Appendix B

Weight-of-Evidence Analysis
San Joaquin Valley Air Basin: Ozone

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Weight-of-Evidence Analysis
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Introduction

Under federal law, the San Joaquin Valley Air Basin (San Joaquin Valley, SJV, Valley, or Basin) is currently classified as a Serious nonattainment area for the federal 8-hour ozone standard. This classification requires attainment by June 15, 2013. Given the magnitude of emissions reductions needed to reach attainment, including reductions relying on new or the improvement of existing control technologies, it is not likely the Valley will meet the 2013 attainment date. In such cases, the federal Clean Air Act allows, and U.S. EPA recommends, bumping-up to an appropriate higher classification with a later attainment date. Based on analyses, an Extreme classification, with an attainment date of June 15, 2024, is the Valley's most realistic option. The following sections describe the air quality, emissions, and supplemental analyses, as well as the photochemical modeling that support the overall conclusion that the San Joaquin Valley can attain the federal 8-hour ozone standard by the 2024 deadline.

U.S. EPA Attainment Demonstration Requirements

The attainment demonstration portion of a State Implementation Plan or SIP consists of the analyses used to determine whether a proposed control strategy provides the reductions necessary to meet the federal standard by the attainment year. This attainment demonstration includes photochemical modeling which predicts that projected controls will result in a high site 8-hour design value for the SJV that is below the level of the federal standard by 2024. While reclassifying as Extreme extends the attainment date, the Valley should nevertheless realize substantial progress over the next decade. Air quality modeling predicts that all sites in the Basin will reach attainment prior to 2024, with the exception of several sites with the most severe air quality problems. However, with the implementation of proposed emissions control measures, ozone air quality in these areas is projected to meet the standard by the 2024 deadline.

Because of the uncertainties inherent in photochemical modeling, U.S. EPA allows states to supplement the modeling results with a "weight of evidence" (WOE) demonstration. The WOE assessment provides a set of analyses that complement the SIP-required modeling. These analyses can include consideration of measured air quality, emissions, and meteorological data, evaluation of other air quality indicators, as well as additional air quality modeling, if appropriate. Because all analysis methods have inherent strengths and weaknesses, examining an air quality problem in a variety of ways helps to offset the limitations and uncertainties inherent to air quality modeling. This approach also provides a better understanding of the overall problem, as well as insight about the level and mix of emissions controls needed for attainment.

The scope of the WOE analysis is different for each nonattainment area, with the level of appropriate detail dependent upon the complexity of the air quality problem, how far into the future the attainment deadline is, and the amount of data and modeling available. This document summarizes the analyses that comprise the WOE assessment for the San Joaquin Valley nonattainment area.

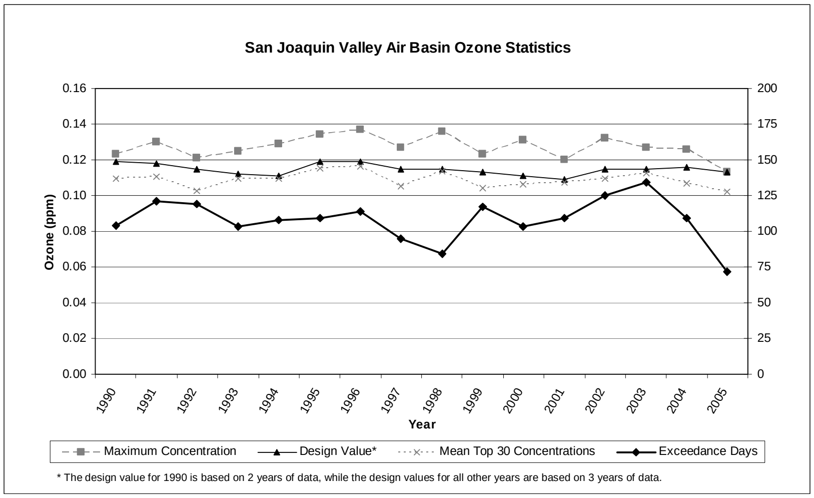
Historical Context

Over the years, ozone has posed a persistent problem in the San Joaquin Valley. Looking at ozone air quality from an historical perspective is challenging because of the lack of long-term sites in this area. Between 1975 and 1990, monitoring began at a number of sites, but was discontinued after several years. Furthermore, these transient monitors did not include sites in the worst areas of the central and southern portions of the Basin. For these reasons, 1990 was chosen as the start year for long-term trends in the SJV. 1990 is the first year for which Arvin, consistently one of the highest sites in the Valley, has complete data during the May through October ozone season. In addition, data are available for a number of other typically high concentration sites, including Clovis, Edison, Parlier, and several Fresno area sites.

Over the long-term, emissions control programs have improved ozone air quality in the SJV, but not to the same degree as seen in other areas of California. Both the climate and geography of the Valley present significant challenges to progress in the SJV. Figure B-1 shows the 1990 to 2005 basinwide trends for several air quality indicators. Because the trend lines for both federal 8-hour exceedance days and maximum concentrations reflect values for individual years, they show a fair amount of variability, with only a small amount of progress over the 15-year period. Overall, the decrease in the number of exceedance days was more substantial than the decrease in maximum concentrations. In contrast to these two indicators, the other two indicators shown on the graph, the design value and the mean of the maximum concentrations on the Top 30 days, are less variable because these indicators are more robust. While these two indicators show even less change over the 15-year period, the 2005 values are lower than the 1990 values.

Although not shown in Figure B-1, perhaps the greatest indicator of ozone air quality improvement in the SJV is the reduction in population-weighted exposure. This indicator shows a 50 percent reduction in exposure to concentrations above the level of the federal 8-hour standard between 1990 and 2005. Despite the gains in improving population-weighted exposure, the overall rate of progress for other indicators in the SJV has been slow, and this area will face tremendous challenges in reaching attainment.

Figure B-1: San Joaquin Valley Air Basin Ozone Statistics 1990 to 2005



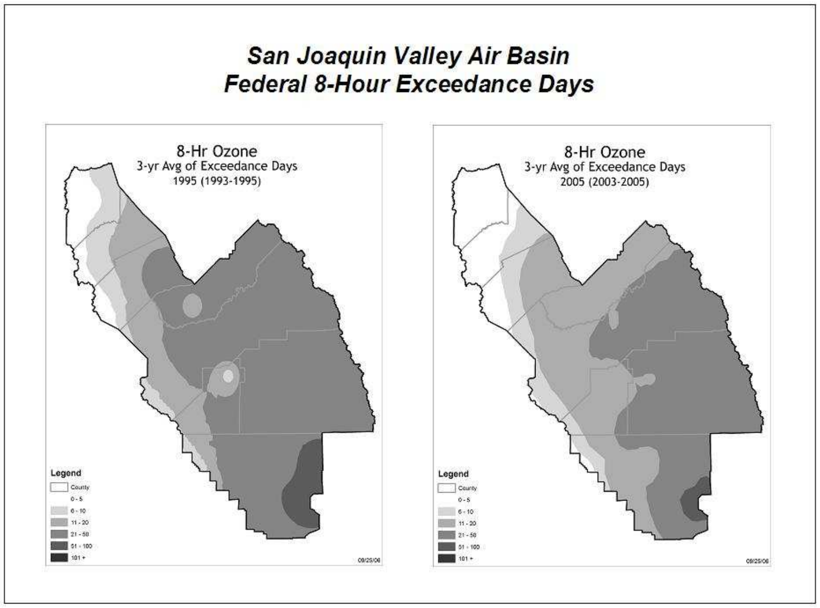
<u>Assessment of Recent Air Quality Trends</u>

General Basinwide Perspective

Over the years, ozone improvement in the SJV has lagged behind other areas of California, and the Valley ranks second only to the South Coast Air Basin with respect to the nation's worst ozone air quality. Modest levels of progress have occurred in the SJV over the last ten years, with a 15 percent drop in maximum concentration, a 5 percent drop in design value, and a 35 percent drop in exceedance days between 1995 and 2005 (refer to Figure B-1). However, most of this improvement has occurred since 2003. While values for 2006 were up slightly from 2005 (maximum concentration of 0.121 ppm and 86 exceedance days), they were still among the lowest values over the last 15 years. Ozone levels in the SJV are not as high as in the South Coast; however, maximum concentrations during 2006 were still more than 40 percent higher than the federal standard, with nearly three months of exceedance days each year.

While ozone levels are still unhealthy, modest improvements over the years have resulted in a reduction of the extent of the problem, especially in the northern portion of the Valley. The maps in Figure B-2 are based on monitoring data and estimate the reduction in days exceeding the national 8-hour standard over the last decade (1995 to 2005), throughout the San Joaquin Valley, thereby providing an estimate of the spatial extent of the ozone problem. Ten years ago (1993 to 1995 average map), more than half of the SJV experienced between 21 and 50 federal 8-hour exceedance days, with the worst site experiencing about 90 days. Areas in the northern SJV were cleaner than areas in the central and southern Valley. However, only a relatively small portion of the Basin averaged 10 or fewer exceedance days.

Figure B-2: San Joaquin Valley Air Basin Change in Federal 8-Hour Exceedance Days 1995 to 2005



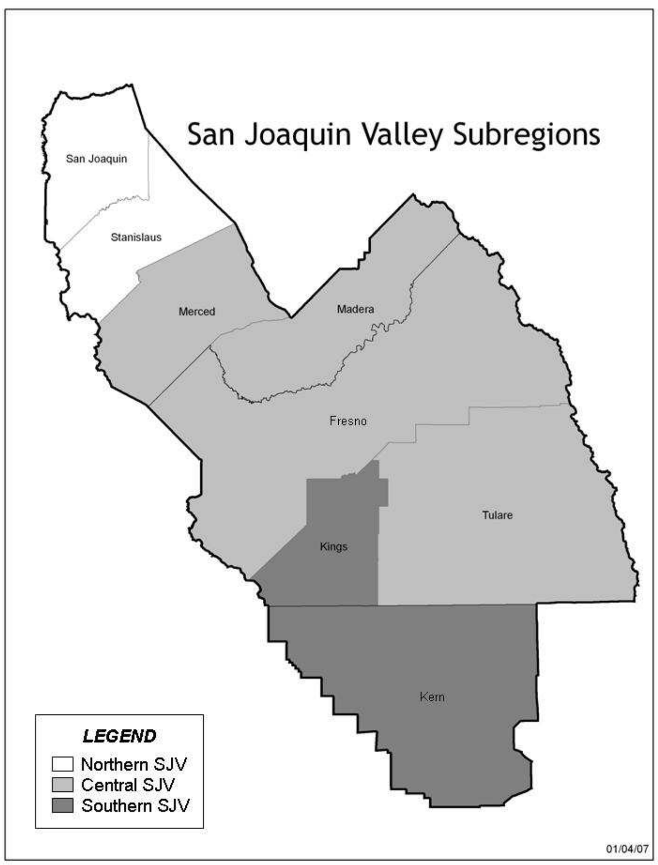
Today (2003 to 2005 average map), we see a substantial expansion of areas with 10 or fewer exceedance days. Ambient concentrations in most of San Joaquin and Stanislaus counties are now below the level of the federal 8-hour ozone standard. Much of the rest of the Valley experiences an average of only 6 to 20 exceedance days per year. Areas with more than 20 exceedance days are now generally limited to the eastern portion of the central and southern SJV. While the extent of these areas is much smaller than during 1995, the areas of poor ozone air quality are also some of the most heavily populated (Fresno and Kern counties). Even though these areas still pose a substantial challenge, the worst sites show an average reduction in exceedance days of approximately 35 percent over the last ten years.

In summary, although there has been some progress in the SJV over the last ten years, the rate of progress has been slow in comparison to other areas of the State. Overall, the trend lines for various air quality indicators, including maximum concentration, exceedance days, design value, and mean of the Top 30 concentrations, are relatively flat, with some year-to-year variability caused by meteorology (refer to Figure B-1). Most of the progress seen over the last 15 years has occurred since 2003. While there has been only a 15 percent decrease in maximum concentration since 1995, the decrease in the number of exceedance days has been more substantial, at close to 35 percent. In spite of the slow rate of progress, the ozone problem is now confined mostly to the central and southern portions of the Valley, as continued emissions reductions have been successful in shrinking the spatial extent of the problem areas. At the same time, the “clean” areas have expanded substantially, and nearly all of San Joaquin and Stanislaus counties now have air quality that meets the federal 8-hour standard. However, although these counties are generally clean with respect to ozone, emissions from these northern SJV areas can impact ozone air quality in other portions of the Valley.

Regional Analyses

The basinwide air quality indicators for the SJV show limited progress because they are dominated by the high sites, which pose the most severe problems. However, when the Basin is subdivided into different regions, different patterns of progress emerge. For the following discussion, the Valley is divided into three general areas, as shown in Figure B-3: the northern SJV, the central SJV, and the southern SJV. For convenience, these regions are divided along county boundaries. However, they generally represent three distinct areas with respect to geography, meteorology, and air quality. While ozone air quality within each of the three subregions tends to be similar, the level of air quality and rates of progress from one area to another can vary substantially.

Figure B-3: San Joaquin Valley Air Basin Subregions



A third of the Basin population lives in the northern SJV. This lowland area is bordered by the Sacramento Valley and Delta lowland to the north, the central portion of the SJV to the south, and on the other two sides by mountains. Because of the marine influence, which extends into this area through gaps in the coastal mountains to the west, the northern SJV experiences a more temperate climate than the rest of the Basin. These cooler temperatures and the predominant air flow patterns generally favor better ozone air quality.

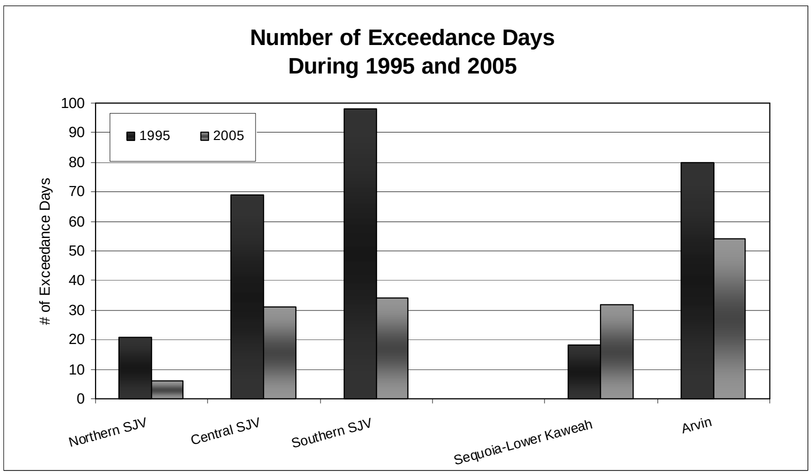
In contrast to the northern SJV, most of the Valley population lives in the central and southern portions of the Basin, in and around the Fresno and Bakersfield urban areas. Sites in the central and southern areas exceed the federal standard by the greatest margin, and geography, emissions, and climate pose significant challenges to air quality progress. Similar to the northern SJV, the central and southern SJV are also low lying areas, flanked by mountains on their west and east sides. The southern SJV represents the terminus of the Valley and is flanked by mountains on the south, as well. The surrounding mountains in both areas act as barriers to air flow, and combined with recirculation patterns and stable air, trap emissions and pollutants. The higher temperatures and more stagnant conditions in these two regions lead to a build-up of ozone and overall poorer air quality. In addition to the urban air quality problems, emissions and pollutants from these areas are transported downwind, making for even poorer air quality in downwind areas such as Arvin and the Sequoia National Park.

ARB staff completed an analysis of ozone episodes that occurred in both the central and southern SJV during 2004 and 2005. Based on these data, high ozone concentrations occurred as multi-day episodes more than 65 percent of the time, in both regions. Furthermore, episodes with higher federal 8-hour concentrations typically spanned a greater number of days, with the highest concentrations occurring in the middle of the episode period. During 2004 and 2005, more than 75 percent of the central SJV ozone episodes showed their highest 8-hour concentration at sites located within the Sequoia National Park. During more than 40 percent of the episodes, exceedances were limited only to sites located within the Sequoia National Park. While the downwind Sequoia sites tend to be the most problematic in the central SJV, is it interesting to note that very few central SJV episodes began prior to the start of an episode in the southern SJV. In fact, nearly 90 percent of the central SJV episodes started on the same day or during an ozone episode in the southern SJV. The most problematic site in the southern SJV is Arvin, and during 2004 and 2005, about 95 percent of the southern SJV ozone episodes showed their highest 8-hour concentration at Arvin.

Figure B-4 shows the average number of exceedance days during 1995 and 2005 for each of the subregions mapped in Figure B-3. Two sites, Sequoia National Park-Lower Kaweah and Arvin are plotted separately, and therefore, data for these two sites are not included in the totals for the central and southern SJV areas. The Sequoia National Park-Lower Kaweah and Arvin sites are located downwind of the Fresno and Bakersfield urban areas, respectively, and tend to have poorer air quality.

The northern SJVAB continues to be far cleaner than the other areas of the SJV. Over the last decade, the number of exceedance days in this area has decreased about 70 percent. During 2005, about 80 percent of the days during the May through October ozone season were below the more stringent State 8-hour standard. However, while the number of days in this region has shown improvement, Modesto stands out as the high site in the northern SJV.

Figure B-4: San Joaquin Valley Air Basin Change in Number of Federal 8-Hour Exceedance Days by Subregion 1995 and 2005



From north to south, the severity of the ozone problem in the SJV generally increases. Between 1995 and 2005, the number of exceedance days at sites in the central SJV (excluding the Sequoia area) decreased 55 percent. Although the decrease is still relatively high, the number of days in the central SJV during 2005 was five times higher than in the northern SJV. The number of exceedance days in the southern SJV (excluding Arvin) decreased about 65 percent during the last decade, and the number of exceedance days during 2005 was just slightly higher than the number of days in the central SJV. With respect to days below the State 8-hour standard, about 40 percent of the days during the ozone season were below this level in both the central SJV and the southern SJV areas during 2005. Similar to the basinwide trends, most of the progress in the central and southern SJV subregions has occurred since 2003.

The sites downwind of the Fresno and Bakersfield urban areas continue to pose the most severe problems in the SJV, and improvements in these areas have been much slower than in other areas. Arvin has always been one of the high sites in the Basin. Between 1995 and 2005, federal exceedance days declined about 30 percent, which is lower than the rate seen at other sites in the southern SJV region. In contrast, sites located at higher elevations in the Sequoia National Park have shown worsening ozone air quality over the last several years. Between 1995 and 2005, the number of federal exceedance days actually increased more than 75 percent at the Sequoia-Lower Kaweah site. This increase highlights the problem of transported emissions and pollutants from the upwind urban area. The Sequoia-Lower Kaweah site was used in this comparison because it is a long-term site with data for both 1995 and 2005. However, it should be noted that during 2005, the Sequoia-Kings Canyon site had even poorer air quality. In fact, during 2005, the Kings Canyon site had the same number of exceedance days as Arvin, as well as a similar maximum concentration.

Similar to exceedance days, concentrations have also been decreasing at a faster rate in the urban areas than at Arvin or Sequoia. Peak concentrations, as measured by the mean of the Top 4 daily concentrations, decreased only 3 percent over the last five years at Arvin and increased in the Sequoia area. However, the same indicator decreased at twice that rate in the Bakersfield and Fresno urban areas. Today, the 4th highest 8-hour ozone concentration averages 0.095 ppm for sites in both urban areas, compared with 0.105 ppm five years ago. Similarly, the mean of the Top 30 concentrations for both urban areas is declining and is now close to the level of the federal standard. The mean of the Top 30 concentrations is 0.084 ppm for the Fresno/Merced area and 0.089 ppm for the Bakersfield region. Five years ago, both of these urban areas had mean Top 30 concentrations greater than 0.100 ppm. Although the mean of the Top 30 concentrations is not directly comparable to the federal standard, it is a fairly stable statistic that is less influenced by year-to-year changes in meteorology. Therefore, it provides an indication of how concentrations on the worst days of the year are changing over time.

In summary, there have been changes in the patterns of exceedances on a subregional basis in the SJV over the last ten years. Today, the numbers of exceedance days in all areas except the Sequoia region are smaller than they were ten years ago. The most progress occurred in the northern SJV, and ozone concentrations in this area are now below the level of the more stringent State 8-hour standard 80 percent of the time during the ozone season. Trends in peak ozone concentrations reflect similar subregional differences. Based on current air quality and past trends, the areas downwind of Bakersfield and Fresno will likely pose the most difficulty for attainment.

Meteorology and Air Quality Trends

Ozone in the ambient air is the result of several factors, two of the most important being pollutant emissions and meteorology. The meteorological and photochemical processes leading to ozone formation are complex, involving interactions both at the surface and in the upper air. However, they can be characterized in very general terms: strong sunlight and weak dispersion generate relatively high ozone levels, while weak sunlight and strong dispersion generate relatively low ozone levels. Meteorology, or weather conditions, can vary widely, and these day-to-day conditions strongly influence ambient ozone concentrations.

The previous trends discussion looked at air quality as measured at ambient monitoring sites, without any consideration of or adjustment for meteorological variability. The following discussions characterize the general meteorological conditions leading to high ozone concentrations, as well as several different methods of accounting for meteorological variability. These analyses are an effort to better understand the impact of meteorology on air quality and thereby track improvements attributable to emissions reductions. Another goal of these analyses is to determine the role meteorology has played in the SJV, where ozone improvement has lagged behind other areas of the State. Although ozone improvements have been slower to occur in the SJV, the following analyses show that modest progress has occurred.

Characterization and Frequency of Episodic Conditions

In evaluating the meteorological conditions associated with ozone episodes, ARB staff identified three well-defined patterns as being associated with the majority of episodes. Collectively, these three patterns are associated with nearly 90 percent of the 8-hour exceedances. Summertime meteorology in the Valley is dominated by a constant ebb and flow between high atmospheric pressure over the Southwest Desert and low pressure over the Gulf of Alaska. When a high pressure ridge moves over California, stagnant conditions can persist for several days, resulting in widespread violations of the federal 8-hour standard. When a low pressure trough pushes inland, the Valley floor may see considerable improvements in air quality. However, downwind transport-impacted areas may experience higher concentrations.

In order to categorize the air flow patterns prevalent in the San Joaquin Valley, ARB staff performed a cluster analysis involving all days during May through October, 1990 through 2005. Subsequently, staff considered the meteorological characteristics of a subset of the clusters (2000 through 2005) and the incidence of federal 8-hour ozone episodes found in each cluster. These assessments show that nearly 90 percent of the SJV federal 8-hour exceedances are associated with three meteorological patterns, each distinguishable by the relative dominance of a high pressure ridge versus a low pressure trough. These patterns are generally characterized by high pressure aloft, mostly clear skies, warm temperatures, and strong morning inversions. The differences between the patterns are seen through large-scale variations in atmospheric pressure along the coast.

Under the “high pressure ridge pattern,” a ridge of high pressure covers all of the SJV, leaving the region with clear skies and very warm temperatures. Surface winds are terrain driven, with little or no sea breeze moving through the Carquinez Strait. Average afternoon wind speeds typically range between 3 and 7 miles per hour (mph), with only a few hours above 10 mph recorded in the northern part of the Basin. Maximum surface temperatures normally reach 100 degrees in most areas, with occurrences of 105 degrees or greater during the peak summer months. The resulting stagnant conditions promote the formation of high ozone levels throughout the Basin, with maximum concentrations found close to the major source areas. Areas typically dominated by transport, such as the higher elevations of Sequoia National Park, will exhibit lower concentrations in comparison, as light winds keep pollution movement to a minimum. This pattern has led to the highest ozone readings in the Basin, and was associated with about half of the 8-hour ozone exceedances recorded during May through October of 2000 to 2005.

The “approaching trough pattern” causes ozone and its precursors to move downwind from source locations. Under this pattern, the high pressure ridge over central California is weaker, and this increases the sea breeze flowing through the Carquinez Strait. Average afternoon wind speeds range between 6 and 12 mph, with a few hours above 14 mph recorded in the northern parts of the Basin. The maximum surface temperatures reach into the upper 90s in most southern areas, with northern areas in the upper 80s to lower 90s. High ozone levels are observed downwind of the major urban source areas (for example, downwind of Stockton, Fresno, and Bakersfield). High ozone levels are also observed in the foothill areas, such as the Sequoia National Park area. During this weather pattern, the extreme northern sections of the Valley experience lower ozone concentrations, as increased wind flow pushes pollutants further south and east. During May through October of 2000 to 2005, the approaching trough pattern was associated with about 20 percent of the measured 8-hour ozone exceedances.

Finally, the “trough pattern” results in peak ozone further downwind of the major emission sources, primarily affecting the eastern and southernmost portions of the SJV. Under this pattern, the ridge of high pressure is weakened more significantly. This increases wind flow through the Carquinez Strait, causing temperature and ozone levels to be much lower over the northern and central portions of the Valley. Surface winds are predominantly from the west-northwest in the northern portion of the Basin. As the surface winds move southward, channeled by the terrain, they veer and become a northwest flow. Average afternoon wind speeds range between 8 and 16 mph, with some stronger gusts at night. Maximum temperatures still reach near 90 degrees or slightly above in most low lying areas of Kern and Tulare counties, with the northern areas in the 80s. Under this weather pattern, ozone levels peak in the southern region of the Basin, downwind of major emission source areas. The highest ozone levels are found at sites such as Parlier, Arvin, and Sequoia National Park, where transport is typically the dominant mechanism for ozone and precursor movement. The trough pattern was associated with about 20 percent of the 8-hour ozone exceedances recorded during May through October, 2000 to 2005.

High Ozone Forming Potential

As one approach to help understand the types of meteorological conditions leading to high ozone concentrations, ARB staff completed an analysis of ozone and meteorology using Classification and Regression Tree (CART) techniques. The CART analysis determined rules that separated days into 15 groups, based on the degree to which weather conditions favor ozone formation. The CART rules used daily data for surface air temperature, air temperature at 1500 meters[1], wind speed/direction, atmospheric stability, and other factors in relation to daily maximum 8-hour ozone concentrations. From the 15 groups, a subset with high average ozone levels and containing on average about one-third of the ozone season were considered to represent high ozone forming potential (OFP).

The analysis, presented in Figure B-5, shows the number of days with high OFP along with the number of days exceeding the federal 8-hour ozone standard each year (three-year moving means). The changes in exceedance days relative to the changes in high OFP days helps distinguish changes due to meteorology from changes due to emissions reductions. Progress is shown when the number of exceedance days decreases in relation to the number of high OFP days.

The two lines generally track together, indicating that year-to-year changes in exceedance days have been largely attributable to year-to-year changes in weather, rather than changes in emissions. Relative to the high OFP line, however, the number of exceedance days has decreased. During the 1990's, the trend for exceedance days averaged 14 days above the trend for high OFP days. Since 1999, however, the trend for exceedance days averaged 4 days below the trend for high OFP days, indicating a "real" decrease of about 18 days.

Furthermore, the unsmoothed trends in Figure B-6 show the 68 exceedance days measured in 2005 was a new low for the Basin (note that the 68 exceedance days reflects only those occurring during the May through October ozone season). Three years, 1990, 1997, and 1999, had OFP values similar to 2005, but exceedance days during these years averaged 13 days above the OFP trend. In contrast, the 68 exceedance days measured during 2005 were 13 fewer than the number of high OFP days. These results indicate that some real progress in reducing ozone is now taking place in the SJV, as increasingly adverse meteorological conditions are needed to create ozone levels exceeding the federal 8-hour standard.

[1] Above sea level

Figure B-5: San Joaquin Valley Air Basin Three-Year Means of Federal 8-Hour Exceedance Days and High OFP Days 1990 to 2005

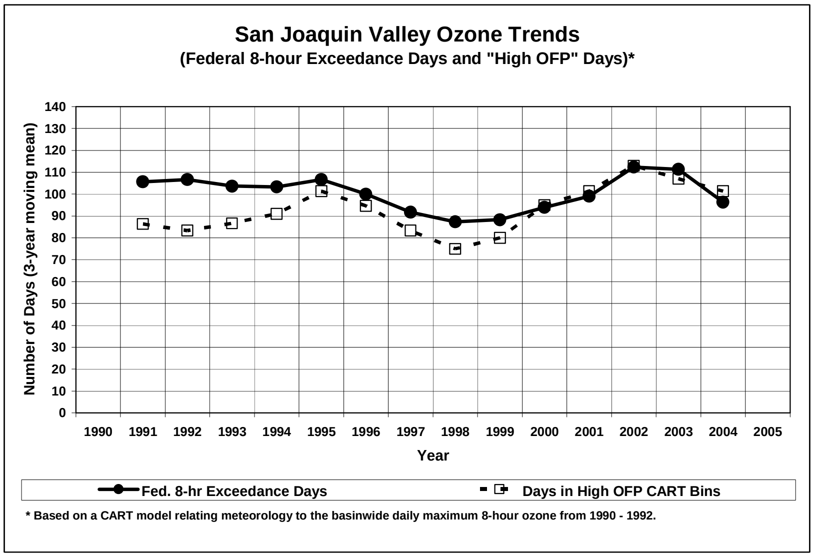
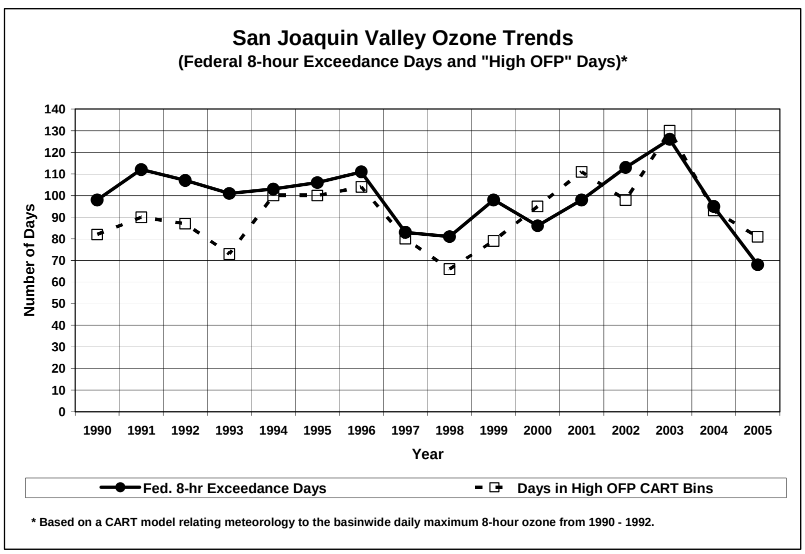


Figure B-6: San Joaquin Valley Air Basin Federal 8-Hour Exceedance Days and High OFP Days 1990 to 2005



Meteorologically Adjusted Trends

As discussed above, meteorological parameters such as temperature, pressure, and wind speed are systematically correlated with sunlight and dispersion, and can be used in formulas that predict daily ozone levels. As a second method to address the role of meteorology, a statistical model that predicts daily maximum ozone on the basis of daily meteorological data was used to adjust daily ozone observations.

First, days from the May through October ozone season for the years 1990 to 2005 were assigned to separate groups based on pressure and temperature gradients, along with selected wind speeds and directions. Together, three of the groups accounted for the vast majority of exceedance days during the ozone season in the San Joaquin Valley. For each of these groups, data from 1990 through 1993 were used to calibrate a within-group model to predict daily maximum 8-hour ozone from daily weather data. The limited span of years was used for calibration so that when it was applied for all the years (1990 through 2005), it would provide a level playing field for meteorological effects, apart from the influence of changes in emissions.

Met-adjusted trends are presented in the following three figures. The figures are based on data for basinwide daily maximum ozone concentrations after these have been reconciled to long-term meteorological norms regarding group frequencies and concentrations within each group. The three lines on each graph represent the mean of the Top 10, Top 20, and Top 30 met-adjusted concentrations. The trends in Figures B-8 and B-9 were smoothed using a three-year moving mean, because the process of met-adjustment does not remove all meteorological effects perfectly, and other factors also affect the year-to-year changes.

Figures B-7 and B-9 show that ozone declined approximately five percent from 1990 to 2005. An upswing in the trend from 2001 to 2004 may be attributable to meteorological effects for which the process of met-adjustment is incomplete. Following the upswing, the met-adjusted values for 2005 reached a new low for all three indicators, indicating that modest improvement (5 percent) in ozone occurred in the San Joaquin Valley in the 2000s, compared to the 1990s. It is also noteworthy that this progress has been similar for all three indicators: mean of the Top10, Top20, and Top30 ozone concentrations. This shows that the Top 30 (top 16 percent[2]) summer ozone concentrations have responded very similarly to emissions reductions in the SJV since 1990.

[2] The May – October ozone season has 184 days, of which 30 is 16%.

Figure B-7: San Joaquin Valley Air Basin Ozone Trends 1990 to 2005 Adjusted for Meteorology

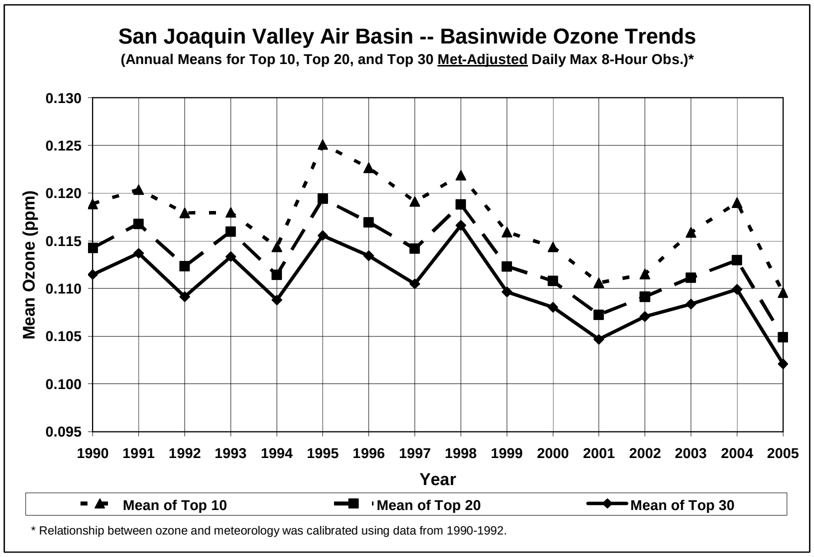


Figure B-8: San Joaquin Valley Air Basin Three-Year Mean Ozone Trends 1990 to 2005 Adjusted for Meteorology

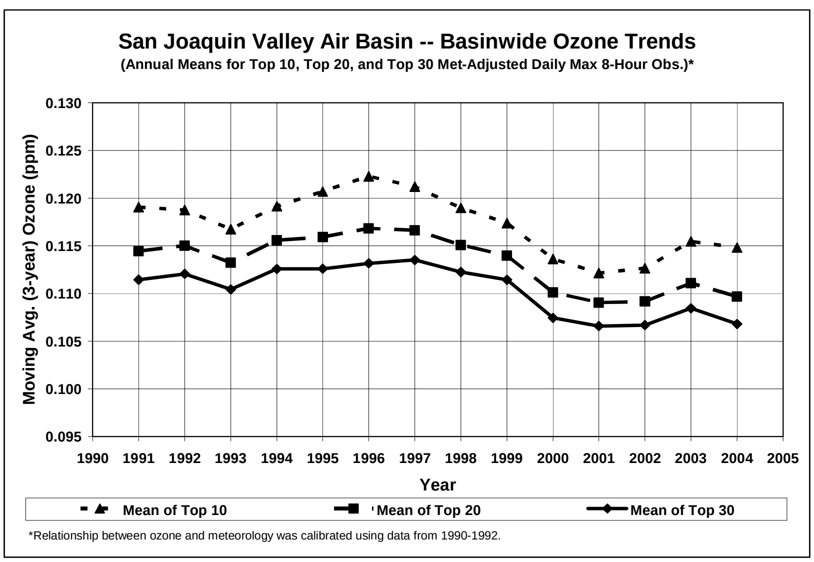
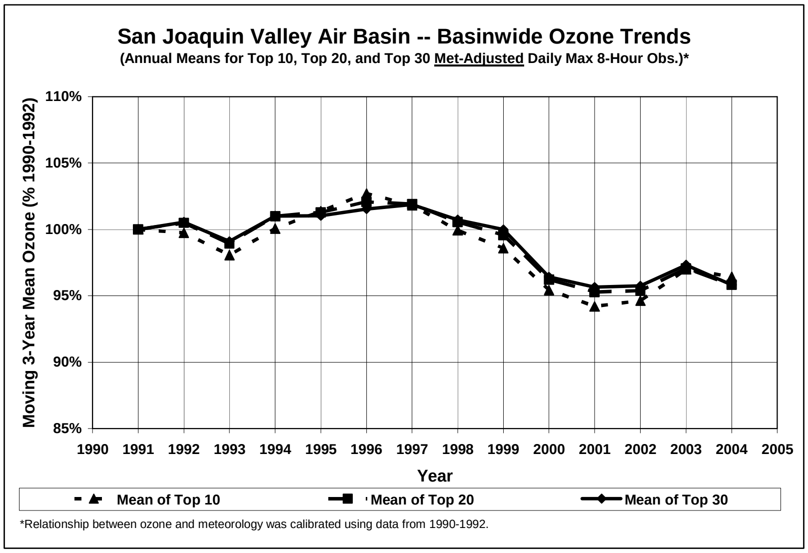


Figure B-9: San Joaquin Valley Air Basin Ozone Trends 1990 to 2005 Adjusted for Meteorology and Expressed as a Percentage of the Base Year



The above analyses use different methods to account for the variable impacts of meteorology on ozone air quality. Results of these analyses confirm that progress has occurred in the San Joaquin Valley Air Basin, especially during the last several years. Although adjusting ozone air quality for meteorology does not change the overall flatness of the trend in the SJV throughout most of the analysis period, it does show some measure of real progress during the most recent years.

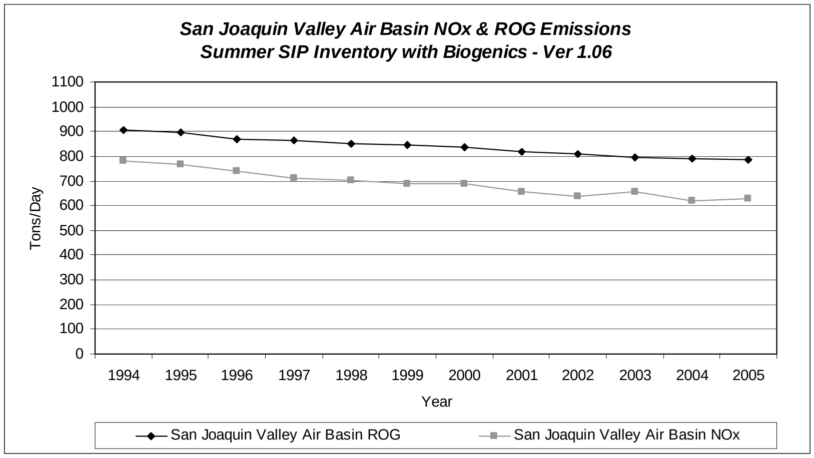
Emissions and Precursor Trends

Oxides of nitrogen (NOx) and reactive organic gases (ROG) are precursors to ozone. Emissions controls have reduced the amounts of these precursors throughout the Basin, resulting in the modest improvement in ozone air quality observed in the SJV. The following sections describe the NOx and ROG emissions trends in the SJV since 1994, as well as the amounts of these precursors measured in the ambient air.

Emissions Trends

Emissions controls have substantially reduced the amounts of both ROG and NOx emitted by various sources throughout the San Joaquin Valley. Figure B-10 shows the estimated basinwide trend in these precursor emissions from 1994 to 2005. The totals reflect estimates for the summer season in tons per day and include emissions from natural biogenic sources.

Figure B-10: San Joaquin Valley Air Basin Estimated NOx and ROG Emissions 1994 to 2005



Since 1994, there has been a fairly steady decrease, basinwide, in both ROG and NOx emissions. While the relative amounts of the two precursors have remained fairly constant over the 12-year period, the overall reduction in ROG emissions (about 15 percent) has been slightly smaller than the overall reduction in NOx emissions (about 20 percent). However, it is important to note that a substantial portion of the ROG emissions (from 45 and 50 percent of the total ROG between 1994 and 2005) comes from biogenic sources. Because the biogenic portion is constant over time, it masks the reductions attributable to emissions control programs. When looking only at the anthropogenic portion of the ROG inventory, ROG emissions impacted by control programs decreased nearly 25 percent between 1994 and 2005.

Figures B-11 and B-12 show the estimated emissions trends for the three SJV subregions. In all three areas, both ROG and NOx emissions are decreasing. Similar to the basinwide trend, NOx emissions are decreasing at a faster rate than ROG in both the central and southern areas, but not in the northern SJV. Another interesting observation is that similar to the basinwide trend, ROG emissions are at a higher level than NOx emissions only in the central SJV. In the other two areas, NOx emissions are higher. Overall, the greatest reductions in NOx emissions (with respect to both percentages and tons per day) occurred in the southern SJV. This area has also seen substantial reductions in the number of 8-hour exceedance days in both the upwind and downwind portions of the region.

Figure B-11: Northern and Central SJV ROG and NOx Emissions 1994 to 2005

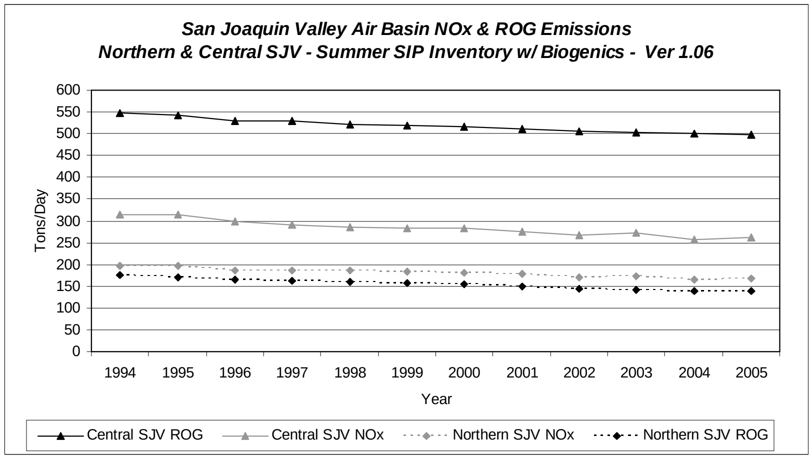
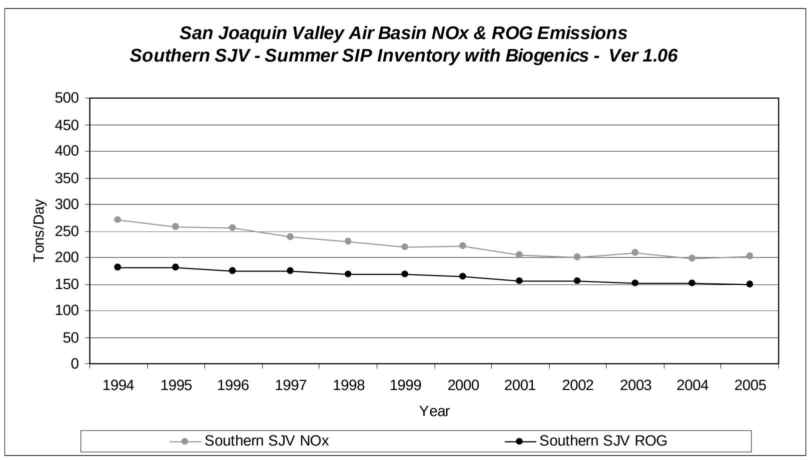


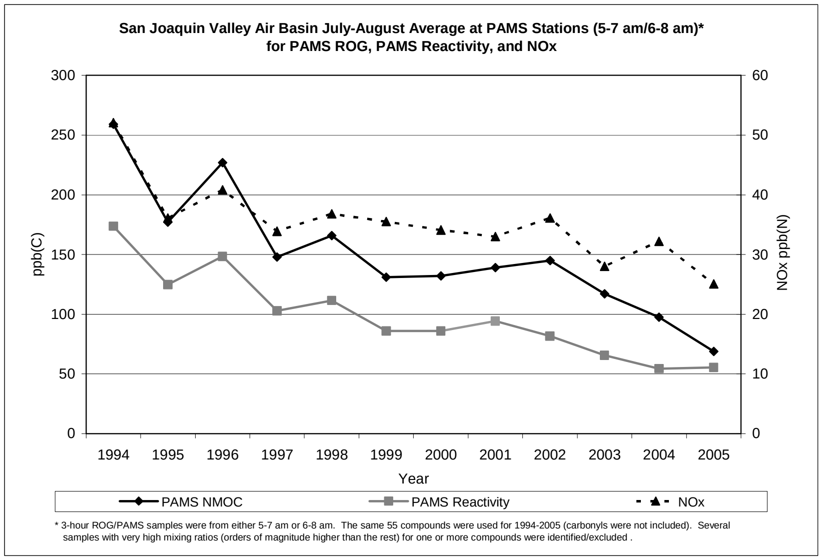
Figure B-12: Southern SJV ROG and NOx Emissions 1994 to 2005



Precursor Trends

In addition to the reduction in overall emissions as estimated by the emissions inventory, measured data show a reduction in the amounts of ROG and NOx in the ambient air. Ambient monitoring data from the Photochemical Assessment Monitoring Stations (PAMS) network are plotted in Figure B-13 and show reductions in both precursors. Since 1994, ROG, as measured by the PAMS network in the SJV, shows an overall reduction of about 75 percent. Coupled with the reduction in ROG is a similar reduction in the reactivity of the hydrocarbon mix (about 70 percent between 1994 and 2005). During this same timeframe, ambient NOx concentrations decreased approximately 50 percent, with the greatest decrease occurring between 1994 and 1995. Between 1995 and 2005, ambient NOx concentrations were flatter, with only a modest overall reduction. The overall trends from the ambient monitoring network are generally consistent with the trends in estimated emissions in that they both show both precursors decreasing.

Figure B-13: San Joaquin Valley Air Basin Summer Morning Average ROG, Reactivity, and NOx at PAMS Stations



Based on the PAMS ambient data, the reductions in precursor and reactivity levels in the Valley suggest there should have been improvements in peak ozone levels. However, SJV ozone levels have changed very little, except during the last three years. This implies that there are other factors at work that affect the production of ozone. Perhaps emissions in the SJV remain in the Valley for longer periods of time, providing additional opportunities for lower reactivity precursors to contribute to peak ozone levels. In addition, because ambient ROG levels have changed faster than NOx levels, the ratio of ROG to NOx has decreased from 5.0 in 1994 to 2.8 in 2005. This change in the precursor ratio has likely changed the responsiveness of the Valley to predominately ROG emissions reductions. As a result, NOx emissions reductions may become more important for future emission control strategies. The greater decrease in estimated NOx emissions, coupled with the substantial drop in exceedance days in the southern SJV, appear to support this conclusion. Finally, meteorology is an important factor. Changes in temperature and vertical mixing are known to impact ozone levels. Therefore, accounting for meteorology is one way to provide a better understanding of the available data (refer to previous section on Meteorology and Air Quality Trends).

Modeling Results

The ozone modeling domain for the SJV was based on the domain defined for the year 2000 Central California Ozone Study (CCOS) and includes not only the Central Valley, but the San Francisco Bay area, as well. The domain comprises a grid measuring 185 by 185 cells with a horizontal resolution of four kilometers. The required meteorological fields were generated using the MM5 prognostic meteorological model, and the required emissions inventories were developed by ARB staff. The ozone air quality modeling utilized the Comprehensive Air Quality Model with Extensions (CAMx) air quality model, with initial and boundary conditions based on estimates of clean-air concentrations.

ARB staff completed ozone modeling for two episode periods – one during July 1999 and the other during July/August 2000. During these episodes, 8-hour ozone concentrations exceeding the federal standard occurred throughout the region. Analysis of the model outputs included the estimation of 1-hour and 8-hour ozone concentrations for each ozone monitoring site within the domain, as well as statistical measures comparing observed and simulated ozone concentrations. These analyses were used to evaluate model performance by subregion within the domain.

As required by U.S. EPA, a relative reduction factor (RRF) approach was used in projecting future year design values. The RRF reflects the ratio between the future year model prediction (in this case the end of 2023) and the reference year model prediction. A reference year design value is then multiplied by the RRF to project a future year design value.

Results of the modeling analyses indicate that NOx reductions will be relatively more effective than ROG reductions in reducing ozone concentrations in the San Joaquin Valley. Therefore, the attainment strategy relies on a 75 percent reduction in NOx, in combination with a 25 percent reduction in ROG, to bring the worst-case sites into attainment.

Because ozone concentrations vary throughout the Valley, the modeling indicates different overall reductions are needed in different areas to reach attainment. However, as emissions controls are implemented, ozone concentrations will decrease in all areas of the Valley. San Joaquin Valley Unified Air Pollution Control District (District) staff estimate that by 2015, over 50 percent of the Valley's population will live in areas that meet the federal 8-hour ozone standard. By 2020, the portion of the population living in clean areas will increase to 90 percent. Although ozone concentrations will drop measurably throughout the entire Valley over time, downwind areas such as Arvin will require the greatest level of emissions reductions to meet the standard. Some of these reductions rely on technological advancements and are expected after 2020, but no later than 2023. These reductions are expected to bring the last remaining nonattainment areas into compliance with the federal 8-hour ozone standard.

Summary

The Weight of Evidence (WOE) package comprises a set of complementary analyses that supplement the SIP-required modeling, thereby providing additional support for the attainment demonstration. Currently, the San Joaquin Valley is classified as a Serious nonattainment area with an attainment date of June 15, 2013. Because of the magnitude of emissions reductions required, the District is requesting reclassification as Extreme, with a required attainment date of June 15, 2024. The Extreme classification allows the attainment demonstration to rely on emissions reductions from measures that anticipate the development of new technologies or improvement of existing technologies. These measures are often referred to as “black box” measures and go beyond the short-term measures that are based on known and demonstrated technologies.

U.S. EPA guidance allows the use of a Weight of Evidence (WOE) analysis to supplement photochemical modeling in demonstrating attainment. The ARB staff’s modeling results indicate substantial NOx and ROG emissions reductions will be needed to bring the Valley into attainment. However, with reclassification as an Extreme nonattainment area, the SJV will be able to reach attainment by the 2024 deadline with a 75 percent reduction in NOx emissions, in combination with a 25 percent reduction in ROG emissions. Based on these reductions, even the worst-case sites will attain the federal 8-hour ozone standard. Based on modeling, as well as supporting analyses completed as part of this WOE evaluation, attainment by 2024 is anticipated because of the following factors:

- Over the last decade, the number of basinwide exceedance days decreased 35 percent. The maximum concentration and design value show more modest reductions, with decreases of 15 and 5 percent, respectively. Because these are basinwide numbers, they reflect the “worst case” sites. On a subregional basis, the amount of improvement during the last ten years is greater. While values for 2006 were up slightly from 2005, they are still among the lowest values over the last 15 years.

- During the mid-1990s, the ozone problem was widespread throughout the San Joaquin Valley. Today, the spatial extent of the relatively clean areas has expanded substantially. The greatest amounts of improvement have occurred in the northern SJV, and ambient concentrations in most of San Joaquin and Stanislaus counties now meet the federal standard. Over the last decade, the number of exceedance days in the northern SJV decreased 70 percent, and during 2005, about 80 percent of the days during the ozone season were below the more stringent State 8-hour ozone standard.

- The ozone problem is now confined primarily to the central and southern portions of the Valley. Sites located downwind of the Fresno and Bakersfield urban areas continue to pose the most severe problems. While the number of exceedance days has declined substantially at most sites in the central and southern SJV (55 to 65 percent between 1995 and 2005), exceedance days have declined more slowly at Arvin, while increasing at sites located at higher elevations in the Sequoia National Park.

- Estimated ROG and NOx emissions trends, as well as measured data from the PAMS monitoring network in the San Joaquin Valley indicate reductions in both precursors since 1994. These reductions have resulted in modest ozone improvements over the last decade.

- Analyses suggest that recent ozone improvements are linked to emissions reductions. The decline in the number of exceedance days relative to the number of days with a high potential for ozone formation indicates that the modest improvements in ozone over the last few years were related to emissions reductions rather than favorable meteorological conditions. Results of these analyses also indicate that increasingly adverse meteorological conditions are now needed to create ozone levels exceeding the federal 8-hour standard.

- Emissions estimates indicate a continuing decline in ROG and NOx emissions as the State and District pursue the aggressive dual pollutant strategy outlined in the SIP. Based on the magnitude of emissions reductions needed for ozone attainment, as well as the readiness of NOx control technologies, a NOx-heavy strategy is proposed and will provide the most efficient path to attainment (75 percent NOx reduction, coupled with 25 percent ROG reduction).

- Photochemical modeling shows all sites in the San Joaquin Valley Air Basin will attain the federal 8-hour ozone standard by the end of 2023, as required for Extreme nonattainment areas. Many areas will reach attainment before this date. The District estimates that by 2015, 50 percent of the Basin population will live in areas attaining the standard, and by 2020, the number will increase to 90 percent.

Taken together, all of these factors indicate that all sites in the San Joaquin Valley can expect to attain the federal 8-hour ozone standard by June 15, 2024, the required attainment date for an Extreme ozone nonattainment area.