Appendix G

Weight of Evidence

2013 Plan for the Revoked 1-Hour Ozone Standard
SJVUAPCD

This appendix was provided by the California Air Resources Board (ARB).

This page intentionally left blank.

Weight-of-Evidence Analysis San Joaquin Valley Air Basin: National Ambient Air Quality Standard for 1 Hour Ozone

1 INTRODUCTION

This weight-of-evidence document provides support for the modeled attainment demonstration that projects the San Joaquin Valley (SJV) will attain the National Ambient Air Quality Standard (standard) for 1-hour ozone by 2017.

An assessment of ozone air quality from a Valley-wide perspective is provided in this introduction, along with a brief description of the elements of a "weight-of-evidence" analysis. The remainder of the document provides a broad foundation of information that corroborates the modeled attainment demonstration.

1.1 <u>Elements Commonly Included in an Attainment Demonstration</u>

The attainment demonstration portion of a State Implementation Plan (SIP) consists of the analyses used to determine whether a control strategy provides the reductions necessary to meet the federal standard by a specified attainment year. This attainment demonstration includes photochemical modeling which predicts that projected reductions in ozone-forming emissions will result in a high site 1-hour Design Value for the SJV that is below the level of the 1-hour ozone standard by 2017.

Because of the uncertainties inherent in photochemical modeling, the U.S. Environmental Protection Agency (EPA) requires states to supplement the modeling results with a "weight-of-evidence" (WOE) assessment. The WOE assessment provides a set of analyses that complement the photochemical modeling. In this document, these analyses include consideration of measured air quality, emissions inventories, and meteorological data. All analysis methods have inherent strengths and weaknesses, so examining an air quality problem in a variety of ways can help to offset the limitations and uncertainties inherent to individual methods. 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. In this case, the SJV is approaching attainment of the 1-hour ozone standard, and the projected attainment date (2017) is based on multiple methods to evaluate the modeling results. This document summarizes the analyses that provide a WOE assessment that complement the model results.

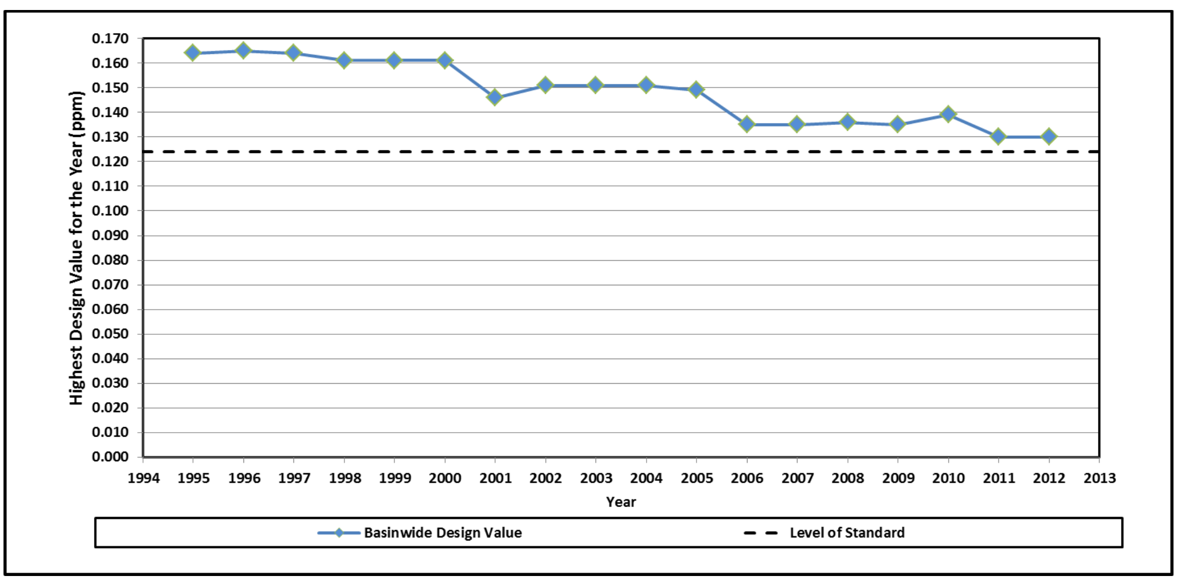
1.2 Assessment of Valley-wide Progress in Ozone Air Quality

The San Joaquin Valley has one of the most challenging ozone problems in the nation. In the early 1990's, much of the Valley exceeded the 1-hour ozone standard, and exceedances of the standard occurred somewhere in the Valley approximately 50 days each summer. However, ozone air quality has improved throughout the region, with the basin-wide Design Value (highest Design Value at any site in the basin) declining by 21% between 1995 and 2012, and basin-wide Exceedance Days declining by more than 90%. Today, only three sites have Design Values that exceed the standard.

Figure 1 shows the trend from 1995 to 2012 for the basin-wide Design Value. The annual values represent four different monitoring sites as the highest Design Value in the Valley has occurred at different locations from year to year. Over the last 18 years, the design site has alternated between the Central sub-region (Clovis or Parlier) and the Southern sub-region (Edison and/or Arvin-Bear Mountain).

Figure 2 illustrates the progress that has been made in reducing the spatial extent of Exceedance Days in the SJV. In 1993-1995, portions of the Central and Southern sub-regions experienced 15 to 25 Exceedance Days and most of the Central and Southern Valley recorded at least one to three Exceedance Days. Today, only a few areas in the Central and Southern sub-regions still experience days when ozone air quality exceeds the level of the standard, and only two sites, Fresno-Drummond and Clovis North Villa measure Design Values above the standard. Current data are not available for the Arvin Bear Mountain site, however the site was also nonattainment at the time of its closure.

Figure 1. Design Value Trend for the San Joaquin Valley Air Basin



* This trend does not include Arvin – Bear Mountain after 2010, as the site closed in 2010.

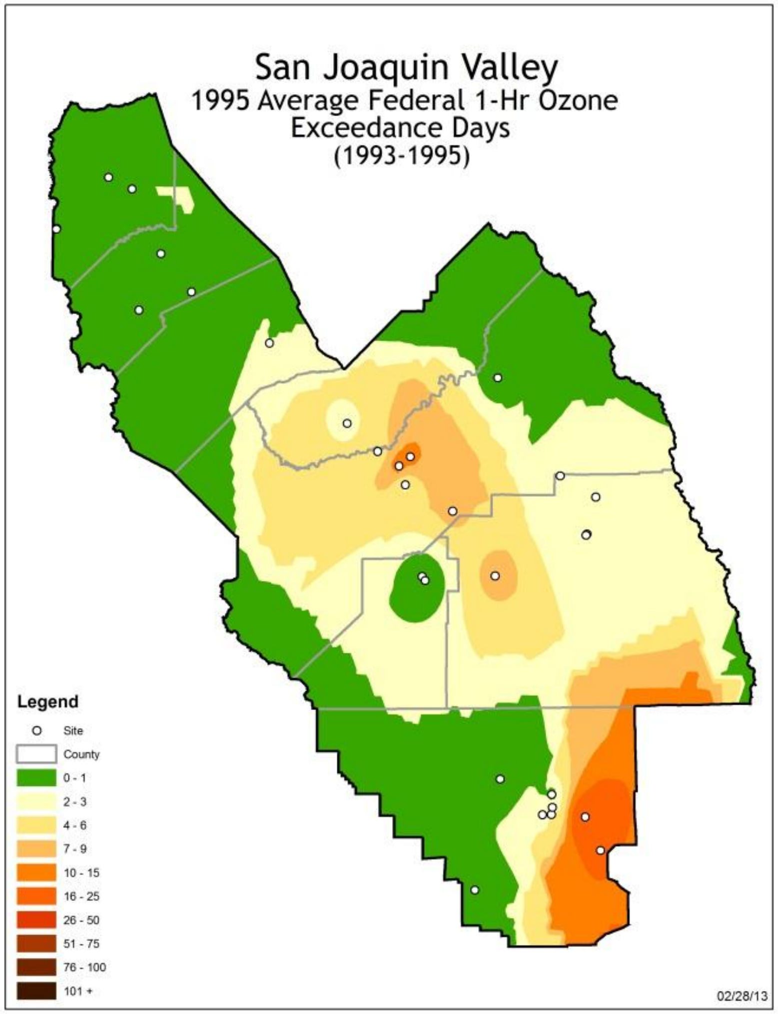
Trends for three air quality indicators – Design Value, Exceedance Days, and Mean of Top 30 – are provided for the three sites that are still above the standard, as well as two sites that have recently come into attainment (Fresno – 1st Street/Garland and Edison). Data for the Fresno – 1st Street and Fresno – Garland sites have been merged into one data record because the EPA considers Garland an official replacement for the 1st Street monitor. The locations of these monitoring sites are shown in Figures 3 and 7. These three indictors address different aspects of ozone air quality, and together provide information to evaluate overall progress in reducing ozone exposure as well as attaining the standard. The Design Value (DV), EPA's compliance metric, is the 4th highest concentration measured in a three year period. A site meets the standard when its DV is less than or equal to 0.124 ppm, the effective level of the standard. Exceedance Days shows how often ozone was above the standard, providing a measure of the frequency of exposure. Finally, the Mean of Top 30 is a stable and responsive measure of progress as it represents the trend in the upper eight percent (8%) of daily 1-hour ozone levels during the year. Additional analysis of ozone trends is provided in Appendix A of the District plan.

In the Central sub-region, ozone levels at Clovis (Figure 4), Fresno – 1st Street/ Garland (Figure 5), and Fresno – Drummond (Figure 6) clearly tend to be lower after 2003 than before 2003 for all three indicators, and Fresno 1st Street/Garland now meets the standard. Since 2008, the trends have been flat or downward for Clovis, which had no exceedances in 2012. At Fresno-Drummond (Figure 6), some upward movement has occurred in all three indicators since 2007, possibly due to year-to-year variability in meteorology. However, the trends for Exceedance Days and Mean of Top 30 give some indication that ozone levels began turning back down in 2012. Clovis still remains the Design Site for SJV, but Fresno-Drummond has had more exceedances in the most recent years. Fresno-Drummond Street had a large gap in ozone data from 9/3/2010 until 11/17/2010, which made it seasonally incomplete.

In the Southern sub-region, ozone levels have improved at Edison (Figure 8), clearly tending to be lower after 2003 than before 2003 for all three indicators. The ozone indicators at Edison in 2011 and 2012 were generally the lowest recorded since 1995, and this site now meets the standard. This is especially encouraging because Edison set or shared the basin-wide Design Value from 1995 to 1997 and again from 2006 to 2009. Further indication of progress in the Southern sub-region is found at Arvin – Bear Mountain (Figure 9), which recorded new lows for Exceedance Days and Mean of Top 30 in 2010 (the last full season of measured data).

The ozone-monitoring station at Arvin – Bear Mountain was closed on October 31, 2010 as ARB was unable to renew the long-term lease at this location. Values for 2011 in Figure 9 were estimated based on imputed values produced by a program called "I-Bot" that was developed by Air Resources Board staff (ARB) (methodology given in Appendix G-1). The imputed data for 2011 indicate that ozone levels at Arvin – Bear Mountain were the lowest since 1995 for all three indicators: Design Value (0.129 ppm), Exceedance Days (1 day), and Mean of Top 30 (0.107 ppm).

Figure 2. Reductions in spatial extent and number of Exceedance Days in the San Joaquin Valley Air Basin



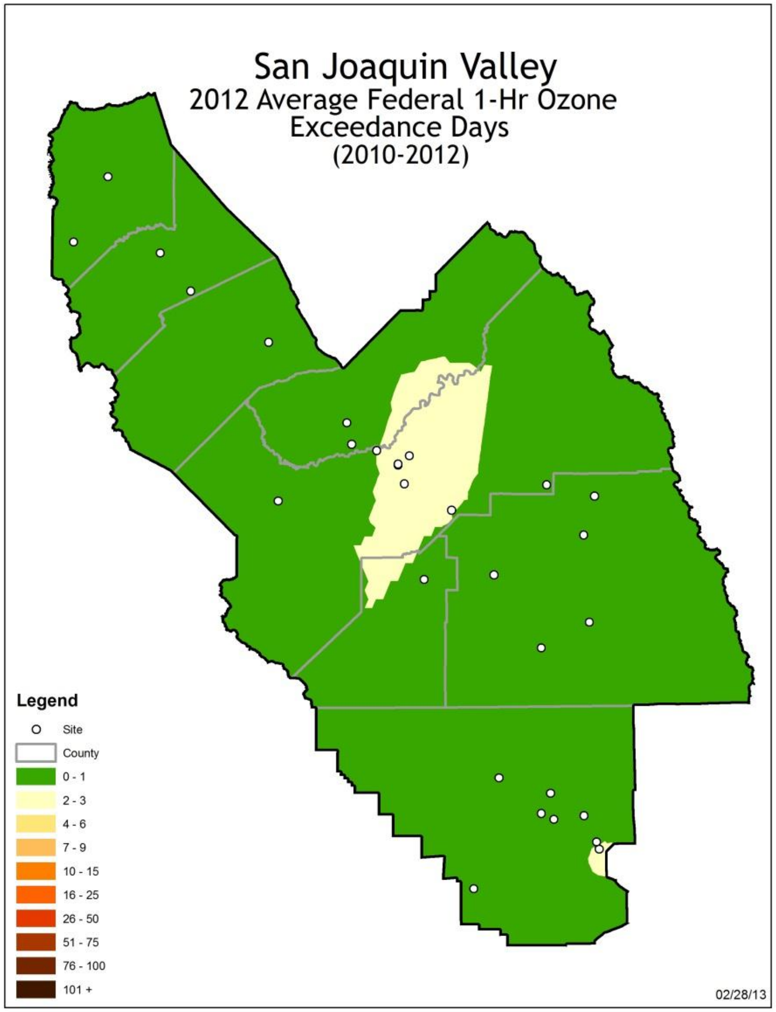


Figure 3. Three High-ozone Sites in the Central SJV

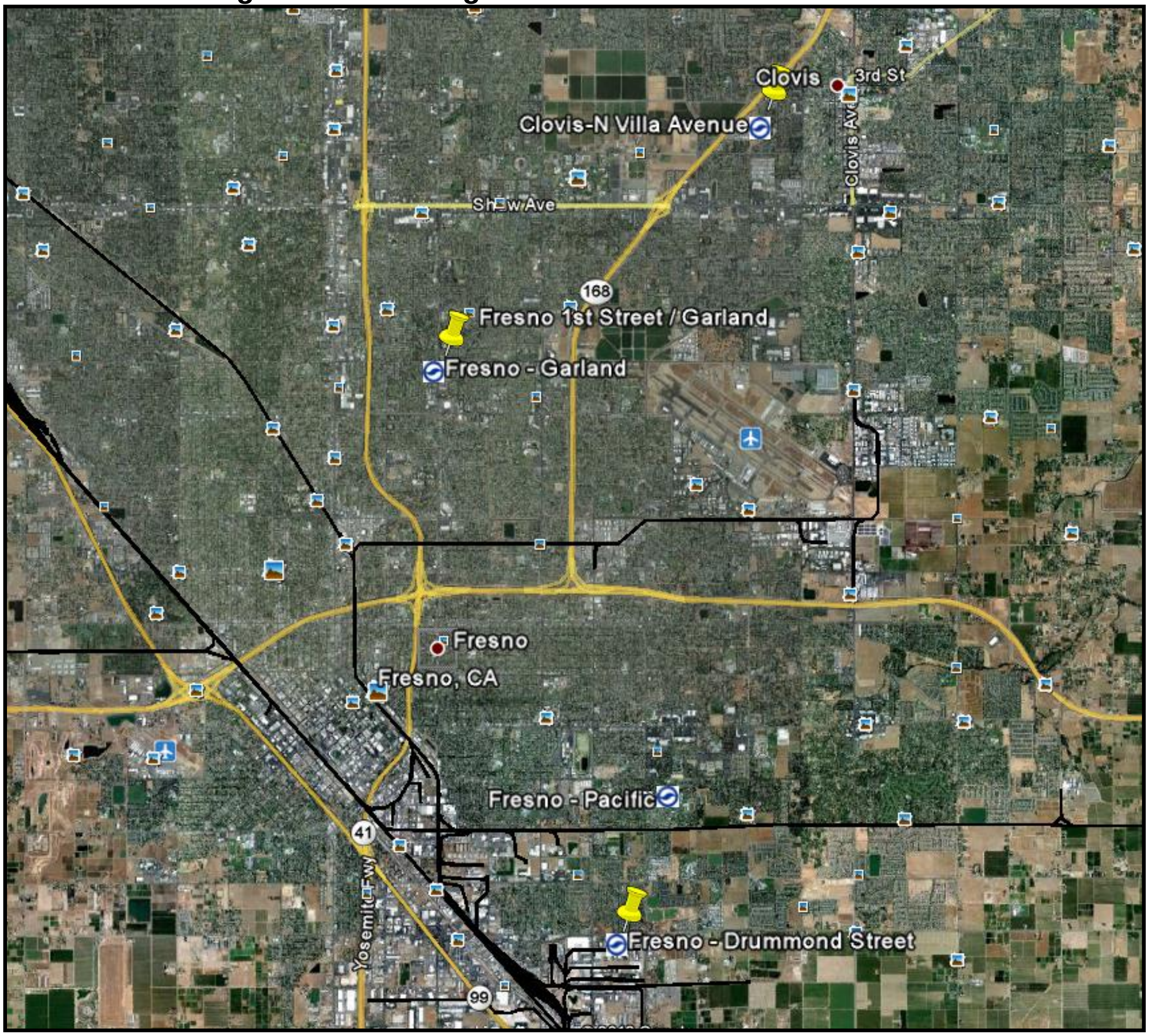


Figure 4. Air Quality Trends for Clovis – N Villa Avenue

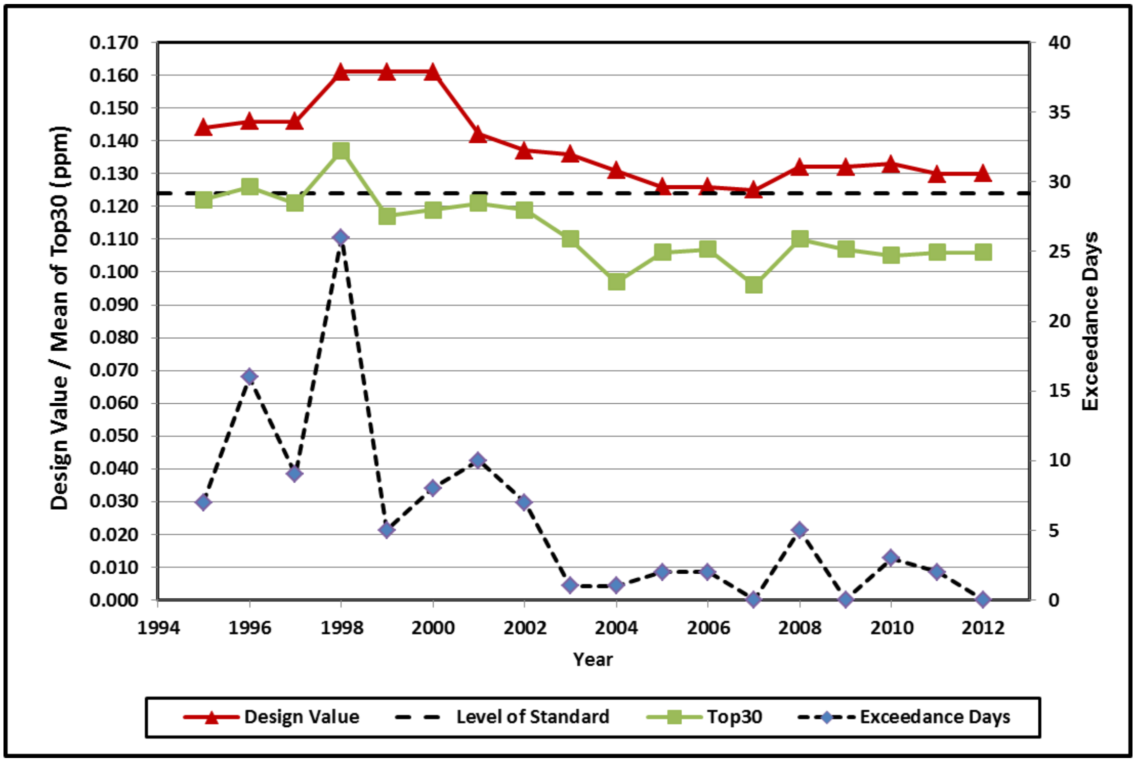


Figure 5. Air Quality Trends for Fresno – 1st Street / Garland

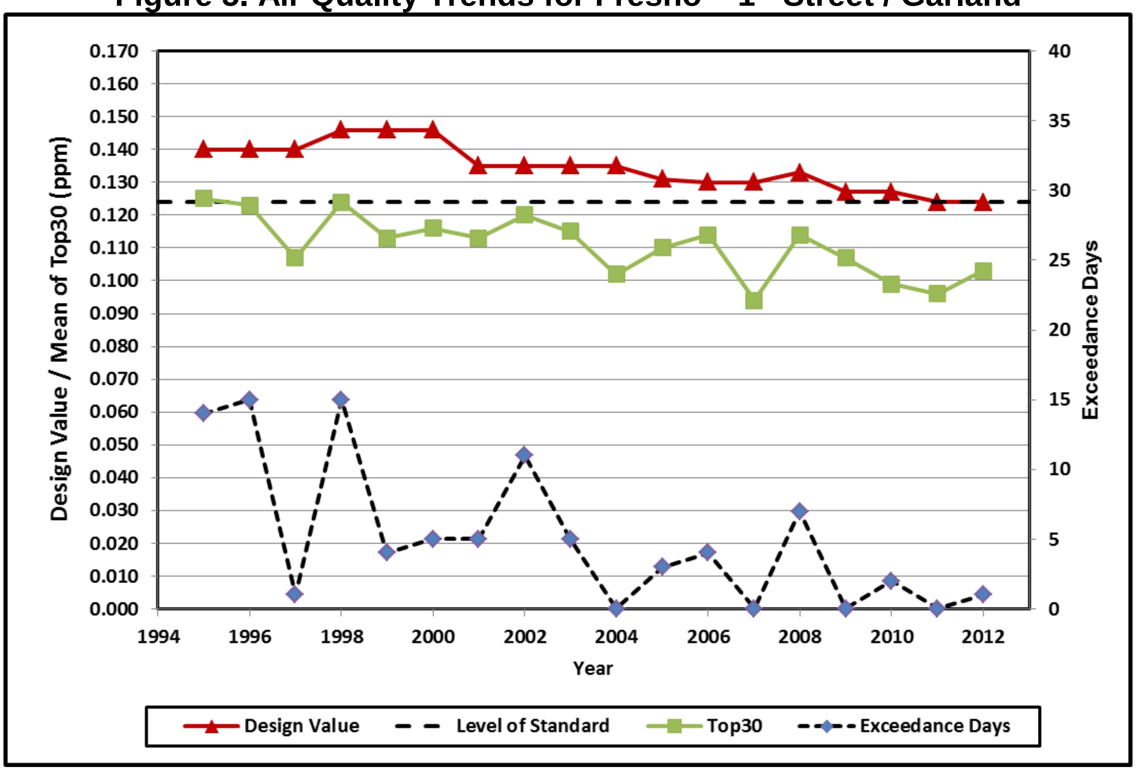


Figure 6. Air Quality Trends for Fresno – Drummond

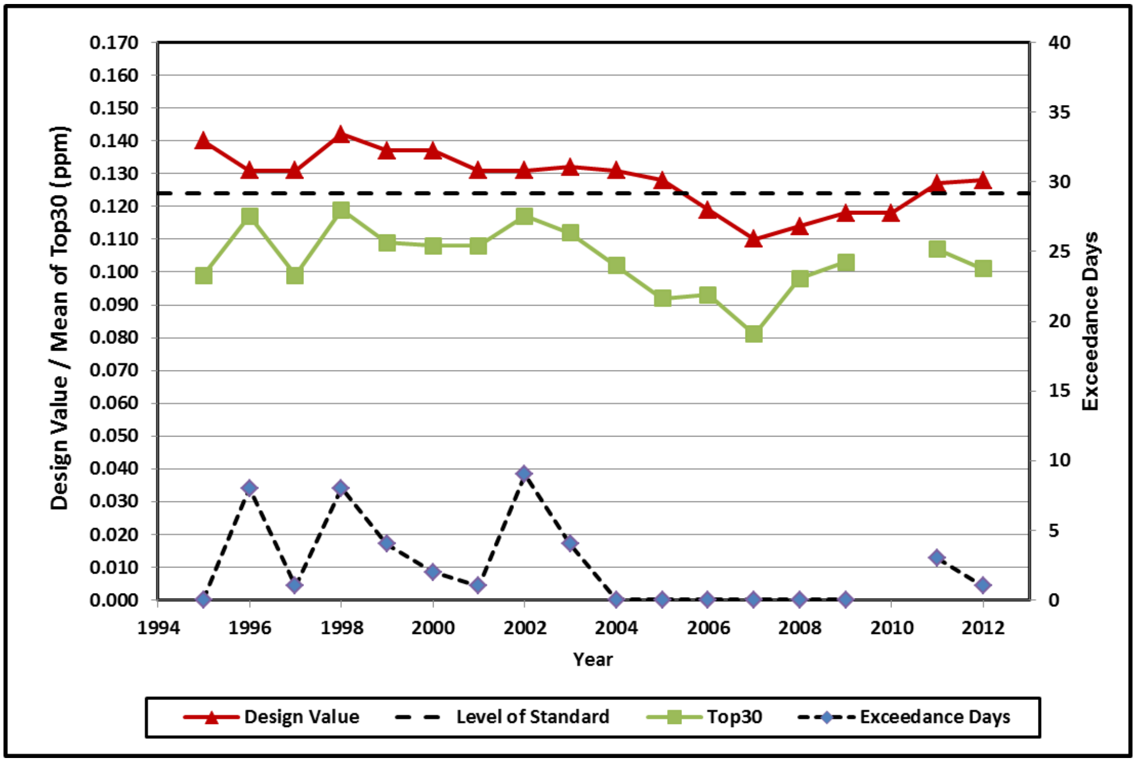


Figure 7. Two High-ozone Sites in the Southern SJV

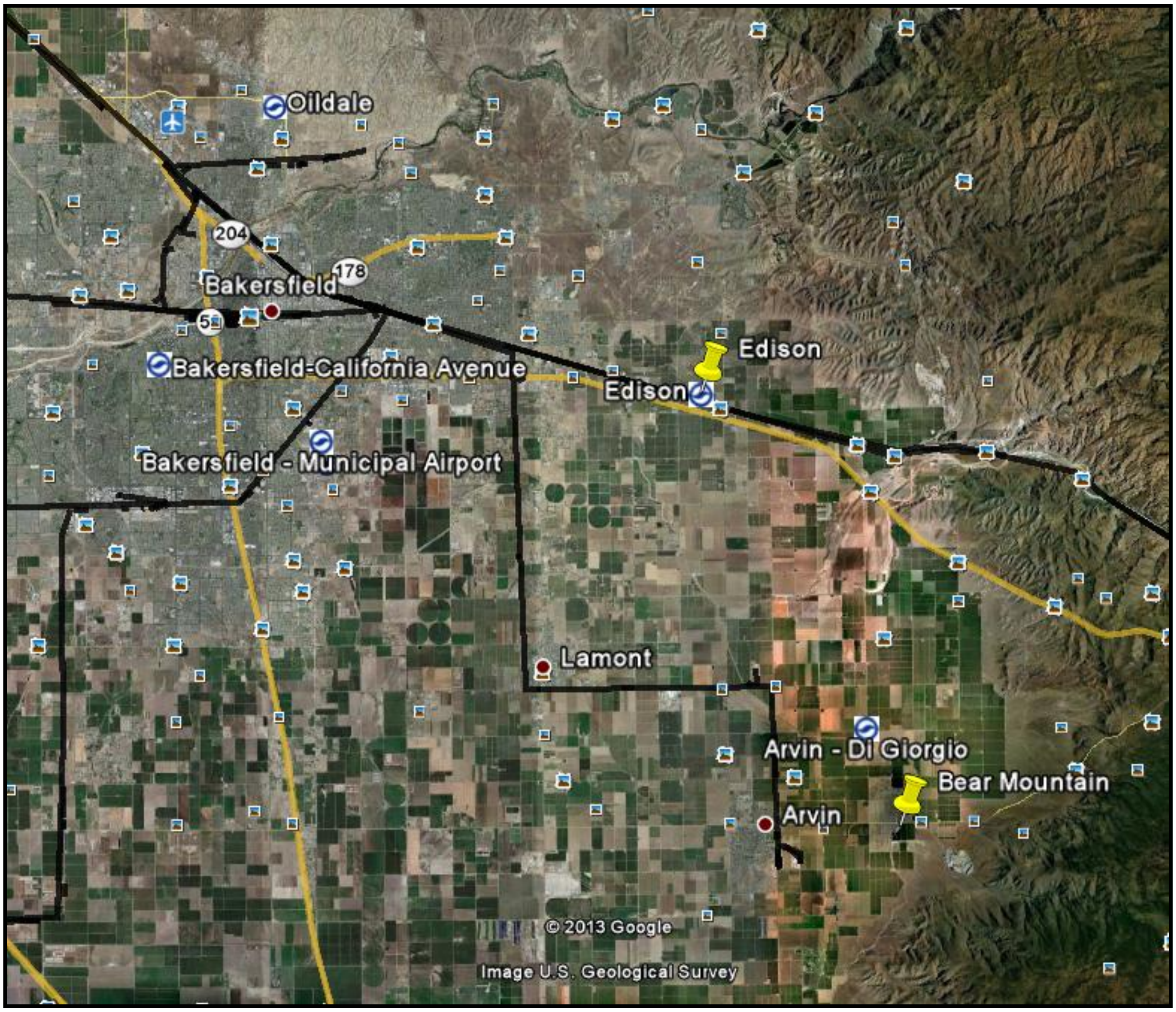


Figure 8. Air Quality Trends for Edison

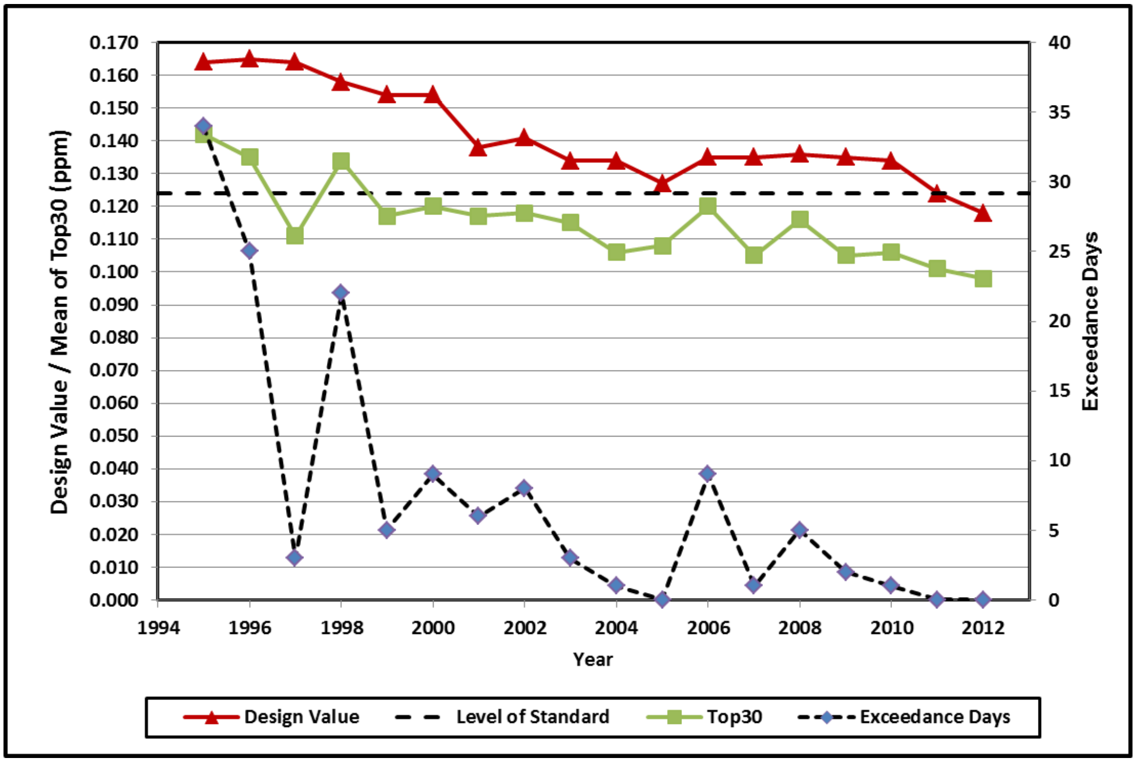
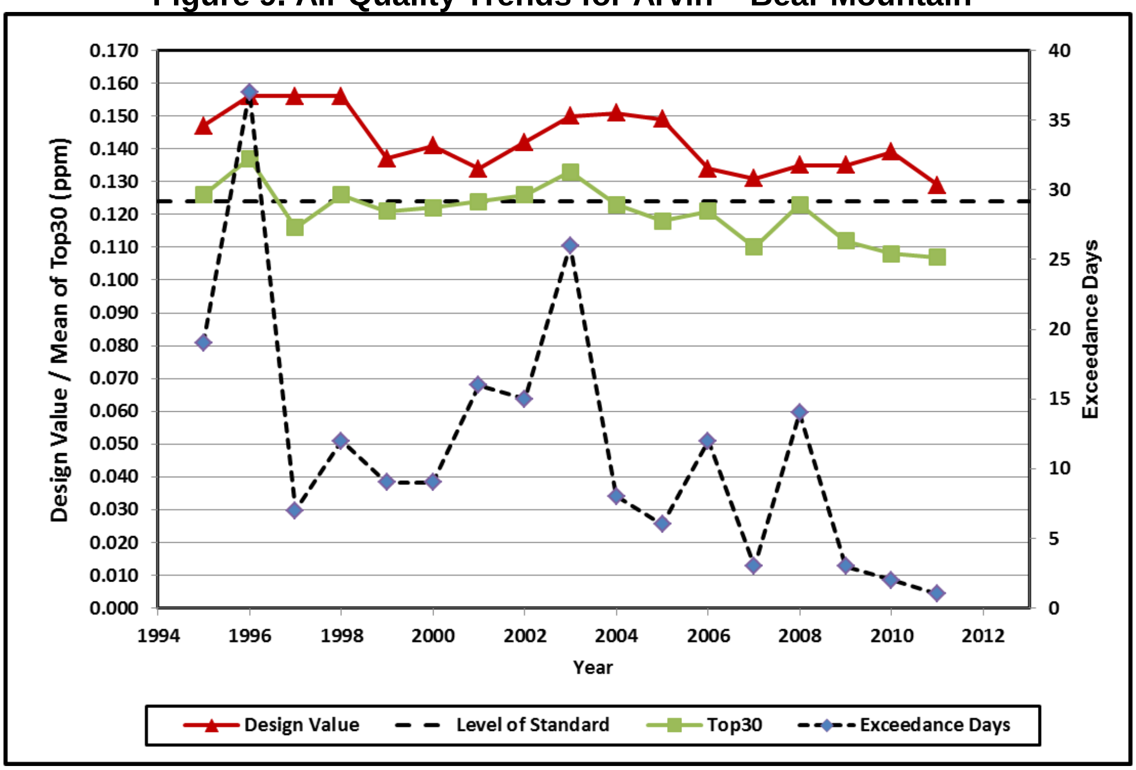


Figure 9. Air Quality Trends for Arvin – Bear Mountain*



* Values for 2011 at Arvin – Bear Mountain are based on imputed data (Appendix G-1).

2 Ozone Air Quality Trends Adjusted to Baseline Meteorology from 2003-2005

Emissions and meteorological conditions are two of the most important factors that determine ozone air quality. If emissions of ozone precursors were to be reduced at a constant rate for many years, year-to-year differences in meteorology would still cause variability in the aggregate downward trend in ozone. The meteorology-induced variability can present the appearance of multi-year ups and downs due to emissions, when no such emissions effects truly occurred. When the trends can be adjusted appropriately to a common baseline for meteorological conditions, the trend due to changes in emissions can be seen more clearly.

2.1 Using Met-Adjusted 8-Hour Ozone Trends to Represent 1-Hour Ozone

For this portion of the WOE analysis, met-adjusted 8-hour ozone trends from 1996 through 2011 were used. The 8-hour trends were developed recently as part of work to understand progress toward the 8-hour ozone standard. These trends are relevant to 1-hour ozone and sufficient for this present work due to the close connection between daily max 1-hour and 8-hour ozone from the same site.

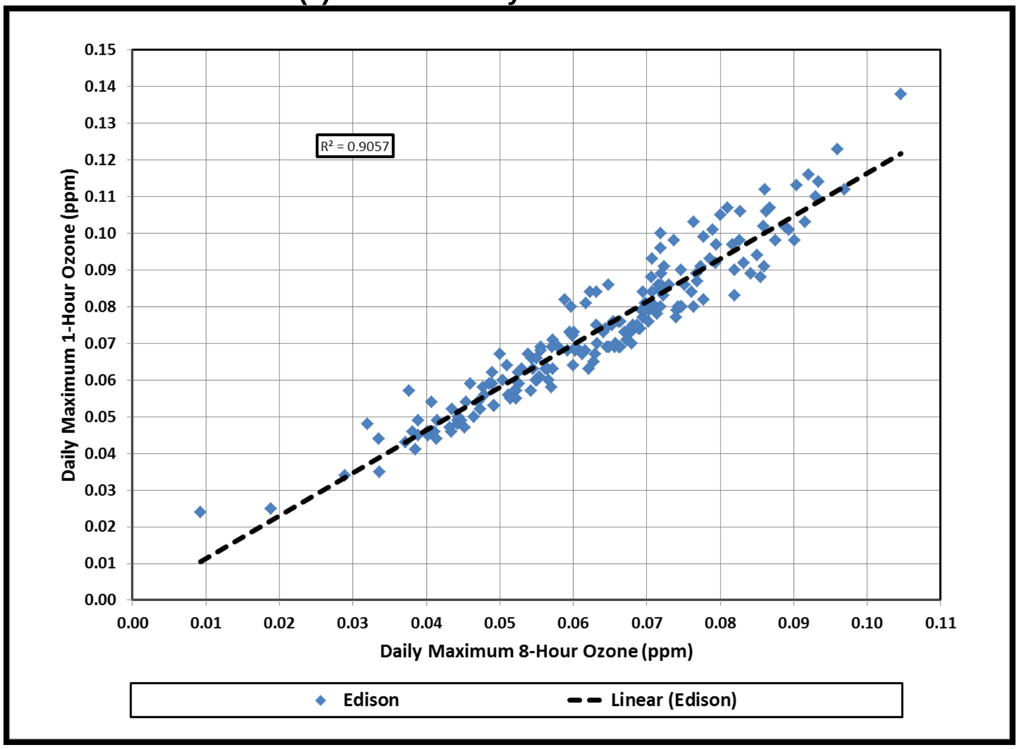
Annual plots for 2006 through 2011 were created for daily maximum 1-hour ozone (Y-axis) versus daily maximum 8-hour ozone (X-axis) during the May-October ozone season for all ozone-monitoring sites in the SJV. Data from 2008 were likely impacted by wildfires; however, no studies have been done to quantify the effects of the wildfire emissions on the concentrations, so no data were excluded on that basis. The smallest correlation between the two variables for all of the site-year plots was 0.95 (r-squared = 0.904).

Scatterplots that show the close connection between daily maximum 1-hour ozone and daily maximum 8-hour ozone at the same monitoring site are given for Edison in Figure 10 and for Fresno – 1st Street / Garland in Figure 11 as examples, with r^2 values ranging from 0.9051 to 0.9623.

The close connection between daily maximum 1-hour and 8-hour ozone means that the two can be expected to track each other as ozone improves. And, if one may improve faster than the other, the widespread expectation is that the 1-hour daily maximum should improve at least as fast as the 8-hour daily maximum. The use of "banded" relative response factors (RRF's) in Section 6.2 is based on this principle. Appendix G-2 presents the methodology used to prepare the met-adjusted trends in this report.

Figure 10. Correlation of Max. 1-hr and 8-hr Ozone at Edison

(a) Data from May – October 2007



(b) Data from May – October 2008

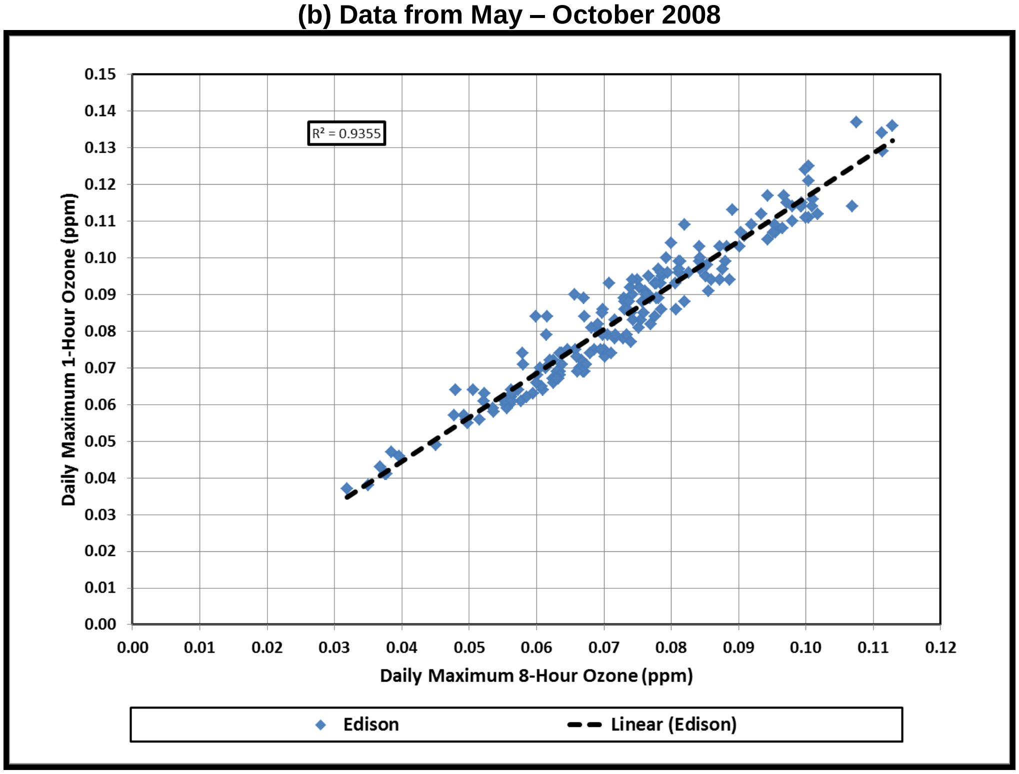
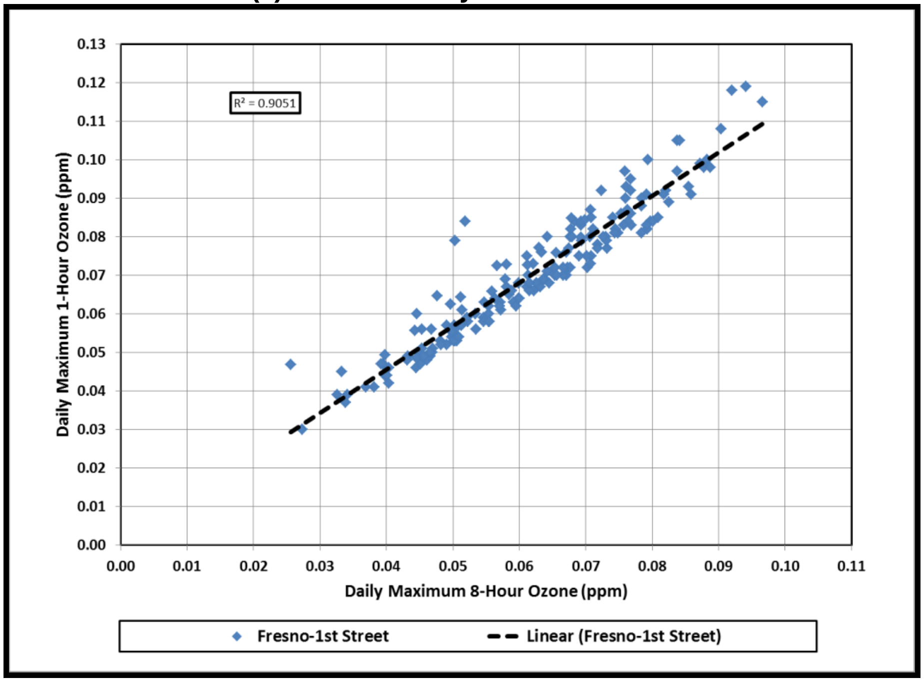
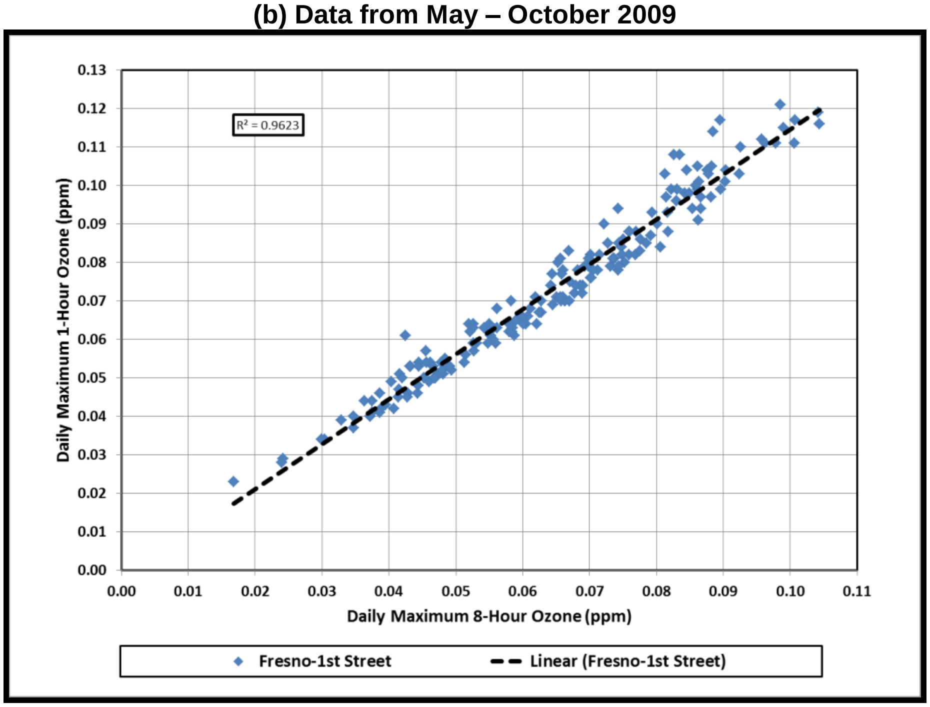


Figure 11. Correlation of Max. 1-hr and 8-hr Ozone at Fresno – 1st Street

(a) Data from May – October 2011



(b) Data from May – October 2009



2.2 Met-Adjusted Trends for the Central and Southern Regions of the SJV

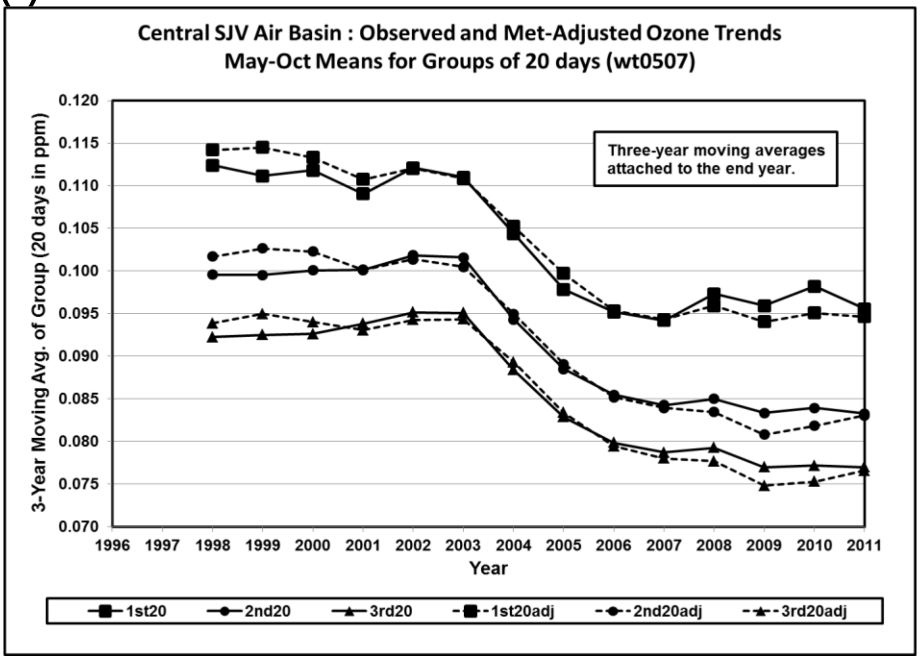
Figure 12 displays both unadjusted and met-adjusted trends. The trends represent the highest 60 days (the highest 1/3rd) of the ozone season, in sets of 20 days each. Trends for the means of the Top 20 (1st20), Top 21 to 40 (2nd20), and Top 41 to 60 (3rd20) are shown in Figure 12(a) for the Central sub-region and Figure 12(b) for the Southern sub-region of the SJV. The trends are given as 3-year moving-averages (attached to the end year) of the unadjusted and the met-adjusted results.

From 1996 to 2011, in the Central and Southern sub-regions of the SJV the overall improvement in the observed ozone trends was about 15 ppb (13% to 17%), with intermediate periods of progress and plateau. The met-adjusted trends indicate slightly greater overall progress (15% to 19%), indicating that emissions reductions have been more beneficial than the unadjusted trends suggest. The similarity of the observed and met-adjusted trends indicates that the observed trends represent emissions effects rather than weather effects, so the ozone improvements are likely due to significant ROG and NOx reductions in the SJV (Figure 13 – Figure 18).

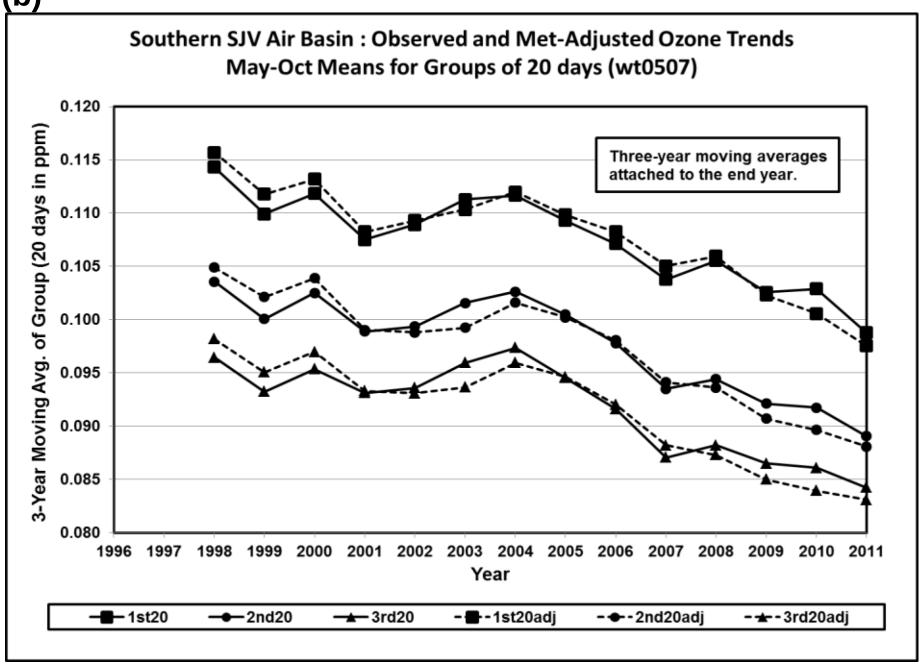
The San Joaquin Valley Air Pollution Control District (District) also prepared met-adjusted and unadjusted trends for the seasonal average of daily maximum 1-hour ozone. Though the District used a different adjustment methodology and a different trend indicator, their findings were similar to the 8-hour ozone results presented here.

Figure 12. Met-Adjusted Trends

(a)



(b)



3 Trends for Ozone Precursors in Ambient Air

This section presents trends in the primary ozone precursors, reactive organic gases (ROG) and oxides of nitrogen (NOx). The data are from a special-purpose network of Photochemical Assessment Monitoring Stations (PAMS) where both ROG and NOx are measured side-by-side. The PAMS network operates during the summer ozone season and collects ROG samples that represent different parts of the day. The work done for this WOE was patterned after previous WOE analyses that focused on the morning hours between 4 am and 7 am.

The ROG data discussed here are the sum of 55 chemical species, sometimes called Non-Methane Organic Compounds (NMOC), an indicator of ROG. These data are known to be lower than total ROG by percentages that differ from place to place. This occurs because ROG includes more than the 55 species, and because only a few of the species – formaldehyde (HCHO), acetaldehyde (CH3COH), and methyl-ethyl-ketone – have oxygen atoms in them when they are emitted. The other species react with OH radicals in the atmosphere and are transformed into oxygenated species that are not included in our ROG data.

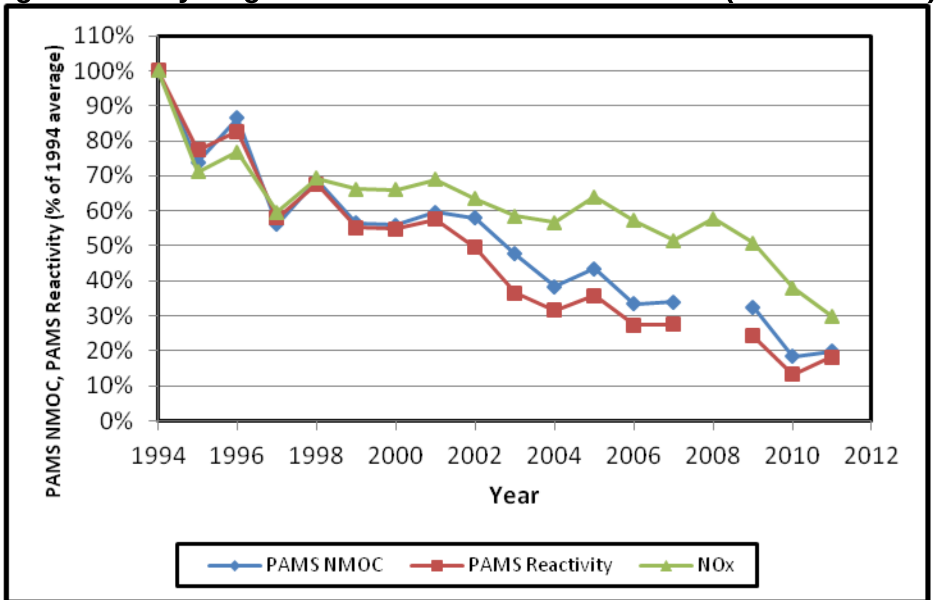
ROG is not measured at many of the monitors in the routine ambient network. The routine network of NOx monitors, however, is extensive. Section 3.2 provides additional NOx trends from this broader network.

3.1 Analysis of PAMS Data

From 1994 to 2011, ambient ROG and NOx concentrations decreased significantly throughout the SJV. Valley-wide trends shown in Figure 13 show some minor peaks within the long term downward trend. This demonstrates that progress has been made in reducing these two key precursors that form ground-level ozone. Since 1994, PAMS data for the SJV indicate that ROG declined by 79%, while NOx decreased by 70%. The trend for reactivity-weighted ROG showed slightly greater progress compared to the un-weighted trend.

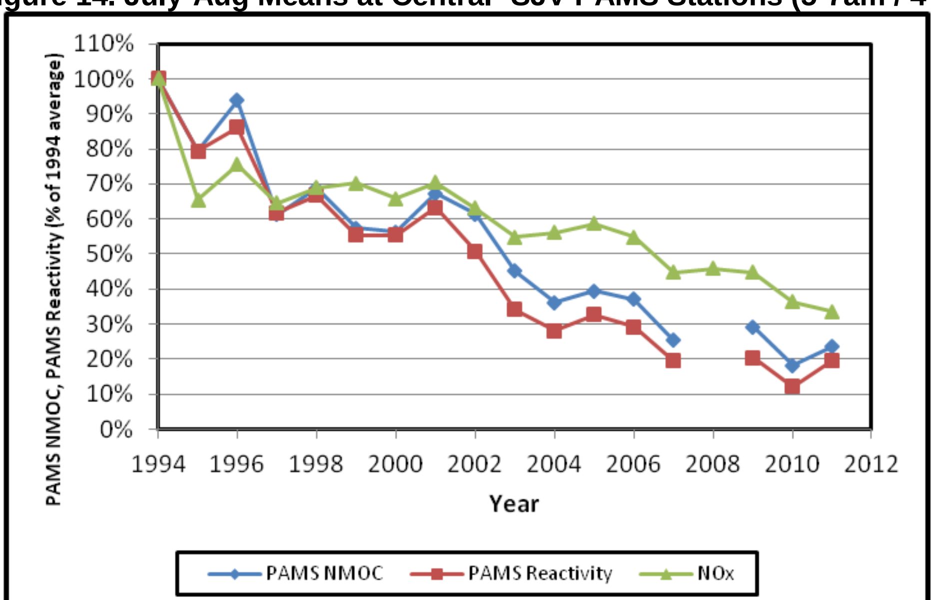
Sub-regional trends in ambient ROG and NOx are shown in Figure 14 for the Central SJV and in Figure 15 for the Southern SJV. The figures show substantial decreases in ROG and NOx for both regions over the trend periods. In the Central SJV, ROG declined 76% and NOx declined 67%. In the Southern SJV, ROG declined 88% and NOx declined 61%. Table 1 provides the data for Figure 13 through Figure 15 in parts per billion instead of percent. Table 1 shows that the levels of ROG and NOx in 2010 remained somewhat higher in the southern region compared to the central region. It should be noted that data after 2009 was unavailable at the Bakersfield – Golden State Highway site and the 2012 PAMS data were not available for any sites at the time this analysis was done.

Figure 13. July-Aug Means at all SJV PAMS Stations (5-7 am/4-6 am)*



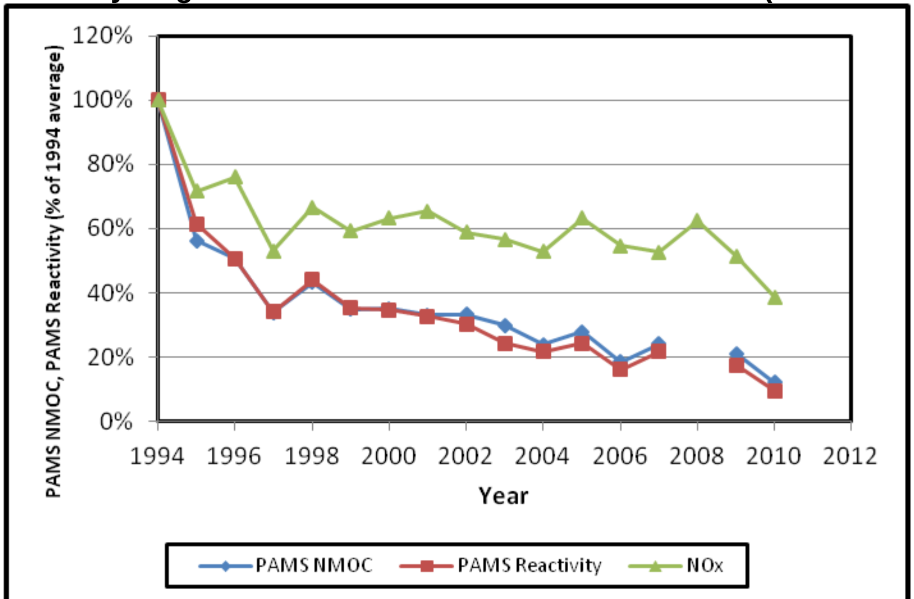
*3-hour NMOC/PAMS samples from 5-7 am or 4-6 am for a standard set of 55 compounds. Some samples with extreme mixing ratios for one or more compounds were identified and excluded. Data for 2008 were not available for this area during the chosen months and hours.

Figure 14. July-Aug Means at Central† SJV PAMS Stations (5-7am / 4-6am)



†Central San Joaquin Valley sites include Parlier, Fresno-1st Street, Clovis - N. Villa Avenue, and Madera-Pump Yard. Data for 2008 were not available for this area during the chosen months and hours.

Figure 15. July-Aug Means at Southern‡ SJV PAMS Stations (5-7 am / 4-6 am)



‡Southern San Joaquin Valley sites include Arvin-Bear Mountain, Shafter-Walker Street, and Bakersfield-Golden State Hwy. Data for 2008 and 2011 were not available for this area during the chosen months and hours.

Table 1. ROG (ppbC) and NOx (ppb) Concentrations in the SJV

	SJV Basinwide			Central SJV			Southern SJV		
Year	ROG	Reactivity	NOx	ROG	Reactivity	NOx	ROG	Reactivity	NOx
1994	225.4	189.9	53	190.2	178.3	47.5	433.4	320.4	63.8
1995	166.5	147.0	38	150.9	141.4	31.1	244.0	197.1	45.6
1996	194.9	157.0	41	178.6	153.7	35.9	219.3	161.9	48.5
1997	126.5	109.9	32	116.6	110.3	30.7	146.5	109.1	33.8
1998	155.0	128.4	37	130.8	119.0	32.7	187.2	140.9	42.5
1999	127.2	104.9	35	109.3	98.6	33.3	151.0	113.2	37.8
2000	126.2	104.0	35	107.1	98.9	31.3	151.7	110.9	40.3
2001	134.1	109.4	37	128.1	112.7	33.4	143.2	104.6	41.7
2002	130.6	93.9	34	116.9	90.7	30.0	144.3	97.2	37.6
2003	107.4	69.3	31	85.7	60.9	26.1	129.2	77.7	36.2
2004	86.3	59.9	30	68.7	50.2	26.6	103.9	69.6	33.7
2005	97.8	68.1	34	75.2	58.2	27.9	120.5	77.9	40.4
2006	75.4	51.8	30	70.4	52.1	26.1	80.4	51.5	34.9
2007	76.4	52.2	27	48.3	34.9	21.3	104.5	69.5	33.5
2008			31			21.8			39.8
2009	73.4	46.1	27	55.7	36.4	21.3	91.1	55.7	32.9
2010	41.6	25.2	20	34.7	21.8	17.2	52.1	30.2	24.7
2011	44.9	34.7	16	44.9	34.7	15.9			

3.2 Analysis of Routine Ambient NOx Data

The trends in Section 3.1 represent ambient ROG and NOx at sites in the limited PAMS network during July and August for the hours between 4 am and 7 am.

The trends in this section represent ambient NOx for May-October for all hours of the day from 1995 – 2012. Results are shown for the Central SJV (Figure 16) and the Southern SJV (Figure 17). Figures 16 and 17 use 3-year averages, with one year in a 3-year period sufficient to calculate a moving 3-year average. Therefore, the gaps (or missing years) in the annual trends mean NOx data for three consecutive years were not available.

Both figures show strong downward trends in ambient NOx at the more urbanized sites where NOx emissions are highest. These ambient NOx trends are similar to those from the specialized PAMS sites (Section 3.1) and corroborate the emissions data (Section 4) that NOx emissions have decreased substantially.

Figure 16. Central SJV Trends for Ambient 24-hour NOx from May-Oct.

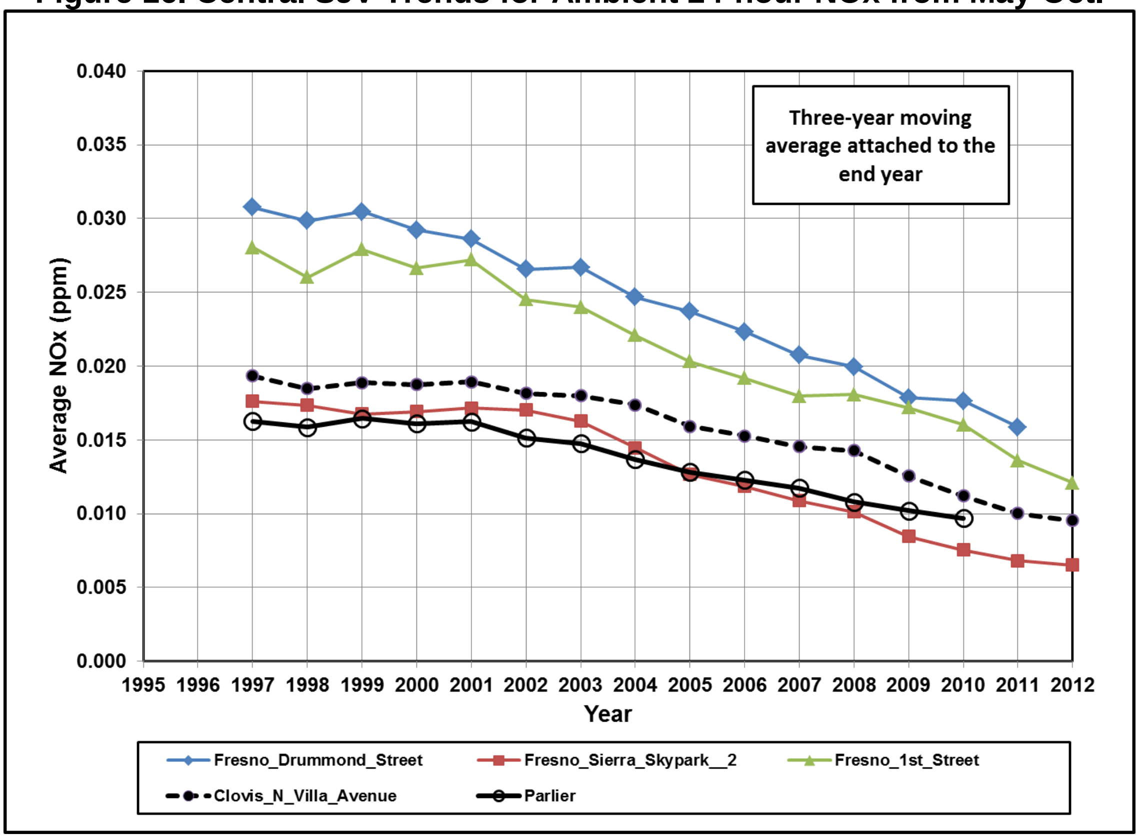
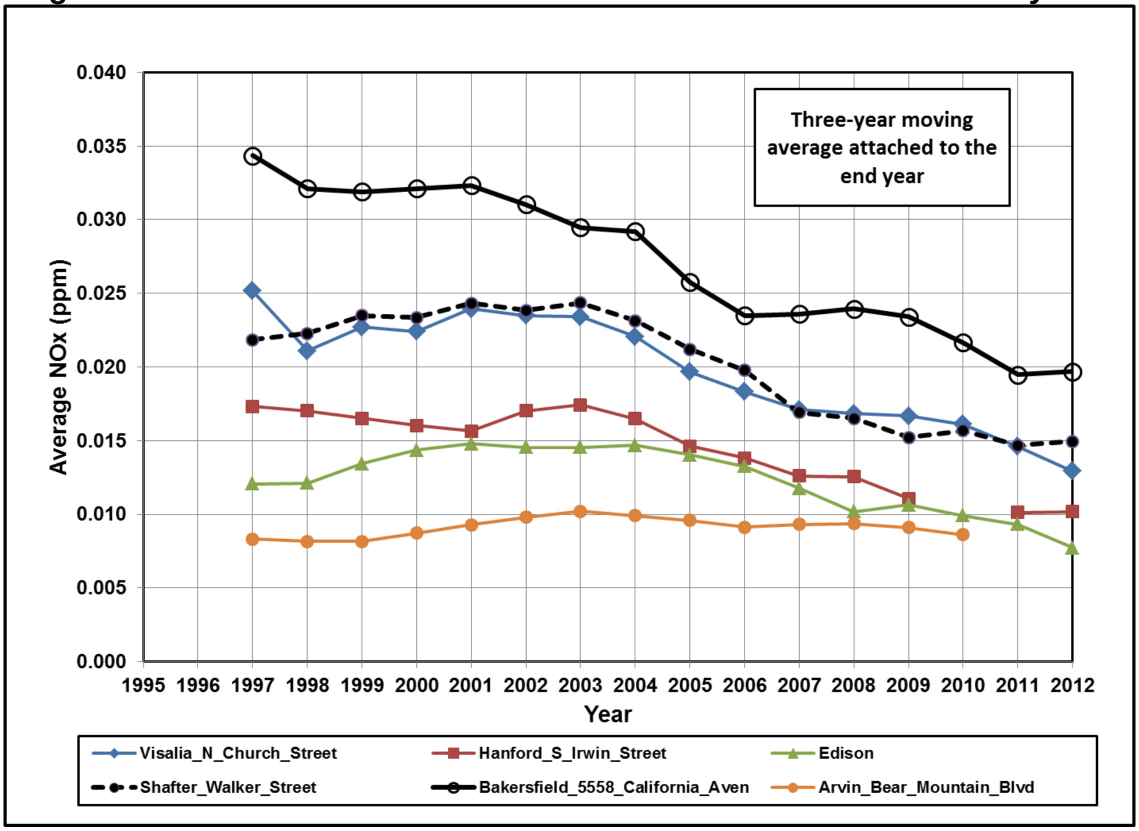


Figure 17. Southern SJV Trends for Ambient 24-hour NOx from May-Oct.

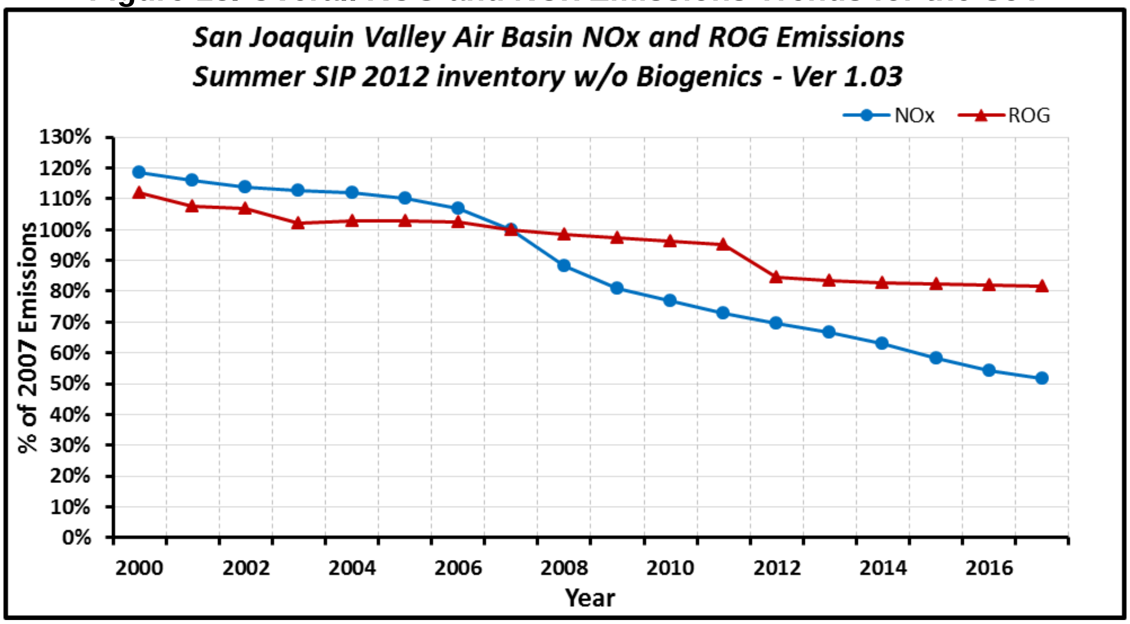


* This trend does not include Arvin – Bear Mountain after 2010, as the site closed in 2010.

4 Trends for Emissions Inventories of Ozone Precursors

Emissions trends for ROG and NOx in the SJV as a whole are shown in Figure 18, excluding emissions from natural sources. The estimates are based on a 2005 emissions inventory together with relative growth and control factors for 2000 – 2017. The figure shows that from 2000 – 2017 anthropogenic NOx is predicted to decrease by 67% and ROG by 30%.

Figure 18. Overall ROG and NOx Emissions Trends for the SJV



The ROG/NOx ratio is an important consideration when planning emissions reduction strategies. A ROG/NOx ratio greater than 1 indicates higher ROG emissions. For higher ROG/NOx ratios ROG emissions reductions will be less effective in lowering ozone while NOx emissions reductions will be more effective. This is known as a NOx limited regime. A ROG limited regime occurs when the ROG/NOx ratios are lower, indicating higher NOx emissions. In this regime, ROG emissions reductions will be more effective than NOx emissions in reducing ozone concentrations.

Figure 18 shows summer emissions of anthropogenic NOx and ROG from 2000 to 2017 as a percent of emissions in 2007, the base year for modeling. With respect to 2007, the 2017 emissions represent a 48% decrease in NOx and a 18% decrease in ROG. Accordingly, the ROG/NOx ratio for anthropogenic emissions in 2017 is expected to be almost 1.6 times the ratio that prevailed in 2007. The ratio of ambient ROG to ambient NOx is likely to increase even more, as non-anthropogenic ROG is the majority of the total ROG inventory in the SJV for most of the ozone season, while non-anthropogenic NOx is a tiny fraction of the total NOx inventory. The trend towards higher ROG/NOx ratios in the SJV indicates that the area will become more NOx limited, thus NOx controls will become increasingly more effective for lowering ozone concentrations.

Trends in summer emissions of anthropogenic NOx and ROG for the Central SJV are shown in Figure 19 and for the Southern SJV in Figure 20. These trends show similarities that reflect the Valley-wide adoption of significant rules regarding control of ROG and NOx emissions. In the Central and Southern sub-regions of the SJV, emissions inventories show greater overall reductions in NOx (55% in Central and 60% in Southern SJV) than ROG (24% in Central and 31% in Southern SJV) from 2000 – 2012, with downward pattern continuing through 2017. The key feature of these trends is the similarity in both regions of the SJV.

Figure 19. ROG and NOx Emissions Trends for the Central SJV

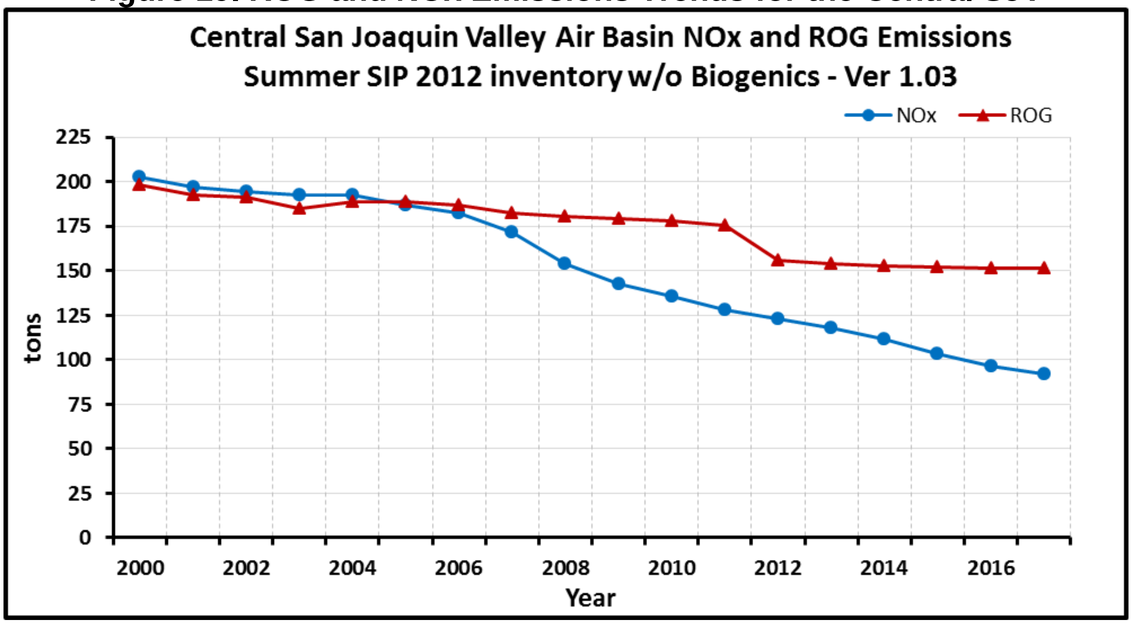
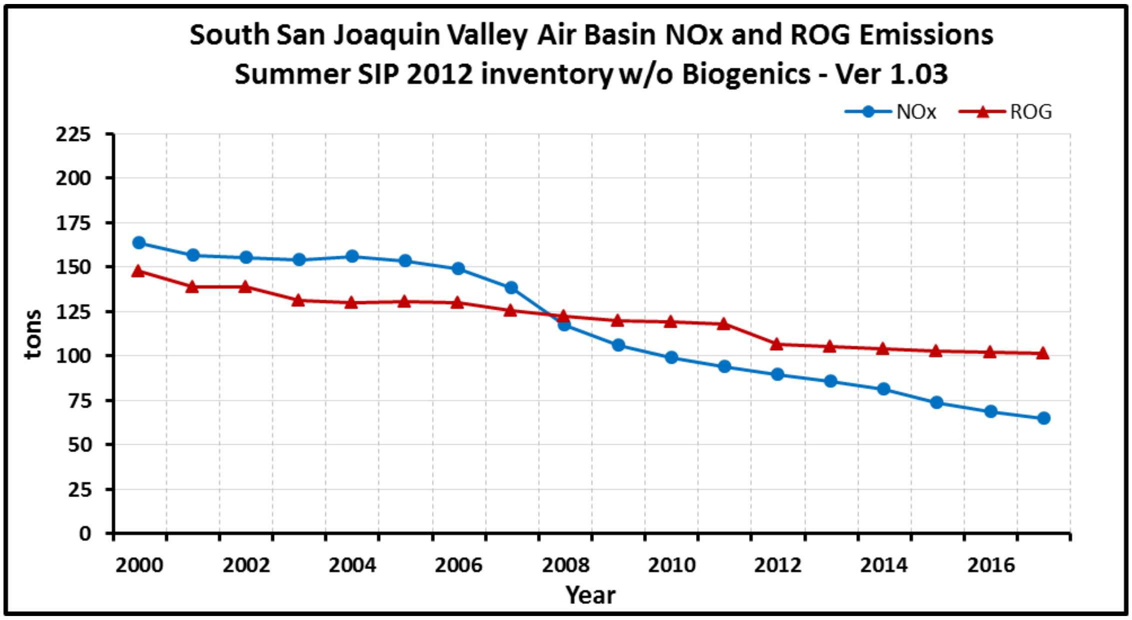


Figure 20. ROG and NOx Emissions Trends for the Southern SJV



The county-by-county trends in Figure 21 and Figure 22 have largely similar shapes but differ in the magnitude of the emissions, with highest NOx and ROG emissions in Kern County.

Figure 21. Summer NOx Emissions by County

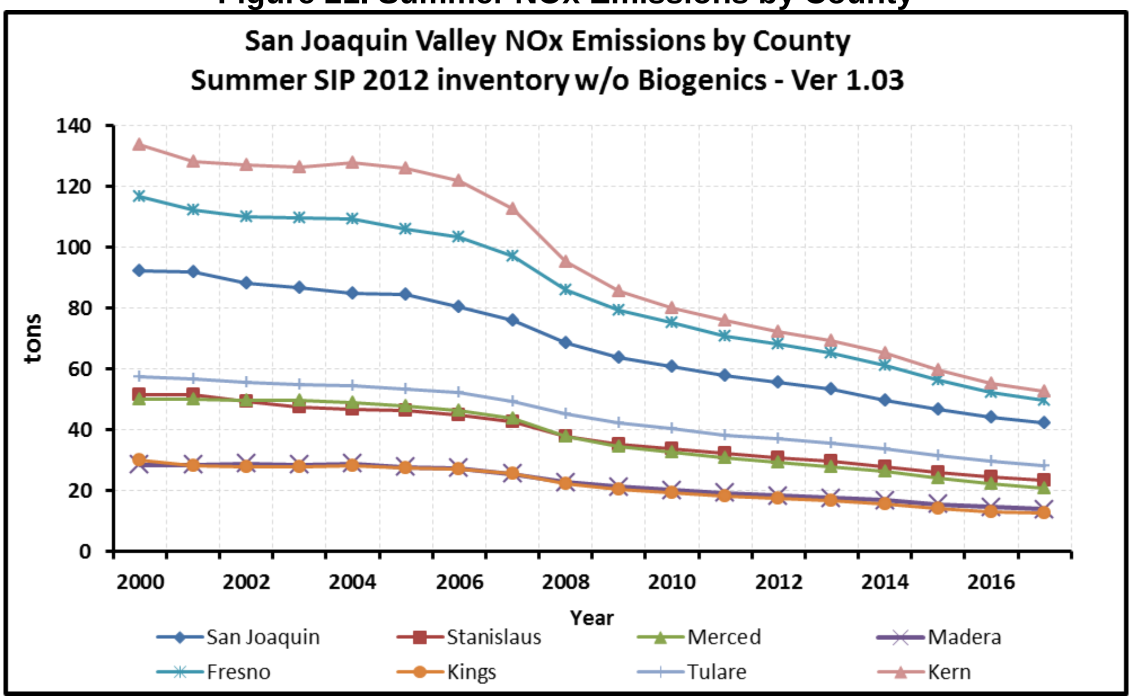
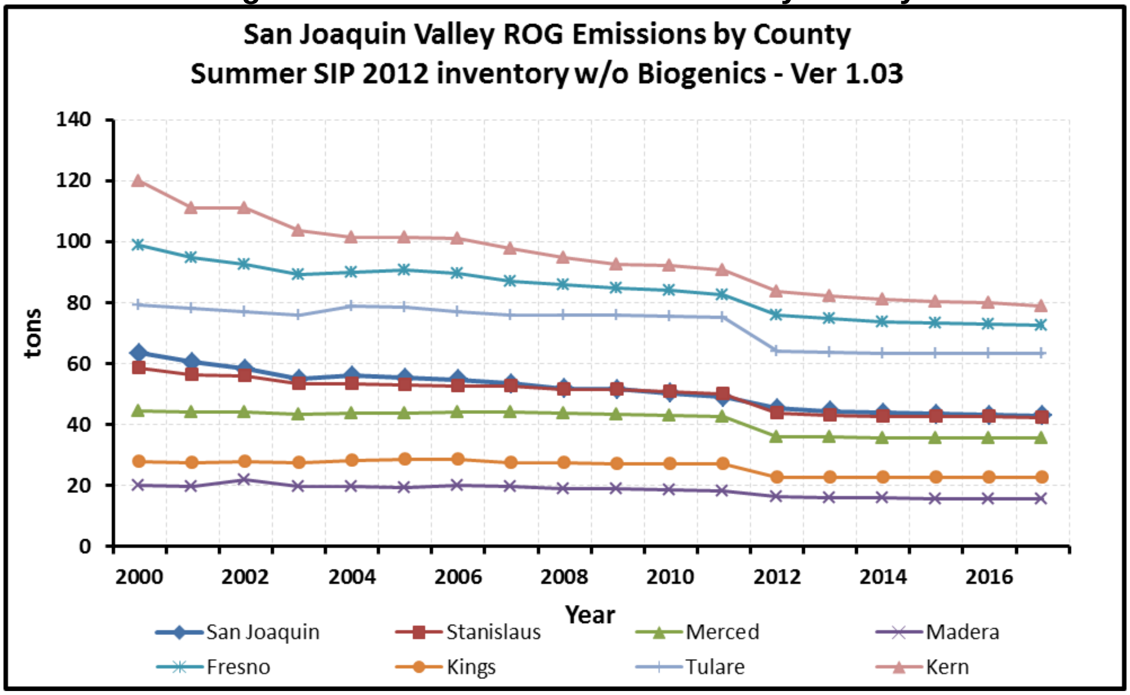


Figure 22. Summer ROG Emissions by County



5 Ambient Analysis of Ozone Sensitivity to ROG and NOx

In addition to both the ambient and emissions ROG/NOx ratio discussed in the previous sections, the sensitivity of ozone to changes in ROG and NOx can be assessed using other patterns in the ambient data. Analysis of indicator species, especially their ratios, has been used in this regard, but the needed data are very limited for the SJV at this time. However, an analysis of ozone on weekdays and weekends provides another indicator that reductions in NOx should be effective in reducing ambient ozone in the SJV.

As discussed in Section 4, substantial reductions in NOx emissions are forecast for the SJV in the coming years. Reductions in ROG emissions are also forecast but at a slower pace, with biogenic ROG emissions remaining unchanged. As a result, the ratio of ROG to NOx in the ambient air is expected to increase markedly.

The modeling exercises summarized in Chapter 2 of the *2013 Plan for the Revoked 1-hour Ozone Standard* and supported by additional modeling analyses in Section 6 of this Appendix provide evidence that the planned emphasis on NOx reductions for the next four years (and beyond) should result in significantly lower ozone levels and attainment of the 1-hour ozone NAAQS by 2017. The models' responsiveness to NOx reductions indicates that the photochemical system in the SJV is NOx-limited now, or very soon will be.

5.1 <u>ROG vs. NOx Sensitivity Based on Weekday vs. Weekend Ozone</u>

The Ozone Weekend Effect (WE) is a well-known phenomenon in some major urbanized areas where emissions of ozone precursors are substantially lower on weekends than on weekdays, but measured levels of ozone are significantly higher on weekends than on weekdays. Though common, the WE is not the same in all urban areas of the state.

The WE has been viewed by some as a demonstration that NOx reductions can cause ozone disbenefits – higher not lower ozone levels – if not coupled with concurrent ROG reductions. If interpreted in this way, the analysis presented in Table 2 would indicate that future NOx reductions in the SJV should be beneficial in reducing ozone levels.

Table 2 presents the average WE based on daily maximum 8-hour ozone at six sites in the Central sub-region and six sites in the Southern sub-region of the SJV. The results are pertinent to the WE for daily maximum 1-hour ozone, which closely tracks the 8-hour maximum as illustrated in Figure 10 (Edison) and Figure 11 (Fresno – 1st Street) shown earlier. The sub-regional averages and site-by-site results are shown in the table for three five-year periods – 1996 to 2000, 2001 to 2005, and 2006 to 2010. For the five-year period from 2006 – 2010, the WE for daily maximum 8-hour ozone averaged <1% in both the Central and Southern sub-regions of the SJV.

Another interesting feature of the results in Table 2 is the WE sequence across the three periods. In the Central sub-region, the decrease went from 9.0 ppb to 4.3 ppb to 0.8 ppb, and in the Southern sub-region the decrease went from 2.7 ppb to 3.5 ppb to 0.0 ppb. These patterns suggest that the decreasing WE is linked to the declining ambient NOx trends shown in Figure 16 and Figure 17. The methodology used in the analysis of the WE is further described in Appendix G-3.

The WE for 1-hour ozone was also analyzed by the District using a different methodology, and they similarly conclude that weekend ozone is not elevated with respect to weekday ozone at this time.

Table 2. Site-by-Site and Regional "Ozone Weekend Effects" (%)* in the Central and Southern Sub-regions of the SJV

Sub-region and Site	1996 to 2000	2001 to 2005	2006 to 2010
SJV – Central			
Clovis	8.8	3.0	1.0
Fresno – Drummond	14.4	6.1	2.4
Fresno – First Street	9.9	4.1	0.5
Fresno – Sierra Sky Park #2	9.6	3.6	-0.4
Parlier	3.6	1.3	-0.7
Visalia	7.7	7.8	2.1
Average for SJV Central	**9.0**	**4.3**	**0.8**
SJV – South			
Arvin – Bear Mtn. Road	0.7	1.4	-3.5
Bakersfield – CA Avenue	2.3	3.7	0.4
Bakersfield – Golden St. Hwy.	10.1	7.9	4.0
Edison	3.8	3.5	-1.1
Maricopa	-1.9	1.5	-0.8
Oildale	1.1	2.9	1.0
Average for SJV South	**2.7**	**3.5**	**0.0**

* (Weekend avg. - Weekday avg.) / Weekday avg. as % change + or -). A positive value means the average Weekend ozone was that % higher with respect to the average Weekday ozone.

6 Modeling Results

This section presents additional modeling results that corroborate what was presented in Chapter 2 of the *2013 Plan for the Revoked 1-hour Ozone Standard*. Multiple modeling metrics were evaluated to determine whether the Valley would attain by 2017. These metrics are briefly described below and in more detail in the Appendix E of *2013 Plan for the Revoked 1-hour Ozone Standard*.

Modeling results began to be used in a relative sense (using Relative Response Factors or RRFs) in the context of the 8-hour ozone standard. Until then, modeling results were used in a direct or deterministic sense, mainly because computing resources were sufficient to simulate very few episodes (one in most cases). From these simulations, a limited number of days were used to determine future-year attainment. For this 1-hour ozone plan, the simulations covered a 5-month period (May-September 2017) of ozone concentrations.

6.1 Single RRF Approach

The first approach was to use the model in a relative sense following the procedure in the 8-hour ozone modeling guidance. Accordingly, a single average RRF was calculated for each site in Table 3, and the 2005-2007 DV was multiplied by that RRF. One modification to the procedure was to use the values simulated in the grid cell containing the monitoring site to calculate RRF, instead of using the maximum value within a radius of 15 km.

The DVs based on the single average RRF approach are shown in the third column (DV-Single (2015-2017)) in Table 3. These future DVs are below the standard for all stations. Therefore, based on a single RRF for each site, the standard will be met at all sites in 2017.

6.2 Comparison of Single vs. Band RRF

The second metric is based on the recognition that higher ozone concentrations are generally more responsive than lower ozone concentrations to the control of precursors. Band RRFs, described in Chapter 2 of the *2013 Plan for the Revoked 1-hour Ozone Standard*, allow this concept to be incorporated in an attainment demonstration. The fourth column of Table 3 lists the DVs calculated using band RRFs.

As described in Chapter 2 of the *2013 Plan for the Revoked 1-hour Ozone Standard*, the top 10 observed ozone concentrations during the 2005-2007 base-case period were projected to 2017 using band RRFs. The fourth highest future value was then selected as the future DV. This is the value that was compared against the standard (124.0 ppb in this case). The other projected values were also compared to the standard, and the results are given in Table 4, which shows that the top 10 values for each site are all projected to be at or below the standard in 2017 with the exception of one value at Edison using the single RRF approach. As demonstrated in this section, the two different attainment tests indicate that all monitoring sites in the Valley will attain the 1-hour ozone standard by 2017.

Table 3. Design Values (in ppb) in 2007 and 2017 for Monitoring Sites in the SJV

Monitoring Station	DV (2005-07)	DV-Single (2015-17)	DV-Band (2015-17)
Edison	135	120	119
Arvin-Bear_Mountain_Blvd	131	113	107
Fresno-1st_Street	130	117	103
Clovis-N_Villa_Avenue	125	111	104
Fresno-Sierra_Skypark_#2	124	110	98
Parlier	121	105	97
Sequoia_and_Kings_Canyon	119	102	102
Bakersfield-5558_Califor	117	102	98
Sequoia_Natl_Park-Lower	113	98	98
Visalia-N_Church_Street	112	96	94
Oildale-3311_Manor_Stree	112	97	95
Fresno-Drummond_Street	110	99	93
Hanford-S_Irwin_Street	110	98	92
Modesto-14th_Street	109	102	95
Bakersfield-Golden	108	97	96
Shafter-Walker_Street	105	92	87
Turlock-S_Minaret_Street	104	95	91
Merced-S_Coffee_Avenue	102	90	85
Stockton-Hazelton_St	101	92	86
Maricopa-Stanislaus_Stre	100	88	83
Madera-Pump_Yard	95	84	82

Table 4. Projected values in 2017 for the top 10 base-case observations of 1-hour ozone (ppb) at SJV sites using single and band RRFs

Site	Date	Obs	Band RRF	Band RRF 2017 DV	Single RRF	Single RRF 2017 DV
Arvin-Bear_Mountain	8/28/2006	135	0.82	110	0.86	116
	6/23/2006	134	0.82	109	0.86	115
	7/18/2005	133	0.82	109	0.86	114
	9/12/2006	131	0.82	107	0.86	113
	7/27/2005	131	0.82	107	0.86	113
	9/5/2006	130	0.82	106	0.86	112
	6/24/2006	130	0.82	106	0.86	112
	5/11/2006	130	0.82	106	0.86	112
	9/13/2006	129	0.82	105	0.86	111
	9/1/2005	129	0.82	105	0.86	111
Bakersfield-5558_Cal	9/13/2006	123	0.84	103	0.87	107
	6/23/2006	120	0.84	100	0.87	104
	8/6/2005	117	0.84	98	0.87	102
	7/5/2007	117	0.84	98	0.87	102
	6/24/2006	117	0.84	98	0.87	102
	9/12/2006	115	0.84	96	0.87	100
	6/22/2006	113	0.84	94	0.87	98
	5/11/2006	112	0.84	93	0.87	97
	8/23/2006	111	0.84	93	0.87	96
	9/29/2006	110	0.84	92	0.87	95
Bakersfield-Golden	7/5/2007	127	0.84	106	0.9	114
	7/17/2005	110	0.89	98	0.9	99
	9/13/2006	108	0.89	96	0.9	97
	6/23/2006	108	0.89	96	0.9	97
	8/6/2005	105	0.89	93	0.9	94
	9/6/2006	103	0.89	91	0.9	93
	8/23/2006	103	0.89	91	0.9	93
	9/12/2006	102	0.9	92	0.9	92
	7/9/2006	102	0.9	92	0.9	92
	7/14/2006	101	0.9	91	0.9	91

Site	Date	Obs	Band RRF	Band RRF 2017 DV	Single RRF	Single RRF 2017 DV
Clovis-N_Villa_Avenue	9/2/2006	127	0.83	105	0.9	113
	8/27/2005	127	0.83	105	0.9	113
	7/27/2005	127	0.83	105	0.9	113
	7/20/2006	125	0.83	104	0.9	111
	9/6/2007	121	0.83	100	0.9	108
	7/16/2005	117	0.85	99	0.9	104
	6/24/2006	116	0.85	98	0.9	103
	8/10/2006	115	0.85	97	0.9	102
	7/15/2005	115	0.85	97	0.9	102
	9/3/2005	114	0.85	96	0.9	102
Edison	8/28/2006	141	0.88	124	0.9	126
	7/5/2007	138	0.88	122	0.9	123
	6/26/2006	135	0.88	119	0.9	120
	6/24/2006	135	0.88	119	0.9	120
	6/23/2006	134	0.88	118	0.9	119
	8/22/2006	130	0.88	114	0.9	116
	9/6/2006	129	0.88	114	0.9	115
	7/21/2006	129	0.88	114	0.9	115
	9/5/2006	126	0.89	112	0.9	112
	9/13/2006	125	0.89	111	0.9	111
Fresno-1st_Street	6/24/2006	138	0.77	106	0.9	124
	7/27/2005	134	0.8	106	0.9	121
	7/15/2005	131	0.8	104	0.9	118
	7/15/2006	130	0.8	103	0.9	117
	7/16/2005	128	0.8	102	0.9	115
	7/20/2006	127	0.8	101	0.9	114
	6/23/2006	126	0.8	100	0.9	113
	7/26/2006	124	0.8	99	0.9	112
	7/16/2006	123	0.8	98	0.9	111
	7/17/2005	122	0.8	97	0.9	110
Fresno-Drummond_Stre	6/23/2006	121	0.83	100	0.9	109
	7/15/2005	119	0.83	98	0.9	107
	7/20/2006	114	0.84	96	0.9	102
	9/6/2007	110	0.84	93	0.9	99
	7/27/2005	108	0.84	91	0.9	97
	6/24/2006	106	0.87	92	0.9	95
	8/6/2005	105	0.87	91	0.9	94
	7/16/2005	105	0.87	91	0.9	94
	7/24/2005	103	0.87	89	0.9	92
	7/1/2005	103	0.87	89	0.9	92

Site	Date	Obs	Band RRF	Band RRF 2017 DV	Single RRF	Single RRF 2017 DV
Fresno-Sierra_Skypar	9/2/2005	129	0.78	101	0.89	114
	6/23/2006	129	0.78	101	0.89	114
	7/15/2005	126	0.78	98	0.89	111
	6/24/2006	124	0.78	97	0.89	110
	7/20/2006	123	0.81	99	0.89	109
	7/13/2005	116	0.81	93	0.89	103
	7/16/2005	114	0.81	92	0.89	101
	8/6/2005	112	0.81	90	0.89	99
	9/22/2005	111	0.81	89	0.89	98
	7/27/2005	111	0.81	89	0.89	98
Hanford-S_Irwin_Stre	6/23/2006	127	0.83	105	0.89	113
	7/15/2005	120	0.84	101	0.89	107
	9/2/2005	112	0.84	94	0.89	99
	7/27/2005	110	0.84	92	0.89	98
	7/22/2006	110	0.84	92	0.89	98
	8/6/2005	105	0.87	91	0.89	93
	7/6/2007	102	0.87	88	0.89	91
	9/30/2005	101	0.87	87	0.89	90
	7/5/2007	100	0.87	86	0.89	89
	7/26/2006	99	0.87	85	0.89	88
Madera-Pump_Yard	6/23/2006	113	0.85	95	0.89	100
	6/24/2006	105	0.85	89	0.89	93
	7/10/2006	101	0.85	85	0.89	89
	9/12/2006	95	0.87	82	0.89	84
	9/2/2005	95	0.87	82	0.89	84
	9/7/2006	94	0.87	81	0.89	83
	7/26/2005	92	0.87	79	0.89	81
	7/20/2006	92	0.87	79	0.89	81
	7/6/2007	91	0.87	78	0.89	80
	6/22/2006	91	0.87	78	0.89	80
Maricopa-Stanislaus_	6/24/2006	104	0.83	86	0.88	91
	7/27/2005	102	0.83	85	0.88	89
	6/23/2006	101	0.83	84	0.88	89
	7/15/2005	100	0.83	83	0.88	88
	9/29/2006	98	0.83	81	0.88	86
	7/28/2005	98	0.83	81	0.88	86
	10/1/2005	97	0.83	81	0.88	85
	9/7/2007	97	0.83	81	0.88	85
	9/1/2005	97	0.83	81	0.88	85
	7/16/2005	97	0.83	81	0.88	85

Site	Date	Obs	Band RRF	Band RRF 2017 DV	Single RRF	Single RRF 2017 DV
Merced-S_Coffee_Aven	7/5/2007	105	0.85	89	0.9	94
	7/6/2007	103	0.85	89	0.9	92
	7/21/2006	102	0.85	87	0.9	91
	9/6/2007	100	0.85	85	0.9	90
	7/14/2005	100	0.85	85	0.9	90
	6/19/2007	99	0.85	84	0.9	89
	8/12/2005	98	0.85	83	0.9	88
	7/20/2006	98	0.85	83	0.9	88
	6/30/2005	98	0.85	83	0.9	88
	7/19/2006	97	0.85	82	0.9	87
Modesto-14th_Street	7/21/2006	120	0.86	103	0.94	112
	7/26/2005	115	0.86	98	0.94	107
	8/10/2006	113	0.86	97	0.94	105
	7/16/2005	109	0.88	95	0.94	102
	6/24/2006	108	0.88	95	0.94	101
	6/30/2005	107	0.88	94	0.94	100
	7/26/2006	106	0.88	93	0.94	99
	7/18/2006	105	0.88	92	0.94	98
	7/14/2005	105	0.88	92	0.94	98
	8/23/2005	103	0.88	90	0.94	96
Oildale-3311_Manor_S	9/13/2006	118	0.85	100	0.87	103
	9/6/2006	117	0.85	99	0.87	102
	6/23/2006	114	0.85	96	0.87	99
	7/14/2006	112	0.85	95	0.87	97
	7/5/2007	112	0.85	95	0.87	97
	7/22/2006	110	0.86	94	0.87	96
	6/24/2006	110	0.86	94	0.87	96
	8/23/2006	109	0.86	93	0.87	95
	7/16/2005	109	0.86	93	0.87	95
	9/12/2006	108	0.86	92	0.87	94
Parlier	6/23/2006	131	0.79	103	0.87	114
	7/27/2005	125	0.79	98	0.87	109
	7/16/2005	124	0.79	98	0.87	108
	9/13/2006	121	0.81	97	0.87	105
	7/19/2006	121	0.81	97	0.87	105
	6/24/2006	121	0.81	97	0.87	105
	7/8/2006	120	0.81	96	0.87	104
	7/26/2006	119	0.81	95	0.87	104
	9/2/2006	118	0.81	95	0.87	103
	7/16/2006	118	0.81	95	0.87	103

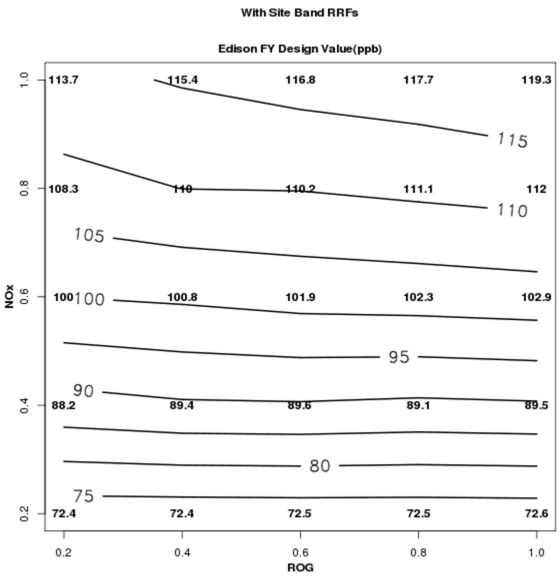
Site	Date	Obs	Band RRF	Band RRF 2017 DV	Single RRF	Single RRF 2017 DV
Sequoia_and_Kings_C	7/16/2005	127	0.87	110	0.87	110
	7/19/2005	123	0.87	106	0.87	107
	7/18/2005	119	0.87	103	0.87	103
	9/13/2006	118	0.87	102	0.87	102
	6/21/2006	117	0.86	100	0.87	101
	8/23/2006	116	0.86	100	0.87	100
	7/19/2006	116	0.86	100	0.87	100
	7/4/2007	116	0.86	100	0.87	100
	6/13/2007	116	0.86	100	0.87	100
	9/7/2007	114	0.86	98	0.87	99
Sequoia_Natl_Park-Lo	7/16/2005	119	0.87	103	0.87	103
	7/18/2005	115	0.87	100	0.87	100
	6/24/2006	115	0.87	100	0.87	100
	6/23/2006	113	0.87	98	0.87	98
	7/19/2005	112	0.87	97	0.87	97
	7/16/2006	111	0.87	96	0.87	96
	6/21/2006	111	0.87	96	0.87	96
	7/20/2005	109	0.87	94	0.87	94
	6/13/2007	109	0.87	94	0.87	94
	7/21/2005	108	0.87	93	0.87	94
Shafter-Walker_Stre	7/5/2007	111	0.86	95	0.88	97
	6/23/2006	106	0.83	88	0.88	93
	9/13/2006	105	0.83	87	0.88	92
	6/22/2006	105	0.83	87	0.88	92
	7/27/2005	104	0.83	86	0.88	91
	6/14/2005	104	0.83	86	0.88	91
	9/6/2006	103	0.83	86	0.88	90
	7/17/2006	103	0.83	86	0.88	90
	7/20/2006	102	0.83	85	0.88	89
	7/14/2005	101	0.83	84	0.88	89
Stockton-Hazelton_St	7/25/2006	109	0.85	92	0.92	99
	7/21/2006	105	0.85	88	0.92	96
	6/23/2006	102	0.85	86	0.92	93
	7/18/2006	101	0.85	85	0.92	92
	7/4/2005	99	0.87	86	0.92	90
	7/26/2005	97	0.87	84	0.92	88
	7/26/2006	96	0.87	83	0.92	87
	7/13/2005	96	0.87	83	0.92	87
	6/26/2006	95	0.87	82	0.92	87
	7/16/2006	94	0.87	82	0.92	86

Site	Date	Obs	Band RRF	Band RRF 2017 DV	Single RRF	Single RRF 2017 DV
Turlock-S_Minaret_St	7/21/2006	113	0.88	99	0.92	103
	6/24/2006	111	0.88	97	0.92	101
	6/23/2006	106	0.88	93	0.92	97
	7/22/2006	104	0.88	91	0.92	95
	7/25/2006	103	0.88	90	0.92	94
	7/20/2006	103	0.88	90	0.92	94
	7/19/2006	103	0.88	90	0.92	94
	7/26/2006	102	0.88	90	0.92	93
	6/25/2006	102	0.88	90	0.92	93
	7/6/2007	101	0.88	89	0.92	92
Visalia-N_Church_Str	7/27/2005	117	0.84	98	0.86	101
	7/8/2006	116	0.84	97	0.86	100
	7/16/2005	114	0.84	96	0.86	98
	7/15/2005	112	0.84	94	0.86	96
	7/9/2006	112	0.84	94	0.86	96
	8/11/2006	110	0.84	92	0.86	94
	7/16/2006	110	0.84	92	0.86	94
	10/1/2005	109	0.84	92	0.86	94
	7/24/2006	109	0.84	92	0.86	94
	6/14/2005	109	0.84	92	0.86	94

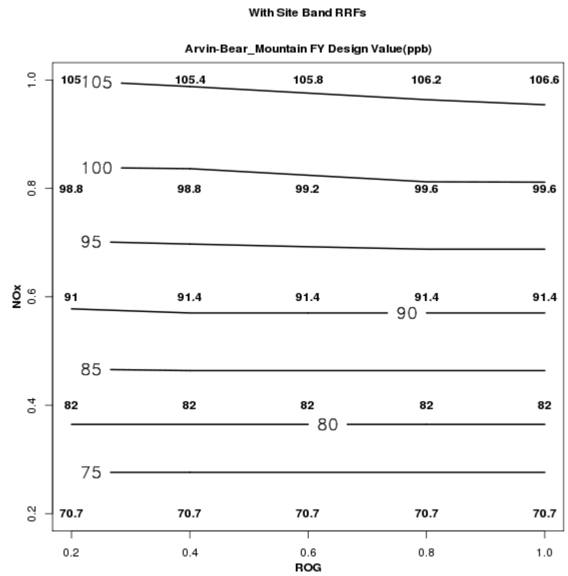
6.3 Carrying Capacity Diagrams

This section presents 2017 carrying capacity diagrams (Figure 23) for the sites listed in **Table 3**. Each plot shows the domain-wide anthropogenic ROG (x-axis) and NOx (y-axis) emissions in 2017 as fractions of the 2007 emissions. It is assumed that biogenic ROG remained constant between 2007 and 2017. Band-RRFs (see Chapter 2 of the *2013 Plan for the Revoked 1-hour Ozone Standard*) were applied to each fractional ROG and NOx combination on the diagram to calculate the future DV for that point. The top right point on each diagram is the projected DV for the attainment demonstration. The isopleths in the diagrams show that future ozone concentrations throughout the SJV are predicted to be strongly sensitive to NOx reductions and negligibly sensitive to ROG reductions.

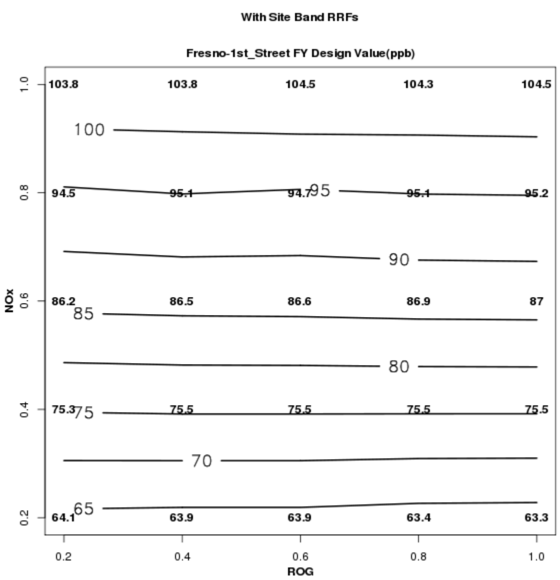
Figure 23. ROG and NOx Carrying Capacity in 2017 for Sites in the SJV



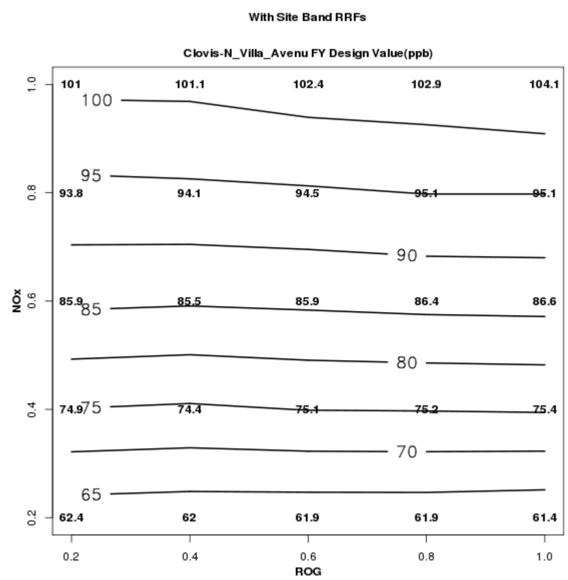
Edison



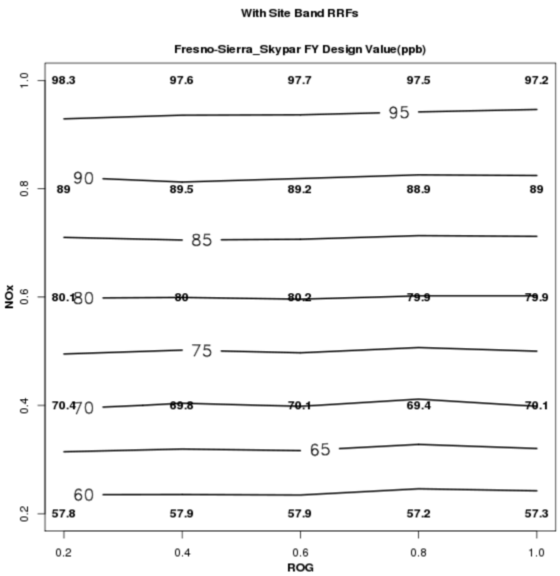
Arvin – Bear Mountain Blvd



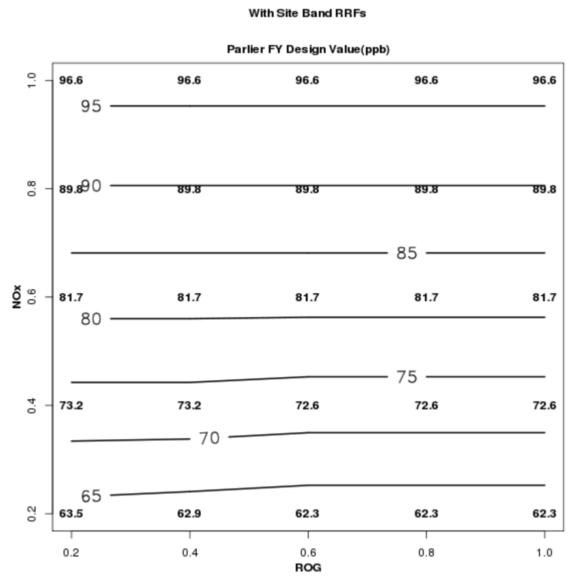
Fresno – 1st Street



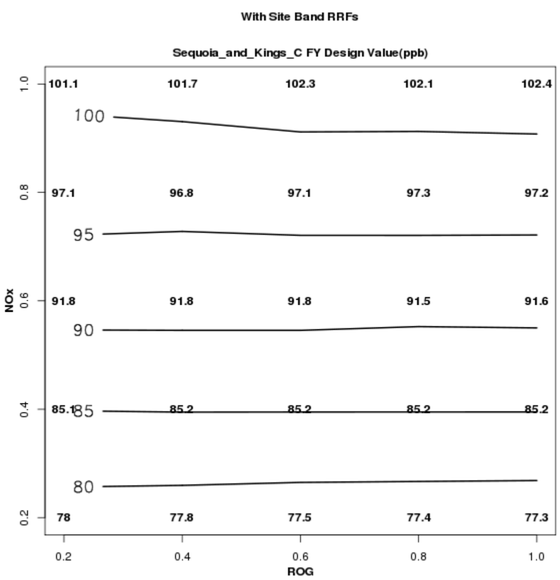
Clovis – North Villa Avenue



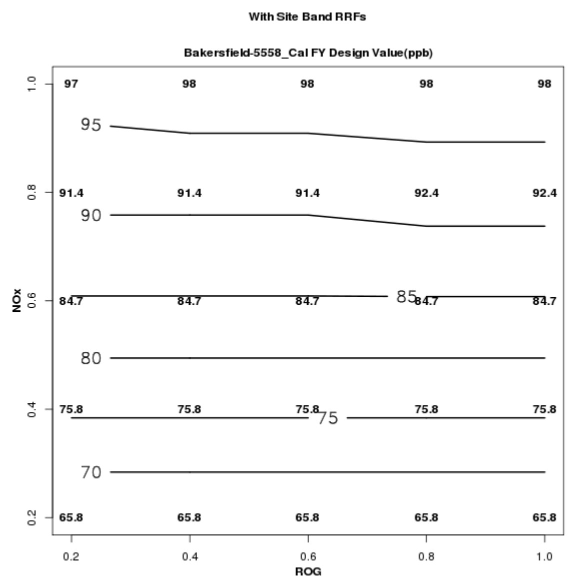
Fresno – Sierra Skypark



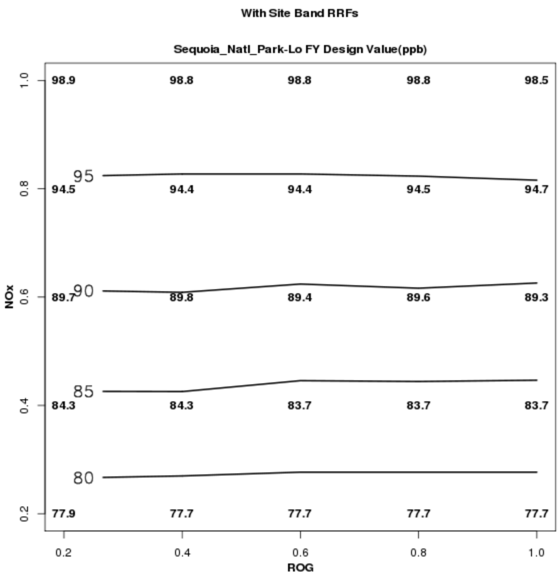
Parlier



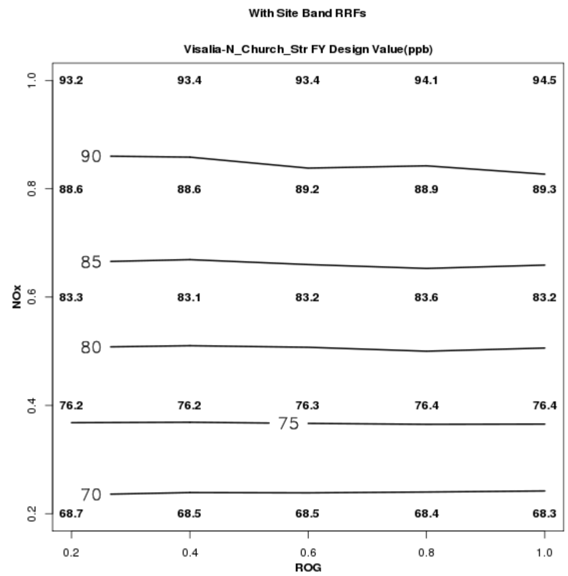
Sequoia and Kings Canyon



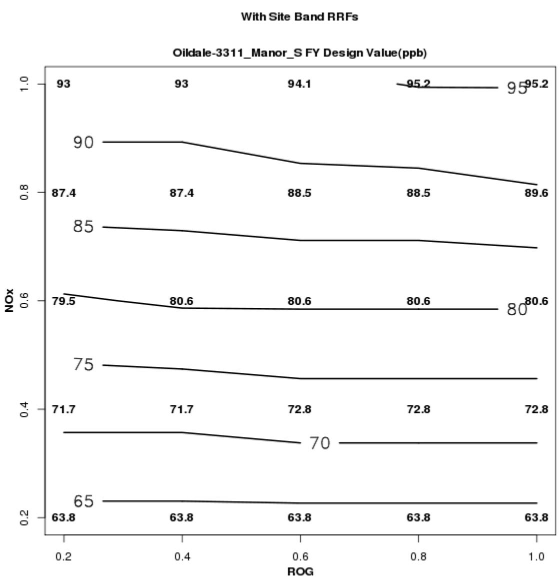
Bakersfield – California Avenue



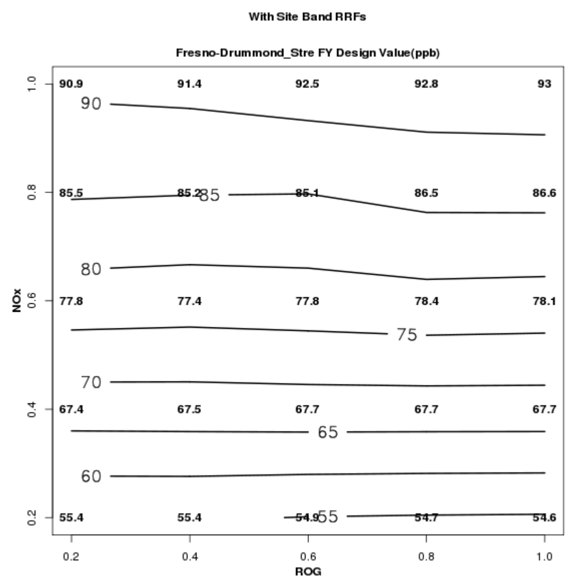
Sequoia Natl Park – Lower Kaweah



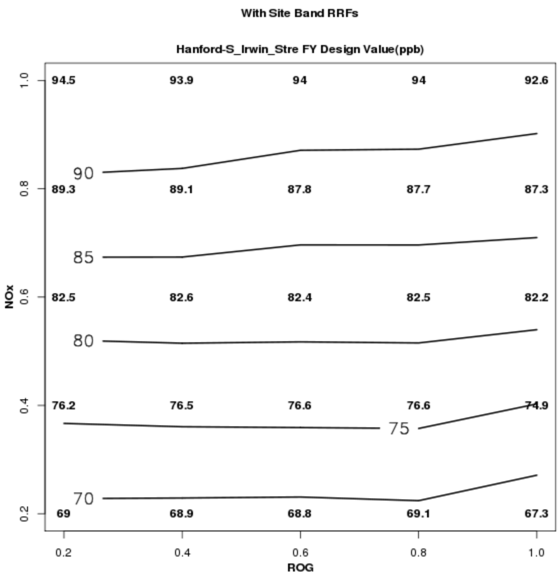
Visalia – North Church Street



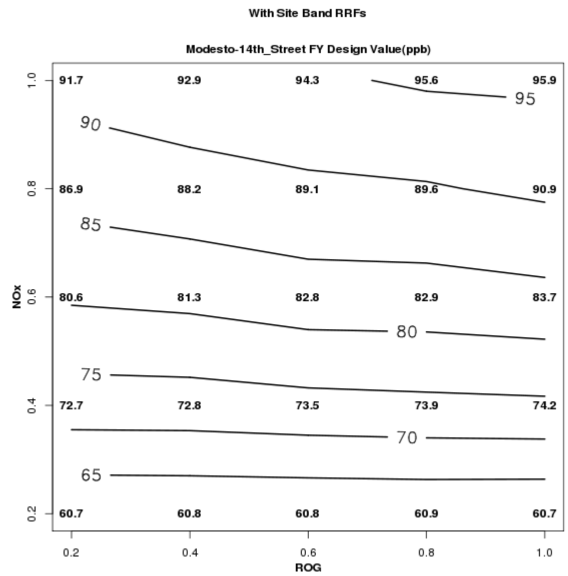
Oildale – Manor Street



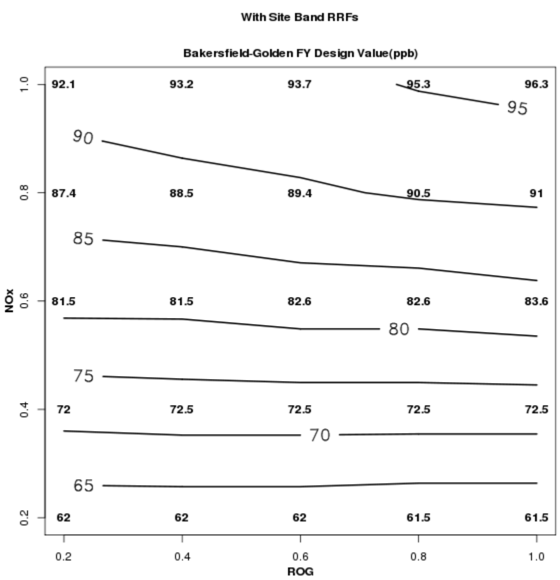
Fresno – Drummond Street



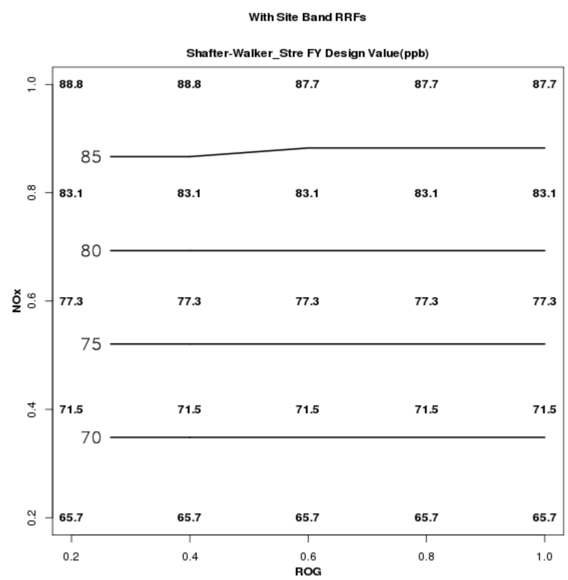
Hanford – S. Irwin Street



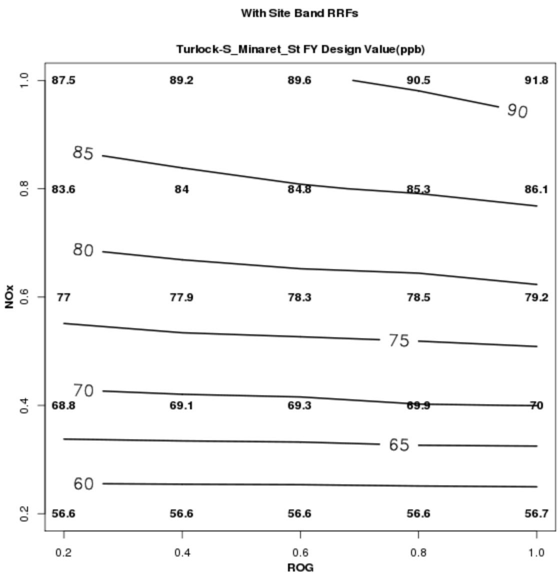
Modesto – 14th Street



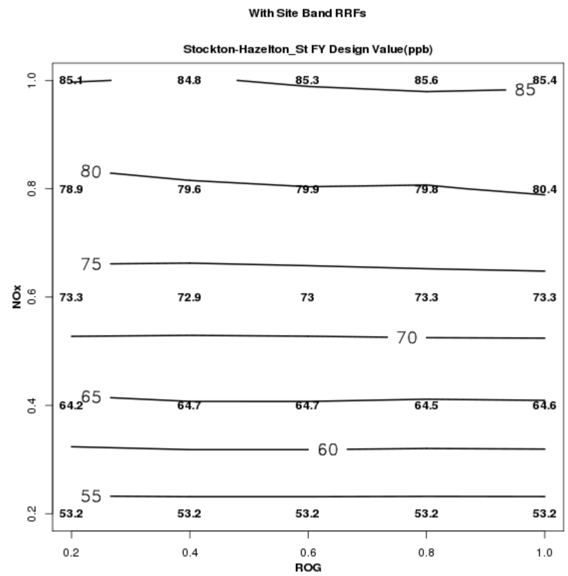
Bakersfield – Golden State Highway



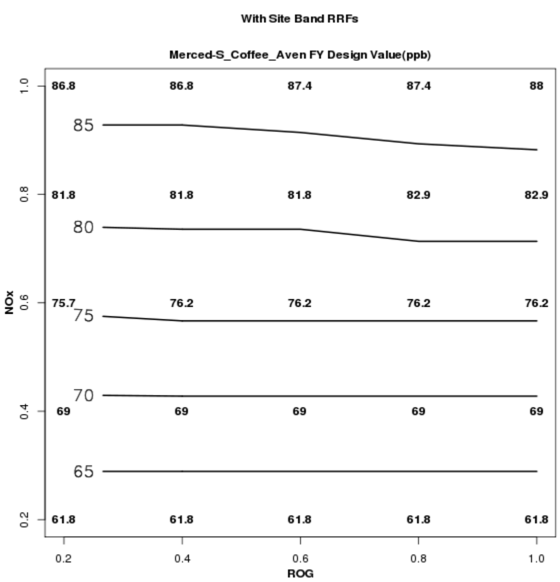
Shafter – Walker Street



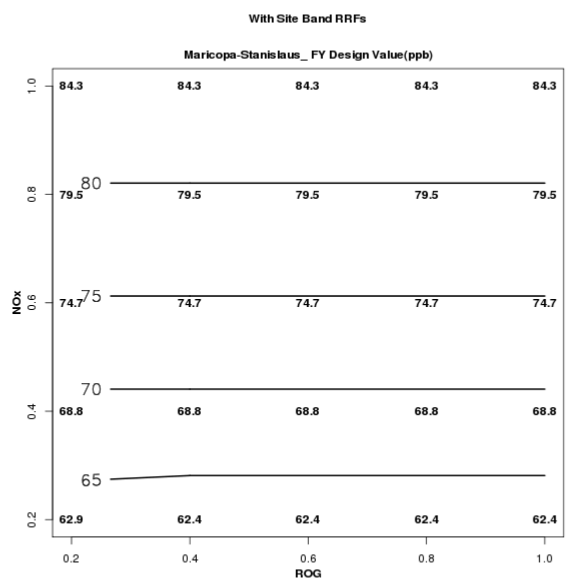
Turlock – S. Minaret Street



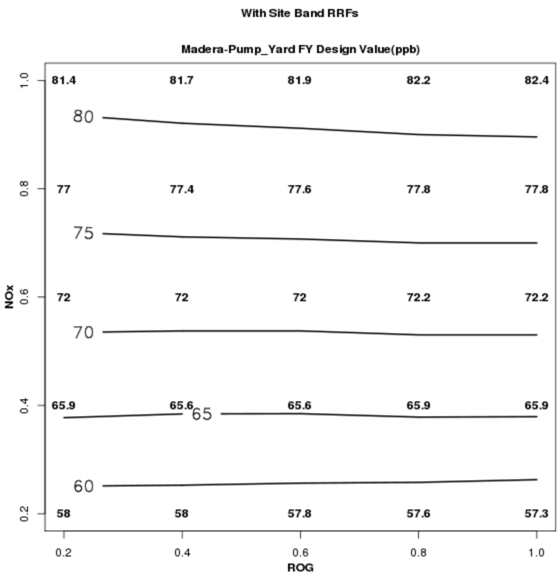
Stockton – Hazelton Street



Merced – S. Coffee Avenue



Maricopa – Stanislaus Street



Madera – Pump Yard

7 Summary

The San Joaquin Valley is nearing attainment of the 1-hour ozone standard. An attainment demonstration based on photochemical simulation modeling and corroborating analyses of ambient air quality and emissions data combine to establish a WOE demonstration that the SJV is predicted to attain the standard by 2017.

Trends for multiple indicators of ozone air quality have shown progress in the SJV, with a decrease in the basin-wide DV of 20% since 1995, and greater than 90% reduction in Exceedance Days. Today, only three sites have DVs above the standard, and these sites have recorded three or fewer exceedances in the last few years.

Of the remaining sites still above the standard, there has been some indication of a plateau in ozone concentrations over the last few years in the Fresno region. Ozone trends in the SJV have included periodic plateaus in the past, embedded within a longer term trend of overall decreases in ozone. These plateaus can occur due to year to year variability in weather conditions, as well the incremental pace of emission reductions in different ozone precursors.

Evaluation of a number of air quality and emissions indicators, however, suggests that ozone levels in the Valley should become increasingly responsive to the NOx reductions that will be occurring between now and 2017. Between 2007 and 2017, NOx reductions are set to decline steadily for a total reduction of more than 50%.

The air quality modeling was evaluated using several different approaches to estimate future 1-hour ozone DVs. Both the single RRF and band RRF approaches predict that the highest basin-wide DV in 2017 will be below the 1-hour standard. The results of modeling carrying capacity diagrams also indicate that ozone in the SJV is NOx-limited, and thus the continuing NOx reductions from ARB and District control programs will be the most important contributor to achieving the 1-hour ozone standard in the SJV.

This section intentionally left blank.

Appendix G-1: Methodology Used to Impute Values for Missing Data

INTRODUCTION

The State Implementation Plan for the 1-hour Ozone NAAQS in the San Joaquin Valley Air Basin included a Weight-of-Evidence Analysis that depended in part on imputed values that replaced missing data.

Two key analyses for which imputed data were used are:

1. Estimation of the 2011 design value for the Arvin – Bear Mountain monitoring site, where three months of the 2011 ozone season were missing, and
2. Preparation of met-adjusted ozone trends from 1996 – 2011, where large amounts of missing data for ozone and for several meteorological parameters were imputed.

The performance of the I-Bot method for ozone at Arvin – Bear Mtn. is shown graphically at the end of this document.

The imputation methodology was developed by ARB staff and subjected to expert external review. A limited discussion of the method is given here, and a manuscript for publication is in preparation at this time.

What methodology was used to produce "imputed" values?

ARB staff developed a method of imputing values, called I-Bot, that is tailored to the situation where missing data come from a network of environmental monitors.

The I-Bot method has been reviewed by Dr. Robert Harley (UC Berkeley), Dr. David Rocke (UC Davis), and Dr. Charles Blanchard (ENVAIR) who were engaged through Central California Ozone Study funds for this purpose. Their consensus review was positive, and each offered possible improvements, some of which have already been incorporated. All reviewers suggested that the method be published, and a manuscript is in preparation.

What are imputed values and how are they created?

Every data source is imperfect, so some data are almost always missing for any extended period of time. For example, a monitor may begin operating after the start of the period of interest. A monitor, such as the ozone monitor at Arvin – Bear Mtn., may stop operating before the end of the period of interest. A monitor may collect some bad data that QA/QC checks then delete. Additionally, a power outage may cause hours or days of missing data.

Imputed values are estimates of what should have or would have been measured. Imputed values done well can be very valuable. Many imputation methods have been invented to fit different situations.

The I-Bot method is tailored to impute values for missing data in datasets that come from networks of environmental monitors. Because ARB staff uses data from air monitoring networks and from networks of meteorological instruments, a method (I-Bot) suited to these situations was developed.

Why does the I-Bot method work?

Nearby monitors tend to share a common context, such as meteorological conditions and emissions due to the activities of humanity and of nature. Nearby air quality monitors tend to be receptors for emissions from similar source regions. So, readings of a pollutant or a meteorological parameter at nearby monitors tend to be strongly correlated with each other. These connections are often consistent enough to use data from one site to impute accurate values for missing data at another site.

What is the I-Bot method?

The I-Bot system is “context intensive.” That is, an imputed value is based on the relationship between highly relevant data at the target site and highly relevant data at nearby sites. Relevance is usually limited to data within a few years of the current date, in the same season of the year, and around the same time-of-day.

Example context for imputing daily max 1-hour ozone at Fresno – 1st Street on August 1, 2010:

- Consider ozone monitoring sites within 50 km of Fresno – 1st Street
- Consider the season from July 18 to August 15 (+/- 14 days)
- Consider +/- 365 days from each day in the season (+/- 1 year)
- So, there are 86 relevant days (3 years x 29 days/year), less one day, as August 1 is treated as missing = 86 days
- These criteria are defined in a “control” file and can be modified at will

For the 86 days, use the “paired” values at Fresno – 1st Street and at each potential “buddy” site to fit the relationship between them (currently done as a simple linear fit). Pick the strongest linear relationship (largest correlation or smallest uncertainty) and use it together with the measured daily max 1-hour ozone at the corresponding buddy site to impute the missing daily max 1-hour ozone at Fresno – 1st Street on August 1, 2010.

To impute the daily max 1-hour ozone at Fresno – 1st Street on the following day (August 2, 2010), the relevant window moves forward one day and the process starts all over again. Insistence on tight context is what makes the I-Bot method unusual. Results show, for example, that the best buddy site for Fresno – 1st Street can change from one day to the next, and different buddy sites may be preferred during different portions of the ozone season.

Safeguards that minimize unreliable imputations are included in several ways through “control” files. A maximum distance is specified for potential buddy sites. A minimum correlation (or maximum uncertainty) is imposed. A minimum number of data pairs (target with buddy site) must be available. If safeguard limits are not met, the system will not report an imputed value.

What does the I-Bot method produce?

For daily imputations, the I-Bot method produces a dataset that includes the information shown in Table 1. Hourly output includes the hour of the record.

Table 1. Key information contained in I-Bot output

YEAR	MONTH	DAY	OBS	NAME	IMP	SEP	BUD
2003	7	1	0.075	Fresno-1st Street	0.073	0.003	245
2003	7	2	0.09	Fresno-1st Street	0.088	0.003	2
2003	7	3	0.077	Fresno-1st Street	0.071	0.003	2
2003	7	4	0.082	Fresno-1st Street	0.085	0.005	2
2003	7	5	0.087	Fresno-1st Street	0.089	0.005	2
2003	7	6	0.071	Fresno-1st Street	0.07	0.005	2
2003	7	7	0.076	Fresno-1st Street	0.078	0.005	2
2003	7	8	0.081	Fresno-1st Street	0.084	0.005	2
2003	7	9	0.105	Fresno-1st Street	0.103	0.005	2
2003	7	10	0.093	Fresno-1st Street	0.094	0.005	2
2003	7	11	0.091	Fresno-1st Street	0.095	0.005	2
2003	7	12	0.079	Fresno-1st Street	0.082	0.005	2
2003	7	13	0.069	Fresno-1st Street	0.067	0.005	2
2003	7	14	0.096	Fresno-1st Street	0.093	0.005	2
2003	7	15	0.108	Fresno-1st Street	0.123	0.005	246
2003	7	16	0.131	Fresno-1st Street	0.12	0.005	246
2003	7	17	0.105	Fresno-1st Street	0.102	0.005	246
2003	7	18	0.129	Fresno-1st Street	0.117	0.004	246
2003	7	19	0.082	Fresno-1st Street	0.075	0.005	246
2003	7	20	0.102	Fresno-1st Street	0.102	0.005	246
2003	7	21	0.116	Fresno-1st Street	0.114	0.005	246
2003	7	22	0.107	Fresno-1st Street	0.108	0.005	246
2003	7	23	0.095	Fresno-1st Street	0.093	0.005	246
2003	7	24	0.094	Fresno-1st Street	0.099	0.005	246
2003	7	25	0.094	Fresno-1st Street	0.094	0.005	246
2003	7	26	0.095	Fresno-1st Street	0.1	0.005	246
2003	7	27	0.091	Fresno-1st Street	0.093	0.005	246
2003	7	28	0.098	Fresno-1st Street	0.096	0.005	246
2003	7	29	0.127	Fresno-1st Street	0.128	0.005	246
2003	7	30	0.096	Fresno-1st Street	0.096	0.004	246
2003	7	31	0.078	Fresno-1st Street	0.074	0.006	157

OBS = observed daily max 1-hour ozone
IMP = imputed daily max 1-hour ozone
SEP = uncertainty (standard error of prediction)
BUD = Index that identifies the "buddy" site used to determine IMP

The buddy sites and their distances from Fresno – 1st Street are Fresno – Drummond (#2, 9.0 km), Clovis (#157, 6.6 km), Fresno – Fremont School (#245, 5.1 km), and

Fresno – Mobile (#246, 2.4 km). The I-Bot method automatically selects the best available buddy site. Though more distant, Fresno – Drummond was often selected. On July 31, 2003, both Fresno – Drummond and Fresno – Mobile were missing data and could not be used, and Clovis was selected as the best available buddy site.

How well does the I-Bot method work?

The "standard error of prediction" (SEP) values in Table 1 quantify the uncertainty of the imputed values (IMP) based on the statistical modeling. When SEP is divided by IMP, the result is a type of coefficient of variation (CV). Using this CV approach, the relative uncertainty of the imputed values in the table ranges from ~2% to ~6%. The high values tend to be imputed with relatively greater accuracy (~2.5%) compared to the accuracy of the low values (~4.3%).

Taking the measured values (OBS) as a "gold standard", relative errors can be calculated as (IMP – OBS) / OBS. Using this approach, the imputed values in the table above have relative errors from -6% to +10%. The highest 10 observed values were under-predicted on average by 1.1%, while the middle 10 observed values were over-predicted on average by 1.1%.

Comparisons of observed and imputed values are shown in **Figure 24**and **Figure 25**. **Figure 24** presents observed and imputed values for daily maximum 1-hour ozone at Fresno – 1st Street for 2011. **Figure 25** presents observed and imputed values for daily maximum 1-hour ozone at Arvin – Bear Mountain for May – October 2010.

An unusual benefit of the I-Bot method is seen when entire years of data are treated as missing, values are imputed, and the actual and imputed data are compared to the imputed values. This type of evaluation has been done for a variety of pollutants and meteorological parameters, with largely satisfying results.

Weight-of-Evidence analysis for 1-hour and 8-hour ozone in the San Joaquin Valley, have benefited from the use of imputed values that have filled large gaps in the records for some long-term sites, such as Hanford (2008 and 2009) and Arvin – Bear Mountain (2011 and 2012).

Figure 24. Observed and Imputed Values for Daily Max. 1-Hour Ozone at Fresno – 1st Street in 2011 (Open circle = observed and Dot = imputed).

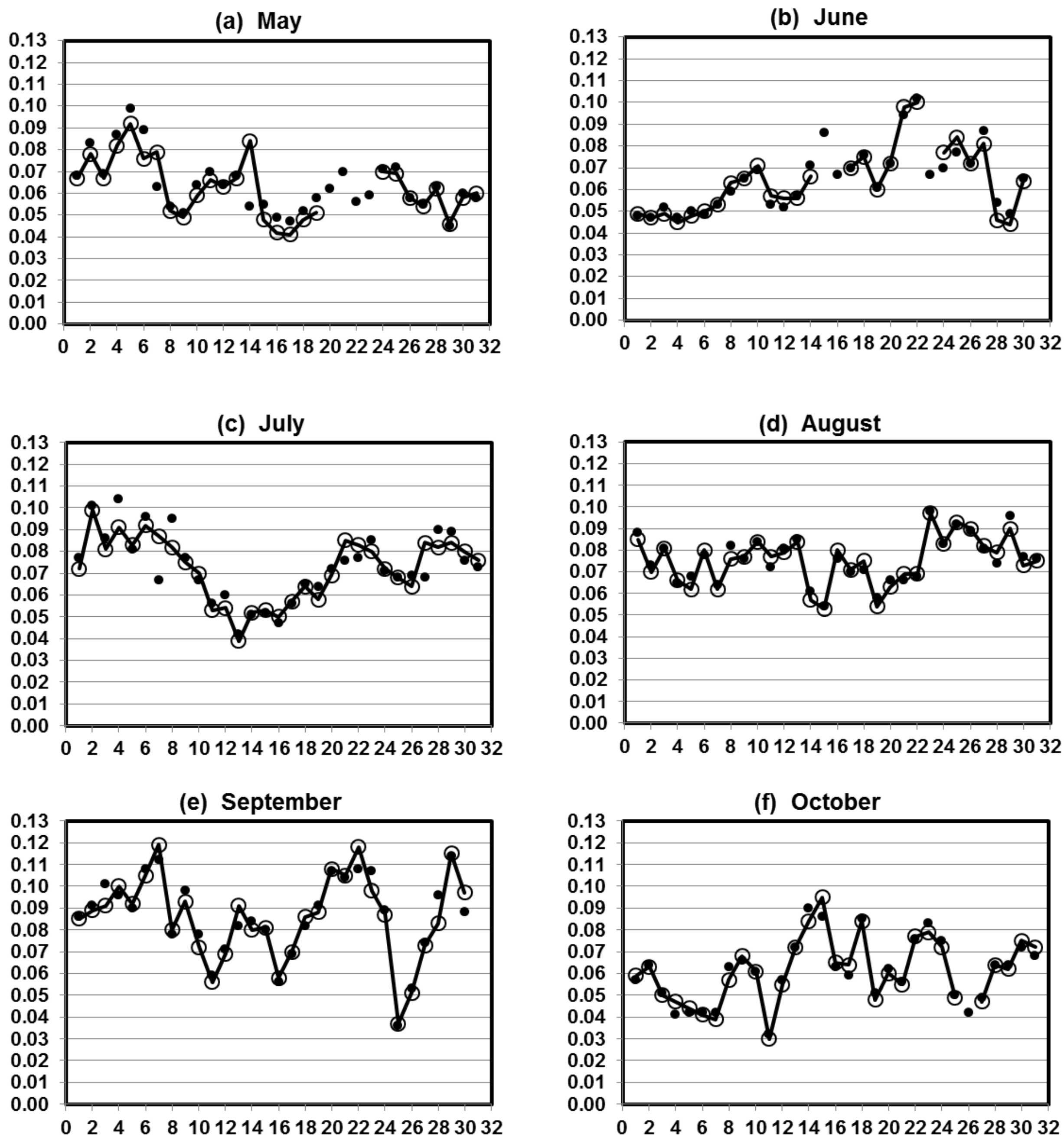
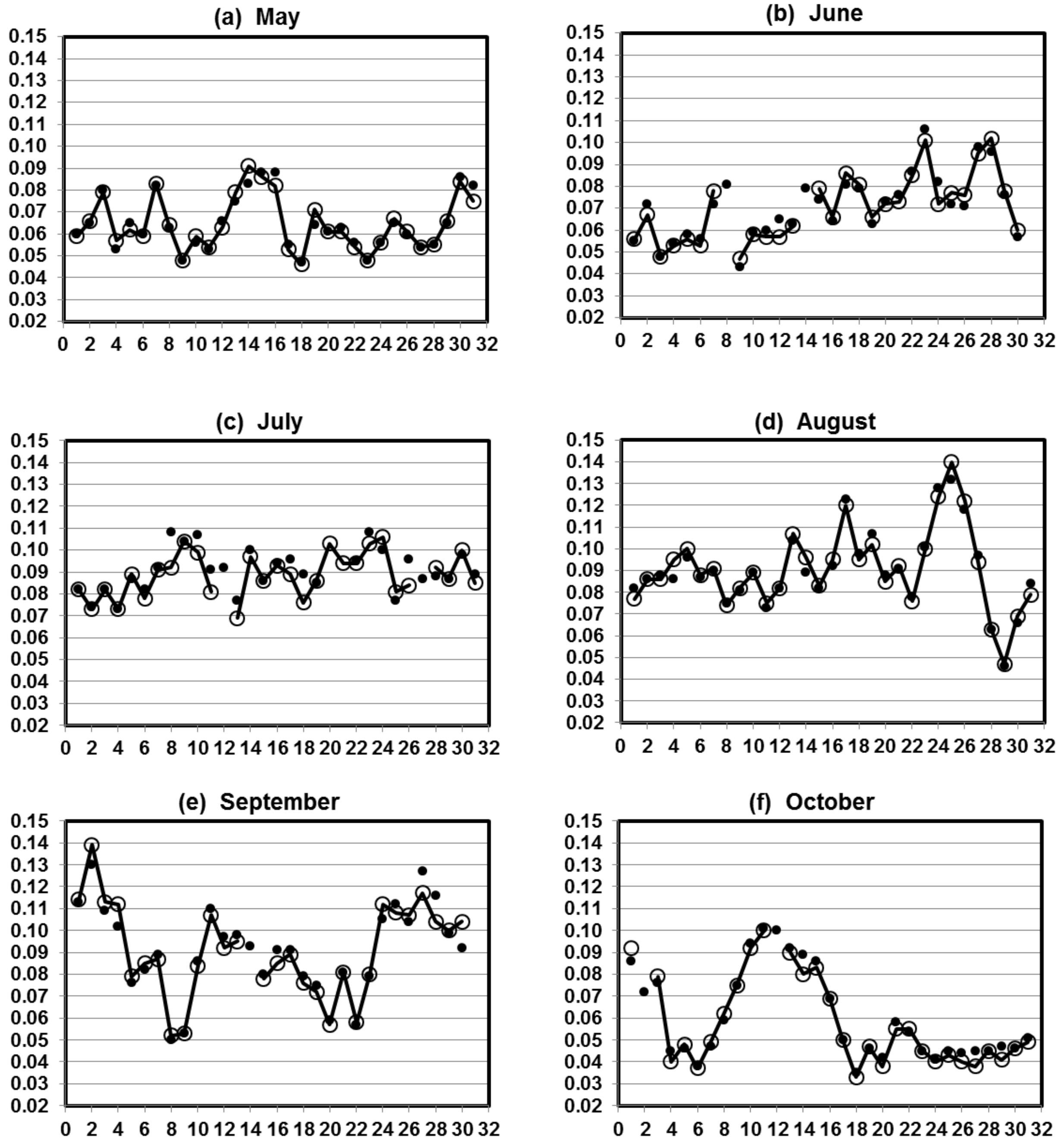


Figure 25. Observed and Imputed Values for Daily Max. 1-Hour Ozone at Arvin – Bear Mountain in 2010 (Open circle = observed and Dot = imputed).



Appendix G-2: Methodology Used to Prepare Meteorologically Adjusted Ozone Trends for the San Joaquin Valley

Introduction

What methodology was used to prepare met-adjusted trends?

Air quality trends that are adjusted to reduce the effects of meteorology as much as possible can be very valuable. When adjusted trends are similar to raw trends, they indicate that the raw trends are likely to reflect changes in emissions. When adjusted and raw trends differ markedly, however, they indicate that the raw trends are affected by both emissions and weather, in which case the adjusted trends are likely to be the better measure of emissions effects.

The effects of meteorological conditions on ozone forming potential (OFP) can be quantified with a wide variety of statistical methods. ARB is an active participant in testing and developing such methods in California. For this work, OFP was quantified in the Central and Southern sub-regions of the SJV using “multiple regression” models. Because OFP does not respond to meteorological parameters the same way for each month of the May through October ozone season, a separate model was prepared for each month. The combined explanatory power (R^2) of the models-in-months approach is shown in Figure 1 for the Central sub-region and in Figure 2 for the Southern sub-region.

The models-in-months were built using the regression procedure (PROC REG) in SAS statistical software. Six meteorological and day-of-week parameters (T850AM, ST_mid6, stability_PM, wsinv, WD, and Sun) from those listed in Table 2 were used in a stepwise model building process for each month. The following control language is an example for fitting models to the data for 2005 – 2007:

```
proc reg data=sjvc_reg_dataset;
  model sjvc = T850AM ST_mid6 stability_PM WD Sun wsinv /
      selection = stepwise maxstep = 12 sle = 0.25 sls = 0.25;
  by month;
  weight w0507;
  output out=sjvc_reg_dataset
        p=pred_wt0507;
run;
```

Figure 26

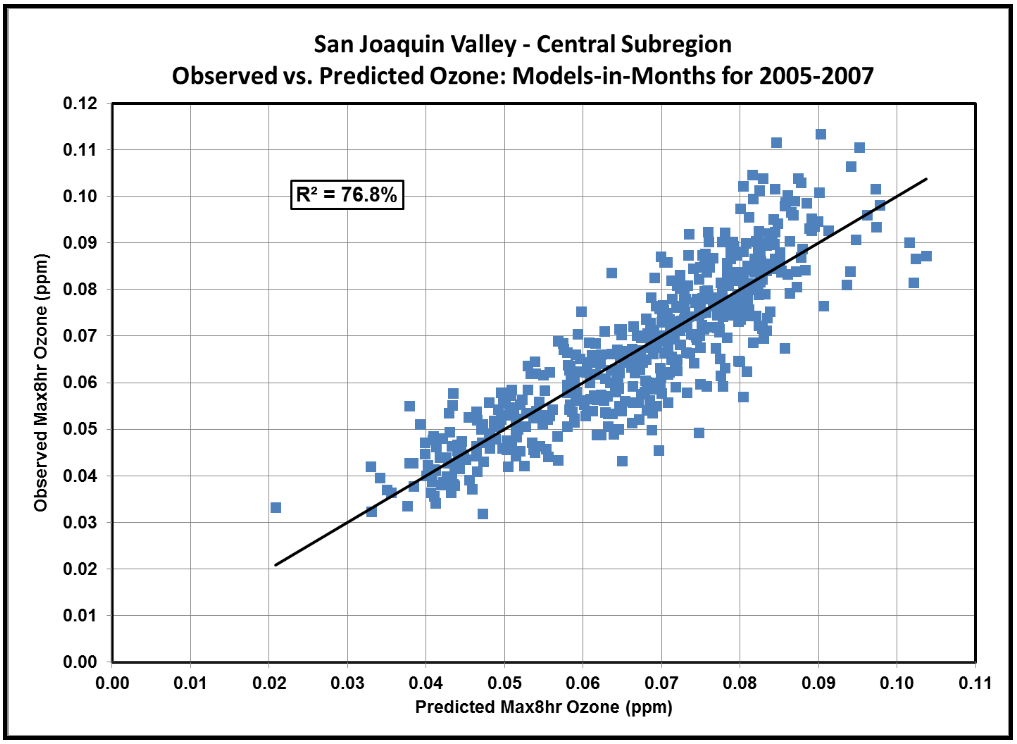


Figure 27

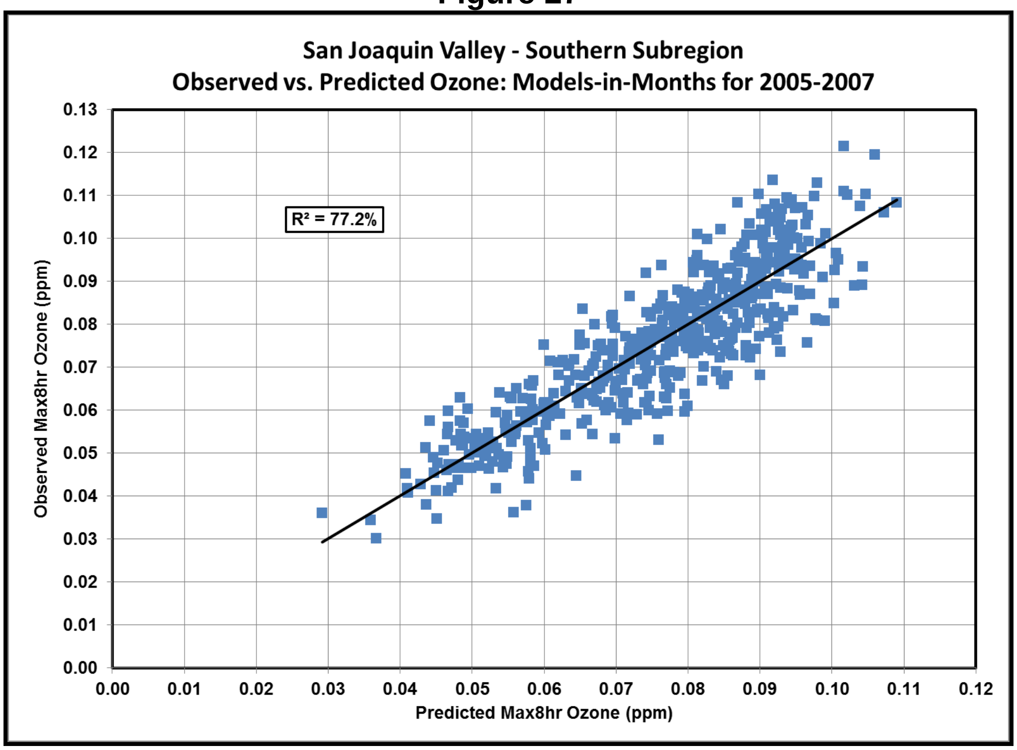


Table 5. Meteorological and day-of-week parameters used in statistical models to quantify daily ozone-forming potential (OFP) in the SJV during selected sets of calibration years.

General category	Particular form of parameter	Identifiers
Surface temperature	**Sub-regional average of site-by-site values for:** **daily minimum temperature** **daily maximum temperature** **average temperature from 10 a.m. to 4 p.m. ***	**ST_min** **ST_max** **ST_mid6**
Temperature aloft	**Oakland Rawinsondes (weather balloons)** **850 mb temperatures at 4 a.m. and 4 p.m.**	**T850AM** **T850PM**
Atmospheric stability	**Temperature difference: Oakland RAOB ** minus Surface** **T850AM - ST_min** **T850PM - ST_mid6**	**stability_AM** **stability_PM**
Wind speed	**Sub-regional average of site-by-site values for:** **average wind speed from 10 a.m. to 4 p.m.** **inverse of (WS_mid6 + 1)**	**WS_mid6** **ws_inv**
Day-of-Week	**Categorical Day-of-Week Average Offsets** **Weekdays (overall average difference)** **Saturday (overall average difference)** **Sunday (overall average difference)**	**WD** **SAT ***** **SUN**

* Indicated times are PST (Pacific Standard Time)
** Rawinsonde (weather ballon)
*** Only WD and SUN were used to avoid numerical instability due to multi-collinearity

Several different sets of years were used to fit the statistical models-in-months. The different sets of years led to similar results, and the years 2005 – 2007 were selected as a recent set of years that were not affected by serious wildfires (2008) and were not affected by serious economic turmoil. The explanatory power of the models-in-months is summarized in Figure 1 (R^2 = 76.8%) for the SJV's Central sub-region and in Figure 2 (R^2 = 77.2%) for the SJV's Southern sub-region. The variables included in the models-in-months are listed in Table 2 in the order of their importance.

Table 6. Variables used for Models-in-Months based on data from 2005 – 2007

Central Sub-region	**May**	**st_mid6, stability_PM, Sunday, wsinv**
	June	**T850AM, wsinv, st_mid6, stability_PM**
	July	**st_mid6, stability_PM, Sunday**
	August	**st_mid6, stability_PM, Weekday, wsinv**
	September	**T850AM, wsinv, st_mid6, stability_PM**
	October	**st_mid6, Weekday, wsinv, T850AM**
Southern Sub-region	**May**	**st_mid6c, T850AM, Sunday, stability_PM, wsinvc, st_mid6** (underlined variables are for the “Central” sub-region)
	June	**st_mid6, wsinvc, stability_PM**
	July	**st_mid6, stability_PM, wsinvc, Sunday**
	August	**st_mid6, stability_PM, wsinv, Sunday, st_mid6c**
	September	**T850AM, wsinv, Weekday, stability_PM, st_mid6, st_mid6c**
	October	**st_mid6, Weekday, wsinvc, wsinv**

The meteorological conditions connected with OFP in each month are summarized in Table 3 for the Central sub-region and in Table 4 for the Southern Sub-region. In each month, the days were split into four “quartile” groups according to increasing OFP, so “ofp1” was the lowest 25% of OFP days, “ofp2” was the next 25% of OFP days, and so on. The average values for the key meteorological variables are given for each OPF group in each month.

Table 7.

OFP Bins for SJV Central: calibrated with 2005 - 2007 Data
Days from 1996 - 2011 (May-Oct) were assigned to the OFP Bins
Bin Means are based on all days (1996 - 2011) that were assigned to the bin

Overall Rank of Bin for OFP	month	OFP Group in Month	OFP (ppm)	ST Central (°C)	Stability PM (°C)	T850 AM (°C)	WS Central (m/s)
2	5	ofp1	0.045	19.8	-14.8	4.5	3.0
8	5	ofp2	0.059	23.8	-13.7	9.5	2.8
12	5	ofp3	0.068	26.9	-13.2	13.3	2.7
20	5	ofp4	0.080	31.5	-12.6	18.3	2.4
5	6	ofp1	0.054	24.3	-13.7	9.8	2.8
11	6	ofp2	0.067	28.3	-13.0	15.1	2.7
16	6	ofp3	0.074	30.7	-12.3	18.1	2.5
21	6	ofp4	0.084	34.1	-12.2	21.7	2.3
7	7	ofp1	0.056	29.1	-12.5	16.4	2.3
13	7	ofp2	0.068	31.6	-11.5	19.8	2.3
17	7	ofp3	0.075	33.3	-11.5	21.9	2.3
24	7	ofp4	0.086	36.0	-11.3	24.6	2.2
10	8	ofp1	0.065	28.5	-12.0	16.0	2.4
15	8	ofp2	0.073	31.1	-12.0	19.1	2.2
19	8	ofp3	0.078	32.8	-11.6	20.7	2.1
22	8	ofp4	0.085	34.9	-11.1	23.5	2.0
4	9	ofp1	0.053	25.1	-12.9	11.7	2.5
14	9	ofp2	0.070	28.8	-11.5	17.2	2.1
18	9	ofp3	0.078	31.3	-11.3	19.7	2.0
23	9	ofp4	0.086	33.2	-10.4	22.5	1.8
1	10	ofp1	0.036	17.8	-9.7	7.4	2.7
3	10	ofp2	0.047	21.7	-10.2	10.9	2.2
6	10	ofp3	0.055	24.6	-9.6	14.8	1.8
9	10	ofp4	0.064	28.3	-10.4	18.2	1.6

ST Surface temperature (average of hours 10 - 16)
WS Wind speed (average of hours 10 - 16)

Table 8.

OFP Bins for SJV South: calibrated with 2005 - 2007 Data
Days from 1996 - 2011 (May-Oct) were assigned to the OFP Bins
Bin Means are based on all days (1996 - 2011) that were assigned to the bin

Overall Rank of Bin for OFP	month	OFP Group in Month	OFP (ppm)	ST Central (°C)	ST South (°C)	Stability PM (°C)	T850 AM (°C)	WS Central (m/s)	WS South (m/s)
2	5	ofp1	0.053	19.9	19.7	-14.8	4.4	3.1	3.0
7	5	ofp2	0.066	24.3	23.9	-14.3	9.6	2.9	2.8
9	5	ofp3	0.075	27.5	27.0	-13.7	13.3	2.9	2.7
18	5	ofp4	0.087	32.1	31.4	-13.2	18.4	2.7	2.4
4	6	ofp1	0.061	24.7	24.2	-14.3	9.9	3.0	2.9
10	6	ofp2	0.075	29.1	28.3	-13.8	15.1	3.0	2.7
15	6	ofp3	0.083	31.6	30.8	-13.1	18.1	2.9	2.5
22	6	ofp4	0.094	35.2	34.0	-13.4	21.5	2.8	2.2
8	7	ofp1	0.074	30.2	29.5	-13.3	16.6	2.7	2.5
13	7	ofp2	0.081	32.7	31.8	-12.8	19.7	2.7	2.3
17	7	ofp3	0.086	34.3	33.2	-12.4	21.7	2.7	2.2
21	7	ofp4	0.093	37.3	35.7	-12.5	24.7	2.8	2.1
12	8	ofp1	0.075	30.0	28.9	-13.7	16.2	2.7	2.3
16	8	ofp2	0.083	32.3	31.3	-13.2	18.7	2.6	2.2
19	8	ofp3	0.089	33.7	32.5	-12.7	20.6	2.5	2.1
23	8	ofp4	0.096	36.4	34.7	-12.3	23.6	2.5	2.0
5	9	ofp1	0.063	25.7	25.2	-13.4	11.8	2.7	2.5
14	9	ofp2	0.082	30.0	29.2	-12.6	17.2	2.4	2.1
20	9	ofp3	0.090	32.0	31.0	-12.1	19.7	2.3	2.0
24	9	ofp4	0.100	34.1	32.9	-11.3	22.4	2.2	1.9
1	10	ofp1	0.043	18.0	17.8	-10.3	6.7	2.9	2.5
3	10	ofp2	0.055	22.3	21.8	-10.6	11.1	2.4	2.2
6	10	ofp3	0.064	25.4	24.6	-10.3	15.0	2.1	1.9
11	10	ofp4	0.075	29.3	28.1	-11.4	18.3	2.0	1.9

ST Surface temperature (average of hours 10 - 16)
WS Wind speed (average of hours 10 - 16)

After the models were fitted, every day of the ozone seasons for 1996 through 2011 had a model-predicted value for daily maximum 8-hour ozone along with the measured value. The predicted values represent the ozone that would occur with each day's meteorological conditions if emissions were kept at the levels that prevailed during the calibration years, 2003 – 2005.

For each month, the predicted values for all years were combined to produce a "standardized" set of values for the month, from low to high. For example, June would have 30 values taken at equal intervals through the distribution of the combined set of predicted values for June.

Then for a given year, each month's set of predicted values (sorted from low to high) was compared to that month's respective standardized values. For each pair, the difference between the standardized value and the specific value (standard – specific) was added to the measured daily max 8-hour ozone value to calculate that day's met-adjusted 8-hour ozone.

When met-adjusted daily values had been calculated for all days, trend statistics could be based on the data as measured to produce raw trends and on the data as adjusted to produce met-adjusted trends.

Appendix G-3: Methodology Used to Evaluate the Ozone Weekend Effect in the San Joaquin Valley

Introduction

This appendix addresses the methodology used to evaluate the ozone weekend effect (WE) in the San Joaquin Valley (SJV).

What is the Ozone Weekend Effect?

The WE is a well-known phenomenon in some major urbanized areas where emissions of ozone precursors are substantially lower on weekends than on weekdays, but measured levels of ozone are significantly higher on weekends than on weekdays. Though common, the WE is not the same in all urban areas of the state. As of 2010, the WE has all but disappeared in the Central and Southern sub-regions of the SJV.

Analytical Method for Ozone Weekend Effect

The analytical method was applied to the ozone data for each site separately. The method was designed to emphasize systematic day-of-week effects and to eliminate some of the values at each end of the distribution of differences from one day to the next, as such differences tend to represent large shifts in meteorology (e.g., passage from low pressure to high pressure, or from one transport direction to a very different direction) rather than systematic day-of-week emissions of ozone precursors. This approach is a special case of the well-known “trimmed mean” concept, adapted to emphasize typical day-of-week differences in measured ozone levels.

Therefore, sequential (day-to-day) differences in daily maximum 1-hour ozone were calculated for each site. The differences were then sorted from smallest to largest (or most negative to most positive). Major holidays were excluded because they do not behave like “normal” days, so Memorial Day, July 4th, and Labor Day were removed from each year before sequential differences were calculated. Within each month and for each day-of-week transition (e.g., Monday to Tuesday), the dates of the lowest 4 and the highest 4 differences were discarded, so the remaining days represented typical behavior with respect to the previous day. Using the typical days, average ozone by day-of-week was calculated for each month, and monthly average ozone was calculated from the day-of-week averages, so each day of the week was equally represented.

For the seasonal, May-October, results shown in Table 2 of Appendix G, day-of-week values were averaged over the six months, and the “ozone weekend effect” is the percent of the weekend average (Sunday and Saturday) with respect to the weekday average (Monday through Friday).