Chapter 2

PM2.5 Trends and Challenges in the San Joaquin Valley

2015 Plan for the 1997 PM2.5 Standard
SJVUAPCD

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While presented with unique geographical and meteorological challenges, the San Joaquin Valley (Valley) has made significant progress in reducing total PM2.5 emissions and PM2.5 precursor emissions and in improving air quality for Valley residents. Through progressively more stringent regulations and improved control technologies, the annual average amount of directly emitted PM2.5 emissions has been steadily decreasing. Similarly, the overall amount of NOx and SOx emissions continue to decrease.

Achieving PM2.5 reductions has been challenging given frequent meteorological conditions conducive to PM2.5 formation that are characteristic of the Valley, and which are outside human (and regulatory) control. Annual fluctuations in weather patterns affect the Valley's carrying capacity (the ability to disperse pollutants), which is reflected in long and short-term ambient air quality trends. Until the exceptional weather conditions experienced due to the recent drought, the District was on track to attain the 1997 annual PM2.5 standard before the federally mandated deadline of December 2014.

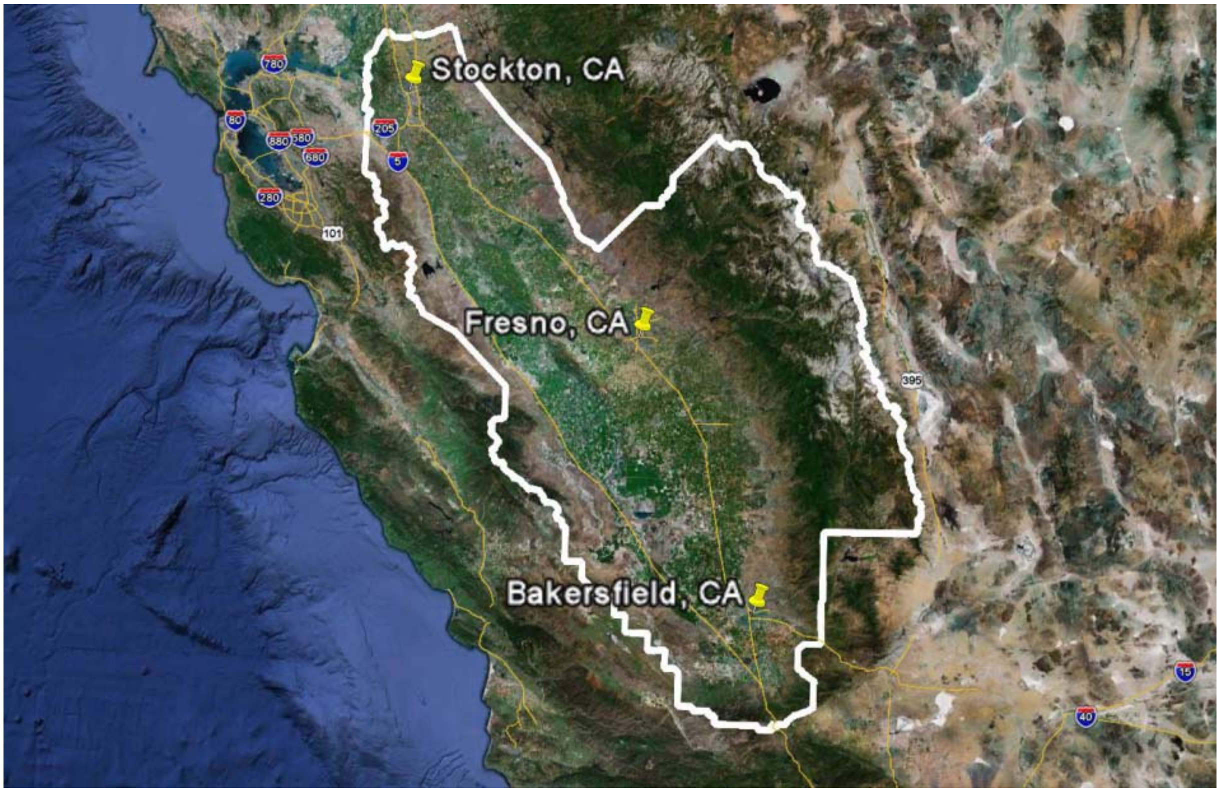
2.1 CHALLENGES OF THE NATURAL ENVIRONMENT

The Valley's natural environment supports one of the most productive agricultural regions in the country: the Sierra Nevada provides the necessary water for growing the abundance of crops, and a temperate climate provides a long growing season. However, these same natural factors present significant challenges for air quality: the surrounding mountains trap pollution and block air flow, and the mild climate keeps pollutant-scouring winds at bay most of the year. Despite the challenges, the District and the Valley are making progress in attaining the national air quality standards and improving public health for Valley citizens.

2.1.1 Unique Climate and Geography

The challenge of PM 2.5 NAAQS attainment in the Valley is grounded in the unique topographical and meteorological conditions found in the region. The Valley, as seen in Figure 2-1, is an inter-mountain valley encompassing nearly 25,000 square miles. Surrounded by mountain ranges to the west, east, and south, the air flow through the Valley can be blocked, leading to severely constrained dispersion. During the winter, high-pressure systems can cause the atmosphere to become stagnant for longer periods of time, where wind flow is calm and air movement is minimal. These stagnant weather systems can also cause severe nighttime temperature inversions, which exacerbate the build-up of PM2.5 and related precursors both beneath and above the evening inversion layer.

Figure 2-1 San Joaquin Valley Air Basin



Normally, temperature decreases with increasing altitude, but during temperature inversions the normal temperature gradient is reversed, with temperatures *increasing* with altitude, causing warmer air to be above cooler air. Figure 2-2 shows that this reversal of the "normal" pattern impedes the upward flow of air, causes poor dispersion, and traps pollutants near the surface. Temperature inversions are common in the Valley throughout the year. Since the inversion is often lower than the height of the surrounding mountain ranges, the Valley effectively becomes a bowl capped with a lid that traps emissions near the surface. When horizontal dispersion (transport flow) and vertical dispersion (rising air) are minimized, PM2.5 concentrations can build quickly, especially in the winter. These naturally occurring meteorological conditions have the net effect of spatially concentrating direct PM2.5 concentrations near their sources; promoting the formation and regional buildup of secondary species, particularly ammonium nitrate; and chemically aged organic carbon species, resulting in an increase in their relative toxicity. Given these challenges, the Valley needs even more effective emissions reductions to attain the PM2.5 NAAQS; and the District continues to pursue these reductions through its numerous air quality attainment plans, prohibitory regulatory control strategy and innovative non regulatory emission reduction strategy which includes a robust incentive program, a comprehensive legislative platform, and rigorous outreach and education efforts.

Figure 2-2 Atmosphere with and without a Temperature Inversion

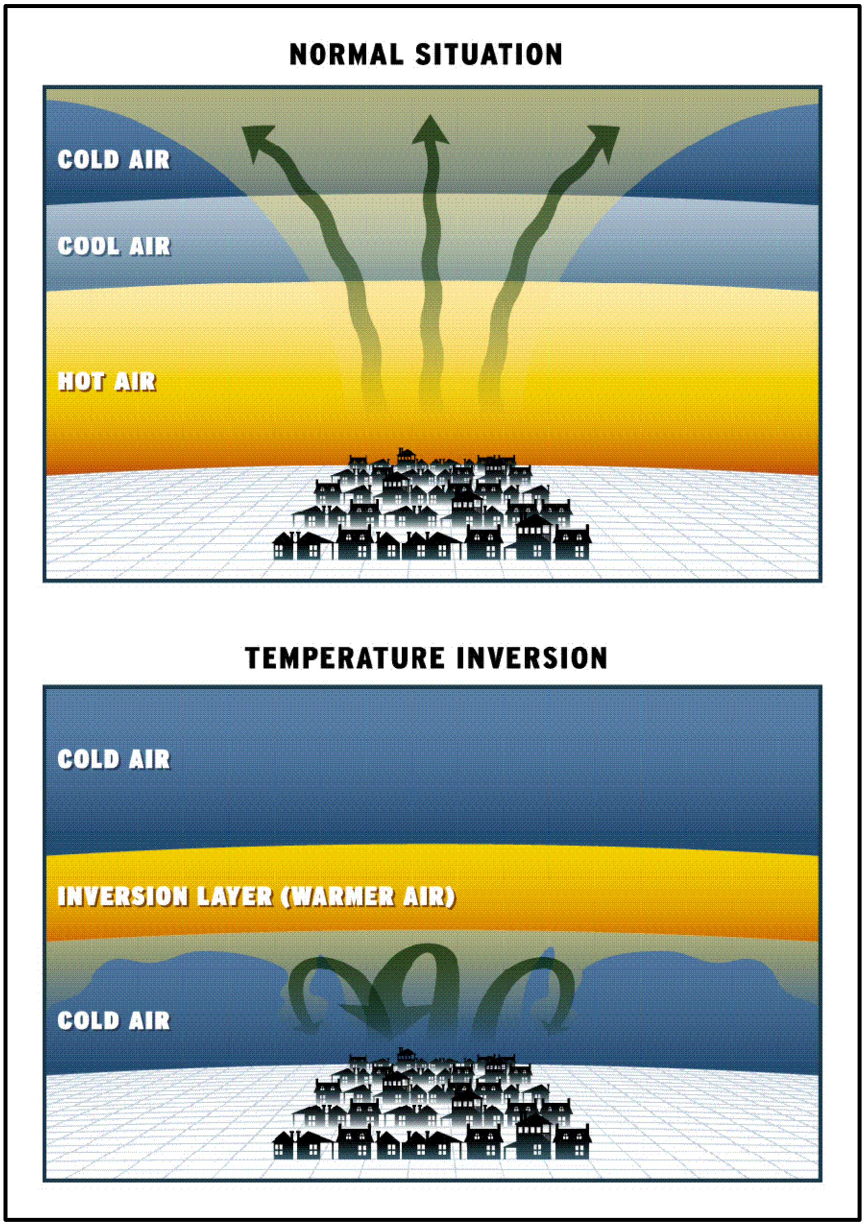


Image source: http://ffden-2.phys.uaf.edu/212_spring2007.web.dir/Amber_Smith/Effects_of_Inversions.htm

2.1.2 Valley Carrying Capacity

Carrying capacity, in the context of air quality, refers to the density of emissions that an air basin can "absorb" or "carry" and still meet ambient air quality standards for a given pollutant. The key factors that shape variations in a regional carrying capacity include meteorology, climate, and the topography. Some air basins may have a high total pollutant emission rate (emissions per person or area), but if those emissions are easily dispersed or removed from the basin, that basin is much more likely to meet ambient standards despite high emission rate. On the other hand, an air basin may have a lower emission rate (or the same rate, over the same time period), but because of unfavorable environmental factors (low air flow, stagnant air, inversions) those pollutant concentrations typically accumulate (possibly above the standard) and remain in the air basin until weather patterns change. The latter scenario describes the San Joaquin Valley, and the first scenario is analogous to the Los Angeles (L.A.) air basin, especially for NOx emissions and the formation of ozone.

As an example, total NOx emissions for the L.A. basin were 754 tons per day (tpd) in 2008. During that year, the L.A. basin recorded 80 days above the 1997 national 8-hour ozone standard. For the same year, the total NOx emissions for the Valley air basin were 409 tpd (over a larger area), yet the Valley recorded 82 days above the standard. NOx dispersal is primarily dependent on summertime weather patterns. The L.A. basin experiences regular coastal winds through much of the summer that not only disburse pollutants from the air basin, but also moderates temperatures. Conversely, the Valley, surrounded by mountain ranges, routinely experiences stagnant weather patterns (less wind) and extended periods of high temperatures, both of which build and concentrate ozone to levels above the standard. In this real example, it is obvious that the Valley has a much lower carrying capacity than the L.A. basin for NOx, a precursor to ozone formation.

While not as drastic as the NOx-ozone example above (in terms of emission rate), the Valley's carrying capacity for PM2.5, when compared to the L.A. basin, is greatly affected by prevailing weather during the winter months and the region's topography (surrounding mountains). For 2008, the annual average direct PM2.5 emission rate for the L.A. basin was 80 tpd; during that year, that basin recorded 19 days above the national PM2.5 24-hour standard. For the same year, the Valley's annual average direct PM2.5 emission rate was 82 tpd; however, the Valley recorded 66 days above the 24-hour standard. During this same time period, the NOx and SOx emissions, which are also precursors to PM2.5, were significantly lower in the Valley compared to the L.A. Basin (NOx—409 tpd and 754 tpd, respectively, as stated above; and SOx—13 tpd and 54 tpd, respectively). As noted in Section 2.2.1, temperature inversions are common during the winter months in the Valley. During these sometimes lengthy stagnant air episodes, PM2.5 emissions from daily activities rapidly build up to levels above the standard. It is during these events (or anticipation of these events) that the District's Check-Before-You-Burn program and Real-time Air Advisory Network (RAAN) system intervene to inform (or require) the public to limit activity that generates PM2.5 emissions.

The District uses quantitative carrying capacity analysis in its modeling of attainment demonstrations. Such analyses can determine which combinations of PM2.5 and PM2.5 precursor emissions reductions can contribute to future attainment given anticipated population and activity growth, potential regulations or control measures, and the unchanging natural physical constraints.

2.2 PM2.5 EMISSIONS INVENTORY TRENDS

The emissions inventory is the foundation for the attainment planning process. The District and the California Air Resources Board (ARB) maintain an accounting of PM2.5 and precursor emissions for the Valley based on known sources within the Valley and those sources outside the Valley that influence Valley air quality (inter-region transport). The District requires detailed accounting of emissions from regulated sources throughout the Valley. ARB makes detailed estimations of emissions from mobile, area, and geologic sources using known emissions factors for each source or activity and accounting for relevant economic and population data. Together, these feed into the emissions inventory that represents an estimate of how much direct pollution is going into the Valley air basin as a result of the cumulative pollutant-generating activities and sources.

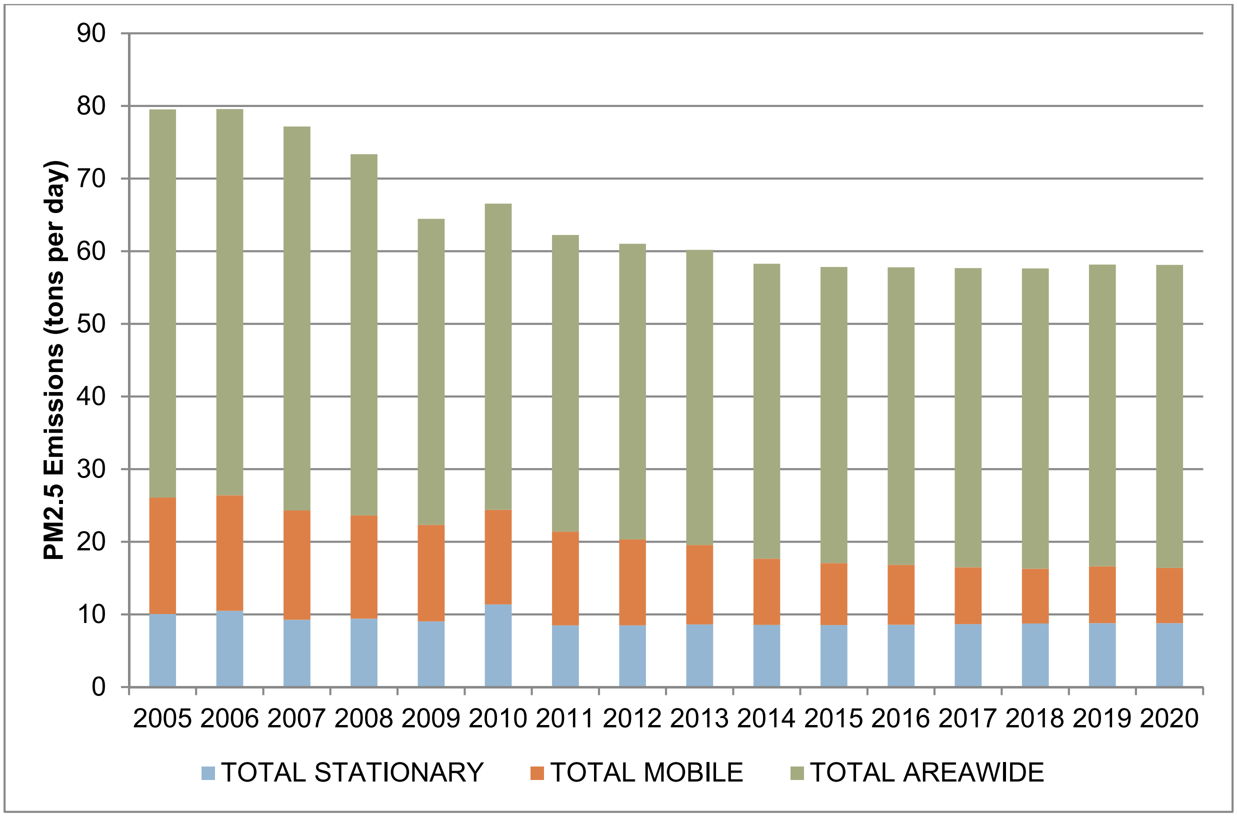
The District uses the emissions inventory to develop control strategies, to determine the effectiveness of permitting and control programs, to provide input into air quality modeling, to fulfill reasonable further progress requirements, and to screen regulated sources for compliance investigations.

The following general list represents the major inventory categories for which emissions are recorded and tracked. Appendix B to this plan contains the detailed accounting of the emissions inventory with projected emissions based on anticipated growth of each source and the anticipated control (regulatory or non-regulatory) of each source, if applicable.

- **Mobile sources** – motorized vehicles
  - On-road sources include automobiles, motorcycles, buses, and trucks
  - Other or off-road sources include farm and construction equipment, lawn and garden equipment, forklifts, locomotives, boats, aircraft, and recreational vehicles
- **Stationary sources** – fixed sources of air pollution
  - Power plants, refineries, and manufacturing facilities
  - Aggregated point sources, i.e. facilities (such as gas stations and dry cleaners) that are not typically inventoried individually, but are estimated as a group and reported as a single source category
- **Area sources** – human activity that takes place over a wide geographic area
  - Includes consumer products, fireplaces, controlled burning, tilling, and unpaved road dust
- **Natural sources** – naturally occurring emissions
  - Geologic sources, such as petroleum seeps
  - Biogenic sources, such as emissions from plants
  - Wildfire sources

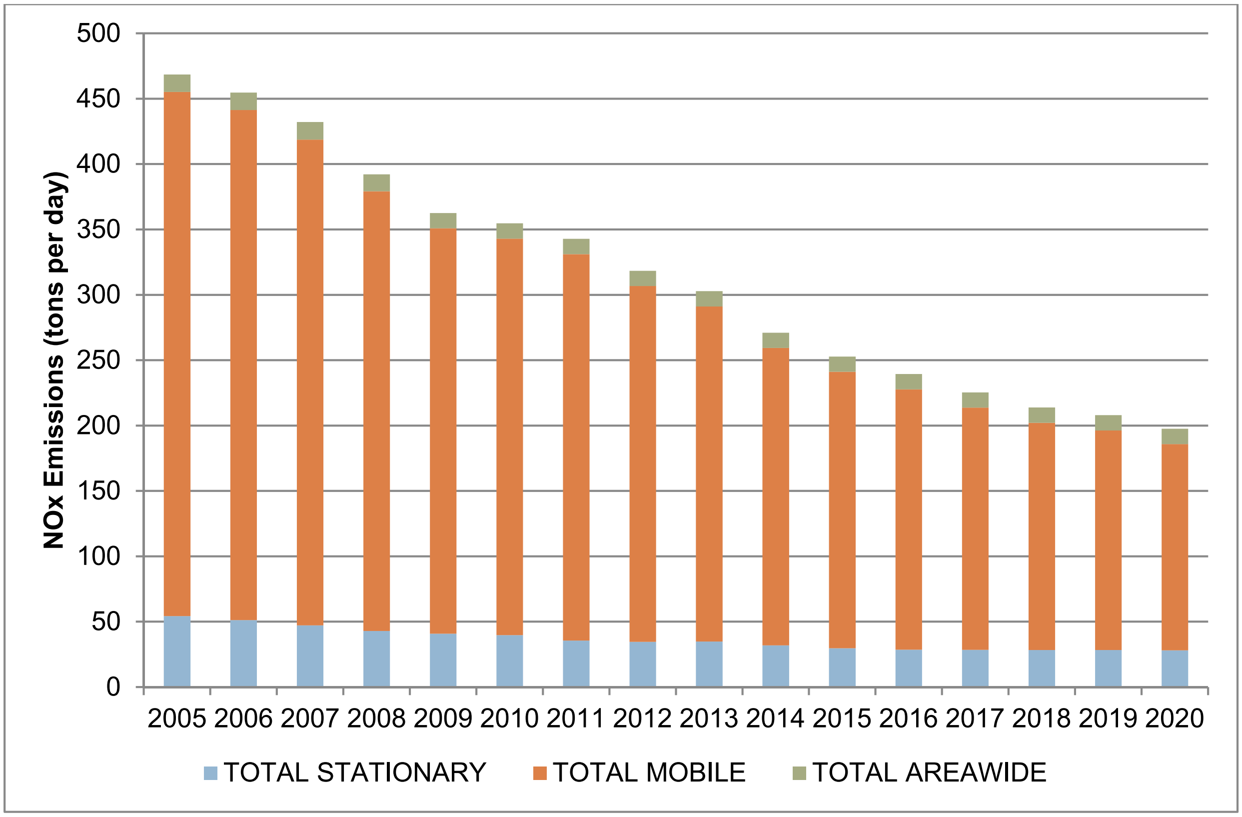
Figure 2-3 shows the PM2.5 emissions inventory trend for the mobile, stationary, and area source categories.

Figure 2-3 Valley PM2.5 Winter Emissions Inventory Trend



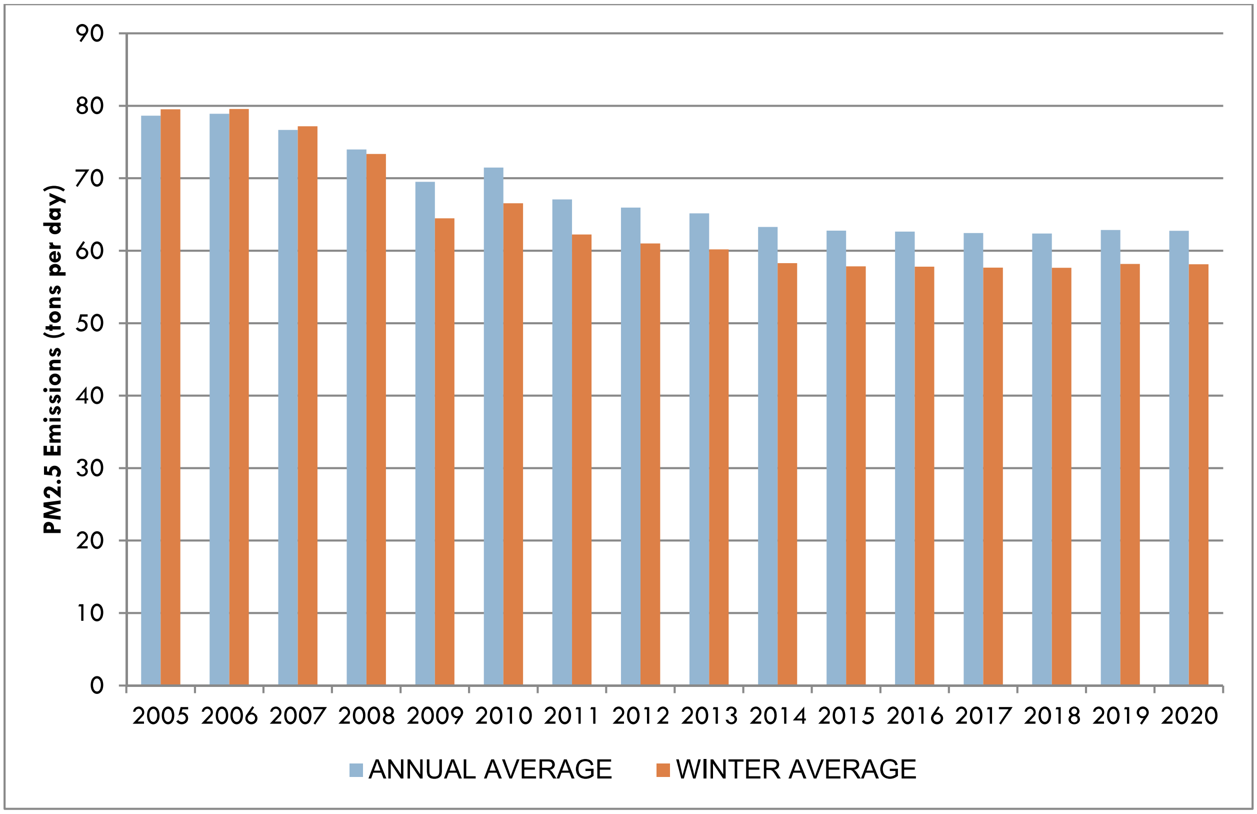
Because NOx is a significant PM2.5 precursor, the District relies heavily on NOx emissions to also reduce PM2.5 emissions. Figure 2-4 summarizes the NOx emissions inventory trends for the mobile, stationary, and area source categories. District and ARB control strategies for NOx play a significant role in reducing both ozone and PM2.5 emissions.

Figure 2-4 Valley Winter NOx Emissions Inventory Trend



Emissions inventory trends show the progress made through progressive regulatory and non-regulatory activities, e.g. as rules are amended with tighter emission limits, or as reduction technologies improve, overall emissions decrease. Figure 2-5 shows how the overall tons of PM2.5 emissions per day have decreased in the past and are anticipated to continue decreasing in the future based on anticipated growth and controls. Figure 2-5 also shows the comparative emission inventory reduction of winter PM2.5. Winter PM2.5 emissions have decreased significantly, in large part due to the effectiveness of Rule 4901 (Wood Burning Fireplaces and Wood Burning Heaters). Continued emissions reductions are based on current control strategies that will continue to take effect into the future. In light of the Valley's projected increase in population, the projected emissions reductions highlight the success of the control measures adopted and enforced by the District, ARB, and other regulatory agencies.

Figure 2-5 Valley PM2.5 Annual and Winter Inventory Trends



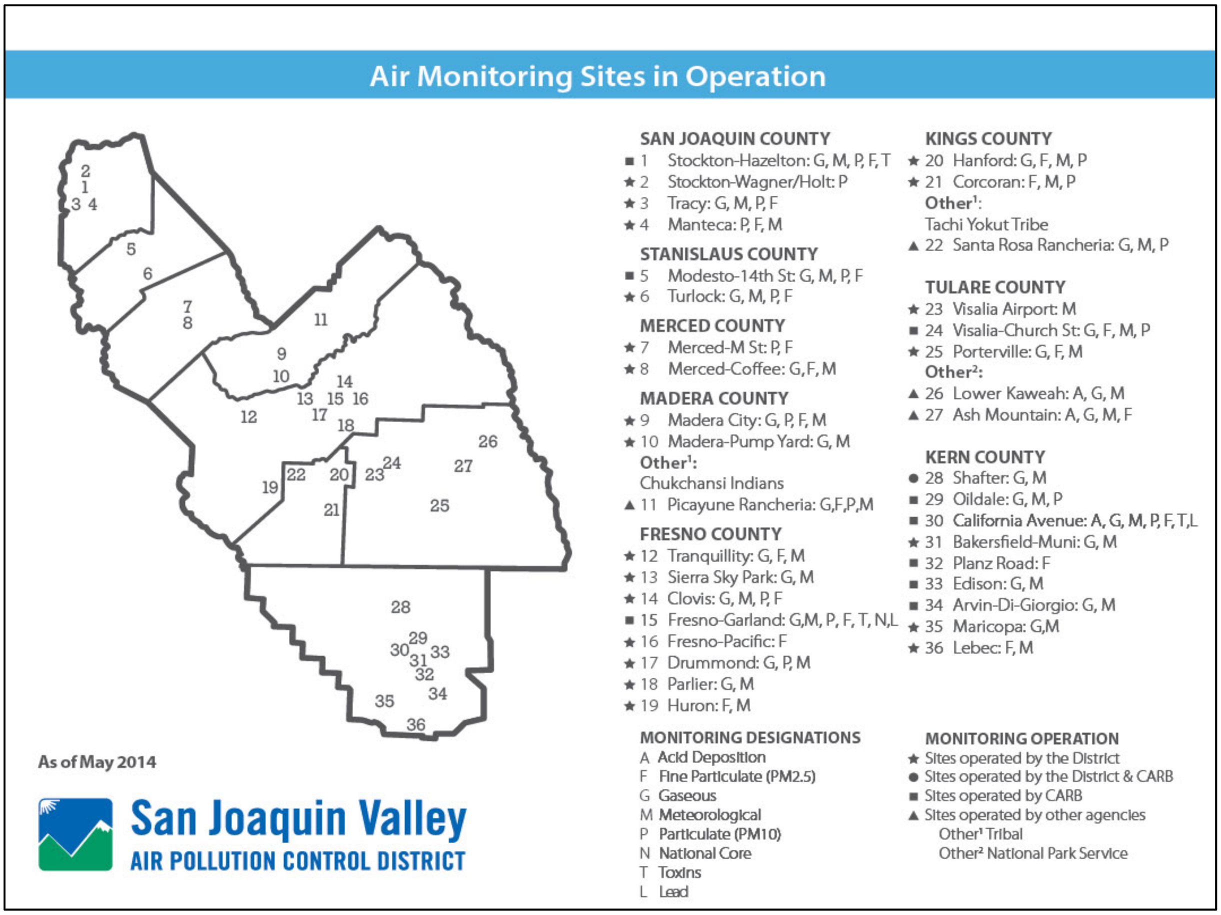
2.3 PM2.5 AIR QUALITY TRENDS

As a public health agency charged with monitoring Valley air quality and ensuring progress toward meeting national air quality standards, the District has established an extensive air monitoring network that provides ongoing data for evaluating such progress. Information from this extensive monitoring network, which began measuring PM2.5 concentrations in 1999, allows the District to track air quality trends that show progress toward attainment and inform the planning process for reaching attainment.

2.3.1 Air Monitoring Network

Numerous pollutants and meteorological parameters are measured throughout the Valley on a daily basis using an extensive air monitoring network managed by the District, ARB, and other agencies. This network measures pollutant concentrations necessary to show progress toward compliance with the NAAQS. The network also provides real-time air quality measurements used for daily air quality forecasts, residential wood-burning declarations, Air Alerts, and RAAN. Air quality monitoring networks are designed to monitor areas with high population densities, areas with high pollutant concentrations, areas impacted by major pollutant sources, and areas representative of background concentrations. Together, the District and the ARB operate 33 air monitoring stations throughout the Valley; 20 of these sites measure PM2.5, either through the use of filter-based monitors that measure each 24-hour period or hourly monitors that use light energy to provide near-continuous concentration levels. Figure 2-6 shows the Valley's network of air monitoring sites.

Figure 2-6 Air Monitoring Sites in the Valley



PM2.5 is measured and expressed as the mass of particles contained in a cubic meter of air (micrograms per cubic meter, or $\mu g/m^3$). The data collected from the District's network of PM2.5 monitors is used to calculate design values for the 24-hour and annual PM2.5 standards, as outlined in U.S. Environmental Protection Agency (EPA) guidance and regulations.[1,2]

2.3.2 Air Quality Progress

Air quality progress can be assessed in several ways. The calculation of *design values* is the official method used to determine whether an area is in attainment of a standard; however, other indicators can reveal more about the progress being made toward attaining that standard. Comparing the days per year when each monitor exceeded the

[1] Environmental Protection Agency [EPA]: Office of Air Quality Planning and Standards. (1999, April). *Guideline on Data Handling Conventions for the PM NAAQS* (EPA-454/R-99-008). Retrieved from http://www.epa.gov/ttn/oarpg/t1/memoranda/pmfinal.pdf

[2] Interpretation of the National Ambient Air Quality Standards for PM2.5, 40 C.F.R. Pt. 50 Appendix N (2012).

PM2.5 24-hour NAAQS threshold from year to year shows the progress in reducing the number of days with the highest concentrations, while quarterly averages can help to show progress with respect to seasonal peaks in concentration levels. Some of the conclusions from these analyses are included below, followed by a more detailed discussion in Appendix A, which also provides analysis results for a number of other air monitoring sites in the Valley.

Rather than using yearly maximum concentrations for the PM2.5 standards, EPA requires the use of design values for the attainment metric. Design values represent a three-year average and help to smooth out outlier years with exceptional meteorology or exceptional events. Details on how PM2.5 design values are calculated are provided in Appendix A of this plan. As seen in Figure 2-7, the Valley maximum 24-hour and annual average PM2.5 design value trends show that although there is some year-to-year variation significant progress has been made in reducing long-term PM2.5 concentrations. Valley 24-hour design value maximums have decreased by 40% over the 1999–2013 time period.

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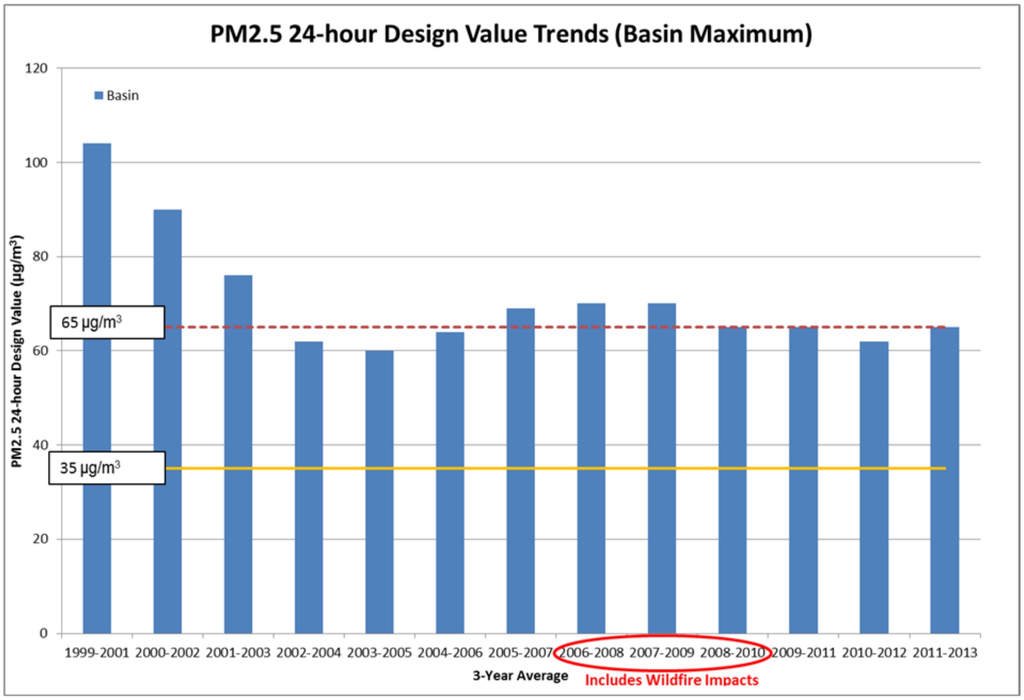
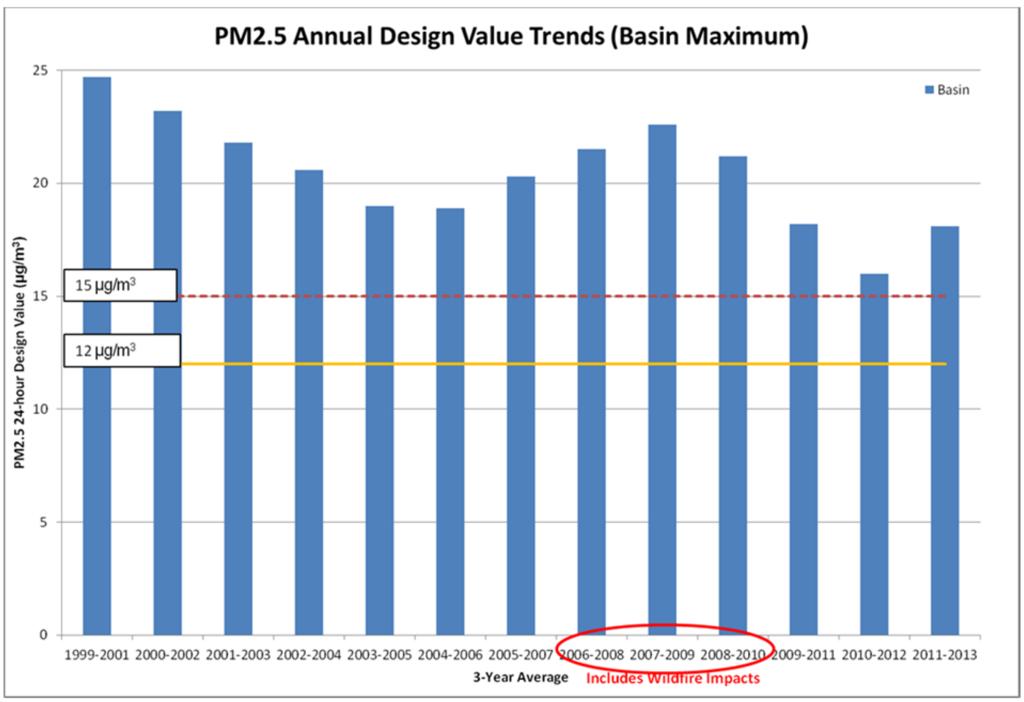
Figure 2-7 Historical PM2.5 24-hour and Annual Design Value Trends





Since monitoring began, the Bakersfield-California and Bakersfield-Planz air monitoring sites in Kern County have consistently been among the highest PM2.5 design values in the Valley. Figure 2-8 shows the trend of the 24-hour average design value at Bakersfield-California through 2013, as demonstrated with the 2011-2013 design value (3-year average). Figure 2-9 shows the trend of the annual average design value at

Bakersfield Planz through 2013, as demonstrated with the 2011–2013 design value (3-year average).

Figure 2-8 Trend of 24-Hour Average PM2.5 Design Values at Bakersfield-California

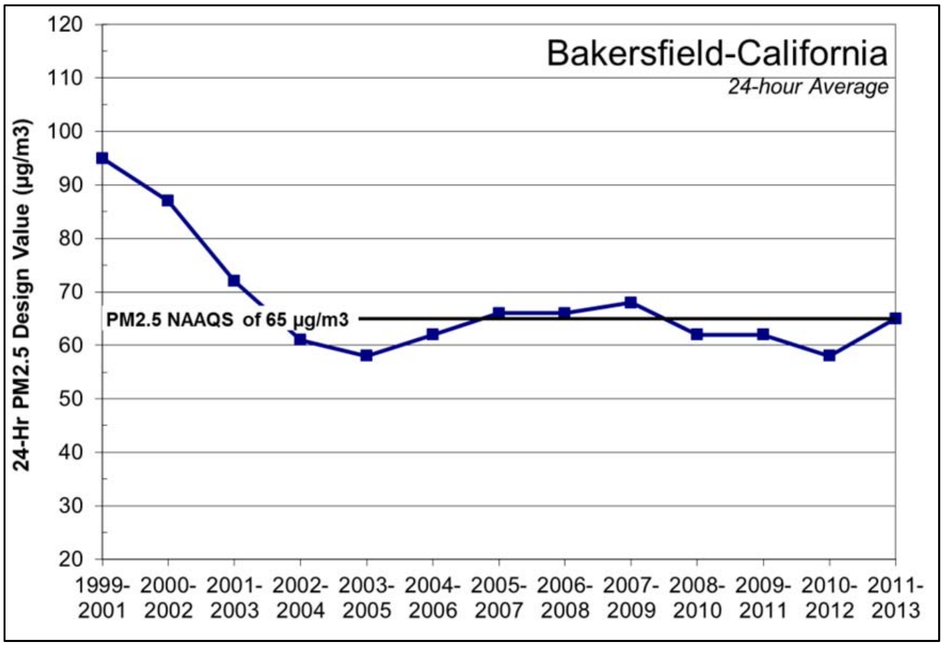
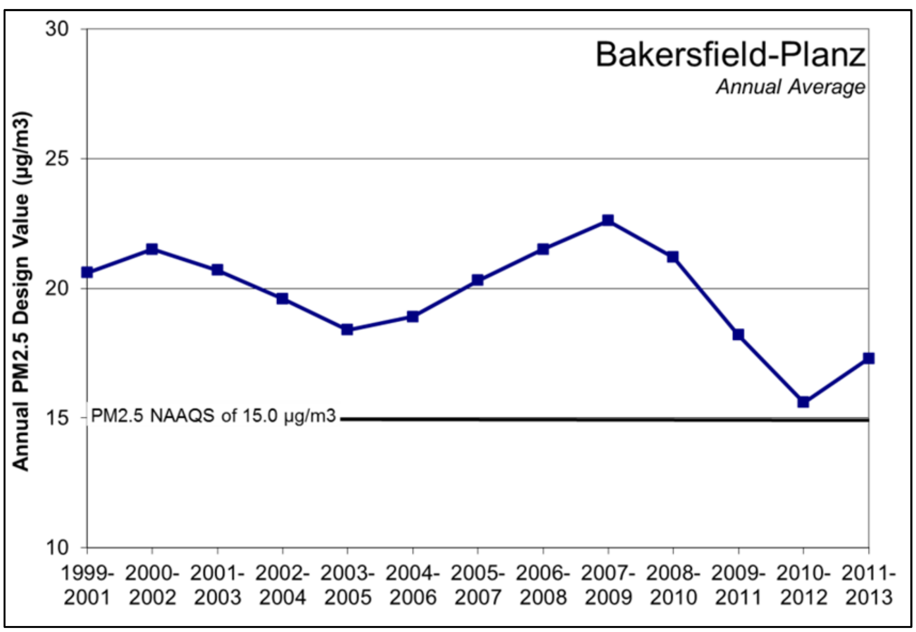


Figure 2-9 Trend of Annual Average PM2.5 Design Values at Bakersfield-Planz

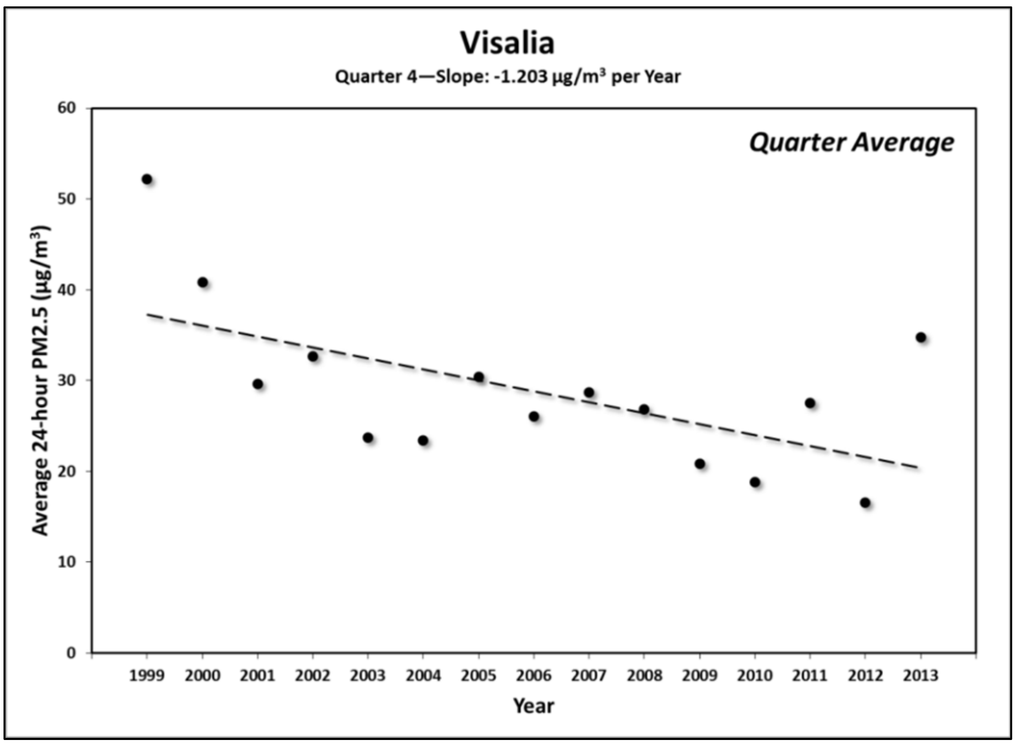


Overall decreasing PM2.5 concentrations at the Bakersfield-California and Bakersfield-Planz air monitoring sites are shown in the design value trends for those sites. Figure 2-8 shows that the Bakersfield-California site now has a 24-hour design value at or below the 1997 24-hour PM2.5 standard of 65 μg/m^3. Figure 2-9 shows that the annual average design value for the 2011–2013 time period has continued to trend lower for Bakersfield-Planz at 17.3 μg/m^3. This downward trend will need to continue at all sites within the Valley as the Valley strives for attainment of the 2006 PM2.5 NAAQS.

Since the Valley's highest PM2.5 concentrations occur during the fall and winter months, the first (January through March) and fourth (October through December) quarters tend to have the highest average concentrations. Observing the trend in these quarterly averages can shed light on how the peak of the PM2.5 season is changing over time.

Data from the Visalia monitoring site, as shown in Figure 2-10, is representative of fourth-quarter averages among the PM2.5 sites in the Valley. This data also shows a downward trend of 1.20 μg/m^3 per year. The District anticipates continuation of this trend as the Valley gets closer to attaining the annual average PM2.5 standard of 15 μg/m^3. Appendix A contains detailed results of this analysis.

Figure 2-10 Trend of Fourth-Quarter Average at Visalia



2.3.3 Impact of Exceptional Drought-Related Weather Conditions on Valley PM2.5 Concentrations

In 2012, the Bakersfield-Planz air monitoring site, which is the current peak PM2.5 site in the District, recorded an annual average value of 14.7 µg/m^3, below the standard of 15.0 µg/m^3. This site, along with the rest of the District's PM2.5 air monitoring sites, was making significant progress towards attaining the 1997 annual PM2.5 standard. However, due to the exceptional weather conditions experienced during the winter of 2013-2014, exceedingly high PM2.5 concentrations were experienced, causing a 2013 annual average of 22.8 µg/m^3 for the Bakersfield-Planz site, and an annual design value (2011-2013) of 17.3 µg/m^3 (see Figure 2-9 above).

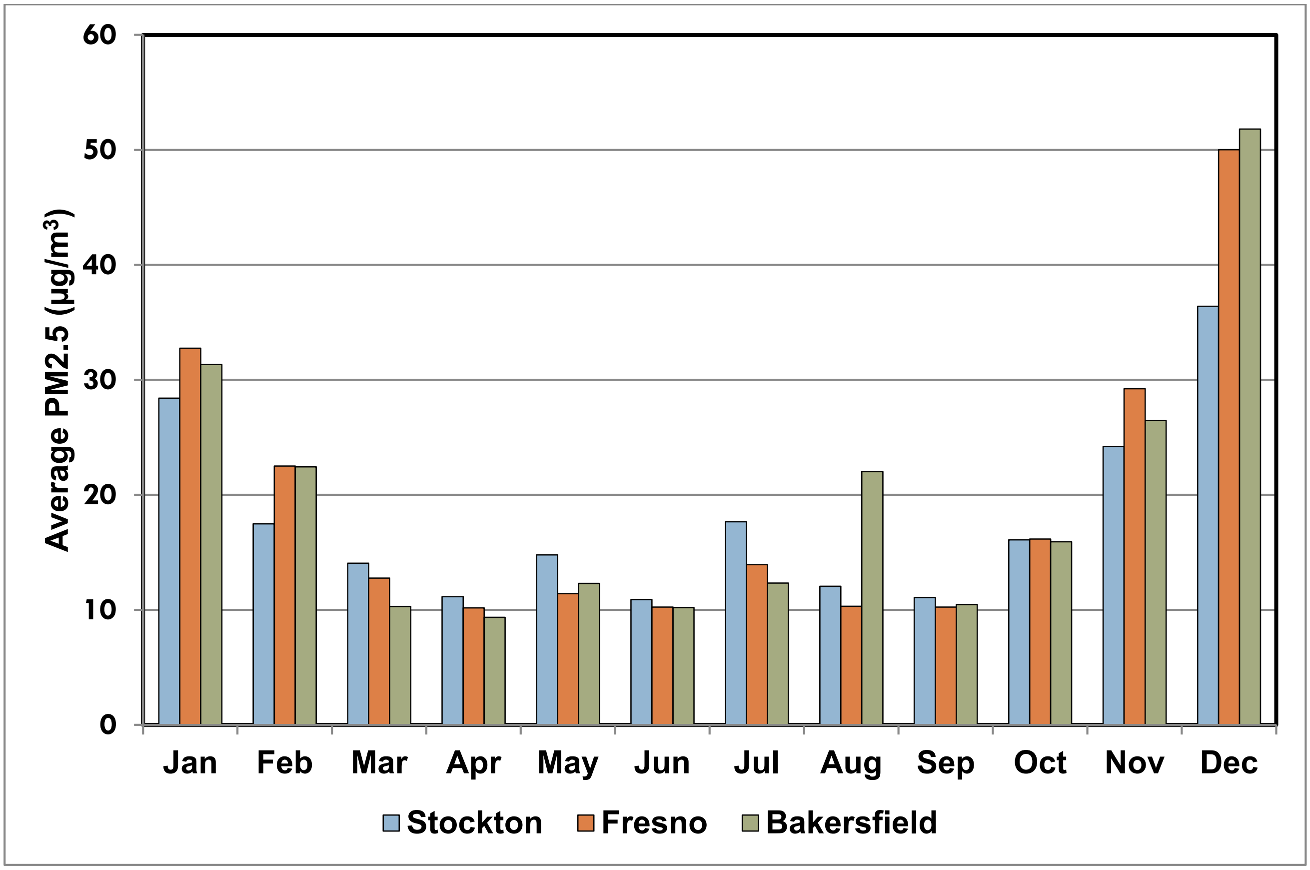
As detailed further below, due to the extreme weather and high values already experienced at this site in the 1st quarter of 2014, the averages for the 2nd, 3rd, and 4th quarters of 2014 would need to be zero for Bakersfield-Planz to reach attainment for the 2012-2014 period. The following discusses the magnitude of the weather conditions experienced during the winter of 2013-14, and its impact on the Valley's ability to attain the 1997 annual PM2.5 standard.

Meteorology during the Winter Season of 2013-2014

This past winter, California Governor Jerry Brown declared a state of emergency due to extreme drought conditions in the state. This emergency declaration was based on record-low precipitation in 2013 and snow pack levels at only 20 percent of the normal amount of snow to provide water for the year. Specifically in the San Joaquin Valley, 2013 represented the driest year since the start of record keeping in 1895. The Valley is currently experiencing an exceptional level of drought not seen in at least 119 years.

Although the Valley has experienced reductions in PM2.5 concentrations over the last 15 years since the pollutant first began to be measured, the winter months of November through February continue to record the peak levels of each year. The following Figure 2-11 displays the relative comparison between the lower concentrations in March through October, and the higher concentrations experienced during the winter.

Figure 2-11 Average PM2.5 by Month in 2013 in Stockton, Fresno, Bakersfield



Stable meteorology during the winter season can increase PM2.5 concentrations to high levels by providing strong temperature inversions and low wind speeds. When this occurs, the PM2.5 concentrations during the winter months of November to February can climb to very high levels. As seen in Figure 2-12, the winter of 2013-2014 experienced the strongest average atmospheric stability over the last 15 years (period during which PM2.5 concentrations have been recorded), creating conducive conditions for the formation and retention of high PM2.5 concentrations. This was a result of a persistent, strong high pressure ridge over the eastern Pacific that effectively blocked weather disturbances from entering California, which inhibited dispersion during November, December, and January of this last winter season.

In addition to the historically strong atmospheric stability, the winter of 2013-2014 also experienced record low precipitation totals, with some locations breaking records over 100 years old (see Table 2-1). These unprecedented dry conditions exacerbated the air quality challenge during the winter of 2013-2014. As a result of the extreme meteorology experienced in the Valley this last winter, PM2.5 concentrations reached peak levels that had not been recorded in over a decade, which in turn has increased the Valley's federal PM2.5 design values, making the journey to attainment of the PM2.5 standards even more difficult.

Figure 2-12 Average Atmospheric Stability per Winter Season

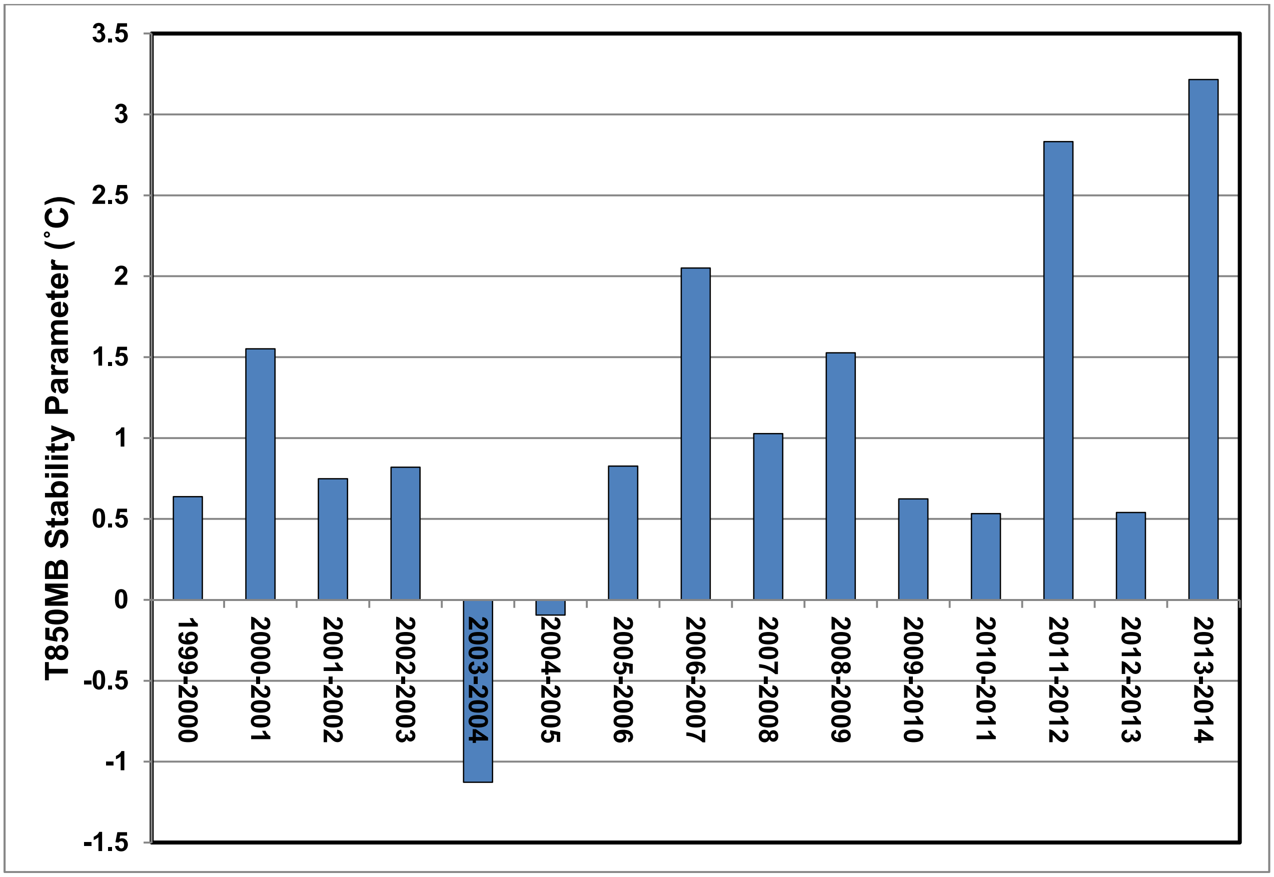


Table 2-1 Calendar Year Rainfall Totals for Select California Cities

City	1981-2010 Average (inches)	2013 Total (inches)	Previous Record Low (inches)	Previous Record Year
Modesto	13.11	4.70	5.70	1929
Merced	12.50	3.79	6.00	2007
Fresno	11.50	3.01	3.55	1947
Visalia	10.93	3.47	4.10	1910
Bakersfield	6.47	3.43	1.87	1959
Sacramento	18.52	5.81	6.67	1976
San Francisco	23.65	5.59	9.00	1917
San Jose	14.90	3.80	6.04	1929
Los Angeles	12.82	3.65	4.08	1953
San Diego	10.34	5.57	3.41	1953