were then performed on the winter and non-winter values for each site, the results of which are quoted in the main text.

APPENDIX C: COUNTY POPULATION GROWTH, VEHICLE TRAVEL, AND ECONOMIC DEVELOPMENT TRENDS

To put the air quality trends described in this report into context, data on vehicle and economic activity within the county as well as population are provided in this appendix. Population data were downloaded from the California Department of Finance's population estimates website,[‡] and cross-checked against US Census population data. Motor vehicles are the largest emission source in the county, so Annual Vehicle Miles Traveled (AVMT) within the county was used to compare activity in this source category against air quality measurements over the same period. The AVMT data were provided by the San Luis Obispo Council of Governments (SLOCOG). Finally, Gross Domestic Product (GDP) for the San Luis Obispo—Paso Robles metropolitan statistical area (MSA) was used as an indicator of economic activity within the county. These data were downloaded from the U.S. Department of Commerce, Bureau of Economic Analysis website.[§] GDP data were only available for 2001-2011. **Table C1** summarizes these data.

Figure C1, below, shows how each of these factors changed over time. In order to display all three on the same graph, each was indexed to the first year of available data by dividing each year's value by the value for the index year. For population and AVMT, the index year was 1990; for GDP it was 2001. As seen in the graph, population has steadily increased over this period. GDP has also enjoyed a steady increase except for a two year decline during the recession. AVMT increased until the recession in 2008, after which it fell and has remained fairly constant since then.

Figure C1: Population, Gross Domestic Product, and Annual Vehicle Miles of Travel in San Luis Obispo County During the Study Period



[‡] <http://www.dof.ca.gov/research/demographic/data/>

[§] <http://www.bea.gov/regional/index.htm>

**Table C1: Population, Gross Domestic Product, and Annual Vehicle Miles of Travel in
San Luis Obispo County During the Study Period**

Year	Population	Annual Vehicle Miles of Travel (millions of miles)	Gross Domestic Product (millions of current dollars)
1990	217,808	2,181	
1991	220,814		
1992	223,080		
1993	225,975		
1994	228,100		
1995	230,222	2,324	
1996	233,534		
1997	237,858		
1998	240,433		
1999	243,726		
2000	247,724	2,630	
2001	251,652		6,913
2002	253,549		7,871
2003	255,609		8,578
2004	258,483		9,353
2005	259,943	2,875	10,088
2006	261,803		10,487
2007	264,162		10,806
2008	266,850	2,992	10,656
2009	268,224	2,840	10,338
2010	269,753	2,820	10,771
2011	270,119	2,819	11,010
2012	271,021		

Revisions to Language in the Executive Summary and the Summary and Conclusions section of the Report

EXECUTIVE SUMMARY (pages 4 & 5, paragraphs 4,5 & 6)

Airborne particulate levels have also declined significantly in most areas of the County. Emission reductions achieved from District implementation of residential woodburning and open burning control programs have been effective in reducing wintertime PM levels and exceedances of health standards in the North County and at our inland Nipomo site. PM₁₀ and PM_{2.5} levels continue to frequently exceed health standards in the South County ~~and appear to be increasing at the Mesa2 site with no evidence of improvement~~. District studies show dust from the Oceano Dunes State Vehicular Recreation Area to be the primary emissions source contributing to this problem. The District is currently working with the California Department of Parks and Recreation on the development of Particulate Matter Reduction Plan for that facility. Implementation of the dust control measures in that plan is scheduled to begin within the next year.

Measurements of PM_{2.5} in our county began in 1999, with monitoring initially confined to San Luis Obispo and Atascadero. PM_{2.5} monitoring on the Nipomo Mesa started more recently, with measurements at our Mesa2 and CDF stations commencing in 2009 and 2010, respectively. Trends in annual average concentrations, exceedances of the federal 24-hr standard, and days exceeding 12 µg/m³ are analyzed in this report. The data shows steady improvement in PM_{2.5} levels at Atascadero and San Luis Obispo, ~~with an average of 7% of days exceeding 12 ug/m³ at these sites for 2010-11; and~~ exceedances of standards are rare at these sites. PM_{2.5} levels are highest during the winter in Atascadero, and improvements in wintertime levels are driving the overall decrease in PM_{2.5} observed there; San Luis Obispo shows less seasonality. In contrast, PM_{2.5} levels are much higher on the Nipomo Mesa at the CDF and Mesa2 stations, ~~where on average 23% of days exceeded 12 ug/m³ at these sites for 2010-11, and there is no evidence of improvement there~~. Like Atascadero, PM_{2.5} levels on the Nipomo Mesa display a strong seasonality, except the pattern is reversed, with the spring wind season showing the highest concentrations while the winter months are generally the cleanest time of the year.

Monitoring of PM₁₀ is currently performed in Paso Robles, Atascadero, San Luis Obispo and on the Nipomo Mesa at Mesa2, CDF, and Nipomo Regional Park; PM₁₀ was also monitored in Morro Bay through 2010. Trends in annual average concentrations and exceedances of state and federal standards are analyzed. As with ozone, three patterns emerge in the PM₁₀ data, though the sites fall into different geographic groups. Exceedances of the state 24-hr PM₁₀ standard have always been rare in San Luis Obispo and Morro Bay, and these cities show either continued improvement in PM₁₀ air quality (San Luis Obispo) or are

maintaining historically low levels (Morro Bay). PM₁₀ levels have steadily decreased in the North County, and concentrations in that region now look very similar to those in San Luis Obispo. The greatest degree of PM₁₀ pollution is found on the Nipomo Mesa in the South County, where the state standards for 24-hr and annual average concentrations are routinely exceeded at the CDF and Mesa2 sites. In contrast to the North County and San Luis Obispo, these sites show no improvement; ~~in fact the situation may be worsening~~. At the Nipomo Regional Park site—also on the Nipomo Mesa but further inland—PM₁₀ levels are not as elevated and some measures analyzed even indicate improvement.

SUMMARY AND CONCLUSIONS *(page 35, paragraph 2)*

Airborne particulate levels have also declined significantly in most areas of the County. Emission reductions achieved from District implementation of residential woodburning and open burning control programs have been effective in reducing wintertime PM levels and exceedances of health standards in the North County and at our inland Nipomo site. PM₁₀ and PM_{2.5} levels continue to frequently exceed health standards in the South County ~~and appear to be increasing at the Mesa2 site with no evidence of improvement~~. District studies show dust from the Oceano Dunes State Vehicular Recreation Area to be the primary emissions source contributing to this problem. The District is currently working with the California Department of Parks and Recreation on the development of Particulate Matter Reduction Plan for that facility. Implementation of the dust control measures in that plan is scheduled to begin within the next year.

ADDENDUM

Subsequent to the publication of Air Quality Trends, San Luis Obispo County, 1991-2011 (Trend Report) and its presentation to the SLOAPCD Board of Directors on March 27, 2013, questions were raised by an APCD Board member regarding the treatment and analysis of data from the Mesa2 site. Specific issues raised included:

- the exclusion of non-AQS data from the trend analysis,
- the handling of years with incomplete data,
- the comparability of Federal Equivalent Method (FEM) to Federal Reference Method (FRM) data,
- potential uncertainty introduced by the one-in-six day FRM sampling schedule,
- the appropriateness of using ordinary least squares (OLS) statistical tests for this trend analysis.

The purpose of this addendum is to further explain why data was handled as it was in the report and to explore how alternative data handling methodologies and statistical approaches could have affected the report's conclusions.

With regard to particulate matter at Mesa2, the Trend Report as originally presented to the Board concluded that *"PM₁₀ and PM_{2.5} levels continue to frequently exceed health standards in the South County and appear to be increasing at the Mesa2 site ... PM_{2.5} levels are much higher on the Nipomo Mesa at the CDF and Mesa2 stations [than elsewhere in the County], and there is no evidence of improvement there ... The greatest degree of PM₁₀ pollution is found on the Nipomo Mesa in the South County, where the state standards for 24-hr and annual average concentrations are routinely exceeded at the CDF and Mesa2 sites. In contrast to the North County and San Luis Obispo, these sites show no improvement; in fact the situation may be worsening."*

These conclusions were based on the following results:

- A statistically significant positive trend in the frequency of days exceeding 12 $\mu\text{g}/\text{m}^3$ PM_{2.5} at Mesa2 for 2009-2011. (See **Figure 14** and related discussion in the Trend Report.)
- A statistically significant positive trend in the annual average PM_{2.5} level at the site for 2009-2011. (See **Figure 16**.)
- A statistically significant or borderline significant—depending on the handling of partial years—positive trend in the frequency of days exceeding 50 $\mu\text{g}/\text{m}^3$ PM₁₀ at Mesa2 for 1995-2011. (See **Figure 24**.)
- A lack of a significant trend in the PM₁₀ annual average at this site for 1995-2011. (See **Figure 27**.)

The alternative analyses discussed below yield results very similar to those enumerated above; thus, they do not change staff's original conclusion that the improvements in PM levels observed elsewhere in San Luis Obispo County are not being seen at Mesa2, and that PM levels may be increasing there.

Data Sources

Air quality data for San Luis Obispo County are available from at least four sources: AQS, the EPA's official air quality database; AQMIS and iADAM, web accessible databases maintained by ARB; SLOAPCD reports; and SLOAPCD's internal database. While the data in these sources is nearly identical, there are small but important differences.

The EPA's AQS database is the highest quality of these sources. Data collected in the field undergoes several levels of review before being "posted" to "production status" and eventually being certified as of

sufficient quality to support regulatory decision making. First, raw data collected in the field along with all associated quality assurance and quality control records are reviewed by APCD staff. Data not meeting stringent criteria are invalidated, or in some cases adjusted based on set criteria. The validated data are then submitted to the AQS pre-production database where additional statistical tests are run to identify outliers and potentially questionable data points. APCD staff reviews and takes appropriate action on any data flagged by AQS, then moves the data to production status. Finally, in recent years EPA has added a certification step: Once all air quality and quality assurance data for an entire calendar year have been submitted and moved to production status, final reviews of the dataset for completeness and of precision and accuracy records are performed. Only data meeting strict federal quality assurance standards are certified.

The ARB databases are currently populated “on the fly”: Data is uploaded directly to their website within minutes of being collected in the field. While automated algorithms may filter some questionable values from the database, these data are not reviewed by APCD staff and cannot be considered validated. In some instances, the ARB databases may eventually be backfilled with validated data from AQS, but this can lag by several years. Furthermore, if data is revised in AQS, these changes may not filter back into the ARB databases.

For sites run by the SLOAPCD, the first stop for raw field data is SLOAPCD’s in house database, which, though 2012, was compiled by and retained in E-DAS Ambient for Windows from Environmental Systems Corporation. At the top of every hour, a SLOAPCD computer polls each site, stores the retrieved data in the database, and then uploads this raw data to ARB. The stored raw data is reviewed by APCD staff, validated or invalidated as necessary, and then submitted to AQS. Until recently, changes made to data during and after the AQS submission stage were not consistently mirrored in the in-house database, leading to small differences between the AQS production database and the in-house database. Differences in the handling of decimals (i.e. rounding versus truncating) also result in small differences between the databases. A change in data handling protocols now ensures consistency between the databases.

As noted in the **Introduction and Background** section of the Trend Report, prior to undertaking any trend analyses we chose to use AQS as the source for all data, because it is the most rigorously reviewed of the various databases and it is the official dataset that EPA uses for attainment determinations. An exception was made for the first several years of ozone data from Red Hills, which was never uploaded to AQS because it was designated a research site for those years and the data was not federally reportable. Since the data was collected by SLOAPCD, was reviewed and validated using the same protocols as data from other SLOAPCD sites, and the raw data was still available for review, staff felt confident that this non-AQS data was of high quality. Additionally, excluding this data would have greatly impacted the statistical power of the trend analysis by reducing the number of years available for regression analysis from 12 to only 5.

After the Trend Report was published on the SLOAPCD’s website, a Board member questioned the exclusion of some early years of Mesa2 PM₁₀ data, specifically 1991-1993. While these data appear in an ARB database, they are not available in AQS and therefore did not meet the criteria for inclusion in the analysis. During that period the site was run by a contractor and ARB was responsible for submitting data to AQS; it is not known why ARB never submitted this data to AQS. Additionally—and in contrast to the non-AQS Red Hills ozone data—SLOAPCD had no role in the collection of these data and the raw data was not available for inspection. Furthermore with 15 to 17 years of AQS data already available (depending on whether partial years are excluded), including the additional 2 to 3 years of non-AQS data would be less likely to improve the statistical power of the Mesa2 dataset. Therefore, it was appropriate to exclude this

data from the trend analysis. Nonetheless, trends including this additional non-AQS data are included in this **Addendum** for the sake of transparency.

Incomplete Years

As noted in several places in the Trend Report, the default data handling procedure was to include all years for which there were data in the trend analyses—even if data covered only part of the year. The choice to handle incomplete years in this manner was made principally for two reasons:

- to include as many years in the trend analysis as possible, and therefore maximize the statistical power of the trend analysis; and
- to avoid having to make somewhat arbitrary judgments as to whether a year was sufficiently complete for inclusion.

As noted in the discussion of ozone trends, the downside of this approach is that it assumes exceedences occur randomly throughout the year; in reality, many pollutant concentrations vary seasonally, including ozone and particulate matter. A board member questioned the use of partial years of PM₁₀ data at the Mesa2 site given the seasonal nature of the dust events in that area. Thus, PM₁₀ trends are presented below both with partial years included and excluded.

Comparability of Federal Equivalent Method (FEM) data to Federal Reference Method (FRM) data

A Board member questioned the comparability of combining both FRM and FEM data in the PM trend analyses for the Mesa2 site. Between 2009 and 2011, FRM samplers were phased out and replaced with FEM samplers. While FEM instruments are sanctioned for regulatory-use by the EPA, there are known, acceptable differences between the performance of FEMs and FRMs. The comparability of FEMs with FRMs can vary based on a number of factors including the local environment of the samplers, the time of year, and the specific type of FEM being compared, but typically FEMs produce results that are slightly higher than those of FRMs. There appear to be a few reasons for this, with the most important being:

- The gravimetric FRM method is prone to evaporative loss of some of the Volatile Organic Compounds (VOCs) that typically constitute a portion of the PM₁₀ & PM_{2.5} aerosol mass present in ambient air. This evaporation can occur because the one-in-six day sampling schedule for the gravimetric method can result in filters sitting in the sampler in the hot sun for up to 5 days after sample collection. This does not occur with continuous methods because the measurement is recorded instantaneously every minute (TEOM) or at the end of each hour (BAM).
- The inlet design of the continuous FEMs used by SLOAPCD differs from that of the hi-volume FRM samplers previously employed. Under high wind conditions, the FRM inlet is subject to an artificial reduction in the cut point of the particle size entering the sampler, because fast moving heavy particles cannot make the turn into the inlet. The net result is that under high winds, the FRM sampler can under-sample large particles.

The EPA presumes FEM data to be comparable to FRM data and does not permit the use of scaling factors or other manipulations of FEM data that is submitted to AQS. Nonetheless, for purposes of long-term trend analysis it could be useful to apply a scaling factor to FEM data to make it more comparable to FRM data. An extended period of data from a collocated FEM-BAM pair would be needed to derive such a factor, but unfortunately this dataset is not available. This leaves two options available for trend analysis: combining data from the two methods, as was done in the Trend Report, or analyzing the FRM and FEM data separately. FRM-only trend analyses were performed for the Mesa2 site to see if it would show a

different result than the combined data presented in the report; the results of this analysis are shown below. (With only one to three years of FEM data available per site, no FEM-only trend analyses were performed.)

Re-analysis of Mesa2 Trends Under Alternative Data Handling Procedures

For Mesa2, trends in the frequency of exceedences of state PM standards were analyzed both including and excluding non-AQS data, FEM data, and partial years. A partial year was defined as having less than 75% data coverage. For an FRM year this equals less than 45 samples, and for an FEM year it is less than 274 samples; no consideration was given to what season data gaps occurred in. The following summary statistics were examined for each analysis: slope of the trend line (expressed as the change in the number of exceedence days per year), p-value of the slope, and correlation coefficient (r^2) of the relationship. In the Trend Report, slopes with p-values less than 0.05 were deemed statistically significant, and those between 0.05 and 0.10 were deemed borderline significant. These criteria were also applied in the present analyses. Negative slopes indicate improvement in air quality (i.e. fewer days each year exceeding the standard); positive slopes indicate deterioration.

Table 1, below, summarizes the results of various alternative trend analyses for the frequency of state PM₁₀ standard exceedences at Mesa2. Significant and borderline significant p-values are shown in **bold**; datasets discussed in the Trend Report are highlighted with *italics*. Dataset M-1, which was included in the Trend Report, used only data from AQS and included years with incomplete data coverage (1995 and 2005). It covered the period 1995 through 2011, and used FEM-only data for 2010 and 2011. The point for 2009 included data from both the FRM, which operated for the entire year, and the FEM which began sampling in August. This model has a statistically significant positive slope of 1.45 more exceedences per year. Dataset M-2, also analyzed in the Trend Report, excludes partial years, and thus covers 1996–2004 and 2006–2011. This dataset has a shallower slope and is only borderline significant. Including data that is in ARB's database but not AQS introduces 1991–1993; however, 1991 is a partial year. (Neither database includes data for 1994, so none of the datasets analyzed in **Table 1** include this year.) Finally, excluding FEM data (datasets M-5 through M-8) had the effect of removing 2010 and 2011 from the trend analysis. The datum for 2009 was also recalculated using only FRM data.

All analyses that used only AQS data (and thus omitted 1991–1993) showed statistically significant or borderline significant positive slopes of between 1.04 and 2.00 more exceedence days per year, indicating and positive trend in PM₁₀ exceedences at the Mesa2 site for the years analyzed. Backfilling the years 1991–1993 with ARB data yielded shallower, non-significant slopes. Including incomplete years increases the slope (compare, for example, the results for datasets M-1 and M-2 or for M-5 and M-6), while excluding FEM data increases both the steepness of the slope and the statistical significance, despite reducing the number of years in the regression analysis and thus its statistical power (compare, for example, the results for datasets M-1 and M-5 or M-2 and M-6.)

A similar set of analyses was undertaken for the Mesa2 PM₁₀ annual average, and the results are shown in **Table 2**. As with the analyses of exceedences, the original dataset (M-1) covers 1995 through 2011. Including non-AQS data adds years 1991–1993, while excluding incomplete years removes 1991, 1995 and 2005 from the analysis; excluding FEM data removes 2010 and 2011 and revises the value for 2009. All datasets yielded non-significant shallow slopes, all but one of which (M-6) was negative.

Table 1: Results of Alternative Analyses of the Mesa2 PM₁₀ Exceedence Day Trend

Dataset	Data source	Include incomplete years?	Include FEM data?	Slope (days/year)	P-value of slope	r ² of regression	Number of years in regression
M-1	AQS only	Yes	Yes	+1.45	0.023	0.30	17
M-2	AQS only	No	Yes	+1.04	0.074	0.22	15
M-3	AQS & ARB	Yes	Yes	+0.41	0.452	0.03	20
M-4	AQS & ARB	No	Yes	-0.02	0.974	0.00	17
M-5	AQS only	Yes	No	+2.00	0.019	0.36	15
M-6	AQS only	No	No	+1.67	0.044	0.32	13
M-7	AQS & ARB	Yes	No	+0.56	0.424	0.04	18
M-8	AQS & ARB	No	No	+0.14	0.845	0.00	15

Table 2: Results of Alternative Analyses of the Mesa2 PM₁₀ Annual Average Trend

Dataset	Data source	Include incomplete years?	Include FEM data?	Slope (µg/m ³ per year)	P-value of slope	r ² of regression	Number of years in regression
M-1	AQS only	Yes	Yes	-0.04	0.691	0.01	17
M-2	AQS only	No	Yes	-0.01	0.917	0.00	15
M-3	AQS & ARB	Yes	Yes	-0.15	0.103	0.14	20
M-4	AQS & ARB	No	Yes	-0.17	0.119	0.15	17
M-5	AQS only	Yes	No	-0.02	0.895	0.00	15
M-6	AQS only	No	No	+0.05	0.787	0.01	13
M-7	AQS & ARB	Yes	No	-0.16	0.169	0.11	18
M-8	AQS & ARB	No	No	-0.18	0.215	0.12	15

PM_{2.5}, measurements at Mesa2 have always been made via FEM, so an FRM-only analysis of the PM_{2.5} data is precluded. Likewise, there does not appear to be any additional data in the ARB databases that is not available in AQS. The data for 2009 is incomplete, with samples collected for only about half of the year. Removing this year from the dataset leaves the slopes virtually unchanged for both the trend in the frequency of exceedences and the annual average trend; however with the number of data points reduced to only two, an analysis of statistical significance is precluded.

Taken together, these results reinforce the original conclusions of the Trend Report. Regardless of the handling of incomplete years, non-AQS data, and FEM data, trend analyses show increases in the frequency of PM₁₀ exceedence in seven of eight models; in four cases these upward trends are significant or borderline. No models indicate even borderline significant improvement in the annual average. Thus, the conclusion that “In contrast to the North County and San Luis Obispo, these sites [Mesa2 and CDF] show no improvement; in fact the situation may be worsening,” remains valid. For PM_{2.5}, removing the year of partial data leaves the upward trends in exceedence frequency and annual average intact, but precludes testing for statistical significance; thus, the conclusion in the Trend Report that “there is no evidence of improvement” in PM_{2.5} is still warranted. With both of the measures of PM_{2.5} showing positive trends and one of the PM₁₀ metrics increasing, the original conclusion that “PM₁₀ and PM_{2.5} ... appear to be increasing at the Mesa2 site” remains valid.

Re-analysis of Other Monitoring Sites Under Alternative Data Handling Procedures

For consistency, the datasets for all other PM monitoring sites were examined and reanalyzed in the same manner as Mesa2. The ARB databases do not contain data for these sites that are absent from AQS, so these re-analyses only considered removing partial years and FEM data. As with **Tables 1** and **2** above, if the p-value of the slope is statistically significant or borderline significant it is shown in **bold**, and the datasets originally evaluated in the Trend Report are shown in *italics*.

Table 3 below shows the results for the re-analyses of PM₁₀ exceedance days. For Paso Robles, the years 1991, 1993, and 1994 were incomplete; removing them yields a shallower but nonetheless still negative and significant slope (dataset PR-2) compared with the original analysis (dataset PR-1). The FRM at this site was replaced with an FEM in mid-2009; excluding the FEM data yields a significant negative slope if partial years are included. Removing partial years and FEM years (1991, 1993, 1994, and 2009-2011) yields a shallower, non-significant slope.

For Atascadero, 2002 and 2010 were partial years and the FRM was replaced with an FEM in mid-2010. Excluding partial years and/or FEM data makes virtually no difference in the results: all slopes show a decrease between of -0.65 and -0.71 exceedance days/year and all significant or borderline significant.

For Nipomo, 1998 and 2010 were partial years and the FRM was replaced with an FEM at the beginning of 2011. No matter how the data are handled, similar slopes result (from +0.29 to +0.55); however, all except dataset NP-4 are non-significant.

Including FEM data, all years at San Luis Obispo were complete, however the FRM to FEM transition occurred in mid-2011, so excluding FEM data makes 2011 a partial year. Regardless of the dataset used, the results are nearly the same: a negative slope of between -0.22 and -0.26 days/year that is significant or borderline significant.

Table 3: Results of Alternative Analyses of the PM₁₀ Exceedance Day Trends for Other Sites

Model	Site	Include incomplete years?	Include FEM data?	Slope (days/year)	P-value of slope	r ² of regression	Number of years in regression
<i>PR-1</i>	<i>Paso Robles</i>	Yes	Yes	-1.74	0.013	0.28	21
PR-2	Paso Robles	No	Yes	-0.54	0.029	0.26	18
PR-3	Paso Robles	Yes	No	-2.03	0.016	0.29	19
PR-4	Paso Robles	No	No	-0.55	0.107	0.19	15
<i>AT-1</i>	<i>Atascadero</i>	Yes	Yes	-0.65	0.027	0.23	21
AT-2	Atascadero	No	Yes	-0.65	0.047	0.21	19
AT-3	Atascadero	Yes	No	-0.70	0.030	0.24	20
AT-4	Atascadero	No	No	-0.71	0.053	0.21	18
<i>NP-1</i>	<i>Nipomo</i>	Yes	Yes	+0.29	0.289	0.06	20
NP-2	Nipomo	No	Yes	+0.39	0.181	0.11	18
NP-3	Nipomo	Yes	No	+0.39	0.192	0.10	19
NP-4	Nipomo	No	No	+0.55	0.088	0.18	17
<i>SL-1</i>	<i>San Luis Obispo</i>	N/A	Yes	-0.22	0.086	0.15	21
SL-2	San Luis Obispo	Yes	No	-0.26	0.048	0.19	21
SL-3	San Luis Obispo	No	No	-0.26	0.068	0.17	20

For the analyses of PM₁₀ annual averages, the handling of incomplete years and FEM data had little effect on the results, as shown in **Table 4**. For example, for Paso Robles, the slopes varied between -0.14 and -0.52 µg/m³ per year; all were statistically significant. Alternative data handling had the largest effect on Nipomo, where excluding the FEM year reduced statistical significance to borderline (dataset NP-3) or non-significant (dataset NP-4); nonetheless, it had little effect on the slope.

For PM_{2.5}, only the Atascadero and San Luis Obispo datasets could be affected by alternatives to the default data handling procedures. With FEM data included, all years were complete for both sites; however with FEM data excluded (2011 for San Luis Obispo; 2009-2011 for Atascadero) transition years became incomplete. Regardless, the additional analyses yielded results very similar to those of the default analyses discussed in the Trend Report. As shown in **Table 5**, the trend in PM_{2.5} exceedence days for Atascadero became more steeply negative and more significant when FEM data was removed, regardless of how incomplete years were handled. For San Luis Obispo, the trend also became more steeply negative.

Trends in the annual averages for PM_{2.5} are tabulated in **Table 6**; excluding partial years and/or FEM data leaves the trends virtually unchanged.

Table 4: Results of Alternative Analyses of the PM₁₀ Annual Average Trends for Other Sites

Model	Site	Include incomplete years?	Include FEM data?	Slope (µg/m ³ per year)	P-value of slope	r ² of regression	Number of years in regression
PR-1	Paso Robles	Yes	Yes	-0.38	0.007	0.33	21
PR-2	Paso Robles	No	Yes	-0.14	0.031	0.26	18
PR-3	Paso Robles	Yes	No	-0.52	0.002	0.43	19
PR-4	Paso Robles	No	No	-0.21	0.018	0.36	15
AT-1	Atascadero	Yes	Yes	-0.34	0.000	0.52	21
AT-2	Atascadero	No	Yes	-0.30	0.001	0.46	19
AT-3	Atascadero	Yes	No	-0.40	0.000	0.57	20
AT-4	Atascadero	No	No	-0.34	0.001	0.51	18
NP-1	Nipomo	Yes	Yes	-0.20	0.039	0.22	20
NP-2	Nipomo	No	Yes	-0.17	0.049	0.22	18
NP-3	Nipomo	Yes	No	-0.18	0.085	0.16	19
NP-4	Nipomo	No	No	-0.14	0.147	0.13	17
SL-1	San Luis Obispo	N/A	Yes	-0.37	0.000	0.71	21
SL-2	San Luis Obispo	Yes	No	-0.44	0.000	0.78	21
SL-3	San Luis Obispo	No	No	-0.41	0.000	0.74	20

Table 5: Results of Alternative Analyses of the PM_{2.5} Exceedence Day Trends for Other Sites

Dataset	Site	Include incomplete years?	Include FEM data?	Slope (days/year)	P-value of slope	r ² of regression	Number of years in regression
AT-11	Atascadero	N/A	Yes	-2.65	0.059	0.29	13
AT-12	Atascadero	Yes	No	-3.99	0.002	0.63	12
AT-13	Atascadero	No	No	-3.49	0.012	0.53	11
SL-11	San Luis Obispo	N/A	Yes	-4.11	0.002	0.57	13
SL-12	San Luis Obispo	Yes	No	-4.82	0.000	0.68	13
SL-13	San Luis Obispo	No	No	-4.83	0.002	0.63	12

Table 6: Results of Alternative Analyses of the PM_{2.5} Annual Trends for Other Sites

Dataset	Site	Include incomplete years?	Include FEM data?	Slope (µg/m ³ per year)	P-value of slope	r ² of regression	Number of years in regression
AT-11	Atascadero	N/A	Yes	-0.25	0.000	0.69	13
AT-12	Atascadero	Yes	No	-0.28	0.001	0.70	12
AT-13	Atascadero	No	No	-0.24	0.004	0.62	11
SL-11	San Luis Obispo	N/A	Yes	-0.21	0.000	0.65	13
SL-12	San Luis Obispo	Yes	No	-0.29	0.000	0.74	13
SL-13	San Luis Obispo	No	No	-0.24	0.001	0.68	12

There is little difference between the original analyses presented in the [Trend Report](#) and the alternative models presented in **Tables 3** through **6**. Therefore, no changes to report's conclusions are warranted.

Potential Uncertainty Associated with One-in-Six Day Sampling

As noted already, between 2009 and 2011 FRM samplers were phased out and replaced with FEM samplers. While FEM samples sample continuously, FRM samplers collected only one sample every sixth day, for 60 samples in a non-leap year (assuming no missed or invalidated samples.) Sampling every sixth day in theory yields a representative sample, but with a relatively small sample size, this procedure could nonetheless yield results that are subject to large random errors.

A Board member questioned the effect of this uncertainty on conducting PM trend analyses using FRM data, and presented an analysis similar to that shown in **Table 7**, below, as an example. This table presents the frequency of PM₁₀ exceedences at Mesa2 for 2010 and 2011 that would have been measured using the every sixth day FRM sampling schedule rather than sampling continuously, and shows how that frequency could vary as a function of the start date of the sampling sequence. These years were sampled continuously by FEM, so there is a valid 24-hour PM₁₀ measurement available for nearly every day of these years. Sequence 1 simulates the results of a one-in-six day sample schedule starting on January 1, 2010 (i.e., sampling January 1, 7, 13, 19, 25, etc); Sequence 2 simulates the results with sampling starting on January 2, and so forth. The Daily Sampling column shows the actual results of the nearly daily FEM measurements recorded during that period. The first number in each cell is the number of exceedences that would have been observed on the hypothetical FRM schedule, the next is the number of valid samples, and the last is the frequency of exceedences expressed as a percent.

For 2010, the frequency of exceedences that would have been observed using one-in-six sampling ranged from 8% to 14%; the frequency actually observed in the near daily sampling was 11%. For 2011, the spread is larger: 3% to 12%, with a frequency of 9% observed in almost daily sampling.

To assess whether this seemingly large variability is reasonable or is instead indicative of a problem, confidence intervals were estimated for the frequencies of exceedences tabulated in **Table 7**. The most extreme deviation is for Sequence 6 in 2011, which resulted in an estimated exceedence frequency of 3% under the FRM sample schedule, while the actual frequency measured for the year using continuous FEM sampling was 9%—a threefold difference. If the 95% confidence intervals for this datum contain the actual frequency, then there would be reasonable certainty that this point is not an outlier, and that the uncertainty introduced by one-in-six sampling is random. This would imply that none of the points in the Mesa2 dataset are outliers.

Table 7: Simulated 1-in-6 Day Sampling for Mesa2, 2010 and 2011

Year	Exceedence Days, Total Sample Days, and Frequency of Exceedences (%)						
	Sequence 1	Sequence 2	Sequence 3	Sequence 4	Sequence 5	Sequence 6	Daily Sampling
2010	7, 61, 11	7, 60, 12	5, 60, 8	7, 60, 12	6, 59, 10	8, 59, 14	40, 358, 11
2011	5, 60, 8	6, 60, 10	7, 59, 12	6, 60, 10	6, 59, 10	2, 58, 3	32, 356, 9

Calculating confidence intervals for this situation presents some challenges. The frequency of exceedence data can be assumed to follow the binomial distribution, in that each sample can be thought of as an independent trial, the outcome of which is either a “success” (i.e. an exceedence occurred) or a “failure” (i.e. no exceedence occurred). Confidence intervals for frequencies of success derived from such distributions are often estimated using the Wald method, which approximates the binomial distribution with a normal distribution. This method, however, fails for frequencies close to 0 and 100%. Most textbooks consider this approximation acceptable provided that $n\hat{p} > 5$, where n is sample size and \hat{p} is the observed frequency of the event. For the FRM data considered here, the sample sizes are about 60, thus the approximation would be valid only for observed frequencies in excess of 8.3%; many frequencies in **Table 7** are less than this. Wald intervals were therefore considered inappropriate.

An alternative method that yields accurate confidence intervals even for low probability events is the Wilson interval, shown below:

$$\left[\frac{1}{1 + \frac{1}{n}Z^2} \right] \left[\hat{p} + \frac{1}{2n}Z^2 \pm z \sqrt{\frac{1}{n}\hat{p}(1 - \hat{p}) + \frac{1}{4n^2}Z^2} \right]$$

where Z is the $1 - \frac{1}{\alpha}$ percentile of the standard normal distribution, e.g. for 95% confidence intervals, $z = 1.96$. While the Wald interval tends toward zero as \hat{p} goes to zero (i.e. if no successes are observed and $\hat{p} = 0$, then the confidence interval produced is 0 ± 0), the Wilson interval is non-zero even when $\hat{p} = 0$. In this situation, the lower bound of the Wilson interval is 0, and the upper bound becomes $Z^2/n + Z^2$. This yields more reasonable confidence intervals: even if no exceedences are observed among the 60 samples collected during a year, there is still some small chance that exceedences occurred on non-sample days, and the Wilson interval acknowledges this. (In the case of no exceedences in 60 samples, the upper bound of the Wilson interval is an exceedence frequency of 0.060 or 6%).

Another problem with the usual methods for constructing binomial confidence intervals is that they assume that the sample is drawn from a large population, i.e. $n \ll N$, where N is the size of the population being sampled. In the case at hand, N is the number of days in the year, so a sample size of 60 is about 16% of the entire population; clearly the condition that $n \ll N$ is not met. Furthermore, as n approaches N , the uncertainty associated with the sampling frequency should go to zero. In other words, if samples had been collected every day of the year, then there would be no uncertainty about the frequency of exceedences, assuming measurement error to be negligible. Neither the usual Wald nor the Wilson interval has this property. To overcome this, the Wilson interval equation was modified to include a finite population correction, f , defined as:

$$f = \frac{N - n}{N - 1}$$

The modified Wilson interval is thus:

$$\left[\frac{1}{1 + \frac{f}{n} Z^2} \right] \left[\hat{p} + \frac{f}{2n} Z^2 \pm z \sqrt{\frac{f}{n} \hat{p}(1 - \hat{p}) + \frac{f^2}{4n^2} Z^2} \right]$$

This interval captures the realities of the PM sampling situation that the standard Wald interval does not: if $n = N$, then $f = 0$ and the confidence interval collapses to \hat{p} ; if $n \ll N$, then $f \approx 1$ and the equation reduces to the standard Wilson interval; if $\hat{p} = 0\%$ and $n < N$, then the upper bound of the confidence interval is non-zero; similarly, if $\hat{p} = 100\%$ and $n < N$, then the lower bound of the interval is something less than 100%. Finally the confidence intervals calculated using this equation are somewhat narrower than unmodified Wilson intervals, reflecting the greater certainty associated with sampling a relatively high portion of a finite population.

Returning to the issue of the simulated data in **Table 7**, a modified Wilson interval was calculated for the result of Sequence 6 in 2011—the simulation that differed most from the value actually obtained in near daily sampling. For this simulation, which had an exceedence frequency of 3.4% and was derived from two exceedences observed in 58 samples, the corresponding modified Wilson interval at the 95% confidence level is 1.0% to 10.8%. This interval includes 9.0%, the frequency actually observed in the near daily sampling. Thus, there is reasonably certain that the uncertainty introduced by one-in-six sampling is random, and that none of the points in the Mesa2 frequency of exceedence dataset are outliers.

This technique was also used to generate 95% confidence intervals for the Mesa2 exceedence frequency dataset. These are presented later in this **Addendum**.

Appropriateness of Statistical Methods

A Board member also questioned the validity of the type of statistical analyses used to evaluate the data in the Trend Report. Two main critiques were leveled at the statistical analysis:

- that measurement error was not accounted for, and
- that ordinary least squares (OLS) regression analysis is not an appropriate tool for analyzing trends in the frequency of exceedences because these data may not be normally distributed.

With regard to the first charge, it is true that the analyses in the Trend Report did not explicitly consider measurement error; however, we did not believe it necessary or appropriate to do so. SLOAPCD is required to report all data to ARB and the EPA; these agencies then determine whether attainment is achieved. In their regulatory determinations, no consideration is given to measurement error that is within the established acceptable range for each instrument, or to the possibility that an observed exceedence may not be real. Any value exceeding the standard is taken to be an exceedence, even if it is “close to the line.” Such exceedences are not afforded different weight or significance than exceedences that are far above the standard. Similarly, no account is taken of values that are just below the standard, even though some of those values might have been recorded as exceedences but for measurement error that was within acceptable limits. Since the goal of the Trend Report was to assess progress toward achieving and/or maintaining the standards, it was appropriate to consider exceedences as ARB and EPA do, i.e., as binary events: a sample either exceeded the standard or it did not. There is no maybe, and there is no error to be considered.

Furthermore, actual measurement error is believed to be quite small. For most of the period analyzed in the Trend Report, there were actually two PM₁₀ FRMs at the Mesa2 site operating simultaneously on the same schedule, a so-called “primary monitor” and a “collocated monitor.”¹ Of the 677 days on which both monitors collected valid samples, there were only four occasions when the primary monitor recorded an exceedence but the collocated monitor did not; and there was just one day when the collocated monitor recorded an exceedence but the primary did not. Thus, misclassification of non-exceedence days as exceedence days and vice-versa would appear to be rare.²

If measurement errors are relatively small, then a small change in the threshold used for classifying days as exceedence or non-exceedence should have little effect on the trend. This was explored using the M-1 dataset, and the results are shown in **Table 8**, below. Increasing the threshold (and thus decreasing the chance of misclassifying a non-exceedence day as an exceedence day, while conversely increasing the chance of the opposite misclassification error) had little effect on the observed trend: all slopes are statistically significant and vary between +1.24 and +1.45 days/year. Reducing the threshold (thus increasing the chance misclassifying a non-exceedence day as an exceedence day) results in shallower and less significant positive slopes. Overall, this analysis provides evidence that misclassification errors are not likely to influence the results presented in the Trend Report, at least for the analysis of Mesa2 data.

¹ To be consistent with EPA practice, only data from the primary monitor was used in trend analyses, except on rare occasions when a day had data from the collocated monitor but not the primary monitor, in which case the value from the collocated monitor was used.

² There are an additional 14 sample days with both FRM and FEM samples. The FRM recorded three exceedences while the FEM recorded four. This difference suggests there could be a real difference in the ability of the methods to detect an exceedence. Accounting for this is discussed above in the **Comparability of Federal Equivalent Method (FEM) data to Federal Reference Method (FRM) data** section.

Table 8: The Effect of Misclassification on the Results of Trend Analysis for Mesa2 Exceedences

Threshold for Exceedence ($\mu\text{g}/\text{m}^3$)	Slope (days/year)	P-value of slope	r^2 of regression
54	+1.24	0.035	0.26
53	+1.44	0.025	0.29
52	+1.38	0.036	0.26
51	+1.33	0.034	0.27
50	+1.45	0.023	0.30
49	+1.02	0.065	0.21
48	+0.95	0.081	0.19
47	+0.85	0.171	0.12

To address the second charge—that OLS is inappropriate for analyzing trends in the frequency of exceedence—additional diagnostics for the analyses presented in the report are also furnished. These demonstrate that the OLS was indeed appropriate. It should also be noted that OLS has been used by other researchers for trend analysis of the frequency of exceedence of air pollution standards.^{3,4} Alternative statistical approaches were also explored and are presented below; all gave results similar to those presented in the Trend Report.

Ordinary least squares assumes that the error in the response variable (in this case, the frequency samples exceeding a threshold) is constant across all observations and is normally distributed. Standard tests of these assumptions include residual plots and Q-Q plots. For a well-behaved model in which the response variable is indeed linearly related to the independent variable and the assumptions of normality and constant error are sufficiently valid, the residual plot should show no obvious pattern and the Q-Q plot should show all points lying approximately along the $y=x$ line. These plots are shown below for the M-1 and M-2 datasets (i.e. the Mesa2 analyses presented in the Trend Report), and indicate that OLS was a reasonable model for the data.

More sophisticated statistical methods that rely upon different assumptions about the error distribution were also tested. The Mesa2 PM_{10} data was selected for testing rather than data from other sites because it is this data series that came under scrutiny. Also, the trends at this site are among the most sensitive to changes in data handling (as shown above), so it seems likely these trends would also be among the most sensitive to changes in statistical methodology. Datasets M-1 and M-6 were selected for testing since among the AQS-only datasets, they have the least and most restrictive data inclusion criteria, respectively. As discussed below, the alternative statistical approaches yielded results very similar to those derived from OLS, therefore the other six Mesa2 datasets and the 18 datasets for the other site/PM combinations were not examined by these alternative approaches.

The first alternative method to be tested was logistic regression. Logistic regression models are often employed to model binary events, where the response variable is the frequency that the event occurs and can only take values between 0 and 100%; it is assumed to follow the binomial distribution. This is more

³ Lin, C.-Y.C., Jacob, D.J., and Fiore, A.M. (2001). Trends in exceedences of the ozone air quality standard in the continental United States, 1980-1998. *Atmospheric Environment* 35, 3217-3228.

⁴ In addition, staff discussed this issue with on two separate occasions with faculty at California Polytechnic State University, San Luis Obispo—one a professor of economics, the other of statistics—and both agreed that OLS was likely an acceptable approach. These discussions also yielded several useful suggestions for additional analyses, many of which have been incorporated into this **Addendum**.

realistic than assuming the data are normally distributed, since the frequency of days exceeding the standard can never be less than zero or greater than 100%, so positive errors are more likely for low values and negative errors are more likely as values approach 100%. Relatedly, OLS might predict exceedence frequencies greater than 100% or less than zero, while a logistic regression will yield predictions that only asymptotically approach these values.

Figure 1: Residual and Q-Q Plot for the Ordinary Least Squares Fit of the M-1 Dataset

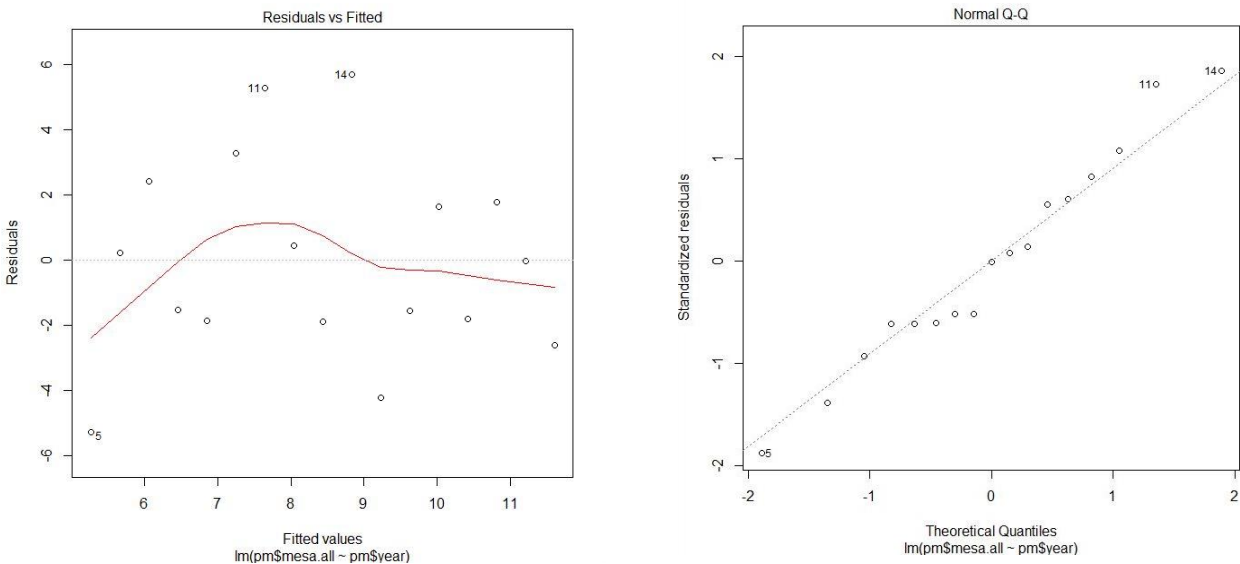
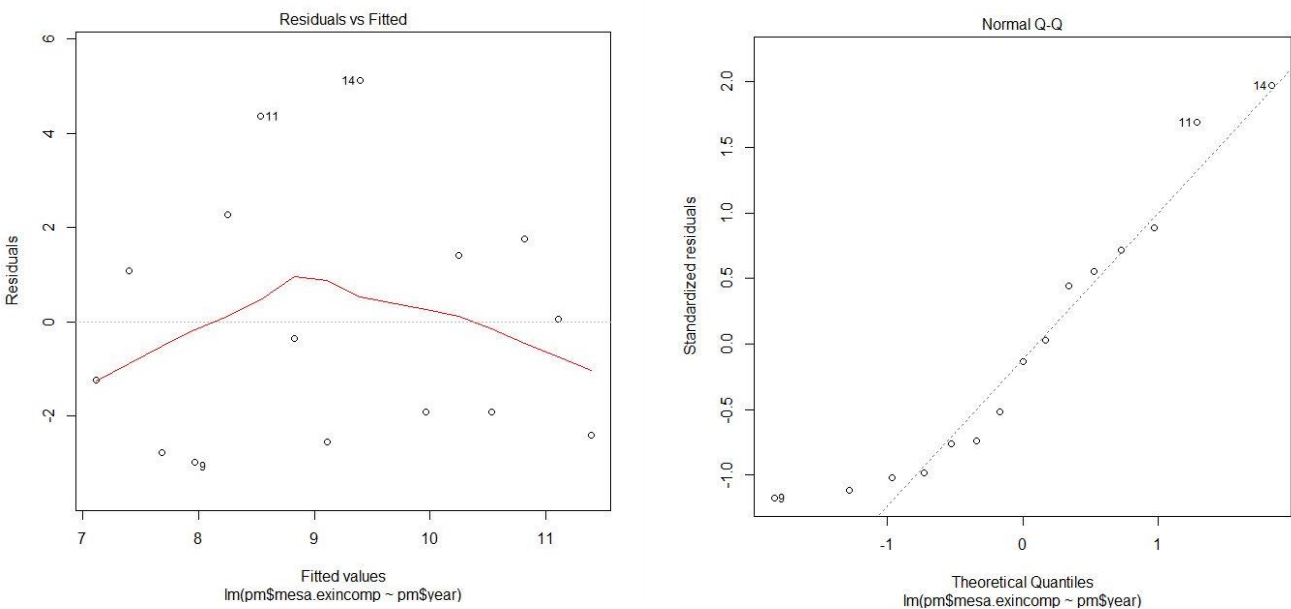


Figure 2: Residual and Q-Q Plot for the Ordinary Least Squares Fit of the M-2 Dataset



Logistic regressions were performed on the Mesa2 PM₁₀ dataset using the software package R.⁵ The samples were treated individually, with the year being the independent variable and exceedence outcome being the response variable; samples not exceeding the standard were coded as zeroes and those that did were coded as ones. Since the regression was run on the individual observations rather than on data aggregated by year, the model implicitly accounts for the different sample sizes for each year. Using the M-1 dataset (i.e., AQS-only data including partial years and FEM data) the regression yielded a statistically significant model (p-value = 0.046) with a positive coefficient of 0.376 for the predictor variable (year). This is interpreted as a yearly increase of 3.8% in the odds of sample being an exceedence. Over the observation period (1995-2011) this translates to an average increase of 0.95 exceedences per year. Using the M-6 dataset (i.e., AQS-only data, excluding partial years and FEM data) the regression yields a coefficient of +0.0425 (increased yearly odds of 4.3% or an average of 1.11 more exceedences per year during the observation period) but the model is not significant (p-value = 0.190).

These datasets were also examined using the Theil-Sen approach as implement in the OpenAir package in R.⁶ This is a non-parametric method that makes no assumptions about how the data are distributed and is insensitive outliers. The Theil-Sen approach estimates the slope of a linear trend by calculating the slope between all pairs of points in the dataset, ordering them, and then selecting the median slope as the most likely value for the trend. Using the M-1 dataset, a statistically significant slope (p-value = 0.012) of +1.40 days/year was obtained. Using the M-6 dataset, a statistically significant slope (p-value = 0.027) of +1.45 days/year was obtained.

Figures 3 and 4 plot the trend lines produced by the OLS, Theil-Sen, and logistic models for the M-1 and M-6 dataset, respectively. In these graphs, different markers are used to distinguish FRM data from FEM data and to indicate incomplete years. These figures also include 95% confidence intervals, calculated as modified Wilson intervals that incorporate the finite population correction. Non-significant trends are indicated with dashed lines. As seen in the figures, all indicate very similar trends (in fact, for the M-1 dataset the OLS and Theil-Sen trends lines are nearly co-linear), and all are statistically significant except for the logistic regression on the M-6 dataset. Therefore, it is unlikely that the conclusions of the Trend Report would have been different had either of these approaches been employed in place of the OLS approach.

⁵ R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

⁶ Carslaw, D.C. (2013). The openair manual — open-source tools for analysing air pollution data. Manual for version 0.8-0, King's College London.

Figure 3: OLS, Theil-Sen, and Logistic fits of the M-1 Dataset

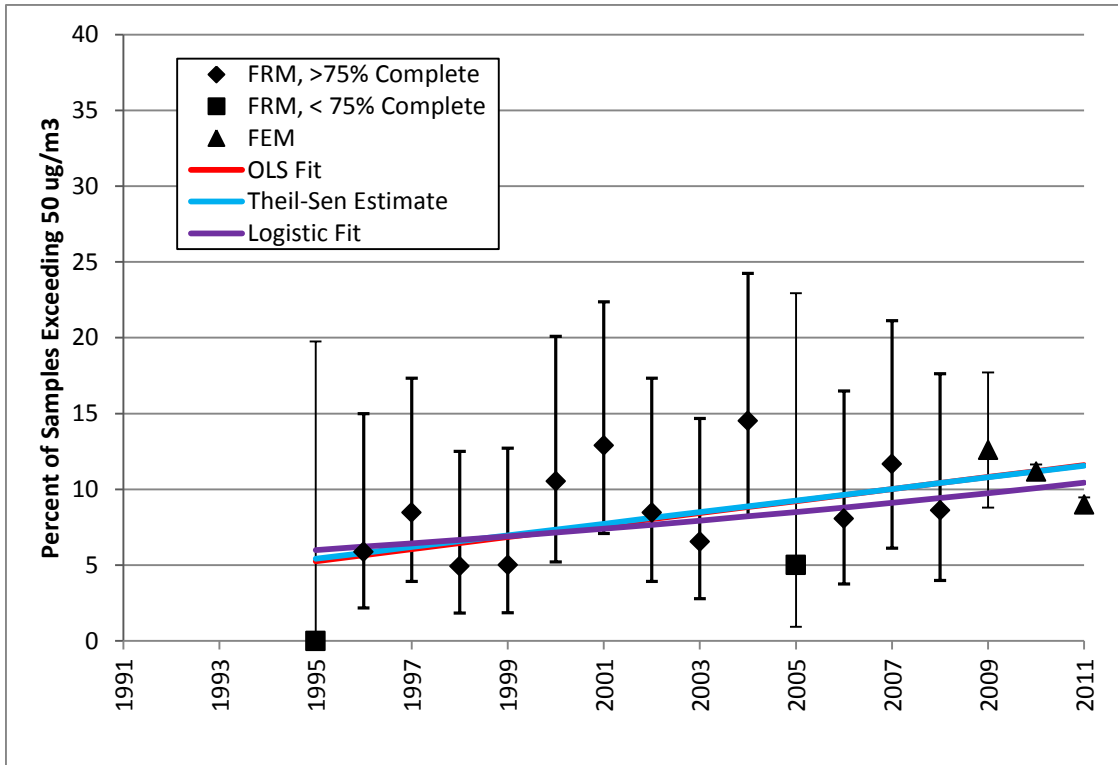
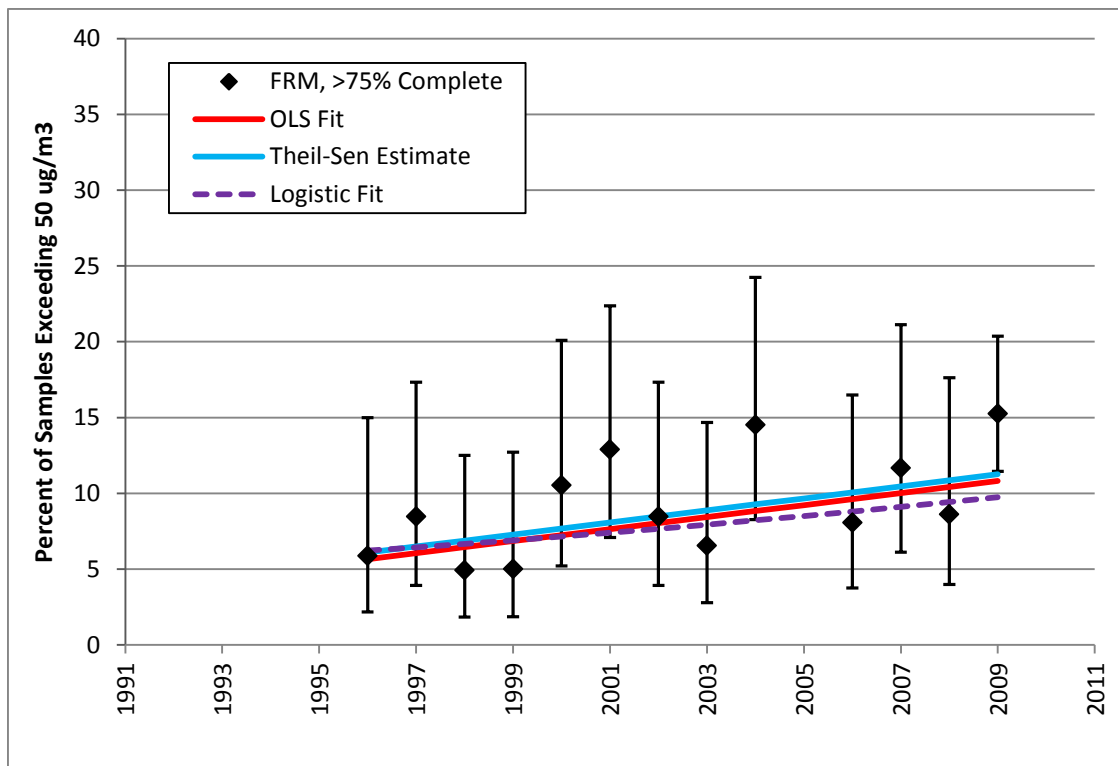


Figure 4: OLS, Theil-Sen, and Logistic fits of the M-6 Dataset



Conclusions

In response to questions raised by a Board member regarding data handling and analysis methodologies used in the Trend Report, a large portion of the PM data presented in that report has been reanalyzed. As shown in **Tables 1** through **6**, trends in PM levels were found to be relatively insensitive to how incomplete years and FEM data were handled; in almost all cases non-significant trends remained non-significant when incomplete years and/or FEM data were removed; meanwhile, significant trends remained significant or borderline under these alternative conditions. The magnitudes of these trends tended to remain similar to what was presented in the original report. Alternative statistical methods were also explored for the analysis of Mesa2 exceedence days; these produced results very similar to those produced by the method employed in the Trend Report.

While insensitive to the handling of partial years and FEM data, the trend in the frequency of PM₁₀ exceedences at Mesa2 was sensitive to the inclusion of non-AQS data (**Table 1**). Including this data reduced both the steepness of the trend and its significance. In fact, regardless of the handling of incomplete years and FEM data, none of the trends were significant when non-AQS data was included; however, as described above it was appropriate to excluded this non-AQS data from the analyses presented in the report due to the inability to verify the quality and validity of that data.

These analyses affirm the conclusions of the original Trend Report regarding Mesa2 PM trends, which stated: “PM₁₀ and PM_{2.5} levels continue to frequently exceed health standards in the South County and appear to be increasing at the Mesa2 site ... PM_{2.5} levels are much higher on the Nipomo Mesa at the CDF and Mesa2 stations [than elsewhere in the County], and there is no evidence of improvement there ... The greatest degree of PM₁₀ pollution is found on the Nipomo Mesa in the South County, where the state standards for 24-hr and annual average concentrations are routinely exceeded at the CDF and Mesa2 sites. In contrast to the North County and San Luis Obispo, these sites show no improvement; in fact the situation may be worsening.”

These conclusions were based on the following results:

- A statistically significant positive trend in the frequency of days exceeding 12 µg/m³ PM_{2.5} at Mesa2 for 2009-2011.
- A statistically significant positive trend in the annual average PM_{2.5} level at Mesa2 for 2009-2011.
- A statistically significant or borderline significant—depending on the handling of partial years—positive trend in the frequency of days exceeding 50 µg/m³ PM₁₀ at Mesa2 for 1995-2011.
- A lack of a significant trend in the PM₁₀ annual average at this site for 1995-2011.

As discussed earlier in this **Addendum**, removing partial years from the analysis of PM_{2.5} trends leaves only two years, and thus precludes a determination of statistical significance. The slopes are still positive, so the conclusion that “there is no evidence of improvement there” remains justified. Alternative data handling had no effect on the trend in the PM₁₀ annual average, and only by including non-AQS data does the trend in the frequency of PM₁₀ exceedences become non-significant; as noted above, however, the quality of the non-AQS data cannot be verified. Furthermore, this non-AQS data covers 1991-1993, and regardless of its quality excluding it suggests that since about 1995 PM₁₀ levels at Mesa2 have trended upward. Thus, the conclusion that Mesa2 “show[s] no improvement; in fact the situation may be worsening” still appears warranted.

As the alternative analyses discussed above yield results very similar to those in the Trend Report, they do not change our original conclusion that the improvements in PM levels observed elsewhere in San Luis Obispo County are not being seen at Mesa2, and that PM levels may be increasing there.