APPENDIX F
Weight of Evidence (WOE)

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F. Weight of Evidence (WOE)

F.1. Introduction

The air districts of the Sacramento Federal Ozone Nonattainment Area (SFNA) are the Sacramento Metropolitan Air Quality Management District (SMAQMD), Yolo-Solano Air Quality Management District (YSAQMD), Placer County Air Pollution Control District (PCAPCD), El Dorado County Air Quality Management District (EDCAQMD), and Feather River Air Quality Management District (FRAQMD). Each district manages the part of the nonattainment area that lies within its jurisdiction. Because the area could not meet the attainment date for the serious classification, as part of this State Implementation Plan (SIP), the SFNA air districts requested to voluntarily reclassify to a severe nonattainment area for the 0.070 parts per million (ppm) federal 8-hour ozone standard (0.070 ppm standard) with a 2032 attainment deadline (CARB, 2022). For areas classified as moderate nonattainment or above, photochemical modeling is a required element of the SIP to ensure that existing and planned control strategies provide the reductions needed to meet the 0.070 ppm standard by the attainment deadline.

To address the uncertainties inherent to modeling assessments, the United States Environmental Protection Agency (EPA) guidance, *Modeling Guidance for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze (EPA, 2018),* recommends that supplemental analyses accompany all modeled attainment demonstrations. Accordingly, to supplement the regional photochemical modeling analyses, the SFNA air districts and California Air Resources Board (CARB) prepared the following Weight of Evidence (WOE) demonstration, which includes area description, a conceptual model with detailed analyses of anthropogenic emissions, monitored ambient ozone data and concentration trends, and population exposure trends. Analyses of the number of exceedances on weekends versus weekdays and meteorological patterns coincidence with elevated ozone in three subregions within the SFNA are also presented.

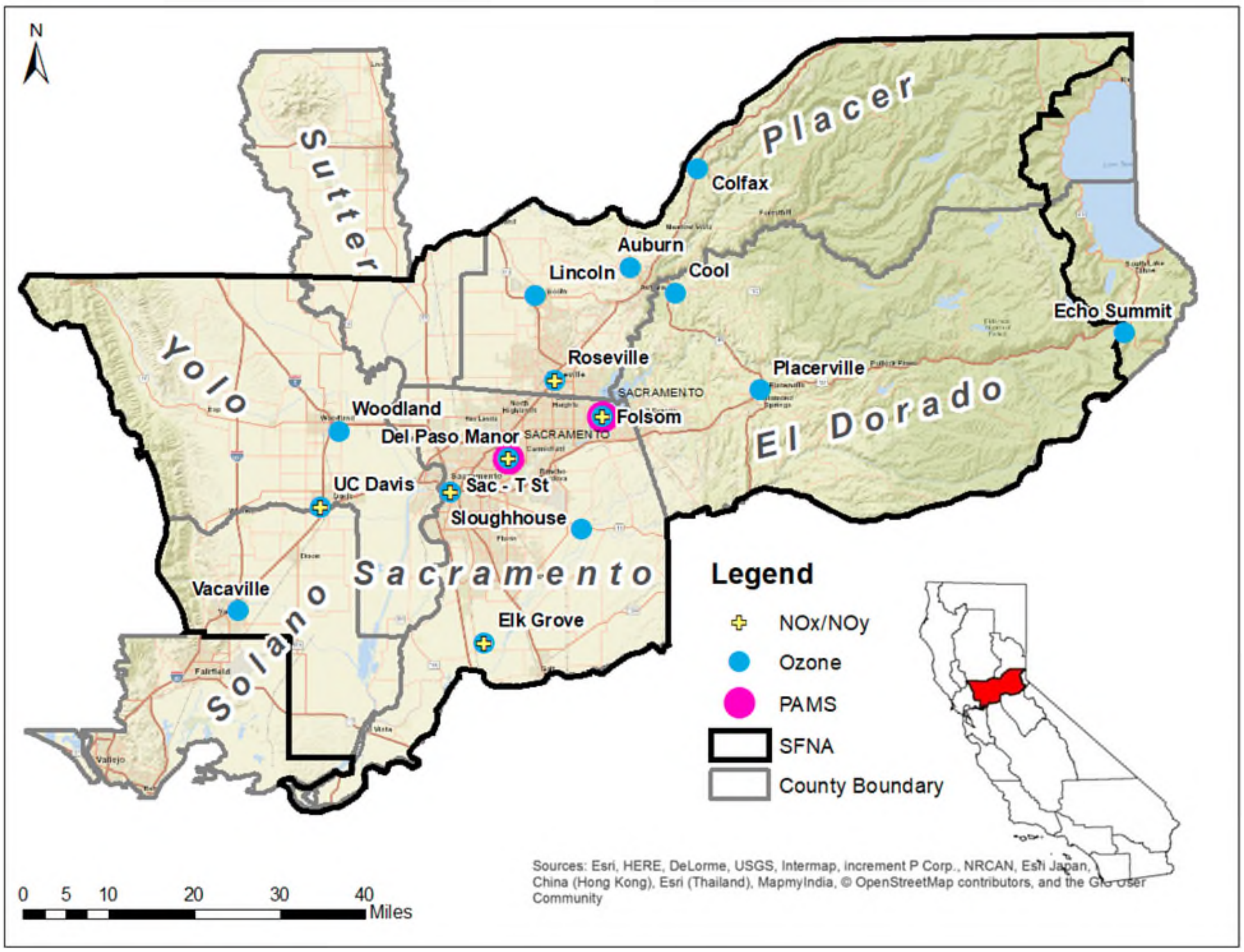
In 2021, as shown in Table F-1, data indicate that 6 out of 16 monitoring sites in the SFNA were in attainment with the 0.070 ppm standard and the design values exceeded the 0.070 ppm standard at the remaining monitoring sites by 1 to 17 percent. Photochemical modeling analyses conducted by the CARB demonstrate that control measures currently in place and the proposed measures in the 2022 State SIP Strategy are adequate for all sites in the SFNA to meet the 0.070 ppm standard by the 2032 attainment deadline.

Analyses of air quality data from the past 22 years show that progress is being made at all monitoring sites in the Sacramento region. However, the extent of progress varies considerably by site and by indicator. The presence of varied terrain, persistent summertime climatological patterns, and diverse precursor emission sources highlights the complex nature of the ozone problem in the SFNA and underscores the utility of examining multiple indicators.

F.2. Area Description

The SFNA encompasses all of Sacramento and Yolo Counties; the northeastern half of Solano County, the southern portion of Sutter County, and large portions of Placer and El Dorado Counties on the eastern side of the region (Figure F-1[1]). Topographically, the SFNA is located at the southern end of the north-to-south running Sacramento Valley and stretches from the Coastal Range Mountains in the west to the crest of the Sierra Nevada Mountains in the east. The SFNA encompasses an area of nearly 7,000 square miles, with elevations ranging from near sea level in the southwestern Sacramento River Delta (the Delta) portion of the region to over 7,000 feet above sea level in the east.

Figure F-1 Location of Monitoring Sites in the SFNA as of 2021



The SFNA is home to nearly 2.5 million people, based on the 2020 U.S. Census, and is located at the intersection of three major highways in northern California, namely Interstate 80, Interstate 5, and State Route 99. Consequently, the movement of goods and people is a significant source of emissions in the region. As shown in Figure F-1, the

1 Figures F-1 and F-2 display monitoring stations that were active.

SFNA hosts a few major freeways to accommodate the millions of vehicle miles driven in the region each year.

Beyond the developed city areas within the SFNA, a large portion of the area contains substantial agricultural operations consisting of numerous crop types that use a wide range of fossil-fueled equipment throughout the year. Much of the undeveloped land area also allows for off-road recreation vehicle use, while the numerous lakes and rivers allow for the use of motorboats.

Most of the population and anthropogenic emissions are concentrated in the central portion of the SFNA, which is bounded by mountains on two sides. In addition, semi-permanent high-pressure systems over the eastern Pacific Ocean and western U.S. lead to stable weather patterns, sunny skies, and limited wind flow during the late spring, summer, and early fall months. These conditions are highly conducive to the accumulation of emissions and subsequent photochemical production of ozone. A regional, thermally driven sea breeze pattern between the Pacific Ocean and Sacramento also promotes a large gradient in ozone concentrations across the SFNA. The lowest concentrations are typically measured at the upwind sites on the western and southwestern side of the region and the highest concentrations are typically measured in eastern Sacramento County and at the foothill sites in El Dorado and Placer Counties. To characterize ozone air quality, CARB, SMAQMD, YSAQMD, and PCAPCD share monitoring responsibilities across the SFNA through the operation of an extensive monitoring network that included 16 ozone monitoring sites in 2021. These monitoring sites are shown in Figure F-1 and listed in Table F-1.

Because the SFNA consists of distinct topographic features; a varied distribution of population; and a predominant wind flow direction from southwest to northeast in the summer months, it is logical to subdivide the SFNA for analytical and discussion purposes as shown in Figure F-2.

F.3. Conceptual Model

Local anthropogenic emissions, varied terrain, and favorable meteorological conditions for the formation of ozone contribute to the ozone air quality challenges in the SFNA.

F.3.1. Emissions

Ozone is a secondary pollutant that is produced in the atmosphere through a complex series of photochemical reactions involving oxides of nitrogen (NO_X) and reactive organic gases (ROG). The concentrated population in the central portion of the SFNA, the extensive use of automobiles and agricultural equipment, and the availability of biogenic ROG produced by plants and trees in the foothills of the eastern portion of the region provide a setting in which the suite of anthropogenic emissions and biogenic emissions is quite favorable for ozone formation.

Table F-1 Recent Ozone Design Values at Sites in the SFNA

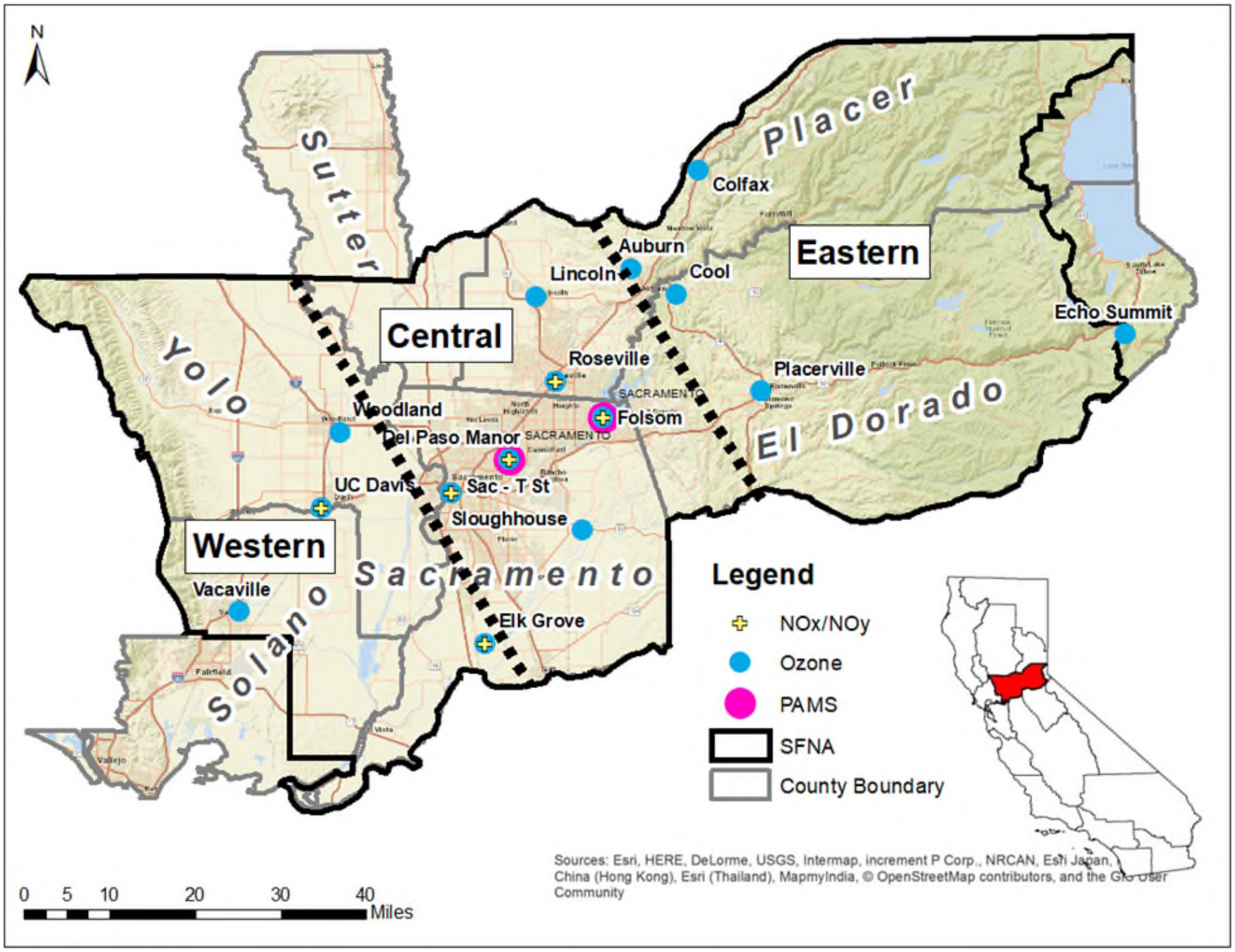
	Site Name	AQS ID	County	2021 Design Value (ppm)	Percent of 0.070 ppm Standard	2021 Design Value Meets Standard
Western	Elk Grove-Bruceville Rd.	060670011	SAC	0.070	100%	Yes
	Vacaville-Ulatis Dr.*	060953003	SOL	0.065	93%	Yes
	Davis-UCD Campus	061130004	YOL	0.065	93%	Yes
	Woodland-Gibson Rd.	061131003	YOL	0.067	96%	Yes
Central	Roseville-N Sunrise Ave.	060610006	PLA	0.070	100%	Yes
	Lincoln-Moore Rd.*	060612002	PLA	0.075	107%	No
	North Highlands-Blackfoot Way[1]	060670002	SAC	0.071	101%	No
	Sacramento-Del Paso Manor	060670006	SAC	0.075	107%	No
	Sacramento- T St.	060670010	SAC	0.066	94%	Yes
	Folsom-Natoma St.[2]	060670012	SAC	n/a	n/a	n/a
	Sloughhouse	060675003	SAC	0.071	101%	No
Eastern	Auburn-Atwood Rd.*	060610003	PLA	0.082	117%	No
	Colfax-City Hall	060610004	PLA	0.076	109%	No
	Placerville-Gold Nugget Way	060170010	ELD	0.077	110%	No
	Echo Summit (seasonal)[3]	060170012	ELD	0.071	101%	No
	Cool (seasonal)	060170020	ELD	0.076	109%	No

* Some of the monitoring sites were combined in this document as follows:
- Vacaville-Elmira Rd. (2001-2003) and Vacaville-Ulatis Dr. (2003- present)
- Lincoln-L St. (2012), Lincoln-1445 1st St. (2012-2017) and Lincoln-Moore Rd. (2018-present)
- Auburn-Dewitt Ave. (2001-2011) and Auburn-Atwood Rd. (2011- present)

1 North Highlands-Blackfoot Way site closed in July 2022
2 Folsom-Natoma St. was shut down on 7/22/2019 for renovation; operations resumed on12/10/2020
3 Echo Summit did not operate in 2015-2017

Note: Sacramento-Airport Rd. site operated during 2001-2008 and Sacramento-Goldenland Ct. site operated during 2008-2017. They are not included in this table.

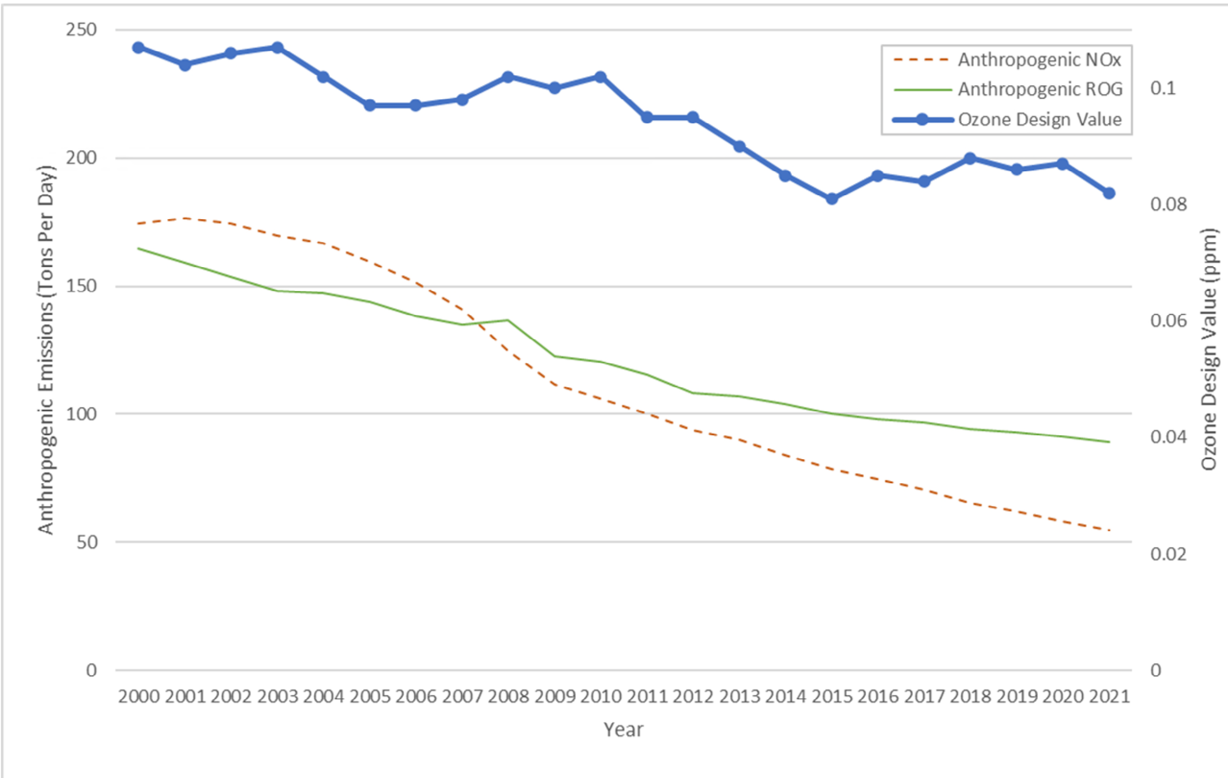
Figure F-2 Map of Subregions within the SFNA



Anthropogenic ozone precursors in the SFNA are largely derived from mobile source emissions, which include passenger vehicles, heavy-duty diesel trucks, recreational boats, and off-road and agricultural equipment, as well as consumer products, which include hair spray, personal fragrance, and all-purpose cleaners. Stationary sources are scattered throughout the SFNA, and all but a few are classified as minor sources. Controlling emissions in the SFNA demands a coordinated, multi-faceted approach at the local, state, and federal levels.

A combination of federal, state, and local emission control programs has significantly reduced emissions in the SFNA during the past 22 years. As shown in Figure F-3, ozone design values have persistently declined in response to precursor emissions reductions. The SFNA is not typical of most urban areas with high ozone concentrations, which tend to have abundant NO_X emission sources and limited ROG emissions. This region has abundant anthropogenic NO_X emissions and abundant ROG emissions from biogenic sources. Biogenic ROG emissions are more than 1.5 times the anthropogenic ROG emissions in the SFNA during the ozone season (May-October) of 2018. Much of the land in the eastern portion of SFNA consists of forest land that contributes to these biogenic emissions. This mixture of sources, some of which can be controlled (anthropogenic) and others which cannot (biogenic), creates a challenging scenario for reducing ozone concentrations.

Figure F-3 SFNA Precursor Emissions and Ozone Design Values



As the SFNA has progressed towards attainment, the quantity and composition of precursors has changed. In recent years, NO_X has become the primary focus of control efforts. State of the art photochemical modeling assessments are necessary to understand the current and future mechanisms of ozone formation in the SFNA. The most recent modeling indicates that the dominant precursor controlling ozone production is NO_X, which means a NO_X-focused control strategy for the SFNA will be the most influential and effective to achieve the 0.070 ppm standard by the attainment year of 2032.

F.3.2. Meteorology and Complex Terrain

F.3.2.I. Statewide Weather Patterns

The weather throughout most of California is dominated by an extensive area of high pressure over the eastern Pacific Ocean, which generally produces mild weather year-round. Along the California coast, daily sea breezes and a marine layer are common occurrences. Summer days in the inland portions of the State tend to experience clear skies, light winds, cool morning, and warm afternoon temperatures, and limited vertical mixing due to persistent temperature inversions. Occasionally, the Pacific High will weaken or move to the south, allowing the storm track to shift over California, producing cloudy skies, moderate-to-strong winds, rain, and thorough mixing of the atmosphere.

The stormy periods tend to last not more than a few days and typically occur between the months of October and March.

During the transitional spring and fall months, another pattern often develops, lasting for one to three days, which is defined primarily by northerly winds that tend to be strong and gusty. The winds are produced by storm systems passing California to the north and swinging down into the Great Basin, east of California. Under this pattern, skies tend to be clear, and the atmosphere is well mixed, but wind-blown dust, wildland fires, and smoke can be an issue. While these broad, generalized weather patterns are relevant to most of the State, localized weather features and topography play a critical role in the air quality within the SFNA.

F.3.2.II. SFNA Weather Patterns

As previously discussed, the SFNA is directly bounded by mountains to the west and east, and to a lesser extent, to the north at the northern end of the Sacramento Valley by the Cascade Mountains near Redding. The mountain ranges act as large barriers to wind flow in the west-to-east direction and have a profound impact on vertical mixing within the lower levels of the atmosphere and the buildup and transport of air pollution within the SFNA. The terrain constrains air flow within the SFNA to either winds from the south, which flow northward or northeastward from the Delta (Delta breeze), or winds from the north that travel southward through the SFNA toward the Delta. As a result, even under moderate wind speeds, pollutants tend to remain within the SFNA and are transported between the various counties in the nonattainment area. In particular, the Delta breeze weather phenomenon, occurring more prominently from late spring to early fall, transports emissions toward the eastern portion of the SFNA, where the highest ozone concentrations have been observed during the past 22 years.

The Coastal Range on the western side of the SFNA prevents the cooler, humid, ocean air from flowing freely into the region, resulting in hot temperatures in the summer that are conducive to ozone formation. However, the lack of a mountain barrier at the southern end of the region enables ocean air to flow into the Sacramento area via the Carquinez Strait under certain weather patterns, allows for Delta breeze ventilation within the SFNA. Due to the frequent separation of the SFNA from the marine influence and prevailing upper-level high pressure producing general sinking motion and clear skies over California, the SFNA experiences low relative humidity and large diurnal temperature swings during much of the year.

Another key meteorological factor for air quality in the SFNA is the formation of ground-based temperature inversions, which are indicated by temperatures warming with height in the atmosphere rather than the expected cooling with height. Since warmer air is above cooler air in this situation, the atmosphere is very stable, and vertical mixing is limited. In the summer, the inversions extend up to around 1,500 feet above ground level and are typically strong and persistent, preventing vertical mixing on most hot summer days and allowing pollutant concentrations to build underneath them.

During the summer days, pollutant emissions within the SFNA react in plentiful sunlight to form ozone, which becomes trapped under a temperature inversion on most days.

During the afternoons, the light Delta breeze helps mix the atmosphere under the inversion while transporting the emissions and ozone into the eastern portion of the region, where there are fewer fresh NO_X emissions available for breaking down ozone and more ROG from biogenic sources to enhance ozone production. Soon after sundown, the Delta breeze usually weakens and the air in the foothills begins to cool, causing the air to flow back down into the Sacramento area and making the pollutants available for increased ozone formation potential and higher concentrations the next day.

Both wind flow patterns can be observed in Figure F-4, where 24-hour backward trajectories were prepared for 51 days in 2018 through 2020 during which the Placerville-Gold Nugget Way monitor exceeded 0.070 ppm standard (September 12, 2020, is missing due to model data not being available). The trajectories were run at the end height of 500 meters (m) to represent air within the boundary layer and typically below the temperature inversion during hot, stagnant days. The trajectories coming from the southwest are the Delta breeze days and the looping in trajectories to the north and south of Placerville indicate the recirculation pattern along the Sierra Mountains. The trajectories to the north indicate that high ozone concentrations are possible on days with light northerly wind flow as well.

The upslope/downslope recirculation pattern is very pronounced in the Sacramento area and is a key factor during multi-day, high ozone concentration episodes. The recirculation is also a key mechanism in the transport of pollutants such as wildfire smoke from the foothills down into the valley floor during overnight periods. This can be an issue since wildfire smoke can contain large amounts of ozone precursor emissions.

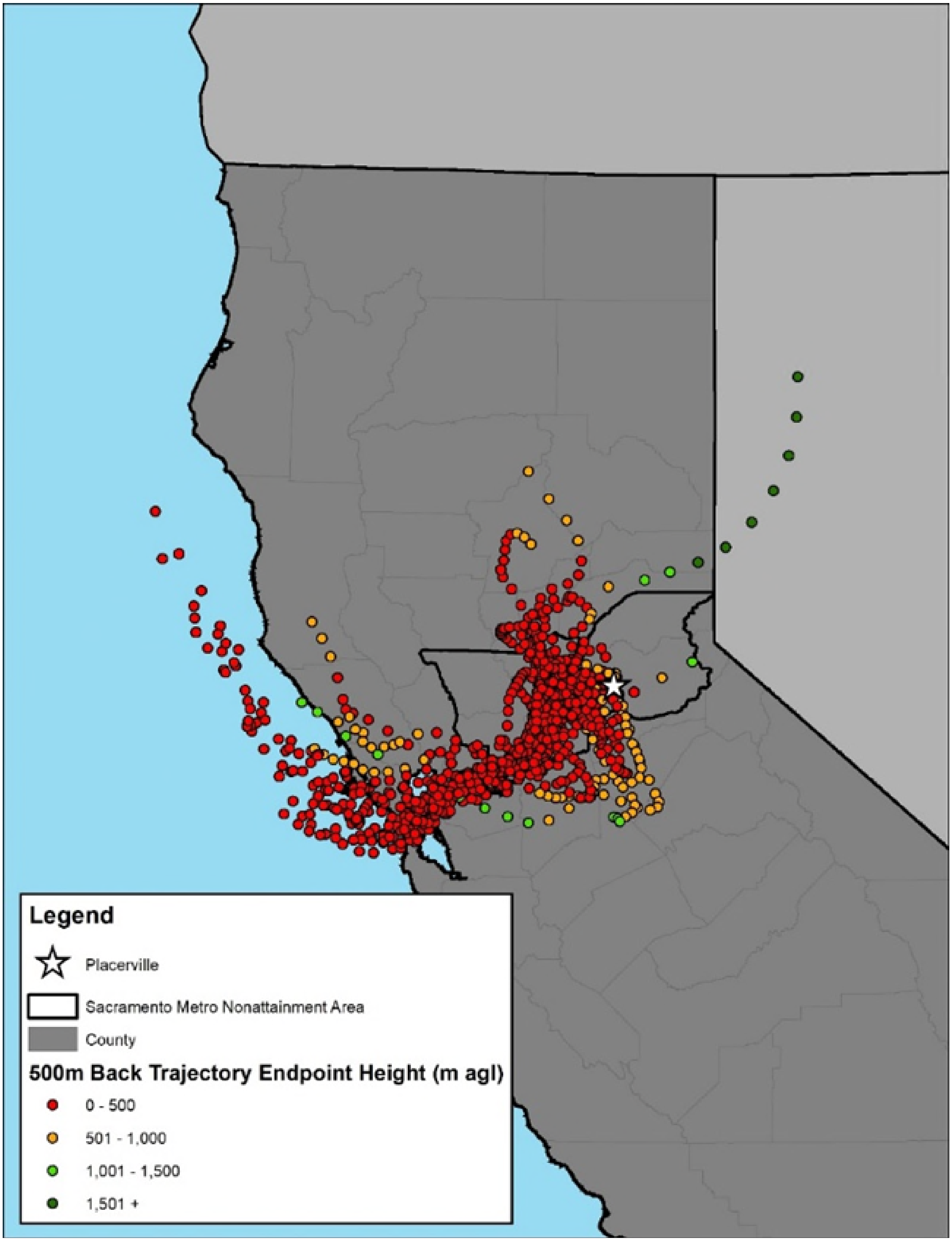
F.3.2.III. Diurnal Ozone Patterns

The diurnal ozone patterns for the three Sacramento subregions are discussed in this section. The typical diurnal (midnight to midnight) pattern in ozone concentrations measured at individual locations provides additional insight into the general processes that contribute to ozone air quality in the SFNA.

Diurnal patterns at monitoring sites in large urban core areas, which are densely populated, are often characterized by narrow periods of peak concentrations coincident with peak solar insolation. Nighttime/early morning minimum concentrations are typically at, or near, zero due to the availability of NO_X for titration, or the breakdown of ozone, thereby suppressing ozone concentrations. In suburban and rural locations, peak concentrations are typically higher than in urban core areas, occur later in the day, and persist for an extended period resulting in a broader peak. The nighttime/early morning minimum concentrations are dependent on each monitoring site’s distance from the urban core and other site characteristics, but do not typically reach zero in suburban/rural areas.

The SFNA is comprised of a few small urban cores and many suburban and rural communities. Therefore, most of the monitoring sites exhibit suburban/rural site characteristics. However, under certain meteorological conditions and emission patterns, even those sites could have short-term, nighttime NO_X concentrations near zero.

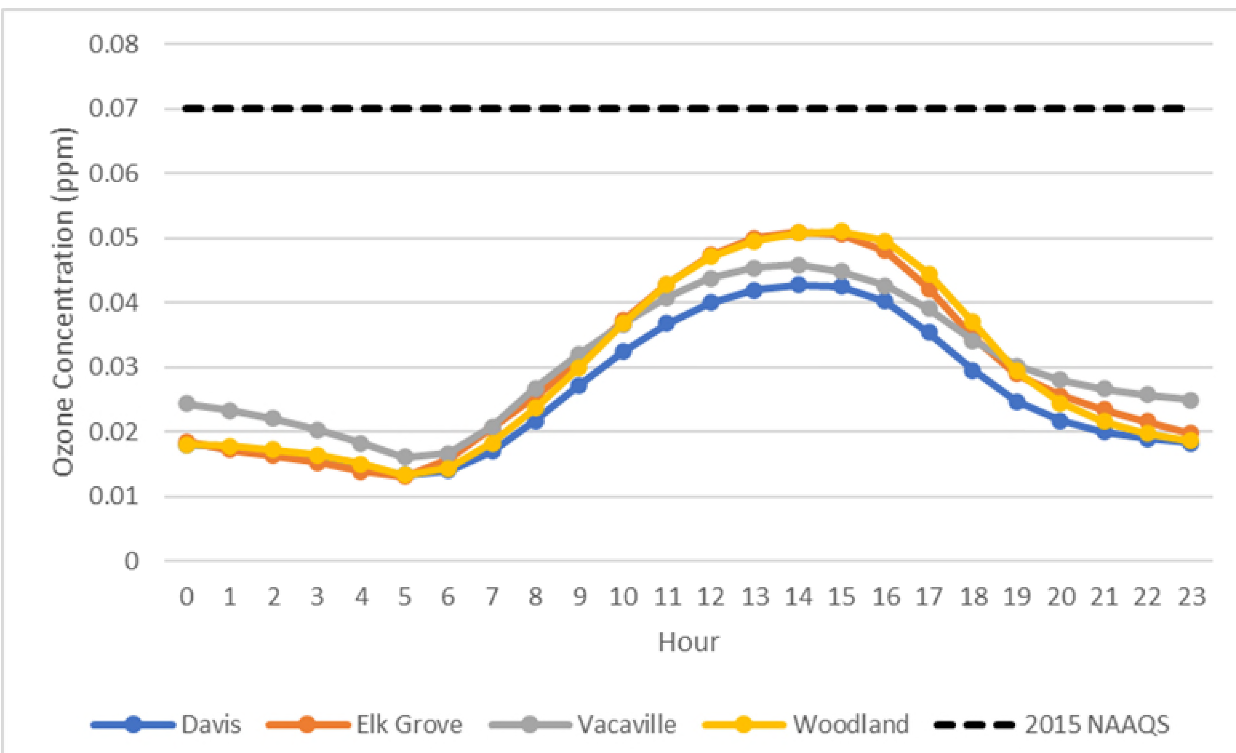
Figure F-4 24-hour Back Trajectories on Ozone Exceedance Days in 2018 through 2020 at the Placerville-Gold Nugget Way Site



In an effort to represent the current state of air quality dynamics in the SFNA, as well as maintain a large sample size to compensate for inter-annual variability, the six-year period of 2016 through 2021 was selected for evaluation. Furthermore, the hourly data were limited to ozone months of May through October for those same years to focus the analyses presented here on periods when high ozone concentrations typically occur.

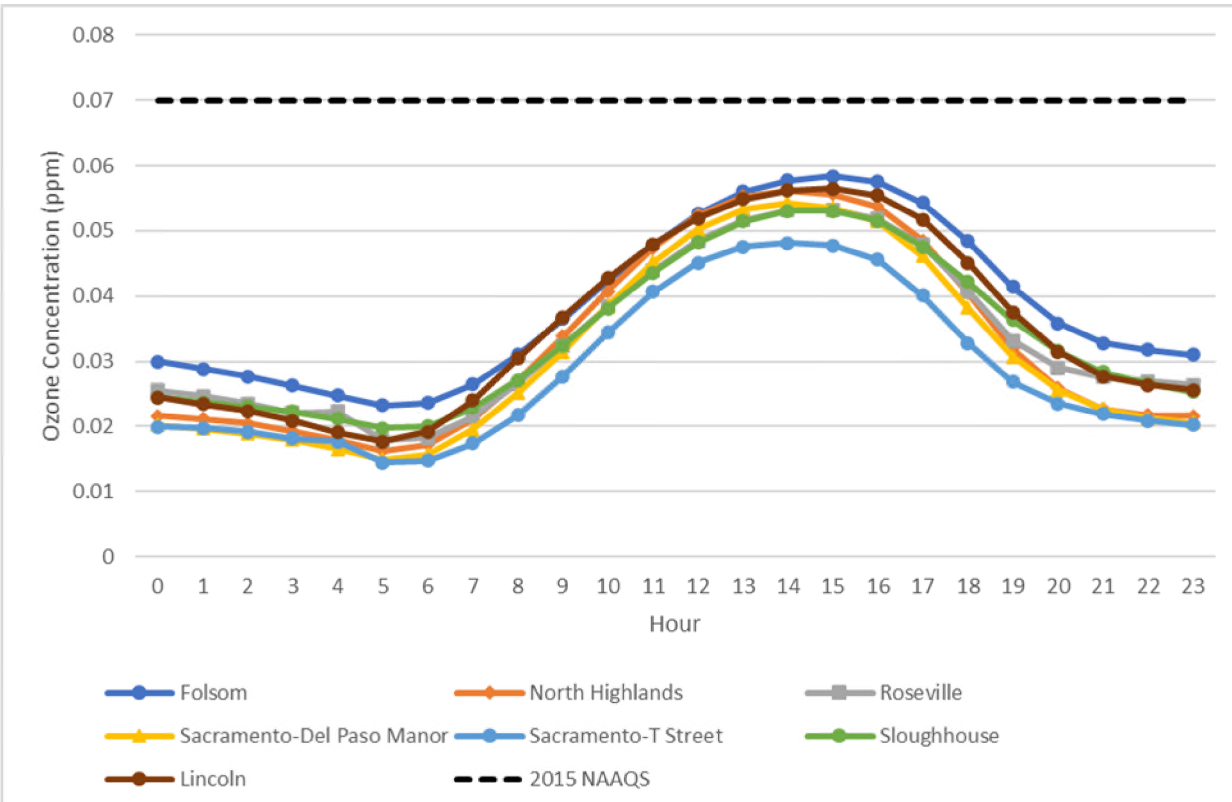
In the western portion of the SFNA, the average diurnal profiles were similar among sites and were characterized by broad peaks between 1400 and 1500 Pacific Standard Time (PST) that included maxima ozone ranging from 0.043 ppm to 0.051 ppm (Figure F-5). Among monitoring sites, the average nighttime minima decreased with distance from the Suisun and San Pablo Bays in the Delta, but remained above zero, on average, at all sites. The western subregion is largely rural with isolated suburban centers and the overall profile of the peaks is somewhat broad, as expected for non-urban core locations. Due to the western subregion's proximity to the coastal bays and limited emission sources, more frequent Delta breezes suppress peak temperatures and disperse pollutants, limiting ozone buildup. It also shows that the further inland sites have relatively higher peaks, indicating the contribution of ozone precursor emissions from the Bay Area to ozone formation in the downwind Sacramento Area.

Figure F-5 Average Diurnal Profiles for 1-Hour Ozone Concentrations at Western Subregion Sites (May-October 2016-2021)



In the central portion of the SFNA, the average diurnal profiles were generally similar among sites and were characterized by broad peaks between 1300 and 1600 PST that included maxima ozone ranging from 0.048 ppm to 0.058 ppm (Figure F-6). Among monitoring sites, the average nighttime minima increased with distance from the Delta region but remained above zero at all sites. In addition, the large Sacramento urban and suburban area were characterized by a profile of lower ozone peaks on the western edge and higher, time-delayed peaks in the north and northeastern portion. This spatial distribution is borne out by Sacramento-T Street's (western edge) peak ozone concentration of 0.048 ppm, North Highlands' (to the north) peak ozone of 0.056 ppm, Roseville's (to the northeast) peak ozone of 0.053 ppm, and Folsom's (to the northeast) peak ozone of 0.058 ppm.

Figure F-6 Average Diurnal Profiles for 1-Hour Ozone Concentrations at Central Subregion Sites (May-October 2016-2021)

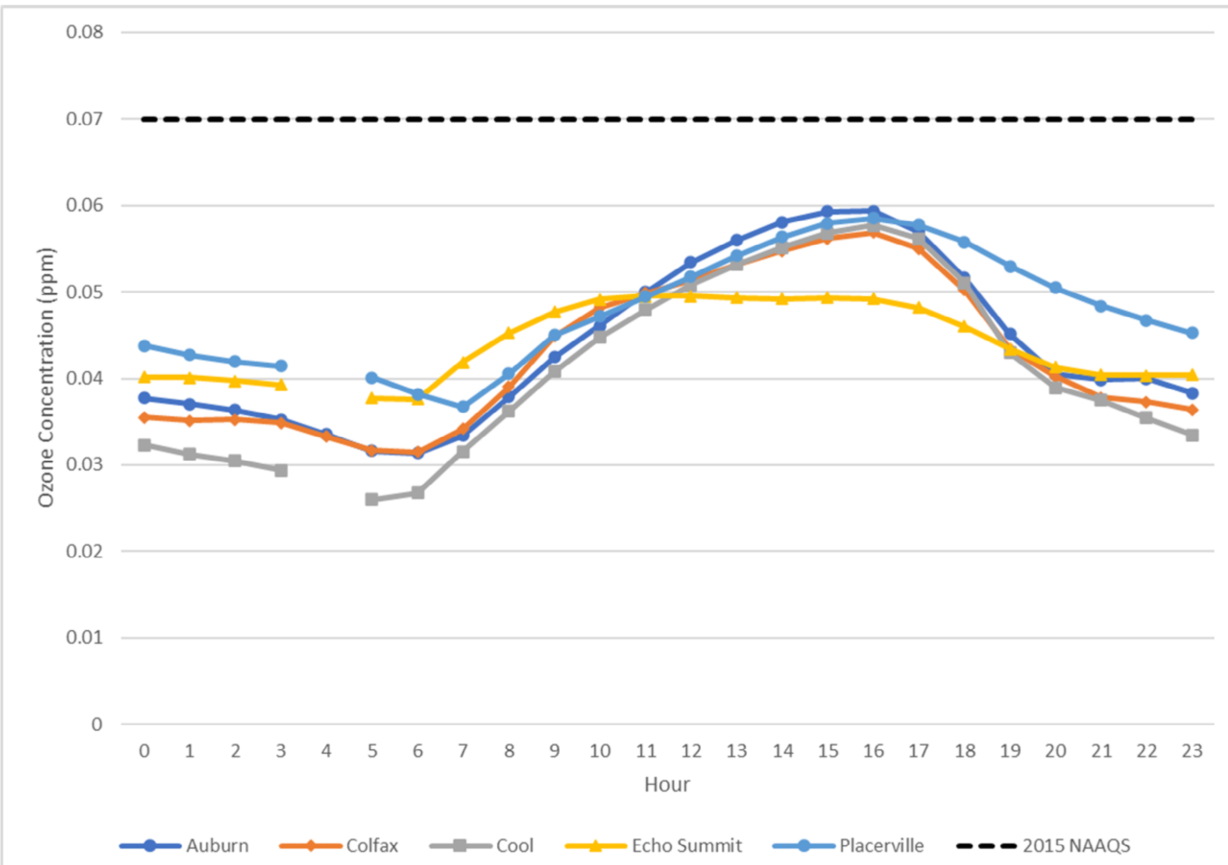


The increasing ozone concentrations from the western edge to the northeastern portion of this subregion demonstrate the role of meteorology in the diurnal ozone cycle. The daily summertime Carquinez to Sacramento Valley Delta breeze transports the region's highest ozone precursor emissions, located within Sacramento's central business district, to the north and east. Additional emissions along the urban transport path enhance the downwind ozone concentrations. Finally, ozone concentrations are enhanced by higher temperatures downwind due to the greater distance from the moderating effect of the ocean, coastal bays, and Delta, as well as substantial biogenic ROG emissions associated with the foothills on the eastern side, which increase as temperature increases.

In the eastern portion of the SFNA, the diurnal profiles differ from those in the other two subregions. The eastern sites were characterized by very broad peaks between 1400 and

1600 PST and included maximum ozone concentrations ranging from 0.049 ppm to 0.059 ppm (Figure F-7). In addition, they were characterized by slower growing mid-day profiles than the central subregion sites. Among the eastern sites, the average nighttime minimum increased with distance downwind of Sacramento on the Highway 50 corridor (Placerville and Echo Summit), while remaining flat along the I-80 corridor (Auburn, Cool, and Colfax). The nighttime minimum remained above zero, on average, at all sites. The mid-afternoon peak profiles were characteristic of downwind rural areas impacted by ozone transport and highlight the significant role of transport within the SFNA.

Figure F-7 Average Diurnal Profiles for 1-Hour Ozone Concentrations at Eastern Subregion Sites (May-October 2016-2021)

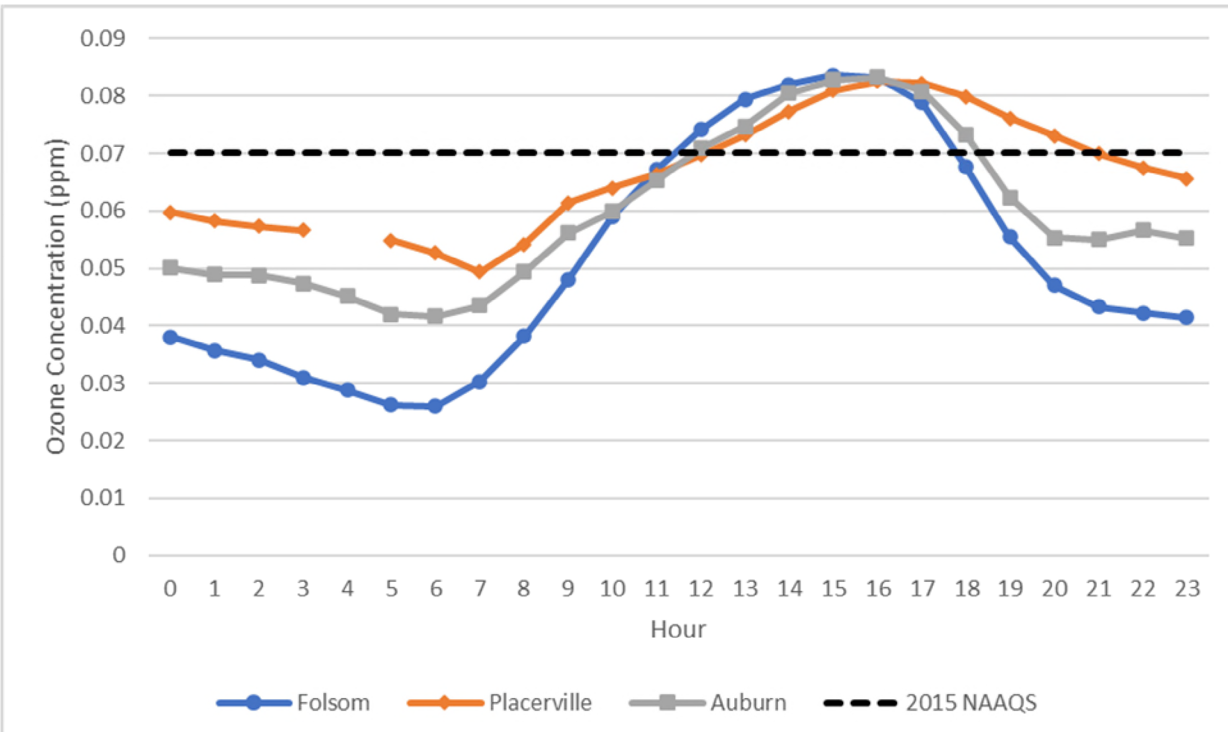


Note: Invalidated data at Auburn and Colfax Stations in 2016 to 2018 were used to calculate the average diurnal concentrations. More information on these data can be found in Section 6.1.I.

The average diurnal profiles were consistent among sites, except for Echo Summit, which exhibits much lower ozone concentrations and a very broad peak compared to the other sites in the subregion. This result is largely due to the site's location far downwind of urban and suburban areas at a relatively high elevation of 7,382 feet. The Echo Summit site is closer in proximity to the Lake Tahoe Air Basin and was sited to intercept transport entering the Lake Tahoe Air Basin.

The central and eastern subregion monitoring sites of Folsom, Placerville, and Auburn, in particular, pose a key challenge for attainment due to their high late night/early morning ozone concentrations, especially at Placerville, and the number of hours that ozone concentrations frequently persist above the 0.070 ppm standard on high ozone days (Figure F-8). All three sites have six or more hours with ozone concentrations above 0.070 ppm, which will need to be reduced for these sites to attain the standard. Folsom, the previous design site from 2003-2014, has seen a much more rapid decline in design values than Placerville and Auburn. (Design value trends are discussed later in this document). Due to the rapid progress at Folsom, either Placerville or Auburn has been the design site since 2015 and is anticipated to remain among the highest ozone sites in the SFNA as the area approaches attainment.

Figure F-8 Average Diurnal Profiles for 1-Hour Ozone Concentrations at Folsom, Auburn, and Placerville on Days with Peak 8-Hour Ozone Concentrations > 0.070 ppm (May-October 2016-2021)



Note: Invalidated data at the Auburn Station in 2016 to 2018 were used to calculate the average diurnal concentrations. More information on these data can be found in Section 6.1.I.

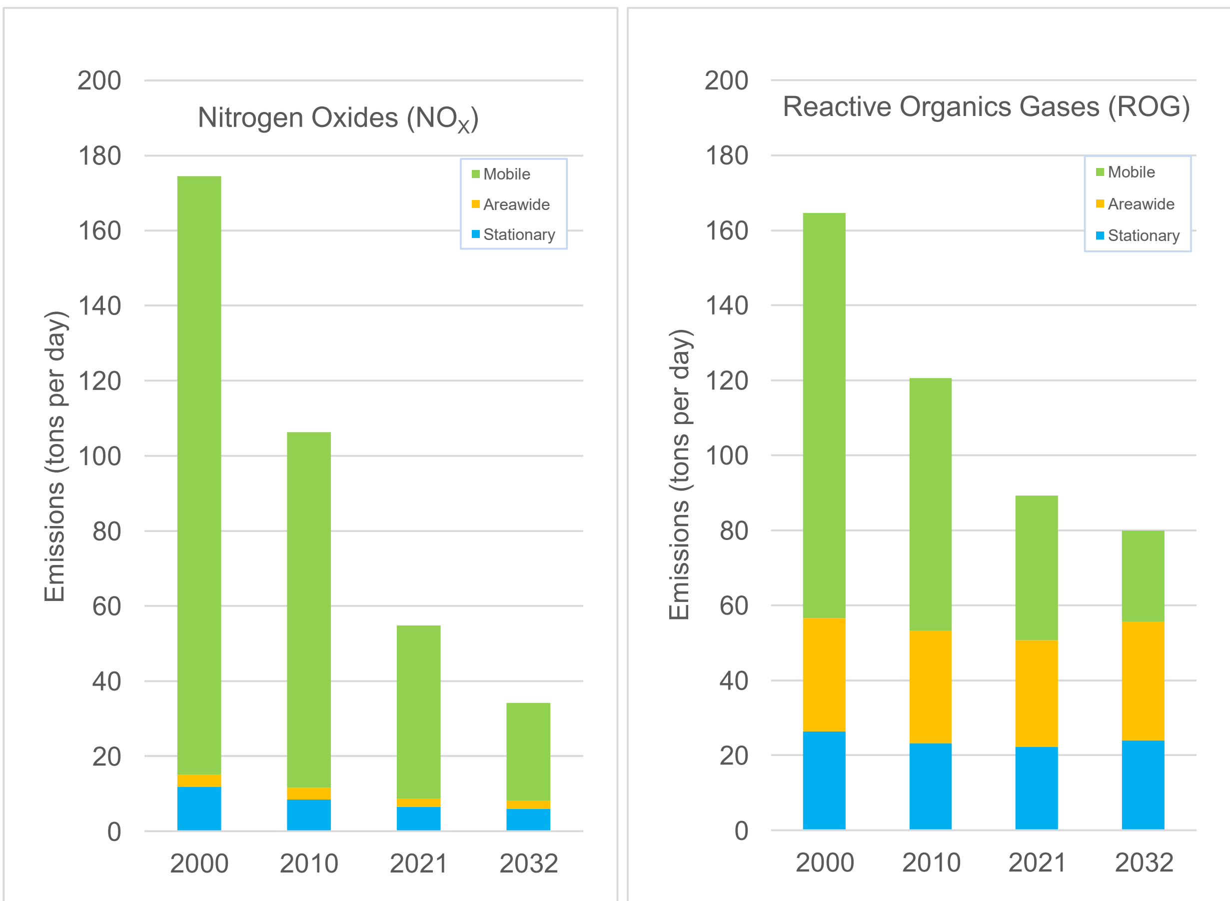
F.3.3. Conceptual Model Summary

Meeting the 0.070 ppm standard is a complex challenge in the SFNA. A diverse suite of precursor emissions results from central urban core surrounded by heavily traveled highways and major agricultural activities. The area is characterized by varied terrain, which limits dispersion and effectively traps emissions in the region. Furthermore, meteorological conditions are dominated by a semi-permanent high-pressure system, which enhances the trapping effect of the local terrain; and a thermally driven afternoon Delta breeze wind and a nighttime, downslope drainage flow recirculation pattern, which serves to routinely transport emissions from the central portion of the region up into the foothills in the eastern portion during the day and then back down toward the valley floor overnight. State-of-the-art photochemical modeling, supported by extensive monitoring and research efforts, indicates that the path towards attainment of the 0.070 ppm standard is with a NO_X-focused control strategy.

F.4. Anthropogenic Emissions

Data from the CARB's California Emissions Projection Analysis Model (CEPAM), 2019 Sacramento SIP Ozone Nonattainment Area Ver 1.04, were used to evaluate trends in anthropogenic emissions of ozone precursors, NO_X, and ROG. Federal, State, and local programs have yielded significant overall reductions in emissions of ozone precursors in the SFNA. From year 2000 to 2021 total summer emissions of NO_X have decreased by approximately 69 percent with ROG abated by 46 percent. The decreasing trend is expected to continue to 2032 as shown in Figure F-9.

Figure F-9 Summer Ozone Precursor Emissions Inventory in SFNA



According to Figure F-9, mobile sources dominate the emission inventories of ozone precursors; the emissions inventory indicates that mobile sources accounted for 84 percent of NO_X emissions and 43 percent of anthropogenic ROG emissions in 2021. In 2032, mobile sources are still expected to be the largest contributing source of NO_X emissions (76 percent), followed by stationary (17 percent) then areawide (6 percent) sources. In contrast, for ROG emissions, areawide will make up the largest contributing source (40 percent); and mobile and stationary will contribute equally to ROG emissions (about 30 percent each).

On a subregional scale, the Sacramento County portion of the area accounts for the largest portion of anthropogenic NO_X and ROG emissions, followed by the SFNA portion of Placer County, Yolo County, and the SFNA portions of Solano, El Dorado, and Sutter Counties. As shown in Figures F-10 and F-11, Sacramento County NO_X emissions remain more than two times greater than other SFNA counties in 2032, and ROG emissions are more than triple those in other SFNA counties. However, NO_X and ROG emissions decline in all counties between 2000 and 2032; and the magnitude of decline was largest in El Dorado for NO_X and Sutter for ROG.

As discussed earlier, prevailing southwesterly winds provide a persistent mechanism by which emissions from these areas are routinely transported eastward into the foothills, disproportionately promoting elevated ozone at sites downwind of these peak emission areas.

F.5. Ambient Ozone Precursor Concentrations

Ambient air measurements of the primary ozone precursors, NO_X and ROG, are gathered at a special-purpose network of Photochemical Assessment Monitoring Stations (PAMS). The PAMS network is operated during the summer ozone months (typically from July through October). In addition to hourly NO_X and meteorological measurements, multiple three-hour ROG samples are collected every three to six days. The ROG data discussed here are the sum of 55 PAMS targeted chemical species, called Non-Methane Organic Compounds (NMOC), which are considered important in the role of ozone photochemical processes. ROG and NO_X data at PAMS sites in the SFNA are analyzed where available from 2000 to 2021.

The ROG and NO_X data analysis are restricted to only two sites due to the limited ROG data availability. Analysis is focused on the morning commute hours between 5 am and 8 am in the summer peak ozone season of July to September. The morning time period was selected because it represents the hours before photochemistry (and therefore ozone formation) is triggered, and the ambient concentrations of ozone precursors are usually at higher levels during this period.

Figures F-12 and F-13 show the ROG and NO_X ambient concentrations from 2000 to 2021 at Folsom Natoma St[2] and Sacramento Del Paso Manor[3]. In these figures, each data point represents an average of all available morning (5 am-8 am) ROG and NO_X concentrations from July to September for each year. The ROG concentration is from the

2 Figures F-12 and F-13 include NO_X data ranging from 7/6/2015-8/28/2015, 9/5/2015-9/11/2015, 9/19/2015-9/27/2015 from Folsom that are currently under review and may be invalidated.

3 Figures F-12 and F-13 include NO_X data ranging from 4/28/2014-5/30/2014, 6/3/2015-6/17/2015, 1/1/2016-10/14/2016, 2/2/2017-2/10/2017, 3/10/2017-3/26-2017, 7/24/2018-12/31/2018, 1/1/2019-4/3/2019, 20/3/2019-12/31/2019, 1/1/2020-12/21/2020, and 1/1/2021-11/29/2021 from Del Paso Manor that are currently under review and may be invalidated.

three-hour canister samples collected during 5 am to 8 am, and the daily value of NO_X concentrations is the average of hourly measurements of NO_X covering the same three-hour period.

Both sites show downward trends in ROG and NO_X concentrations from 2000 to 2021 despite year-to-year variations. These trends are due to the result of successful ROG and NO_X emission control measures. For example, at the Folsom Natoma St. site, the ROG concentration decreased by 56 percent from 2000 to 2019, while the NO_X concentration decreased by 73 percent from 2000 to 2021 (2020 ROG and NO_X data are not available due to a temporary site closure; 2021 ROG data are not available due to instrument malfunction). At the Sac-Del Paso Manor site, the ROG and NO_X concentrations decreased by 16 percent and 65 percent, respectively, from 2000 to 2020. (2021 data are not available due to instrument malfunction). The fact that the NO_X concentrations declined more rapidly than the ROG concentrations is most likely due to more NO_X-focused control strategies being advanced in recent years.

Figure F-10 County-Level Anthropogenic NO_X Emissions in the SFNA

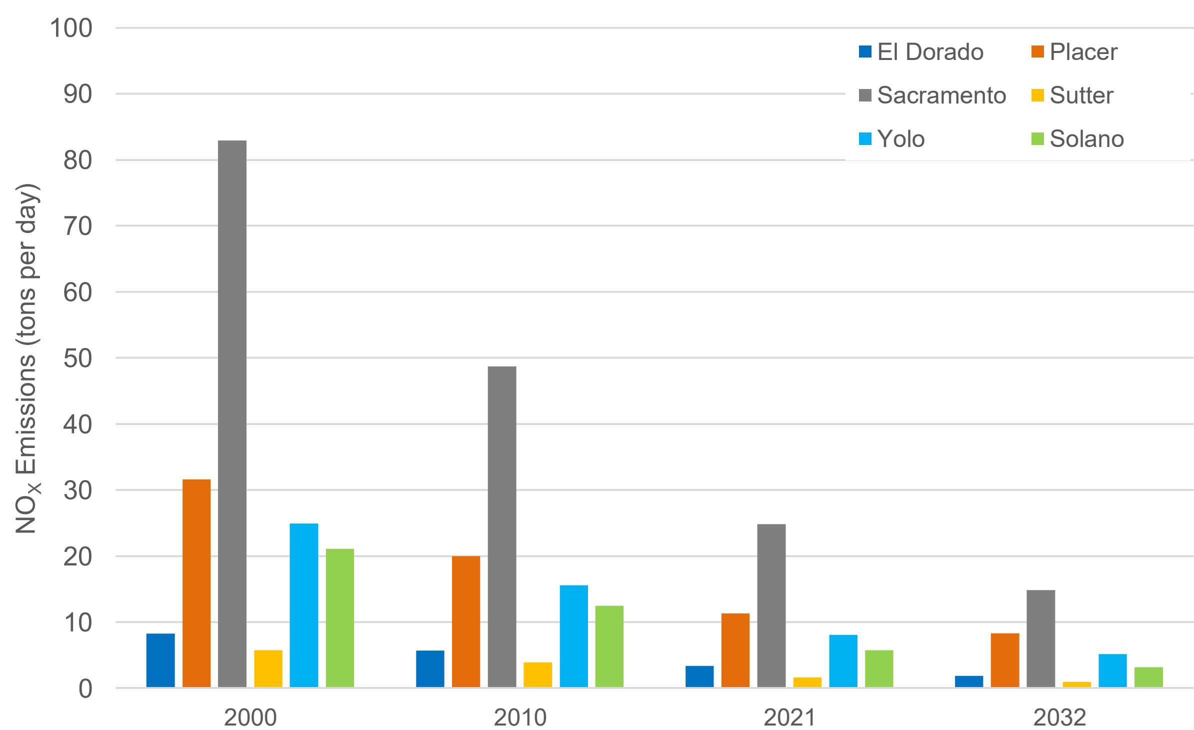


Figure F-11 County-Level Anthropogenic ROG Emissions in the SFNA

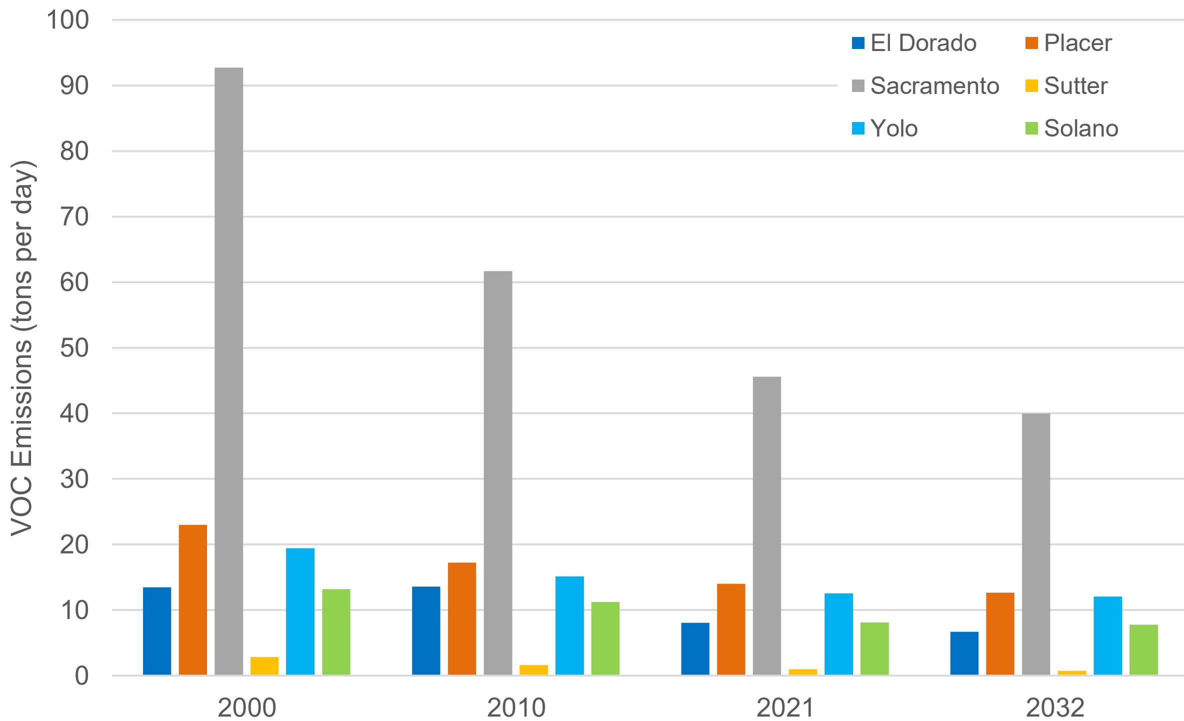


Figure F-12 July-September Averages of ROG and NOx at Folsom Natoma St. (5 am-8 am)

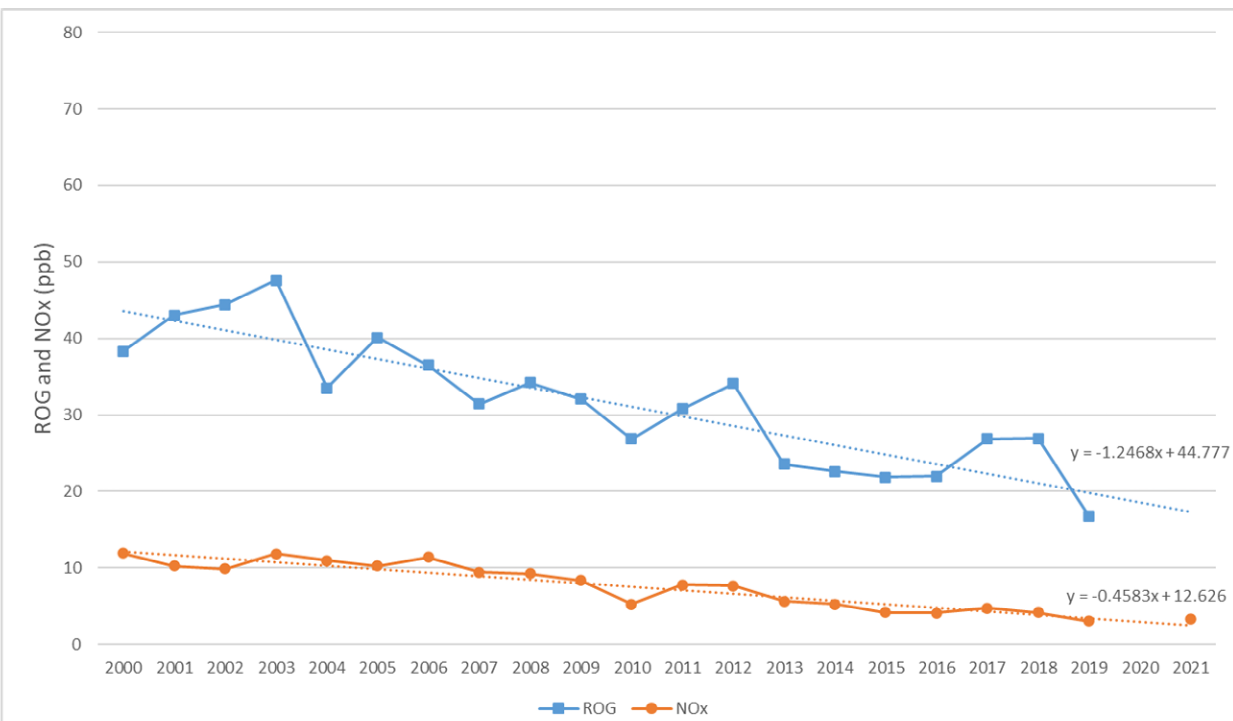
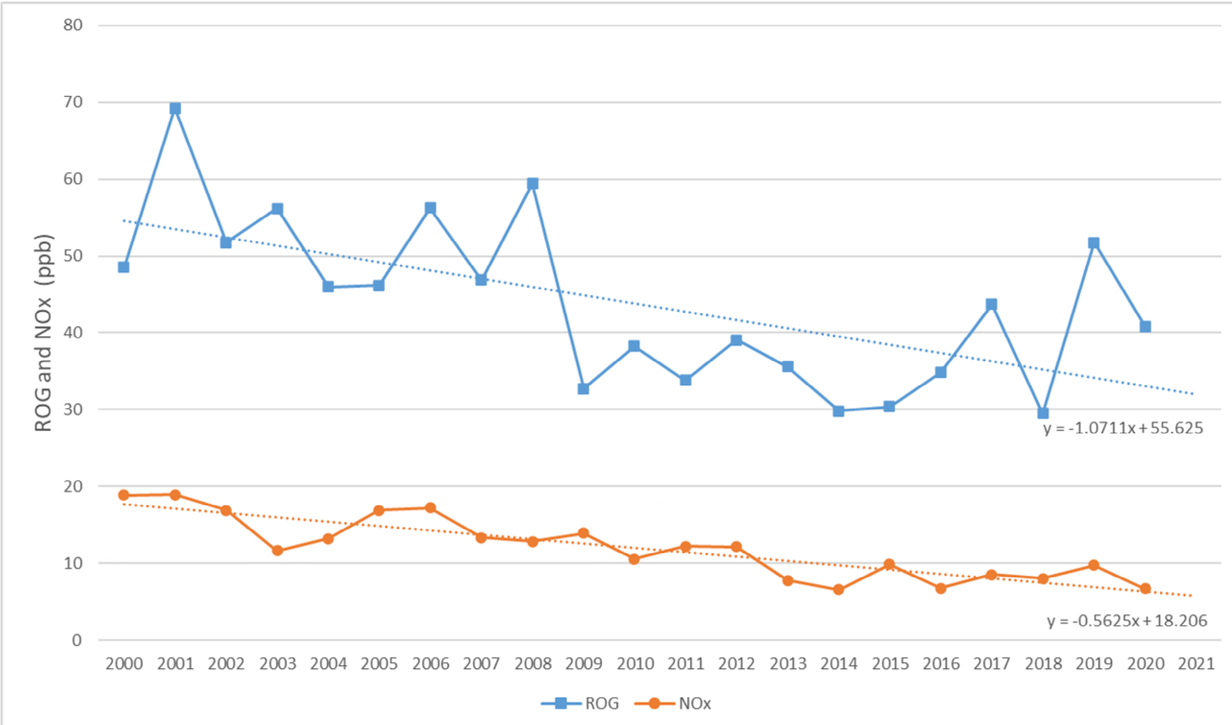


Figure F-13 July-September Averages of ROG and NO_X at Sac-Del Paso Manor (5 am-8 am)



F.6. Ozone Air Quality

The design value is the key metric for assessing the state of ozone air quality in a nonattainment area, and it can be directly compared to the federal ozone standard for the purpose of determining attainment status. The design value is computed as the three-year average of the fourth-highest daily maximum 8-hour average ozone concentration from each year and is determined for each monitoring site. The ozone design values are then collectively evaluated, and a region-wide design value is determined based on the highest design value across all sites within the SFNA.

Ozone air quality within the SFNA has significantly improved for the past 22 years. As shown in Figure F-14, the SFNA's ozone design value decreased by 20 percent between 2000 and 2021, from 0.107 ppm to 0.082 ppm despite significant wildfire impacts to ozone levels in the SFNA in recent years, such as in 2018. During this same period, the annual fourth-highest daily maximum 8-hour ozone concentration decreased by 17 percent, from 0.103 ppm in 2000, to 0.085 ppm in 2021. Total number of exceedance days across all monitoring stations in the region decreased by 35 percent from the year 2000, when the 0.070 ppm standard was exceeded on 81 days, to the year 2021, when there were 52 exceedance days. The substantial reductions in design values, fourth-highest concentrations, and exceedance days demonstrate that the nonattainment area is well on its way towards attainment of the 0.070 ppm standard. However, there have been different rates of progress in the western, central, and eastern subregions.

The following sections focus on long-term trends in design value concentrations throughout the Sacramento subregion and briefly discuss year-to-year variability in meteorology and wildfire impacts on design values. In addition, the spatial variability of air quality and population exposure is examined to provide insight on the extent of progress towards attainment.

F.6.1. Ozone Design Values

As previously discussed, ozone air quality in the SFNA varies between the western, central, and eastern subregions. In the western subregion, the 2021 design values at all four sites met the 0.070 ppm standard with values ranging from 0.065 to 0.070 ppm. In the central subregion, the 2021 design values met the 0.070 ppm standard at some sites but exceeded the 0.070 ppm standard at other sites with values ranging from 0.066 ppm to 0.075 ppm. In the eastern subregion, the 2021 design values at all sites exceeded the 0.070 ppm standard with values ranging from 0.071 to 0.082 ppm.

Figure F-14 Ozone Air Quality in the SFNA

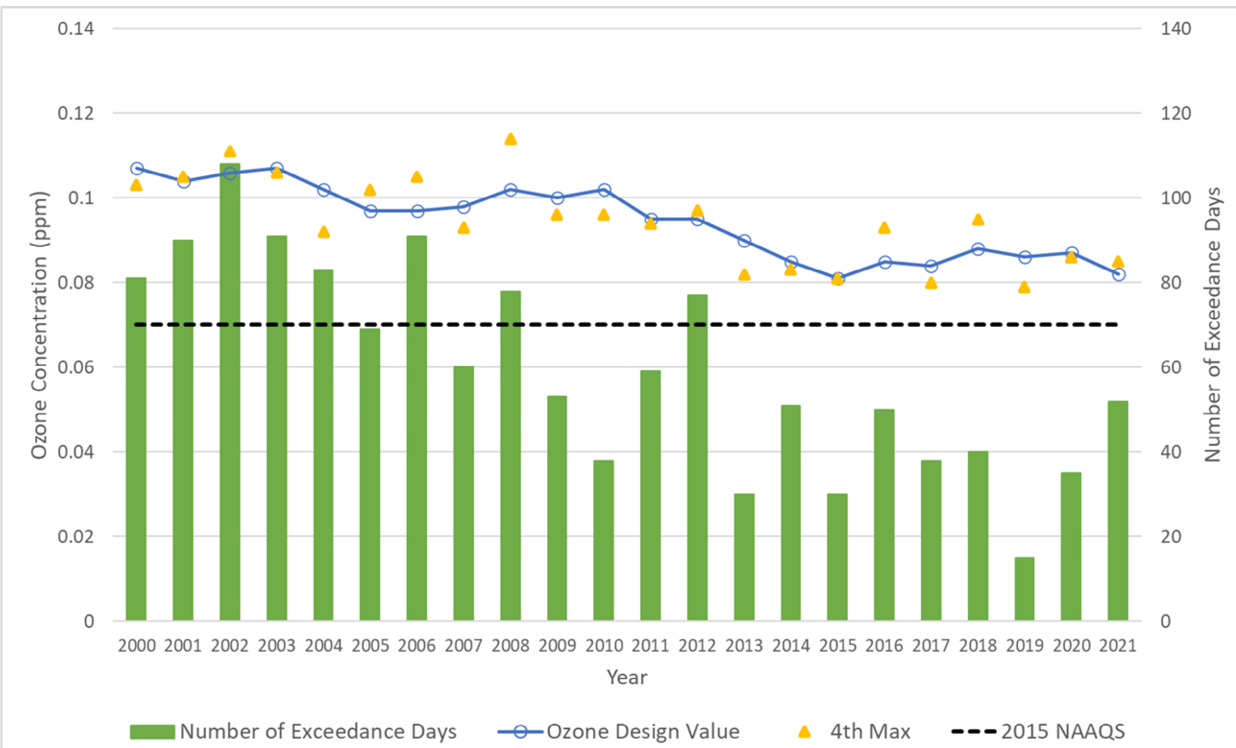
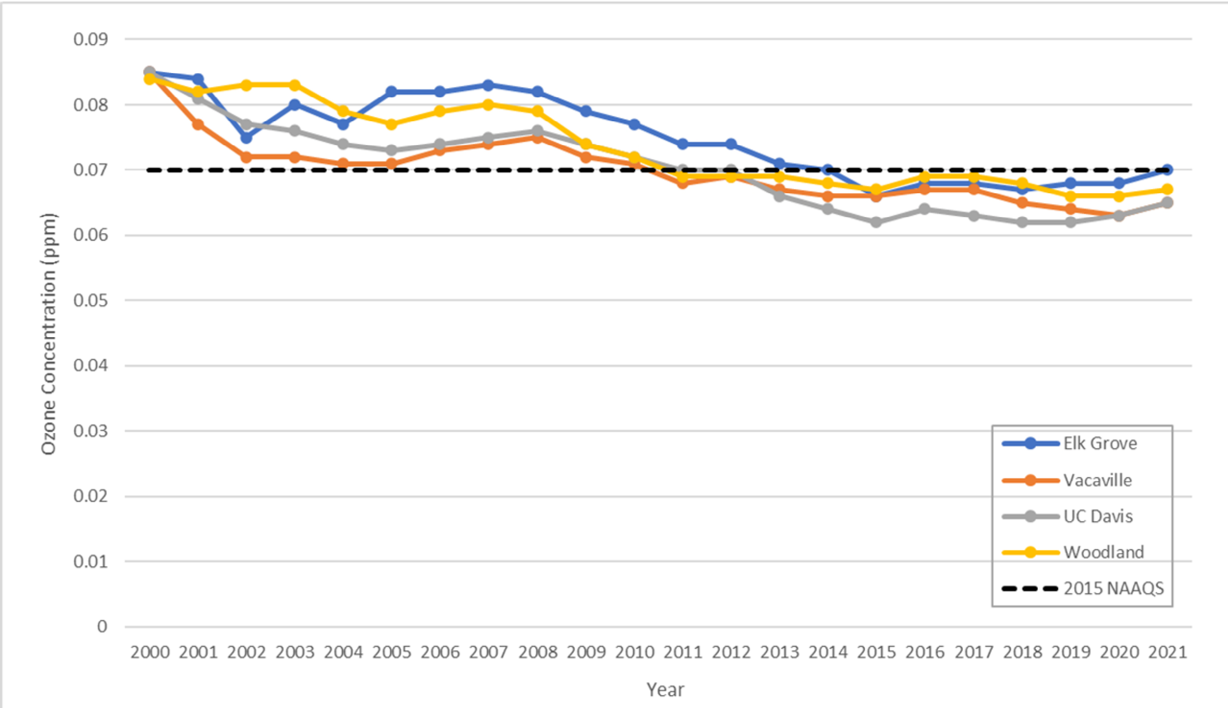


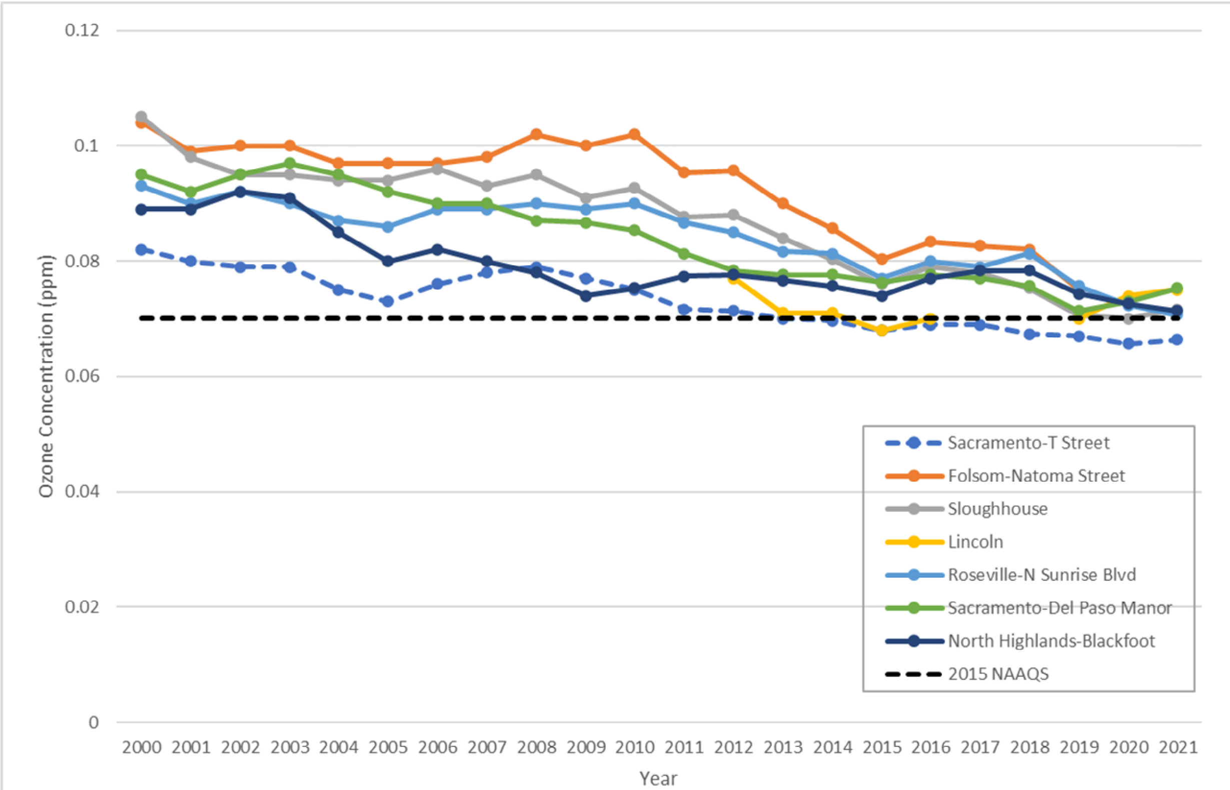
Figure F-15 2000-2021 Design Values at Sites in the Western Subregion



In the western subregion, the downward trend of design values at all four sites was significant from 2000 to 2021 (Figure F-15). The design value trends remained relatively flat from 2000 to 2008, then decreased more rapidly until 2015. Since 2016 the downward trend slowed down again and leveled off. Vacaville, Davis, and Woodland sites have remained in attainment for the 0.070 ppm standard since 2011 and Elk Grove site since 2014.

In the central subregion, ozone design values have declined since 2000, but similar to the western subregion, the most rapid decreases have occurred between 2010 and 2015 (Figure F-16). Most notably, Folsom, the design site for many years, showed rapid progress with a 26 percent decline in the design value since 2010. Other high ozone concentrations sites in the central subregion also showed similar progress, including Sloughhouse (24 percent) and Roseville-N Sunrise (20 percent). Most of the monitoring sites in the central region are close to meeting the 0.070 ppm standard. The Sacramento-T Street site has remained in attainment for the 0.070 ppm standard since 2013.

Figure F-16 2000-2021 Design Values at Sites in the Central Subregion

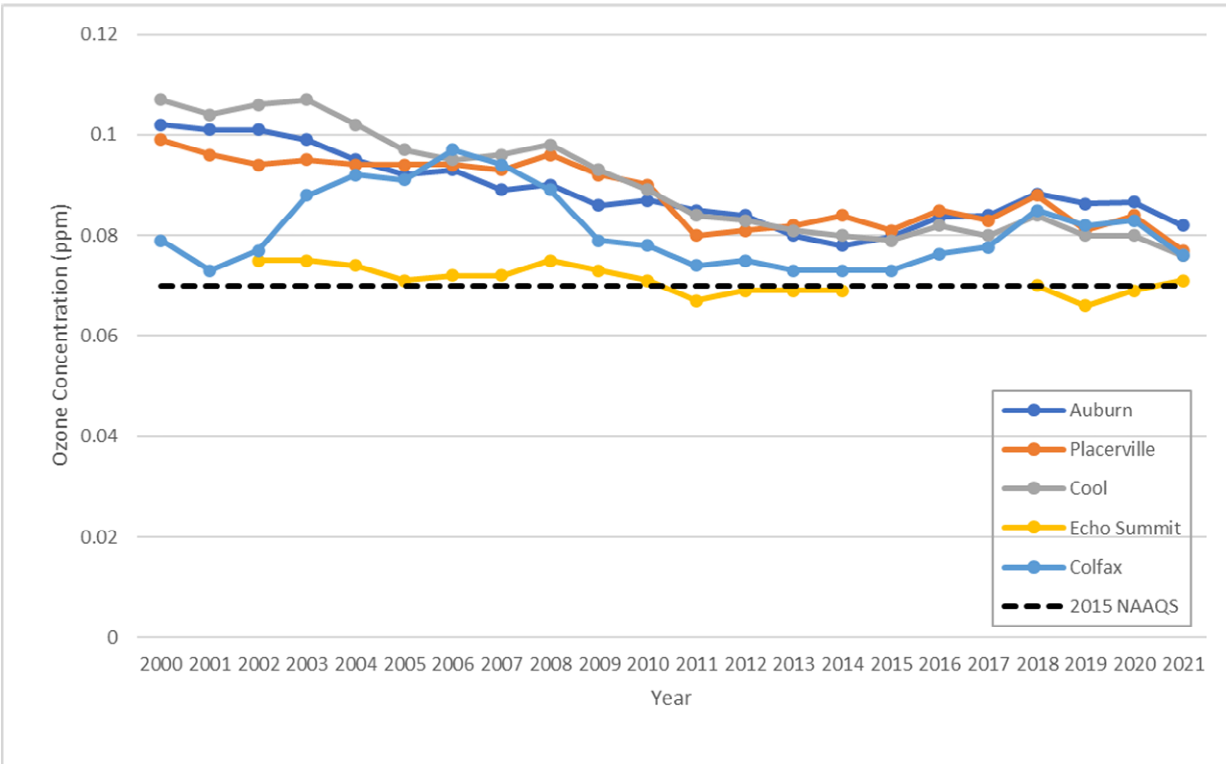


In the eastern subregion, ozone data monitored during January 2015 through May 2019 period at the Colfax, Auburn and Lincoln sites in the Placer County were invalidated as a result of an EPA technical systems audit (TSA) finding. This WOE used those invalidated monitoring data in the analyses. More detailed information and rationale for utilization of the data can be found in the following section, Section F.6.1.I.

Ozone design values at all sites in the eastern subregion except Colfax showed a significant downward trend from 2000 until 2014, then have remained relatively flat or have slightly increased during recent 6 years (Figure F-17). The ozone design value at Colfax site increased until 2006 then decreased rapidly until 2011, then followed the same trend with other sites in the eastern subregion.

The downward trend slowed and leveled off, likely because of variations in large-scale meteorological patterns during the summer months. Some of the variability in the design values during the past six years can be attributed to two of the cleanest years recorded for ozone in the SFNA in 2013 and 2015, when large-scale weather patterns for both years favored moderate to strong Delta breezes, cooler temperatures, and increased dispersion of emissions. However, in 2014 and 2016, broad high-pressure systems over the western U.S. limited vertical mixing in the atmosphere, weakened the Delta breeze, and increased temperatures, which led to more stagnation and extended high ozone episodes. For instance, half of the exceedance days in 2016 were concentrated during a five-day period in July and an 11-day period in mid-August. These two periods resulted in that summer having higher than average number of exceedances, which combined with the cleaner 2013 dropping out of the three-year design value calculation, caused the 2016 design values to increase at most of the sites in the SFNA. Furthermore, massive wildfires in 2018 impacted most of the monitoring sites in the eastern region and contributed to elevated ozone concentrations (The following section discusses wildfire impact on ozone concentration in more detail).

Figure F-17 2000-2021 Design Values at Sites in the Eastern Subregion



Based on Figures F-15, F-16, and F-17 above, it is evident that not all sites experience progress during the same years or the same rate. For example, Folsom and Placerville are significantly different beginning in 2011, when Folsom began a steep decline in design values while Placerville maintained a fairly flat line. However, Placerville experienced a significant decrease in the design value during the few years prior to 2011, while Folsom was flat at that time.

Since 2010, the SFNA has seen rapid progress in the central subregion, with slower progress in the eastern subregion. The higher biogenic emissions in the SFNA, which are concentrated in the eastern portion of the area, add a much greater challenge to attainment. In addition, as described above, there is considerable year-to-year variability, especially pronounced in the eastern region, due to yearly meteorological differences, which impact the amount of transport into the eastern subregion from the other parts of the nonattainment area.

F.6.1.I. Invalidated Data at the Colfax, Auburn and Lincoln Sites

Ozone data collected from January 2015 through May 2019 at the Colfax, Auburn, and Lincoln monitoring sites in Placer County were invalidated as a result of an EPA technical systems audit (TSA) finding that the calibration procedures did not fully meet EPA's data quality regulations. Since Auburn and Colfax are two of the high ozone sites in the SFNA, it is important to look at their air quality trends to make sure these two sites will also attain the 0.070 ppm ozone standard by 2032. The SFNA districts believe that using the invalidated data with additional analyses outlined in the WOE is the most conservative and most health protective approach. Therefore, WOE used those invalidated monitoring data in the analyses. The analysis described below provides evidence for this determination.

Correlations were examined between 3 invalidated sites and nearby sites in the central and eastern subregions using all the concentration data. As shown in Table F-2, all three invalidated sites showed strong correlations with nearby sites except Echo Summit. Echo Summit is located in a remote area and has consistently shown one of the lowest design values in the SFNA. However, when only ozone observations in the peak ozone season are selected for the analyses, the correlations become much less significant.

Table F-2 Correlations (Pearson Correlation Coefficients) Among Central and Eastern Subregion Sites During Summer Ozone Months

	Auburn	Colfax	Lincoln
Auburn	1		
Colfax-City Hall	0.95	1	
Lincoln	0.95	0.91	1
Cool (seasonal)	0.92	0.86	0.85
Echo Summit	0.46	0.56	0.45
Folsom-Natoma Street	0.93	0.87	0.93
North Highlands	0.92	0.87	0.95
Placerville-Gold Nugget Way	0.91	0.90	0.87
Roseville-N Sunrise Blvd	0.92	0.87	0.94
Sacramento-Goldenland	0.88	0.82	0.91
Sacramento-Del Paso Manor	0.89	0.83	0.91
Sacramento-T Street	0.85	0.80	0.88
Sloughhouse	0.85	0.79	0.87

Although there could be some uncertainties due to the relatively poor correlations for high ozone concentrations, design values at the Auburn and Colfax sites were estimated based on the regression analyses using ozone concentrations at nearby sites, and then those design values were compared to design values calculated from the invalidated ozone data.

Cool and Placerville sites were selected to determine linear regression equations for ozone design values at the Auburn and Colfax sites, respectively. As shown in Table F-3, ozone design values calculated using observed but invalidated data are about 9 percent and 12 percent higher at the Auburn and Colfax sites, respectively, than using the estimated data based on the regression analyses. These results suggest that utilizing observed invalidated data for the trend analysis is more conservative.

Table F-3 Ozone Design Values at Auburn and Colfax

	Using Observed Data		Using Regression Data	
	Auburn	Colfax	Auburn	Colfax
2015	0.079	0.073	0.078	0.072
2016	0.083	0.076	0.081	0.076
2017	0.084	0.077	0.080	0.075
2018	0.088	0.085	0.084	0.079
2019	0.086	0.082	0.079	0.073

Note: Lincoln site was not included due to insufficient data to determine design values.

F.6.1.II. Invalidated Placer County Ozone data between January 01, 2015, and September 21, 2019

A spreadsheet “Appendix F-6-1-II.xls” is available separately and included all observed data which were invalidated by EPA as discussed above.

Tab	Description
Colfax-3002	Hourly 8-hour ozone data for 2015. 2008, and 1997 O_3 Standards at Colfax monitoring site between 01/01/2015 and 09/21/2019
Auburn-3789	Hourly 8-hour ozone data for 2015. 2008, and 1997 O_3 Standards at Auburn monitoring site between 01/01/2015 and 09/21/2019
Lincoln-3796	Hourly 8-hour ozone data for 2015. 2008, and 1997 O_3 Standards at Lincoln – 1st St monitoring site between 01/01/2015 and 09/30/2017
Lincoln-3841	Hourly 8-hour ozone data for 2015. 2008, and 1997 O_3 Standards at Lincoln – 2885 Moore Road monitoring site between 10/07/2018 and 09/21/2019
Site	Monitoring Site information
Ozonedailysite	Detailed ozone data for the invalidated sites
Column def	Column definition for the ozonedailysite tab

F.6.2. Wildfire Emission Impacted Days and Ozone Design Values

F.6.2.I. Wildfire Information

In the SFNA, a significant number of days were impacted by the 2018 wildfires as shown in Table F-4. Although not all wildfires impacted each monitor on any given day, all these fires contributed to the accumulating smoke layers that overlayed California, making identification of the impact of just one particular wildfire difficult. Most of these fires, including all large megafires, occurred on wildland or in the urban/wildland interface.

For the model to project the future ozone design value and designation status, a baseline ozone design value is needed. In the ideal modeling scenario, the baseline ozone design value would represent the true ozone concentrations in the county without influence from exceptional events such as wildfires. While wildfires certainly impacted ozone values on many more days and at multiple sites, this WOE focused on the Auburn and Colfax sites, which are two sites located in Eastern subregion of the SFNA and monitors for ozone and fine particulate matter ($PM_{2.5}$).

The Table F-5 lists those impacted days and daily maximum ozone concentrations on those days at the Auburn and Colfax sites[4]. Additional details on the impact of 2018 wildfires on ozone air quality in Northern California can be found in the "Exceptional Events Demonstration for Ozone Exceedances: Northern California July-August 2018 Wildfire Events". This document can be accessed on the CARB website at *https://ww2.arb.ca.gov/sites/default/files/2021-09/2018_Northern_California_EE_Full_Demo_2.pdf* .

Table F-4 Major Wildfires Active during July 26-August 10, 2018 Events

Fire	Start	Containment	Latitude	Longitude	Total Acres
Ferguson	7/13/18	11/28/18	37.655	-119.886	96,901
Natchez	7/15/18	1/4/19	41.951	-123.546	38,134
Klondike	7/16/18	11/28/18	42.369	-123.86	175,528
Taylor Creek	7/16/18	10/11/18	42.528	-123.571	52,389
Carr	7/23/18	8/30/18	40.654	-122.624	229,651
Mendocino Complex (Ranch)	7/27/18	9/19/18	39.243	-123.103	410,203
Mendocino Complex (River)	7/27/18	8/10/18	39.047	-123.120	48,920
Butte	7/31/18	8/2/18	39.186	-121.793	1,200

4 The modeling discussed in Chapter 6 and Appendix B excluded the wildfire impacted days from the Auburn site; the wildfire-impacted days from the Colfax site were not included because the modeling showed that with and without the wildfire-impacted days, the 2032 design value at the Colfax site will be below 70 ppb.

Donnell	8/1/18	1/4/19	38.349	-119.929	36,450

Table F-5 Summary of Wildfire Impacted Days at Auburn and Colfax

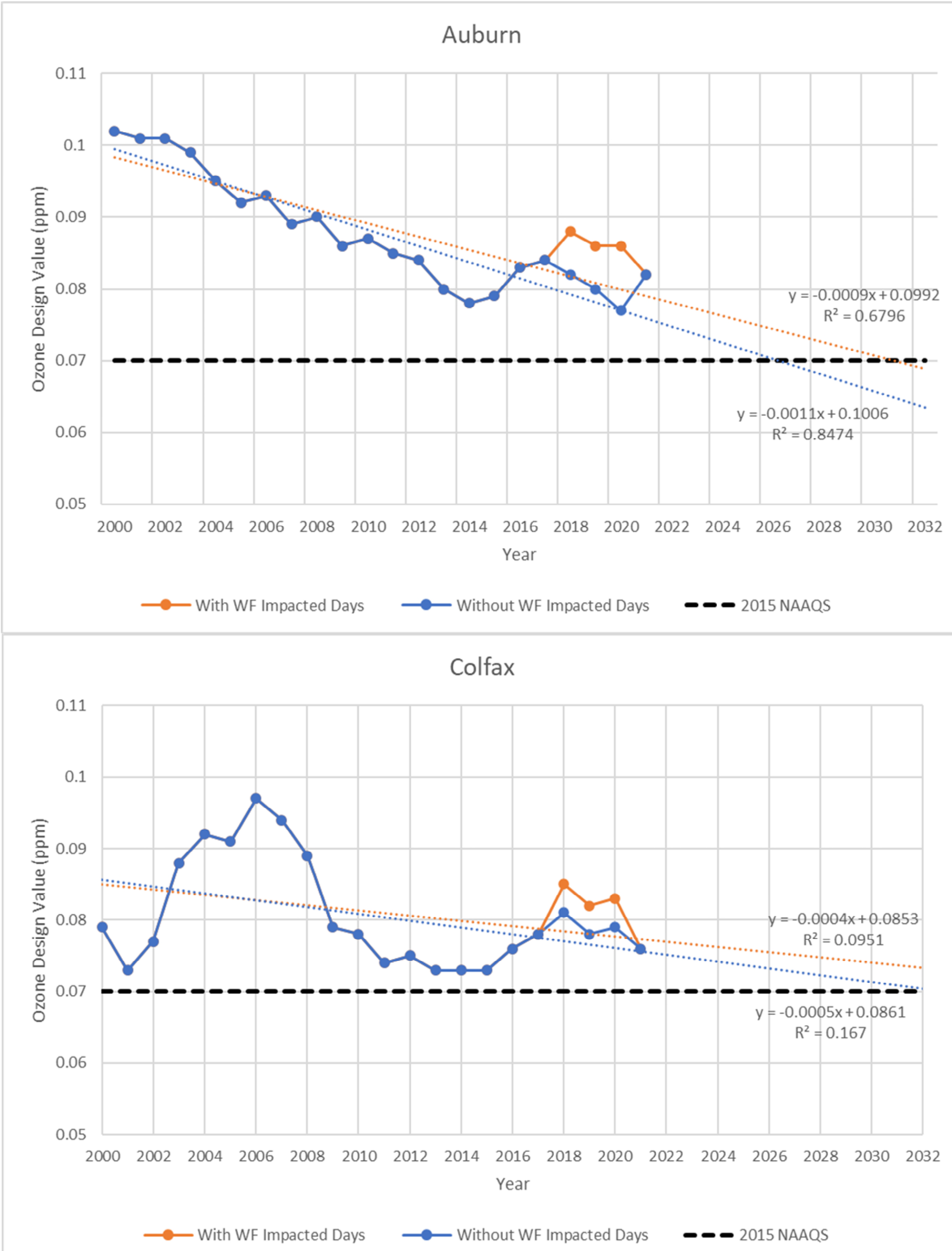
Date	8-Hour Ozone Concentration (ppm) at Auburn	8-Hour Ozone Concentration (ppm) at Colfax
7/31/2018	0.107	0.108
8/1/2018	0.106	0.086
8/2/2018	0.115	0.114
8/8/2018	0.097	0.103
8/9/2018	0.098	0.097
8/10/2018	0.092	0.090

F.6.2.II. Excluding Wildfire Impacted Days

As demonstrated above, all the sites in the SFNA have shown downward trends of ozone design values from 2000 to 2021. Excluding wildfire impacted days would bring down design value further. Wildfires are considered natural events, which are not reasonably controllable using techniques that may be implemented by state or local air districts. The days impacted by wildfires can be excluded to avoid imposing any unreasonable planning requirements on air quality agencies related to violations of the federal standards. Therefore, it is rational to evaluate the air quality impact of wildfires - on an area’s ability to meet the 0.070 ppm ozone standard and whether the nonattainment area could meet the standard if no wildfires had affected the area.

Figure F-18 shows 8-hour ozone design value trends with and without wildfire impacted days listed in Table F-5 for the Auburn and Colfax sites. With wildfire impacted days, the trendlines in Figure F-18 indicate that the Auburn site will attain the 2015 ozone standard by 2032 while Colfax will not. Excluding wildfire impacted days in 2018, the trendlines show both Auburn and Colfax will attain the standard by 2032. This demonstrates the significance of accounting for impacts of wildfires to design value calculations. Note that the trendlines below are estimations of the future design values based on the historical ozone design values at the monitors. They provide additional support to the photochemical modeling results and are not a glide path for the attainment projection.

Figure F-18 8-hour ozone design values at Auburn and Colfax



F.6.2.III. Evidence of Wildfire Impacts Based on $PM_{2.5}$ Observations

Winds can transport wildfire smoke and ozone precursors to a certain area and cause simultaneous increases in ozone and $PM_{2.5}$ concentration. Elevated $PM_{2.5}$ concentrations recorded at a site could support the presence of wildfire smoke in the areas.

Unusually high daily average $PM_{2.5}$ at Auburn and Colfax sites were examined for days impacted by wildfires and co-occurrence with ozone increases in July and August in 2018. Figure F-19 shows daily average $PM_{2.5}$ and daily maximum 8-hour ozone concentrations from April 1 to September 30 in 2018. Unusual high daily average $PM_{2.5}$ days are shaded to identify days on which wildfire emissions likely impacted the ozone monitors. From Figure F-19, it is evident that many of the 8-hour ozone exceedance days in 2018 were likely impacted by wildfire emissions.

F.6.3. Exceedance Days

Significant progress has occurred in reducing the frequency, magnitude, and spatial extent of 8-hour ozone exceedance days in the SFNA over the past 20 years, even with wildfire impacts. The analysis for this section includes data potentially impacted by wildfires. In terms of frequency, the 3-year average of annual number of exceedance days for all 16 SFNA monitoring sites decreased by 76 percent from the period of 2000-2002 to the more recent period of 2019-2021. On a subregion basis, all three subregions saw a dramatic decrease in exceedance days:

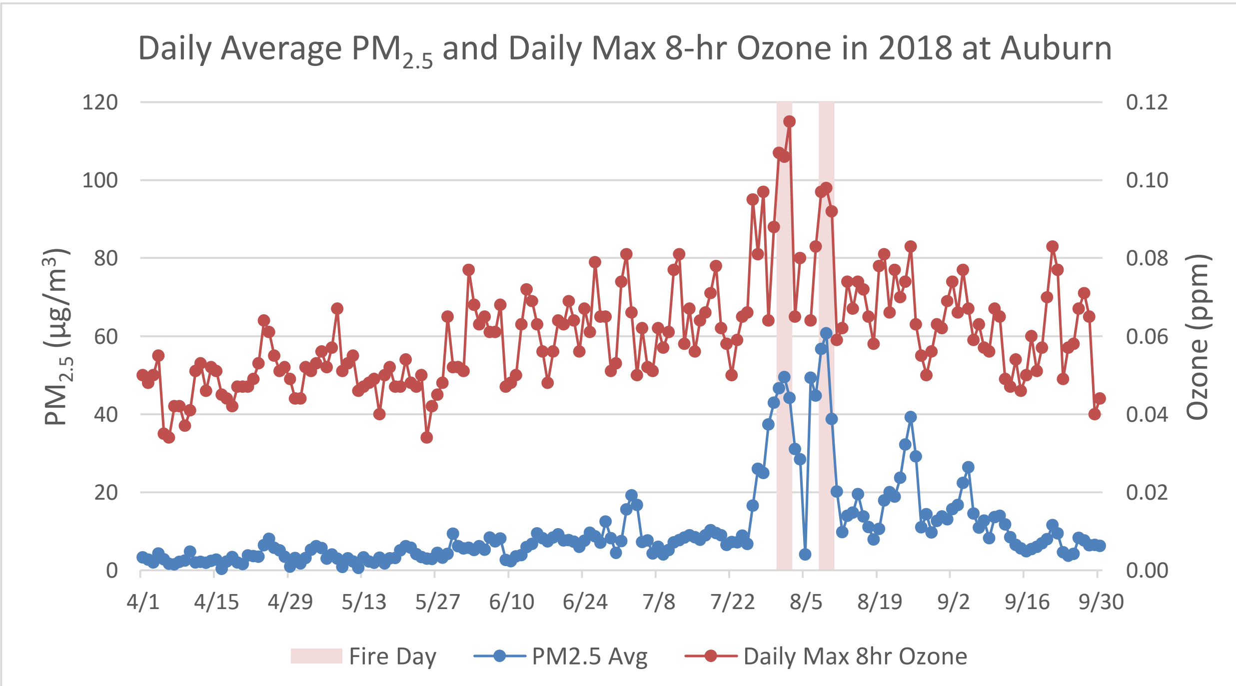
- Western: 3-year average of annual number of exceedance days for 2000-2002 ranged from 5 (Vacaville) to 15 (Woodland) but decreased to 1 (Woodland) to 7 days (Elk Grove) for 2019-2021.
- Central: 3-year average of annual number of exceedance days for 2000-2002 ranged from 10 (Sacramento T Street) to 48 (Folsom) but decreased to 2 (Sacramento T Street) to 10 (Folsom) for 2019-2021.
- Eastern: 3-year average of annual number of exceedance days for 2000-2002 ranged from 18 (Echo Summit) to 78 (Cool) but decreased to 4 (Echo Summit) to 22 (Auburn) for 2019-2021.

Figure F-20 illustrates the dramatic progress made in reducing the number of exceedance days and the magnitude of ozone concentrations on those days. During the most recent 3 years, there were only 7 exceedances in the western subregion, with declines of two-thirds or more in the other two subregions, as discussed earlier. Besides, the magnitude of exceedance days has declined significantly with the majority of ozone exceedances falling below the 0.085 ppm level.

For all SFNA sites, in 2000-2002, the magnitude of the three-year average of annual peak ozone concentrations ranged from 0.080 ppm (Vacaville) to 0.120 ppm (Cool), as shown in Table F-4. Comparatively, the magnitude of the three-year average for 2019-2021 ranged from 0.071 ppm (Davis) to 0.094 ppm (Auburn). The elevated concentration averages at the stations located in the eastern subregion are likely impacted by wildfire events that occurred in 2018. Moreover, for 2000-2002, nine SFNA sites had an annual peak 8-hour ozone concentration greater than 0.095 ppm. However, by the period 2019-

2021, there were only four SFNA sites with a peak 8-hour ozone concentration greater than 0.095 ppm (Table F-4).

Figure F-19 Daily $PM_{2.5}$ and Maximum 8-Hour Ozone Concentration in 2018 in Auburn and Colfax



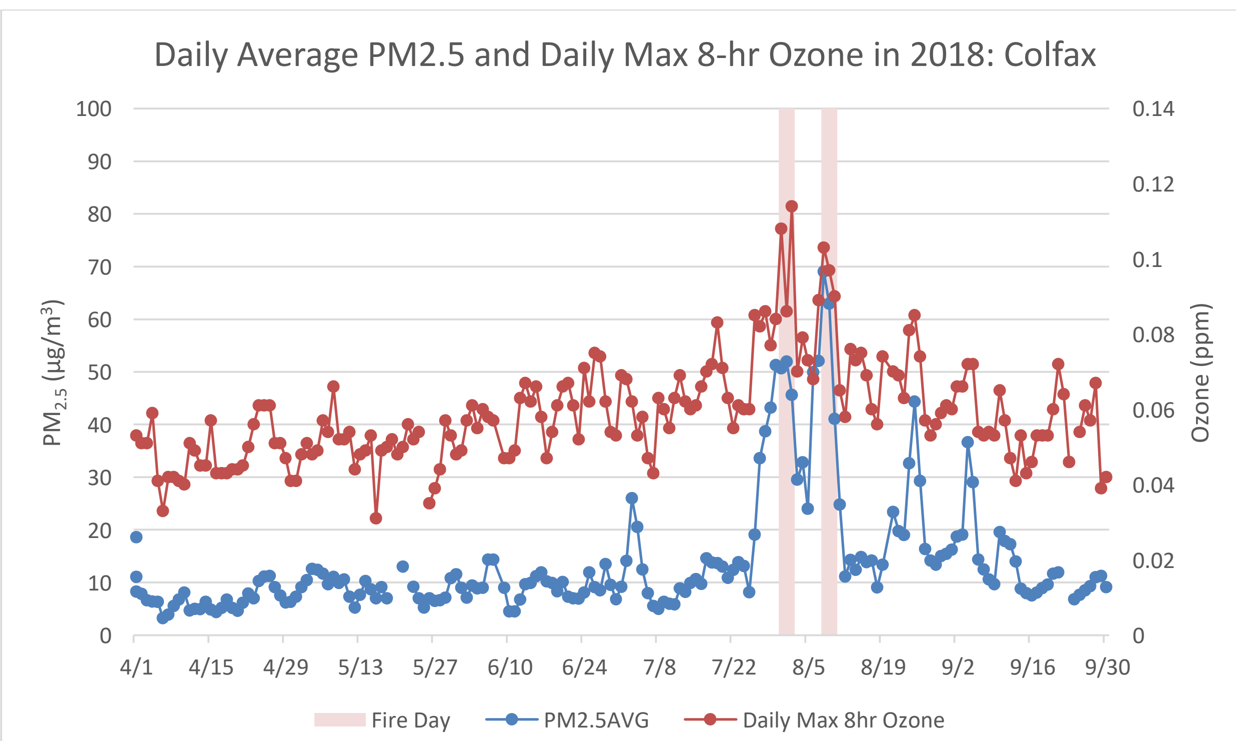
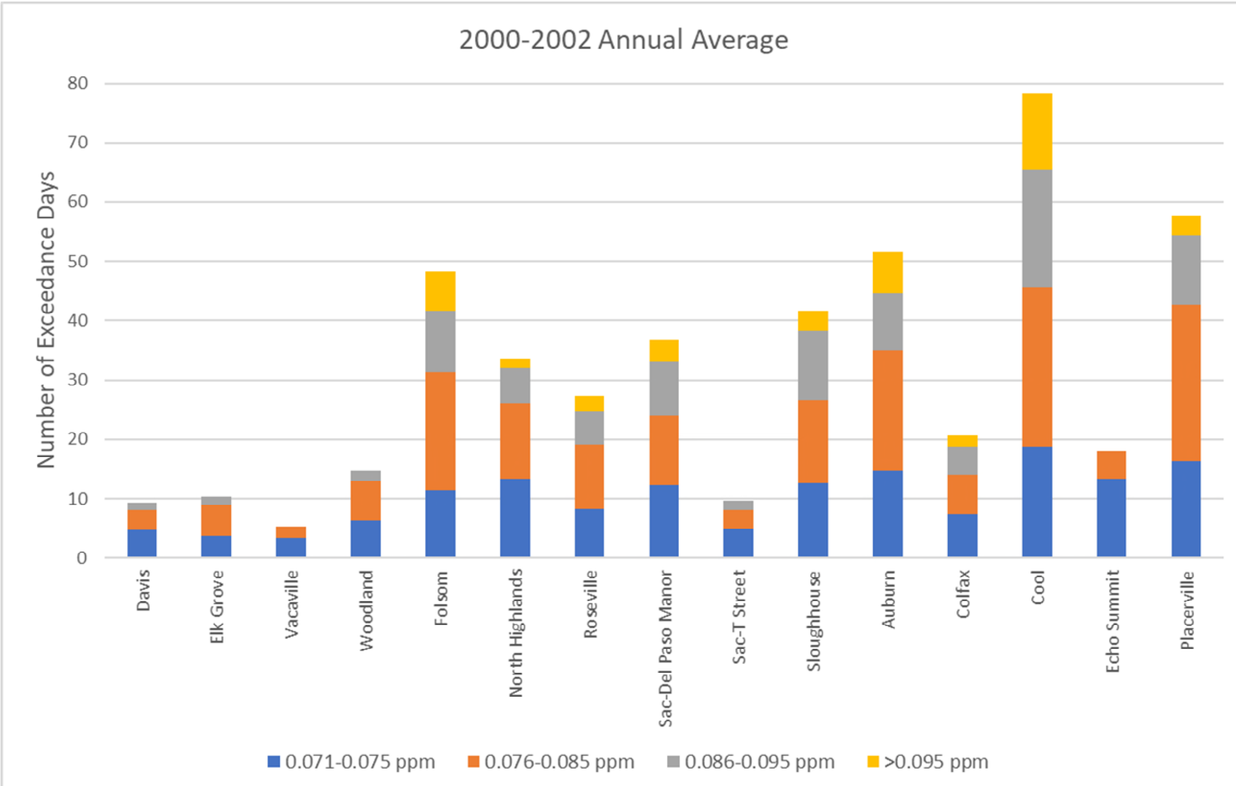


Figure F-20 Average Annual Number of 8-hour Ozone Exceedance Days



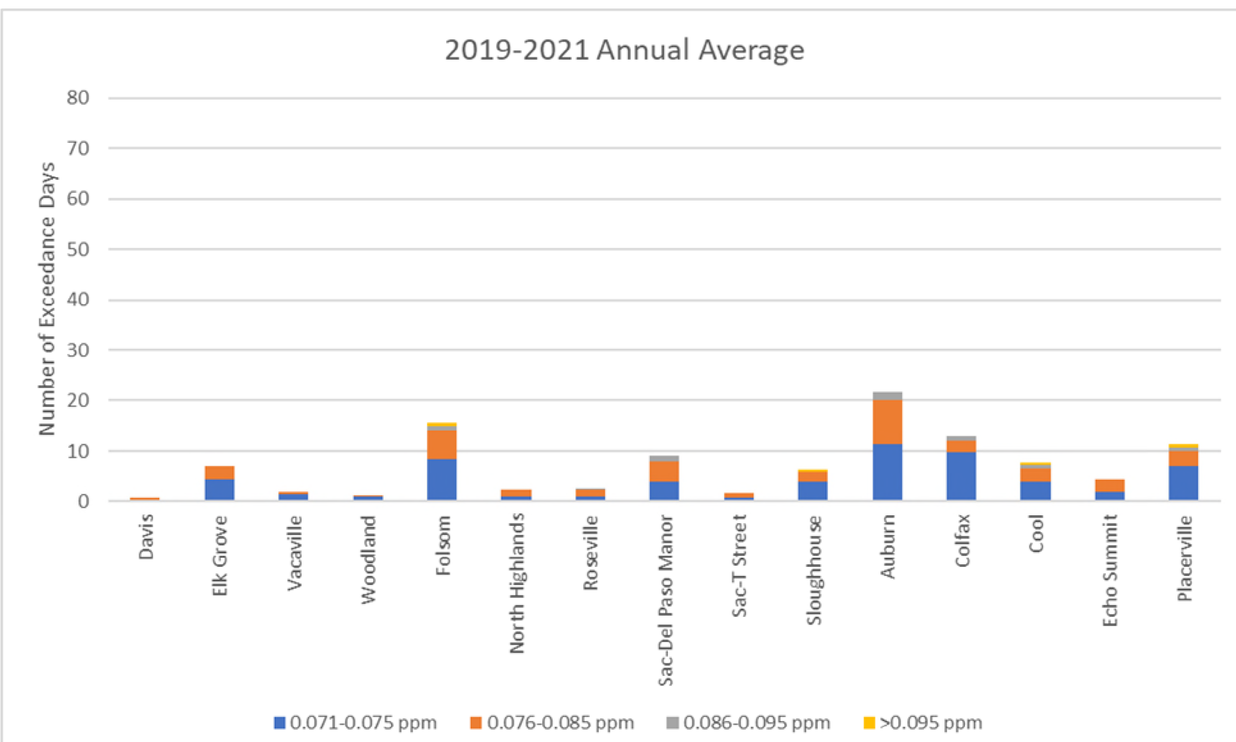


Table F-6 Annual Peak 8-hour Ozone Concentrations

	Site Name	2000	2001	2002	2000-2002 Average	2019	2020	2021	2019-2021 Average
Western	Elk Grove-Bruceville Rd.	0.094	0.092	0.082	0.089	0.077	0.082	0.080	0.080
	Vacaville	0.081	0.081	0.077	0.080	0.069	0.073	0.078	0.073
	Davis-UCD Campus	0.089	0.093	0.088	0.090	0.066	0.068	0.081	0.072
	Woodland-Gibson Rd.	0.083	0.089	0.091	0.088	0.067	0.075	0.082	0.075
Central	Roseville-N Sunrise Blvd.	0.100	0.102	0.105	0.102	0.076	0.080	0.090	0.082
	Lincoln-1445 1st St.	--	--	--	--	0.075	0.088	0.087	0.083
	North Highlands-Blackfoot Way	0.100	0.094	0.101	0.098	0.082	0.085	--	0.084
	Sacramento-Del Paso Manor	0.100	0.107	0.114	0.107	0.069	0.085	0.091	0.082
	Sacramento- T St.	0.079	0.094	0.091	0.088	0.074	0.076	0.080	0.077
	Folsom-Natoma St. [5]	0.102	0.108	0.120	0.110	0.072	0.036	0.096	0.068
	Sloughhouse	0.108	0.097	0.105	0.103	0.071	0.077	0.097	0.082
Eastern	Auburn	0.107	0.107	0.115	0.110	0.081	0.089	0.094	0.088
	Colfax-City Hall	0.058	0.088	0.113	0.086	0.077	0.092	0.083	0.084
	Placerville-Gold Nugget Way	0.100	0.100	0.111	0.104	0.075	0.101	0.080	0.085
	Echo Summit	0.076	0.084	0.079	0.080	0.063	0.079	0.085	0.076
	Cool	0.113	0.109	0.137	0.120	0.077	0.096	0.091	0.088

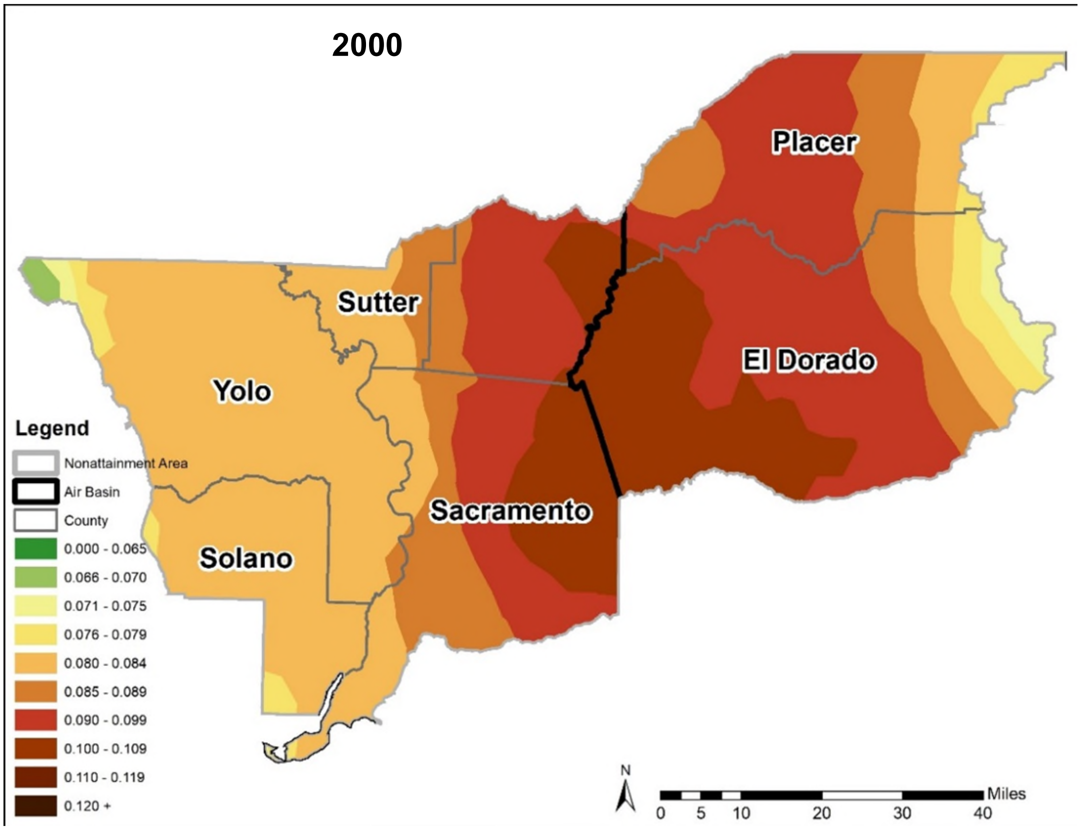
“--” indicates that no data were available

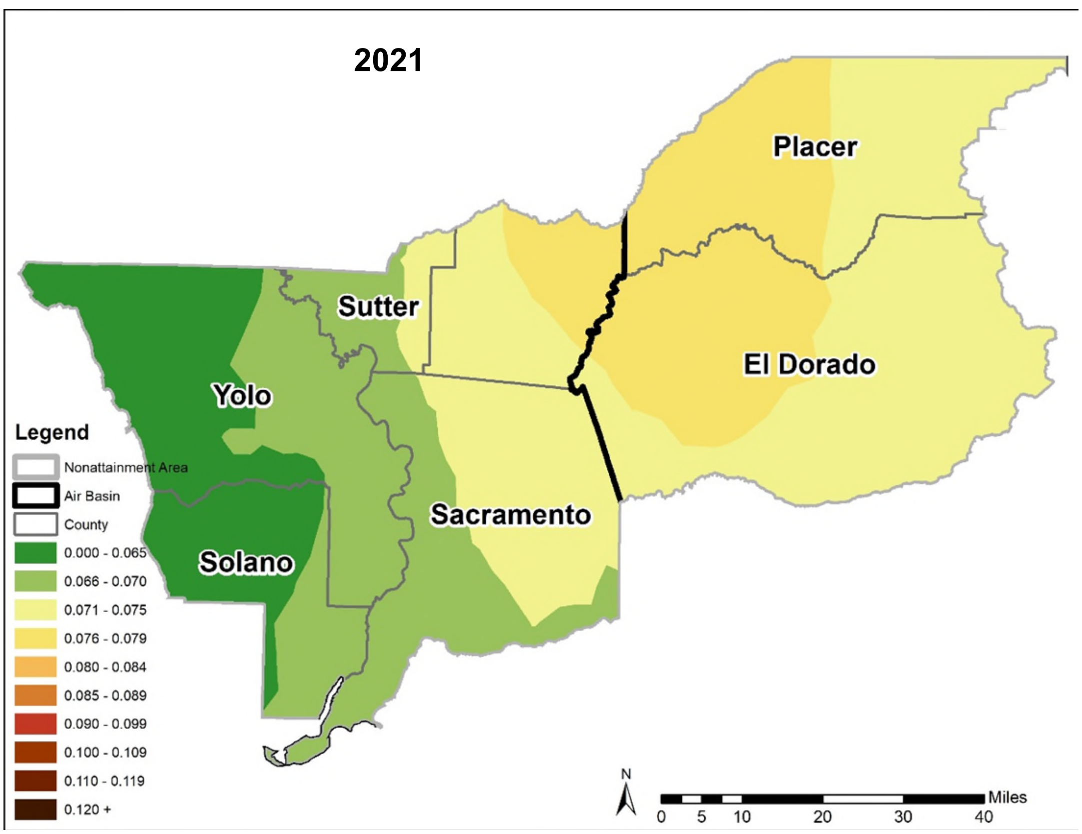
F.6.4. Population Exposure

To spatially and temporally evaluate ozone air quality across the SFNA, maps showing interpolated 8-hour average ozone design values for the years 2000 and 2021 were produced using an inverse distance weighting (IDW) method for the contouring (Figure F-21). In 2000, the entire SFNA exceeded the 0.070 ppm ozone standard, with a majority of the most populated areas of the region also exceeding the prior 0.075 ppm federal 8-hour ozone standard.

Figure F-21 Contour Maps of Design Values in the SFNA

5 The Folsom-Natoma Street monitor was undergoing major renovation between July 21, 2019, and Dec 10, 2020. The 2019 and 2020 annual peak 8-hour concentrations do not cover the entire ozone seasons.

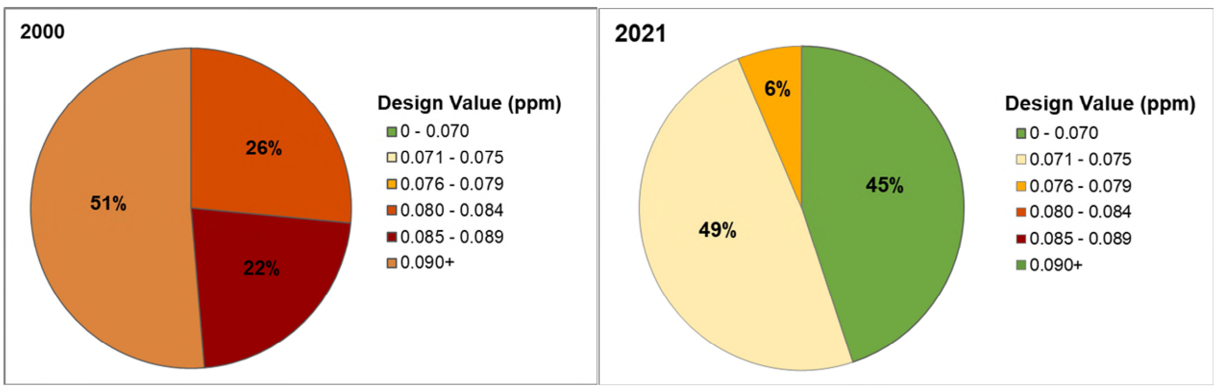

2000
Placer
Sutter
El Dorado
Yolo
Legend
Nonattainment Area
Air Basin
County
0.000 - 0.065
0.066 - 0.070
0.071 - 0.075
0.076 - 0.079
0.080 - 0.084
0.085 - 0.089
0.090 - 0.099
0.100 - 0.109
0.110 - 0.119
0.120 +
Sacramento
Solano
N
0 5 10 20 30 40
Miles


2021
Placer
Sutter
El Dorado
Yolo
Legend
Nonattainment Area
Air Basin
County
0.000 - 0.065
0.066 - 0.070
0.071 - 0.075
0.076 - 0.079
0.080 - 0.084
0.085 - 0.089
0.090 - 0.099
0.100 - 0.109
0.110 - 0.119
0.120 +
Sacramento
Solano
N
0 5 10 20 30 40
Miles

In contrast, by 2021, ozone air quality dramatically improved as evident by the entire western subregion area below the 0.070 ppm ozone standard. Areas where the ozone design values were greater than 0.080 ppm were mostly limited to eastern Sacramento County and the foothill areas of Placer and El Dorado counties, with only one localized area an 8-hour ozone design value slightly above 0.084 ppm.

Interpolated design values derived using IDW were overlaid with U.S. 2021 population census data to provide the quantitative estimates of population exposure in the SFNA (Figure F-22). In 2000, none of the people within the SFNA lived in areas where the ozone design values were at or below 0.070 ppm. However, by 2021, the percentage of the population living in areas with ozone design values below 0.070 ppm increased to 45 percent, indicating a major improvement in ozone air quality during the 21-year period.

Figure F-22 Population Exposure to Ozone in the SFNA



Analysis of design values provides significant insight into the compliance status of a region as well as specific monitoring sites. However, design values are limited in their ability to assess all aspects of ozone air quality progress within a large area, such as Sacramento, that has terrain and complex, localized meteorological patterns which impact ozone formation and buildup. Thus, looking beyond the design values provides a more thorough evaluation of the nature of progress and the factors that contribute to exceedances of ozone air quality standards in a region.

F.6.5. Summary of Ozone Air Quality

The assessment of long-term design value trends between 2000 and 2021 indicated a major improvement in ozone air quality across the entire SFNA. While a few site-specific design values indicate a near-term slowing in progress, the overall trends during the past 20 years are downward. To examine the trends beyond the design values, additional indicators were considered to provide further insight into ozone air quality in the SFNA.

Decreases in the number of annual exceedance days and, the magnitude of ozone concentrations on exceedance days were consistent with the decreases in design values and confirmed that the design value trends were reflective of the improvement in overall ozone air quality.

F.7. Weekend/Weekday Differences

The ozone weekend effect is the occurrence of higher ozone concentrations on weekends than on weekdays (California Air Resources Board, 2003). These differences have been documented in many urban areas and have been extensively studied and discussed in the scientific literature for decades. Emissions data show that NO_X emissions are usually lower on the weekend due to less heavy-duty diesel vehicle activity. However, historical data in the 1990s showed that more ozone exceedance days were observed on weekends. Peer-reviewed scientific studies conducted within the SFNA and downwind Mountain Counties Air Basin (MCAB) indicated the presence of the weekend effect in the 1985 to 2002 period (Blanchard and Fairley 2001; Marr and Harley 2002; Murphy et al. 2006; Murphy et al. 2007) and concluded that the SFNA was a VOC limited regime during that time. Regulations in the 1990s focused on reducing VOC emissions, which led to significant reductions in VOC emissions. These regulations prompted the Sacramento region to shift away from the VOC limited regime towards a NO_X limited regime. For example, implementation of the California Phase 2 Reformulated Gasoline in 1996 resulted in about 50% more reductions in VOC emissions compared to NO_X emissions (CARB 2003; Austin and Tran 1999), decreasing the VOC to NO_X ratio. More recent analyses indicate that the weekend/weekday differences have diminished and that there is no discernible difference in the SFNA (Wolff et al. 2013). A study on Central California Ozone in 2009 found that the SFNA demonstrated NO_X-limiting behavior (BAAQMD 2009), and a more recent smog chamber study in Sacramento observed ozone production to experience higher sensitivity to changes in NO_X concentrations during both the weekdays and weekends in the summertime months when biogenic VOC emissions are expected to be the greatest (Wu et al. 2022). In fact, in the following analysis, data from all sites that were evaluated showed more ozone exceedances on weekdays than on the weekends, following the behavior of NO_X concentrations. Furthermore, as the SFNA sees more significant reductions in NO_X concentrations due to control measures along with smaller reductions in VOC concentrations, the VOC to NO_X ratio will continue to increase and the ozone production rate will become more NO_X-limited. This supports the efficacy of NO_X emissions controls in reducing ambient ozone concentrations in SFNA.

F.7.1. Weekday/Weekend Trends

F.7.1.I. Day of the Week: Exceedance Days

In this WOE, the distribution of the day of the week on which exceedance days occurred was examined to evaluate weekend/weekday differences. The focus was on the central and eastern subregions because these areas potentially drive attainment demonstration in the SFNA. In addition, there were too few exceedances at a few of the central subregion sites (Sacramento-T Street, Sacramento-Goldenland, and Lincoln) and in the western subregion to evaluate monitors for differences. The period considered was 2016 to 2021, which had a similar design value trend for many of the sites in the SFNA.

As shown in Figures F-23 and F-24 below, in general, exceedance days in the central and eastern subregions occurred more frequently on weekdays than weekends. This is believed to be caused by significantly lower NOx emissions during the weekend, indicating that NOx emission reduction is effective in reducing ozone in the SFNA.

Figure F-23 Distribution of Exceedance Days by Day of the Week at Sites in the Central Sacramento Subregion (2016-2021)

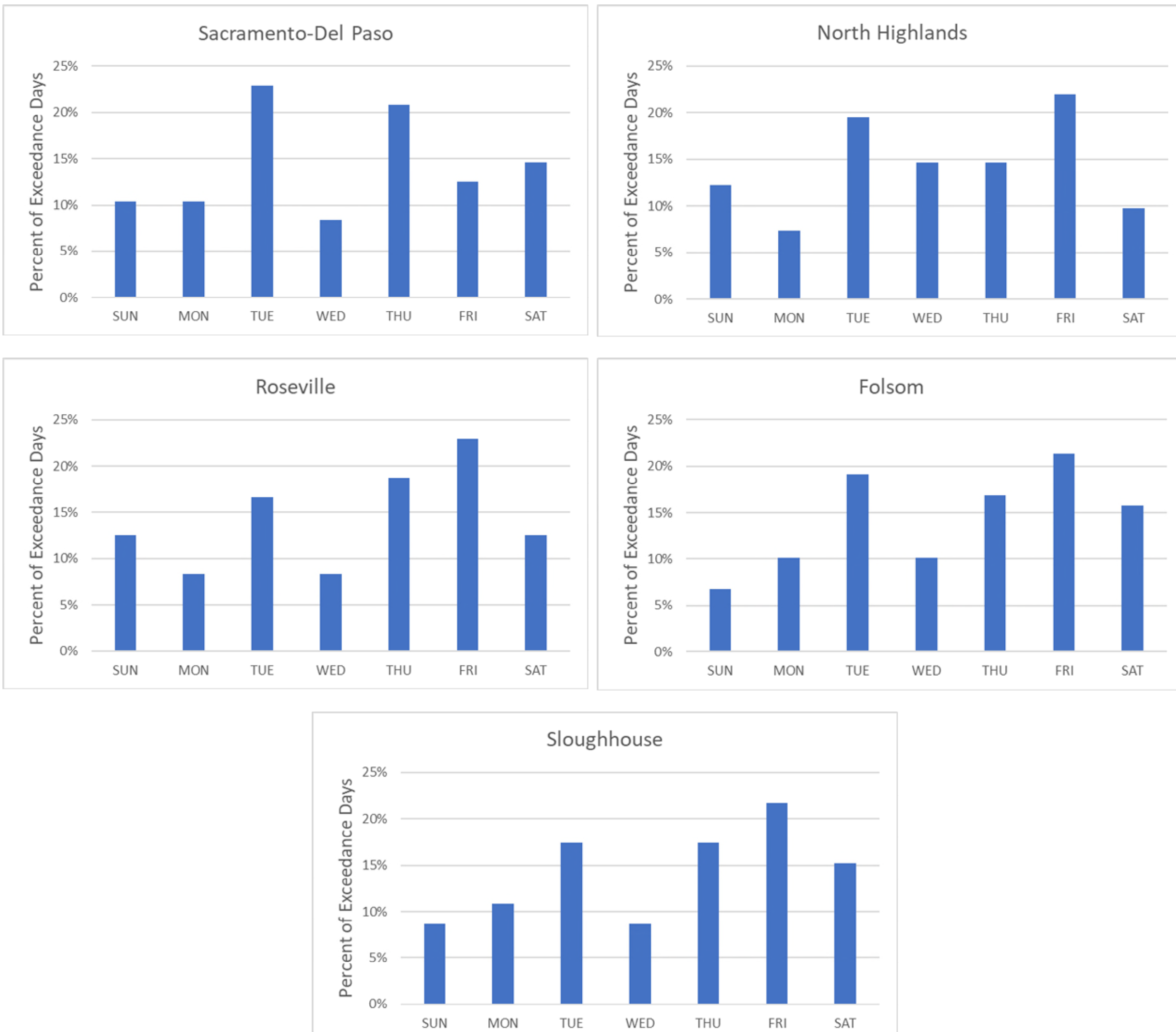
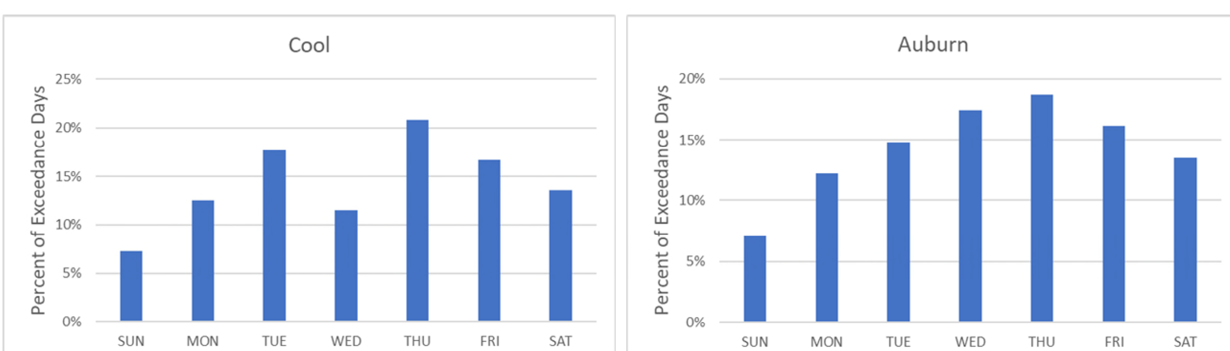
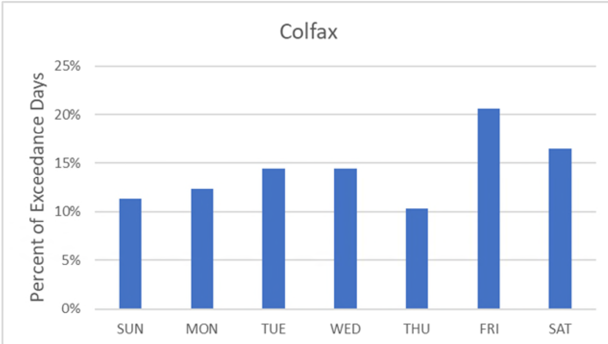
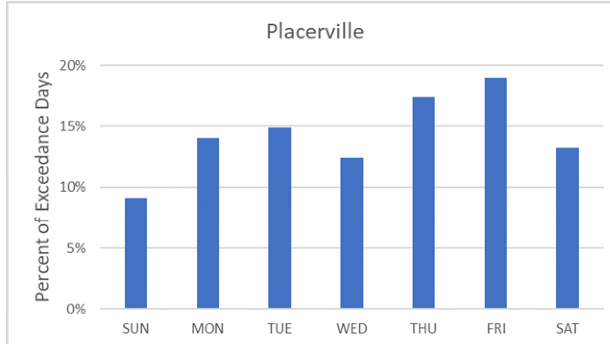


Figure F-24 Distribution of Exceedance Days by Day of the Week at Sites in the Eastern Sacramento Subregion (2016-2021)



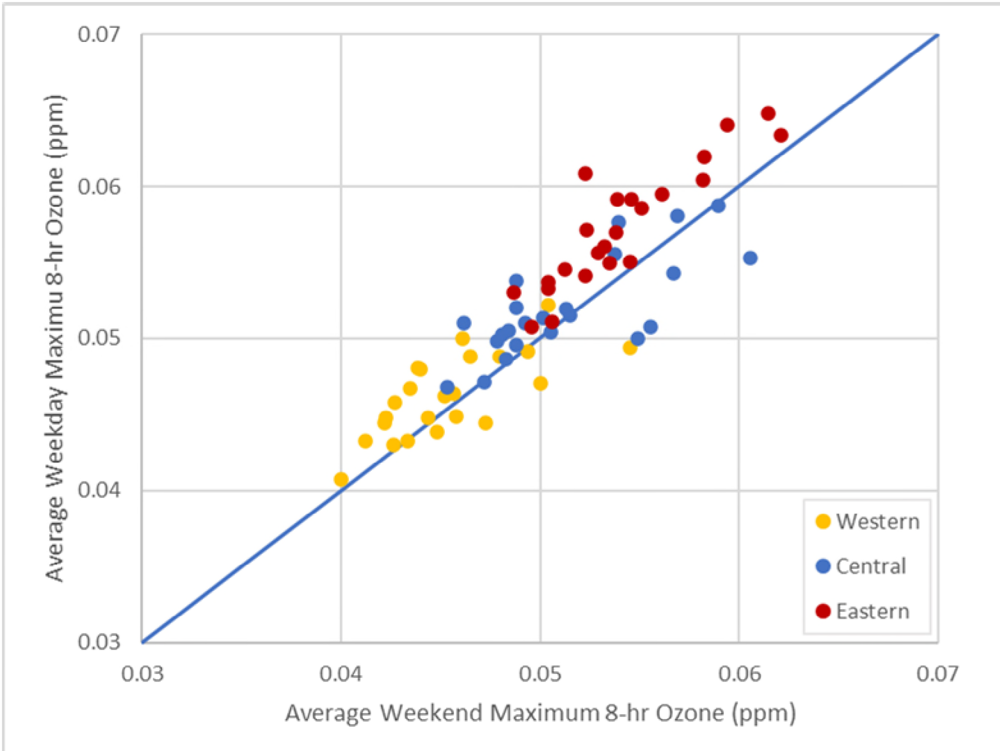




F.7.1.II. Weekday vs. Weekend Concentration

The day-of-week dependence of ozone in the Sacramento area was also investigated using the average weekday (Tuesday and Thursday) and weekend (Sunday) maximum 8-hour ozone concentrations observed in the ozone season (May through October) from 2000-2021. As shown in Figure F-25, for most of the past 22 years, daily maximum 8-hour ozone concentrations were generally higher on weekdays than on weekends, an indication that the SFNA no longer experiences the weekend effect. The occasional shift in weekday/weekend ozone levels near the 1:1 line and crossing over the line is likely due to inter-annual variability in meteorological conditions and its impact on the regional transport patterns and local biogenic VOC emissions. NO_X concentrations in the SFNA follow similar patterns to the ozone trends displayed in Figures F-23, F-24, and F-25, with elevated concentrations during weekdays compared to the weekend, demonstrating a notable correlation. A study found that NO_X concentrations in the SFNA were significantly lower on the weekend whereas VOC concentrations were not significantly different between the weekdays and the weekend (Murphy et al. 2006). Figure F-9 shows greater NO_X reductions compared to VOC reductions during 2000-2021 demonstrating that long-term control strategies are proving to substantially reduce NO_X. Continued current and future emissions controls are expected to decrease NO_X concentrations faster than VOC concentrations, thereby increasing the VOC to NO_X ratio and reinforcing the SFNA as a NO_X limited regime. This supports the conclusion that the SFNA no longer yields a weekend effect and NO_X control strategies serve as an important role in regulating ozone production.

Figure F-25 Average Weekday and Weekend daily Maximum 8-Hour Average Ozone for Each Year from 2000 to 2021



F.8. Attainment Projections

As discussed in this WOE, ozone production is a non-linear process, and the drivers of production can vary over relatively short spatial and temporal scales. The rate of historical ozone air quality improvements has varied over time in response to the change in composition and quantity of NO_X and ROG emissions across the SFNA. Both photochemical modeling and the air quality analysis presented in this WOE demonstrate that the path to attainment in the SFNA is a NO_X-focused control strategy. Therefore, it is expected that the ozone air quality will keep improving as controls are implemented within a NO_X-limited ozone production regime. Photochemical modeling and air quality data analysis presented in this WOE document both project that all sites will be able to meet the 0.070 ppm ozone standard by the attainment year of 2032.

F.9. Conclusions

The SFNA has requested to be a severe ozone nonattainment area with an attainment date of 2032 for the 0.070 ppm ozone standard. The SFNA has faced several challenges that impact ozone and ozone precursor concentrations, but analyses demonstrate that the SFNA will be able to achieve attainment by the 2032 attainment deadline. This WOE evaluated ambient air quality and emission trends along with photochemical modeling analyses to assess progress and demonstrate that the SFNA will be able to meet the 2032 deadline with the currently adopted control measures and commitment to reduce NO_X emission from mobile sources.

The SFNA is characterized by varied terrain, which limits dispersion and effectively traps emissions. Meteorological conditions in the SFNA are dominated by a semi-permanent high-pressure system that enhances the trapping effect of the local terrain, a thermally driven afternoon Delta breeze, and a nighttime downslope drainage flow recirculation pattern that routinely transports emissions between the central region and the foothills in the eastern region of the SFNA. The SFNA is also home to nearly 2.5 million people and the intersection of three major highways, and consequently, the movement of people and goods is a significant source of emissions. These meteorological, topographical, and population characteristics lead to effectively trapped pollutants in the region.

Despite these features, concentrations of ozone precursors, NO_X and ROG, and ozone have declined substantially over the past two decades with a significant reduction in exceedance days. Between 2000-2021, total NO_X emissions in the SFNA decreased by 67 percent and total ROG emissions by 44 percent. In 2021, 6 of the 16 monitoring stations met the ozone standard with the remaining sites within 17 percent of the standard. Long term ozone trends show that the design value and the annual fourth highest ozone concentration decreased by 20 and 18 percent, respectively, during the same period. The frequency of exceedance days and the magnitude of concentrations on exceedance days, which are measures of population exposure, have improved dramatically. The annual average number of exceedance days declined by 76 percent from the period 2000-2002 to the period 2019-2021. In addition, an estimated 45 percent of the population, as of 2021, live in areas that meet the standard, compared to 0 percent in 2000.

Prior studies conducted within the SFNA, and downwind Mountain Counties Air Basin have indicated differences in the number of exceedances occurring on weekends versus weekdays between 1985 and 2002 (Blanchard and Fairley 2001, Marr and Harley 2002, Murphy et al 2006, and Murphy et al 2007); however, more recent analyses indicate that there is no notable weekend/weekday difference in the SFNA. Photochemical modeling, supported by extensive monitoring and research efforts, indicate that the SFNA has transitioned to be in a NO_X-limited regime in recent years and the path towards attainment of the 0.070 ppm ozone standard is with NO_X-focused control strategies.

Air quality analyses included in this WOE indicate that substantial progress has been made in the SFNA, and all sites within the region are expected to meet the 0.070 ppm ozone standard by the attainment deadline of 2032.

F.10. References

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